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Small Ruminant Production in the Humid Tropics

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SMALL RUMINANT PRODUCTION IN THE HUMID TROPICS
(with special reference to Indonesia)

EDITORS
MANIKA WODZICKA-TOMASZEWSKA,
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FOREWORD

The Indonesia Australia Eastern University Project is a cooperative project between the Australian International Development Assistance Bureau (AIDAB) and the Directorate General of Higher Education (DGHE), Department of Education and Culture to develop university education in Eastern Indonesia. This development emphasises three different areas of this project namely :

1. the development of the capabilities of the academic staff
2. course development and
3. development of teaching methods

in Basic Sciences, Agriculture and Animal Science. To develop those three areas in these faculties high quality resource materials need to become available and among those, libraries and text-books are most important.

This book which has been produced by Indonesian, Australian and American experts represents an important work which will benefit university lecturers in Eastern Indonesia in particular and related institutions in general.

It is also important because little has been published about small ruminants in Indonesia or indeed in the tropics. The bulk of literature about small ruminants is from the temperate zones. Thus this book should be used, not only by lecturers in Indonesia, but also by students, extension staff and researchers working with farm animals in our country. Indeed this book is valuable for raising animal productivity in

Indonesia. Why? Because it covers broad areas of animal production (management, adaptation, breeding, nutrition, reproduction, diseases and parasites, agricultural economics and sociology) as well as the farming systems approach and the linkages between farmers, extension workers and researchers. This work reflects international cooperation between scientists in Indonesia, Australia, Canada and USA without which the book would never be published.

It is a pleasure to acknowledge the cooperation of authors from various countries: Indonesia, Australia, Canada and The United States.

When I was asked as Head, Central Project Implementation Unit, Indonesia Australia Eastern Universities Project by Manika Wodzicka-Tomaszewska to write this preface, I felt honoured, because not everyone has the opportunity to contribute a few words to such a work of substance and quality.

Best wishes for the publication of this book.

Dr John I Pariwono
Head CPIU, IAEUP

FOREWORD

One of the major contributions stipulated in the Memorandum of Understanding between the Indonesian and the Australian Governments concerning the IPB (Institut Pertanian Bogor) - Australia Project was the production of educational materials, in the form of textbooks as well as, of theoretical and laboratory manuals. Within the various areas of animal science 24 manuals have been written and are used extensively by IPB staff. In addition, two drafts of text-books have been written and one was translated by staff from the Faculty of Animal Science (FAPET). These staff members were granted six-monthly visits to Australia to make use of libraries to update their texts. These three books are still looking for a publisher. Finally, the senior editor of this book working with staff from IPB and from other institutes has succeeded in publishing three text-books.

This book entitled Small Ruminant Production in the Humid Tropics (with special reference to Indonesia) is a multi - author book edited by Manika Wodzicka-Tomaszewska (formerly IPB-Australia Project, now Indonesia Australia Eastern Universities Project), Susan Gardiner (IPB Australia Project), Andi Djajanegara (Balai Penelitian Ternak), I Made Mastika (Universitas Udayana) and Tantan Rustandi Wiradarya (IPB). The idea for this book was put forward by the senior editor at an Indonesian Small Ruminant Network meeting attended by senior researchers on small ruminants from the major universities and research institutions, organized by the Small Ruminant - Collaborative Research Support Program (SR-CRSP) and Balai Penelitian Ternak

(BALITNAK) held in 1988. During the deliberations at the meeting, it became apparent to the group that a large amount of data, the result of past and current research work on small ruminants was published in proceedings of conferences held in the past by various research institutions and universities, in Indonesian journals and in other forms of publications, all with limited circulation and mostly in Indonesian. Therefore, many findings have not reached the international scientific audience nor been included in world literature. A compilation of the known scientific data that has come from efforts to improve productivity of small ruminants in the humid tropics into a single comprehensive multi-author book appeared to be a necessary task. This idea was brought-up at the meeting and supported with enthusiasm by all participating parties.

Andi Djajanegara and Tantan R. Wiradarya came up with the first list of prospective authors, all of whom were authorities in their respective fields. After several meetings, the lists of chapters and authors were finalized and the tedious task of organizing and scheduling the work was started.

This book is mainly intended for students, academic staff and researchers interested in small ruminant production. The first chapter was prepared by the internationally recognized authority in goat and sheep production, C. Devendra to enable the reader to perceive the context of small ruminant production in Asia. A complete coverage of most aspects of production with extended reference lists makes the book an almost complete resource book. It has also been written with the intention of stimulating other lecturers and researchers to comment, extend and update the information and especially, to fill-in the many gaps in existing knowledge which therefore, cannot be found in this publication.

I would like to thank all the authors for all the time and effort put into writing their contributions. The cooperation between the various institutes involved has been most impressive and enthusiastic. My special thanks go to the editors for their tremendous effort to deliver the manuscripts for the timely publishing of this book. It was supported financially by the Australian International Development Assistance Bureau (AIDAB), the Small Ruminant Collaborative Support Program (SR-CRSP), the International Development Program of Australian

Universities and Colleges (IDP), the IPB - Australia Project and the Indonesia Australia Eastern Universities Project. It was also supported by staff from a total of twelve different institutes including the Faculty of Animal Science, as well as the Faculty of Veterinary Medicine, IPB, BALITNAK, SR-CRSP, IPB - Australia Project, Indonesia Australia Eastern Universities Project, Balai Penelitian Veteriner (BALITVET), Department of Primary Industry, South Australia, the Upland Agriculture and Conservation Project, Fakultas Peternakan and the Study Program in Veterinary Medicine, Udayana University and the Department of Animal Science, University of Edmonton, Canada.

I wish to thank the former Dean FAPET, IPB, Dr. Lily Amalia Sofyan for hosting the endeavour. Also, our thanks go to the Dean FKH, the past Directors of BALITNAK Dr. M. Sabrani and Dr. Benny Gunawan, the former Coordinator SR-CRSP, Dr Luis Iniguez, the former Director of BALITVET, Dr. Poernomo, the Dean, FAPET, Udayana University, Professor I M. Mastika, the Team Leader IPB-Australia Project, Dr. J.D. Conroy and the Project Manager, Indonesia Australia Eastern Universities Project, Dr. Alan Wilson for encouraging their staff to participate in this project.

Bogor, September 1993

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PREFACE

Small ruminant production plays an important role within farming systems in the humid tropics as an income-generating activity (especially for landless farm labourers), as a living bank for emergencies and large expenses, as a source of fertiliser for crops, as well as playing an important role in the social life of the village.

The authors and the editors have tried to produce a book on small ruminants in the humid tropics with special emphasis on Indonesia. We have concentrated on smallholder production because most goats and sheep in this area are owned by smallholders, in small flocks four to seven animals per farmer.

We found some excellent local data and we found also some big gaps in information on small ruminants. Unfortunately, most of the information is hidden in proceedings of numerous meetings, unknown to many workers in these areas, not abstracted in the various data base systems and thus not included in world scientific literature. At first sight this book appears to be over-referenced. However, we included a large number of relevant references on purpose to make information contained in them available to a wider audience around the world.

The opinions expressed by the authors are not necessarily those of the editors and in some areas different authors have different opinions about the same topic. For example, in Chapter X Dr. K. Suradisastra draws on evidence which indicates that women play a relatively unimportant part in decision-making within the farming

systems generally and especially in relation to small ruminants. However, Dr. Sabrani and Dr Levine, in Chapter XI as well as Dr. Ludgate and Dr. Rangkuti in Chapter XII draw on evidence that indicates that women's role in this area is important and that distribution of resources must take this into consideration.

Although the editors indicated to the authors the areas to be covered, as with any book, the chapters would have been different if other authors had written them. But of course, a book cannot contain all the information on small ruminants in one volume!

The editors have tried to check all the tables, figures and references, but we may have missed some inconsistencies. If this is so, we apologise.

Where data from the humid tropics especially those from Indonesia, are available, they have been quoted and discussed, rather than data from the temperate zones, pointing to our gaps in knowledge.

Ours has been a fascinating task and we would like to thank the many people who have made it possible. We wish to thank the Australian International Development Assistance Bureau (AIDAB) for a generous special grant for publishing this book. We would like to thank the Small Ruminant Collaborative Research Support Program (SR-CRSP) for their financial support. We would like to thank the International Program of Australian Universities and Colleges (IDP), the Institut Pertanian Bogor - Australia Project and the Indonesia Australia Eastern Universities Project for helping to finance this undertaking.

We thank the authors without whom there would be no book. We thank them for their patience as we went through up to fourteen drafts per chapter, trying to make the book into a cohesive whole.

We are very grateful to people who have refereed the various chapters and offered valuable constructive criticism: Dr. R.A. Abdelsamie, Professor R.F.S. Campbell, Professor Harimurti Martojo, Dr. J.J. Lynch, Dr. G. McCrabb, Dr. K.L. MacMillan, Dr. R. Payne, Dr. S.P. Rajasingham and Dr. D. Stoltz. We wish to thank Dr John Hecker who read the entire manuscript, pointed out some glaring mistakes and made numerous useful suggestions which have been incorporated into the text.

We thank Dr Evangelos Derviniotis for promoting this book and

Mr Bill Gresham for the cover design. We wish to thank Mrs Meryl Wilson for help with editing and proof-reading.

We want to thank Ibu Sri Budyarti, who cheerfully typed numerous drafts in bad writing and with illegible editorial corrections, as well as doing capably the formatting and much of the proof-reading. Finally, we wish to thank Ibu Henny Nailiu and Pak Yoyok Agoes Firmanto for ably formatting and typing the updated final copy.

We dedicate this book to the hard-working smallholder farmers in the humid tropics. May their work become easier and more pleasant, may they prosper and increase their income from goats and sheep. We also dedicate it to our fellow research workers in this field who will fill-in gaps in our knowledge in the future.

To small ruminant production in the humid tropics!

Editors
Manika Wodzicka-Tomaszewska
A. Djajanegara
Susan Gardiner
I M. Mastika
T.R. Wiradarya

CHAPTER I
GOATS AND SHEEP IN ASIA

C. Devendra*

INTRODUCTION

Goats and sheep in Asia are discussed in this Chapter with reference to their origin, classification, size, changes in their relative populations, available genetic resources, productivity, economic importance, significance of ownership, production systems, comparative feeding and nutrition as well as strategies for development. The importance of these aspects is reflected in the fact that goats and sheep in the region account for about 51 percent and 21 percent of the total world population respectively, and include over 60 potentially important indigenous breeds useful for a variety of functions. Currently, the goat population is growing faster than that of sheep. Analysis of output and demand for meat suggests that the gap between the two is widening. Considerable opportunities exist for increasing productivity of both species, especially through improved and more efficient systems of feeding and management and reduced mortality. The development strategies include clear production objectives, exploiting more fully the avenues of production, definition of

* Senior Program Officer, Division of Agriculture, Food and Nutrition Sciences, International Development Research Centre, Tanglin, Singapore

priorities and continuing research, all year round feeding systems based on available feed resources, improved research-extension linkages, on-farm validation of results and dissemination of appropriate results. The last two aspects merit participatory research with farmers.

Goats and sheep constitute important renewable resources in the Asian region. They are part and parcel of various types of farming systems and the socio-economic life of several million poor people throughout the region: small farmers, peasants and landless agricultural labourers. In this context and in comparison with other ruminant species, goats and sheep are uniquely distributed in all types of agro-ecological conditions throughout Asia: from the high altitude Himalayas, arid and semi-arid areas of Pakistan, India and Mongolia, to the high rainfall, high humidity countries that are characteristic of most parts of South-East Asia.

The various agro-ecological zones are also the reservoirs of variable populations of a bewildering variety of goats and sheep which demonstrate the ability to adapt, survive and reproduce within the existing climatic extremes. In these situations, they perform a number of primary and secondary functions which are extremely important to the small farmers and landless peasants. In many instances, this contribution forms a significant proportion of the total farm income and the stability of farming systems.

It is emphasized at the outset that, despite the value and considerable contribution of both these species to existing farming systems, the average productivity from them is generally low. Considerable possibilities exist therefore for increasing this contribution further, which might be of direct benefit especially to the livelihood and nutrition of poor rural people.

This Chapter addresses various aspects of goat and sheep production, the value of the focus of increased research to promote development, and stresses important development strategies. Attention to these aspects is especially significant in efforts to increase productivity from both species, commensurate with their current and potentially important future economic contribution in the development of sustainable agriculture.

A. ORIGIN AND CLASSIFICATION

The domestication of goats is considered to have occurred in the mountainous area of western Asia some 9,000 to 11,000 years ago[1-5]. The goat is possibly the earliest domesticated animal[6] or at least the next one after the dog[7]. It is generally agreed that domestic goats are mainly descended from the bezoar.

At least six methods of classifying domestic goats have been advocated based on origin, utility, body size, ear shape and ear length. Each of these has its special attributes and limitations. For example, utility is too broad in scope, especially as goats in the tropics are often non-specialized, all-purpose animals. However, country of origin is of some importance in indicating adaptation to a particular climate and environment. Devendra and Burns have classified goats into three categories on the basis of body size[8]. Using height at withers as the criterion, the three groups were: large (over 65 cm), small (51 to 65 cm) and dwarf breeds (under 50 cm). It was found that the large breeds weighed 20 to 63 kg and were mainly dual-purpose in function, small breeds weighed 19 to 37 kg and the very small goats 18 to 25 kg. Goats in the last group were kept exclusively for meat production. Dwarf goats are of two types: achondroplastic and non-achondroplastic. The former occur particularly in the humid tropics to which they are believed to be adapted. More recently, Mason classified goats primarily on horn and ear characteristics, with geographical and functional considerations as supplementary criteria[9].

Sheep also originated in Asia. A total of seven distinct wild forms divided into some 40 varieties have been recognized. Among the wild species which are believed to have contributed to domesticated sheep are the Argali (*Ovis ammon*) of Central Asia, the Urial (*Ovis vignei*) also of Asia, and the Moufflon (*Ovis muimon*) of Asia Minor and Europe. The original centre of domestication seems to have been the Arlo-Caspian Steppe, including the area occupied today by Iran and Iraq. From Asia, sheep spread westward to Europe and Africa, and eastward to the Indian sub-continent, South-East Asia and Oceania.

B. GOAT AND SHEEP POPULATIONS

Table 1 indicates that goats and sheep in Asia and the South Pacific account respectively for 53 percent and 21 percent of the total world population of these species. Within these areas, the corresponding figures for the goat and sheep populations in China were 13.4 percent and 8.6 percent. The ratio of sheep to goats is about 1 : 1. The rates of growth of the individual species over the last 10 years from 1980 to 1990 were 2.0 percent and 0.9 percent for goats and sheep respectively, indicating that the goat population is growing faster than the sheep population in Asia and the South Pacific.

Table 1. The goat and sheep resources of Asia and the South Pacific region[10].

Species	Population (million)	As % of total world population*	(%) Rate of growth/yr (1980-1990)	As % of total grazing ruminants in Asia**
Goats	294.4	52.9	2.0	24.4
Sheep	254.4	21.3	0.9	22.3

* Goats - 556 million and sheep - 1194 million

** Buffalo + cattle + goats + sheep

C. BREEDS

Asia is a very important reservoir of widely different and well adapted indigenous goat and sheep breeds. They are very diverse and classification is not easy, especially since there has been considerable crossbreeding between the breeds. The goats are extremely varied, and are concentrated mainly in the north-east and the north-west in the Ganges and along the Himalayas, throughout the Sind and the Punjab and in the mountain valleys of Baluchistan and around Kashmir. Although there is a diversity of breeds and types of goats, there are certain external features which are prominent. Black is a dominant colour and horns, where present are usually scimitar-shaped. Drawings of scimitar-horned goats have been found in vase

fragments near Baghdad going back to about 3000 B.C., and ceramic art involving goats around 1000 B.C. is known to be associated with the Indus civilization and the Chalcolithic cultures of Central India. Reference is also made to a description of breeds of goats and sheep in China[11, 12].

Table 2 identifies the more important indigenous goat breeds in Asia with reference to such specialized attributes as milk, meat, prolificacy, cashmere, pashmina and skin production. These breeds either have potential 'mprover' capacity and have above average productivity in one way or other, or they are specially adapted to a particular environment. A total of about 50 important indigenous breeds is identified which are worthy of more research and development.

Table 3 lists the more important indigenous sheep breeds in Asia with reference to mutton, milk, fine wool, carpet wool and prolificacy. A total of 16 important indigenous breeds is identified.

Tables 2 and 3 are not exhaustive, simply because of lack of more complete information. It is quite likely that many more potentially important goat and sheep breeds present in Asia are also worthy of more investigation and documentation.

Fig. 1 illustrates a Javanese Fat-tailed sheep in Indonesia, and Fig. 2 shows four `improver' Indian goat breeds.

D. PRODUCTIVITY

Table 4 summarizes the amounts of the different types of products from each species in Asia and the South Pacific. Goats produced approximately 53 percent of the goat meat and sheep 17 percent of mutton and lamb as percentages of total world production of these kinds of meat. Corresponding contributions for milk were 32 percent and 11 percent for goats and sheep respectively as percentages of total world production.

Table 2. Important indigenous goat breeds in Asia.

Speciality	Country	Breed
I) Medium milk yield	India	Beetal and Jamnapari
	Pakistan	Damani, Dera Din Panah, Kamori
II) Meat	Bangladesh	Black Bengal
	China	Banjiao, Chengdu Ma, Du An, Fuquing, Guizbou White, Haimen, Huai, Leizhou, Longlin, Ma'Tou, Shanxi White
	India	Barbari, Black Bengal, Cutchi, Ganjam, Khasi (Assam Hill goat), Malabari, Marwari, Osmanabadi, Sangamaneri, Sirohi (DP)*
	Nepal	Changra, Khari, Sinhal, Terai
	Pakistan	Barbari (DP, 'Barri'), Bengal (Teddy), Bugri, Chappar (DP), Damani, Jattan (DP), Kacchan (DP), Kaghani, Kail, Lehri, Patteri, Topri
	Sri Lanka	Kotukachchiya
	Thailand, Malaysia, Indonesia and Philippines	Katjang (or Kacang)
III) Prolificacy	Bangladesh, Pakistan	Black Bengal
	China	Ma' Tou
	India	Barbari, Black Bengal
	Malaysia	Kacang
	Indonesia	Etawah
IV) Pashmina (Cashmere)	China	Liaoning
	India	Kashmiri
V) Skins	Bangladesh, India and Pakistan	Black Bengal

* Means dual-purpose (meat and milk)

Table 3. Important indigenous sheep breeds in Asia.

Speciality	Country	Breed
I) Mutton	India	Mandya, Muzzafarnagri, Balkhi, Rakshani, Kaghani, Dumbi
II) Milk	Pakistan	Damani
III) Fine wool	India	Chokla
IV) Carpet wool	India Pakistan	Magra, Marwari Baluchi, Buchi
V) Prolificacy	China Bangladesh Indonesia	Hu Bangladeshi Javanese Thin-tail Javanese Fat-tail

Table 4. Productivity of goats and sheep in Asia and the South Pacific (1990)[10].

Species	Meat (10^3 tonnes)	Milk (10^3 tonnes)	Wool, greasy (tonnes)	Skins, fresh (tonnes)
Goats	1476	2835	-	256.6
Sheep	1316	1341	357.7	223.3

Turning to wool production, sheep in this region produced about nine percent of the total world production of greasy wool. Fresh skins are an important by-product of goat and sheep production and the extent of the contribution as percentages of total world production were 58 percent and 19 percent respectively.

The meat production of both species is inadequate to meet current demands. Thus, considerable opportunities exist for increasing the current level of supply. With specific reference to goat meat, an analysis of past and projected trends suggests the following conclusions[13]:

Fig. 1 Photograph of an East Javanese Fat-tail sheep in Indonesia.

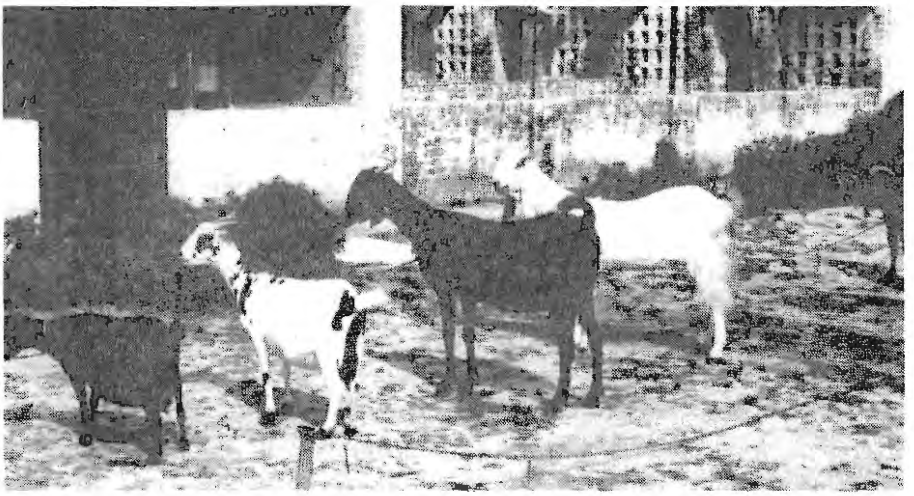

Fig. 2 Photograph of four 'improver' Indian goat breeds: Black Bengal, Barbari, Beetal and Jamnapari (from left to right).

- Inadequate supplies of goat meat have resulted in a trend towards the increased price per unit of goat meat relative to all other meats. This is reflected in many countries, especially in South-East Asia[14].
- There have been increased imports of feral goat meat notably from Australia and New Zealand to markets in the Middle East and the West Indies.
- The high price of goat meat has encouraged unscrupulous substitution with imported mutton from poorer quality sheep.
- Inadequate supplies of goat meat have also resulted in the increased price of live goats, including breeding animals.
- The demand for goat meat has encouraged increased slaughter of breeding animals with a consequent erosion of the base population in quantitative and qualitative terms.
- The reduced availability of improved breeding animals has also resulted in some countries shifting from goat to sheep production.

Self-sufficiency ratios calculated on assumptions concerning population growth, trends in *per capita* income, income elasticity of demand and projected consumption of meat in 1990 and 2000, including detailed analyses of projected production and demand for all meats, suggest that the trend will be towards a widening gap between production and demand[15]. Table 5 indicates that the self-sufficiency ratios for meat and milk are lowest in North Africa/Middle East and Sub-Saharan Africa, followed by Asia and Latin America.

E. SIGNIFICANCE OF OWNERSHIP

Goats and sheep are raised with several objectives to serve the material, cultural and recreational needs of farmers. The advantages of keeping goats and sheep are outlined below[8, 16]:

- Income: small ruminants are an important means of earning supplementary income.
- Food: goats and sheep provide animal protein (milk and meat) that is important for the nutritional wellbeing of peasants.
- Security: they are sources of investment, security and stability.

Table 5. Percentage of self-sufficiency of livestock products by region, 1961-1965 and 1973-1977 averages and projections to 1990 and 2000[15].

Product/Period	Asia	North Africa/ Middle East	Sub-Saharan Africa	Latin America
Meat*				
1961-65	97	95	103	112
1973-77	94	89	103	108
1990	73	62	77	96
2000	61	52	57	91
Milk**				
1961-65	94	94	91	92
1973-77	93	87	82	92
1990	79	67	53	91
2000	71	57	38	96

* Includes beef, veal, buffalo meat, mutton and goat, pig and poultry meat

** Includes cattle, buffalo, goat, sheep, camel and milk products (expressed as whole milk equivalents)

- Employment: they create employment including effective utilization of unpaid family labour.
- Fertilizer: they contribute to farm fertility by the return of dung and urine to the soil for crops.
- By-product utilization: they enable economic utilization of non-marketable crop residues converting them to useful animal products (meat, milk, fibre and skins).
- Social values: the ownership of animals has been shown to increase cohesiveness in village activities.
- Recreation: the socio-economic impact of animal ownership also includes a recreational contribution to small farmers, for example in Indonesia the fighting rams of Garut provide entertainment in the village.

F. SOCIO-ECONOMIC SIGNIFICANCE

The socio-economic importance of rearing goats and sheep is reflected in a study of rural households in West Java, Indonesia, where up to 30 percent of the farmers reared goats or sheep[17]. The contribution to the total farming income is substantial, and was about 17, 26 and 14 percent for the three categories of lowland, rubber plantation and upland areas respectively (Table 6); these increased as the farmer's resource base, especially land, decreased.

Table 6. Estimated share of income from small ruminants as percentage of total farm income in West Java[17].

Location	No. of farms surveyed	Annual income per farm (1980) (Rp)	Small ruminant total income (Rp)	% total income
Cirebon (lowland)	79	220,000	37,593	17
Ciburuy (rubber plantations)	66	180,000	46,671	26
Garut (upland)	135	300,000	41,466	14

In South Asia, several studies have been reported which clearly show that rearing small ruminants is a remunerative proposition[18, 19]. Of particular significance is the fact that both species are usually owned by poor farmers and landless agricultural labourers to whom ownership of these animals often provides the main source of livelihood. In South Asia, small ruminants often provide the sole source of income for the landless. It has been reported that marginal and poor farmers are unable to maintain either buffalo or cattle because of the high initial investment involved. On the other hand, they are able to rear dairy goats. Analysis of the economics of milk production between goats and buffalo showed that the returns to investment were higher in goats, which further supports their ownership by poor people[20].

The economics of goat keeping have been studied in Punjab, one of the states in India from where the Beetal breed originates. The analysis of small (five to nine head), medium (nine to 16 head) and large flocks (> 16 head) indicated that the gross income per goat was highest for the small flock in the plains region, probably because these were managed better, and that for the hilly regions, the net income was higher for the bigger flocks. Table 7 presents the sources and extent of the income from rearing goats in the two regions. Of the sources of income, milk gave the largest percentage (74 to 77 percent), followed by the sale of animals (21 to 24 percent) and finally income from the production of manure was two to three percent[21]. More recently, the magnitude of the annual economic contribution of goats in India in terms of products and by-products has been estimated to be 1.6 US billion dollars in which skins and offal and meat contributed 7 and 79 percent respectively[22].

Table 7. Income from rearing goats in the Punjab, India (Rs).*

Size of flock	Sources of income			Gross income	Gross income/goat
	Milk	Animals	Manure		
Hilly region					
Small	1891	852	95	2838	415
Medium	3084	1407	139	4630	388
Large	8927	1400	195	10522	328
Average**	**3387**	**1088**	**125**	**4600**	**354**
	(73.6%)	**(23.7%)**	**(2.7%)**	**(100.0%)**	
Plains region					
Small	3730	1387	28	5117	686
Medium	5822	1688	102	7612	585
Large	8946	1837	3358	11120	401
Average**	**5871**	**1636**	**146**	**7655**	**521**
	(76.6%)	**(21.4%)**	**(2.0%)**	**(100.0%)**	

* Adapted from[21]

** Less variable costs

In China, similar limited data exist concerning intensively cultivated upland areas in the Sichuan province involving wheat-barley-rape-rice cropping systems where dairy goats and pigs are commonly reared by farmers. In these situations, it has been estimated that the income generated from all these animals was 29 percent of the total farm income, of which pigs contributed 19 percent and goats ten percent. The goats in particular were associated with the poorer farming families.

G. PRODUCTION SYSTEMS

Small ruminant production systems in Asia have persisted together with the overall patterns of crop production and farming systems. They are especially dependent on the agro-ecological environment and because of the ruminant digestive system, must always depend on high fibre vegetation or crop residues for their feed base.

Table 8 attempts to bring together types and characteristics of predominant farming systems involving goats and sheep in Asia. This Table identifies the cropping patterns (wheat, rice, maize or a combination of these, coconuts, oil palm and rubber), including mixed cropping, type of ruminants reared, production objectives and also gives approximate sizes of goat and sheep flocks. The latter are variable and partly dependent on the nature and extent of the crop residues produced. The last column in Table 8 gives an indication of the current importance of goats and sheep in each of the main systems, based on average ownership by small farmers, landless labourers and peasants.

Small ruminant production systems have recently been discussed at several international meetings and fall within three categories[23]:

1) Extensive systems
2) Systems combining arable cropping
   i) Roadside, communal and arable grazing systems
   ii) Tethering
   iii) Cut-and-carry feeding
3) Systems integrated with tree cropping.

Table 8. Types and characteristics of farming systems involving small ruminants in Asia[22].

Main type of farming system	Cropping pattern	Type of ruminants*	Small ruminant production	Average size of goat and sheep flock*	Current importance*
Crops**	Rice	B,C	Goat meat/mutton	1 - 5	Low
Crops	Mixed, rice-maize	C,B,G,S***	Goat meat/mutton	1 - 5	Low
Crops	Mixed, rice-wheat	C,B,G,S	Goat meat/mutton/milk	10 - 30	Medium/low
Crops	Mixed rice	B,C,G,S	Goat meat/mutton	1 - 5	Low
Crops	Wheat	C,B	Goat meat/mutton/milk	10 - 30	Medium/low
Crops	Wheat-rice	C,B	Goat meat/mutton	10 - 30	Medium/low
Crops	Coconuts	G,S	Goat meat/mutton	10 - 40	Medium/low
Crops	Oil palm	B,G,S	Goat meat/mutton	8 - 30	Medium/low
Crops	Rubber	C,G,S	Goat meat/mutton	8 - 30	Medium/low

* Based on average ownership by small farmers, landless labourers and peasants

** Refers to root crops, oil seeds, cash crops, vegetables and also other fodders

*** B = buffalo, C = cattle, G = goats, S = sheep

I. EXTENSIVE SYSTEMS

This system is the most common system and applies to all types of ruminants in the Asian region. It is characterized by small ruminants, usually owned by smallholder farmers, grazing on all available grazing areas, largely uncultivated, including marginal land, for varying periods during the day. Fig. 3 illustrates this system in Pakistan. The length of the grazing period is dictated primarily by the type of ruminant and the objectives of production, i.e. meat or milk.

The system has certain very definite features. Rearing ruminants is secondary to crop production, consistent with the pattern of agriculture. Usually, more animals tend to be carried than in the intensive system, probably because these animals have access to plenty of grazing land. Buffalo and cattle tend to be grazed separately, but where goats and sheep are reared, these small ruminants are grazed together, probably because goats tend to lead the herd. Additionally, the small ruminants tend to be herded over longer distances compared with buffalo and cattle, which are relatively more sedentary.

Fig. 3 Photograph showing extensive system of grazing of goats on marginal land in Sind, Pakistan.

The flock sizes are often larger (up to fifteen head) and animals, often goats and sheep belonging to several owners, are run together and brought back in the evening. Stocking rates are usually in the range of one to four head/ha. Very extensive systems are rare in the humid tropics, probably because of the availability of more forage and crop residues and use of most land for food crops.

An additional feature of this system is the use of a high level of unpaid family labour, in which women and children are usually involved. The involvement of women and children in rearing small ruminants is very common throughout the Asian region. The extent of this gender component is often underestimated and justifies more development attention. In Indonesia, women are very much involved in decision making concerning small ruminants in mixed farms[24]. Fig.

4 illustrates a common situation in West Java illustrating the involvement of women in small ruminant production. The contribution by women and children represents an aspect of effective labour use whereby both cropping and rearing of ruminants represent important components of farm income. Except for the use of this high labour input, the system is principally one of low resource use, and a generally low level of productivity emerges from substandard nutritional management where very little or no concentrates, salt, or mineral licks are provided.

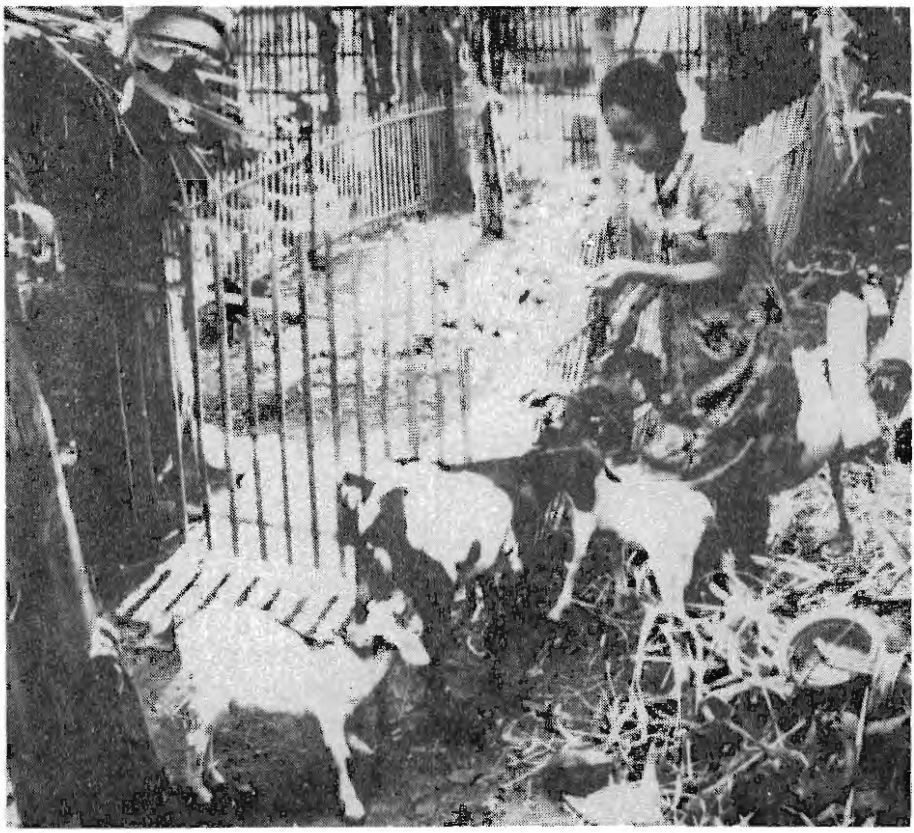

Fig. 4 Women are significantly involved in small ruminant production and management as seen in this photograph in West Java.

II. SYSTEMS COMBINED WITH ARABLE CROPPING

Ruminant production systems combining arable cropping have evolved in situations where crop production plays an important contribution to the stability of the system. Animals do not compete for the same land and play a supplementary role to arable cropping. Three types of systems are common: roadside; communal and stubble grazing; tethering; and cut-and-carry feeding.

The three systems are not mutually exclusive. Grazing on roadsides and on communal (waste) land may be practised by landless stock owners as well as others when their privately owned lands are under arable crop cultivation. Grazing in rice fields is restricted to periods immediately after harvest when the feeds available consist of the aftermath of the rice crop (i.e. rice stubble and some regrowth from the stubble), any weeds that grow in the paddies, the grasses that are found on paddy bunds, and browse from shrubs and trees that grow in these areas. Where multiple cropping is practised, the crop aftermath may be burnt after the harvest and stubble grazing may be severely restricted or non-existent.

Tethering is adopted when there is a need to prevent animals from wandering into areas being cropped and to ensure that they graze down the available feed in a given area before they are moved. This type of confinement feeding is most popular in South-East Asia because multiple cropping is widespread in this region. The animals may be tethered on waste grazing areas close to the farm, or on rice fields after harvest to regulate stubble grazing or close to stacks of rice straw to allow self-feeding.

In the cut-and-carry system, a large proportion of the feed is usually brought in from outside the holding area because of the small size of holdings in relation to the number of animals kept. This system is subject to the vagaries of seasonal abundance and shortage of forage that characterize it. Because the livestock is housed most of the time, their growing dependence on high-priced concentrate feeds during lean periods may increase.

The system has had limited success because of the value of arable land for food production. This also presents a constraint to forage production for animals. The emphasis on crop production,

however, makes large quantities of crop residues available, which are valuable as feeds, especially to ruminants.

The cut-and-carry or stall-feeding system requires high labour and capital investment. Bamboo and other local materials are cheap, but not durable. It is a system that favours situations where there is no land or, more particularly, where abundant supplies of crop residues and agro-industrial by-products are available. Probably because of the higher capital investment, it has not been adequately used as a system.

III. SYSTEMS INTEGRATED WITH TREE CROPPING

Systems integrated with tree cropping are especially common in the humid and subhumid regions where there is intensive tree-crop production. Although the system is not new, integration with these tree crops to ensure more complete utilization of the land has not been given adequate attention. The advantages of the system are:

- availability of shade for the animals. Presence of shade reduces heat stress
- increased fertility of the land through the return of dung/urine
- increased quality of feed for small ruminants
- control of weed herbage growth
- reduced use of weedicides
- reduced fertilizer wastage
- easier management of the crop, and
- distinct possibilities for increases in crop yields, consistent with greater economic gains including sale of animals and their products.

Abundant shade offered by the trees is an important advantage inherent in the system. This creates an environment that reduces heat stress in grazing animals and is likely to be critical especially for imported animals from temperate countries. Fig. 5 illustrates a system of sheep production integrated into rubber plantations in Malaysia.

Fig. 5 Photograph showing sheep integrated with rubber plantations in Malaysia.

The potential for this kind of activity is reflected in an estimated area of 20.3 X 10^6 ha under tree crops in South and South-East Asia[25]. Many of the Pacific island territories, notably Papua New Guinea, New Hebrides, Fiji, the Solomon Islands, and Western Samoa, have large land areas under coconuts, implying that there is much potential for integrating goats or sheep into them[26].

It is suggested that the prevailing ruminant production systems are unlikely to change in the foreseeable future. Major shifts in resource use would be difficult unless returns from the new proposed system were likely to be demonstrably superior. Changes must, therefore, be introduced gradually and must ensure income stability and low risk. The principal aim should be to make maximum use of the basic feed resources available, which are essentially crop residues or low-quality roughages or both. In addition, delivery systems should be developed for the supplementary feeds (leguminous forages, agro-industrial by-products, or other feed concentrates).

H. FEEDING AND NUTRITION

Of the factors affecting productivity in both species, feeding and nutrition represent the principal constraint. Efficient feeding and nutrition, more than any other factors, are the most important means for increasing productivity. Efficiency in this case implies not only achieving the biological limits of production for a particular purpose (meat, milk, fibre or skin), but also the use of different inputs within a system to derive the product output, so that it is compatible with economic production.

The efficiency of goat and sheep production depends to a large extent on the type of feeding system, the level of feeding management and the availability of nutrients for high production. The importance of all three aspects in controlled management for high production cannot be over-emphasized. The components of quality, quantity and appropriate systems of management are involved together, and the application of these concepts in recent years has demonstrated quite forcefully, the impact of nutrition in stimulating high productivity.

There are two related issues concerning feeding systems and productivity. One is the need for accelerated lambing/kidding development in the prevailing challenging situation in which the demand for goat meat especially far outweighs supplies, partly because of the tremendous export potential of the Middle East markets. The second issue which needs to be kept in perspective is the fact that smallholder farming systems constitute the pivot of traditional agriculture, and the key elements in this type of farming are production for subsistence rather than for sale, low income and illiteracy. Within the small farm scenario involving mixed cropping and animal-based systems, goats and sheep play an important role, and their socio-economic contribution is more significant than is commonly realized. The fact remains however, that inadequate nutrition, consistent with a low level of production, remains a conspicuous feature of production in the Asian region[16].

It is especially important in addressing efficient utilization of the available breeds with a view to increasing productivity from them, to recognize that goats and sheep do have differences that are characteristic of the species. The differences relate to feeding behaviour, aspects of digestive function and utilization of nutrients.

Many of these features, and especially the aspects related to digestive physiology are not well understood. The differences are nevertheless sufficient to warrant a different set of nutrient requirement standards for goats compared with sheep[27]. Similarly, the differences in feeding behaviour and utilization of nutrients suggest that, although they may be herded together for grazing, management and feeding, strategies need to take cognisance of the apparent and real differences in order to ensure high performance in both species.

Table 9 brings together comparative differences in feeding behaviour and nutrition, based on available knowledge. Some 16 main differences are identifiable, but these are by no means exhaustive nor meant to be complete. This Table does list, however, the main differences, both inherent, and in response to environmental factors.

A number of differences are worth emphasizing. These include in the goat, the bi-pedal stance[28], relatively higher activity and a distinctly greater preference for a greater variety of herbage, though the last is reduced with increasing intensification. Under stall-feeding conditions, goats and sheep are also selective, but the former has a greater intake of roughages[29]. Other differences are related to taste, water economy, dehydration, salivary secretion, recycling of urea and digestive efficiency.

Goats are essentially browsing animals and, by comparison, sheep are grazing animals. Goats have a competitive advantage over sheep in woodland and shrubland, are generally more active, selective, walk longer distances in search of feed and relish variety in feeds[30, 31]. Thus they are natural leaders of mixed goat and sheep flocks in many developing countries. Sheep are less selective and utilize pasture more effectively. Another feature of the feeding behaviour of goats is their discerning taste-preferences for particular feeds.

In cognisance of these species' characteristics and the objective of ensuring high performance from both species, every effort must be made to improve the current level of feeding and management. The advantage of doing so is reflected in reports of potential improvements in goats[32, 33] and sheep[34]. Table 10 demonstrates one example of this concerning the effects of improved nutritional management of Kacang (or Katjang) goats from experimental stations compared with village

Table 9. Comparative feeding behaviour and digestive physiology in goats and sheep[28].

Characteristics		Goats	Sheep
1.	Activity	Bipedal stance and walk longer distances	Walk shorter distances
2.	Feeding pattern	Browser, more selective	Grazer, less selective
3.	Browse and tree leaves	Relished	Less relished
4.	Variety in feeds	Greater preference	Smaller preference
5.	Taste sensation	More discerning	Less discerning
6.	Salivary secretion rate	Greater	Moderate
7.	Recycling of urea in saliva	Greater	Less
8.	Dry matter intake:		
	- for meat	3% bodyweight (BW)	3% (BW)
	- for lactation	4-6% (BW)	3% (BW)
9.	Digestive efficiency of coarse roughages	More efficient	Less efficient
10.	Retention time	Longer	Shorter
11.	Water intake/unit dry matter intake	Lower	Higher
12.	Rumen NH_3 concentration	Higher	Lower
13.	Water economy	More efficient	Less efficient
	- turnover rate	- lower	- higher
14.	Fat mobilization increased during periods of feed shortages	More evident	Less evident
15.	Dehydration		
	- faeces	Less water loss	Relatively high water loss
	- urine	More concentrated	Less concentrated
16.	Tannins	More tolerance	Less tolerance

animals. Of the parameters measured, liveweight at slaughter, hot carcass weight, dressing percentage, weight of meat and total saleable weight were improved by 54, 79, 7, 47 and 34 percent respectively. Possibilities of significantly improving performance through the use of leguminous forage supplements in both goats and sheep have recently been reviewed[35].

Table 10. Magnitude of improvement feasible in indigenous Kacang goats from rural areas due to improved nutritional management in Malaysia.*

Parameter	Rural goats**	Experimental goats** (%)	Improvement feasible (%)
Liveweight at slaughter (kg)	18.6	28.6	54
Hot carcass weight (kg)	8.2	14.7	79
Dressing (%)	44.2	51.3	7
Weight of meat (kg)	5.5	8.1	47
Meat: bone ratio	4.1	4.9	20
Forequarter (kg)	1.2	2.9	108
Hind leg (kg)	1.2	2.2	83
Total edible weight (kg)	13.2	18.2	37
Total saleable weight (kg)	17.9	24.0	34

* Adapted from[14]
** Adult goats approximately three years of age

I. HEALTH AND DISEASES

Both goats and sheep are affected by a variety of diseases, the extent of which is dictated by the level of management as well as the agro-ecological environment.

In Indonesia, for example, Purnomo and Wilson classified diseases of small ruminants into three categories as follows[36]:

1) diseases of significance in suggested order of economic importance;

2) diseases known to occur and
3) diseases of other livestock involving small ruminants as carriers.

Such a classification applies equally to most other countries in the Asian region. In terms of losses of economic significance, there are two main categories. The first involves the combined losses at birth and up to weaning which can account for as much as 30 to 35 percent losses or even more. Kids are particularly susceptible to respiratory disorders of which pneumonia is very common.

The second major source of loss is gastro-intestinal parasitism in both species, with infection due to a complex of nematode parasites of which *Haemonchus* is most common. The annual cost of haemonchosis to the small ruminant industry in Indonesia is estimated at around US $16 million[36]. Regular drenching strategies are therefore most important to reduce the effects of, and magnitude of losses, due to gastro-intestinal parasites. These preventive measures necessitate the use of several anthelmintics to offset development of resistance to the active ingredient. However, smallholders usually cannot afford anthelmintics. In view of this reason, there is a place for the development of traditional medicines for use as drenches and also against external parasites. Farmers do indeed resort to these, but these methods presently remain inadequately studied. A program of evaluation of cheap traditional medicines from local plants is warranted.

Associated with the need for good management is the need to ensure that these animals are adequately fed in such a manner that the daily intake of nutrients matches their maintenance and production requirements. Failure to do so reduces the condition and health of the animals, therefore increasing the susceptibility to diseases.

J. SMALL RUMINANTS AND THE DEVELOPMENT OF SUSTAINABLE AGRICULTURE

An important contribution of small ruminants, especially in integrated systems, is the development of sustainable agriculture [37].

This concerns their valuable role in crop-animal and agro-forestry systems, and one which is evident in many parts of South-

East Asia within two prevailing production systems: systems combining arable cropping and systems integrated with tree cropping.

Evidence for this is seen on the results of two sets of data from Indonesia and one from Malaysia:

I. BALI, INDONESIA

In this dryland farming system in the drier parts of Bali, availability of feeds is a major constraint for ruminants. This led to the successful development of the Three Strata Forage System by Nitis and his colleagues involving grasses and ground legumes (first stratum), shrub and legumes (second stratum) and fodder trees (third stratum). Bali cattle and goats are used to harvest the residues of the cash crop and the other fodders in the system[38]. Over eight years of effort, the project demonstrated increased forage biomass production, higher stocking rates and animal performance, increased fuelwood supply, reduced soil erosion and increased income for farmers[38]. The data also showed that integrating goats with cattle further increased income. Fig. 6 illustrates the Three Strata Forage System in Bali, Indonesia.

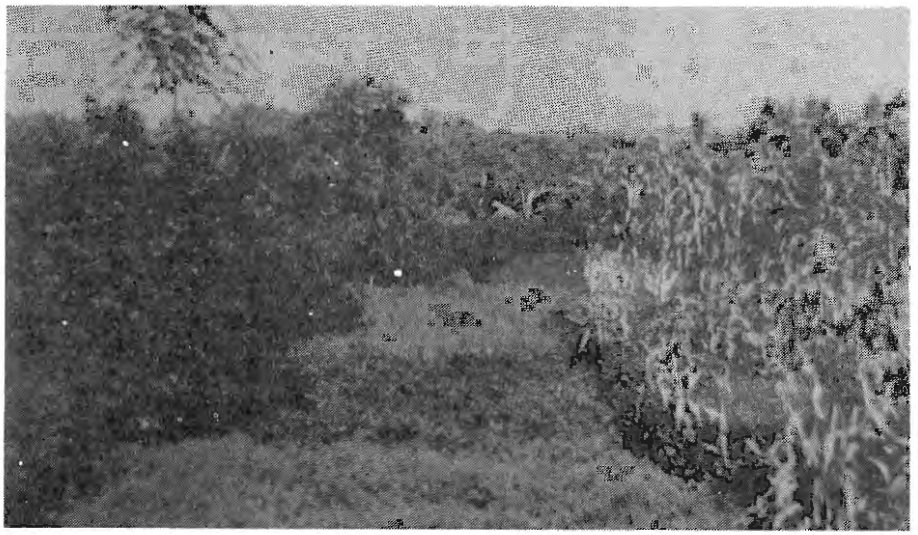

Fig. 6 A photograph of the Three Strata Forage System in Bali, Indonesia (by courtesy I M Nitis); right to left cash crop; shrub and legumes and fodder trees.

II. SUMATRA, INDONESIA

Likewise in Indonesia, Table 11 reflects the value of integrated crop-animal systems in transmigration schemes in Batumarta, Sumatra. It is quite clear from this Table that animals significantly contributed to the development of a sustainable crop animal system.

III. MALAYSIA

In Malaysia, integrating goats and cattle with oil palm cultivation to utilise the herbage undergrowth indicated that, compared to the ungrazed area, this process was advantageous in terms of increased yield of fresh fruit bunches and total economic benefit[26]. The latter aspect is clearly linked to increased sustainability of the system.

Table 11. Economic impact of crop-animal systems in transmigration schemes Batumarta, Sumatra, Indonesia[39].

Farming Systems	US$/ha/year	Contribution to income
Model A	1,230	Rubber - 53 %
Model C	2,055	Food crops - 30 %
Net gain	825	Animals - 17 %

Model A - Farmer's existing system without animals
Model C - Introduced farming system with animals (1 cow + 3 goats + 11 chickens)
1 US$ = 2060 Indonesian rupiah (approx)

K. DEVELOPMENT STRATEGIES

There are a number of important development strategies that are worthy of attention. These include clear production objectives, developing the avenues of production that are consistent with sustainability, continuing research and validation of research results.

I. CLEAR PRODUCTION OBJECTIVES

It is important to decide on clear objectives which are outlined in Table 12. They include improvements in quantity as well as quality of products from small ruminants.

II. DEVELOPING THE AVENUES OF PRODUCTION

The prevailing avenues of production need to be examined critically and exhaustively. Priority should be given to the development of production systems that integrate goats or sheep with mixed cropping, especially in smallholder farm systems. It is essential in this task to use appropriate breed(s) and choose these in relation to production objectives, suitability for a given agro-ecological environment and the development of sustainable agriculture.

III. CONTINUING RESEARCH

Continuing research is vital to sustain and stimulate increased production from goats and sheep. There should be a clearer focus on breed characteristics, genetic potential, feed resources, feeding and nutrition, physiology, breeding and genetics, improved management practices, prevention and control of disease, carcass quality and processing. Research priorities are essential in which there should be a balance between fundamental and applied research.

Much of the current research is not participatory, holistic or multidisciplinary, but these efforts need to be encouraged more vigorously. Research needs to be identified with real problems at the farm level and to include the poor and landless peasants who own goats and sheep.

IV. ON-FARM VALIDATION OF RESULTS

Most research activities within national programs tend to be carried out on experimental stations and are usually intensive in approach, without wider appreciation of farming systems. This tendency needs to be corrected to involve elements of on-farm research (socio-economic surveys and identification of major constraints) from the very commencement of initiating the research.

The value of research results lies in their application and utilization. This is achieved through appropriate extension and validation in real-farm situations, through participatory research with farmers. Practical procedures for conducting on-farm animal research have recently been published[40, 41]. Currently, existing research and extension linkages in most countries are weak and these need to be considerably strengthened.

Table 12. Production objectives for improved quantity and quality of goat and sheep products.

Commodity	To improve quantity (improvement/increase)	To improve quality
Meat (goat meat and mutton)	- Total meat yield per animal - Total amount of lean meat in the carcass - Growth rate - Total number of animals available for slaughter	- Control of the quantity and distribution of fat-excess, undesirable except for some Middle East markets
Milk	- Total yield - Lactation length - Number of lactations	- Control of milk composition (butter-fat and solids-not-fat)
Carpet Wool	- Amount of clean wool	Regulation of the following characteristics by selection (breeding) - Fibre diameter (coarse fibre desirable) - Staple length - Presence of medullated fibres (hair) - Removal of kemp (shed fibres, or those with the medulla occupying 90 % of the diameter) Improved management and quality control to increase the percentage of clean scoured yield.

Attention is drawn to a number of other recommendations for research and development in goats and sheep in three recent proceedings of useful meetings in the Asian region[42, 43, 44].

CONCLUSIONS

Small ruminant production in the Asian region is currently constrained by inadequate and inefficient utilization of the available breeds and need for improved systems of management and production.

The prevailing production systems are unlikely to change in the foreseeable future and, in view of this, more concerted efforts are necessary to improve current feeding patterns and methods, apply more innovative systems of feeding and develop all year-round feeding systems that can maximize the available feed resources. The opportunities for improving this situation are enormous and are clearly associated with potential increases in productivity. These and other approaches need to be considered within the broader context of the search for efficiency in the utilization of the available resources, including goats and sheep within prevailing patterns of farming systems in Asia.

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CHAPTER II
PRESENT MANAGEMENT SYSTEMS

T.D. Chaniago*

INTRODUCTION

Almost all small ruminants in Indonesia are raised by small farmers in villages and are managed in traditional ways. A village, as well as being the home, is also the centre of the social, cultural and economic life of people living in rural areas. The village and the villagers' economy is based on crop production, primarily to provide food for the family in subsistence agriculture, but also to provide some surplus for sale for their cash needs.

The village systems of small ruminant production are subsidiary to food crop production, making use of crop residues and other agricultural waste. In this system, the farmer is an agriculturalist, and livestock constitute a relatively small but nevertheless useful source of income, especially for fulfilling urgent needs. The attention given to the animals is minor since the main task of a farmer is to produce food crops. This type of smallholder management system for small ruminants can be regarded as a feature of most developing countries.

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Java holds 70 percent of the total human population (of about 185 million) in Indonesia on only seven percent of the country's total land area. This crowded island also carries the largest part of the population of small ruminants. This means that little space is available for livestock farming since most arable land is utilized for growing food crops. The bulk of this Chapter refers to conditions pertaining to Java.

Goats and sheep, however, form an important part of the total farming system by providing manure and as a source of cash to buy inputs for the arable system or to meet sudden household needs. For the small and landless farmers, goats and sheep account for a larger proportion of their income. Sociological and economic factors are very important in determining systems for raising goats and sheep, expecially for these smallholder and landless farmers.

Because small ruminants form only a small proportion of the farming enterprise, they are not always sold at the most profitable time. For example, because of the difficulty of obtaining sufficient feed for the animals during the cultivating season and/or lack of time to do so, many farmers sell their stock at a cheaper price and buy again after harvesting time at a higher price, thus losing money. Unexpected emergencies or celebrations (such as funerals, weddings or circumcisions) or larger regular expenditure (such as school fees) may necessitate sales of small ruminants at times which may be inappropriate for biological or economic reasons.

This Chapter contains few references. This is because within the smallholder system, management practices are passed by word-of-mouth from generation to generation and few controlled experiments have been carried out in the area of management of the small ruminant part of the farming enterprise.

A. DESCRIPTION OF VILLAGE

The village generally refers to a group of abodes in rural areas. It contains many households which may be scattered, but are more commonly clustered in a group forming a hamlet. There are great variations in terms of size, population and environment of each village. The range of temperature, rainfall and humidity also causes differences in the natural vegetation.The pressure of human population, especially

in Java and Bali on the limited land available for cultivation and crop production greatly reduces the land available for communal grazing areas. In the past, many villages had communal grazing areas but now very few are left.

Almost without exception, the villagers are involved in, or associated with, farming crops. The slash-and-burn or shifting cultivation system represents another variation of crop farming in Sumatra, Kalimantan and Irian Jaya. Usually two or more animal species are reared by a farmer, such as native chickens, ducks, goats, sheep or large ruminants to meet domestic requirements, to provide cash and to spread the risk of losses. In most cases, chickens are numerically the largest, followed by small ruminants. The number of small ruminants kept by each farmer varies and is relatively small, being in the range of two to ten animals per family. Continuous extension of cultivation for food crops is reducing not only the available grazing areas near the village, but also areas for collecting feed for the cut-and-carry systems.

B. HUSBANDRY SYSTEMS

The existing husbandry management systems in tropical countries such as Indonesia are normally the result of hundreds of years of tradition, but they are often inadequate or inefficient partly because of the increasing pressure on land use by expanding human populations. The local goats and sheep have evolved to suit the local environment and can be highly productive in relation to the low inputs involved.

In the humid tropics, goats and sheep are usually kept in small, family flocks under semi-intensive management. In the outer islands of Indonesia, they are commonly grazed or tethered and housed at night, or they are left free to scavenge around the village by day and housed at night. The housing at night is for security so that animals are not stolen. During the crop-growing season, these animals may be kept under the control of children or of village herdsmen. When tethering is practised, it is of course essential to change the place of tethering at least every day, so that enough fresh herbage and a variety of different plants can be obtained by the animal.

Integration with the cropping systems has been practised in varying degrees in many parts of Indonesia. The nature and extent of the integration depends upon the type of crops being grown. Increasing attention is now being given to integrating small ruminants with rubber, coconut and palm-oil trees to utilize the roughage that normally grows under the trees. The advantages of this system are: increased fertility of the land because of the input of faeces and urine, control of weeds by animals, reduced costs for fertilizers as well as the increase in crop yields with concomitantly greater total income.

I. HOUSING OR *KANDANGS*

Before beginning to raise goats or sheep, the building of an animal house or *kandang* for keeping these animals has to be considered. The animal house should not be located either on the windward side of the prevailing wind or on higher ground in relation to the farmer's house. This is to avoid smells from the animals as well as effluent from the faeces and urine converging on the family home. If possible, it should be located, also for hygiene reasons, some distance from the farmer's house.

Housing of animals has traditionally been part of goat and sheep production systems in the humid tropics. Besides security reasons, housing is also provided for management reasons such as the control of animals to prevent damage to crops, ease of feeding and collection of excreta. Besides its effect on thermoregulation, through reduced heat input from solar radiation, the house also affects challenges due to diseases and both these aspects should be considered thoroughly in designing an animal house. In a confined space, diseases and parasites can be transferred easily among animals.

Housing is very important for efficient reproduction, for example during mating, during late pregnancy, at around parturition, during lactation and for rearing of kids or lambs particularly after weaning.

There are several types of animal house to be found within the Indonesian archipelago. In areas where flooding occurs or where there are predators, farmers build animal houses quite high above the ground (up to four metres above ground level). These types of houses are found in the islands of Sumatra and Kalimantan.

In other areas, farmers may keep their goats or sheep under or inside their houses. The farmer's house may be built one to two metres above ground level with the animals directly underneath or the animal barn may be adjacent to the kitchen, utilizing one of its walls. This is however contrary to Department of Health regulations. Animal houses may also be at ground level. The floor of the ground-level type can be made out of rough concrete, or more commonly consists of rammed clay or earth, or feed waste.

The stilted housing type is more commonly used, since in the humid tropics rainfall is heavy and temperatures are high. This type of housing protects the animal from the wet and facilitates easy cleaning and collection of the faeces and urine for fertilizer. The floor usually consists of slats of bamboo or wood, which allow faeces and urine to fall through and provides greater air movement around the animal. The resulting air movement in stilted houses also reduces the effects of high temperatures on animals.

Generally, animal houses can be built very simply and from cheap local materials such as bamboo and other locally-available wood, the roof often being thatched. Because of the high rainfall and temperature in the humid tropics and the sensitivity of animals to wet floors and parasitism, the most practical and suitable house type is one which is elevated from the ground, well ventilated, and has wide eaves to prevent rain from entering from the side.

Most animal houses in the tropics have open sides for better ventilation to remove both sensible heat and humidity (from the animal and its excreta). The roof provides shade from direct sunlight and from rain. A suitable roof is well insulated, has large overhangs, is sloping so that it does not leak, and may have an open ridge to enhance ventilation. The roof should provide effective shelter from heavy rain and high solar radiation. The roof materials can be made of coconut or palm leaves, bladey grass or *alang-alang* (*Imperata cylindrica*), tiles or zinc.

Whatever the material and type of housing it must provide adequate access for light, be well ventilated, well drained and easily cleaned.

1. *Sub-divisions of Animal Houses or Kandangs*

Usually smallholder farmers keep goats and sheep together in one pen (see Fig. 1). This has distinct disadvantages. Firstly, different categories of animals need different qualities and quantities of feed. For example, weaners as well as females in late pregnancy and during lactation need better feed. Of course it is not possible to feed different classes of stock differently, if there is only one pen. Male animals may disturb others. For example, young females may be mated too early, or unsuitable matings occur. Parturient females should be separated from the rest of the flock, so that they can quickly establish the exclusive maternal-offspring bond. This is not possible when all animals are within one enclosure, often resulting in inadequate bonding and insufficient colostrum with consequently high levels of perinatal mortality. These problems in relation to reproductive efficiency and losses are discussed in Chapter VI.

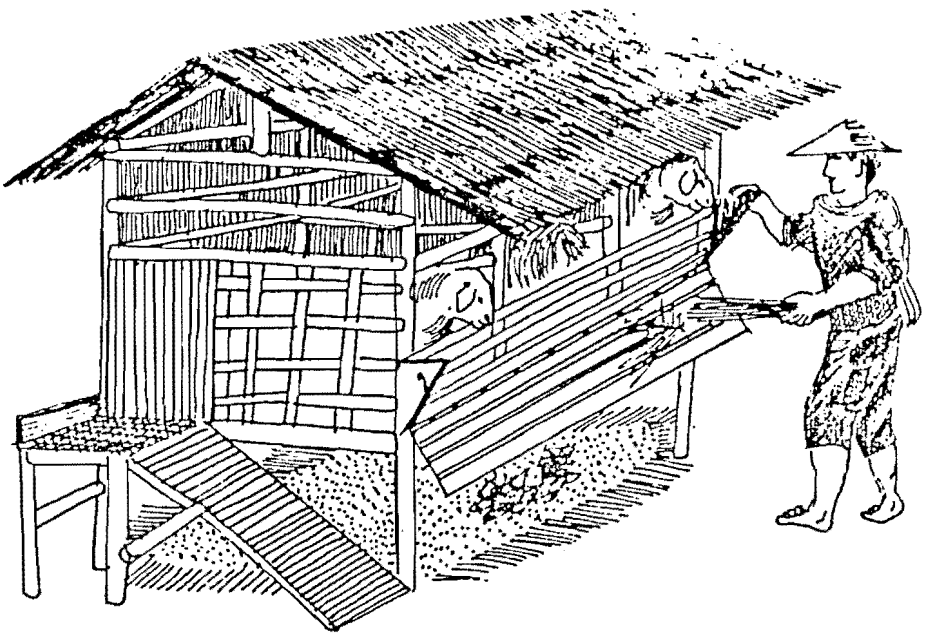

Fig. 1 Traditional house with no sub-division[1]. Note hinged feed trough to facilitate cleaning.

It is suggested that there are four partitions in an animal house: one for the male(s), one for females in late pregnancy and lactation, one for parturient female(s) and one for weaners (see Fig. 2).

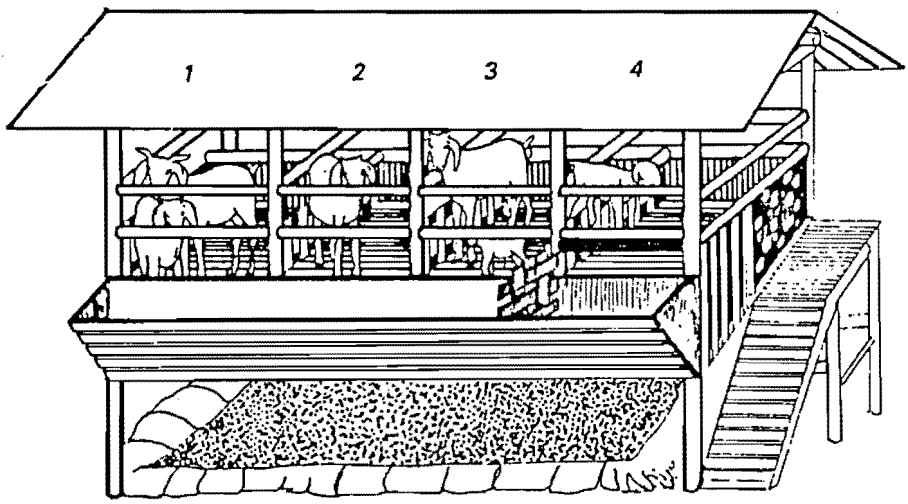

Fig. 2 Sub-division of animal house

1. Male (with females for mating)
2. Pregnant and lactating females
3. Parturient female
4. Young weaners

2. *Manure Handling*

In some areas where farmers grow vegetables, tobacco and pawpaw, manure is a very important by-product of animal production. It improves soil structure and productivity of plants. The faeces of small ruminants consist of relatively dry round pellets which readily fall through the slatted floor. Farmers make a hole underneath to collect faeces. This, plus the residues from the feed, makes valuable compost for improved growth of crops. It is important that animals are not allowed access to feed contaminated by faeces and urine, but that the composting is thorough and long enough to kill the parasites. This aspect is disccussed in Chapter VIII.

II. MATING

Mating management as well as management during parturition and for post-natal survival and growth have been dealt with in detail in Chapter VI on Reproduction. Here only some aspects are dealt with briefly. Farmers prefer keeping female to male animals since each female can rear new offspring whereas one male can mate with a large number of females. Because of this, farmers rarely keep adult male animals. If there is an adult male, it is often kept in a separate pen.

Indonesian small ruminants can breed at any time during the year. Observations have indicated that vigour, stamina and potency of rams are affected by lack of care and proper management. The buck or ram should be well-fed but not over-fat because the latter condition causes losses in *libido* and in dexterity in mating. Being kept permanently in a small pen may depress *libido*.

1. *Age at First Mating*

Although well-fed kids or lambs can be mated at around seven months[2], probably under most village conditions where growth rates are slow, they should not be mated under 12 months of age. In fact many are not mated until 18 months to two years of age. Of course it has to be remembered that the earlier offspring can be produced, the shorter is the growing, unproductive stage of an animal's life. It has not been documented whether too young females have obstetric troubles and whether they are poorer mothers.

2. *Interpartum Intervals*

Under experimental conditions, kidding/lambing intervals in indigenous breeds are on average about 200 days, even in animals that are not well fed (on maintenance diets)[3]. But in fact, *interpartum* intervals in villages are usually at least a year, and sometimes longer. This is almost certainly because females do not meet a male when in oestrus because of the farmer's ignorance or his/her lack of time[4]. This is also discussed in Chapter VI.

III. REARING

1. *Kidding/lambing*

Nutrition during pregnancy is described in Chapter VI. If possible, females should be on a rising plane of nutrition in the last third of pregnancy and separated from the rest of the flock before parturition.

There are no hard data, but the writer believes that there is little human interference during parturition and few obsterical problems. Probably internal examination and manipulation of the fetus would in most cases be unnecessary and would introduce infection.

It is essential to remember that newly-born animals have to drink adequate *colostrum*, since this is their only source of antibodies against diseases, as well as providing energy and acting as a laxative for getting rid of the *meconium*. If doe or ewe *colostrum* is not available, cow *colostrum* can be used. If the neonate is not suckling within three hours of birth, it is necessary to teach it to do so by restraining its mother and directing it to the teat. Otherwise, the suckling instinct will cease within a few hours of birth and it will die. This is however seldom done. There is little interference/help given to the neonate(s) after birth, yet help given to a weak kid/lamb to ensure that first vital drink of *colostrum*, could save many especially in multiple-born litters. Kids and lambs are equipped with only a rudimentary rumen at birth and are therefore unable to digest any quantity of solid high fibre feed. As a result a kid or a lamb must be initially given milk. It begins to nibble at solid food such as grass or concentrate when it is less than a week of age, and this should be encouraged for rumen development. A functional rumen is established by three to four weeks if fibrous food is available from birth or within a few days after birth.

2. *Weaning*

It is reasonable to adopt a system of management which encourages the young to consume the maximum amount of high quality solid feed as soon as possible. However, no kid or lamb should be weaned before it is at least four weeks of age. Farmers generally do not wean early, three months being more usual. Often they allow the young to stay with their dam for six months or more. Weaning enables a farmer to give preferentially better feed to the young if there are

several pens available to separate different groups of animals.

It is advisable to wean kids or lambs by five months. The does or ewes by that time have little if any milk and if the young are separated from their dams they can be given better feed such as rice bran or leguminous leaves. The post-weaning check in growth which is often seen is usually due to inadequate feeding and the effects of internal parasites. Earlier weaning should enable earlier conception *post-partum.*

IV. FEEDING SYSTEMS

Goats have feeding habits which differ from sheep by means of their mobile upper lip and very prehensile tongue[5]. Goats are able to graze on very short grass and to browse on foliage not normally eaten by sheep. Browse and tree leaves are of great importance as feed for goats.

The feeding habits of goats are particularly significant in areas where quantity and quality of feed are low, as they often are in Indonesia. It is said that under such circumstances they meet the basic nutrient requirements for body function better than other species of livestock[6], although experimental evidence is largely lacking in this area.

The range of feeding systems in Indonesian animal husbandry encountered in villages varies depending upon which crops are planted, area, tradition and many other factors. The feeding systems include hand-feeding or cut-and-carry systems, herding, tethering, free-range grazing and combinations of these systems. An important aspect in selection of a particular feeding system is that of traditional rights to use certain areas for grazing and other areas for growing of forage plants. It has been mentioned before that now only some villages have an area of communal grazing where farmers can graze their animals but these are restricted in many locations, whereas access to forage under plantation crops (eg. rubber or palm oil tree) is usually unrestricted. The inclusion of small ruminants in plantations should be encouraged.

1. *Hand-Feeding (Cut-and-Carry) Systems*

Animals are usually kept inside all the time except maybe for mating, bathing or for treatment when sick. This system of

management is generally found in villages with high population densities and intensive cultivation systems. Animals raised under this system generally perform better and are in better body condition than tethered or scavenging animals. This is because with this system it is usually possible to provide the livestock with better quantity and quality of feed and they do not have to spend time and energy walking around looking for feed. However, the quantity and quality of feed offered depends entirely upon the farmers' capability and knowledge of good quality feedstuffs. Also, during times when the farmer is busy with food crops, the quality and quantity of feed harvested probably declines. The health of animals can be more easily watched by the farmer using this system. Usually, water is not supplied to the animals. Animals do not appear to be thirsty because fresh roughage contains a great deal of water, and they may not need it except when the weather is really hot, or when does or ewes are lactating, when water should certainly be supplied. However, it is likely that provision of water and salt improves health and performance of animals.

Animals in pens are fed once, twice or three times daily. Fodder is cut from the harvested paddies, arable land, banks of rivers or sides of irrigation canals, under estate crops, from road sides or from certain other areas and carried by farmers to the animal pens. Hand feeding is practised where grazing areas are limited, but fodder is available for cutting, and/or where local crops are vulnerable to damage through animal grazing. However, hand feeding is often enforced because of shortage of family labour, for herding, or due to tradition, although collecting feed for animals also takes a great deal of time. However, with cut-and-carry systems, the farmer usually brings the feed back when returning from the fields during the day.

2. *Herded Systems*

This management system is more generally used with sheep than with goats because sheep have a stronger flocking instinct. The number of animals in a flock varies widely depending on the area, but usually it is limited to ten to 40 animals. This system can be seen in paddy field areas during the dry season when the fields have not yet been planted, because there is no irrigation water available. When the rainy season comes, farmers start to cultivate the paddy fields and their livestock can only be grazed on roads.

The animals are grazed under the control of a child or herdsman, mainly on communal grazing areas or non-productive land such as fallow rice or other crop land, road sides, river banks or sides of irrigation canals and beneath estate crops. Herding may be practised all year round or for only part of the year.

3. *Tethered Grazing*

The animal is tethered by a rope attached to a pole or peg which enables a small circular area to be grazed with a minimum of labour. It is common in scattered crop lands, on road sides or in Sumatra, Kalimantan and Irian Jaya where greater areas of land are available.

With this system, the access of animals to grasses or leaves can be very limited in term of quality and quantity, so it is necessary to move the animal as frequently as possible, at least once and preferably several times a day. However, pressure of work often prevents the farmers from moving their animals sufficiently often to ensure good nutrition. With this system of raising livestock, the farmers are able to use their time more efficiently for other work. While their livestock are tethered, the farmers can carry out other work including their most important work on paddy fields.

4. *Free-Range Grazing*

In some areas, especially in islands rather than Java, ruminants are allowed to graze and scavenge along road sides, around houses and village surroundings or in fallow lands. This grazing system has a minimum labour demand, although animals have to be rounded up at the end of the day and put in a shed for security reasons.

Livestock with free-range grazing have to walk a distance which may be some kilometres from home looking for roughage. This system of management is found usually in villages in hilly areas where land holdings per family are quite large.

V. OTHER MANAGEMENT PRACTICES

1. *Hoof-trimming*

Hoof-trimming is necessary for animals kept inside as there is insufficient wear and their hoofs can grow too long, resulting in breaks,

injuries and infections. In extreme cases the animal may find it so uncomfortable to stand and walk that it will lie down and not eat sufficient feed. Farmers do not usually trim hoofs.

2. *Culling*

It is important to be able to select animals with skill and judgement for breeding purposes. Selection on appearance alone does not give a true picture of the animal's breeding ability. Culling for the disposal of the inferior members of any breeding flock, whether large or small, should be carried out continuously. Unless this is done, a large percentage of the profits is lost by supplying feed, care as well as time to inefficient stock to maintain them. The best time to select animals is just prior to their being used for mating. The proportion to be culled will depend upon the net reproductive rate, the evenness of the flock and how many animals the owner wants to sell. This in turn may be dictated by sudden or long-term financial needs of the family. Thus, funerals, circumcisions, weddings, or school fees may necessitate sale of stock even though the time might not be right for making most profit and the animals sold may not be the ones that should be culled. Unfortunately, in practice there is often a negative selection for breeding stock, the fastest growing ones being sold (culled) because they fetch a better price. A systematic and continuous culling of the inferior and ageing animals will keep the flock young, improving and build it up for the production of greater profits.

In assessing the value of goats or sheep from external appearances, it is advisable to adopt a definite system so that nothing seriously wrong will be overlooked. There is no special rule as to where to begin to examine an animal but it is suggested to begin at the head and continue back to the tail. Firstly a general assessment is made of the whole animal by walking around it before handling it. Points to observe at first glance are the head, back, withers, how the animal stands and position of the four legs. Examine the teeth to check the age of the animals and for faulty jaws to cull those that are undershot or overshot. Eyes should be checked for good health and ears that they are free of discharge. Check that the animal shows no diarrhea. Check the vulva for abnormal discharge and udder for lumps and abnormalities to make sure that both teats are functional. In the

male, check the penis and testes. Make sure that the penis is normal and both testes descended and of sufficient size.

3. *Determination of Age*

The formation of the teeth of goats or sheep is of considerable importance. The age of the animals can be approximately determined by the number of incisor teeth on the front of the lower jaw.

Teeth can be classified into two types, namely incisor and molar teeth. Teeth can also be divided into two types according to their age of formation, namely milk (temporary) and permanent teeth. Milk and permanent incisors are found only on the front part of the lower jaw. The corresponding part of the upper jaw has no teeth but is provided with a hard pad. Eight milk or permanent incisor teeth grow in pairs, namely central, intermediate, lateral and corner.

The method of determining the age of a goat or sheep by the number of incisor teeth present is not always a completely accurate one. However, at least this system can give us a reasonably reliable indicator or age. Sometimes certain irregularities may occur and teeth do not appear in the usual, regular order, or at the age when they are usually present. Examination of teeth still remains the most accurate method for determining the age of an animal if records of birth date are not kept.

When dentition is complete, the mouth of a goat or a sheep contains 32 teeth including molars and incisors. The molars are conveniently situated for the process of mastication, forming grinding surfaces along both sides of the upper and lower jaws.

To determine the age of an animal, it is necessary to understand the timing of the process of dentition from birth. This is seen in Table 1.

4. *Disease Control*

It should be noted here that disease control with pharmaceutical products (such as for example, anthelmintics for the control of internal parasites) is far too expensive to be used by the smallholder farmer. A survey of traditional medicines for treating health problems listed many readily available, cheap traditional medicines for a wide variety of diseases, including scabies, orf, external and internal parasites, bloat and mastitis[7]. However, most of these have not yet been scientifically

Table 1. Dentition of goats and sheep.

Temporary incisors	Age when cut	Temporary molars	Age when cut
Central and intermediate	At or soon-after birth	1st, 2nd and 3rd	At birth or at a few weeks later
Lateral and corner	3 to 4 months	----------	----------
Permanent Incisors		**Permanent molars**	
Central	1 to 1.5 years	4th	3 to 6 months
Intermediate	1.5 to 2 years	5th	9 to 12 months
Lateral	2.5 to 3 years	6th	18 to 24 months
Corner	3.5 to 4 years	1st, 2nd and 3rd	1.5 to 2 years

evaluated. It is suggested that extensive research is warranted to determine the active ingredients (if any), methods for extraction and preparation, dosage levels, efficacy and possible toxic or side effects.

5. *Recording*

Records are necessary for efficient management but must be kept simple because goats or sheep are only one sideline of a farming enterprise and the smallholder farmer does not have either sufficient time or skill to maintain a complex recording system.

Some system of marking has to be adopted and there are many different kinds, which are not necessarily expensive. These include home-made (wood or tin) neck-tags, ear tags, tattoos, horn brands, etc.

Breeding records that should be kept are: date of mating, date of birth, number of offspring born (dead and alive) and if possible birth weight, survival to and weight at weaning. At present few farmers keep records but they should be encouraged to do so. This has become feasible with almost complete literacy in young farmers.

CONCLUSIONS

It is obvious from the topics discussed in this Chapter that management has a large impact on the productivity of small ruminants. However, definition of efficient management is difficult because it is a complex of interlocking tasks in many areas.

The solutions for many management problems are obvious. But, it must be remembered that almost all small ruminants in Indonesia are kept by smallholders as an activity secondary to the growing of crops and also that they are used as a cash resource for family needs or as a living bank. This means that it is impossible to introduce new technology which requires a greater cash input or an increase in risk.

Among improvements in management which are feasible are subdivision of animal sheds to enable better management of the different classes of stock (e.g. males, growing young stock, females in late pregnancy and lactation, and females during the perinatal period). Better management during mating and during the perinatal period are two areas where improvements could be carried out without extra costs to the farmer. A major problem is the unavailability of bucks and rams at oestrus as well as inability of the farmer to detect oestrus due either to ignorance or to lack time. Sharing of males by a group of farmers is one solution, and less expensive than provision of one male per flock. Extension efforts are needed to improve the farmers' skill in oestrus' detection.

Improvement of management during the perinatal period is another area which would not need extra cash input. This necessitates the subdivision of animal sheds to allow isolation of the dam and her offspring necessary for the establishment of a strong maternal-offspring bond. It means intervention by the farmer to help weak neonates to obtain that first crucial drink of *colostrum* which is necessary for survival. This intervention needs to be skilfully applied and may well require training of the farmer or the farmer's family by extension staff. It does not require great strength, but time, so it could be taught to the wife and older children in the family.

Pharmaceutical remedies for the various health problems are well known and effective. Unfortunately, however, they are also expensive, and outside the reach of the smallholder farmer. Farmers already know and use many traditional remedies which are extracted from local plants. Sufficient to say here that there is urgent need for the evaluation of traditional medicines, which are affordable by the smallholder farmer.

Finally, training and provision of extension personnel knowledgeable in a farming systems approach to whole farm

management, with up-to-date knowledge of research findings in the different areas and able to communicate with smallholder farmers, remains a high priority. This is discussed in Chapter XII.

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CHAPTER III
ADAPTATION OF SMALL RUMINANTS TO TROPICAL INDONESIA

M. Winugroho*, D. Sastradipradja** and B.A. Young***

INTRODUCTION

As a humid tropical country, Indonesia has special problems associated with animal production. Animal production is the result of the interactions of genotypes and environmental factors such as climate, nutrition, disease and management practices. Limitations to production are brought about by poor feed and husbandry, unbalanced feeding, endemic diseases and parasitism. Apart from the direct effects, there are interactions among all these factors.

Animals newly introduced into an environment undergo an environmental change which affects metabolism underlying production processes. The effect of an environmental change on the production process is a consequence of the neuro-endocrine and behavioural responses to the change. On the other hand, indigenous animals are

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well adapted to the agro-ecological niche of the region. How indigenous animals survive and how they cope and even produce to a limited extent, is determined by their physical characteristics, their innate physiological and behavioural capabilities as well as their evolutionary histories.

This Chapter will discuss the present state of knowledge of the adaptability of goats and sheep, the effects of the environment on the physiology of animals, and specifically the adaptation of goats and sheep to agroclimates in the humid tropics, especially in Indonesia. Suggestions will be given for possible practices to reduce the negative impact of the environment on production (meat, milk, skin and wool). Differences in local feed quality as they may interact with the climatic environment will also be discussed briefly. It is hoped that guidelines for successful adaptation of small ruminants will emerge from this Chapter.

The approach chosen in this Chapter is diagrammatically illustrated in Fig. 1 while the discussion is organized under the following headings:

- The Indonesian environment and its special features which determine small ruminant responses and the suitability of various breeds are described.
- Thermoregulation and metabolic responses especially to hot, humid climates are discussed as a basis for selection of small ruminants adapted to local conditions.
- Adaptation of indigenous small ruminants is discussed in relation to problems with the introduction of exotic breeds into hot, humid areas.
- Management practices to alleviate environmental constraints are next briefly discussed.
- Brief mention is also made of the characteristics of indigenous forage growth and of local agricultural by-products.

A. THE INDONESIAN ENVIRONMENT AND ITS SPECIAL FEATURES

This discussion of small ruminants will centre on Java because the majority of goats and sheep in Indonesia live in Java. Fig. 2 shows

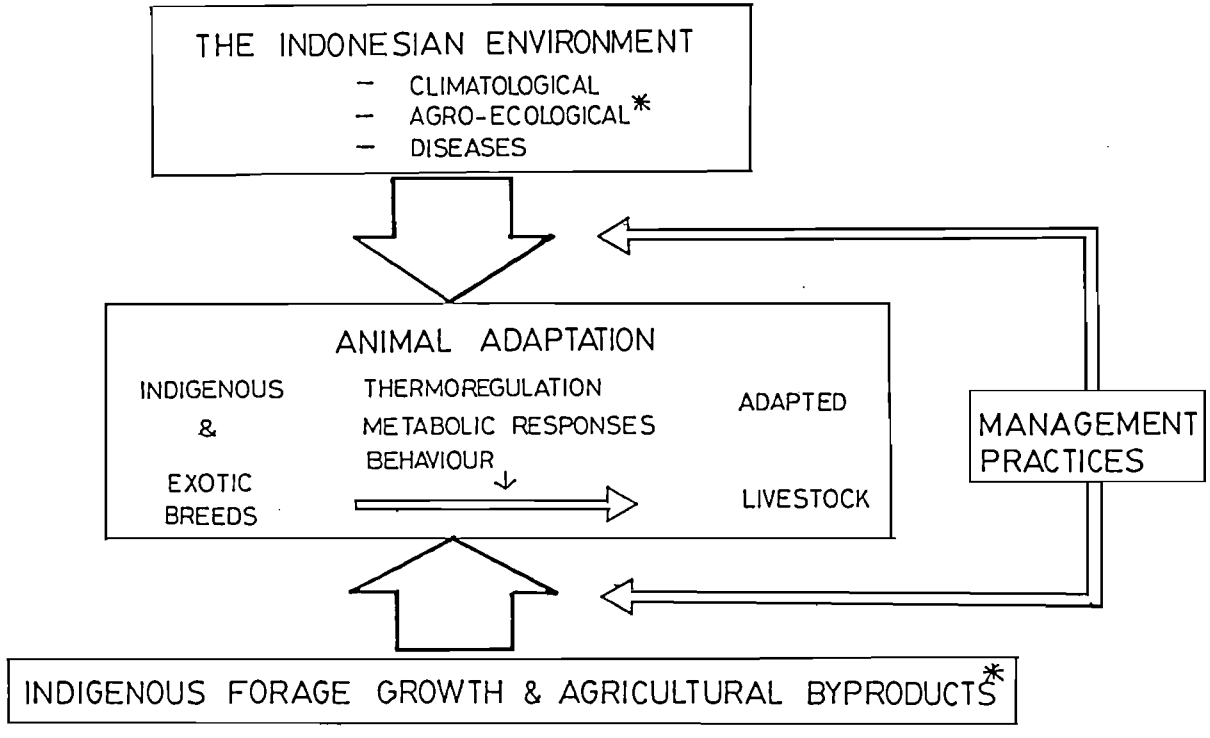

Fig. 1 Diagrammatic illustration of animal adaptation in relation to a humid - tropical environment.

the length of the annual dry season in Java when rainfall is less than 60 mm per month. Fig. 3 shows overall goat density based on districts in Java (Livestock Units (LU)/km^2) while Fig. 4 shows overall sheep density based on districts in Java (LU/km^2). Goats are mainly Kacang and Etawah cross. Indonesian goats are distributed partly in Central (25 percent), partly in East (20 percent) and (14 percent) in West Java (Fig. 3). Sheep are mainly Javanese Thin-tail with Javanese Fat-tail sheep in Central Java. Sheep are found mostly in West Java which has a relatively long wet season (Figs. 2 and 4). Recently, it has been recognized that Indonesia may have two other unique breeds called Sumatran Thin-tail and the Lombok Fat-tail hair sheep[1]. These breeds are discussed in Chapter IV on Animal Breeding.

There are many environmental factors which affect the distribution and types of animals in a given area. These include temperature, humidity, rainfall, type of feed available and their interactions.

Some of the special features associated with goat and sheep production in Indonesia include:

- Traditionally, they are kept mostly as a financial resource and usually housed near a farmer's house as well as being cared for by family members. They may also be kept near to cattle or buffalo.
- There are relatively few breeds of small ruminants in Indonesia - the Kacang and Etawah-cross goats and the JTT sheep are the more common, followed by the JFT, the STT and finally the Fat-tail hair sheep in Lombok.
- Patterns of feeding and management vary greatly - in Java the animals are kept mostly in small elevated pens with cut-and-carry systems of feeding; in other parts of Indonesia, the systems vary from tethering during the entire year to a mixture of grazing/tethering and confinement, depending on season. These aspects are described in Chapter II on Management.
- The feed quality is usually not high. Feeds are usually high in fibre, low in protein and have low digestibility. This is discussed in Chapter V on Meeting Feed Requirements of Small Ruminants.

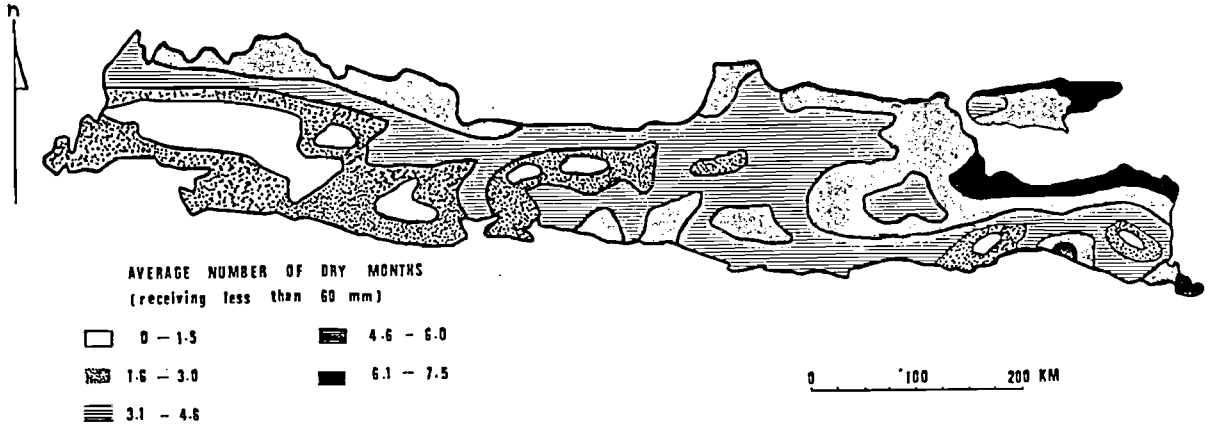

Fig. 2 Length of dry season in Java[2].

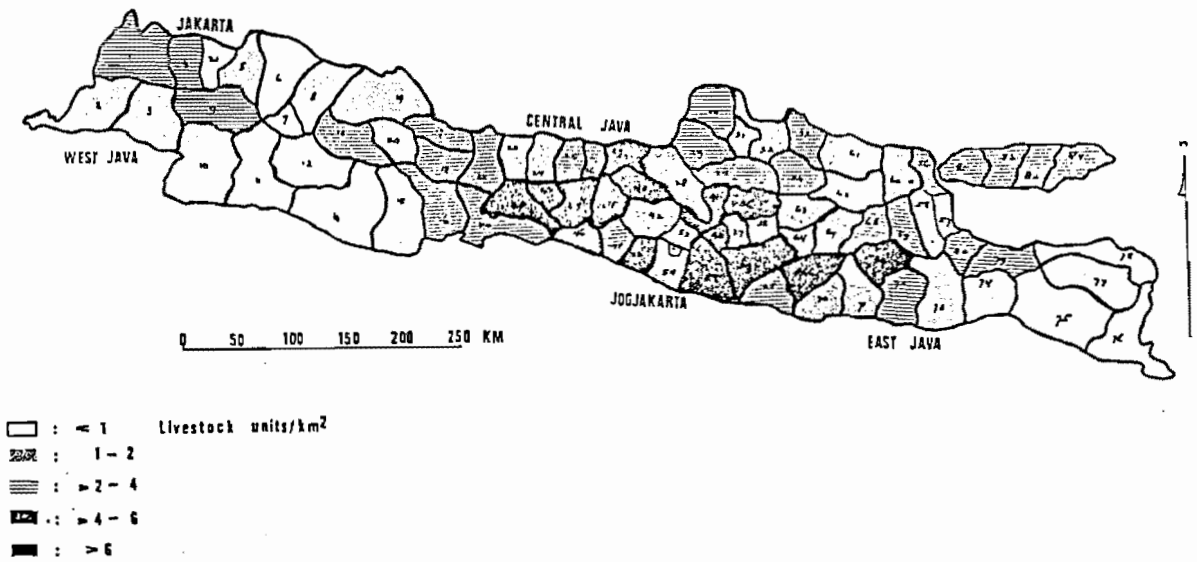

Fig. 3 Overall goat density in districts of Java, Livestock Units (LU)/km^2.[2]

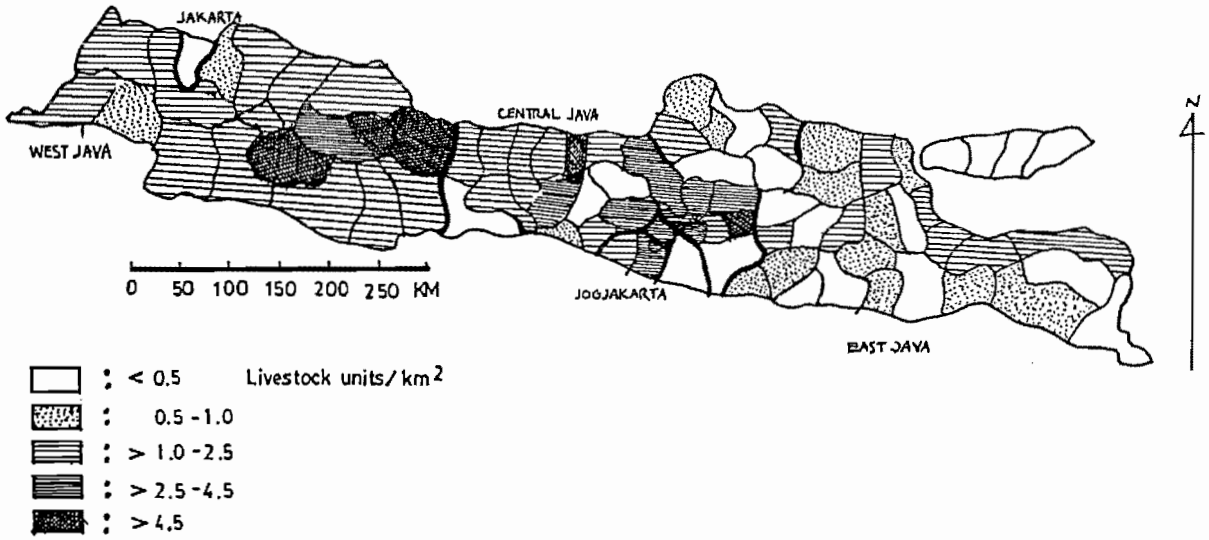

Fig. 4 Overall sheep density in districts of Java LU/km^2.[2]

High parasite burdens are common in small ruminants in Indonesia. These are discussed in Chapter VIII on Endoparasites and Ectoparasites as Constraints to Small Ruminant Production.

Achievable levels of sheep and goat production are obviously influenced by interactions among nutrition, environmental factors and traditional management practices.

B. THERMOREGULATION AND METABOLIC RESPONSES

I. ADAPTABILITY

Animals have to adapt to management practices, available feed resources and environmental conditions. Farmers may select a type of goat or sheep depending on local availability of breeds and one which will match their needs and resources including time available, knowledge of rearing animals, parasites and diseases present. These factors, however, do not ensure high productivity or even the survival of the animals so that environmental conditions should also be considered.

Physiological adaptation is defined as a modification in the animal's behavioural and/or metabolic responses, resulting from previous experience which improves the ability of the animal to cope with subsequent challenges[3]. For example, with thermal adaptation there can be shifts in the thermo-neutral zone (TNZ) and possibly in the thermal sensitivity of the animal. Three types of physiological adaptation have been recognized:

1) Acclimatization, which involves functional tissue or organ responses in an animal and arises from the effects of a complex of naturally occurring environmental variables.
2) Acclimation, which is adaptation arising from effects of a single environmental variable usually in an experimental situation in a climate-controlled room.
3) Habituation, which involves a reduction in response to a repeated stimulus and is usually associated with a reduced perception after repeated stimuli. This change occurs at the

sensory level. These behavioural changes can be important components of acclimatization in animals of an imported exotic breed.

Behavioural and metabolic response mechanisms are activated and operate with different time frames and function from the cellular level to whole-animal behaviour[4]. While most behavioural changes are immediate, changes in behavioural patterns involving adaptation may take a considerable time to develop. Internal metabolic responses may be immediate or slow. The faster responses tend to rely mainly on neural mediation while the slower and adaptive responses usually depend on the endocrine mechanisms. The many types of responses are coordinated by the central nervous and the endocrine systems to protect the overall homeostatic state of the animal.

The ability of an animal to cope with a new environment arises from its capacity to respond to environmental variables while being able to maintain body equilibrium. Each compensating mechanism depends upon, and is a part of, a physiological feedback process. This is illustrated in Fig. 5.

Essential to these processes is the ability of the animal to detect and interpret a disruption in its internal equilibrium and then to initiate appropriate behavioural and/or metabolic responses to restore equilibrium or homeostasis.

An environmental change sufficient to challenge seriously one individual may be insufficient to produce a measurable response in another. Behavioural opportunities are sometimes constrained by management practices and the internal metabolic responses tend to become more prominent in such situations. As a disturbing factor persists, the immediate defensive responses are replaced by longer-term adaptive mechanisms which tend to reduce the physiological burden on the animal. Within its genetic capacity, an animal adjusts continually to cope with new environmental conditions. In harsh environments these adjustments are necessary for the animal merely to survive. The ability to reproduce and grow has to be included in survival.

II. THE EFFECTS OF TEMPERATURE

The basic concepts of metabolic responses to ambient temperature and the thermo-neutral zone (TNZ) expressed in terms of

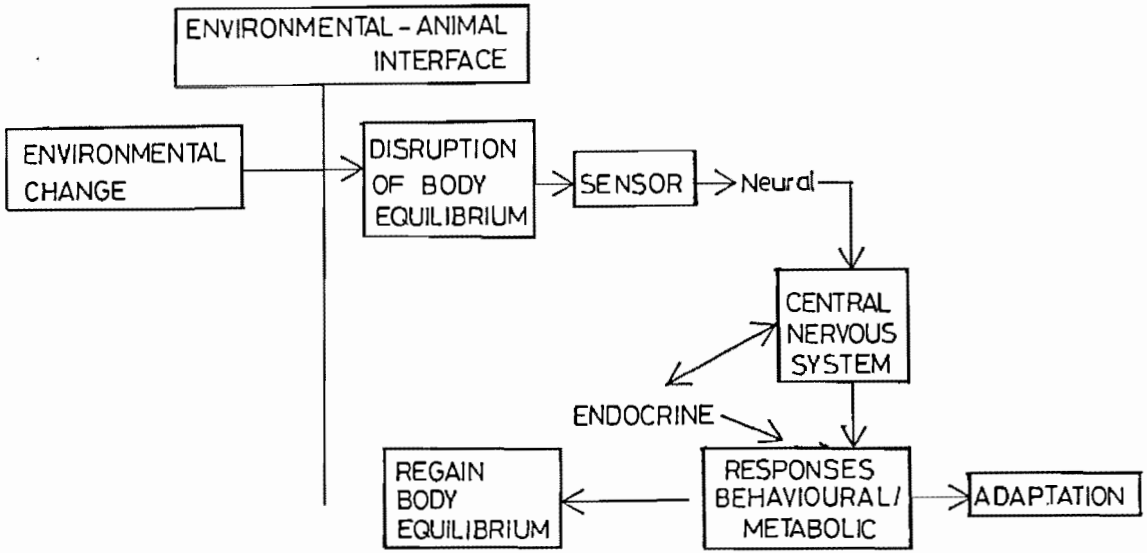

Fig. 5 Physiological feedback processes[4].

ambient temperatures are illustrated in Fig. 6. The TNZ is defined as the range of ambient temperatures within which an animal's metabolic heat production, over the short-term, is independent of ambient temperature. At the higher end of the thermo-neutral zone is the upper critical temperature (UCT) which is the temperature above which an animal must markedly increase its rate of loss of body heat to maintain euthermia. It is defined as the temperature above which thermoregulatory evaporative heat loss processes are recruited to maintain thermal balance. The lower critical temperature (LCT) is the temperature below which an animal must increase its rate of metabolic heat production by shivering and/or non-shivering thermogenic processes to maintain euthermia. This later topic has been reviewed by Young and his colleagues and will not be discussed in this Chapter[3,4].

When subjected to heat stress, the behavioural priorities of ruminants shift from grazing activities and consumption of food to avoidance of uncomfortable conditions. The immediate consequence is reduced feed intake and reduced available metabolizable energy. Other disturbances in energy balance arise from physiological, endocrinological, and digestive changes that further reduce available energy, and consequently reduce animal production[6].

Many metabolic responses to extremes in the environment are energetically costly and may become exhaustive if continued for an extended time. However, adaptive mechanisms may develop upon prolonged or repeated exposure to decrease the burden on the animal. Fig. 7 shows the expected responses in metabolism of a non-adapted animal and an animal, adapted either to hot or to cold conditions.

In laboratories, temperatures are usually expressed in terms of dry, still-air temperature. In practice, the thermal environment experienced by animals can rarely be satisfactorily specified by air temperature alone. Many other variables for example, humidity, solar radiation and air movement are important factors.

The skin plays an essential role in the maintenance of homeothermy. The skin not only contains a high density of thermal sensors but its temperature and thus the rate of heat flow from the body is regulated by peripheral vasomotor mechanisms.

The following results refer to experiments in climate rooms with temperate zone sheep[7]. After prolonged exposure to thermal environments ranging from 0° to 40°C, shorn sheep acclimated and became stabilized with respect to energy and water balance. It was found that respiration rate as well as urine and evaporative water output and thus the daily requirements for drinking water, were directly proportional to ambient temperatures. With the same quantity of intake of energy, a higher daily weight gain was achieved in mature sheep when kept (with limited feed intake) at 40° compared with 20° and 0°C. In the cold environment, 80 percent of the heat loss was via sensible (conduction, convection and radiation) routes while sheep in the hot environment lost 86 percent of their daily heat production by evaporation of mositure. The increased energy requirements of sheep in the cold environment were associated with physiological acclimation and an increased basal metabolism. Average daily urine output was directly related to ambient temperature as was evaporative water loss. Sheep in the hot environment evaporated almost five times more water than those kept in the cold environment. The bulk of evaporative heat loss in goats and sheep is from the respiratory tract. This higher evaporative water loss in the hot environment was associated with higher respiratory rates. Mean respiratory rate per minute increased with higher temperatures from 15 (at 0°C) to 30 (at 20°C) to 116 (at 40°C). There is a dearth of similar data (for hot temperatures) on indigenous small ruminants in Indonesia, the actual values (for example in respiration rates, water intake or urine output) are probably different, but the same principles apply.

Higher liveweight gain for animals kept at higher thermal temperatures does not necessarily mean that those animals have higher body energy reserves. Winugroho (unpublished) found that, given the same quantity of a diet, higher body energy reserves were found in Merino sheep kept in a 20°C thermal environment compared with those kept at either 0° or 40°C. At 0° and 40°C, there was a higher body water content. Apparently, the water had replaced the fat content. However, it should be remembered that lower energy for maintenance is required by sheep kept in a warmer environment and it is well established that if the feed is given *ad libitum* then animals kept in a cooler environment have higher daily liveweight gains.

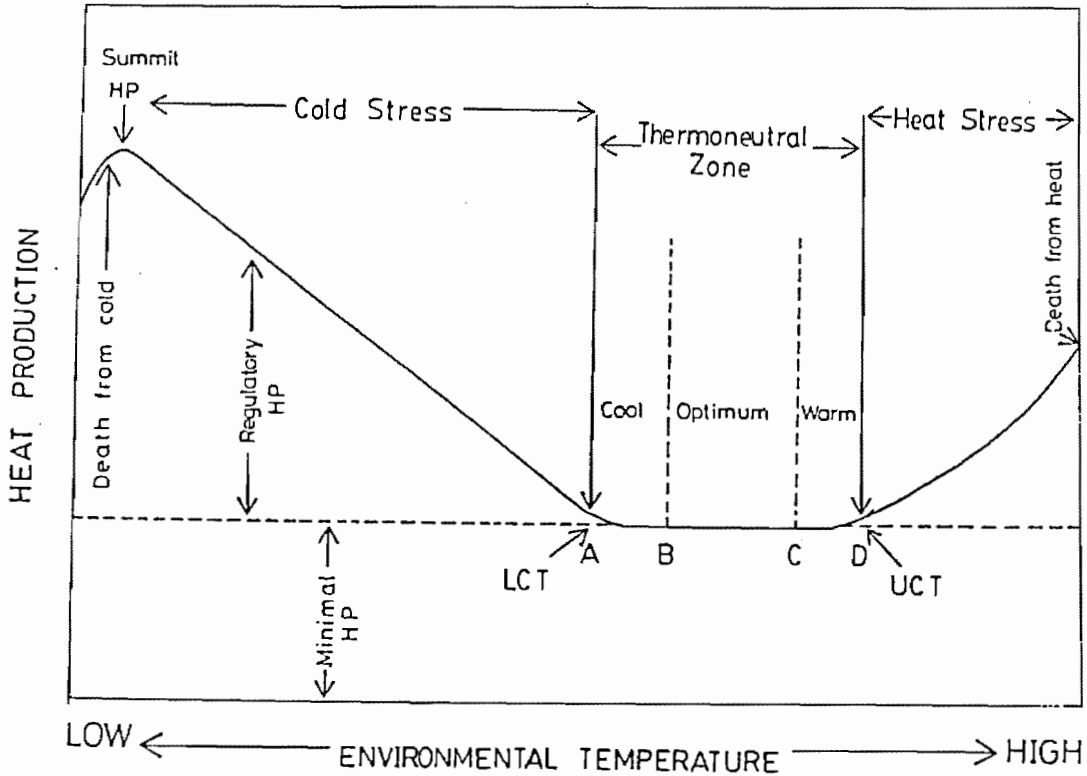

Fig. 6 **Heat production (HP) of animals expressed as a variant of dry bulb (DB) ambient temperature; UCT = upper critical temperature; LCT = lower critical temperature. The thermoneutral zone is boundedby UCT and LCT[5].**

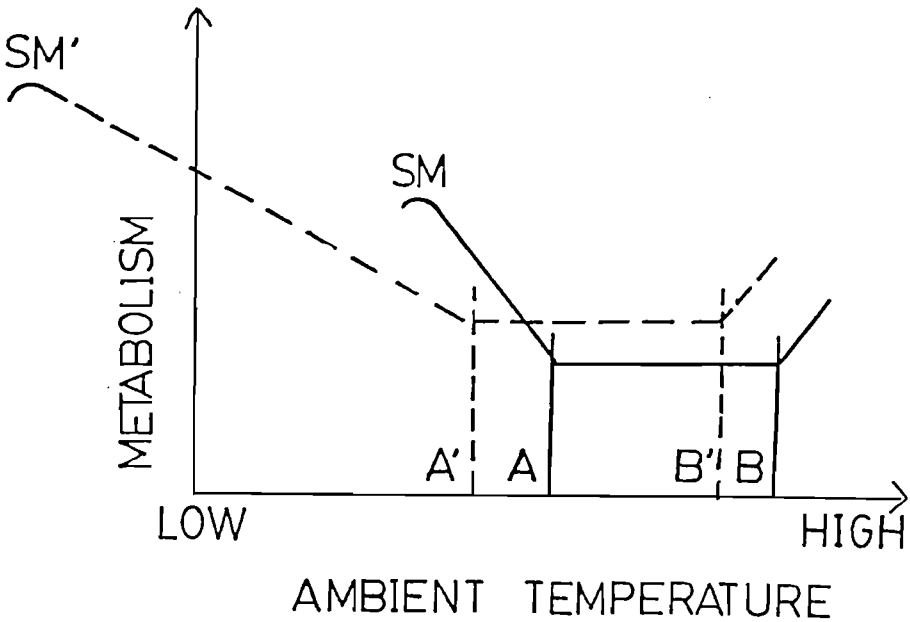

Fig. 7 Relationship between ambient temperature and metabolic responses of an animal before (solid line) and after adaptation (dashed line) to heat or cold; SM = summit metabolism[4].

The effects of heat stress on reproduction are reviewed in Chapter VI. Most work has been with temperate-zone animals in climate rooms. For example, it was found that goats and sheep kept at high environmental temperatures suffered from lower conception rates, increased length between incidence of oestrus, decreased length of oestrus, higher mortality of embryos, low quality of semen, and lighter birthweights resulting in a higher incidence of lamb mortality. Furthermore, high temperatures depressed feed intake in sheep and goats[8].

III. THE EFFECTS OF HUMIDITY

The relative humidity of a region is believed to be a primary determinant of the types of small ruminants that are suitable to these

areas. Goats tend to survive better in drier climates while sheep are likely to be well adapted to more humid climatic areas. This is confirmed by the distribution of goats and sheep in Java (Figs. 2, 3 and 4). In addition, Fat-tail sheep appear to do better in drier areas. Deposition of fat in the tail of Fat-tail sheep is believed to be for storage of energy during the dry periods of the year when food intake is usually low. There is no experimental evidence of the efficiency of using the tail as an energy storage organ to dampen the effects of seasonal periods of feed shortage. It is believed that Thin-tail sheep in dry areas tend to suffer more from heat stress than do Fat-tail sheep. Furthermore it is claimed that goats kept in humid areas tend to succumb more easily to parasite infestation and to other diseases than in dry areas. More information is needed on the adaptation of various breeds of small ruminant to the hot and dry and/or hot and humid climates of Indonesia as there is little experimental evidence to substantiate beliefs outlined above.

IV. THE EFFECTS OF SOLAR RADIATION AND THE ROLE OF PELAGE

Feed and climate are dominating factors in the environmental influences on production. The most important climatic factors are temperature and humidity, but wind and solar radiation affect the temperature-humidity combinations required for optimal production. Animals raised under tethered systems are usually subjected to direct solar radiation and are likely to suffer from heat stress. A feature of tropical animals is the thin pelage which means low heat insulation. However, pelage covering of tropical goats or sheep gives adequate protection against direct solar radiation and contributes to the advantageous heat regulation of animals standing in the sun. Radiation from the sun (up to about 800 kcal/m ^{2}hr) would provide the largest heat load to the surface of the animal, which is the surface of the pelage covering. Some energy is reflected as short-wave radiation. Forced convection rapidly cools the surface, which still heats to 85°C in still air in Merino sheep standing in the sun and radiates much of the energy as low wavelengths[9]. Under such a severe heat load, hyperthermia could exceed the tolerable body temperature which can be avoided only by evaporative cooling. The flow of sweat onto the surface of an animal receiving large amounts of heat from the

environment is an inefficient means for relieving the body from the heat burden. It should be remembered that small ruminants sweat little except from the scrotum of males[10]. The pelage provides physical protection from direct and indirect radiation as well as from the resulting high effective air temperatures.

C. ADAPTATION OF INDIGENOUS BREEDS OF SMALL RUMINANTS

I. ADAPTATION OF METABOLISM

Most physiological experimentation has been based upon exposure of animals for short, acute or long, chronic periods to constant conditions or conditions in which only one climatic variable changes in climate controlled rooms. In contrast, the natural environment is never constant over time. There are diurnal fluctuations, longer period environmental fluctuations such as seasonal changes and even longer-term trends. Moreover, these fluctuations are not only in air temperatures but also in humidity, air movement and solar radiation.

Homeostasis, despite environmental changes, is maintained by neuro-endocrine adaptation of the heat dissipating processes. It is believed that indigenous species are well adapted to their surroundings and at least survive. They select food, graze or browse and can exploit the habitat more efficiently than exotic animals. Available scientific information about the adaptability of indigenous small ruminants in the humid tropics is however, limited.

In his review, Devendra[11] postulated that adaptations of indigenous goats include anatomical, morphological and physiological responses, changes in feeding behaviour, metabolism and performance due to a variety of constraints to enable survival and a viable functional role for this species. However, the evidence he presents is largely anecdotal.

A lowered basal metabolic rate should be advantageous to an animal living at high temperatures, because reduced basal metabolic rate would minimize the production of endogenous heat and reduce the burden of dissipating heat in hot environments. However, lower metabolic rate also means lower productivity. Acclimatization to heat

can be achieved by an animal by raising its rectal temperature to only a very limited extent, but more important is the adjustment of the mean skin temperature to a level which permits thermal equilibrium between the body and its surroundings, maintaining the gradient that allows adequate transport of heat from the inside to the body surface. Information on these metabolic parameters for indigenous sheep and goats adapted to the humid tropical environment is practically non-existent in Indonesia.

Under indoor conditions, heat production of local female non-lactating local Etawah crossbred goats of around 16 kg bodyweight receiving napier grass (*Pannisetum purpureum*) as the sole feed, was comparable with data on small ruminants from temperate regions. The values rose with the supplementation of napier grass with steam-cooked cassava and urea[12]. The same study also showed that indigenous goats have the ability to supply endogenous glucose adequately while lactating and while receiving these supplements. Similar data were obtained with pregnant and non-pregnant indigenous sheep. Glucose flux values were higher in sheep compared with goats[13]. The high glucose fluxes were achieved by high rates of gluconeogenesis which may be the result of increased secretion of cortisol from the adrenal cortex[14]. These data are shown in Table 1 and support the idea that indigenous goats and sheep are well adapted metabolically to the humid tropical environment of Indonesia through intricate neuro-endocrine regulatory mechanisms.

Table 1. Heat production and glucose flux of indigenous goats and sheep kept indoors in hot conditions.

Species/ breed	Heat production (Kcal/Kg $BW^{0.75}$ /day)		Glucose flux mg/min	Reference
	*NG	**NG+C+U		
Goats (Etawah cross)	69	110	30	12
Sheep	120	169	37* – 75**	13

* Napier grass

** Supplemented with cooked cassava and urea

Haematological parameters are closely related to metabolism, since haemoglobin, red blood cells and packed cell volumes are associated with oxygen transport and supply to body tissues. Thus haematology can provide a rapid assessment of the health status as well as haematological status of goats under traditional village conditions. All values measured were within the normal range, however red blood cell counts were significantly higher in females than in males, as well as under conditions of poor management rather than of good management. In addition, it was found that lactation was accompanied by the lowest values of packed cell volume and haemoglobin under conditions of poor management[15]. This study suggests the need for better feeding at critical times for higher and sustained productivity.

II. WATER METABOLISM

The regulation of food and water consumption under tropical hot and humid conditions merits a separate account. The productivity of these geographical areas is very much dependent on water availability within them. The feed intake of farm animals is closely related to productivity of the animals. Feed intake influences heat production and the amount of fat deposited. Water turnover becomes important since it is closely linked with feed intake and energy turnover. Moreover, because evaporative cooling mechanisms require an adequate water supply, water plays an important role, both in thermoregulatory responses and in general metabolism. Indeed, tropical animals are characterized by very high water turnovers[16].

Heat-tolerant ruminants have relatively low water intakes because they use water more efficiently. Ruminants originating from temperate areas but reared in moderately warm environments drank twice as much water as did the more heat-tolerant breeds but their total evaporative heat loss was much lower. Therefore water consumption may not be a satisfactory index of vapourization rate[17]. Evolutionary pressures have produced low metabolic rates in animals living in the desert and high rates for those which have developed either in the humid tropics or in temperate regions. Goats and sheep evolved in the drier fringes of the tropics and sub-tropics relatively late in history. Table 2 shows some water turnover and water intakes of animals of tropical and of temperate origin in hot environments.

Table 2. Water turnover and water intake of goats and sheep of different origin in hot environments.

Species	Breed	Origin	Test environment	Water turn over ml/kg$^{0.82}$/24h	Water intake ml/kg/24h	Reference
Goat	Masai	Hot, dry	Hot, dry	193		18
Sheep	Somali	Hot, dry	Hot, dry	136		18
Goat	Kacang	Hot, humid	Hot, humid	190		*
Sheep	JTT	Hot, humid	Hot, humid	210		*
Sheep	DH	Temperate	Hot, humid		189	19
Sheep	IS	Hot, humid	Hot, humid		171	19
Sheep	DH x IS	Hot, humid	Hot, humid		141	19
Sheep	(F 1)					17
Sheep	DH**					
Sheep	DH	Temperate	Hot, humid	300	354-396	17
Sheep	S					17
Sheep	BL					17
	C					

* Sastradipradja (unpublished data)
** Standing in the sun
JTT = Javanese Thin-tail; DH = Dorset Horn;
IS = Indigenous sheep (to hot climate, peninsular Malaysia);
S = Suffolk; BL = Border Leicester; C = Corriedale

The ability of animals to prevent a rise in body temperature and to increase heat loss by evaporating water through sweating are considered to be reliable indicators of adaptability in cattle. Indices of adaptability for cattle using the sweat gland number per square centimetre of skin, sweat gland length, diameter, area and volume have been developed. However, sweating is not important in goats and sheep except in the scrotal area of males. Thus, Moule[10] reported that the sweating rate of Merino rams from the scrotum rose from 0.8 g/hour at 27°C to 1.5g/hour at an ambient temperature of 41°C. Since most of the evaporation in small ruminants is from the upper respiratory tract, measurement of respiratory rates is a useful indicator of thermal stress and of adaptation to hot environments. Therefore, before any attempts are made to move animals within or between countries, the responses to hot temperatures should be evaluated in terms of the animal's ability to maintain normal body temperatures, respiration and pulse rates. With this simple approach, the ability of an animal to cope with new situations and the role of the adaptative processes can be evaluated. In the case of crossbreeding with exotic and indigenous breeds, the same simple measurements can be used to evaluate the relative potential for adaptability of the exotic animals.

III. THE EFFECTS OF SEASON AND ALTITUDE

Not many data are available on the effects of these environmental variables on small ruminants in Indonesia. It is likely that parasite burdens increase during wet seasons, while the nutrient value of forage is low during the dry period of the year reducing productivity. Furthermore, higher altitudes also have lower air temperatures and thus lower heat stress.

Table 3 shows growth rates before weaning of Etawah cross kids at different altitudes. In each case, growth rate was better at higher than at lower altitudes. The higher rainfall and hence greater availability of feed at the higher altitudes probably contributed to those results did as well as the lower air temperatures.

If it is assumed that fecundity reflects successful adaptation, the experiments of Winantea are of interest. He compared Fat-tailed sheep at Pujon (East Java) at 1300 m above sea level with those at Malang (at 500 m). Similar numbers of sheep lambed in both locations, but the average litter sizes were 2.4 vs 1.6 respectively. Litters of three or more were only found at Pujon during the wet months, probably due to better nutrition, but maybe also due to lower air temperatures[25].

IV. THE EFFECT OF SHEARING/CLIPPING; RESPONSE TO DIRECT SOLAR RADIATION

Shearing sheep kept in indoor pens either during the wet or during the dry seasons did not affect liveweight gains, food or water

Table 3. Growth rates of goats and sheep in different environments at different altitudes, with different amount of rain.

Species	Altitude (m above sea level)	Air temperatures °C		Growth rate (g/day)	References
		Maximum	Minimum		
Goats	700	31.0	6.6	94	20
Goats	300	33.5	20.0	70	
Sheep	700	28.4	22.4	50	21
Sheep	300	35.1	15.7	40	
Goats	925			108	
Goats	Low			86	22,23,24
Sheep	925			120	
Sheep	Low			108	

intakes, rectal temperatures, respiration or pulse rates[26,27]. However, these results could have been different if the sheep were kept outside with effects of solar radiation, as they are when tethered or grazing.

In a recent study of Kacang goats in South Sulawesi, it was observed that animals kept in an enclosure without a roof (and hence with no shade) during the hot season (34 to 35°C at midday), showed significant increases in body temperature and respiration rate during the middle of the day, when compared with shaded animals. Moreover, ovulation rates were lower in the animals with direct sun exposure, (1.6 versus 2.7 $P < 0.05$). There was some indication that this was due to lower rates of release of gonadotrophin hormones. Duration of oestrus and lengths of oestrous cycles were not affected[28].

D. MANAGEMENT PRACTICES

I. THE EFFECTS OF HOUSING

Housing is discussed in Chapter II on Management. Some goats and sheep are kept in indoor pens while others are tethered outside or allowed to graze during the day. The cut-and-carry systems reduce the opportunity for animals to browse and thus to be more selective in their diets. Different types of housing (different elevation above ground level, slatted *versus* solid floors, different roof types, walls *versus* open sides) did not affect either performance or body temperatures or respiration rates of goats and sheep, but probably the environmental conditions in the different types of barns were not very different[29,30,31].

II. THE EFFECTS OF TRANSPORTATION

There are only limited data on the effects of transportation on survival and production. Goats transported from Magelang to Jakarta during October to December lost six to seven percent of their body weight during transportation. Unfortunately, the actual body weights are not given. Body and gut water loss could have been an important factor contributing to the short-term losses in weight during transportation[32].

The Asian Development Bank distributed 29,000 goats by ship from Java, Nusa Tenggara Barat and South Sulawesi to North

Sumatra and Kalimantan between 1982 to 1986, of which 16,000 died (55 percent). In a further shipment in 1987, 3918 out of 8,000 goats (49 percent) died. Losses of up to 70 percent have been reported. It is interesting that much lower losses (three to four percent) were reported when, in a Presidential Assistance Program (Banpres), some 3,000 Etawah goats were trucked from Java to North Sumatra, Aceh and Bali. Whole trucks were loaded onto ferries. There were planned stops when animals were fed, but not unloaded. It is probably possible to reduce losses in transportation and studies on loading, management procedures while travelling and associated problems should come up with guidelines to reduce deaths and improve the health of the survivors[33].

E. INDIGENOUS FORAGE GROWTH AND FEEDS

The most important causes of low productivity of animals in humid tropical countries is the low quality and inadequate supply of feeds. The climatic environment has major influences on the quality and quantity of forage production and therefore feed resources for animals. This means that animals have to adapt to the available feed as well as to the prevailing climate. Factors affecting composition and digestibility of different forages were reviewed by Winugroho[35]. They include the structure of the plant cell wall, compositional and structural factors limiting or inhibiting digestion of the plant cell wall by microbial enzymes, as well as effects of genetic characteristics of plants and environmental factors on the composition and digestibility of a given feed. The reader is referred to Chapter V on Meeting Nutrient Requirements of Small Ruminants, for a more detailed discussion of those topics.

The indigenous species of livestock mostly feed on crop residues or are scavengers of wastes from the households or from the crops, these animals being well adapted to the traditional agricultural systems. Goats and sheep are fed on roughage usually without supplementation with concentrates. Important residues of Indonesian agriculture which have potential as animal feeds are by-products of rice, corn stover, sweet potato and cassava leaves, straw from various legumes and beans, and by-products of the oil, sugar, slaughterhouse and fish

industries. Fresh residues of a number of crops are only seasonally available and it would be most desirable to find good methods for conserving these products so that they could be fed during the entire year[34].

Agricultural by-products and wastes in Indonesia are mainly fed directly to the animals, which may be adequate for maintenance. However, their utilization is considered inefficient and the nutritive values of these feedstuffs are largely unknown. For example, it was found that utilization of cassava-carbohydrate was improved by simple cooking[36]. This resulted in increased digestibility, better rumen microbial protein synthesis, increased daily weight gains, better endogenous glucose production[12] as well as higher milk production in goats and sheep[37].

Rations which consist of native grasses, soyabean meal, coconut meal, corn, dried cassava meal and minerals were given to non-pregnant does, those pregnant with singles and those with twins at levels ranging from 50 percent to 150 percent of the requirements recommended by NRC*. It was found that dry matter and energy digestibilities were affected by the level of nutrition as well as pregnancy being higher at the higher levels of nutrition. Ash, protein, crude fibre and nitrogen-free extract (NFE) digestibilities were also affected similarly. Phosphorus digestibility was affected by pregnancy while there were interactions between nutritional level and reproductive state for fat and calcium digestibilities. These results and others emphasize the need for sustained continuing efforts in finding, evaluating and treatment of cheap feed supplements for supporting improved animal production in the tropics.

CONCLUSIONS

In this chapter, an attempt has been made to reconcile the existing data on adaptability of goats and sheep to a humid tropical environment. At every stage of this discussion from the analysis of animal responses, suitability of various breeds, introduction of exotic

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* National Research Council

Table 4. Digestibility coefficients for dry matter, crude protein, crude fibre, energy, NFE, ash and phosphorus as affected by level of nutrition and reproductive state of goats[38].

Nutrient	Digestibility coefficient					
	Nutritional level			State of gestation		
	R_0	R_1	R_3	B_0	B_1	B_2
				%		
Dry matter	78.45[a]	85.52[b]	86.72[b]	81.39[p]	85.52[q]	84.12[q]
Crude protein	74.29[a]	80.13[b]	85.54[b]	73.71[p]	82.79[q]	83.46[q]
Crude fibre	33.78[a]	55.43[b]	63.12[b]	40.52[k]	55.38[kl]	56.43[l]
Energy	79.29[a]	85.52[b]	89.23[b]	81.75[p]	86.16[q]	86.43[q]
NFE	88.12[a]	91.59[b]	92.75[b]	89.43[k]	91.82[l]	91.27[l]
Ash	44.18[a]	63.02[b]	64.96[b]	45.98[p]	62.30[q]	63.88[q]
Phosphorus	51.39[a]	59.21[b]	60.78[b]	44.47[p]	66.39[q]	64.36[q]

R_0 = 50%, R_1 = 100% and R_2 = 150% of recommended NRC requirement
B_0 = non pregnant, B_1 = pregnant with singles, B_2 = pregnant with twins
Superscripts a and b (for nutritional level), are p and q (for state of gestation) on the same line indicate highly significant differences at $P < 0.01$, whereas k and l, significant at $P < 0.05$

breeds and suitable management practices to discussion of indigenous forage growth and available agricultural by-products, inadequacies in present data and knowledge are limiting factors. Nevertheless, the following points can be made:

1) Local breeds are well adapted to humid, tropical environments, but more information is needed on their physiological characteristics.
2) Careful evaluation needs to be carried out on exotic breeds in terms of potential for adaptation before crossbreeding with (or replacement of) local breeds. Note that useful genetic pools from local breeds can be lost with indiscriminate crossbreeding.
3) Shearing may contribute to animal comfort if they are housed, including lower infestation with ectoparasites, but not if they graze outside, especially if they are tethered in the sun.
4) More work needs to be carried out on transportation to reduce

deaths of animals and losses in weight as well as decline in health of the survivors.

5) Finally, more work should be carried out with goats as most of our information is on sheep and yet goats are more numerous in Indonesia.

Alleviation of these inadequacies of data and knowledge are necessary in view of the importance of small ruminant production to the development of Indonesian and indeed South-East Asian livestock industries. Farmers should be helped to find satisfactory solutions for reduction of production constraints by matching their needs and resources as affected by the humid tropical environment. It is evident that the need for systematic, quantitative investigations of the interactions of genotypic and environmental factors is urgent for increasing the productivity of small ruminants in the humid tropics.

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CHAPTER IV

ASPECTS OF SHEEP BREEDING WITH PARTICULAR EMPHASIS ON HUMID TROPICAL ENVIRONMENTS

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INTRODUCTION

Variability is an inherent condition of living organisms. At any level of organization, characters expressing a given attribute vary from individual to individual. A group of animals or a population share common peculiarities in contrast with other groups/populations, these peculiarities defining racial or breed characteristics. An example of these contrasts in Indonesian sheep is illustrated in Table 1.

Variation has a basic role in the evolution of the species and it is the basis for breeding strategies designed toward improving animal productivity or, in a broader sense, toward changing the present levels of individual productivity.

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Table 1. Habitat and two racial characteristics of two Indonesian sheep populations.

Population	Dispersion area	Tail	Coat colour
JTT	West Java	Thin and long	High frequency of coloured coats
JFT	East Java	Fat and short	Predominantly white

JTT and JFT: Javanese Thin-tail and Fat-tail sheep, respectively

In this Chapter, a brief overview of the genetic basis of variability will be given. It is assumed that the reader has been previously exposed to the foundations of animal breeding and genetics, and that an introductory course in biometry is part of his/her educational background.

In these discussions, attention will be mainly directed to traits that are relevant to animal productivity, or are more conspicuously related to it since in an individual, conceptualized as an organized biosystem, all traits are indeed interconnected. More specifically, the focus will be on sheep productivity, with some reference to crossbreeding experiments in goats.

Different levels of organization in a single individual interact with its environment; this being the peripheral physical environment where the individual develops, as well as the set of all possible other levels of organization contained within it. Moreover, individuals interact also with other individuals included in their surroundings or immediate environment. The expressions of traits are then the resulting product of the interaction of their intrinsic determining factors with those that characterize the surrounding environment. In discussing animal productivity or its improvement this basic fact should not be overlooked and both **nature** and **nurture** should be considered as an integral part of production.

It is believed that sheep originated in Central Asia[1], then colonized and evolved in different climates and regions of the world. Linked to this broad scenario of adaptations and ecosystems is a great variation in production specialization in the cold, temperate and tropical regions.

Within the extreme ecosystems conditioned by the humid tropics, sheep breeds also provide production alternatives for an important sector of the rural population of the world[2,3]. This is the case in Indonesia and in other neighbouring countries of South-East Asia.

A. VARIATION AND TRAITS

I. CAUSES OF VARIATION: PHENOTYPE, GENOTYPE AND ENVIRONMENT

The rest of this Chapter will keep a unifying concept with respect to production traits, as their expression is the result, or more properly a function, of genetic (G) as well as of environmental (E) effects; f(G,E).

Although the nature of f(G,E) is not necessarily linear, the following familiar linear equation has been adopted in animal breeding to summarize the contribution of genetic and environmental causes of variation:

$$\mathbf{P = G + E} \qquad (1)$$

where P, known as phenotype, is the final product; the appearance or the expression of the trait which can measured, categorized, counted or assessed; for example production of milk, bodyweight or litter size.

Observations on traits are confined to their phenotype while neither genetic effects constituting the genotype of traits nor environmental effects can be directly observed or measured. However, it will be seen later that estimation of the relative contribution of each cause of variation is possible.

Differences between individuals with respect to a given trait which are transmitted from generation to generation, depend ultimately on genes making up the genotype of the traits. Two general models are used by animal geneticists to explain the inheritance of these differences: the basic Mendelian model and an expanded model involving polygenic inheritance. These classifications are based on the magnitude of the effect of and the relative number of genes controlling the variability of traits.

II. THE BASIC MENDELIAN MODEL

This model explains the variability of traits regulated by a few major genes, with large effects on P.

An example is given of a single gene with two alternative alleles that apparently regulates the variation of length of ears in sheep[4] and which is present in all Indonesian sheep populations. Homozygotes for the dominant allele (++) have normal ears, heterozygotes (+s) shortened ears while homozygous recessives (ss) are earless; therefore, the three possible genotypes are distinguishable. In many other traits regulated by major genes, no one-to-one correspondence between phenotype and genotype exists. This leads to difficulties in classifying phenotypes according to their corresponding genotypes. For instance, assuming that the gene above is dominant such that ++ and +s have normal ears, identification of genotypes could only be done by planned matings of suspected carriers (heterozygotes) with recessive non-carriers. Suspected ram carriers can be +s or ++. Those producing progeny with only normal ears after being mated to ss ewes could be classified as homozygote, whereas those producing only half of offspring with normal ears would obviously be heterozygotes (Table 2).

Table 2. Example of progeny test to indentify suspected carriers of the gene regulating ear length in sheep, assuming that +s and ++ are not distinguishable.

Test cross		Progeny (%)		Genotype of suspected ram
Suspected carrier (sire)	Recessive (dam)	Normal	Earless	
Normal	Earless (ss)	100	-	Homozygote (++)
Normal	Earless (ss)	50	50	Heterozygote (+s)

The key in this classification is the ability to determine one of the homozygotes, in this case the homozygote for the recessive allele.

Problems in identifying genotypes arise when the alleles have incomplete penetrance and/or are subjected to the influence of considerable environmental fluctuation.

Equation (1) could be rewritten as

$$\mathbf{P = G + \delta \times E}$$

where δ is an indicator variable such that

δ = 1 if the expression of the gene is markedly influenced by environmental effects on P (for example in cases of incomplete penetrance) so as to deviate P from G, or

δ = 0 if genotypes can be detected by direct observation of the phenotype.

An example of situations where $\delta = 0$ is in the case of codominant alleles, such as regulating haemoglobin types A, B, and AB in sheep; corresponding to genotypes $H^A\ H^A$, $H^A\ H^B$, and $H^B\ H^B$ respectively[5].

The contention as to how many genes should be considered in order to define a trait under this model is usually related to the difficulty in identifying genotypes. Note that even with only two gene pairs, the number of genotypes to distinguish is nine and this number increases as 3^n with n representing the number of gene pairs involved.

III. THE EXPANDED POLYGENIC MODEL

This model includes traits whose variability is regulated by many genes each with a small effect on P. The gene action in this model can be additive or through intragenic (dominance) or intergenic (epistatic) interactions (Fig. 1).

The effect of the environment on these types of traits is very important in that it introduces substantial differences which in many cases may mask the effect of genes.

Identification of single genotypes is practically impossible, and would not be of any value, as the number of genes involved is large and usually not known precisely. Estimation of the relative influence of genetic and environmental effects in this case is more meaningful.

An important source of variation under this polygenic model is additive gene action. It is assumed that many traits of sheep production such as growth, wool production and some aspects of reproductive

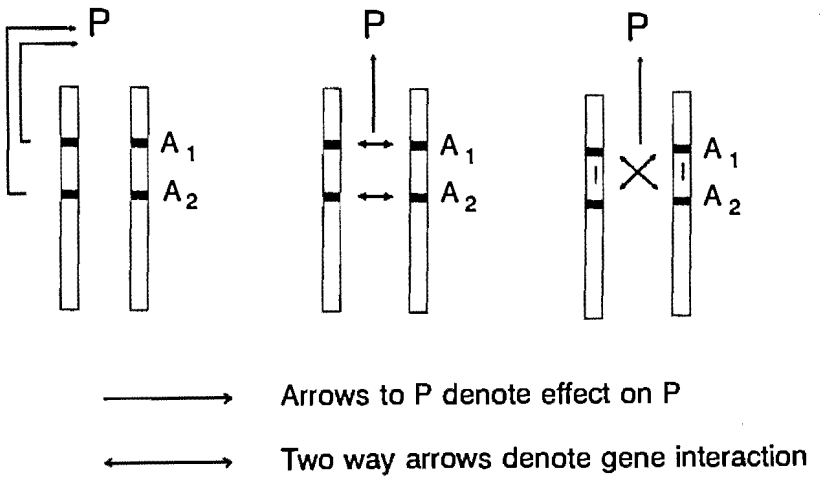


Fig. 1 Alternatives of gene action, genes A_1 and A_2 regulate the expression of trait P and are located in the chromosome pairs specified by the shaded bars.

performance, are in fact regulated by polygenes. Furthermore, additive genetic variation can be utilized by selection constituting one of the most important sources of variability for improvement in animal production.

The phenotypic variation of a trait P in relation to its components can be written as:

$$\sigma_p^2 = \sigma_g^2 + \sigma_e^2 + 2\,cov_{ge}$$

However, within populations maintained in a similar general environment there is usually little or no relationship between an animal's genotype and the environment it experiences so the final term can be ignored giving:

$$\sigma_p^2 = \sigma_g^2 + \sigma_e^2 \qquad (2)$$

σ_g^2 contains additive effects as well as non-additive effects. Non-additive variation is caused by gene interactions involving dominance

(intralocus interaction) and/or epistasis (interlocus interaction) (Fig. 1). Thus, designating the additive, dominance and epistatic effects, as a, id, and ie, respectively:

$$\sigma_g^2 = \sigma_a^2 + \sigma_{id}^2 + \sigma_{ie}^2 \quad (3)$$

In animal improvement, additive variation is the basis for selection whereas non-additive variation is used for strategies involving crossbreeding and exploitation of heterosis.

The relative proportion of σ_a^2 with respect to σ_p^2, is a measurement of the relative magnitude of the variation that could be subjected to selection. This ratio is known as the heritability of the trait in the restricted sense and is designated by:

$$h^2 = \sigma_a^2 / (\sigma_a^2 + \sigma_e^2) = \sigma_a^2 / \sigma_p^2 \quad (4)$$

Thus, the parametric space of h^2 is the interval $0 \leq h^2 \leq 1$. Conceptualized by Lush[6], heritability became an important parameter of modern animal breeding and improvement.

Exhaustion of genetic variability or greater relative influence of σ_e^2 will result in lower values of h^2 suggesting other alternatives for improvement than those based on the application of selection. This is a common trend in many adaptative traits such as those pertaining to reproduction with h^2 levels below 0.1. In contrast, growth traits and wool production, for instance, exhibit more additive variation with h^2 levels varying from 0.2 to 0.5.

The closer h^2 is to its upper limit, the closer it is to a condition explained by the basic Mendelian model in which there is more certainty about individual genotypes. Higher levels of h^2 suggest that a model based on the action of only a few genes could better explain the variability of a trait.

In estimating h^2, non-additive genetic variance is included as part of the environmental component. Therefore, low h^2 levels, leading to practically no selection gains, may be due either to the influence of the environment and/or important effects due to non-additive variation.

With traits exhibiting mainly additive genetic variation the progeny performance values will be intermediate to that of their parents. In contrast, when heterotic effects are more conspicuous, the progeny's performance will exceed the average.

Table 3. Additive and non-additive heterotic genetic action as observed in the production performance of the progeny AB of parents A and B.

Genetic action	Productivity of the progeny
Additive	$P_{AB} = (P_A + P_B)\ 1/2$
Heterotic	$P_{AB} > (P_A + P_B)\ 1/2$ positive heterosis
	$P_{AB} < (P_A + P_B)\ 1/2$ negative heterosis

P denotes the phenotypic value of a trait
Subscripts A, B denote parents of progeny AB

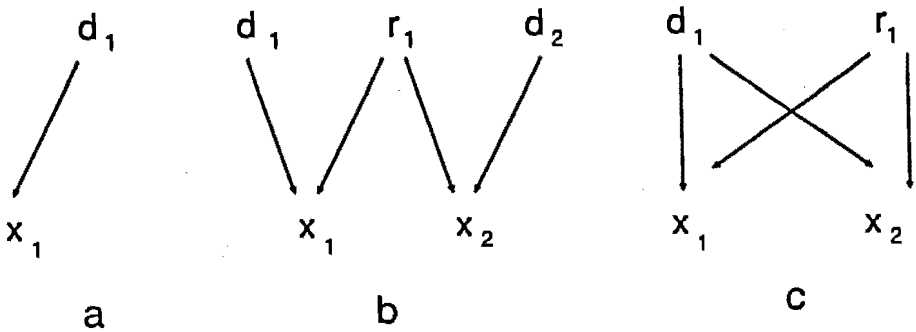
IV. THE ROLE OF RELATIONSHIPS

In estimating the effects of G and E on P under the polygenic model, the degree of relationship among individuals has an important role. The following Table summarizes the contribution of the most relevant relationships to genetic variability and Fig. 2 shows schematically the different relationships among individuals.

Table 4. Relationships and their contribution to the genetic variability.

Relationship	Contribution to genetic variability	
	Additive variance (σ^2_a)	Dominance variance (σ^2_{id})
Parent-offspring	1/2	-
Half-sibs	1/4	-
Full-sibs	1/4	1/2

Note that in most cases, except in those of prolific animals, which produce full-sibs at one time, parent/offspring relationships and those among half-sibs are the only available relationships for estimating genetic parameters in sheep.



a) Parent-offspring $x_1 <> d_1$
b) half-sibs $x_1 <> x_2$ having different dams (d_1 and d_2) and common sire r_1
c) Full-sibs $x_1 <> x_2$ having common dam (d_1) and sire (r_1)

Fig. 2 Schematic representation of relationships between individuals.

1. *Parent/Offspring Relationships*

These are useful in estimating genetic parameters by calculating the covariance between pairs of parent/progeny records which estimates 1/2 of σ_a^2. Let P_p and P_o represent parent and progeny records respectively and σ_p^2 the phenotypic or total variance of P_p, then:

Covariance (Cov) $P_pP_o = 1/2\ \sigma_a^2$ (5)

On the other hand, the regression of offspring on parents is:

$b_{op} = \text{Cov}\ P_pP_o\ /\ \sigma_p^2$ (6)

Thus, solving (5) and (6)

$h^2 = 2\ b_{op}$ (7)

In estimating h^2 for traits largely influenced by the maternal

environment, preweaning growth of lambs for instance, this technique is not to be recommended.

2. *Full-sib and Half-sib Relationships*

These relationships are utilized more frequently in the estimation of genetic parameters.

Records of progeny of rams (r) are used to calculate the variance among them or that of half-sibs. The basic model involved is:

$$Y_{ij} = \mu + r_i + e_{ij} \quad (8)$$

where Y represents an observation on the jth progeny of the ith ram; μ is a general mean; r_i represents a particular (the ith) ram and e is a residual term.

The structure for this type of data is shown in Fig. 3 which includes four sires mated to different ewes, some producing singles, some producing twins or triplets. For instance, ram 2 was mated to two ewes and ram 3 to three ewes. Furthermore, since the variance between rams σ_r^2, also known as the interclass correlation, estimates $\sigma_r^2 = 1/4 \ \sigma_a^2$ (Table 4), $h^2 = 4\sigma_r^2 / (4\sigma_r^2 + \sigma_e^2)$.

If ewes (dams) are randomly mated to rams and each ewe produces one or more progeny, the population will consist of half and full-sibs.

The model involved for this new arrangement is:

$$Y_{ijk} = \mu + r_i + d_{ij} + e_{ijk} \quad (9)$$

where Y_{ijk} is an observation on the kth offspring of the jth dam mated to the ith ram; μ, r_i and e_{ijk} were as defined in (8); and d_{ij} represents a particular (j^{th}) dam within a particular ram.

The variance between dams within sires (σ_d^2), or equivalently, the variance among full-sibs, estimates $\sigma_d^2 = 1/4 \ \sigma_a^2 + 1/2 \ \sigma_{id}^2$ (Table 4).

The data structure for the full-sibs case is also illustrated in Fig. 3. For instance, sire 1 was mated to three dams with two, three and no full-sibs, respectively, while ram 2 to two dams producing singles with no full sibs.

Half-sibs

$$y_{ij} = \mu + r_i + e_{ij}$$

Rams

Dams	1	2	3	4
	v	v	v	v
	v	v	v	v
	v		v	

Full-sibs

$$y_{ijk} = \mu + r_i + d_j + e_{ijk}$$

Rams

1	2	3	4
v v	v	v v v	v v
v v v	v	v	v v
v			

v : an offspring produced by a particular dam mated to a particular ram

Fig. 3 Data structure in analyzing half and full-sibs.

V. TRAITS AND SCALES

Most production traits display continuous variation. For instance, weaning weights of lambs in Indonesian Javanese Thin-tail sheep (JTT) were found to vary from 5.1 to 20.2 kg, with animals fitting into all possible values within that range. In most circumtances, polygenic systems, well-explained by the expanded model, control quantitative continuous variation that is markedly influenced by environmental effects. However, traits also display discontinuous variation by which animals can be classified in qualitative categories or groups such as coat colours and presence or absence of horns. Major 'Mendelian' genes usually control this type of variation less influenced by environmental causes, which is better explained by the basic Mendelian model.

The so called 'threshold' traits are a particular type of quantitative traits displaying discontinuous variation which usually fails to be explained by the basic Mendelian model. These characters are measured by giving them numbers such that the observations consist

of integers as realized values. Disease resistance and litter size are examples of these traits where it is assumed that the visible phenotypic scale has an underlying continuous scale of variation. The change in the visible scale from one level of discontinuity to another, for instance from one to two in litter size, occurs when changes in the underlying scale pass a given limit or threshold. Table 5 summarizes the possible relationships between underlying and visible scales of variation in different populations. In two sheep populations, the Booroola Merino and JTT sheep[7,8], variation in litter size was found to be controlled by major genes, that is by an underlying discontinuous genetic scale.

Exceptional cases of major genes regulating traits continuously distributed and subject to environmental influences are not yet well documented in sheep. An example of this type of gene action, affecting growth in mice, has been reported[9].

B. CHANGES IN THE GENETIC STRUCTURE OF POPULATIONS UNDER THE EXPANDED MODEL

Systematic processes including mutation, migration and selection, and random processes originating from sampling fluctuations change the genetic structure of populations by conditioning changes in the frequency of genes.

Table 5. Relationships between underlying and visible scale of distribution associated with variation of traits.

Underlying distribution	Visible distribution	Examples
Discontinuous	Discontinuous	Most Mendelian traits, regulated by major genes; eg. Litter size in JTT and Booroola sheep[7,8]
Discontinuous	Continuous	Major gene for body weight in mice[9]
Continuous	Continuous	Major production traits; eg. lamb weaning weights in JTT sheep
Continuous	Discontinuous	Threshold traits, such as litter size in Romanoff and Finnsheep

This will be continued in a discussion of systematic processes predictable in magnitude and direction (selection and gene migration), and of dispersive processes only predictable in magnitude (inbreeding).

I. SELECTION

Heritability is a population parameter. It depends on the balance of environmental and genetic effects such that its realized values are peculiar to the populations from which they were calculated as well as to the environments involved. Thus, strictly, speaking, h^2 is only true for a particular population and environment.

Note that for $h^2 = \sigma_a^2 / (\sigma_a^2 + \sigma_e^2)$ $h^2 \rightarrow 0$ if $\sigma_e^2 \rightarrow \infty$ or $\sigma_a^2 \rightarrow 0$.

Selection is the choice of individuals, usually the 'best', to be used as parents in a population. By selecting individuals in a population the breeder is manipulating and changing the frequency of genes; increasing or reducing these frequencies. These changes are reflected in changes in the progeny of the selected animals with corresponding changes in the population variance and mean.

Let us assume that we have a base population with mean and variance (μ_o, σ_o^2), depicted in Fig. 4.

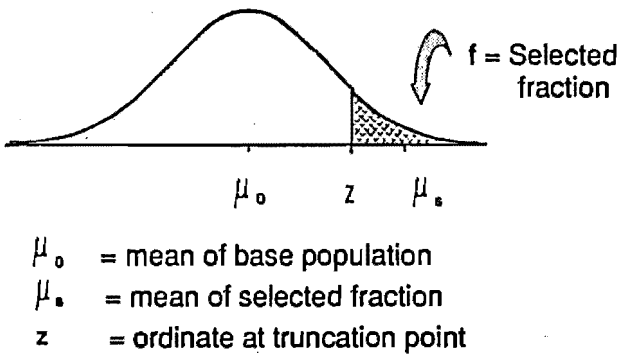


Fig. 4 Population distribution of individuals exhibiting continuous variation for a given trait under polygenic inheritance.

Furthermore, let us consider a subpopulation consisting of a fraction f (shaded area) of outstanding individuals, outliers or 'best' performers, with regard to a given trait with mean and variance (μ_s, σ_s^2), such that $|\mu_s| > \mu_o$ and $\sigma_s < \sigma_o$. The average superiority of this fraction is expressed by $S = \mu_s - \mu_o$ which is known as the selection differential (S) and which measures the selection pressure applied. Let us also assume that the variability of the trait under consideration has an important genetic component such that most of the differences observed in the base population are heritable.

If this subpopulation of outliers is isolated, i.e. 'selected' as parents of the future generation and allowed to reproduce, a change in the mean and variance will occur in the next generation after selection. The change in the population mean is the response to selection (R) which is clearly a function of the magnitude of the differences in means expressed by S and of the degree of the heritability of this difference, h^2. Thus:

$$R = f(S, h^2) = S\ h^2 \qquad (10)$$

Example 1 illustrates the predicted responses that could be obtained, for instance, by selecting for high weaning weights in JTT sheep.

Example 1:

Estimates of heritability of weaning weight in JTT sheep, obtained by daughter/dam regressions at the Cicadas Sheep Research Station flock, yielded $h^2 = 0.27$[10]. The population mean for this trait was estimated as $\mu_o = 10.2$ after correcting for litter size. If individuals with higher weaning weights, for instance with mean $\mu_s = 15$, were selected as parents for the next generation, then:

Average base population; $\mu_o = 10.2$ kg

Average selected parents $\mu_s = 15$ kg;

Selection differential ($S = \mu_o - \mu_s$) $S = 4.8$ kg;

Predicted response ($R = Sh^2$) $R = 1.29$ kg.

Thus, the average weaning weight of the offspring is expected to be 1.29 kg greater than it would have been if there were no selection.

The predicted R is theoretically valid for only the first generation after selection. The heritability should be recalculated after each generation of selection in view of 1) a direct reduction in variance of the selected parents σ_s^2, particularly in earlier generations, and 2) a change in the frequency of genes with a corresponding reduction in additive genetic variance, σ_a^2. However, selection experiments have shown that, from a practical point of view, these changes are not so important as to warrant recalculation of h^2 for about five generations.

Selection is usually conducted by truncation in which a threshold divides the population so that a fraction of individuals will be culled because their performance lies below the threshold while the 'best', with performance above, will be kept for breeding. If in addition to truncation selection, the trait under consideration is normally distributed, S can be easily predicted from the proportion used for breeding. Let z be the ordinate at the truncation point and f the proportion of selected individuals beyond the truncation threshold (Fig. 4). Then i = z/f measures the selection differential in standard deviation units. This is also known as the selection intensity. Thus:

$$i = z / f = S / \sigma_p \qquad (11)$$

and

$$S = i\,\sigma_p \qquad (12)$$

Note that the magnitude of i depends on the magnitude of S. Moreover, the larger the magnitude of S the larger the selection progress achieved, provided heritability is not low. Nevertheless, since, in a selection program, the number of selected individuals is usually small, S should be maximized avoiding the development of some degree of inbreeding, the effects of which will be inevitably negative and confounded with those due to selection.

The effect of different selection intensities is illustrated in example 2.

Example 2:

Table 6 shows selection intensities and predicted expected responses if selection is applied to obtain higher weaning weights in JTT sheep where:

$h^2 = 0.27$; $\sigma_p = 2.60$ and $\mu_o = 10.2$[10].

Table 6. Changes in response due to different selection differentials.

Selected fraction, f (%)	Selection intensity (i)	Expected response (kg) per generation ($R = ih^2_p$)	per year* (R/L)
10	1.75	1.23	0.41
20	1.40	0.98	0.33
30	1.16	0.81	0.27
40	0.97	0.68	0.23

* On the basis of L = 3.01 years

It is preferable to estimate selection responses on a yearly basis rather than on a generation basis. This is done by dividing R by the generation interval L, which is measured by the average age of the parents when their offspring are born; therefore, both estimates of L for males (L_m) and females (L_f) are needed and then a mid-parent L($\bar{L}$ = 1/2 ($L_f + L_m$), should be used. In the Cicadas sheep research flock this average for females only was calculated as L_f = 3.01 for n = 1322 records. R in terms of L_f was included in the last column of Table 6.

The simplest and most frequently used form of selection is mass selection in which individuals are selected on the basis of their own performance.

When selection is practised for sex-limited characters (litter size, milk production, etc), direct mass selection is impossible for males and their genetic merit is usually predicted on the performance of female relatives. Selection on the basis of records from relatives is also needed for traits that can be measured only after slaughter. Family selection may also be useful for traits which have a low heritability, provided the families are large.

Up till the present, no formal selection procedures have been applied to Indonesian sheep populations and no selection experiments have been carried out. This is reflected in the great variability of different production traits within breeds. Differences between breeds (Tables 1 and 7), however, are not only due to distribution and local adaptation but also the selection by the breeders. A special mention should be made of the development of one of the remarkable strains of JTT sheep, the Garut sheep. Rams of this strain are known for their

aggressiveness and are used for fighting. The development of this high level of aggressiveness is undoubtedly due to artificial selection. It is interesting also that the adults are much larger than the other JTT strains and appear to have faster growth rates.

It is generally accepted that all genes have pleiotropic effects; that is they affect the expression of more than one trait. Associations between traits can also be due to linkage between genes or blocks of genes but such associations are temporary compared with association by pleiotropy. The blocks of genes will eventually be broken by crossing-over and segregation of chromosomes. Because of these genetic associations, selection can indirectly affect more than one trait. Therefore it is important to know the direction and magnitude of associations among traits to avoid undesirable effects of selection that may eventually jeopardize a breeding plan.

Table 7. Population distribution of Indonesian sheep breeds.

Breed	%*	Location	Climate characteristics**
JTT	45.2	West Java	Humid (>300 mm rainfall during 6 months of the year)
JFT	17.3	East Java	Subhumid (>300 mm rainfall during only 4 months per year)
STT	8.2	Sumatra	Humid, with uniform rain (1900 mm distribution per year)

* With respect to the total Indonesian sheep population (5.36 million head)

** A defined dry season occurs in West and, particularly, in East Java with rainfall < 300 mm per month during April - October

In practice, when animals are selected, many characteristics are considered simultaneously; for instance, in choosing rams for breeding, tolerance to disease, higher weaning weight, litter size and absence of defects are all considered. Intuitively, one could envisage a function combining all possible information on the animals for one or more characters, that could be used to discriminate among individuals on the basis of their overall genetic merit. A function of this type, known as a selection index, was conceptualized by Smith[11], latter developed by Hazel[12], and has proven to be an effective tool in animal selection.

The development of more effective procedures for selecting animals is due to Dr. Charles Henderson and his colleagues at Cornell University. Henderson developed Best Linear Unbiased Prediction (BLUP)[13,14,15] using mixed model statistical analysis to rank animals according to their genetic merit. This technique, initially applied to selection for milk production in dairy cattle, is being presently used for the improvement of other traits in different species.

II. GENE MIGRATION: CROSSBREEDING

Crossbreeding is a process which controls or restricts the ways in which the parents of a given population are mated. The direct consequence of this process is an increase in heterozygosity. Crossbreeding has two relevant implications in animal improvement: development of new breeds and heterosis.

1. *Development of New Breeds or Types of Animal*

For traits expressing mainly additive genetic variation, crossbreeding is a means of introduction of new gene combinations or increasing the frequency of genes that affect production. If selection operates after crossbreeding, these new combinations can be fixed and a new breed can be developed, which exhibits a 'blend' of the parental populations.

In adopting this method of improvement, the potential of the local (target) population should first be known, as well as the suitability, for the given environment, of the population or breed to be introduced as an 'improver'. Ignoring the genetic potential of local breeds can have serious consequences since unrestricted crossbreeding can lead to the loss of particular characteristics directly related to fitness and adaptation.

For instance, it is believed that the Javanese Fat-tail (JFT) sheep was originally a breed of hair sheep. Considerable changes due to crossbreeding involving woolled sheep breeds used as 'improvers', has resulted in a population with an increased proportion of individuals that have a coarse woolled coat; a process that, if continued, will lead to substitution of coarse wool genes for hair in this population of sheep.

A program evaluating the possibility of improvement of some characteristics of Sumatran Thin-tail (STT) is presently being undertaken by the Small Ruminant-Collaborative Research Support

Program/Balai Penelitian Ternak (SR-CRSP/Balitnak) in North Sumatra. STT sheep, consisting of small animals (22 kg) with a coarse coat, are well suited for producing intensively (at a rate of 1.82 lambings/ewe/year) in systems integrated with tree-plantation crops. There is interest in increasing the size of STT and eliminating their coarse coat. With these aims, two alternative breeding plans have been considered: 1) the formation of a selected nucleus flock of STT sheep and 2) crossbreeding with the white, Virgin Island, Saint Croix hair sheep consisting of heavier (> 30 kg) and mostly hair animals. In the crossbreeding experiment, adaptation of the pure hair sheep and different crosses (F_1 and backcrosses) is under simultaneous evaluation.

In general, as will be seen later, the future of a new breed should not be based only on the evaluation of F_1 animals in view of heterotic effects; moreover, it should include the long-term production performance, particularly reproduction compared on contemporary basis with the pure local breed in the same environment.

2. *Heterosis*

One of the most common utilizations of crossbreeding involves the exploitation of heterosis expressed as the superiority of the first generation after crossing two different breeds or populations.

Hybrid vigour or heterosis is mainly explained by non-additive genetic causes, principally dominance and epistasis. The superiority is manifested most in the first crossbred generation and it is less pronounced, or not completely retained, in further generations of intercrossing. Thus the utilization of heterosis requires continued crossing and the maintenance of pure breeds.

Choice of this method of improvement should be based on careful estimation of its advantages compared with selection procedures on local breed(s). While it fits well in commercial operations it may not be useful for small or medium-size farmers who cannot afford to keep separate flocks of pure breeds or could become totally dependent on the provision, by large enterprises, of crossbred lambs.

III. INBREEDING

Inbreeding is a consequence of random processes occurring in small populations or of directed matings involving closely related individuals in large populations. Inbreeding reduces the heterozygosity

levels in the population. This generally reduces production, particularly in traits related to fitness and adaptation.

In small populations like those of smallholder farmers, most animals are related to some degree, so that unplanned matings can lead to inbreeding problems. Infertile animals and higher frequencies of animals with defects often occur. To avoid these problems, the rotation of unrelated rams between farmers should be encouraged by supervision, training and extension.

C. GENOTYPE X ENVIRONMENTAL INTERACTION

Differential response in performance of genotypes to different environmental niches or conditions is known as genotype x environment interaction (G x E). This may mean a change in magnitude of responses with the ranking of genotypes remaining the same in the different environments or it may involve a change in ranking.

A conceptual scheme for interaction, based on the magnitude of differences of both genotype and environmental effects, is presented in Table 8.

Table 8. Types of genotype x environment interactions according to the magnitude of differences of either component[16].

Magnitude of genetic differences	Magnitude of environmental differences	
	Small	Large
Small	Type 1	Type 2
Large	Type 3	Type 4

Type 1 and type 2 interactions are somewhat difficult to evaluate due to the difficulties involved in identifying small genotypic differences or small environmental differences. However, these interactions may contribute importantly to the variability of traits. In most breeding plans, for reasons of simplicity, genotype x environmental interactions are assumed to be negligible.

The fourth type of interaction is easily visualized by examining the performance of two contrasting breeds such as the JTT and Merino sheep replicated in two contrasting environments, for instance in the humid tropics of West Java (Bogor) and the dry tropics of West Timor (Kupang). Although no data are yet available for such an experiment, differential performance of the breeds in both environments is expected in view of the adaptation of genotypes (in this example represented by the two breeds) to vastly different local conditions.

Type 3 and type 4 are interactions that merit consideration from a practical point of view, especially in evaluating exotic breeds for local conditions.

An interesting example of G x E interaction occurs in sheep in the humid tropics. In general, the presence of wool is a useful characteristic of most sheep. The fleece protects the animal from direct exposure to sunlight which in some environments can raise body temperatures over the animal's tolerance level[17]. It also offers thermal insulation in areas with cold winters. However, in animals kept in sheds in hot environments, a thick fleece prevents heat dissipation and may be a host to external parasites that can reduce animal performance. As a consequence, lower performances have been reported[18,19] among woolled African and JTT sheep compared with those of animals resembling more a hair type sheep.

A second example of genotype x environment interaction has been observed in lamb survival of three lines of JTT sheep[10]. Table 9 illustrates the differential responses of three prolificacy lines developed at Cicadas, during two years of poor feed supply (1985 and 1986) and a year of more stable forage production (1987).

Note that the changes in the high line are more accentuated than in the low and medium lines. For instance, the transition from a 'good' to a 'bad' year represented at most 12 percent and 28 percent survival in the low and medium lines, respectively, in contrast to a substantial drop of up to 48 percent in the high line. Deaths occured around birth and were mainly due to lower lamb birth weights. This is an important result which indicates that high prolificacy genotypes are not suitable for environments or conditions that cannot support the enhanced nutritional demands imposed by a bigger litter.

D. PRODUCTION TRAITS REGULATED BY MAJOR GENES

As mentioned before, most production traits exhibit quantitative variation regulated by many genes. Milk production, growth and wool production are examples of these traits. Single genes usually control differences in kind rather than in degree, and are generally associated with characteristics unrelated to production. Furthermore, the expression of these single genes is not markedly affected by environmental effects. Thus, quantitative genetics has played a more substantial role in the improvement of animal production to the extent that variation produced by single genes has been overlooked if not ignored.

Table 9. Differential responses in lamb survival of three JTT prolificacy lines (genotypes) in 3 contrasting years (environments) at the Cicadas Sheep Research Station, West Java[10].

	Lamb survival (%)			Relative change*		
Lines**	Low	Medium	High	Low	Medium	High
Year						
1985	70	54	37	89	72	52
1986	69	63	47	88	84	66
1987	78	75	71	100	100	100

* Survival in year 1987 is taken as 100

** Low line ewes produce mostly singles and occasionally twins; medium line ewes produce mostly twins; high line ewes produce at least one ovulation rate or litter size ≥ 3

There are no reasons to assume that quantitative variation associated with production traits is regulated only by polygenes. The action of genes is in fact expressed in different facets, and, as conceptualized in the preceeding section, single genes can also control traits exhibiting quantitative variation, this variation being either continuous or discrete.

Litter size is a quantitative threshold trait exhibiting discrete variation. The trait is expressed in classes of one, two, three, etc, lambs born per ewe. Variation for this trait can be found in some prolific

breeds such as the Finnsheep and Romanoff from the temperate zone, which can produce litter sizes ≥ 2. It was found that genetic variation in these breeds is of a quantitative and additive nature and it occurs with other less prolific breeds producing mostly singles and occasionally twins. Thus, litter size could be increased by appropriate crosses between prolific and non-prolific breeds in order to produce an average litter size compatible with available resources. Interestingly, litter size in the above breeds exhibits little genetic variation; for instance in Finnsheep, h^2 for litter size is ≤ 0.1. Thus, selection for this trait does not lead to very substantial modifications or changes in the average litter size.

Prolificacy is a desirable condition that is included as a target of breeding plans in many situations oriented to maximizing overall productivity of sheep kept for meat production. This results in a preference for prolific sheep among sheep breeders. For instance, a survey among sheep farmers in West Java, Indonesia, showed that farmers preferred prolific ewes to those raising only single lambs. They also had a marked preference for a prolificacy maximum of two lambs per ewe per lambing because of high mortality in lambs from larger litters.

Prolificacy represents a special case among quantitative production traits where the genotype x environment interaction is large. It has an intermediate optimum, in relation to the production environment. Under harsh environments with constraints in feed supply and management, a single lamb is usually the optimum. Under more favourable conditions, typically found in areas with higher rainfall or which can be created by strategic supplementation in many crop-livestock systems, birth of twins or even triplets may result in substantial increases in total productivity.

In 1981 a breeding project on prolific sheep was started in Indonesia as an activity of the Small Ruminant-Collaborative Research Support Program (SR-CRSP) involving the University of California, Davis, in collaboration with the Research Institute of Animal Production (RIAP). The project focussed on the evaluation of the mode of inheritance of prolificacy in populations of local sheep and was carried out at Cicadas, near Bogor, West Java, representing the environment of the humid tropics.

The results indicate that control of prolificacy apparently involves a 'major' gene, tentatively designated F^j, in JTT sheep[8]. Ewes carrying this gene (F^j) have mostly two ovulations/oestrus and, at least once, three ovulations/oestrus. Non-carriers (++) have mostly one and very occasionally two ovulations/oestrus. The average ovulation rate and litter size per presumed genotype are shown in Table 10.

Table 10. Ovulation rate and litter size of presumed F^jF^j, F^j+ and ++ in JTT ewes[20].

	Genotype		
	F^jF^j	F^j+	++
Ovulation rate			
First parity	2.52	2.02	1.24
Late parities	2.92	2.19	1.27
Litter size			
First parity	2.37	1.89	1.23
Later parities	2.83	2.11	1.30

When prolificacy is controlled by a polygenic inheritance system, crosses between two distinct populations, such as the prolific D'Man and the non-prolific Sardi from Morocco, the offspring usually have a mean production equal to the average of the two parental breeds. This is indicated in Table 11 containing approximate litter sizes for different combinations between D'Man and Sardi breeds[3].

Table 11. Mean litter size of ewes with different proportion of D'Man and Sardi inheritance[3].

Crosses		Mean
D'Man	Sardi	Litter size
0	100	1.10
25	75	1.35
50	50	1.60
75	25	1.85
100	0	2.10

This information provides the means for developing stock with any desired intermediate litter size, suitable for different production environments.

In contrast, a major gene affecting the expression of a trait, such as F^j, can raise the production to the level of the most productive parent very rapidly, provided carriers can be identified. There are some disadvantages associated with inheritance of prolificacy among Javanese sheep. These include:

- difficulties in identifying carriers due to the marked influence of environmental variation on the expression of the gene, and
- only two litter size options: carriers (F^j) with a mean litter size between two and three (or more) and non-carriers (++) with a mean litter size < 1.5; neither genotype will consistently produce twins which are usually the most desirable option.

Unusually high repeatability and heritability estimates are reasons to suspect single gene inheritance. This is apparently the case for the JTT sheep with consistently high estimates of h^2 (ranging 0.3 to 0.5) in which a quantitative polygenic model failed to explain the variability of the trait[8,20,21].

DETECTION OF CARRIERS OF THE GENE

Identification of carriers of a gene is based on studying segregation patterns. Given a number n of offspring from a suspected carrier of a gene, the probability p of all 'normal' offspring out of n offspring is p. Thus the probability of having at least one 'non-normal' offspring if the suspected carrier is actually a carrier will be $q = 1 - p$.

A general method for identification consists of mating a suspected male (SM) carrier to a group of ewes, the number depending on a desired probability level. If the suspected male is a carrier, the probability of all progeny being normal is $p = (1 - q/2)^n$ and the confidence of detection $= 1 - p$.

Different alternative female genotypes for a test of this kind have been summarized in (Table 12)[22].

By assuming values of p of 90, 95, 99 and 99.9 percent for instance, n is easily calculated as:

$$n = \text{Log } p / \text{Log } x \qquad (13)$$

Table 12. Type of test cross and associated probabilities for detecting male carriers of genes (SM).

Type of female to be mated to SM	Probability of all offspring normal (x^n)	Probability (p) of detecting SM as a carrier ($1 - q^n$)	q
rr	$(1/2)^n$	$1-(1/2)^n$	1
Rr (known)	$(3/4)^n$	$1-(3/4)^n$	1/2
Own daughter	$(7/8)^n$	$1-(7/8)^n$	1/4

Table 13 includes the number (n) of ewes needed to progeny-test suspected male carriers (SM) for each of the discussed cases at a defined probability (p) level.

Table 13. Number of females needed to progeny test suspected male carriers of genes.

	Probability (p) level				
Genotype females	x	10%	5%	1%	0.1%
rr	1/2	3	4	7	10
Rr	3/4	8	10	16	24
Own daughters	7/8	17	22	34	52

E. GENERAL CONCEPTS OF PARAMETER ESTIMATION

Although parameter estimation and related theory are beyond the scope of this Chapter, general concepts associated with the subject and principles of estimation of genetic and environmental effects will be discussed. For more details, the reader is referred to specialized books in this field[23,24,25].

Estimation and prediction of causes of variation aim to elucidate common problems in animal breeding, such as:

- characterization of animal populations and estimation of their production potentials;
- identification of main constraints to production;
- evaluation of breeding programs and genetic trends;

- selection of individuals as parents for the next generation on the basis of their genetic merit.

A first step in this process is to conceptualize a function containing the potential causes that are most likely to produce changes and explain the variation displayed by a given metric trait which has an environmental and a genetic origin. This function, generally linear, is known as a linear model and consists of systematic (fixed) effects representing environmental causes of change (seasonal effects, nutritional treatments, specific treatments, age of ewe) and of random effects usually ascribed to genetic or a combination of genetic and permanent environmental causes.

A typical sheep population consists largely of 1) adult ewes varying in age, lactation and pregnancy status, 2) a number of ewe lambs which will replace dead and culled ewes and 3) a number of males kept for mating. Performance records of ewes in this population could have been obtained, for instance, for over a period of years with ewes lambing in different seasons of the year and subject to specific treatments from year to year. Two characteristics pertain to data of this nature: 1) lack of a defined design and 2) imbalance, that is unequal and frequently empty subclasses.

Estimation of systematic fixed effects is commonly done by the method of Least Squares provided that assumption of homoscedasticity (equal residual variance in each cell or subclass) holds.

Let us assume that the observed value for a given trait, i.e. ewe weights at mating, is represented by the scalar Y and, assuming linearity, by the following linear model:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_{ij} + e_{ijk} \qquad (14)$$

where μ is a general constant (mean), α_i is the effect of the ith class of effects, for instance parity of the dam, with i = 1,2,3,... parity. β is the jth class of effects, for instance season in which the observation is made, with J = 1 (dry season), 2 (wet season). γ_{ij} is the interaction effect of parity x season effects and e_{ijk} is a residual random component. Furthermore, var (Y_{ijk}) = var $(e_{ijk}) = \sigma_e^2$ for all ijk^{th} cells.

If $\mathbf{X_1}$ represents an incidence matrix associating elements of the vector α of fixed effects with the vector of observation $\mathbf{Y}$; $\mathbf{X_2}$ an incidence matrix linking the elements of vector β with $\mathbf{Y}$, and e the

vector of residuals, then we can rewrite (14) as:

$$Y = 1\mu + X_1\alpha + X_2\beta + X_3\gamma + e \qquad (15)$$

and

$$\text{var } Y = \sigma_e^2 I \qquad (16)$$

where I is an identity matrix of order n, the number of observations.

If we let $X = (1\ X_1\ X_2\ X_3)$ and $b' = (\mu\ \alpha\ \chi\ \gamma)$

then (15) still can be rewrittten as:

$$Y = Xb + e \qquad (17)$$

Application of the least squares procedures to estimate b leads to the normal equations represented by

$$X'Xb = X'y \qquad (18)$$

Solution to (18) or the least squares estimate of b is provided by

$$b^o = (X'X)^- X'y \qquad (19)$$

In (19) $(X'X)^-$ is a generalized inverse of $X'X$ resulting after eliminating the singularity of $X'X$.

The **important** consequences of this procedure are:

- b^o depends on the type of generalized inverse used, thus there will be as many solutions as choices of $(X'X)^-$. One of these solutions is known as the least square means;
- solutions **do not** estimate the parameters *per se* but a linear combination of parameters since there is not a unique solution.

Thus, in $b^o = (\mu_o\ \alpha_o\ \beta_o)$ with $^{o'} = (\alpha_1^0\ \ \alpha_2^0\ \ \alpha_3^0)$, α_1^o of α^o does not estimate the effect of α_1 itself but of $\mu + \alpha_1$ or other linear combination provided by the choice of $(X'X)^-$.

Therefore, careful consideration should be made in utilizing or interpreting least squares means or any other solution to (18).

Note that the difference between solutions provides an estimate of differences between effects. Furthermore, these differences are invariant to any kind of solutions or $(X'X)^-$ chosen. Thus: $\alpha_1 - \alpha_2$ is estimable since

$$E[\alpha_1^0 - \alpha_2^0] = (\alpha_1 + \mu) - (\alpha_2 - \mu) = \alpha_1 - \alpha_2$$

Test of the hypothesis of the contribution of fixed effects to differences in the given trait under analysis is made by ANOVA (Analysis of Variance) - like procedures consisting of testing appropriate reduction of sums of squares.

For the model implicit in (14) or (15), these reductions and corresponding tests of hypothesis are shown in Table 14.

Table 14. Reduction in sums of squares and associated hypothesis tests.

reduction	hypothesis test
$R(\alpha \mid \mu, \beta)$	H_o: all $\alpha = 0$
$R(\beta \mid \mu, \alpha)$	H_o: all $\beta = 0$
$R(\gamma \mid \mu, \alpha, \beta)$	H_o: all linear independent combinations of $\gamma = 0$

where R (•) is a notation implying the kind of effect that is being tested (left of the bar), after all other fixed effects were fitted.

General Linear Models (GLM) procedures of a statistical analysis system package (SAS) produces these types of reductions as 'Type II sums of squares' in processing data with unbalanced and empty cells.

I. GENERAL LINEAR TEST OF HYPOTHESIS

Any linear function of the parameters (contrasts) can be tested by a general linear test of hypothesis consisting of:

$F(H) = Q/s\,\hat{\sigma}^2$

where $Q = (K'b^o)'\,(K'G\ \ K)^{-1}\,K'b^o$ and $G = (X'X)$

where K represents the vector (or matrix) with rows consisting of coefficients associated with the hypothesis to be tested. K has as many rows as the order of the vector of fixed effects, s is the number of rows of K', $\hat{\sigma}^2$ is the estimate of the mean squared error (MSE) and H is the hypothesis being tested under the F-statistic with s degrees of freedom (df) and df of the MSE term.

For instance, assuming $b^{o'} = [\mu^o\ \sigma_1^o\ \ \sigma_2^o\ \ \beta_1^o\ \ \beta_2^o\ \ \beta_3^o]$, typical values of H and K' are:

1) testing equalities of α's

$H: \alpha_1 - \alpha_2$

$K' = [\ 0\ 1\ -1\ 0\ 0\ 0\ ]$

2) testing β_1 against the average of β_2 β_3

$H: \beta_1 = (\beta_2 + \beta_3)/2$

$K' = [\ 0\ 0\ 1\ -1/2\ -1/2\ ]$

Example

Consider hypothetically that records made by contemporary ewes (equal age) of two different breeds (b_1 and b_2) during four consecutive years (t_1, t_2, t_3 and t_4), were obtained in a given month.

The following Table contains information on individual records, total numbers per class and cell means corresponding to the overall production per ewe evaluated as lamb weight (kg) weaned per ewe.

Note the unbalanced data structure of this example. Cells differ in number, with the first breed failing to have records in year 3 (empty class).

1. *Analysis Ignoring Interaction*

In analyzing the previous information the following model could be suitable

$$\mathbf{Y} = \mathbf{1}\mu + \mathbf{X}\mathbf{t} + \mathbf{Z}\mathbf{b} + \mathbf{e}$$

where: **Y** is the vector of observations. μ, **t** and **b** are fixed effects representing a general mean, year and breed effects, respectively. **1** is a (17 x 1) vector of ones, and **X** and **Z** incidence matrices associating elements of **t** and **b** to the vector of observation **Y**, respectively and **e** is a random vector of residues.

Furthermore, if $\mathbf{Y}' = [\ 20\ 21\ 19\ 9\ 11\ \ldots\ 21\ 21\ ]$ then, for dots (.) representing zero's:

$$\mathbf{X}' : \begin{bmatrix} 1 & 1 & 1 & 1 & . & . & . & . & . & . & . & . & . & . & . & . & . \\ . & . & . & . & . & 1 & 1 & 1 & 1 & 1 & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . & . & . & 1 & 1 & 1 & . & . & . & . \\ . & . & . & . & . & . & . & . & . & . & . & . & . & 1 & 1 & 1 & 1 \end{bmatrix}$$

$$\mathbf{X}'\mathbf{X} = \begin{bmatrix} 5 & 0 & 0 & 0 \\ & 5 & 0 & 0 \\ & & 3 & 0 \\ & & & 4 \end{bmatrix}$$

Table 15. Information on individual records, total numbers per class and all means corresponding to the overall production per ewe calculated as lamb weight weaned per ewe.

a. Individual records

Breeds	Years			
	t_1	t_2	t_3	t_4
b_1	20,21,19	18,21,22		9,10
b_2	9,11	10,11	18,17,20	21,20

b. Totals: per class and marginal

Breeds	Years				
	t_1	t_2	t_3	t_4	Totals
b_1	3 (60)	3 (61)		2 (19)	8 (140)
b_2	2 (20)	2 (21)	3 (55)	2 (41)	9 (137)
Totals	5 (80)	5 (82)	3 (55)	4 (60)	17 (277)

(In parenthesis, sums of kilograms of lambs weaned)

c. Means: per class and marginal

Breeds	Years				
	t_1	t_2	t_3	t_4	Totals
b_1	20	20.3		9.5	7.5
b_2	10	10.5	18.3	20.5	15.2
Totals	16	16.4	18.3	15.0	

t_1 and t_2 good years
t_3 and t_4 poor years

$$Z = \begin{bmatrix} 1 & 1 & 1 & . & . & 1 & 1 & 1 & . & . & . & . & . & . & 1 & 1 & . & . \\ . & . & . & 1 & 1 & . & . & . & 1 & 1 & 1 & 1 & 1 & . & . & 1 & 1 \end{bmatrix}$$

$$Z'Z = \begin{bmatrix} 8 & 0 \\ & 9 \end{bmatrix} \qquad Z'X = \begin{bmatrix} 3 & 3 & 0 & 2 \\ 2 & 2 & 3 & 2 \end{bmatrix}$$

$$1'Y = 277 \qquad Y'X = [\,80 \;\; 82 \;\; 55 \;\; 60\,] \qquad Y'Z = [\,140 \;\; 137\,]$$

Thus, assembling the previous matrices into the least squares equations (18) the following set is obtained:

$$\begin{bmatrix} 17 & 5 & 5 & 3 & 4 & 8 & 9 \\ & 5 & 0 & 0 & 0 & 3 & 2 \\ & & 5 & 0 & 0 & 3 & 2 \\ & & & 3 & 0 & 0 & 3 \\ & & & & 4 & 2 & 2 \\ & & & & & 8 & 0 \\ & & & & & & 9 \end{bmatrix} \begin{bmatrix} \mu \\ t_1 \\ t_2 \\ t_3 \\ t_4 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} 277 \\ 80 \\ 82 \\ 55 \\ 60 \\ 140 \\ 137 \end{bmatrix}$$

By imposing constraints $\hat{\mu}=0$ and $\hat{t}_4=0$, the following solutions are obtained:

$$\begin{bmatrix} \hat{\mu} \\ \hat{t}_1 \\ \hat{t}_2 \\ \hat{t}_3 \\ \hat{t}_4 \\ \hat{b}_1 \\ \hat{b}_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0.623 \\ 1.023 \\ 5.216 \\ 0 \\ 16.882 \\ 13.118 \end{bmatrix} \quad \text{or the least square solutions} \quad \begin{bmatrix} - \\ 15.623 \\ 16.023 \\ 20.216 \\ 15.000 \\ 18.598 \\ 14.833 \end{bmatrix}$$

The least square solutions have also been added to contrast the different solutions achieved by the different constraints [different (X'X)] imposed.

Therefore, $\hat{t}_1$ does not estimate the real effect t_1 but a function that includes it (in our solutions $E[\hat{t}_1] \neq t_1$ but $E[\hat{t}_1 = \mu + t_1]$). This must not be overlooked in interpreting output analysis.

Note that the differences between two solutions within a class are the same regardless of the type of solution. For instance, $\hat{t}_2 - \hat{t}_3 = 1.023 - 5.216 = -4.193$ from the first solution set is equal to $\hat{t}_2 - \hat{t}_3 = 16.823 - 20.216 = -4.193$ if we use the least square means.

Furthermore, these differences are estimates of actual differences of effects; that is $E(\hat{t}_2 - \hat{t}_3) = t_2 - t_3$.

The following is an F-statistics-based test of hypothesis concerning the influence of years and breeds in producing changes in the variable under study ignoring interactions:

Table 16. The influence of year and breed on the variable under study.

Reduction	Source effect being tested	df	SS	MS	F	P > F
$R(t \mid \mu, b)$	t	3	45.88	15.29	0.56	0.651
$R(b \mid \mu, t)$	b	1	48.19	48.19	1.76	0.209
Error		12	395.53	7.99		

SS and MS: sums of squares and mean squares, respectively
df: degrees of freedom

This ANOVA-like summarization is provided by 'type II sums of squares' of (SAS), as indicated before.

We conclude from this analysis that the two effects of the model (breed and years) do not contribute significantly to changes in overall ewe production.

2. *Analysis Considering Interactions*

The previous conclusion may lead to erroneous interpretations in view of potential interactions between factors in the model.

Inspection of the cell means suggests a differential response by the two breeds in contrasting years (interaction breed x year). The

response seems to change the ranks in 'poor' years with b_2 performing better than b_1. However, we have an empty class that precludes us from knowing if breed 1 consistently performed less than breed 2 in both poor years. Therefore, a test of interactions would be meaningless.

A reasonable option is to change the model by fitting the interaction directly, that is changing to a cell mean model, then:

$$\mathbf{Y} = \mathbf{1}\mu + \mathbf{W}\mathbf{d} + \mathbf{e}$$

where **d** is the vector resulting of the possible combination of t's and b's

$$\mathbf{W} = \begin{bmatrix} 1 & 1 & 1 & . & . & . & . & . & . & . & . & . & . & . & . & . & . & . \\ . & . & . & 1 & 1 & . & . & . & . & . & . & . & . & . & . & . & . & . \\ . & . & . & . & . & 1 & 1 & . & . & . & . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . & 1 & 1 & . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . & . & . & 1 & 1 & 1 & . & . & . & . & . \\ . & . & . & . & . & . & . & . & . & . & . & . & . & 1 & 1 & . & . & . \\ . & . & . & . & . & . & . & . & . & . & . & . & . & . & . & . & 1 & 1 \end{bmatrix}$$

and the least squares equations (18) become:

$$\begin{bmatrix} 17 & 3 & 2 & 2 & 2 & 3 & 2 & 2 \\ & 3 & 0 & 0 & 0 & 0 & 0 & 0 \\ & & 2 & 0 & 0 & 0 & 0 & 0 \\ & & & 3 & 0 & 0 & 0 & 0 \\ & & & & 2 & 0 & 0 & 0 \\ & & & & & 3 & 0 & 0 \\ & & & & & & 2 & 0 \\ & & & & & & & 2 \end{bmatrix} \begin{bmatrix} \mu \\ c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \\ c_6 \\ c_7 \end{bmatrix} = \begin{bmatrix} 277 \\ 60 \\ 20 \\ 61 \\ 21 \\ 55 \\ 19 \\ 41 \end{bmatrix}$$

where:

$[\ c_1\ c_2\ c_3\ c_4\ c_5\ c_6\ c_7\ ] = [\ tb_{11}\ tb_{12}\ tb_{21}\ tb_{22}\ tb_{32}\ tb_{41}\ tb_{42}\ ]$ representing the class combination of t and b. If we impose the constraint $\mu = 0$ then:

$$\begin{bmatrix} \hat{\mu} \\ \hat{c}_1 \\ \hat{c}_2 \\ \hat{c}_3 \\ \hat{c}_4 \\ \hat{c}_5 \\ \hat{c}_6 \\ \hat{c}_7 \end{bmatrix} = \begin{bmatrix} 0 \\ 17 \\ 14.5 \\ 17 \\ 14.5 \\ 16.6 \\ 9.5 \\ 17.5 \end{bmatrix}$$

Note that the solutions correspond to the cells means. The problem now reduces to a one-way ANOVA problem for unequal numbers. Analysis of data under this new model yielded, mean squares = 62.78 and F = 33.34 ($P < 0.01$) with 6 and 10 degrees of freedom corresponding to the effects of year-breed and error, respectively.

Therefore, variation in y resulted as a consequence of different combinations of t and b. Contrasts could be made to compare breeds within years or any type of desired comparison. For instance for k' being a vector of order (1x7) (the number of elements of tb), the following are some possible contrasts to test:

- Average comparison of b_1 vs b_2 in poor years:
  H_o: $(tb_{11} + tb_{21})/2 = (tb_{12} + tb_{22}) / 2$, with
  $k' = [\,1/2 \;\; 1/2 \; - 1/2 \; - 1/2 \;\; 0 \;\; 0 \;\; 0\,]$
- Comparison of performance of b_2 in poor years:
  H_o: $t_3b_2 = t_4b_2$, with
  $k' = [\,0 \;\; 0 \;\; 0 \;\; 0 \;\; 0 \;\; 1 \;\; -1\,]$
- Comparison of average performance of breeds in good years:
  H_o: $t_4b_1 = 1/2(t_3b_2 + t_4b_2)$, with
  $k' = [\,0 \;\; 0 \;\; 0 \;\; 0 \;\; 1 \;\; 1/2 \; - \; 1/2\,]$

Contrast of this type, are easily calculated by using a statistical package such as SAS.

II. VARIANCE COMPONENTS

Estimation of variance components is more complicated and its reliability depends on the nature and quality of the data. Quite often,

negative estimates are obtained as a consequence of the methods of estimation utilized, an inadequate model or data problems (especially reduced number of observations).

It must remembered that the parametric space of the variance is the positive real line so that always $\sigma^2 \geq 0$ holds. When the variance component is near to zero, some methods of estimation such as Henderson's method I and III, which are unbiased, can render negative estimates. On the other hand, the family of Maximum Likelihood (ML) methods (ML or REML) will confine the estimates into their parametric space.

In explaining, methods of variance component estimation, let us assume the following mixed linear model:

$$Y = Xb + Zu + e \tag{20}$$

where Y of order N (number of observations) is a vector of observations, b and u are vectors of fixed effects and random effects, of order f and r respectively, and x and z are incidence matrices that associate elements of b and u to Y. e is a (1xN) vector of random residuals.

Furthermore,

$$E\ y = xb$$

since

$$E \begin{bmatrix} u \\ \\ e \end{bmatrix} = \begin{bmatrix} o \\ \\ o \end{bmatrix} \qquad \text{and}$$

$$\text{Var} \begin{bmatrix} b \\ u \\ e \end{bmatrix} = \begin{bmatrix} o & & \\ & G & \\ & & R \end{bmatrix}$$

In the simplest situation $G = \sigma_u^2\ I_r$ and $R = \sigma_f^2\ I_n$. In this case, the variance of a single observation is $\sigma_y^2 = \sigma_u^2 + \sigma_e^2$ and Henderson's Mixed Model Equations (MME):

$$\begin{bmatrix} X'X & X'Z \\ Z'X & Z'Z + \lambda I \end{bmatrix} \begin{bmatrix} b \\ u \end{bmatrix} = \begin{bmatrix} X'Y \\ Z'Y \end{bmatrix}$$

where $\lambda = \sigma_e^2 / \sigma_u^2$

Let us call C the coefficient matrix of (21) with the following C_{ij} submatrices being:

$$C = \begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix} \tag{22}$$

and a generalized inverse defined as

$$C' = \begin{bmatrix} C^{11} & C^{12} \\ C^{21} & C^{22} \end{bmatrix} \tag{23}$$

1. *Henderson's Method I*

This is the method that involves fewer computational problems. It assumes that all components in (20) are random. The estimation procedure is then applied to equate expectations to different quadratic forms, or reduction in sums of squares for different submodels, each including one of the random effects of the model. Reductions involved are:

$Y'Y$ R(u), Red(b), Red(u)

Expectations of previous reductions are computationally simple since every coefficient matrix in the reduction is diagonal. For instance:

$R(u) = Y'Z\ (Z'Z)^{-1}\ Z'Y$

with diagonal elements of $(Z'Z)^{-1}$ equal to the inverse of the number of observations of every level of u.

Method 1 may produce negative estimates.

2. *Henderson's Method 3*

Let us assume u fixed in (20), $W = (X\ Z)$ and $d' = (b'\ \ u')$. The corresponding least squares solutions are:

$d^{o} = W'W' \quad W'Y$

Variance components are estimated by equating the expectations of reductions of sums squares of the form of R(u | b), containing both fixed and random effects, to their realized values.

σ_e^2 is estimated by

$E[\, Y'Y - R(u,\ b)\,] = \sigma_e^2\,[\,\text{N-rank}\,(w)\,]$

Thus,

* $\hat{\sigma}_e^2 = Y'\,(Y - Xb^{o} - Zu^{o})\,/\,[\,\text{N-rank}\,(w)\,]$

σ_u^2 is estimated by

$E\,[R(u\ \ b)\,] = E\,[R(b, u) - R(b)\,]$

$= \text{tr}\,[\,Z'Z - X(X'X)^{-1}X'\,)\,] \qquad \sigma_u^2 + \sigma_e^2\,[\,\text{rank}\,(W) - \text{rank}\,(X)\,]$

Method 3 may produce negative estimates. Moreover, one of its main limitations is computational, if the order of w'w and the order of other matrices associated with reduction for submodels, is excessively large.

3. *ML family of Estimators*

ML Estimators

$$\hat{\sigma}_e^{2(k+1)} = y'(y - x\hat{b}^{(k)} - z\hat{u}^{(k)}/N \tag{24}$$

$$\hat{\sigma}_u^{2(k+1)} = (\hat{u}^{(k)}\hat{u}^{(k)} + \hat{\sigma}^{(k)}\,\text{tr}\,T_A)\,/\,r \tag{25}$$

where $T_A = C_{22}^{-1} = (z'z + I_r\lambda)^{-1}$ from (21)

REML estimators

$$\hat{\sigma}_e^{2(k+1)} = Y'(Y - X\,\hat{b}^{(k)} - Z\hat{u}^{(k)}\,/\,(\ \text{N-rank}(X)\ ) \tag{26}$$

$$\hat{\sigma}_u^{2(k+1)} = (\hat{u}^{(k)}\hat{u}^{(k)} + \hat{\sigma}_e^{2(k)}\ \ t_r\,T_B)\,/\,r \tag{27}$$

where rank (X) = f, the number of levels of fixed effect, and $T_B = C^{22}$ from (23).

There are no unique solutions for ML and REML estimators. Solutions are obtained iteratively until some convergence criterion is

met. Equations (24) (25) (26) and (27) are obtained according to K+1 rounds of iteration based on $\hat{u}^{(k)}$ and $\hat{\sigma}_e^{2(k)}$ estimates obtained in the previous, k^{th}, iteration.

ML and REML equations always yield positive estimates.

F. POTENTIAL OF INDONESIAN SHEEP BREEDS FOR THE HUMID TROPICS

Sheep production in the humid tropics is constrained by factors that are difficult to control by regular and economic management. Within and between year fluctuations of temperature and humidity interact with changes in forage and the incidence of parasite infestation. Improving or increasing animal productivity under these conditions within the humid tropical ecosystems requires an animal adapted to perform at relatively satisfactory levels of production and reproduction. An animal of this type is rarely available since most of the highly productive breeds have been developed and selected for less extreme environments with better availability and stability in the production of forages.

There are many breeds of sheep adapted to the tropics[26,27]. However, their levels of productivity when compared on a direct output basis are usually inferior to those obtained with temperate breeds. This direct comparison, has led in many circumstances to substitutions of well-adapted breeds or migration of unsuitable genetic combinations for the environments under consideration. Utilization of genotypes based only on their performance within environments distinct from those where they will be introduced can have devastating consequences. Many examples illustrate the consequences of importing non-adapted livestock. Immediate responses due to heat stress and parasite infestation may seriously compromise the health status of, if not decimate, the introduced population while long-term exposure may so reduce its reproductive performance that it precludes the development of the imported pure breeds.

Underestimation of the performance of the native and local breeds commonly occurs when only direct comparisons of lamb growth are made without taking into account the size and reproductive performance.

There are no records of when sheep were introduced into South-East Asia. Small ruminants were found by earlier European travellers and reliefs depicting small ruminants at the Borobudur temple show that these species were in Java before the spread of Islam[28,29]. One can assume that the sources of migration for sheep were associated with trade, Arab invasions and organized introductions from Africa, Europe, China and India.

As a result of a long process of adaptation, the action of natural and artificial selection and gene migration, Indonesia possesses three different indigenous sheep breeds that are distributed throughout its different tropical environments and are well suited for intensive and extensive exploitation. These systems include cut-and-carry feed systems and also grazing under various intensities and conditions such as under tree crops (rubber, palm oil, coconut, etc).

During the last ten years, characterization of these breeds has been carried out in a collaborative research program involving RIAP and the SR-CRSP[3]. A summary of results that illustrates the potential of the breeds for production in the humid tropics, has been discussed by Iniguez and Gunawan[30] and is included in this section.

I. LOCAL BREEDS AND DISTRIBUTION

Three breeds can be well identified in Indonesia: The Javanese Thin-tail (JTT), the Javanese Fat-tail (JFT) and the Sumatran Thin-tail (STT) sheep. Table 7 shows the distribution of these breeds and the main climate characteristics of the environments where they are most frequently found.

Phenotypically, the breeds can be easily distinguished. STT and JTT sheep have thin and long tails differing noticeably from the fat tails found on the JFT sheep. Coloured coats are common in JTT sheep, in addition to the presence of horns in the rams[8]. A low incidence of coloured animals is found among Sumatran sheep which have a light brown coat. Most of the JFT animals are white with no horns.

The JFT population is comprised of a large proportion of hair sheep. Some evidence suggests that, originally, JFT were mainly comprised of hair sheep. For instance, on the island of Lombok, where the breed has been kept isolated, most of the animals could be classified

as hair sheep. On the average, the wool of these animals is coarse and irregularly distributed over the body. Shedding occurs among woolled animals and is apparently related to climate and nutritional fluctuations.

The JTT sheep has some strains or local subpopulations that are named after the local regions where they are prevalent, such as the Garut and the Priangan sheep.

1. *Bodyweights and Growth*

Of the three indigenous sheep breeds, the STT is considered to be the lightest and JFT the heaviest. Averages of 30 and 35 kg for JTT and JFT sheep, respectively have been reported[31-33]. Table 17 includes mean body weights at birth, weaning and at various parities of the three breeds obtained at RIAP's sheep research station at Cicadas, West Java, and at Sei Putih, North Sumatra.

Table 17. Body weights of JTT, JFT and STT sheep[30].

Breed	Lamb weights (kg)			
	Birth		Weaning	
	Singles	Multiples	Singles	Multiples
JTT	2.64	1.68	10.0	7.6
JFT	2.28	1.52	9.7	7.2
STT	2.13	1.50	10.8	7.0

	Ewe weights (kg)				
	Parity				
	1	2	3	4	5
JTT	22.8	25.0	26.9	28.6	29.9
JFT	22.9	25.8	27.1	27.1	26.9
STT	19.5	21.3	22.5	24.2	23.4

At Cicadas, JFT ewes averaged lower weights than those reported in the literature. Estimates of the postweaning growth of lambs have been somewhat variable, either due to differences between

nutritional trials from which they were obtained or due to the intrinsic variability of the trait. Reliable estimates reflecting the potential of JTT for postweaning growth are summarized in Table 18[32].

Table 18. Post-weaning growth of JTT lambs[32].

Prolificacy classes	Bodyweight classes	Average daily gain (g/d)
Low	Low	113
	High	119
High	Low	79
	High	110

2. *Litter Size and Lamb Survival*

Individual ewes with prolific litters are commonly found in all Indonesian sheep breeds[8,20,21,33,34]. Experimental evidence discussed previously, suggests that a single dominant gene, F^j, explains more efficiently the genetic control of prolificacy[8]. Carriers of the gene (F^j) in JTT sheep have an average litter size of 2.28 contrasting with the noncarriers (++) with an average of 1.07.

The distribution of litter size per breed is shown in Table 19. High lamb mortality is usually associated with high prolificacy, as shown in Table 20. Adequate management and nutrition of prolific litters can reduce lamb mortality to acceptable levels[35,36].

Table 19. Litter size of JTT, JFT and STT sheep[30].

Breed	Mean litter size	SD	CV	Litter size distribution (%) 1	2	3	>3	n
JTT	1.79	.81	46	43	41	13	3	658
JFT	1.69	.82	49	50	35	12	3	177
STT	1.54	.68	44	56	36	7	1	379

SD and CV: standard deviation and coefficient of variation, respectively

Table 20. Lamb survival as fraction of lambs born by litter classes in JTT, JFT and STT sheep[30].

	Litter size			
Breed	1	2	3	> 3
JTT	0.80	0.63	0.40	0.12
JFT	0.86	0.62	0.53	0.34
STT	0.92	0.77	0.67	0.55

3. *Lambing Distribution and Lambing Intervals*

The lambing distribution of JTT and STT ewes shows the potential for reproduction year-around (Fig. 5)[37,38]. Ewes can conceive during any month with some months being characterized by a lower conception rate. This seasonal effect, apparently associated with the dry season, is more marked in the JTT sheep.

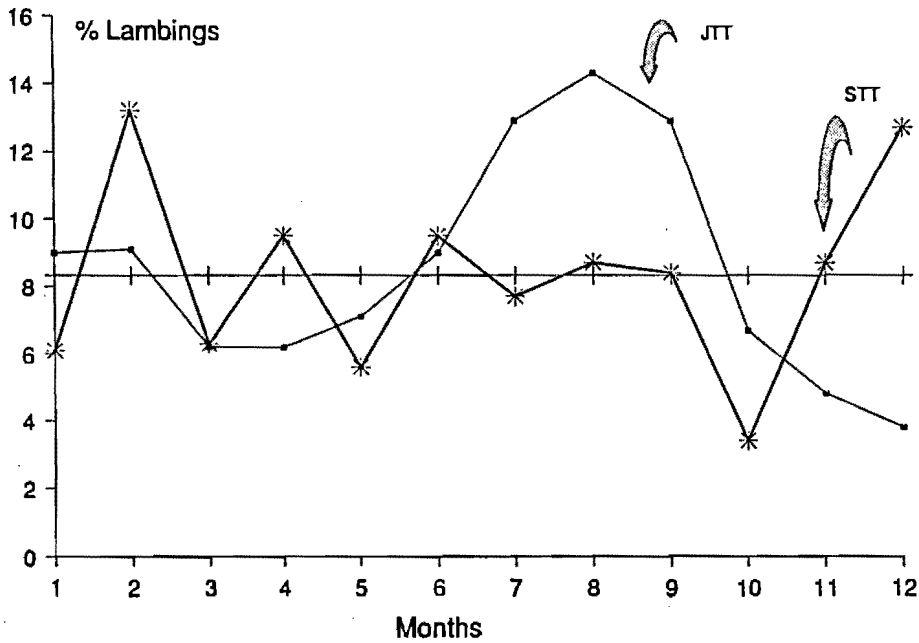


Fig. 5 Lambing distribution in JTT and STT ewes; —— JTT, *——* STT.

Associated with this nonseasonal breeding, the STT and JTT ewes have the potential to lamb more than once a year. In a continuous mating program, Sumatran ewes grazing in a rubber plantation averaged lambing intervals of 201 days with 96 percent of the lambing intervals ranging from 160 to 260 days and producing a mean of 1.82 lambings per year. A selected group of STT ewes completing their seventh parity became pregnant 30 to 50 days after each lambing[33]. *Post-partum* intervals of JTT ewes obtained during the dry season (April to October), averaged 75 days in contrast to shorter intervals (61d) in STT sheep (Fig. 6), but this is probably due to less variable nutrition rather than to real interval differences between the two breeds.

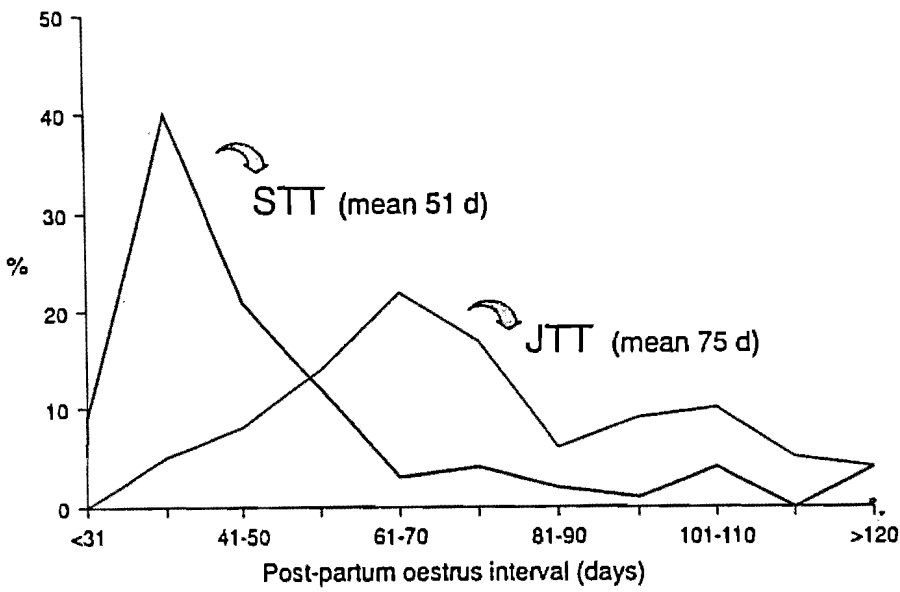


Fig. 6 Distribution of post-partum oestrous interval in JTT and STT sheep.

4. *Overall Productivity*

Table 21 shows the overall productivity of ewes per lambing. Values in this Table are strongly affected by prolific litters having high

lamb mortality (Table 20). With this high lamb mortality, JTT and JFT ewes weaned comparatively fewer kg lamb compared with the STT ewes which weaned up to 95 percent of lambs born. This is especially remarkable when the small size and low bodyweight of STT ewes are considered.

Table 21. Mean weight of lambs weaned per ewe per lambing[30,38].

Breed	Average (kg)	% Ewe body weight	n
JTT	9.29	35	658
JFT	9.04	35	177
STT	11.4	52	329

The prolificacy and suitability for accelerated lambing of Indonesian sheep breeds are very valuable traits with potential for increasing sheep productivity in the humid tropics.

G. BREEDING PLANS FOR SMALL RUMINANTS IN INDONESIA

Breeding strategies for the humid tropics, with emphasis on integrated tree cropping and sheep production systems have been discussed elsewhere[39-41]. A summary of these discussions is provided in this section.

One of the main goals of animal production systems is to maximize returns by optimizing animal production. In pursuing these goals, one needs to address questions such: as what are the attainable conditions for forage production and sustainability; what are the ideal forages for those conditions; what are the most suitable animal breeds or crosses? As mentioned before, fewer animals have been selected for increased productivity in the humid tropics than in temperate climates. In general, the only animals in a given locality are locally adapted populations usually perceived as having 'low' productivity when compared with breeds from temperate climates. Nevertheless, these local breeds have attributes which make them suitable for use in

genetic improvement programs: resistance to disease and to parasitism, tolerance to heat and humidity, and year-around reproduction potential.

Methods available for improvement are selection among and within locally available breeds and development of improved types of animals by crossbreeding or gene migration. This second system should be based on local animals and breeds that are from similar environmental conditions and have desirable characteristics which are lacking in the population to be upgraded. Adoption of the latter strategy should be based on results of a comparative evaluation of performance of the new genotype or its crosses with local pure breeds and with pure exotic breeds within similar environments.

The equatorial tropics are characterized by day lengths with minimal fluctuations during the year. In the humid tropics, rainfall variation in some environments is an important factor affecting the quality and quantity of forages.

In contrast with sheep from temperate climates, most tropical breeds are non-seasonal breeders so that they can be bred year-around, for example, the Indonesian STT sheep breed which under continuous mating, had a mean lambing interval of 201 days[33]. This natural characteristic, allowing for intensive or accelerated lambing, should not be disrupted nor reduced by introducing possible genes for seasonality from temperate climate breeds.

In spite of the apparently low production levels per lambing of local ewes, evaluated as kg of lamb weaned per ewe per lambing, their more frequent lambing will permit total production over a period of years to compare favourably with that of seasonal breeds of much larger mature size. It has been found[33], for instance, that STT sheep produced up to four to six times their own body weight in seven lambings during a period of about 3.5 production years. Lindsay[42] stressed the disadvantages of introducing seasonal breeds resulting in 'the severe penalty of (ewes) failing to breed for periods of the year'. Table 22 illustrates the consequences of introducing seasonality, under the assumption of strictly additive inheritance for this trait. These data were based on two local breeds with year-around reproduction (producing at a rate of at least three lambings every two years), the STT from Indonesia and the Malin or Malaysian Indigenous sheep

from Malaysia. For instance, with 50 percent of inheritance from seasonal breeds, the number of lambings per ewe in a 4-year period would be reduced from 7.26 to 5.16 and to 4.0 by complete replacement with the latter.

Table 22. Potential effects of introducing seasonal breeders in population of year-around breeders, assuming additive inheritance[43-45].

Breed	Lambing interval (days)	Lambings per year	Lambings per ewe over 4 yr	Relative no of lambings
STT	201	1.82	7.26	100
Malin	238	1.53	6.13	84
F_1(STT 50%)	283	1.29	5.16	71
F_1 (Malin 50%)	301	1.21	4.85	67
Seasonal breeds	365	1.00	4.00	55

STT: Sumatran Thin-tailed sheep (Indonesia)
Malin: Malaysian Indigenous sheep

Similar attention needs to be focussed on lesser resistance or tolerance to specific local parasites of the exotic breeds.

I. EVALUATION AND IMPROVEMENT OF LOCAL BREEDS

This is the first step to follow in a breeding program[39-41]. Usually local breeds display considerable variation for most production traits so there is good potential for selection. The evaluation should then be made simultaneously with a selection program, for instance in a ram breeding Nucleus plan. The flock should be established with a wide genetic base comprising a genetic pool of individuals from the local breed. This subpopulation should represent a random sample of the whole population. However since the objective is also to raise production, screening of the local population for outstanding males and females could be useful and provide a one-step improvement of ten to 15 percent in production[39].

Traits to be considered in screening should include:

- selection of wool-free animals;

- selection of twin-producing ewes if the environment allows for this level of prolificacy (for instance by selection of ewes that have produced at least five lambs in three lambings in two years);
- selection for desirable characteristics and against undesirable defects.

Measurements should involve at least the following:

- lambing dates;
- litter size, born and weaned;
- ewe bodyweights at mating, lambing and weaning;
- wool scores at birth and at adult age;
- lamb birth and weaning weights;
- lamb mortality;
- post-weaning growth (up to three months after weaning).

It is essential of course, that all animals be managed similarly within the environment for which selection is made.

The adoption of the 'best' mating system is mainly dictated by availability of labour and the needs to group or 'synchronize' lambings as well as other flock activities.

The simplest system is continuous breeding which implies permanent presence of rams in the ewe flock except during late pregnancy and early lactation (for about 15 days) to maximize bonding and care of recently born lambs. Production under this sytem has proven to be effective for STT sheep[33]. However, this system does not produce a supply of contemporary (and comparable) lambs and it may not meet marketing objectives of a commercial flock.

A non-continuous system could also be implemented. However it increases lambing intervals. For instance, mating the ewes for a one-month period preceded and followed by two months without exposure to rams, increased the lambing interval of STT from 201 to 232 days[33]. If management and labour require a non-continuous system, the accelerated lambing schemes proposed by Hogue[44] could be suitable.

II. NUCLEUS STRUCTURE

Basically, a selection/evaluation program involving direct participation of producers (end-users) would consist of:

1) A Central Nucleus flock, to produce selected rams for breeding,

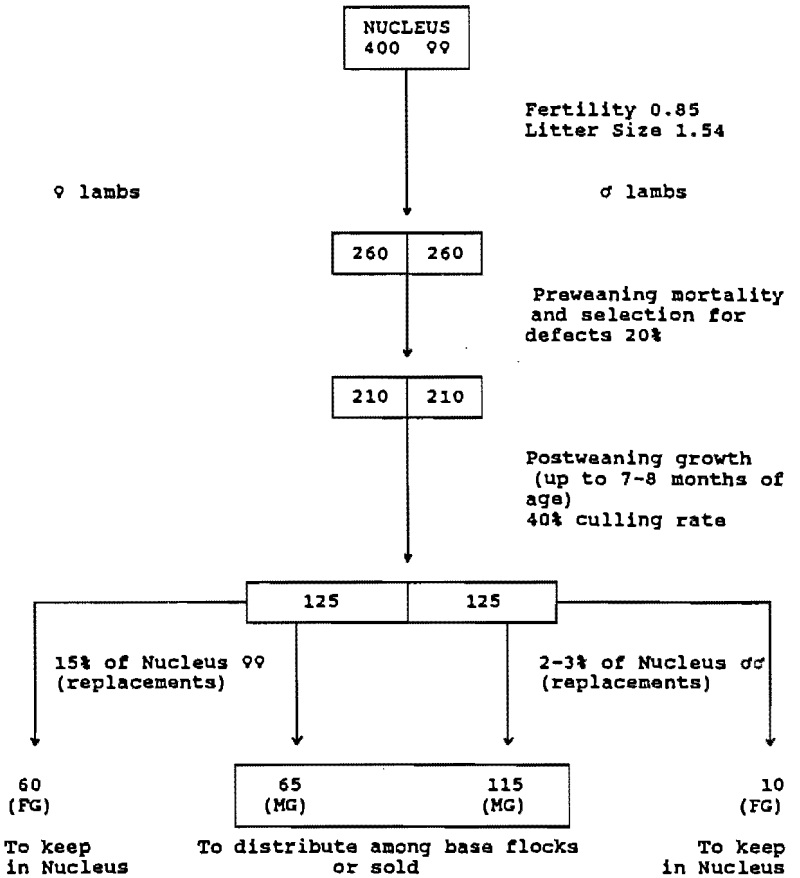
preferably located at a research centre or a government multiplication centre, and 2) Base flocks where rams from the nucleus will be distributed[46,47]. These would consist of smallholder flocks, commercial producers or government multiplication centres; with both types of flocks under performance monitoring.

The Nucleus would require intensive recording of performance of individual ewes as well as rams with identification of all animals and the application of rigorous pressure. It should produce sufficient rams to be distributed among the base flocks for breeding purposes.

The number of animals in the nucleus will be defined on the basis of the number of base participants, or, more properly, the number of animals in the total program. This program is illustrated schematically in Fig.7. For instance, a nucleus flock of 400 STT ewes with an average litter size of 1.54 and with a capacity to lamb at a rate of three lambings in two years can produce at least 260 ram lambs per lambing (assuming 0.85 fertility). Of those there will be a reduction of 20 percent due to preweaning mortality and culling for defects, leaving about 210 rams to be tested for postweaning growth (until three to four months after weaning). Here a culling rate of 40 percent could be applied resulting in about 125 faster growing ram lambs. The top ten best ram lambs will be kept, while 60 to 80 could be distributed as ram lambs to be sold. If two rams are to be used on each farm comprising 20 to 30 breeding ewes, then 30 to 40 farmers could be part of the breeding program. The nucleus will produce its own breeding rams and replacement ewes. Fig. 7 illustrates this program schematically.

The top 60 females will be kept as replacements Nucleus flock. However, outstanding females from the Base flock could be introduced into the Nucleus Central flock during the program to minimize development of inbreeding in the flock. These ewes should be obtained through a fair agreement with participants. The nucleus females, by top rams produced at each lambing should be kept for breeding in the Nucleus flock, for no more than two years or three lambing seasons.

The Participating (Base) flocks would comprise performance-monitored farms, involving mainly groups of farmers such as those of the Outreach Research Project (ORP) of the SR-CRSP/Sub-Balitnak program, Sei Putih, North Sumatra. In this Project, farmers participate in an on-farm research framework aimed at testing



[1] Assuming a productive life of six to seven lambings per ewe.
FG: Fast growth rate
MG: Medium growth rate

Fig. 7 Nucleus scheme operating on a per lambing basis.

different technologies to improve sheep productivity. Initially, the farmers with four to six head / flock were choser for the Project. In the new breeding scheme for the ORP an increase of the flock size up to 20 to 30 ewes to be raised under a combination of cut-and-carry and grazing in the rubber plantations, is being considered. A simple system of identification which has proven to be efficient in other outreach project in West Java could be implemented. Important (minimum) variables to record are:

- litter size, born and weaned;
- lambing date;
- wool scores;
- dam and lamb weaning weights (so that weight of lamb produced/ewe/year can be calculated).

Participating flocks should only use breeding rams produced in the Nucleus. An important condition is that both nucleus and participating flocks must have similar management and mating systems.

A multidisciplinary team of scientists should be part of the monitoring team which, concurrently with the selection program, will test new technologies to improve production.

III. GENE MIGRATION: CROSSBREEDING

In order to avoid losses in adaptation present in the local breed, crossbreeding should be aimed at introducing desirable gene combinations to improve traits of local breeds, while making maximum utilization of local adaptability. The substitution of the local genes by upgrading to exotic breeds should be practised only where there is clear evidence that the resulting animals are more productive on a lifetime basis than the types they replace.

Crossbreeding increases the heterozygosity of a population, permitting the exploitation of heterosis. It may also be used for the formation of a new type of animal, a synthetic or new breed, which will combine desirable features of the parental breeds.

Exploitation of heterosis by systematic repeated crossing systems will not be discussed in this Chapter since it is assumed that this is an unrealistic procedure for small or medium size farmers who cannot afford the maintenance of, or dependence on purebred stocks that the method requires. Moreover, if the cross involves an exotic genotype, maintenance of the latter in the new environment may not be economically feasible due to low reproductive rates.

Discussion will be focussed on the utilization of crossbreeding in the formation of a new type of animal by introducing desirable production characteristics.

To ensure adaptation to a given environment the population to be used as the improver breed should, if possible, come from an

environment similar to that of the local animals that is, equatorial, tropical and humid. Fitzhugh and Bradford[27] documented a number of tropical breeds that may fit these criteria, to which the sheep from Java and Sumatra (JTT, JFT and STT) should be added.

The collaborative program between SR-CRSP and RIAP has recently established a crossbreeding evaluation program involving the Saint Croix hair sheep from the Virgin Islands and STT sheep. The objectives are to assess the suitability of hair sheep for improvement of STT in production systems such as those integrating sheep and rubber plantations and to introduce some desirable characteristics such as larger size and absence of wool into the STT sheep.

Hair sheep are appealing candidates for a crossbreeding program for Integrated Rubber/Sheep Production Systems because of their adaptation to humid tropical ecosystems, higher growth rates than indigenous South-East Asian breeds, capacity to be bred year-around, good prolificacy and possession of hair coats. The latter has the potential of reducing cost and labour involved in shearing wool which is little utilized in Indonesia.

The development of adequate crossbreeding evaluation programs involves large numbers of animals and several years, and may be limited by the difficulties of importing suitable breeds. Sometimes government restrictions, for health or other reasons, are an impediment to the establishment of an evaluation program of this type.

If only males are to be imported, sufficient rams should be used to provide an adequate genetic base. For a flock consisting of 100 breeding ewes 12 to 15 males should provide an adequate sampling of a breed.

The local breed of animals and crossbreds should be treated alike and kept under similar conditions. If the comparisons are to be made on private farms, differential treatment usually cannot be avoided, since there is a tendency to give more care to crossbreds than to local breeds. Under these circumstances statistical contrasts may not be adequate. Pattie[48-50] suggested, for this contigency, a comparison on a qualitative non-statistical basis of the whole output of systems that use introduced animals with those using only pure local ones.

1. *Estimating Crossbreeding Parameters from Analysis by Genotype Means*

Consider a situation where females of a local breed (L) are inseminated with semen from males of an exotic breed (E), then various crosses and backcrosses made among the offspring for several generations. The following model specifies the average phenotype of any particular genotype group (adapted from Dickerson[51]).

$$Y_1 = L + G + M + H_g + H_m$$

where:

- Y_1 = the average of genotype group i
- L = the average of the local breed
- G = additional performance due to direct effect of genes from the exotic breed
- M = additional performance due to genetic difference in maternal ability of the exotic breed
- H_g = additional performance due to direct effect of heterosis
- H_m = additional performance due to heterosis for maternal effects

The terms G, M, H_g and H_m are crossbreeding parameters expressed as deviations from the local breed.

An example will be used from a crossbreeding experiment involving local and imported goats at the Prince of Songkhla University, Hatyai, Thailand. Here, Thai native female goats were inseminated with semen from Anglo-Nubian goats imported from Australia. Various crosses and backcrosses have been made as indicated in Table 23. The body of the Table contains a set of coefficients representing multipliers for the crossbreeding parameter contained in each genotype. The mean of each genotype and its variance are also listed. The coefficients are genetic expectations while the means and their variances would be obtained from analysis of experimental results. Effects of years, age, sex and type of birth have to be taken into account and be removed by use of appropriate linear models. Hypothetical weaning weights are used in this example because the experiment at Hatyai has not progressed to the stage where all genotypes have been produced.

Table 23. Mean, variance and crossbreeding parameters corresponding to different genotypes in a crossbreeding process.

Genotype			Parameter Coefficients					Mean	Variance
Sire	Dam	Cross	L	G	M	H_g	H_m	Y_i (kg)	of Y_i (kg)
L	L	Local	1	0	0	0	0	12.0	.0622
E	L	F_1	1	.5	0	1	0	16.7	.1070
E	F_1	3/4 E	1	.75	.5	.5	1	19.05	.1695
F_1	L	3/4 L	1	.25	0	.5	0	14.35	.1207
F_1	F_1	F_2	1	.5	.5	.5	1	18.3	.1764
F_2	F_2	F_3	1	.5	.5	.5	.5	17.0	.1976

L: Local breed; G: direct effect of exotic breeds; M : maternal ability of exotic breed; H_g: direct heterosis effect; H_m: maternal heterosis

The parameters can be estimated, by treating the set of coefficients and means as simultaneous equations, as:

$$b = [K'K]^{-1}K'Y$$

where:

K = a matrix of expected coefficients

Y = a vector of genotype means

D = a diagonal matrix of variances of the means

b = a vector of the parameters to be estimated

with their standard errors being the square roots of the diagonal elements of the matrix:

$$[K'D^{-1}K]^{-1}$$

This example gives the results shown in Table 24.

Note that only five genotypes are needed to estimate this set of parameters but the F_3 must be produced because the equations for the various second generation crosses are not all independent. In the experiment at Hatyai, the additional crosses were made because several different genotypes were required for testing in villages.

Given the crossbreeding parameters, the expected performance of any cross or synthetic strain, relative to that of local animals, can be

Table 24. Crossbreeding parameter estimates and standard error corresponding to data of Table 23.

Parameter	Estimate	Standard error
L	12.0	0.237
G	3.0	2.353
M	1.2	1.991
H_g	3.2	1.245
H_m	2.6	1.223

L: Local breed; G: direct effect of exotic breeds; M : maternal ability of exotic breed; H_g: direct heterosis effect; H_m: maternal heterosis

estimated. For example, the backcross resulting in 75 percent exotic genotype had the heaviest weaning weights and it may be thought that a new 'breed' based on this cross would be useful. In this example, the backcross contains elements of heterosis that will not be maintained in the progeny of *inter se* matings used to establish the new 'breed'. The multiplying coefficients for the parameters G, M, H_g and H_m for a stabilized breed derived from 75 percent exotics are 0.75, 0.75, 0.375 and 0.375 respectively. Therefore the expected performance of the new breed in terms of the parameters and their coefficients would be:

$$Y = L + .75G + .75M + .375H_g + .375H_m$$

and, using the example results above, this would be:

$$Y = 17.3 \text{ kg}$$

Note that this is almost the same performance as the F_3 which is the expectation for a new 'breed' established from interbreeding half-breeds. This is because heterosis is relatively important here, and a large proportion is lost in a new 'breed' with nominal 75 percent exotic genes. In this case the second cross of the exotic (Anglo-Nubian) would not be needed at the commercial level and it would probably be better to select for improved performance amongst halfbreds.

This example shows the importance of establishing the relative magnitude of both direct and maternal heterosis before making conclusions about the most suitable breed mix for a given production system.

There is in fact another source of variation in later generations of crossbreeding programs not considered here. This is 'recombination loss' which refers to the extent that epistatic combinations are broken up. There are two parameters for recombination loss, one for direct and one for maternal effects. They cannot be estimated in the Hatyai experiments; to do so would require additional lines of *inter se* matings within the backcrosses. Simulations using different levels of recombination loss show that, if it exists, it would cause the maternal effect calculated by the above method to be a slight underestimate while the maternal heterosis would be a slight overestimate. The other parameters would not be affected.

2. *Generations Required for Comparing Crosses*

In most cases it will not be feasible to establish continuous crossing systems for village sheep production in Indonesia. Thus crossing will be used to introduce exotic genes and then a new strain will be developed by interbreeding the crossbred animals. In order to make judgements on the value of such new strains compared with local animals, ideally an experiment to estimate the various parameters outlined above would be carried out. However in many cases this will not be possible but it will still be desirable to compare a new crossbred type with local stock.

A comparison of the coefficient for F_1, F_2 and F_3 crosses in Table 23 indicated how this might be done. There are changes in the coefficients for maternal and heterosis effects in each cross but these have stabilized at the F_3 and in fact there will be no further changes in following generations. Thus comparisons should be made between F_3 and local animals unless maternal effects are known to be important. In that case a comparison between F_2 and local animals would be sufficient.

IV. COMPARISONS

When comparisons are made within a breed, the utilization of actual performance (e.g. in kg/animal) for comparison is permissible. However, in unselected populations such as STT, considerable variation exists with regard to most production traits precluding the generalization of this type of comparison. Thus, production outputs should be corrected for size. The same type of correction should be

made when comparing breeds that are different. For instance total kg lamb weaned per ewe compared on kg basis may lead to classifying local breeds as poor producers compared with breeds from temperate climates. The situation changes when a more equitable base for comparison is used, for instance expressing kg lamb weaned as a proportion or the ewe bodyweight or using metabolic weights. The effect of the comparison base in ranking performance of STT versus temperate sheep breed is shown in Table 25.

Table 25. Total weight of lambs weaned by STT, Finnsheep and Dorset ewes, expressed in kg of lambs weaned and as percentage of ewe weight[33,43].

Breed	Weight of lambs weaned		
	Kg	% of ewe weight	
		lambing basis	yearly basis
STT	11.45	0.52	0.95
Finnsheep	17.6	0.41	0.41
Dorset	21.3	0.42	0.42

Nevertheless, comparisons with breeds from the temperate zones have limited value even though the local breeds may rank higher. Valid comparisons are those of production of breeds under the same conditions and environments.

Comparisons involving breeds and crosses in the same environmental conditions require testable contrasts provided by contemporary individuals. It must be noted that a continuous mating program may interfere to some extent in the provision of batches of contemporary individuals. The adoption of a system of discrete mating periods overcomes this problem but limits the evaluation of the potential of different groups for short lambing intervals and decreases the total number of lambs born.

CONCLUSIONS

1) Indonesia has three local breeds of sheep, the Javanese Thin-tail (JTT), the Javanese Fat-tail (JFT) and the Sumatran Thin-tail (STT) which are remarkably well adapted to the hot, humid tropical environment of Indonesia in terms of survival and reproductive performance.

2) Genetic improvement of sheep for Indonesia can be pursued in two concurrent and different programs: 1) evaluation and selection of local breeds, capitalizing on their adaptive characteristics; 2) crossbreeding in order to introduce desirable gene combinations into the local breeds.
On these bases, a Nucleus scheme for selection and improvement of local breeds is outlined, using a Nucleus flock and participating Base flocks where flocks belong to participating farmers, with STT as the example.
In addition, a crossbreeding program is discussed using the Saint Croix hair-type sheep from the Virgin Islands and the STT sheep. In this program, it is attempted to combine the larger size and the hair coat of the Saint Croix with the exceptional reproductive characteristics and adaptation of the STT sheep.

3) Attention is drawn to the fact that: 1) comparison between local and exotic breeds must be made on an equitable basis, that is on a per unit bodyweight basis, over a lifetime, encompassing all the important production characteristics in the same environment and under the same management; 2) in evaluating crossbred sheep, comparisons of local breeds should not made with F_1 crosses alone because heterosis can lead to overestimating of the desirable characteristics of the exotic breeds and the crosses. Maternal effects can also bias the results.

4) It is essential that the exotic breed chosen for crossing should originate from a similar tropical, equatorial environment. Seasonality in breeding (characteristic of breeds from temperate zones), increases the lambing interval and hence total production of lambs. Moreover, breeds from temperate zones will show irregular cycling and low reproductive rate in the equatorial regions.

5) A Mendelian model based on the segregation of a major gene with large effect on the phenotype, apparently explains the genetic variability for the exceptional prolificacy in the Javanese sheep. Provided feed resources are sufficient to keep low levels of lamb mortality, prolificacy has the potential to raise substantially productivity per ewe per lambing. This characteristic, in addition to the potential to produce at a rate of at least three lambings in two years, are important attributes for accelerated lambing and intensive production systems for the humid tropics.

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CHAPTER V
MEETING NUTRIENT REQUIREMENTS OF SMALL RUMINANTS

B. Haryanto* and A. Djajanegara*

INTRODUCTION

Small ruminant production systems in Indonesia are basically the traditional systems in which feeding practices depend on readily available forages (grasses and shrubs) with little or no supplementation. Management practices vary from completely confined in a cut-and-carry feeding system to partial grazing with a shepherd. This Chapter describes briefly the important nutrients in the diet, factors involved in the regulation of intake and digestion, feeding values of forages frequently used by farmers in the villages i.e. grasses, legume tree and shrub leaves, agricultural by-products and crop residues. Chemical composition and digestive characteristics are considered as far as it is possible, with emphasis on available energy and protein. Since these are often inadequate, feeding of supplements is to fulfil energy and protein requirements.

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A. CHARACTERISTICS OF THE DIGESTIVE SYSTEM

Goats and sheep are ruminant animals that have a multicompartmental stomach which distinguishes them from simple-stomach non-ruminants such as pigs and poultry (see Fig. 1) higguspad.

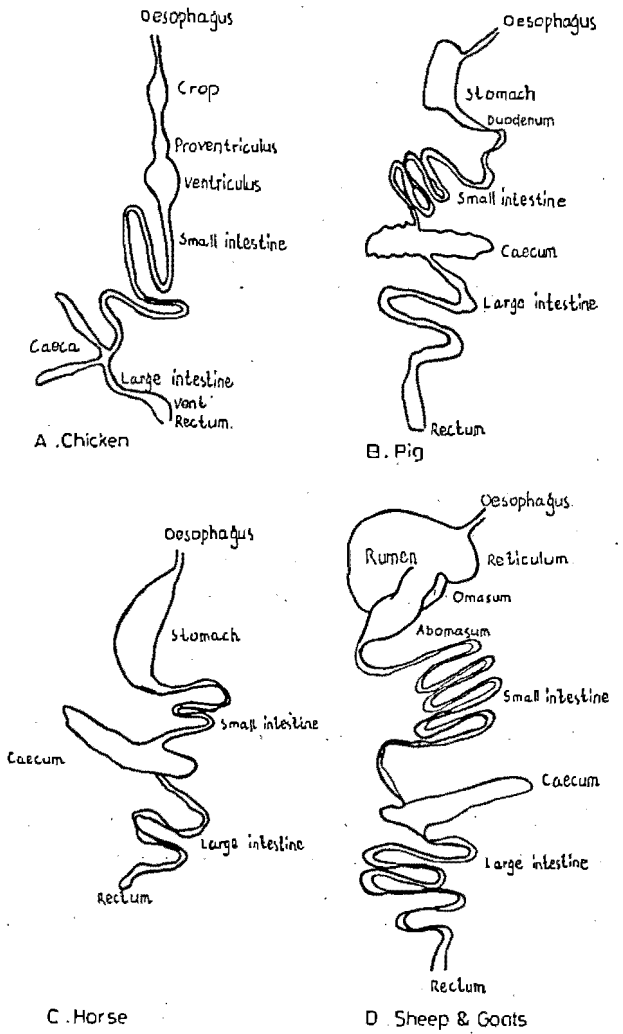

Fig. 1 Schematic diagram of digestive system of: A. chicken, B. pig, C. horse and D. sheep or goat.

They regurgitate and re-masticate their feed and are physiologically adapted to eat high fibre diets (grass and other forages) which cannot be used directly by humans and non-ruminants. Thus, they are generally not considered to be competing with human beings for food. The high fibre diets fed to goats and sheep are converted to meat and milk, products which are rich in protein, fat, vitamins and minerals, for human consumption.

The fore-stomach (the reticulo-rumen) comprises the largest compartment of the gastro-intestinal tract (GIT) in which a major proportion of the feed consumed is being digested. Digestion of feed is primarily carried out by micro-organisms (mainly bacteria and protozoa) in a fermentation process. The microbial mass in turn is a valuable protein source for the host ruminant animal, thus, in optimizing microbial protein synthesis it is important to provide the host ruminant animal with sufficient nitrogen and some protein for microbial synthesis. The 'fermentation end products' i.e. simple sugars, amino acids, glucose, fatty acids, mono-glycerides, as well as minerals and vitamins, are absorbed through the mucous membranes inside the GIT into the circulatory system (blood and lymph) mainly in the small intestine, whereas massive amounts of volatile fatty acids (VFA) and ammonia are absorbed from the rumen. The role of the reticulo-rumen is important and meeting the nutrient requirements of rumen micro-organisms should therefore be considered for optimum utilization of feed.

B. NUTRIENTS AND THEIR REQUIREMENTS

Nutrients are chemical substances in feed that can be metabolized and utilized for maintenance and, when present in sufficient quantities, for growth, reproduction, lactation and exercise as well as work by the animal. Two or more of these functions often occur simultaneously. For example, a doe or ewe may be both growing and pregnant, or a lactating doe/ewe may be pregnant. Their total nutrient requirements should therefore be met concurrently. Nutrient requirement tables for goats and sheep in their different physiological conditions and for various weights and growth responses are available. However, these were derived from data originating in the temperate

regions with temperate breeds of goats and sheep and they do not cover the requirements of indigenous small ruminants living in the tropics[1,2,3]. The latter are generally smaller in size and have a lower liveweight. Some attempts have been made to estimate protein and energy requirements for goats and sheep using data derived from experiments carried out in Indonesia (see Appendix 1)[4]. It is unfortunate that the available data for Indonesia are limited to experiments with growing lambs only, hence at present it is not possible to provide a complete list of nutrient requirements for goats and sheep of different physiological states. The animals used in these experiments were generally non-descript animals and information about their breed, origin, previous feeding management and type of birth (single, twin, triplet etc.) is usually not given. It is obvious that collaborative efforts should be undertaken to establish better estimations of the nutrient requirements for goats and sheep in Indonesia of different sizes and physiological state.

The major nutrients considered in this Chapter are proteins and carbohydrates which are sources of energy, as well as minerals, and vitamins. Water is essential for all animals and it is involved in the dilution of nutrients for absorption and in their transport throughout the body, in maintaining body temperature, in functioning as a lubricant, in gaseous exchange, in dilution of toxic substances etc. Water can originate from drinking water, water contained in feeds, as well as metabolic water. Research on water requirements of goats/sheep in Indonesia is limited. Measurements of voluntary water consumption by sheep kept under confinement in sheds showed that animals may drink two to three litres of water per day in addition to that ingested in the feed. There is a general belief among farmers in Indonesia that goats/sheep do not need drinking water. The general practice of feeding fresh forages may supply sufficient amounts of water to meet the animal's requirements without any drinking water. However, provision of water that is clean and readily available daily, especially when the animals receive dry feed/dried forages and especially during hot days during the dry season, is recommended. Furthermore, water requirements vary depending upon the different physiological states of the animal (e.g. growing, pregnant, lactating), exercise, as well as salt and mineral content of the diet. Information on

water needed for lactating and pregnant goats and sheep in Indonesia is scarce.

I. PROTEIN

Amino acids are the building blocks of polypeptides, which form macromolecules of complex nitrogen-containing substances called proteins. Amino acids are thus required for the synthesis of proteins, which include enzymes, as well as some of the hormones involved in cell metabolism. Amino acid requirements of ruminant animals are similar to those of monogastric animals. However, the advantage of ruminants is that the rumen microbial mass forms an excellent source of essential and non-essential amino acids for the host animals. There are limited reports in Indonesia on protein requirements of small ruminants during periods of high production i.e. early lactation, late pregnancy, especially in multiple bearing females, etc. Most nutritional studies carried out so far used growing animals and for these it was shown that protein requirements are related to the energy availability. Reports on feeding trials with various feed supplements indicated a good relationship between protein intake and weight gain[4]. The relationship was $Y = -2.89 + 0.47$ CPI ($P<0.01; r = 0.62$); where Y = weight gain; CPI = crude protein intake. A ratio of total protein (g) and metabolizable energy (Mcal) requirements of 1 : 32 has been recommended with a total protein (TP) or digestible protein (DP) requirements for goats suggested to be at 4.15 g and 2.82 g per kg metabolic bodyweight, respectively, for maintenance, and an additional 0.284 g TP and 0.195 g DP being required per g of liveweight gain[2]. The maintenance requirements were higher, but the values being required per g of liveweight gain were slightly less than those found by Haryanto and Djajanegara[4].

It is believed by Leng's group in Australia that in the tropics it is the non-protein nitrogen (NPN) and protein, not energy that is in short supply because much less energy is needed for maintenance in hot climates, while rumen microbes need nitrogen to function efficiently[5]. This can be supplied by the cheaper non-protein nitrogen (NPN), such as urea in Molasses Urea Blocks (MUB).

II. ENERGY

Dietary energy (gross) intake is utilized by animals initially to

satisfy the requirements for maintaining basal metabolism and for growth or production if intake exceeds the maintenance requirements. Due to the physico-chemical characteristics of feeds and passage through the GIT, a portion of the gross energy intake cannot be utilized. The loss of energy in the form of undigested nutrients excreted as faeces can be subtracted from the gross energy intake to obtain digestible energy (DE) intake. If energy loss in the form of gaseous products in the rumen and urine is subtracted from this digestible energy intake, this is termed the metabolizable energy. The metabolizable energy (ME) intake can be further partitioned into retained energy (RE) or net energy (NE) depending on the pathway of energy utilization by the animal, for maintenance, growth, lactation, fetal development etc. Energy partitioning of dietary energy sources is shown in Fig. 2.

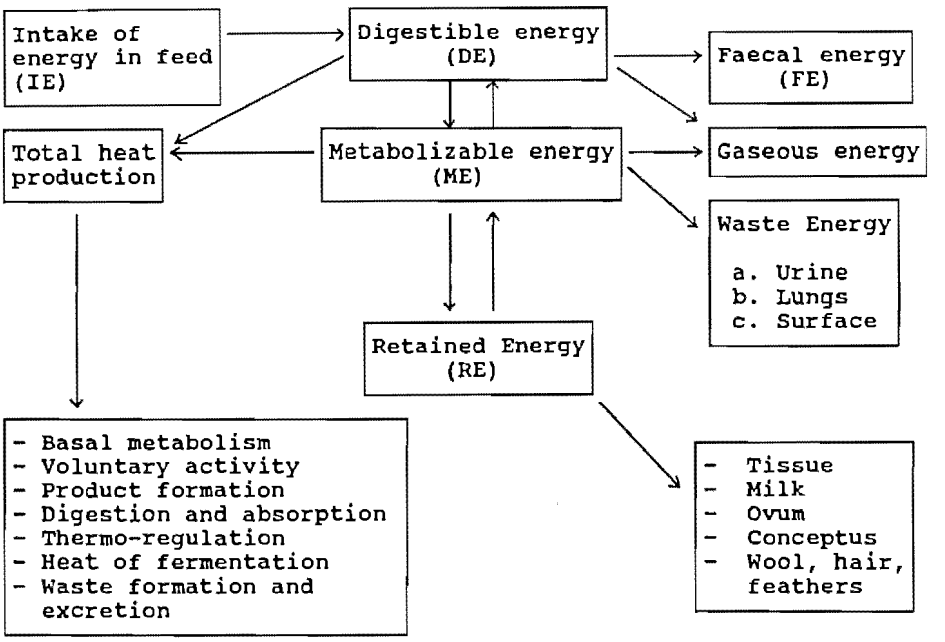

Fig. 2 Partitioning of energy utilization by animals[6].

Energy requirements for goats and sheep have been summarized and recommendations have also been published for temperate zones[1,2].

The energy requirements depend upon the size of the animal and its physiological state e.g. growing, pregnancy, or lactation. Environmental conditions such as temperature, humidity and air movement also affect energy requirements. For sheep, the energy requirements for maintenance, expressed in terms of digestible energy (DE) or metabolizable energy (ME), are related to the body weight (W) to the power of 0.75 or metabolic bodyweight expressed:

Maintenance requirement for DE = 119 W ($kg^{0.75}$)

Maintenance requirement for ME = 98 W ($kg^{0.75}$)

where W is expressed in kg, DE and ME are in kcal per day.

For goats, a value of 101.4 kcal ME per kg metabolic body weight has been suggested for the daily maintenance requirements. Furthermore, the provision of an additional 0.7 Mcal ME for every 100 g daily weight gain has been recommended. Whether these recommendations are also applicable to goats and sheep in Indonesia requires further investigation.

Products of anaerobic fermentation in the reticulo-rumen in the form of VFAs are the primary sources of energy in ruminants. Therefore dietary nutrients should contain substances that are fermentable in the rumen and appropriate for the dynamics of rumen microbial systems.

A schematic degradation of forage polysaccharides into simple substances (oligo-, di-, and monosaccharides) available for further metabolism by microbial fermentative processes is shown in Fig. 3.

III. MINERALS

Minerals are required for the development of bones, teeth and muscle tissues, as well as being required as components of enzymes, hormones and other substances necessary for the normal metabolic processes in living organisms. Mineral requirements for ruminants may be categorized into two major groups: macro-elements (Ca, P, Na, Cl, K, Mg, and S) and micro/trace-elements which include Fe, I, Cu, Mo, Zn, Mn, Cr, F, Ni, Co, and Se.

Calcium is essential for all species of livestock. It is an essential component of bones and teeth. Larger amounts are required for growth of young animals, and also for lactating does/ewes. If calcium in the diet is deficient, then growth and development of the young

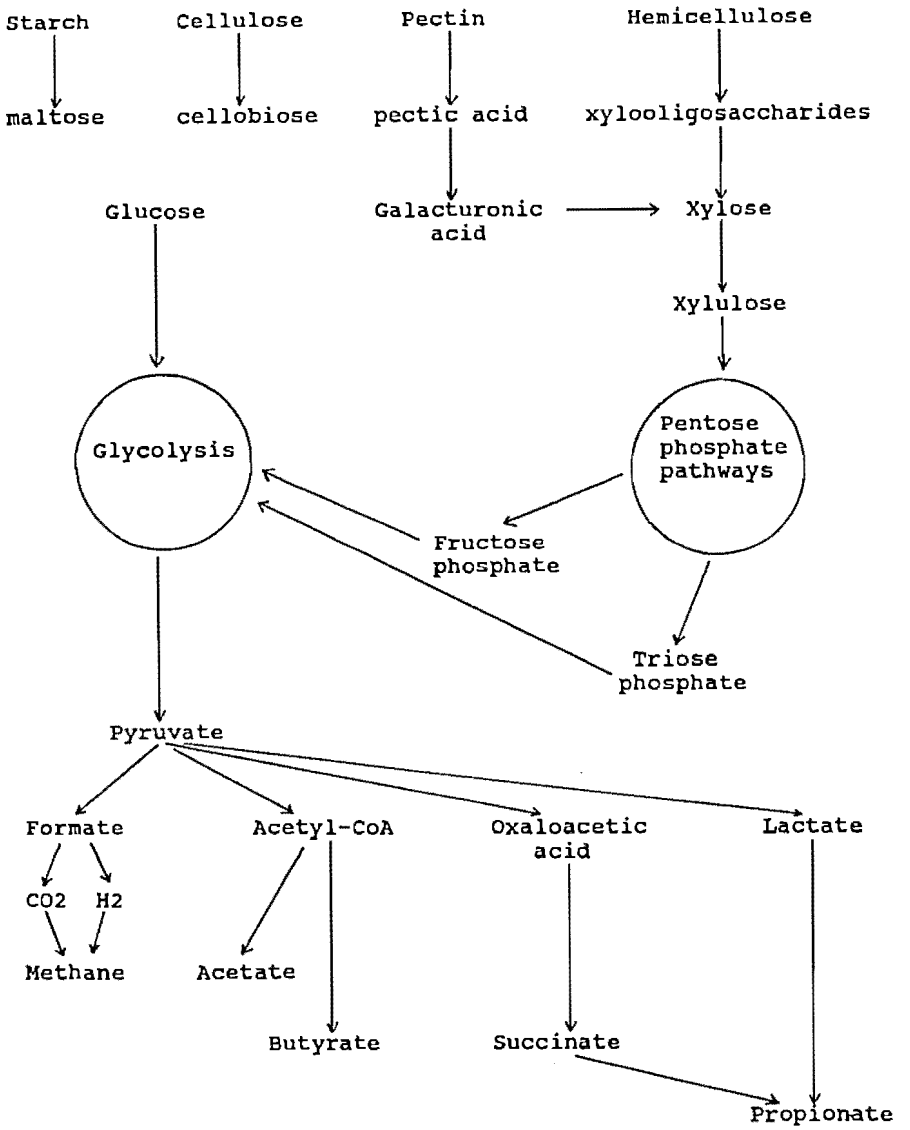

Fig. 3 Simplified pathways of dietary polysaccharide degradation in the rumen and yield of rumen microbial fermentative processes[7].

animal will be retarded, while in lactating does/ewes milk production will decrease.

Phosphorus is also required for muscle tissues and bones. Deficiency in phosphorus will lead to retarded growth and development as well as unthrifty appearance and a depressed appetite. Leguminous shrub and tree leaves contain more phosphorus than grasses. Therefore, feeding a combination of grasses and legumes will reduce the likelihood of phosphorus deficiency. The inclusion of a mineral mixture that supplies adequate amounts of phosphorus in the diets will ensure that phosphorus requirements are satisfied. A ratio of 2:1 between calcium and phosphorus is generally recommended in diets.

Sodium and chlorine may be provided as common salt. Sodium is more commonly required than chlorine, since sodium in forages is more likely to be deficient. Salt can be provided continuously as a salt block. Salt can also increase appetite. The behaviour of eating soil and debris may be used as an indication that the animal does not receive adequate salt, although it may point also to other deficiencies.

Potassium is usually adequate in the forage diets and therefore it is unlikely that deficiencies of potassium occur even though potassium is required in relatively large amounts.

Magnesium is required for the proper functioning of the nervous system. It is also essential for the functioning of enzymes. A deficiency in magnesium may lead to hypomagnesaemia as shown by symptoms such as anorexia, excitability, and calcification of soft tissue. Grass tetany is related to magnesium deficiency which usually occurs in temperate regions in early spring when pastures are very low in magnesium. Acute hypocalcaeamia as well as hypomagnesaemia can be treated by intravenous administration of calcium boro-gluconate and magnesium boro-gluconate respectively.

Sulphur is important as it serves as a component in sulphur-containing amino acids (methionine, cysteine and cystine) which are essential for a ruminant animal. Sulphur is also an essential element in the synthesis of microbial protein required by the rumen microbes. It is likely that sulphur-containing amino acids are inadequate in most forage diets. The utilization of sulphur by ruminants is interrelated with the utilization of copper and molybdenum.

Iron is necessary being a component of haemoglobin and enzymes involved in the process of oxidation-phosphorylation to generate energy. However, a deficiency in iron is unlikely to occur since the turnover of iron in the body is very efficient. Nevertheless, iron deficiency with symptoms of anaemia may be observed if there is a disruption in the process of haemoglobin synthesis due to copper deficiency.

Iodine is required for the synthesis of thyroid hormones (triiodothyronine (T_3) and thyroxine (T_4) which control metabolic rate. Whereas mature ruminants seldom experience iodine deficiency, the fetus and the neonate are very susceptible. Iodine deficiency in pregnancy produces young that are weak and often die. A cheap source of iodine is iodized salt.

Copper and molybdenum interact with sulphur utilization in ruminants. High copper and molybdenum in the diets may result in decreased sulphur utilization by the animal. A high molybdenum concentration in the diets, may lead to a high excretion of copper and therefore, induce copper deficiency.

Zinc is essential for the production of more than 200 enzymes involved in metabolic processes. It is also important for the stability and integrity of bio-membranes. Deficiency in zinc may lead to parakeratosis, retarded growth and reduced spermatogenesis. Reduced feed intake may also be associated with zinc deficiency in diets.

Manganese is essential for the functioning of enzymes. Symptoms of manganese deficiency can be observed in reluctance to walk, deformation of the forelegs and reduced reproductive efficiency.

Chromium, fluoride, nickel, cobalt and selenium are also essential elements for goats and sheep. Chromium is involved in the process of glucose utilization, while nickel is essential for rumen microbes. Cobalt is a component of vitamin B_{12} complex (cyanocobalamin). Selenium is important as a sparing element for sulphur (less S required) and is essential in the peroxidation processes.

Both macro- and micro-elements may be obtained from dietary sources. The mineral content of plant tissues is related to the mineral content of the soil and the soil pH. If the soil is deficient in a certain mineral, it is likely that the plants growing on this soil will be deficient in that particular mineral.

As a general rule, adequate minerals should be provided in diets to meet the ruminant's daily requirements. Calcium and phosphorus are the two major elements of interest. It is only in special circumstances that trace elements become a problem. A combination of grass and leguminous forages is considered to contain good sources of minerals. However, inclusion of a mineral mixture in diets in a cut-and-carry feeding system may be advantageous to ensure that the mineral requirements for ruminants are met. The results of an on-farm research activity conducted in West Java in which sufficient mineral supplements known to be needed for small ruminants were provided to goats and sheep under village conditions, were not conclusive[8,9].

IV. VITAMINS

Ruminants do not require the B vitamins from dietary sources since rumen micro-organisms and the animal body are able to synthesize these. Vitamin C and K are unlikely to be deficient. Vitamin A, D and E should be provided in the diet.

The function of vitamin A lies in its contribution to the light-sensitive pigments in the retina. Other functions may involve the maintenance of epithelial tissues. Carotene, especially the B-carotene serves as the precursor of vitamin A. Carotenoids (pigmented compounds) are present in relatively high concentrations in green plant tissues[10]. A deficiency in vitamin A is unlikely to occur if the animals are fed on green forage-diets, and often carotene is stored in the liver and fat. Vitamin D is important for the calcification processes of bones. In young animals, deficiency of vitamin D will result in reduced growth as well as in reduced feed efficiency. Vitamin D is involved in the metabolism of calcium and phosphorus with parathyroid hormone and calcitonin playing important functions in regulating this process. Vitamin D may be synthesized in the subcutaneous cells aided by ultraviolet (UV) light from the sun. In the process, 7-dehydro-cholesterol is activated to produce compounds having antirachitic activity (vitamins D_2 and D_3). Vitamin D deficiency is unlikely to occur in Indonesia, especially if the animals are allowed to graze at least part of the time. Vitamin E is involved in the process of maintaining the integrity of bio-membranes. This is presumably related to the function of vitamin E as an antioxidant which prevents the peroxidation of polyunsaturated fatty acids of the cell membrane.

Vitamin E may also prevent the development of nutritional muscular dystrophy, a condition related to a lack of selenium-vitamin E interaction. Vitamin E can be administered intravenously, but this is impractical.

C. INTAKE AND DIGESTION

As indicated earlier, the major feed sources for small ruminants in Indonesia are the available forages and agricultural by-products. These are obtained sometimes from areas close to, but often at a great distance from, the farmer's house i.e. home garden, agricultural land, waste land, roadsides, other land resources and factories. The quality of feed offered therefore may vary between days depending upon the farmer's capacity to obtain the feed including different types of forages. Agricultural by-products likewise may be available near to or far from the farmer's house.

The total amount of feed consumed, or intake, is probably the most important single determinant of the amount of nutrients that an animal will obtain and hence the level of production. However, the regulation of intake in ruminants is complex and the many factors involved are often classified into broad areas namely: feed characteristics, animal factors and environmental factors. Importantly, grazing animals select their feed from among the available forage and this also determines the quality of feed ingested. Under a cut-and-carry feeding system, the possibilities for selection are likely to be reduced.

1. FEED CHARACTERISTICS

Most information on the feeding values of feed offered to small ruminants in Indonesia indicates that the quality of roughages is low with a high cell-wall content. For ruminants, the portion of plants that merits deeper investigation is the cell wall, since the true digestibility of non-cell wall material from all forage diets is over 90 percent, hence, it is the rate at which the cell-wall is being digested that affects the extent of feed utilization. The chemical composition of feedstuffs usually offered to small ruminants in Indonesia is presented in Appendix 2. The values for energy as well as for digestible protein in Appendix 2 were calculated using mathematical models[11]. It is only recently that

measurements of cell-wall constituents in feeds for ruminants are being determined, while earlier, crude fibre was used as the sole criterium.

Physico-chemical characteristics of plant tissues differ from one species to another and contribute to the variability in forage quality and biological value for ruminants. In addition, the quality of forage consumed influences the availability of nutrients for rumen microbes. The characteristics of forages may be measured by chemical determinations which assess the amounts of cell-wall constituents present and the concentration of essential nutrients, together with biological measurements of digestibility. Undoubtedly, there are considerable variations between and within plant species. The differences within a plant species may be due to variability in the proportions of plant parts comprising the roughage and/or due to differences in the composition of particular plant parts. A clear example is wheat straw as the stem segments can contain from 75 to 93 percent cell-wall and seven to 25 percent cell soluble contents[12].

A number of factors can contribute to the variation in the proportions of different components within a plant species and to differences in the chemical composition and digestibility. These are:

1) species and genotype;
2) environmental factors affecting plant growth such as soil type and fertility, temperature, availability of water and disease;
3) age at harvest, method of harvesting and height of cutting and
4) post-harvest handling including storage practices.

II. ANIMAL FACTORS

It is well known that smaller animals have relatively higher nutrient requirements per unit bodyweight than larger ones, and that the requirements for growth, pregnancy and lactation are considerably greater than for maintenance only. Voluntary intake of young growing animals is generally higher than that of mature ones ; lactating animals eat more than non-lactating animals ; and thin animals eat more than fat ones. However, these differences in intake have generally been observed when medium or high quality diets were given. It is not clear whether the higher demands of lactating animals compared with non-lactating ones can be met by higher intakes if these animals are given relatively low quality roughages. Those forages which contain low

amounts of essential nutrients and have low digestibility cannot support high production in an animal e.g. rice straw or even elephant grass.

1. *Level of Feeding*

Another factor affecting intake is the level of feeding. Intake of tropical forages becomes greater as the level of feed offered in excess of voluntary intake is increased[13]. Increased intake resulting from increased levels of feed offered is due to the ability of the animals to select the parts of the plant they prefer when more food is on offer. The leaves of tropical forages are consumed in larger amounts than the stems and it is generally agreed that ruminants prefer leaf material to stem. Both goats and sheep given cut forage are capable of selective feeding and leaf material is generally more digestible than stems. It has been suggested that selection of leaf over stem may be largely due to the different physical characteristics of these plant parts. Leaves that are hairy may not be acceptable, suggesting that selection occurs not because of nutritional wisdom, but rather due to differences in texture which may also influence palatability.

2. *Supplements*

When supplements are provided, they should not cause a reduction in or substitution of the amount of the basal roughage previously consumed. Low quality roughages such as straw, when combined with small amounts of rumen degradable nitrogen plus small amounts of readily available energy, protein and minerals can increase straw intake and digestibility[14,15]. However, the effects of nitrogen supplementation are mediated not only by increased microbial activity in the reticulo-rumen, but also through increased flow of microbial and dietary protein resulting in greater amino acid absorption from the small intestine[16]. As mentioned before responses to mineral supplements are only likely to occur if energy and protein supplies are adequate[17,18].

3. *Passage of Digesta and Particle Size Reduction*

Physical factors involved in the regulation of intake are often considered to be the major limitation to intake of medium and low quality roughages. They are concerned with the capacity of the GIT to handle *digesta*, such as particle size reduction, the amount of *digesta*

in the reticulo-rumen and the clearance of *digesta* from that organ. One of the major factors influencing passage of *digesta* from the reticulo-rumen is the selective retention of larger particles in the reticulo-rumen. The critical size for passage from the reticulo-rumen is considered to be around 1.2 mm. There is some uncertainty whether a precise critical size for passage exists, however, it is apparent that separation into large and small particles occurs prior to flow from the rumen and that the mechanism of particle separation is unlikely to be a simple sieving process governed by the size of the reticulo-omasal orifice[19].

Reduction of particle size in feed is largely accomplished by chewing during eating and rumination. While microbial degradation and detrition through abrasion also contribute, these are considered to play a relatively minor role[20]. Microbial action may be important in reducing the resistance of *digesta* particles to size reduction. Chewing during eating and rumination not only reduces particle size and alters its shape, but it also determines the total surface area exposed to the rumen micro- organisms. Essentially, the degree of particle size reduction will be determined by the time spent in eating and ruminating, by the number of chews performed per unit of time in each of these activities and by the extent to which chewing effectively reduces the distribution of particle size in ingested feed or ruminated material.

There is some evidence that the time spent chewing has an upper limit. With conserved forages, sheep spent only 12 hours per day (12 h/d) in chewing activity[21] when consuming high quality forages [dry matter digestibility (DMD): 0.81; neutral detergent fibre (NDF) 430 g/kg DM], however, this increased to 16 to 17 h/d when either medium (DMD: 0.72; NDF 560 g/kg DM) or low quality (DMD: 0.56; NDF 670 g/kg DM) forages were given. There seems also to be a limit of eight to ten h/d in rumination time and increasing the indigestible fibre load in the reticulo-rumen did not increase it beyond this[19,22]. The total time spent chewing during eating and rumination are only descriptive terms and taken alone they may not provide a clear insight of the extent of particle size reduction. Few studies have examined the effectiveness of chewing to reduce particle size during ingestion and rumination. In sheep given lucerne hay, fifty percent of the feed particles greater than one mm in size were reduced to less

than the critical size by chewing during ingestion[20]. The processes of chewing during both eating and ruminating are considered complementary in particle size reduction.

Surface area of the feed ingested is inversely related to particle size which also affects rate of degradation of the cell wall fraction of plant tissues. The smaller the size of feed particles the larger the surface area and the greater the number of sites for rumen micro-organisms to attack and digest the feed. Hence, the digestion rate should be faster. A direct relationship between substrate surface area and rate of enzymic solubilization of cellulose was shown using crystalline hydrocellulose type I and cellulose enzyme derived from *Trichoderma viride*. The extent of digestion is, however, not only determined by the digestion rate of the *ingesta*, but also by the time it remains in the rumen. Smaller particles may have a relatively shorter retention time in the rumen; therefore, a negative relationship exists between size and the extent of digestion and probably also with the rate of digestion. The rationale is that the shorter retention time (faster passage rate) : 1) will not give sufficient time for the micro-organisms to attack and degrade, or 2) the micro-organisms that are attached to the forage cell-wall will be rapidly moved off and leave the rumen, thus decreasing the ruminal microbial population. It is therefore logical that the increased rate of passage of *digesta* may explain the results of experiments in which decreased digestibilities were obtained when ground or ground and pelleted forages were offered with increasing levels of intake.

4. *Digestibility and Rate of Digestion*

Digestibility of forages can be measured *in vitro* under laboratory conditions and/or *in vivo* in living animals. *In vitro* digestibility is relatively easier to measure than *in vivo* digestibility and intakes are easier to measure in cut-and-carry systems than at pasture. Laboratory estimates of digestibility in rumen fluid or by enzyme assays have limitations in that these do not take into account the effect of rate of passage. *In vitro* digestibility can be used to predict digestibility *in vivo* since it has a positive relationship with *in vivo* digestibility. In addition to the difficulties of making *in vivo* measurements, animal factors such as age and physiological state may affect the results obtained. Digestibility measured in different ruminant species indicates only

apparent digestibility. Furthermore, the interactive effects of rates of passage and digestion on the digestibility of the ingested forage also influence digestion of forage.

The concept of rate of digestion was first introduced into the nomenclature of ruminant nutrition in the 1950s by Blaxter and his colleagues[23] with the development of an *in vitro* technique. This was, however, based on qualitative measurements with subjective interpretation of cumulative digestion curves. Nevertheless it has been suggested to be a good tool for initial screening of forages[24].

Digestion rate is generally defined as the portion of feed which is digested per unit of time, expressed in percent/hour, or amount per day. It may also be expressed as the regression slope of the natural logarithm of potentially digestible fractions remaining versus time. Complex inter-relationships are involved that cannot be reliably predicted by a single analysis. The relationships between chemical composition, structure and linkages, preparation of feed, microbial activity and enzyme systems in the GIT as well as with many other environmental conditions can influence rate of digestion. These factors can be classified into two major groups[24]:

1) those inherent in the cell-wall of forage, and
2) those affecting the microbial population or their enzyme systems.

It is a fact that ruminants could not degrade the forage cell-wall fraction without the presence of rumen micro-organisms.

The major fractions in the cell walls are cellulose, hemicellulose, lignin and ash.[22] Cellulose can be divided into two major pools: (1) potentially digestible, and (2) indigestible pools[25]. The potentially digestible cellulose will escape from the rumen in two ways: digestion and passage, while the indigestible fraction will disappear only by passage through and from the GIT. The mathematical model for measuring the rate of disappearance involves the estimation of: (1) the rate of digestion as well as (2) the rate of passage, which is assumed to follow first order kinetics.

Pioneering studies on rate of cellulose digestion were carried out 20 to 30 years ago in temperate climates[26-33]. However, it is the introduction of a mathematical model for cellulose disappearance from the rumen that is generally considered as the basis of development of modelling[25]. The proposed model is shown in the following equations:

$$\frac{dA}{dt} = - k_1 A - k_2 A$$

$$\frac{dB}{dt} = - k_2 B$$

where: A = amount of potentially digestible cellulose in the rumen
B = amount of indigestible cellulose in rumen
k_1 = digestion rate
k_2 = passage rate t = t ime in hours

The curve of digestion usually shows a typical pattern which can be separated into several phases, i.e., lag phase, rate slope and extent of digestion[34]. These equations of Waldo and his colleagues were limited only to the slope area and, if the total cellulose was subjected to the rumen environment, then the extent of digestion would be a function of time with respect to the rate of digestion.

The division of the forage fibre fraction into three fractions: (1) fast-digestible, (2) slow-digestible, and (3) indigestible fractions was proposed by Mertens and Ely in 1973[35]. This was later supported by other findings[36,37] that forage plants have three morphological types of plant tissue that have different rates of degradation. These are mesophyll and phloem tissues as fast-digestible, bundle sheaths and epidermal cells as slow-digestible, and lignified vascular bundles and sclerenchyma tissues as the relatively indigestible portion.

An earlier study[32] using an *in vitro* digestion technique to investigate digestion rates of cell-wall components of six forages with variable cell soluble proportions, indicated that the rate of cell-wall digestion fell within the range of 5.65 and 27.03 percent/hour. Furthermore, rates of cell- wall digestion were negatively correlated with lignin: acid detergent fibre (ADF) ratio (r = -0.60), lignin : cellulose ratio (r = -0.57), and positively correlated with cell soluble contents in the DM (r = 0.77). The highest rate of digestion was obtained in immature ryegrass (*Lollium perenne*) associated with a greater percentage of soluble cell constituents and with less developed structural components, thus, being more susceptible to microbial degradation. The lowest was obtained in mature timothy grass (*Poa*

protense). It is likely that similar relationships may also apply to the different tropical forages.

It has been found that the rate of cell-wall digestion was highly correlated with the ratio between hemicellulose:ADF in some of the grasses, but not in legumes[33]. This finding suggests that, in grasses that contain proportionally greater amounts of hemicellulose, the digestion of the cell-wall fraction will be faster than in those with lower hemicellulose content. It is therefore of interest to and a challenge for forage geneticists to select and develop forage species containing a larger hemicellulose fraction in plant cell walls.

The degree of cellulose crystallinity is another factor that affects digestion rate of cell walls. The crystalline structure of plant cellulose in which cellulose molecules are closely aligned in the crystalline regions, may slow down the rate of digestion because of increased inhibition of digestive enzymes to penetrate the cell-walls[24]. The interest in this area of research extends to the question as to whether there are different digestibilities between leaf and stem fractions of the forage plants. In examining the digestibility of a tropical legume (*Lablab purpureus*), it was found that NDF digestibilities of the leaf and stem fractions were significantly different (55.2 vs. 44.9 percent respectively measured in cattle and 61.8 vs. 42.9 percent in sheep). However, the rate of digestion constants were not greatly affected, i.e., 1.8 vs. 1.1 percent/hour in cattle and 4.2 vs. 3.8 percent/hour in sheep for the leaf and stem fractions, respectively[38]. These results also suggest that sheep may digest feed more effectively than cattle.

Other factors that affect digestion rate of forages are those related to the physiological state of the rumen that may modulate the microbial population and GIT motility. The digestibility of cellulose and hemicellulose in the large intestine from several experiments[39] with quantities of cellulose and hemicellulose reaching and digested in the large intestine being calculated, showed variable results in that 42.8 to 85.9 percent of cellulose and 32.2 to 77.9 percent of hemicellulose eaten were digested in the rumen. Digestion of cellulose and hemicellulose fractions that entered the hindgut were in the range of 18.5 and 49.5 percent; and 2.5 and 46.0 percent, respectively.

The environmental factors within the reticulo-rumen, for example the rumen pH, are affected by feed intake. A pH of less than

5.5 has been shown to inhibit rumination, depress protozoal growth, inhibit growth of cellulolytic bacteria, but the population of lactobacillic bacteria was increased. Changes in microbial population will affect the rate of digestion which in turn determines the extent of digestion. It was observed that rumen motility was affected by volatile fatty acids (VFA) produced from microbial fermentative processes[40].

Similarly, concentration of ammonia in the rumen can affect the rate of cell wall digestion through its effect on growth of micro-organisms in the rumen. It was shown that a faster rate of digestion in sheep compared with cattle was associated with higher ammonia concentrations (107 to 204 mg/l rumen fluid in sheep and 64 to 116 mg/l rumen fluid in cattle)[41]. The ranges of ammonia concentrations, both in sheep and cattle, were higher than those required for optimal growth of rumen microbes (50 mg/l rumen fluid) suggested previously[42]. While the latter was determined from in *vitro* studies, the in *vivo* situation may require different concentrations.

It is therefore most important for effective digestion in the rumen that microbial activity is not impaired by nutrient deficiencies. Other essential nutrients can also influence rate of digestion, for example available minerals and trace elements/compounds, anti-microbial agents, such as monensin and avoparcin, etc. Factors affecting the rate of digestion of forage are shown in Fig. 4.

III. EFFECT OF PLANT SPECIES

The chemical composition of forage varies among plant species and even within the same plant variety. This variation, for example in the proportion of lignin, cellulose and hemicellulose in plant cell wall, is clearly found among grasses and legumes. Lignification of the cell-wall is significantly greater in legumes compared with that in grasses but grasses become mature earlier than legumes. This may reduce the digestion rate of available cellulose in the cell-wall. Conversely, it determines the proportion of unavailable cellulose. Nevertheless, generally the digestibility of organic matter is greater in tropical legumes; grasses become mature and less digestible earlier than legumes. Digestion rate of cellulose in grasses is related to the lignin : cellulose ratio. Cellulose when completely freed of lignin and other interfering matter is more or less completely digestible in the rumen.

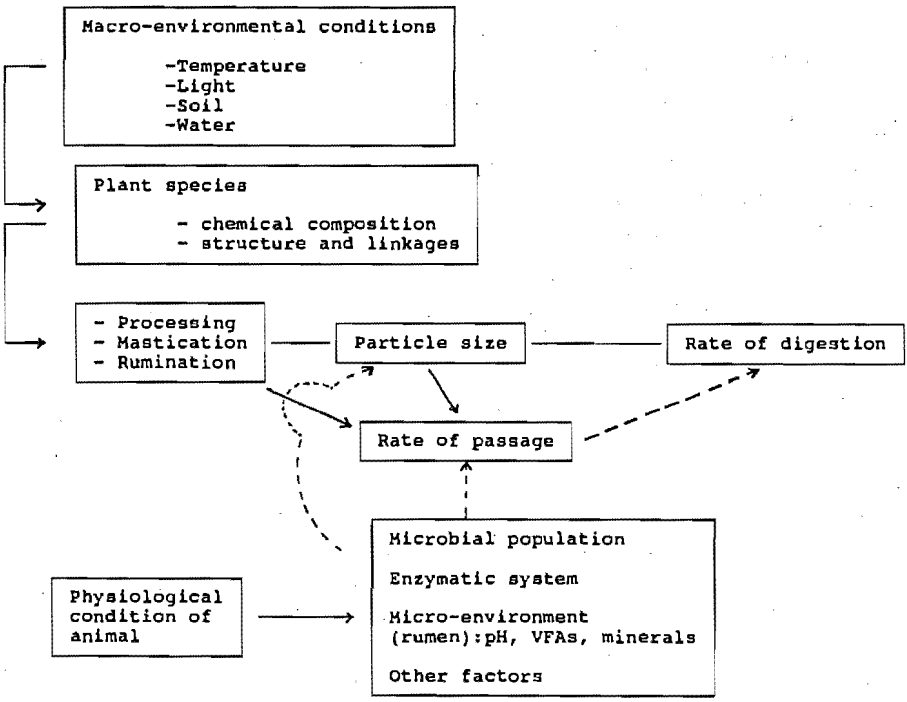

Fig. 4 Some related factors affecting digestion rate of forages by ruminants.

However, delignified cellulose requires a longer lag time for digestion to start compared with intact cellulose[43]. It was shown that the negative effect of lignin upon digestibility of forages depends on the covalent linkage between lignin and the carbohydrate residues[44]. The influence of environmental conditions on the degree of lignification is indicated by the fact that temperate grasses have a range of lignin : cellulose ratios between 0.08 to 0.21 while those of tropical grasses vary between 0.11 to 0.24. The differences in digestibility of forages and their relation to the ratio between lignin : cellulose are shown in Table 1.

IV. ENVIRONMENTAL FACTORS

Environmental factors such as temperature, light and soil conditions, are factors which determine forage chemical composition.

Table 1. Digestibility of cellulose in forages by ruminants[34].

Material	Digestibility (%)	Lignin : cellulose ratio
Alfalfa	40 – 60	0.18 – 0.30
Temperate grasses	48 – 90	0.08 – 0.20
Tropical grasses	30 – 60	0.11 – 0.24
Straws	40 – 60	0.10 – 0.26
Soy bean hulls	94	*
Cottonseed hulls	50	0.55
Rice hulls	0	0.45

* Negligible amount of lignin

For example, the concentration of total cell-wall constituents (CWC), ADF and cellulose in napier grass (*Pennisetun purpurum*) increased more rapidly during the warmer season than in winter while dry matter and CWC digestibility decreased[45]. Environmental temperature affects indirectly forage chemical composition and may contribute to the existing negative relationship between maturity and forage nutritive value because high temperatures lead to rapid plant maturity.

The factors associated with the chemical and physical structure of the feed influence efficiency of digestion. Lignification, for example, protects the internal polysaccharides of the cell walls from degradation by microbial enzymatic action. Cellulose and hemicellulose differ in their susceptibility to enzymatic degradation. In grasses, the hemicellulose appears to be more degradable than cellulose. On the other hand, cellulose in leguminous plants is more degradable than hemicellulose. The cellulose fraction, if released from lignin and other secondary compounds, is apparently fully digestible and the extent of its degradability is determined by time.

The effect of structural and chemical characteristics of the cell-wall fraction on digestibility has been reviewed by van Soest[46]. The rate of digestion of available cellulose has a negative relationship with the proportion of the unavailable cellulose, meaning that the smaller the proportion of unavailable cellulose, the greater the rate of digestion of available cellulose. The explanation for this is that a lower proportion of unavailable cellulose indicates less lignification, which is

associated with less developed structural components. This then allows rumen micro-organisms to have greater access to digestion of the cell-wall.

Obviously, interactions among feed characteristics, animal factors and environmental factors exist in the control of forage intake and should not be dealt with in isolation. Voluntary feed intake is of primary importance in evaluating feeding value, although it is time-consuming and costly to measure, especially in grazing animals, and can be affected by the phenotype and condition of the animal used. It is generally accepted that maximum intake of ruminants is around three to four percent bodyweight/day when fed a roughage diet. Difficulties exist in comparing intake data between and within experiments as the animals used may have been different genetically and may have varied in size, weight and/or condition. Animals with the same recorded weight can vary widely in gut-fill, total body fat content and with some sheep, fleece weight. Thus, bodyweight can be an imprecise indicator of body size. Weighing the animal after a predetermined fasting period will reduce errors due to gut-fill. For between species comparisons, $W^{0.75}$ is commonly used as a scaling factor to make comparisons of intake more meaningful. However, $W^{0.90}$ may be more appropriate for comparisons between adult sheep and cattle. Perhaps, $W^{1.0}$ or actual bodyweight may be even better for comparing breeds of sheep and with various species comparisons. Recently, reticulo-rumen *digesta*-free live weight has been introduced as a scaling factor. While its use would reduce the effects of variable fill, measurements of the quantity of *digesta* in the reticulo-rumen are not common. Nonetheless, more meaningful comparisons of data on levels of intake could be achieved if adequate descriptions of the animals were given.

D. FEEDING SYSTEMS

When the behaviour of goats and sheep is compared, goats have a greater tendency for selection of feeds when high quality forages are offered, but the reverse is true when the quality of feed on offer is low. When low quality feeds are given, goats will consume more but digestibility may be lower than in sheep[47]. The lower digestibility could

be associated with the higher intake by goats or lower capacity to digest fibrous material. In addition to the different digestibilities of forage fibre fractions, sheep and goats have the ability to select parts of plants with higher nutritive value. Parts of plants with higher contents of hemicellulose and protein are generally chosen, even in a stall-feeding system[48]. Comparative studies between goats and sheep are difficult as many factors are involved in determining their ability to utilize different feeds, and more studies need to be carried out in this area. (Appendix 2 lists the chemical composition of commonly fed supplements and by-products in Indonesia).

I. CUT-AND-CARRY SYSTEMS

In a cut-and-carry feeding system, feed is brought to the animals and the quality and quantity of feed on offer is primarily determined by the farmer.

As discussed earlier, the requirements for nutrients of goats and sheep are influenced by age, physiological status, level of production (weight gain, milk production, work etc.), and environmental conditions such as temperature, humidity, sun, wind velocity, etc. In a cut-and-carry feeding system, it is therefore necessary to ensure that the quality and amount of feed offered be sufficient to meet the animals' requirements. The diets should be balanced and formulated according to the level of production.

When feeding goats and sheep, the physiological state and the productive performance of the animals should be considered. For example, the rations should be different when feeding does/ewes during late gestation or early lactation, when feeding kids/lambs during pre-weaning and post-weaning stages, and when feeding mature non-pregnant, non-lactating does and ewes or bucks and rams. This area is discussed in Chapter VI in the section Nutrition for Efficient Reproduction. The rations presented in Table 2 are examples of diets for each physiological status.

II. FEED SUPPLEMENTATION

Feed supplementation is given to provide additional nutrients to meet the requirements of animals of a certain physiological status and productive performance. Energy and protein are the two major

Table 2. Examples of daily rations for maintenance in cut-and-carry feeding systems (dry matter basis).

Ingredients	Physiological state			
	Ewe 30 kg	Lamb 15 kg	Mature 30 kg	Pre-weaning
	....kg....			%
Pennisetum purpureum	0.9	0.4	-	-
Leucaena	0.3	0.2	-	-
Rice bran	0.24	-	-	20
Mixed native grasses	-	-	0.7	-
Cassava leaves	-	-	0.2	-
Soy bean meal	-	-	0.15	18.5
Corn	-	-	-	60.0
Limestone	-	-	-	1.0
Trace elements	-	-	-	0.5
Chemical composition				
Dry matter (kg)	1.44	0.6	1.05	
Digestible energy (Mcal)	3.86	1.60	2.60	
Total protein (g)	186.8	81.0	133.0	19.0

requirements that should be met adequately. As mentioned before, while mineral and vitamin supplementation is also important and may determine the level of production, it will not affect productivity significantly if the requirements for energy and protein have not been met. However, this should not imply that mineral and vitamin requirements should be overlooked.

Results of a number of supplementation experiments in Indonesia, with the basal forage being napier or native grasses have been compiled and discussed, and the responses obtained are summarized in Table 3. Note that there can be problems with getting goats and sheep to eat new supplements that they are unfamiliar with. This is particularly true for goats. For example, many animals used to green forages will not eat dry concentrates. Thus, a period of forcing them to eat a new supplement by offering it without other feed being available, is required.

1. *Rumen Microbial Mass Production*

Rumen microbial mass production has a positive correlation with the products of anaerobic fermentation. Higher animal production in the form of meat, milk or wool may be related to higher rumen microbial protein synthesis[50].

A microbial population that is in equilibrium is necessary for the optimum utilization of organic matter in forage because of competitive and mutually symbiotic utilization of nutrients and energy substrates among microbial species in the rumen, including protozoa and fungi. It is believed by Leng's group that the number of protozoa in the rumen should be reduced as much as much as possible as they are largely parasites and compete with the animal for N. The role of fungi is almost unknown, although they may help in fibre degradation.

Table 3. Response of goats and sheep to supplementation[49].

Species	Basal forage	Supplement	Range of intake/$W^{0.75}$ DDM	CP	Range of average daily gain
			g		
Goats	*Pennisetum purpureum*	none	34 to 42	6 to 7	-8 to -2
		Gliricidia	37 to 59	8 to 15	18 to 53
		Leucaena	37	9	22
		Sesbania	34	10	20
		Cassava leaves	32 to 54	7 to 14	13 to 37
	Native grass	none	28 to 43	6 to 7	1 to 9
		Gliricidia	27 to 46	6 to 13	-4 to 53
		Leucaena	37 to 52	9 to 13	17 to 30
		Cassava leaves	48 to 54	11 to 14	13 to 31
Sheep	*Pennisetum purpureum*	none	28 to 48	6 to 10	20 to 35
		Gliricidia	34 to 59	9 to 16	36 to 53
		Leucaena	30 to 39	8 to 14	35 to 57
		Sesbania	35 to 57	8 to 17	57 to 100
		Cassava leaves	34 to 58	9 to 13	33 to 59

DDM: digestible dry matter; CP: crude protein

Manipulation of the microbial population in the rumen ecosystem is aimed towards enhancing the production of glucogenic precursors such as propionic acid. The nutrients required for microbial growth should contain not only nitrogen, either in the form of non-protein nitrogen (NPN) or protein nitrogen, but also readily fermentable carbohydrates as energy sources; and minerals.

The availability of nutrients for microbial fermentative processes will affect the chemical composition of microbial yield[51]. This may be due to changes in the chemical composition of cells or changes in the proportion of microbial species in the population. Low quality diets, low in nitrogen and high in fibre content, resulted in increased production of carbohydrates in the microbial cells, while with a good quality diet, i.e., high in nitrogen and low in fibre content, more protein was being synthesized by the microbial cells.

Nitrogen in the form of ammonia-N has been shown to be the major source of nitrogen necessary for the synthesis of microbial proteins. The carbon chains which are essential for the carbon skeleton of the amino acids may be derived from the degradation of dietary polysaccharides. The availability of carbon chains and ammonia-N, with regard to timing, is important to maximize the production of rumen microbial proteins. Further elucidation of this, however, needs further studies.

Minerals are also necessary for the synthesis of microbial proteins. Phosphorus and sulphur are the two elements of major importance. Many references on mineral requirements of rumen microbes are available[29,52,53].

Efficiency of microbial growth in the rumen can be expressed as grams of microbial nitrogen synthesized/kg organic matter digested in the rumen, and may range from 6.3 to 30.7[54].

The utilization of NPN such as urea was not always increased when added to a basal low-quality forage diet when ammonia levels were high. An increase in ammonia-N concentration in the rumen following the feeding of urea was observed immediately. Even though rumen microbes require ammonia N for their cell protein production, it is believed by the authors that the low quality forage diets may not provide adequate energy necessary for optimal microbial mass production. Urea is readily hydrolyzed in the rumen into ammonia and

CO_2. There are two ways for ammonia-N to be dissipated from the rumen fluid, either it is absorbed within the animal's system through the wall of the reticulo-rumen or it is utilized by microbes for their growth and multiplication. For the latter, the efficiency of ammonia utilization will be affected by energy charge, which may be expressed in terms of Adenosine Triphosphate (ATP) availability. The energy (carbon chains) source for microbial mass production is primarily derived from the hydrolysis of components of forage cell wall (cellulose and hemicellulose) and the cell saps (NDS) such as pectin, starch, etc. with different solubilities, resulting in different rates of hydrolysis and availability. Given that other nutrients are available, ammonia-N and ATP concentration will determine the efficiency of microbial growth or the level of microbial protein synthesis. This needs to be understood in order to find the appropriate strategies of feeding management for better ruminant production. It is believed by Leng's Armidale group that ammonia is often too low in high fibre diets for efficient bacterial function.

When feeding readily hydrolyzable nitrogen such as urea, the availability of carbon chains to utilize efficiently the substrate for microbial growth should be considered. Legume tree foliages which are high in crude protein content are often used as protein supplements. The rate of nitrogen solubility of some legume tree foliages has been shown to be quite high (2.6 percent/h) in which 27.4 to 42.5 percent of total nitrogen became soluble during the first two hours in the reticulo-rumen, with a total of approximately 22 percent nitrogen being unavailable for digestion[55]. If this is true, then supplementation with legume tree foliages should also be accompanied by supplementation with energy and/or additional supplementation with rumen by-pass protein.

2. *Rumen By-pass Protein*

Rumen microbial protein can be considered as a major source of protein (amino acids) for the host animal. In a traditional management system an estimate of rumen microbial protein production in goats fed native grasses with legume tree foliage and urea as supplements was significantly higher than on diets without protein supplementation[4]. A possible alternative to providing soluble protein for the host animal is by means of 'rumen by- pass protein' supplementation. The term "by-

pass protein' is in fact not correct and probably better described as 'rumen less-degradable protein'. However, in this Chapter the term 'by-pass' will be used for simplicity. Dietary proteins having low rumen solubility (<30 percent) can be considered as sources of rumen by-pass protein, since solubility and degradability are positively correlated. It is important that chemical or physical pre-treatments to protect dietary proteins from degradation in the rumen are applied, but that the dietary protein passing through the rumen is available for digestion and absorption in the abomasum and the small intestine, thus, increasing the total amount available for the animal. Otherwise, the protected protein will not be utilized and will be excreted in faeces. Proteins in legume tree foliages vary in their solubility. This opens the possibility of using legume tree foliages as sources of rumen by-pass protein. It is obvious that there is a need to determine the rate of protein solubility of legume tree foliages if they are to be used effectively as feed for ruminants.

Experiments have indicated that up to 83 percent protein from rumen micro-organisms is digested in the lower digestive tract of lambs[56]. Optimizing microbial protein synthesis is essential and if this does not reach the level required for a given stage of production then supplementation with 'rumen by-pass protein' could be advantageous. Leng has recent evidence that animals on roughage with low digestibility and low protein should be supplemented partly with NPN with high rumen solubility and partly with by-pass protein[5].

III. USE OF CROP BY-PRODUCTS

Production of food crops is the primary agricultural production system in Indonesia. Therefore there is an abundance of crop residues such as straws that are potentially useful for ruminants. Straws of rice, corn, as well as vines of soybean and peanut are examples of these food crop residues for feeding ruminants. Since food crops are harvested after the plants are fully matured, these straws usually have low nutritive values for animals. This is due to the high content of lignocellulosic materials which results in the polysaccharides being less degradable by the microbial fermentative processes in the rumen. Pre-treatments of these crop by-products can be used to increase their nutritive value. These pre-treatments are principally aimed to make the lignocellulosic materials more degradable. It is known that the

cellulosic materials are degradable when freed from lignin[34]. These pre-treatments can be biological, chemical or physical. Although these treatments can slightly improve intake and digestibility, cost of treatment has to be considered in relation to the cost of improved products making these often uneconomic.

Intake of dry matter from a rice straw diet by sheep, whether untreated or treated with alkali, increased with increasing particle size of the straw[57]. Inoculation with fungi *Pleurotus sp.* can increase the *in vitro* organic matter digestibility of rice straw[58].

Results of experiments on the use of several food crop by-products (straws) in rations for goats and sheep are summarized in Table 4.

Goats and sheep can use rice straw as a basal diet but this should be supplemented with additional nutrients, especially NPN and by-pass protein due to the low nitrogen content in rice straw which is mostly linked with the indigestible fraction. Corn stalks or straw can also be fed to small ruminants either on their own or with other grasses. Dried soy bean and peanut vines have also been fed to goats and sheep. However, when dried, the vines become unpalatable and the leaves drop. Hence, these feeds are probably useful only if the material is offered to animals while fresh.

IV. LEGUME TREES AND SHRUBS

A diet of mixed native tropical grasses fed to animals is generally low in nitrogen content and high in fibre. These two characteristics often result in limitation to intake necessary to meet the minimal nutrient requirements of animals. The high intake of fibre due to the high fibre content of the feed results in inefficient utilization of the cell wall itself due to insufficient nutrients being available for the rumen microbes. Since protein degradation in the rumen into ammonia and its keto- acids is required before the synthesis of microbial protein in the rumen, dietary protein that can be degraded in the rumen at a level high enough to meet the microbial growth requirements is of primary importance. Tree and shrub legume foliages are usually high in nitrogen content, however, the degradability varies depending upon the linkages with other secondary compounds (e.g. tannin) which can affect the solubility as well as digestibility and palatability.

Table 4. Utilization of crop by-products in rations for goats and sheep[4].

Species	Major crop by-product used	Daily total dry matter intake (g)	Average daily gain (g)	Reference
Goats	Corn straw	327	9	59*
		336	2	
		256	-8	
		397	21	
Sheep	Cashew waste	767	46	60
		841	56	
		897	76	
		1010	81	
Sheep	Mixed straws (rice, corn, sorghum straw)	472	30	61
		451	20	
		465	29	
Sheep	Rice straw, soy bean and rice bran	868	120	62
		833	110	
		1028	140	
Goats	Soy bean cake untreated	393	37	63
	Formaldehyde treated	398	48	
Goats	Sugarcane tops	541	30	64**
		615	37	
		525	34	
		667	36	
Sheep	Sugarcane tops	510	39	64**
		581	49	
		473	26	
		572	42	
Goats	Sugarcane tops	339	3	65

* plus *Leucaena leucocephala or lamtoro*

** plus *gliricidia and lamtoro*

A mixture of grasses and legumes is advantageous to improve the low nutritive value of tropical grasses in a cut-and-carry feeding system. Some legume tree foliages that can be used include *Leucaena leucocephala, Gliricidia sepium, Sesbania grandiflora and Callandra callothyrsus.*

Results of experiments on the resistance of protein to degradation in the rumen in which nineteen feedstuffs, including legume tree foliages and industrial by-products were fed, are shown in Table 5. Different patterns and rates of degradation for protein were observed. A group of feedstuffs showed increasing rates of degradation with increasing quantity of feedstuff; included in this group were soy bean cake, soy sauce waste, *leucaena* leaves, banana stem and *calopogonium*. Another group of feedstuffs indicated an easily degraded protein when the quantity was small which become less degradable when the quantity was large. Included in this group were soy bean curd waste, napier grass, corn leaves, *stylosanthes*, sweet potato vines, cassava leaves, *Imperata cylindrica*, mixture of native grasses, and palm oil cake. *Panicum maximum* showed a decreased rate of protein degradation with increasing quantity of material which follows the Michaelis-Menten equation.

1. *Leucaena leucocephala*

The leaves of this legume tree contain protein with a relatively low rumen degradability which thus can be considered a good source of protein for ruminants. However, it contains mimosine which may create problems when fed to ruminants. It has been found in Australia that ruminants consuming high mimosine levels may show hair loss. However, with appropriate micro-organisms mimosine is degraded to 3-hydroxy-4(1H)-pyridone (3,4 DHP) in the rumen. These appear to be present in the rumen of ruminants in the humid tropics. Heating the leaves increased the degradation of mimosine into 3,4 DHP[67]. The attack of *Leucaena leucocephala* by a scillid has made this exceedingly useful tree legume no longer easily grown for forages and fuel.

2. *Gliricidia sepium*

Fresh foliages of *gliricidia* are not readily eaten by goats and sheep due to unpalatable secondary compounds. A period of adjustment is required before continuous feeding with *gliricidia* foliages. When wilted overnight, they will be readily eaten[68,69]. However, it is not certain which compound(s) cause it to be unpalatable, probably the coumaric acids. This warrants further investigation. Results of experiments indicated that *gliricidia* foliage can be given only at a

Table 5. Protein degradability of several feedstuffs by rumen microorganisms[66].

No.	Feedstuff protein (%)	Crude	a	b	Rate of degradation (%/h)
1.	Soy bean cake	44.8	0.111	47.2	0.24*
2.	Soy sauce waste	24.9	0.483	36.4	1.33*
3.	*Leucaena* leaves	28.1	0.413	35.7	1.16*
4.	Soy bean curd waste	25.2	-0.015	35.5	0.04**
5.	Beer waste	31.1	0.438	25.7	1.70*
6.	Napier grass	10.1	-1.060	35.6	2.98**
7.	Peanut cake	33.9	0.075	22.4	0.33*
8.	Coconut oil cake	22.6	0.002	21.8	0.01*
9.	*Panicum maximum*	9.6	5.520	-19.8	27.88***
10.	Corn leaves	16.9	-0.176	16.8	1.05**
11.	*Stylosanthes*	16.0	-0.360	15.4	2.34**
12.	*Sesbania*	26.6	0.476	11.8	4.03*
13.	Banana stem	6.4	0.012	10.4	0.11*
14.	Sweet potato vines	17.3	-0.319	11.4	2.80**
15.	Cassava leaves	27.1	-0.180	10.1	1.78**
16.	*Imperata cylindrica*	7.8	-0.000	8.7	0.00**
17.	Native grasses	9.1	-0.202	9.2	2.21**
18.	Palm oil cake	17.7	-0.033	8.2	0.41**
19.	Calopogonium	19.6	1.520	7.2	21.08*

a: intercept; b: regression coefficient

*: minimum rate of degradation; the rate increased with increasing quantity of feedstuff

**: protein of these feedstuffs is easily degraded when the quantity is small, but becomes less degradable when the quantity is large

***: maximum rate of degradation

maximum of 30 percent in the diet to obtain optimal growth in goats. More than 30 percent *gliricidia* foliages in diets may reduce the cellulose digestion[70]. Whether this is related to the acid content which also reduces palatability remains to be clarified.

3. *Sesbania grandiflora*

The protein degradability of leaves of this legume in the rumen is quite high[55]. This may result in an inefficient utilization of the nitrogen

for rumen microbial growth if energy availability does not match the available nitrogen. Therefore feeding *sesbania* foliages should be accompanied by feeding readily available (degradable) carbohydrates.

4. *Caliandra callothyrsus*

Caliandra foliages can be mixed with grasses for feeding small ruminants. Feeding entirely with *caliandra* foliages may reduce the efficiency of nutrient utilization[71] which is probably due to the imbalance in availability of the nitrogen and energy substrates. There is also a possibility that the nitrogen is associated with the structural polysaccharides, resulting in less nitrogen being available for the synthesis of rumen microbial protein.

CONCLUSIONS

Most of the nutritional studies in Indonesia have been carried out with growing animals. It is therefore necessary to establish further the nutrient requirements of small ruminants in different physiological states. The recommendations presented in this Chapter on energy and protein requirements need further assessment in view of the limited data that are currently available. The authors believe that sheep require more energy as well as protein, while in goats, protein seems to be the main nutrient that is lacking. This should be further investigated. It is apparent that mineral requirements will be the next most important area in which work should be carried out, especially on those minerals that may be deficient in particular regions.

Further attention should be focussed on crop by-products, with special reference to fibre utilization. The possibility of applying available pre-treatment technologies on crop by-products to improve their nutritive value should be explored, but the economics of the treatments must be evaluated. Feeding strategies with regard to effective utilization of the rumen microbial protein and the role of rumen 'by-pass' proteins, are other areas of research that warrant urgent further investigation.

Finally, it should be noted that most of the studies to-date have been on sheep, yet there are twice as many goats as sheep in Indonesia, so that more studies on the goats are necessary since there

are important differences between the two species in various aspects of behaviour and nutrition.

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Appendix 1. Daily nutrient requirements of growing goats and sheep in Indonesia[4].

a. Goats

Body weight (kg)	Gain (g/d)	Energy DE (Mcal)	Energy ME (Mcal)	Protein TP (g)	Protein DP (g)	Dry matter* Total	Dry matter* %BW
10	0	0.75	0.62	49.7	34.2	0.26	2.6
	50	0.85	0.70	88.2	66.4	0.29	
	100	0.95	0.78	126.8	98.6	0.33	
12	0	1.07	0.88	53.1	36.1	0.37	3.1
	50	1.17	0.96	91.7	68.3	0.40	
	100	1.27	1.04	130.2	100.4	0.43	
14	0	1.39	1.14	56.5	37.9	0.48	3.4
	50	1.49	1.22	95.1	70.1	0.51	
	100	1.59	1.30	133.6	102.3	0.54	
16	0	1.71	1.40	59.9	39.8	0.58	3.6
	50	1.81	1.48	98.5	72.0	0.62	
	100	1.91	1.56	137.1	104.1	0.65	
18	0	2.03	1.67	63.3	41.6	0.70	3.9
	50	2.13	1.75	101.9	73.8	0.73	
	100	2.23	1.82	140.5	106.0	0.76	
20	0	2.35	1.93	66.8	43.5	0.80	4.0
	50	2.45	2.01	105.3	75.7	0.84	
	100	2.55	2.09	143.9	107.8	0.87	

DE: digestible energy; ME: metabolizable energy; TP: total protein; DP: digestible protein

* Assuming 2.4 Mcal/kg dry matter of feed

Appendix 1. Continued.

b. Sheep

Body weight (kg)	Gain (g/d)	Energy DE (Mcal)	Energy ME (Mcal)	Protein TP (g)	Protein DP (g)	Dry matter Total	Dry matter %BW
10	0	1.00	0.82	44.7	16.5	0.34	3.4
	50	1.49	1.22	73.7	35.2	0.51	
	100	1.98	1.62	102.7	54.0	0.68	
12	0	1.17	0.96	51.3	24.9	0.40	3.3
	50	1.65	1.35	80.3	43.6	0.56	
	100	2.14	1.75	109.3	62.3	0.73	
14	0	1.33	1.09	57.9	33.2	0.45	3.2
	50	1.81	1.49	86.9	52.0	0.62	
	100	2.30	1.89	116.0	70.7	0.79	
16	0	1.49	1.22	64.5	41.6	0.51	3.2
	50	1.97	1.62	93.6	60.3	0.68	
	100	2.46	2.02	122.6	79.1	0.84	
18	0	1.65	1.35	71.2	40.0	0.56	3.1
	50	2.14	1.75	100.2	68.7	0.73	
	100	2.62	2.15	129.2	87.4	0.90	
20	0	1.81	1.49	77.8	58.4	0.62	3.1
	50	2.30	1.88	106.8	77.1	0.78	
	100	2.78	2.28	135.8	95.8	0.95	

Appendix 2. Chemical composition of feedstuffs (on dry matter basis)*.

No.	Name	Dry matter	Feed energy		Crude fibre	Ether extract	Nitrogen free-extract	Protein					
								Crude protein	Digestible protein				
		%	TDN %	DE Mcal/kg	ME Mcal/kg	CF %	EE %	NFE %	CP %	Goats %	Sheep %	Ash %	Ca %	P %
1	*Andropogon timorensis*	91.0	48.45	2.14	1.75	36.17	1.35	49.56	3.22	-0.4	-0.5	9.70	0.40	0.11
2	*Albazia falcata*	86.5	.	.	.	.	5.71	.	18.66	13.9	13.3	9.73	1.56	0.03
3	*Hardeum vulgare* barley beer waste	92.3	73.80	3.25	2.67	18.05	4.53	49.89	23.47	8.4	17.6	4.06	0.32	0.45
4	*Arachis hypogaea* pea nut leaves	92.6	63.95	2.82	2.31	14.20	2.72	47.16	19.17	14.4	13.7	16.75	0.45	0.52
5	*Arachis hypogaea* pea nut stem	93.2	49.87	2.20	1.80	36.23	0.65	45.81	7.10	3.1	2.9	10.21	0.88	0.28
6	*Elaeis guineensis* palm oil cake	88.5	66.89	2.95	2.42	17.19	1.95	48.66	22.50	17.5	16.7	9.70	0.31	0.65
7	*Glycine max* Soybean cake	88.8	91.62	4.04	3.31	6.03	3.32	40.02	42.85	36.5	35.0	7.78	0.67	0.63
8	*Macademian* nut cake	95.6	45.03	1.99	1.63	5.00	43.87	13.77	31.00	25.4	24.3	6.36	0.52	1.05
9	*Cocos nucifera* coconut oil cake	90.2	78.99	3.48	2.86	12.78	8.98	48.89	21.21	16.3	15.6	8.14	0.46	0.40
10	*Elaeis guineensis* palm kernel cake	89.3	59.93	2.64	2.17	30.41	4.02	41.45	18.16	13.5	12.8	5.96	1.36	0.55
11	*Saccharum officinarum*, Baggase	91.9		.	.	.	.	.	.	.		2.71	.	.
12	*Brachiaria brizantha*	93.5	53.22	2.35	1.92	30.08	2.20	47.19	10.08	5.9	5.6	10.45	0.59	0.26
13	*Brachiaria brizantha* stem	94.7	67.08	2.96	2.43	27.26	0.62	30.32	32.53	26.9	25.7	9.27	0.25	0.41
14	*Brachiaria brizantha* leaves	93.3	57.64	2.54	2.08	25.20	3.41	49.14	12.28	8.0	7.5	9.97	0.56	0.39
15	*Brachiaria decumbens*	91.8	53.37	2.35	1.93	28.87	1.57	48.77	10.21	6.0	5.7	10.58	0.49	0.16
16	*Gynura procumbens*	87.4	.	.	.	.	2.49	.	15.22	10.7	10.2	21.35	3.74	0.26
17	*Calopogonium caerelium*	90.4	56.66	2.50	2.05	31.03	4.16	37.64	18.14	13.4	12.8	9.03	1.68	0.28
18	*Calopogonium mucunoides*	91.8	57.37	2.53	2.07	31.06	2.75	38.19	18.70	14.0	13.3	9.30	1.40	0.24
19	*Calopogonium* spp	92.6	.	.	.	.	4.96	.	13.76	9.4	8.9	8.83	2.21	0.21
20	*Erythrine variegata*	87.7	70.44	3.11	2.55	23.02	5.85	36.15	29.61	24.1	23.1	5.37	0.97	0.34
21	*Desmodium* spp	90.9	54.76	2.41	1.98	29.19	2.01	47.58	11.58	7.3	6.9	9.64	0.65	0.13
22	Digitaria decumbens	91.2	67.52	2.98	2.44	17.40	4.81	63.40	8.90	4.8	4.5	5.49	0.61	0.12
23	*Gliricidia sepium*, stems	91.2	50.55	2.23	1.83	49.68	1.63	30.05	10.17	6.0	5.6	8.47	0.97	0.31

* Results of laboratory analysis and calculations using mathematical models in Balai Penelitian Ternak (Research Institute for Animal Production); Bogor. (B. Haryanto and S.Askar, Unpublished data).

Appendix 2. Continued.

No.	Name	Dry matter	Feed energy		Crude	Ether fibre	Nitrogen extract	free-extract	Protein					
									Crude protein	Digestible protein				
		%	TDN %	DE Mcal/kg	ME	CF %	EE %	NFE %	CP %	Goats %	Sheep %	Ash %	Ca %	P %
24	*Gliricidia*	90.5	63.40	2.80	2.29	24.00	4.29	38.28	23.62	18.6	17.7	9.81	2.35	0.35
25	*Triticum aestivum* sprouts	87.2	103.86	4.58	3.76	1.48	8.45	51.15	32.93	27.2	26.1	5.99	0.21	1.05
26	*Triticum aestivum* bran	91.1	74.85	3.30	2.71	7.11	4.55	55.74	18.66	13.9	13.3	13.94	4.50	1.14
27	*Imperata cylindrica*	92.7	52.23	2.30	1.89	31.25	1.88	49.81	7.68	3.7	3.4	9.38	0.55	0.14
28	*Phaseolus radiatus*	86.8	79.05	3.49	2.86	6.67	1.49	57.81	28.33	22.9	21.9	5.70	0.20	0.35
29	*Psophocarpus tetra-gonolobus*	92.7	104.23	4.60	3.77	7.26	17.75	31.64	38.98	32.9	31.5	4.37	.	0.56
30	*Zea mays* Klobot	89.1	52.69	2.32	1.90	26.47	0.53	66.56	3.75	0.0	-0.0	2.69	0.03	0.25
31	*Solanum tuberosum*, leaves	89.3	65.80	2.90	2.38	14.35	4.67	49.88	16.65	12.0	11.5	14.45	3.85	0.60
32	*Theobroma cacao*, meat part of fruit	88.8	47.08	2.08	1.70	33.03	11.75	34.88	14.61	10.1	9.6	5.73	0.37	0.40
33	*Cofea spac* coffee seedhulls	86.6	53.54	2.36	1.94	37.07	1.35	42.45	11.54	7.3	6.9	7.59	0.33	0.02
34	Red bean hulls	90.3	.	.	.	.	.	.	18.12	13.4	12.8	11.69	1.11	0.39
35	*Phaseolus vulgaris* seed hulls	95.0	52.62	2.32	1.90	48.31	0.35	41.62	5.26	1.4	1.2	4.46	0.47	0.05
36	*Arachis hypogaea* seed hulls	89.5	.	.	.	.	0.72	.	10.15	6.0	5.6	9.38	0.48	0.48
37	*Glycine max* dry soy bean seed	93.2	.	.	.	.	.	.	18.02	13.3	12.7	5.78	0.75	0.38
38	*Marquissa* skin	90.6	52.51	2.31	1.90	35.75	1.65	47.40	8.04	4.0	3.7	7.16	0.20	0.14
39	*Musa paradisiaca* peelings	86.7	67.60	2.98	2.44	9.82	4.03	69.49	6.46	2.5	2.3	10.20	0.21	0.42
40	*Manihot esculenta* root peelings	90.8	58.66	2.59	2.12	14.77	1.55	56.67	11.95	7.7	7.2	15.06	0.64	0.36
41	*Sesamum orientale* seed hulls	88.5	.	.	.	18.12	.	.	50.73	43.8	42.0	7.59	0.40	0.64
42	*Raphanus sativus* leaves	89.9	63.18	2.79	2.28	14.55	6.23	45.63	16.15	11.6	11.0	17.44	5.67	0.57
43	*Manihot esculenta* leaves	91.8	72.99	3.22	2.64	17.51	8.64	39.45	26.29	21.0	20.1	8.11	1.73	0.42
44	*Saccharum officinarum*, sugarcane mollases	65.8	.	.	.	.	0.1	.	2.40	-1.2	-1.2	6.15	1.55	0.49
45	*Artocarpus integra* leaves	90.3	.	.	.	.	.	.	15.22	10.7	10.2	18.40	.	.
46	*Oryza sativa*, rice bran, first grade	88.1	82.60	3.64	2.99	9.36	9.81	57.59	14.61	10.1	9.6	8.63	0.30	1.12

Appendix 2. Continued.

No.	Name	Dry matter	Feed energy			Crude fibre	Ether extract	Nitrogen free-extract	Protein					
									Crude protein	Digestible protein				
		%	TDN %	DE Mcal/kg	ME Mcal/kg	CF %	EE %	NFE %	CP %	Goats %	Sheep %	Ash %	Ca %	P %
47	*Oryza sativa*, rice bran, second grade	86.8	71.38	3.15	2.58	13.53	10.31	50.14	14.49	10.0	9.5	11.53	0.51	0.98
48	*Oryza sativa*, rice broken	88.5	82.76	3.65	2.99	0.87	3.84	78.45	12.46	8.1	7.7	4.38	0.15	0.07
49	*Panicum maximum*	92.9	52.26	2.30	1.89	30.36	2.15	46.82	9.43	5.3	5.0	11.24	0.99	0.23
50	*Paspalum dilaltatum*	92.4	54.92	2.42	1.99	29.15	3.34	43.95	12.94	8.6	8.1	10.62	1.00	0.31
51	*Saccharum officinarum*, sugarcane tops	92.6	49.90	2.20	1.80	40.82	4.24	45.68	3.51	-0.1	-0.2	5.75	0.41	0.12
52	*Pennisetum purpureum*	92.2	.	.	.	.	.	.	10.79	6.6	6.2	17.64	0.69	0.26
53	*Musa paradisiaca*, banana stems	95.0	48.58	2.14	1.76	39.04	2.12	46.30	3.51	-0.1	-0.2	9.03	.	.
54	*Musa paradisiaca*, banana leaves	93.0	57.78	2.55	2.09	21.91	9.07	41.45	15.22	10.7	10.2	12.35	1.30	0.35
55	*Musa paradisiaca*, banana petiole	94.9	50.90	2.24	1.84	37.01	1.86	45.47	7.11	3.1	2.9	8.55	1.26	0.10
56	*Pueraria javanica*	90.9	65.81	2.90	2.38	19.97	2.70	50.47	19.57	14.8	14.1	7.29	0.94	0.16
57	Native grasses	91.4	.	.	.	.	1.33	.	9.83	5.7	5.3	17.25	1.29	0.25
58	*Sesbania grandiflora* leaves	91.1	48.20	2.12	1.74	40.42	5.22	17.56	25.99	20.8	19.8	10.81	2.34	0.27
59	*Setaria kazangula*	92.3	54.48	2.40	1.97	28.43	3.06	45.29	11.99	7.7	7.3	11.23	0.70	0.33
60	*Setaria sphacelata*	91.7	53.78	2.37	1.94	26.32	3.19	43.96	12.46	8.1	7.7	14.07	0.60	0.34
61	*Sorghum bicolor* flower	90.9	53.11	2.34	1.92	33.80	1.42	48.23	9.04	4.9	4.6	7.51	0.48	0.18
62	*Sorghum bicolor* stems	93.4	50.59	2.23	1.83	35.03	1.53	45.86	7.57	3.6	3.3	10.01	0.63	0.26
63	*Sorghum bicolor* leaves	93.4	52.01	2.29	1.88	36.49	2.18	39.83	11.70	7.4	7.0	9.80	0.61	0.27
64	*Glycine max* soy bean expeller	89.9	93.84	4.14	3.39	6.19	3.69	35.86	46.38	39.8	38.1	7.88	0.45	0.65
65	*Glycine max* soy bean flour	86.6	108.31	4.78	3.92	3.23	11.30	41.27	39.05	32.9	31.6	5.15	0.42	0.20
66	*Daucus carota* leaves	93.5	48.94	2.16	1.77	16.77	3.41	23.95	19.99	15.2	14.5	35.88	0.06	0.65
67	*Caliandra callothyrsus* red flowered stems	91.2	55.99	2.47	2.02	34.14	2.91	34.26	19.43	14.6	14.0	9.26	1.62	0.33
68	*Caliandra callothyrsus* red flowered leaves	89.7	62.12	2.74	2.25	28.94	3.30	30.82	27.72	22.4	21.4	9.22	1.49	0.27
69	*Zea mays* stems	89.0	53.06	2.34	1.92	26.47	0.91	58.74	6.57	2.6	2.4	7.31	0.35	0.16
70	*Zea mays* leaves	89.9	58.09	2.56	2.10	22.95	2.71	45.45	15.78	11.2	10.7	13.11	0.89	0.33
71	*Zea mays* grain	88.3	84.34	3.72	3.05	2.14	4.44	79.76	11.06	6.8	6.4	2.60	0.16	0.35

CHAPTER VI
IMPROVEMENT IN SMALL RUMINANT PRODUCTIVITY THROUGH MORE EFFICIENT REPRODUCTION

I K. Sutama*, I G. Putu*, and Manika Wodzicka-Tomaszewska**

INTRODUCTION

Why the concern about reproduction in a book on goat and sheep production? The answer is simple - without efficient reproduction there cannot be either genetic improvement or profit in a production enterprise. Reproductive rate has to be above that necessary for replacement and sufficient young animals must be produced for growth and sale.

In this Chapter we will summarize briefly what is known about reproductive processes and their neurohumoral controls. We will then review the present status of reproductive performance including reproductive wastage in Indonesia. It will be seen that except for studies of lactation, there are more data for sheep than for goats. This

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Chapter will conclude with a brief discussion of techniques for improvement of reproductive efficiency which are not practicable at present and which may be applicable to Indonesia only in the future. Reproductive rate can be defined as the number of offspring reaching reproductive age per doe or ewe joined with buck or ram respectively. It is, of course, related to reproductive efficiency as well as to productivity and profit in a small ruminant enterprise. It is determined by various components: reproductive behaviour and fertility or capacity of the male and female to produce offspring, fecundity and the number of offspring born per parturition, the survival of the young until reproductive age and the intervals between parturitions.

A. REPRODUCTIVE PROCESSES AND THEIR NEUROHUMORAL CONTROLS

These aspects, with data from Indonesia, are covered in a recent book by Wodzicka-Tomaszewska, Chaniago, Putu and Sutama[1].

I. THE MALE

1. *Anatomy*

Fig. 1 shows the testis of a ram. That of a buck is similar. For further anatomical and histological details of the male and female tracts, the reader is referred to any detailed text on reproduction which includes goats and sheep. In this Chapter, only those features of anatomy and histology of special significance to reproductive efficiency are described in any detail.

The reproductive tract of the male consists of paired testes enclosed in the scrotum, the epididymis, the vas deferens and the penis (with Cowper's or bulbo-urethral glands, prostate glands and seminal vesicles). The testes in the buck and the ram are pendulous and suspended between the thighs. They contain seminiferous tubules and interstitial tissue. Sixty to ninety percent of the testicular tissue consists of seminiferous tubules. The rest is classified as interstitial tissue. The tubules contain the smaller germinal cells in various stages of spermatogenesis. They also contain the larger Sertoli cells which support the developing germinal cells. The functions of Sertoli cells

include sustenance and helping the movement of developing spermatozoa from the base membrane where they are formed towards the lumen. Sertoli cells also secrete inhibin and perhaps some steroid hormones.

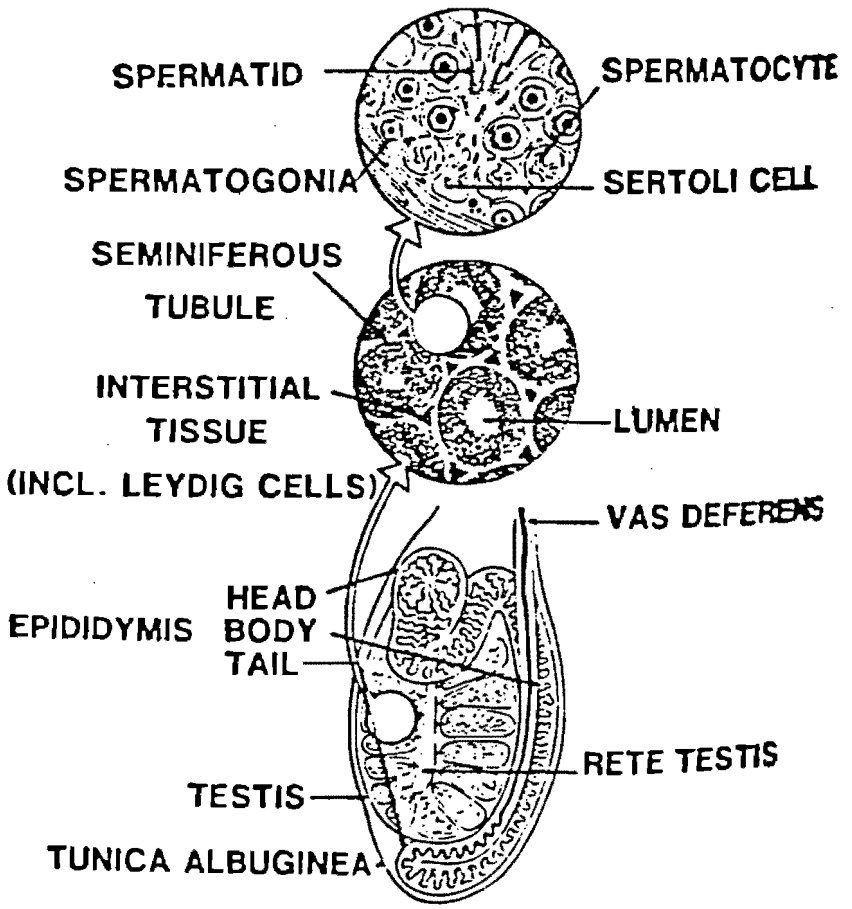

Fig. 1 Diagram of the anatomy of the ram testis shown at three levels of magnification[2].

The interstitial tissue consists of the Leydig cells which produce steroid hormones as well as vascular and connective tissue. In goats

and sheep the testes normally descend into the scrotum during fetal life or shortly after birth. This means that the testes and the epididymis are 4 to 7° C cooler than if they had remained within the abdominal cavity. Cryptorchids (naturally occurring or artificially produced) are infertile although hormonal function is close to normal. It is not known whether this dependence on temperature is a consequence or a cause of testicular descent.

The testes have several mechanisms which help to keep them cool: the dartos muscle (which moves them closer to or further from the abdominal cavity), sweat glands and the pampiniform plexus (Fig. 2). Sweat glands, even in species like goats and sheep which do not rely on sweating to keep cool, function very efficiently in the scrotum. Early work has shown that the sweating rate in Merino sheep rose from 0.8 g per scrotum per hour at 27° C to 1.5 g at 41° C[3].

The coiled testicular artery is surrounded by the pampiniform plexus which consists of many very small veins arising from veins coming out of the testis. These small veins join to form a single vein near the inguinal canal. This complex vascular system results in the arterial blood being pre-cooled before reaching the temperature-sensitive testes, while the venous blood is heated to body temperature before it reaches the abdomen.

2. *Spermatogenesis*

The testes produce spermatozoa or sperm by a process named spermatogenesis, with the first sperm being produced at puberty. The process is then continuous throughout life.

Spermatogenic cells are arranged in rows between the Sertoli cells, beginning with the most primitive spermatogonia, which lie as a single layer beneath the basement membrane. As they divide and develop, their descendants move progressively closer to the lumen. In the second stage, the primary spermatocytes divide by meiotic (reduction) division to form secondary spermatocytes, then spermatids and finally spermatozoa, which have a flagellum (tail), but are immotile until after maturation in the epididymis. The spermatozoa pass from the *rete testis* through 15 to 20 efferent tubules or ducts into the

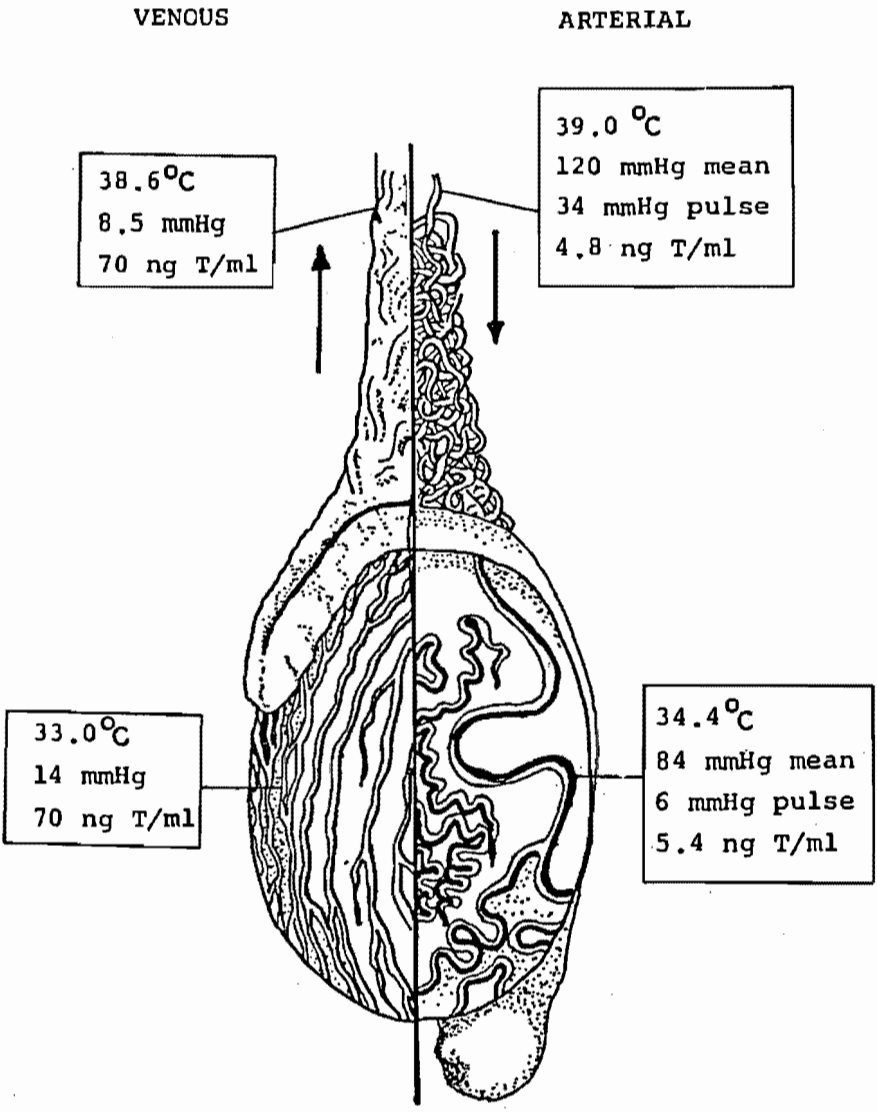

Fig. 2 The temperature, mean blood pressure and concentration of testosterone (T) in nanograms/ml in blood vessels leading towards and away from the testis of a ram; [in millimetres mercury (mmHg)][4].

epididymis. The epididymis is a long, convoluted tube where the sperm become motile and begin to acquire the ability to fertilize an ovum.

On ejaculation, the motile sperm move from the tail of the epididymis through the *vas deferens* (or *ductus deferens*) and out of the penis.

The penis has a rich blood and nerve supply, the nerves being both from the autonomic and the somatic nervous systems. Erection of the penis occurs as a result of the distention of the cavernous spaces with blood.

The seminal vesicles, the prostate and the bulbo-urethral or Cowper's glands provide fluid to dilute the concentrated spermatozoa after they emerge from the tail of the epididymis. An excellent review on spermatogenesis is provided by Setchell[4].

3. *Neurohumoral Controls*

Fig. 3 shows the control systems governing reproduction. Table 1 shows the main hormones governing reproduction, as well as the main sites of production, the chemical class to which each belongs and a simple summary of their principal functions[5]. Fig. 4 shows the main hormones governing reproduction in the male and their interactions. It can be seen that the main hormones necessary for spermatogenesis are follicle stimulating hormone (FSH), luteinizing hormone (LH) and testosterone, with inhibin also being important. Not all the actions and interactions of these hormones are completely understood. However, it is known that FSH and LH act on spermatogonia within the seminiferous tubules causing spermatogenesis. FSH stimulates inhibin production by Sertoli cells, but has less effect on the production of testosterone and other androgens. LH, on the other hand, stimulates the production of the sex steroids. Testosterone acts in a negative feedback at both the hypothalamic and the pituitary levels, while inhibin is believed to act (in a negative feedback) on FSH alone.

The role of prolactin in male reproduction is not certain, but receptors for prolactin are found in Leydig cells. Furthermore, in our own species, men with increased prolactin secretion due to pituitary tumours have diminished *libido*, inability to attain and maintain erections and lowered testosterone levels.

The hypothalamic hormone, GnRH (gonadotrophin releasing hormone), which causes the release of both FSH and LH is a peptide GnRH was characterized structurally and synthesized artificially by two Nobel Prize winners - Roger Guillemin and Andrew Schally. PIH may be dopamine[6]. The pituitary hormones are glycoproteins with the common α chain whereas their β subunits differ. They have not been chemically synthesized. Inhibin has been recently characterized and cloned. Testosterone and other androgenic hormones (as well as oestrogenic hormones and progesterone) are steroids and can be artificially synthesized. The importance of chemical structures will become obvious later when discussing hormonal manipulations for increased reproductive efficiency. Thus the structure of those hormones with simpler structures (eg. releasing hormones and steroids) has been determined and it has been easy to synthesize them as well as to develop analogues which can be tailored to be cheaper, more specific and more powerful than the naturally occurring hormones. These analogues can then be used to manipulate reproductive processes.

An excellent text by Austin and Short[5] reviews in detail neurohumoral controls of various aspects of reproduction.

II. THE FEMALE

1. *Anatomy*

Fig. 5 shows the anatomy of the reproductive tract of the reproductive tract of the ewe. It contains two ovaries, two Fallopian (or uterine) tubes, a cervix, a vagina and a vulva. That of a doe is similar. It also shows diagrammatically the position of the embryo at different stages of its development.

2. *Oogenesis*

Ovaries like testes are both cytogenic and endocrine organs. The story of formation, growth and maturation of the female gamete is called oogenesis and it is the equivalent of spermatogenesis in the male. As in the male, at puberty, the first ovum (or ova) is (or are) produced at ovulation. Oogenesis differs from spermatogenesis because formation of female germ cells ceases at around birth and also because ovarian

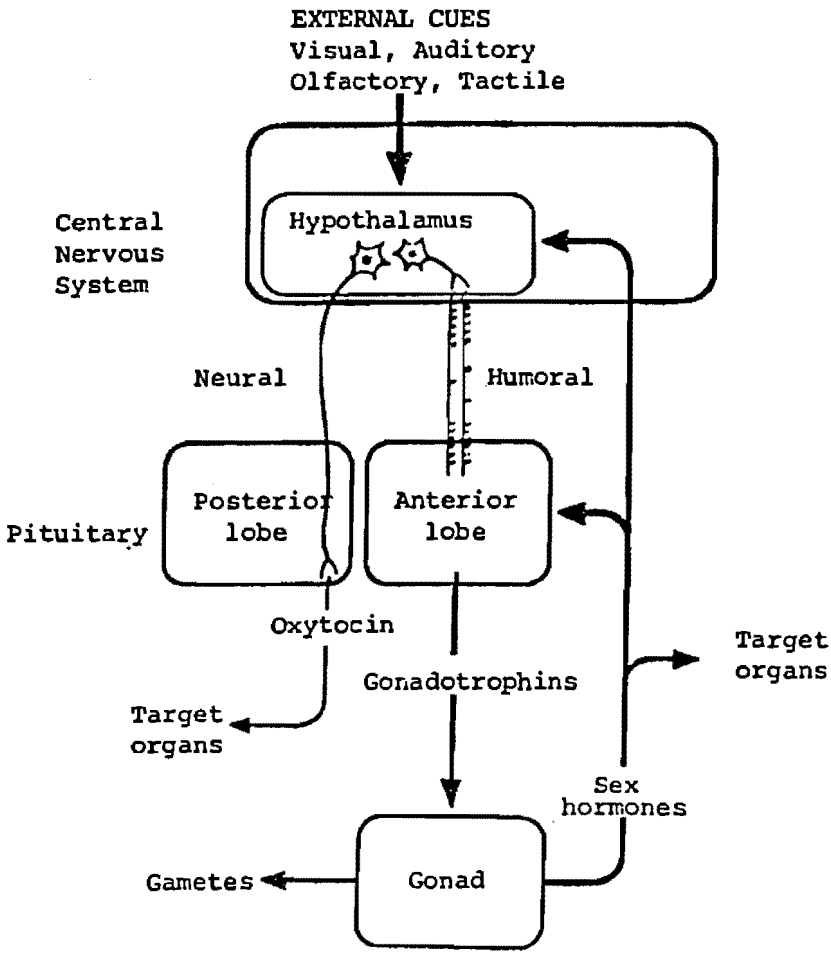

Fig. 3 Organization of control systems governing reproduction[6].

events are cyclical, not continuous. Furthermore, only a small fraction of ova is ovulated in a lifetime compared with the production of spermatozoa. For example, in a woman, only about 300 to 500 ova ovulate out of about seven million follicles present at about the time of birth. As in spermatogenesis, meiosis (or a reduction division) has to

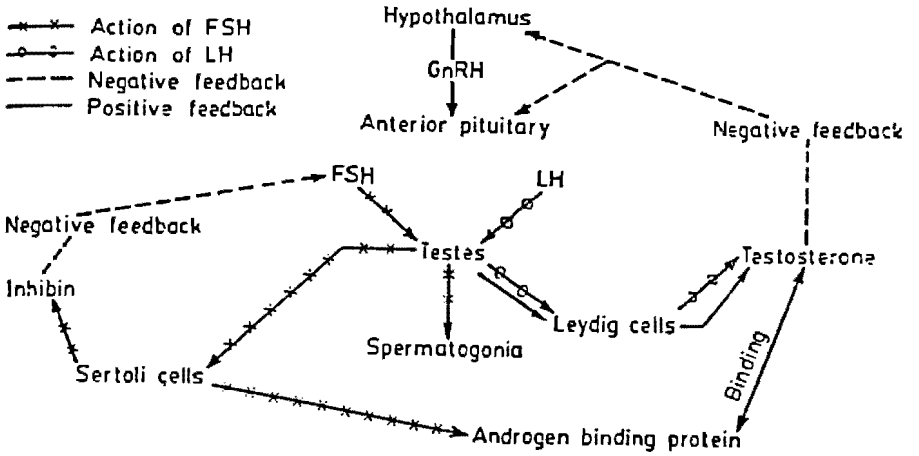

Fig. 4 Interrelationships of the main hormones regulating reproduction in the male, GnRH-gonadotrophin releasing hormone; FSH - follicle stimulating hormone; LH-luteinizing hormone.

take place, so that after fertilization the embryo contains 2n chromosomes.

Figs. 6 and 7 show stages of follicular growth and development. Waves of follicular growth and development occur with one (or more) ovum (ova) developing to ovulation while the rest become atretic and die. Follicles are vehicles for ova and as they grow, they produce several hormones including oestrogens and some androgens. After ovulation, a *corpus luteum* (CL) is formed from the remains of the follicle, which produces mainly progesterone.

3. *Neurohumoral Controls*

Figs. 8 and 9 show the interrelationships of the nerves and hormones governing reproduction in the female. Fig. 10 shows the sequence of events leading up to ovulation in the ewe. It is similar in the doe although the cycle is longer. It is obvious that both the ovarian and uterine events as well as their neurohumoral controls, are cyclical. As in the male, GnRH causes the release of both FSH and

Table 1. Main hormones that regulate reproduction.

Site of production	Hormone	Chemical class	Principal functions
Hypothalamus	Gonadotrophin releasing hormone (GnRH)	Peptide	FSH and LH release
	Prolactin inhibiting hormone (PIH)	Amino-acid derivative	Prolactin retention
	Corticotrophin releasing hormone (CRH or ACTHRH)	Peptide	ACTH release
Anterior Pituitary	Follicle stimulating hormone (FSH)	Protein	(1) Follicle growth (2) Oestrogen production and release (3) Spermatogenesis
	Luteinizing hormone (LH)	Protein	(1) Ovulation (2) *Corpus luteum* (CL) formation and function
	Prolactin (PRL)	Protein	Milk synthesis
	Adrenocorticotrophic hormone (ACTH)	Protein	Release of glucocorticoids from adrenal cortex
Posterior Pituitary	Oxytocin	Peptide	(1) Parturition (2) Milk ejection
Ovary (follicles)	Oestrogens (oestradiol)	Steroid	(1) Mating behaviour (2) Secondary sex characteristics (3) Maintenance of female mammary duct system (4) Mammary growth
CL	Progestins (progesterone)	Steroid	(1) Maintenance of pregnancy (2) Mammary growth
	Relaxin	Polypeptide	(1) Expansion of pelvis (2) Dilation of cervix
	Inhibin	Protein	Inhibits release of FSH
Testis	Androgens (testosterone)	Steroid	(1) Male mating behaviour (2) Spermatocytogenesis (3) Maintenance of male duct system (4) Function of accessory glands
	Inhibin	Protein	Inhibits release of FSH
Adrenal Cortex	Glucocorticoids (cortisol)	Steroid	(1) Parturition (2) Milk synthesis
Placenta	Human chorionic gonadotrophin (HCG)	Protein	LH-like
	Pregnant mare serum gonadotrophin (PMSG)	Protein	(1) FSH-like and partly LH-like (2) Supplementary CL in mare (3) Maternal recognition of pregnancy in mare
	Other gonadotrophins	Protein	Maternal recognition of pregnancy in various species
	Oestrogens	Steroid	Maternal recognition of pregnancy in pig
	Progestins	Steroid	Maintenance of pregnancy
	Relaxin	Polypeptide	Expansion of pelvis
Uterus	Prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$)	Fatty acid	(1) Regression of CL (2) Parturition
Conceptus	Early pregnancy factor	Protein	(1) Maternal recognition of pregnancy
	Trophoblastin	Protein	(2) Maintenance of CL

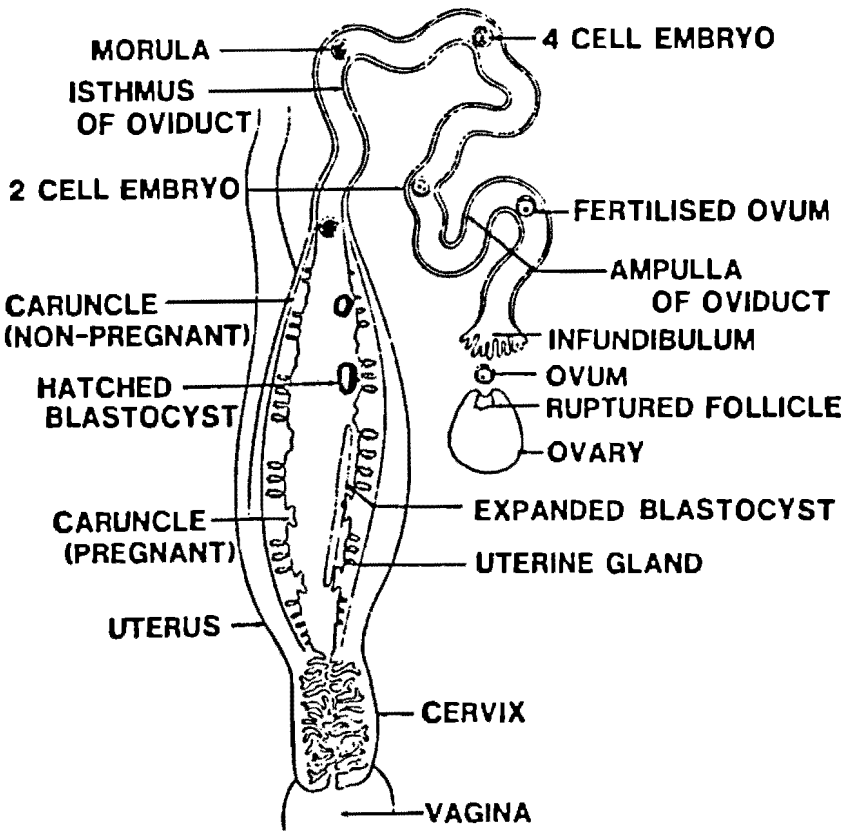

Fig. 5 Diagrammatic representation of a longitudinal section through the reproductive tract of the ewe showing the position of the embryo at various stages[2].

LH. FSH causes the growth of follicles. As follicles grow they produce oestrogens (and some androgens) plus inhibin. Oestrogen can act both in a negative and in a positive feedback. In large amounts and in the absence of progesterone, a surge produces a positive feedback, which triggers LH (and FSH) release and ovulation. In small amounts or in the presence of progesterone, it acts in a negative feedback at the pituitary and the hypothalamic levels. Inhibin

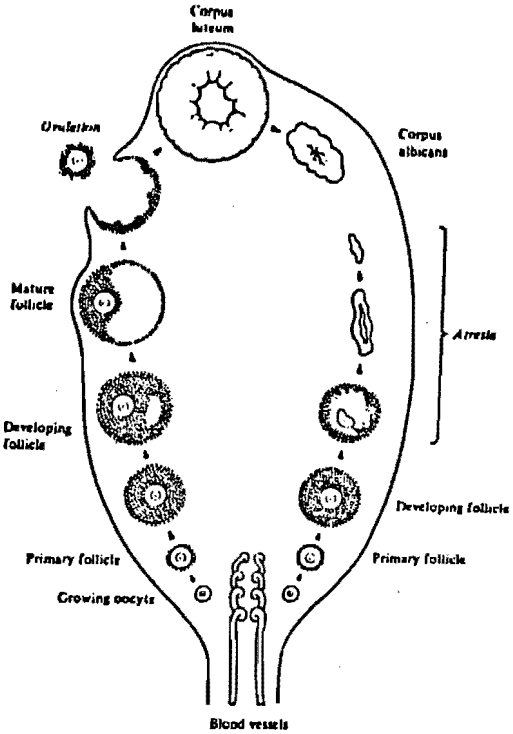

Fig. 6 Life-cycle of the female germ cell[7].

acts in a negative feedback to FSH alone. The CL persists for 12 days in the ewe (a bit longer in the doe) before being destroyed by prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) from the uterus. Another cycle then begins. If pregnancy ensues, the CL persists and another cycle does not occur.

4. *The Oestrous Cycle*

The ensuing more detailed description is for the ewe, but the picture is similar for the doe, although the cycle is longer, being 16 to 17 days in the ewe and 18 to 22 days in the doe. It is described in some detail, because manipulations of the cycle require knowledge of how it works[9].

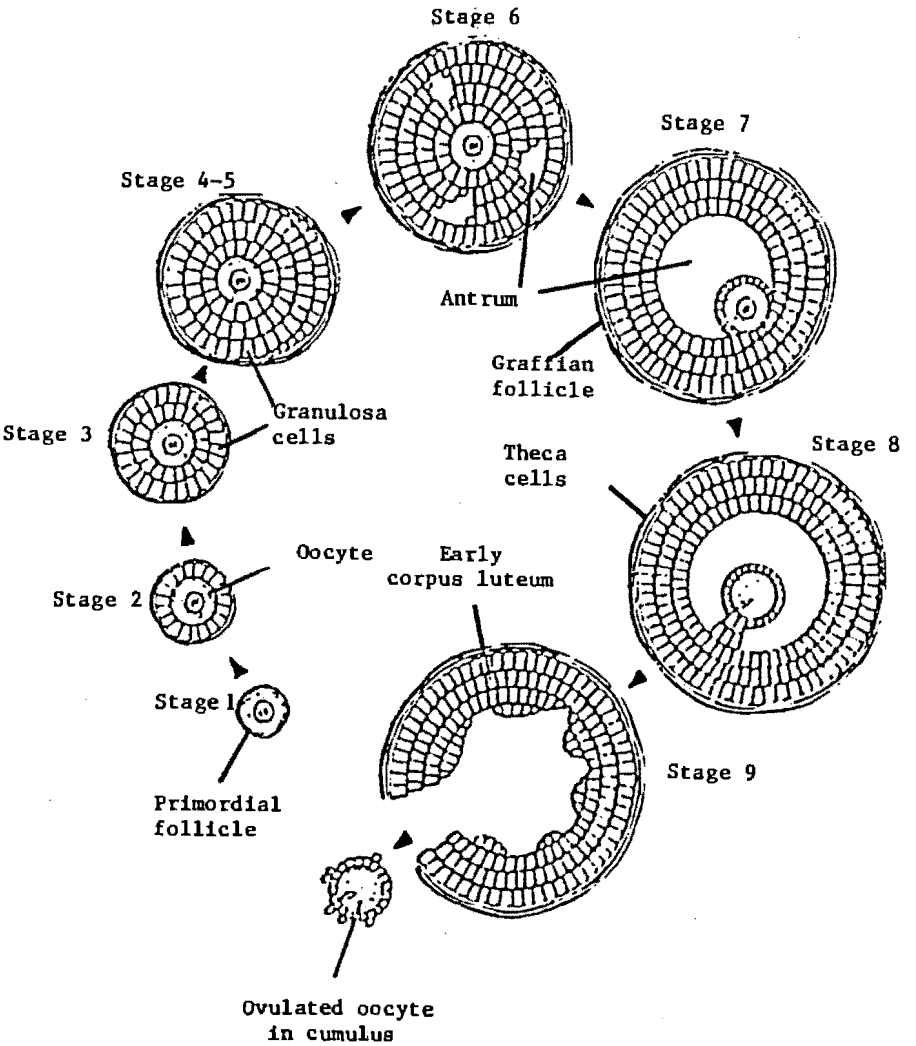

Fig. 7 Stages of follicular growth. In stage 1, the structure is called a primordial follicle, in stages 7 and 8, a Graafian follicle. Stage 9 represents the early CL with the ovulated oocyte[8].

Starting from day 15 of the cycle (see also Figs. 9 and 10), the sequence is as follows:

1) On day 15, the CL regresses abruptly. Luteolysis is due to the lytic action of $PGF_{2\alpha}$, formed in the endometrium after exposure to progesterone for 12 days.
2) Graafian follicles begin to grow as a result of falling progesterone and rising FSH levels. As they grow, they produce increasing levels of oestrogens and androgens which reach peak levels at about 24 hours. Both oestrogens and androgens may be responsible for the ewe's receptivity to a ram as well as her attractiveness to him.
3) FSH and LH surges from the anterior pituitary are triggered by the rising oestrogen levels after a time-lag of 12 hours. This positive feedback can only occur in the absence of progesterone. Note that this is a reason for the absence of ovulation during pregnancy when oestrogen levels are high, but so are progesterone levels.
4) These events lead to behavioural oestrus which actually occurs when oestrogen levels have already begun to fall.
5) Ovulation occurs 24 hours after the LH surge.
6) One CL (or more) form(s), start(s) to secrete significant amounts of progesterone by day 3 and continue(s) doing so for 12 days. During this luteal phase, the uterus prepares for the arrival of the embryo. If the conceptus does not arrive in the uterus, the uterus secretes $PGF_{2\alpha}$ which leads to luteolysis and the cycle begins again. If there is a conceptus, the CL persists and continues to secrete progesterone. In the doe, the process is essentially the same with the timing being slightly different.

5. *Transport of Sperm, Ova and Fertilized Eggs*

With fertilization taking place in the ampullae of the tubes, how do spermatozoa get there?

In goats and sheep, spermatozoa at mating are deposited into the vagina near the cervical os. They have to get out of the vagina quickly because the acidity of the vagina will kill them quickly - the pH of seminal plasma being 7.2 to 7.8. They are propelled into the cervix by vaginal contractions rather than by their own motility. However, in the cervix they swim through mucus which at about the time of ovulation is thin and watery (during the luteal phase it is thick and rubbery).

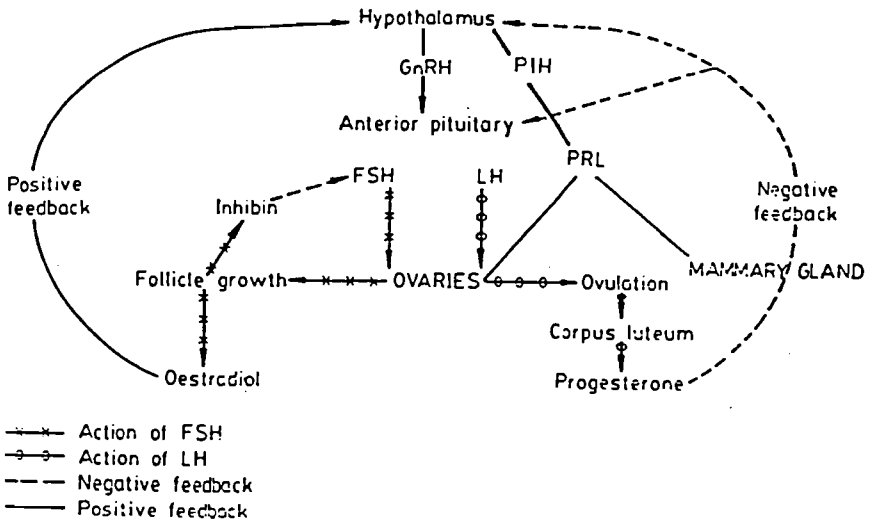

Fig. 8 Interrelationships of the main hormones regulating reproduction in the female; PIH-prolactin inhibiting hormone; PRL-prolactin. LH - luteinizing hormone, FSH - follicle stimulating hormone, GnRH - gonadotrophin releasing hormone.

They are transported rapidly through the uterus by strong uterine contractions until they reach the utero-tubal junction, which may act as a valve, open at the time of ovulation. Motility probably plays a role in negotiating this junction. Motility is also important in the tubes where the sperm are active with lashing tails which increases a sperm's chances of colliding with the egg and also helps it to penetrate through the *cumulus* and *corona* cells surrounding the egg[11].

The sperm acquire motility in the epididymis, but they need to undergo other maturational changes in the female tract known as capacitation and the acrosome reaction. These involve modification or removal of some protein components in the head at the surface which enables them to penetrate an egg.

The ovum gets from the ovary to the Fallopian tube partly due to the help of cilia lining the tube and partly due to fluid in the tube which

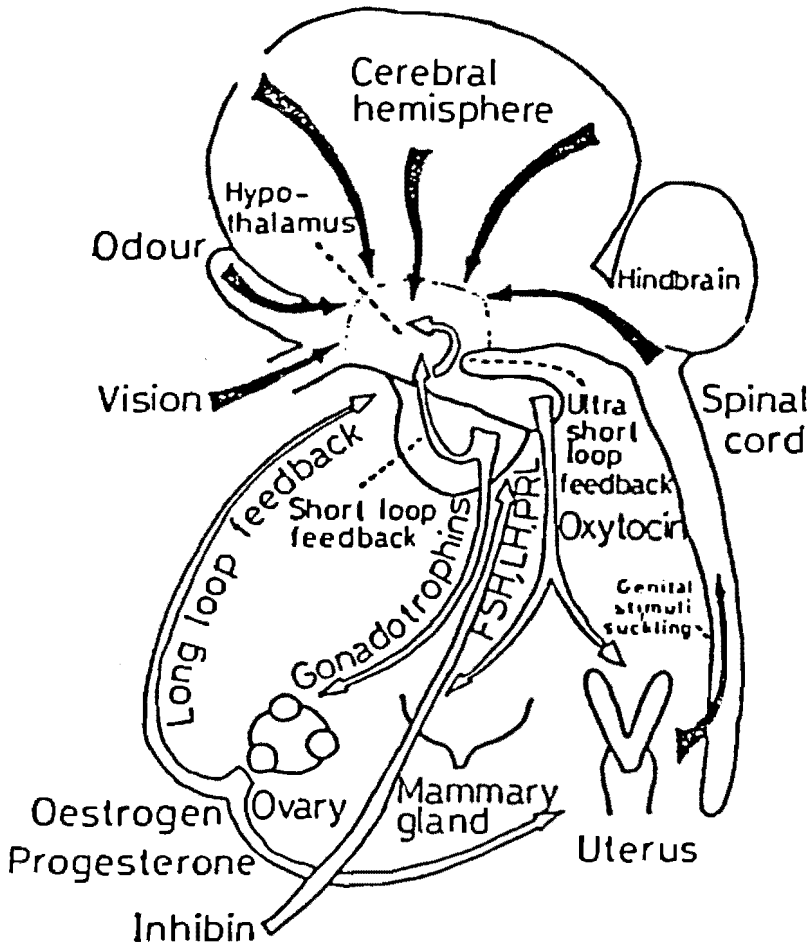

Fig. 9 **This shows the nervous inputs (dark arrows) and hormonal influences (pale arrows) impinging on thehypothalamus. The main target organs of the reproductive hormones from the pituitary, ovary, mammary gland and uterus are also shown. Note the three postulated hormonal feed backs - long loop (from ovary), short loop (from anterior pituitary) and ultra-short loop (from hypothalamus itself); (adapted from[10]).**

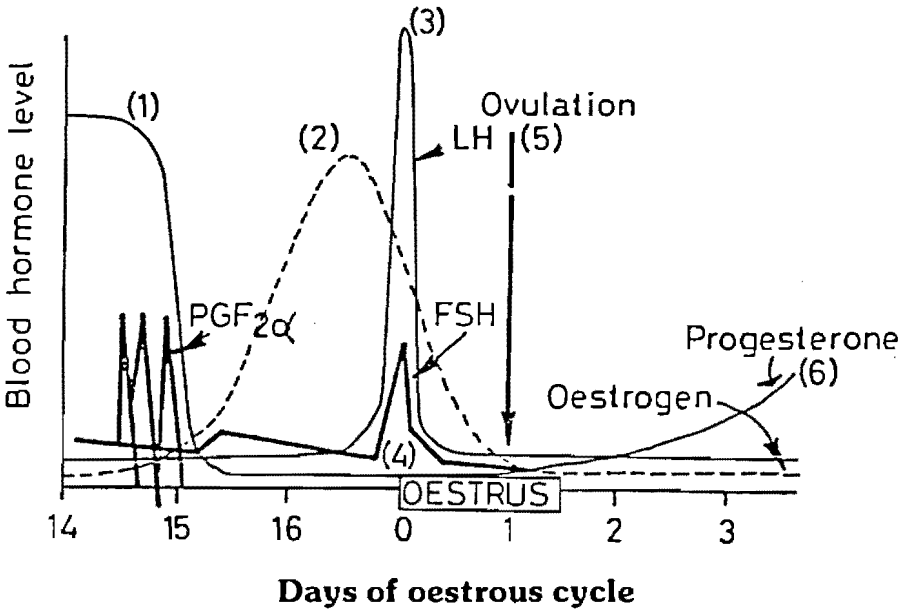

Fig. 10 Sequence of hormone changes leading up to oestrus and ovulation; (see text).

carries the egg towards the site of fertilization. After fertilization, the dividing zygote is taken to the uterus by tubal fluid flowing in the opposite direction.

The process of sperm and ovum transport has to be precisely timed because spermatozoa have a life of a day or two, while ova live for only about a day after ovulation. Note that the ovum remains fertilizable for longer than it is capable of developing into normal offspring. It is essential to the survival of a normal embryo that one ovum is fertilized by one sperm only. It is the egg which defends itself to block the entry of all sperm (except the one fertilizing spermatozoon) by physiological barriers which 'harden' the *zona pellucida* after the first sperm has entered. This defence may fail with an aged ovum and the most common abnormality is polyspermy, the fertilization of an ovum by more than one sperm. In natural mating, the sperm and ova do meet at the right time because does and ewes show sexual

receptivity (oestrus) only close to ovulation. So, normally the process of fertilization is remarkably efficient being of the order of 85 to 90 percent. There can be a problem, however, with artificial insemination (AI), if oestrus detection is not accurate and insemination is not carried out at the correct time.

Note also that the arrival of the dividing fertilized egg in the uterus also has to be precisely timed, because the uterus is inhospitable to the embryo except at the 'right' time. Thus, even as little as 12 hours' asynchrony will greatly decrease embryo survival because the uterine environment changes rapidly under the influence of hormones, especially progesterone.

6. *The Embryonic Period and Implantation*

The fertilized egg takes three to four days to travel from the ampullary region of the tube to the uterus, dividing as it travels into two, four, eight, sixteen etc cells. From a ball of cells, the *morula*, it becomes a hollow mass, the blastocyst. It sheds the *zona pellucida* seven to eight days after fertilization and hatches. Up till then the embryo is relatively independent of the mother, living on uterine secretions. As it grows bigger it needs a more efficient food supply and implantation takes place[12,13]. Implantation begins in goats and sheep at about day 15 and is complete by about day 35. This process is shown in a simplified form in Fig. 5. Note that the pre-implantation period is the most dangerous one for the embryo. It is also most sensitive at that time to external deleterious agents, which will cause embryonic abnormalities or abortion.

In goats and sheep, the embryo does not implant by burrowing into maternal tissues as it does in our own species. The attachment in all ruminants is through a number of discrete, button-like placentomes (about 100), which form during the period of attachment. These form from the fusion of the embryo's outer membrane with the specialized areas of the uterus called caruncles or cotyledons. The placenta of ruminants is classified as cotyledonary or epitheliochorial.

The embryonic and maternal circulations come into close contact so that the exchange of nutrients from the mother to the fetus and that of elimination of waste products in the opposite direction can take place. The placenta also produces hormones and growth factors necessary for the well-being of the developing embryo-fetus.

7. *Maternal Recognition of Pregnancy*

The question of how a female animal realizes that it is pregnant is an intriguing one. Why does the mother not reject an immunologically foreign allograft? How is luteolysis prevented as well as oestrous cycles?

The mechanisms are interestingly different in different species and only those of the goat and the sheep will be discussed.

As to the rejection problem, it is true that the embryo is genetically and immunologically distinct from the mother. So, to survive it must establish an immunological truce with her. Note that the pregnant uterus will promptly reject foreign tissue but not the intact embryo.

It has been suggested by recent work that a very early embryo (within a few hours after fertilization) produces an immunosuppressive factor, called the Early Pregnancy Factor which protects it from the maternal immune system. The presence of this factor is due to a living embryo, being due neither to ovulation nor to the presence of spermatozoa in the uterus.

The mechanisms for preventing luteolysis are different in different species, but in the doe and the ewe it is believed that its prevention is by the trophoblast secreting a protein, trophoblastin which prevents the action of $PGF_{2\alpha}$ and extends the life of the CL beyond one cycle.

8. *Maintenance of Pregnancy*

Progesterone is the major hormone of pregnancy. Sheep and goats are closely related phylogenetically and have morphologically similar forms of placentation. However they differ as far as the importance of luteal progesterone secretion in the maintenance of pregnancy. In the ewe the placenta takes over progesterone production as well as producing a luteotrophic hormone. Hence, pregnancy will continue in the ewe following ovariectomy and hypophysectomy in the second half of pregnancy. In goats, both the ovaries and the pituitary are necessary during the whole pregnancy and a doe will abort promptly following the removal of either[14].

9. *Developments During Pregnancy*

We can divide pregnancy conveniently into three periods, although of course it is not so strictly defined physiologically. During the first period, cell differentiation and organ formation take place and the embryo is extremely sensitive to deleterious agents (eg. viruses or drugs). In the middle period of growth and differentiation of cellular function in organs, the embryo is relatively insensitive to deleterious agents and also to nutrition because it is still small. In the third and final period, it grows rapidly and the rate of growth is dependent on the nutritional status of the mother. Thus, overnutrition during the last period can produce a too large fetus with attendant dystokia problems through being too large to squeeze through the birth canal. On the other hand, undernutrition during this period will produce a too small neonate, weak and without adequate body reserves with subsequent problems of survival. Note that the size of the kid or lamb at birth depends on the level of nutrition during the last part of pregnancy much more than that of the child or calf. This is probably because it takes, for example, a 55 kg woman nine months to produce a 3 kg baby and a 25 kg ewe only five months to produce a 2.5 kg lamb.

10. *Initiation of Parturition*

The ewe has been used extensively for studies of factors responsible for initiation of parturition and the model developed by the great G.C. Liggins is based on his elegant work with sheep. Fig. 11 shows how the lamb controls the onset of labour as well as the experimental procedures that lengthen or shorten pregnancy[15].

Briefly, at about the time when birth is due, the fetal hypothalamus produces the releasing hormone for adreno-corticotrophic hormone (ACTH). This results in a surge of fetal ACTH and cortisol which causes the maternal release of $PGF_{2\alpha}$, an increase in oestrogen production as well as a drop in progesterone.

$PGF_{2\alpha}$ causes myometrial contractions in the uterus, which are continued by massive subsequent releases of oxytocin. Both those hormones maintain contractions. In addition $PGF_{2\alpha}$ and relaxin may be involved in cervical softening which is necessary so that the fetus can squeeze through the birth canal.

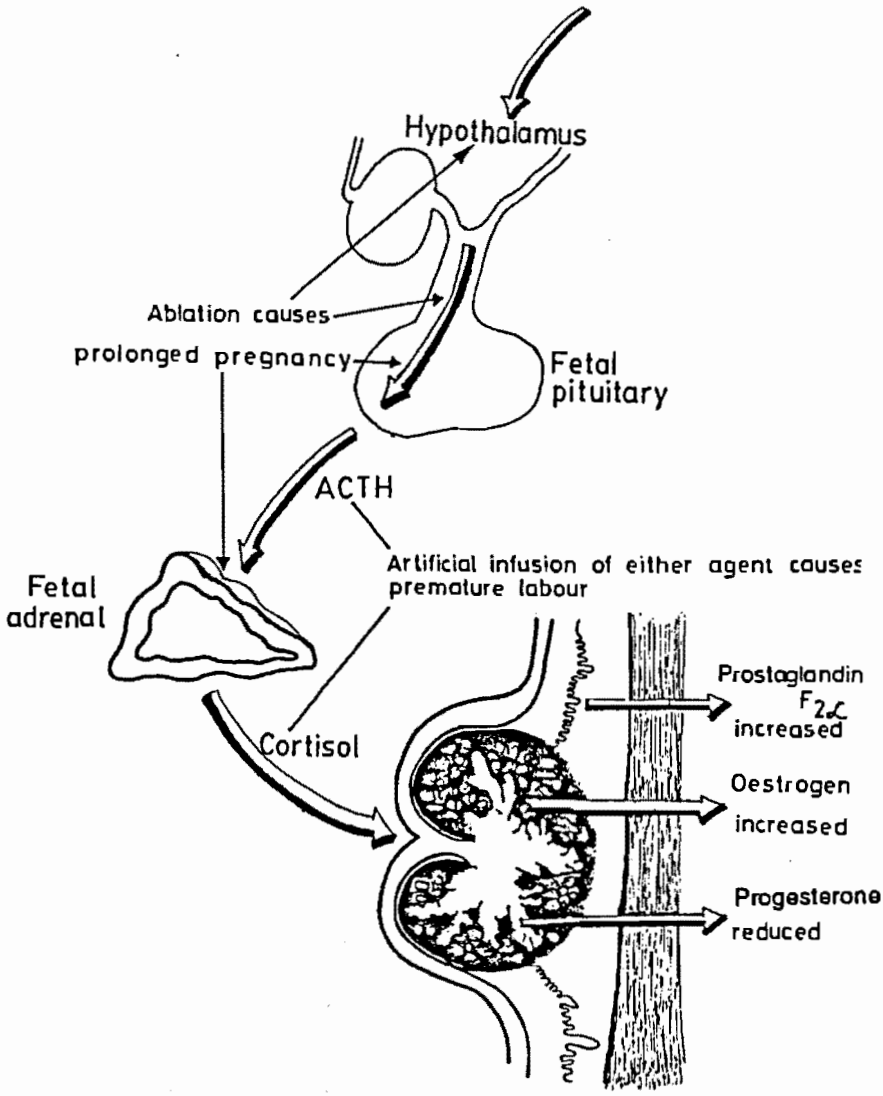

Fig. 11 Diagrammatic summary explaining how the fetal lamb controls the onset of labour. Experimental procedures that lengthen or shorten pregnancy are shown[15].

The picture is similar in the goat except that $PGF_{2\alpha}$ leads to luteolysis or destruction of the CL. This is because a functional CL is necessary in this species throughout pregnancy.

This explanation is given because the work of Liggins and later on of other groups has led, not only to better management of human labour and care of the premature infant, but also to manipulations of the time of parturition in farm animals. This aspect is covered in Section C which describes ways of increasing animal production by newer technology and techniques.

11. *Lactation*

Mammals derive their name from their possession of mammary glands, which form part of their reproductive apparatus with lactation being the final phase of reproduction. A good review on lactation is given by Cowie[16].

The doe and the ewe have paired mammary glands in the inguinal region. A gland consists of secretory tissue, the parenchyma surrounded by the supporting tissue or stroma. The cells which secrete milk are epithelial in origin, occur in clusters and are called alveoli. Each alveolus opens into a small duct. These ducts then open into increasingly bigger and bigger ducts which eventually open to the outside. Fig.12 shows this for the goat and it is similar for the sheep. Fig.13 shows the arrangements in some other species. A great deal of work on lactation has been carried out using goats as experimental animals. Lactation consists of two different phases or components: 1) milk secretion and 2) milk removal and these are shown in Table 2.

Table 2. The phases and components of lactation[16].

Lactation

1. Milk secretion	2. Milk removal
a. Synthesis of milk constituents within alveolar cell	a. Passive removal of milk from cisterns and large ducts
b. Intracellular transport of constituents	b. Reflex ejection of milk from alveoli (milk let-down)
c. Discharge of constituents from cell into alveolar lumen	

a. Hormonal control of milk secretion

Milk secretion means formation of the protein, fat and carbohydrate components of milk. It begins in the last part of pregnancy with the onset of lactation being due to changes in the hormonal levels of the dam at about the time of parturition (see section 10. Initiation of Parturition). The secretion produced around birth is called *colostrum*, which differs in composition from the milk that follows a few days later. It contains antibodies which help the newborn animal to combat diseases in the period when its own immune system is not yet completely competent. This is why it is important that the neonate does get *colostrum* rather than ordinary milk after being born. It also contains higher levels of solids, which thus give the neonate concentrated energy to be able to survive after birth. Protein levels in particular are high, being about four times as high as the milk produced later[17].

The hormones necessary for initiation and maintenance of lactation differ between various species of mammals. The anterior pituitary is involved and following hypophysectomy, milk secretion ceases. In goats and sheep prolactin, ACTH and thyroxine stimulating hormone (TSH) are essential to initiate lactation, but once it is established, prolactin is not necessary. Growth hormone (GH) is essential for maintenance of lactation in ruminants with high producing animals having higher levels of GH, but not differing in prolactin levels.

Milk secretion does not depend upon secretory nerves. This was shown when mammary glands of goats were transplanted to the neck where they continued to secrete high levels of milk after severance of all nerves to and from the mammary gland.

b. Suckling and milk removal

Fig. 14 shows how suckling results in neural impulses passing up the spinal cord to the hypothalamus which causes the release of oxytocin from the posterior pituitary. This causes milk let-down so that milk can be obtained by the suckling animal or with a milking machine. Suckling also results in a rapid reflex release of prolactin and probably GH.

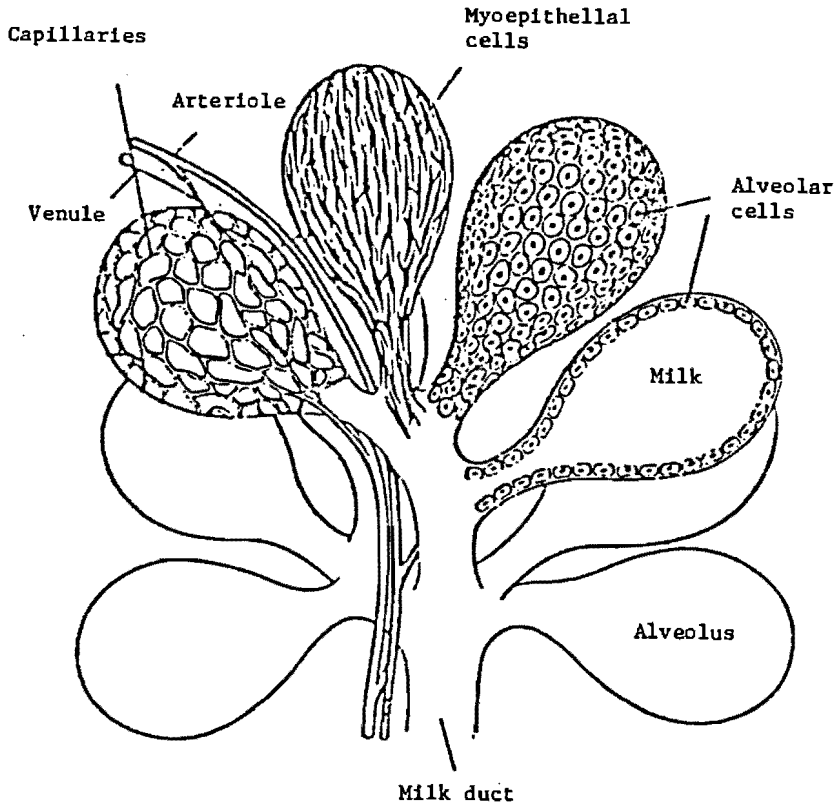

Fig. 12 A cluster of alveoli in the mammary gland of a goat[16].

The second requisite for the continuation of lactation is, of course, milk removal. The more frequent the suckling or milking, the greater the milk production. This is probably due to increased oxytocin, prolactin and GH release. It is unlikely to be due to stopping of milk synthesis through too long an interval between milkings. This could happen if milk filled all ducts and alveoli. That this is true is suggested by results from high producing dairy cows where there was no difference in total milk production of cows milked every 12 hours and those milked alternately at 8 and 16 hour intervals. However, animals

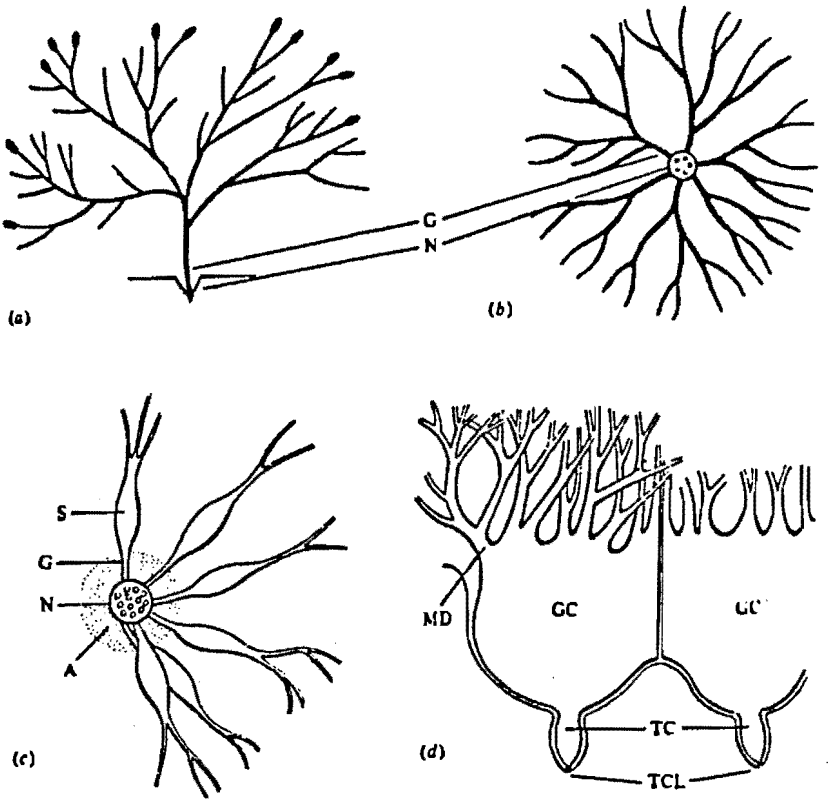

Fig. 13 Diagram showing four different arrangements of the mammary duct system. (a) Rat: ducts all unite to form one main duct or galactophore (G) which opens at the tip of a nipple. (b) Rabbit: ducts unite to form several main ducts. (c) Woman: each main duct is dilated near the base of the teat to form a sinus. (S); the nipple is surrounded by the dark-coloured areola (A). (d) Ruminant: the main ducts (MD) open into a single large gland cistern (GC) which in turn opens into the teat cistern (TC); TCL, teat canal[16].

milked three times a day produce more milk than those milked twice, showing the importance of each suckling/milking stimulus.

c. Post-partum/lactation anoestrus

Following parturition there is a period of *post-partum*/lactation anoestrus when the female does not ovulate and does not become pregnant. There is evidence that this period is shorter in Indonesian goats and sheep than in European breeds (see part B of this Chapter).

III. PUBERTY

The Oxford dictionary definition of puberty as 'the stage or condition of having become functionally capable of procreating offspring' is a useful one.

Puberty and sexual maturity are sometimes confused. Sexual maturity, which is the time when an animal reaches its full reproductive potential is reached at a later age, so that usually young goats and sheep have lower reproductive performance. In fact, puberty requires a sequence of steps and often these are not synchronized at the same point in time. For example, in females even when synchronization is reached in one cycle, this may not happen in each subsequent cycle during the peri-pubertal period. This lack of synchrony is at least partly the reason why fertility and fecundity are lower at this time. This is discussed for Indonesian goats and sheep in section B. Early puberty is advantageous because: 1) it reduces the non-productive and non-profitable time in an animal's life and 2) it enables faster genetic gains to be made through decreasing the generation interval where accurate selection is practised and where selection programs are effective.

1. *Mechanisms Controlling Onset of Puberty*

In an intact animal before puberty, the animal's own pituitary produces very small amounts of gonadotrophins. Yet, if exogenous pituitary hormones are administered before puberty, gonads will develop. It used to be thought that after birth, the hypothalamus and the pituitary were extremely sensitive to the inhibitory effects of gonadal steroids. It was thought that puberty was due to a gradual loss of these sensitivities to the inhibitory effect of steroids. Thus, gradually increasing amounts of hypothalamic and pituitary hormones were produced with consequently increasing amounts of gonadal steroids, so, it was all a matter of resetting a 'gonadostat' in the brain.

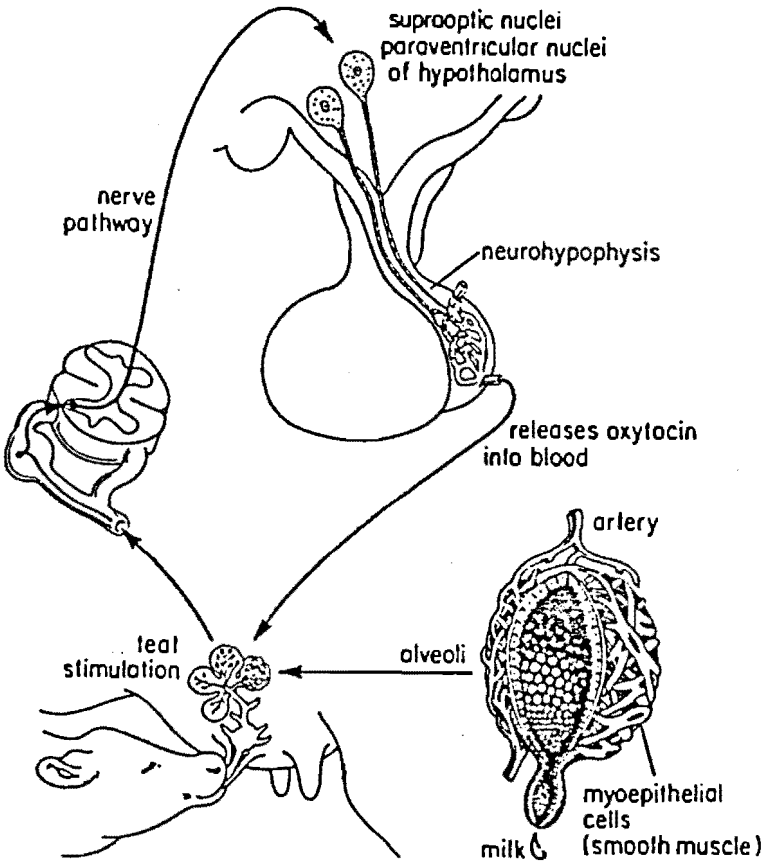

Fig. 14 **Diagram to indicate relationships between mammary gland and the brain. The act of suckling triggers off nerve impulses which pass from the teat or nipple to the spinal cord and thence to the brain. Impulses pass through the hypothalamus (i) to the posterior pituitary causing the release of oxytocin into the blood which, when it reaches the mammary gland, induces contraction of the myoepithelial cells and milk ejection; (ii) to the hypothalamic regions controlling the anterior pituitary and so leading to the release of anterior pituitary hormones, including prolactin, necessary for milk secretion[16].**

However, it has been found in ewes and rhesus monkeys that if you castrate them before puberty (thus removing all gonadal hormones) there is no post-castration rise in hypothalamic hormones. Therefore, in the intact pre-pubertal animal, it cannot be the minute amounts of steroids that stop the gonadotrophins from rising.

It is now believed that there is a GnRH inhibition, independent of steroids, which holds gonadotrophin production back at the time. As puberty approaches, there is an increasing frequency of GnRH discharge pulses and consequently, the testes or ovaries become increasingly stimulated. This has been supported by work with rhesus monkeys[18]. When prepubertal animals were given frequent pulsatile infusions of GnRH, ovulatory cycles began. When the infusions were stopped, the monkeys reverted to a pre-pubertal state. What is not yet known is what factors influence the hypothalamus to increase GnRH pulsatility at puberty.

2. *Factors Affecting Timing of Puberty*

The timing of puberty depends on age x weight x (perhaps) body composition x season (in temperate zones) x genetic interactions. Seasons are not a factor in tropical breeds and will not be discussed further. Effects of age and nutrition on the age of onset of puberty in Indonesian goats and sheep are discussed in Section B.

3. *Social Effects*

a. Rearing

Isolation from the mother and other conspecifics markedly decreased the reproductive performance of monkeys[19] and boars[20].

The evidence for the necessity of social contact within and between sexes during early life for efficient later reproductive behaviour is not as strong for goats and sheep. Moreover, goats and sheep kept in barns in Indonesia are seldom isolated and have contact with conspecifics often of both sexes.

b. Short-term deprivation

Isolation of prepubertal females from the male followed by his introduction will hasten and synchronize puberty in gilts[21,22] and lambs[23] as well.

However, under smallholder conditions in Indonesia the females are seldom totally isolated from the male for the period of about a month considered by most researchers to be necessary, before the introduction of a male will advance and synchronize puberty as well as synchronize the oestrous cycles of adult females. Of interest in Indonesia is a recent report which shows that isolation was not necessary to ensure an ovulatory response to subsequent ram contact, when new rams were introduced to a group of ewes previously run with other rams[24]. So, there may be scope for using 'buck' and 'ram' effects in Indonesia.

In temperate zones, the introduction of the male advances the transition from anoestrus to breeding season and synchronizes it. Of course in the tropics there is no seasonal anaestrus and goats and sheep breed continuously.

B. PRESENT STATUS OF REPRODUCTIVE PERFORMANCE IN INDONESIA AS WELL AS REPRODUCTIVE WASTAGE AND WAYS OF IMPROVING EFFICIENCY

Goat and sheep production in Indonesia is traditionally managed as a secondary enterprise on a farm. The number of animals raised per farm is relatively small (two to ten head). In Java, the average goat and sheep ownership is 6.3 and 6.0 head per farm, respectively[25] and in North Sumatra the figures are 5.0 and 4.7 head per farm respectively[26]. Each farm usually breeds its own animals and therefore about 40 percent of animals in a flock consist of mature does/ewes, followed by young, both weaned and suckling.

The majority of goats and sheep in Indonesia are concentrated in the most densely populated island of Java. In this island, grazing is very limited and the animals are usually kept under total confinement in cut-and-carry systems. With this kind of management system, the level of productivity of the animals is largely determined by the farmer, particularly because it is the individual farmer as well as the area he/she lives in that determines the quantity and quality of feed given to the animals. It is not surprising that there is a wide variation in reproductive efficiency among farms with apparently similar resources.

This variation is largely attributable to variability in intensity and efficiency of the management systems, particularly in management during growth, mating, the perinatal period and during lactation. A survey in several villages in West Java showed that there was an average of 14 rams per 100 ewes available, a much higher proportion than commonly found in western countries[27]. However, the rams were not well distributed among farms. Since a small number of ewes is reared in an individual farm, keeping a ram on every farm is not efficient as, especially on these small farms, it increases significantly feeding costs. But if the farmer does not own a male, he/she must rely on his/her ability to detect oestrus and arrange to obtain a male for mating at oestrus. It is certainly easier to detect oestrus if the rams are within sight, smell and sound of ewes. Moreover, a lack of understanding of reproductive physiology and behaviour, as well as time constraints for mating management due to other work carried out by the farmer, make the presence of a ram on every farm desirable. Alternatively, collective ownership of a ram by a group of neighbouring farmers may be an option to increase the efficiency of utilization of males for breeding. These comments on sheep apply also to goats. The problems with not having a male on each farm are discussed in the section on *interpartum* intervals.

I. PUBERTY

1. *Gradual Onset*

Table 3 shows the gradual onset of puberty in Javanese Thin-tail (JTT) ram and ewe lambs, as well as the effects of different planes of nutrition.

Sutama and his colleagues studied ovarian activity of lambs by laparoscopy and by measuring progesterone profiles of JTT ewe lambs from 13 weeks of age until five weeks after conception[30,31]. During the pubertal period they found that in a high proportion (67.5 percent) of ewe lambs, ovulation occurred without oestrus, while 12.5 percent showed oestrus without ovulation occurring. Furthermore, 39.5 percent of the CL formed were not fully functional and in some lambs, regular ovarian activity following the first ovulation was not maintained. The lengths of cycles, unlike those of older ewes, were also irregular (range 10 to 62 days). Peak progesterone levels in cycles

with silent ovulations were lower than in normal cycles in which oestrus and ovulation occurred simultaneously. This supports the hypothesis that a period of normal (high) progesterone levels is required to facilitate the subsequent rise in oestradiol levels necessary for ovulation accompanied by oestrus[32].

Table 3. Effects of high and low planes of nutrition on thedevelopment of puberty in Javanese Thin-tail sheep (growth=g/day; weight=kg; age=months)[28,29].

	Low (L)	High (H)
Male		
Growth (weaning to puberty)	59.5	102.4*
Age of mounting oestrous ewes	6.8	5.4*
Age of first sperm in ejaculate	7.6	6.3*
Age of full penis development	7.4	6.0*
Age of attaining mating capability	8.3	6.8*
Weight at attaining mating capability	15.3	20.3**
Females		
Growth (weaning to puberty)	46.4	79.9*
Age at first ovulation	8.5	6.3**
Age at first oestrus	9.4	7.1**
Age at simultaneous oestrus and ovulation	9.6	7.6*
Bodyweight at simultaneous oestrus and ovulation	16.7	17.7NS
Age at conception	10.3	7.4**
Ovulation rate at conception	1.36	1.85*

Differences between (L) and (H) * $P < 0.05$
** $P < 0.01$
NS non-significant

In addition, it has been found in temperate zones that many ewe lambs do not show the full range of courtship responses that adult ewes do (see Fig. 15)[33]. Mattner and his colleagues[34] found that a proportion of young Merino rams were not interested in mating, although they had normal semen. They coined the term 'non-workers' for those. Later, some, but not all became 'workers' and mated normally. Conversely, Kilgour and Winfield[35] noted that some young Romney rams were dexterous, mated frequently, but got few ewes pregnant. In the latter case, mating behaviour was ahead of the physiological development of sperm production. Similar detailed

behavioural and physiological studies have not been carried out in Indonesian goats and sheep, but it is likely that there is asynchrony not only in physiology, but also in behaviours necessary for successful mating and conception at around puberty. Thus, in the experiments of Sutama and his colleagues, while it took three cycles for all ewes to conceive during their first breeding season (only 55 percent conceiving to first service), all except two ewes conceived at their first *post-partum* oestrus. In one experiment Etawah-cross buck kids at puberty had a relatively low percentage of live sperm (60 percent) with low sperm volume (0.26 ml compared to about one ml for adult bucks)[36].

2. *Nutritional Factors*

Table 4 shows the ages and weights at puberty of various breeds of Indonesian goats and sheep. Note that when well-fed they reach puberty as early as the early maturing D'man sheep, which reach puberty at about seven months[37]. In some of these studies, unfortunately, information on planes of nutrition is incomplete. Generally, better nutrition advances puberty.

Thus, for example, when Sumatran Thin-tail ewe lambs grazing under rubber trees were fed at different levels of concentrate supplementation at 0, 0.6, 1.0 and 1.4 percent of bodyweight, this produced liveweight gains of 37, 48, 57 and 64 g/day, and puberty occurred at 10, 9, 8 and 7 months respectively in the different groups[38].

Sutama and his colleagues, (Table 3) found that ram lambs which were better-fed reached puberty earlier, but at a heavier bodyweight. In the ewe lambs, as expected, puberty was reached earlier in the high plane group, but the bodyweights at puberty were not significantly different between the two groups.

Although no details of growth rate are given for goats and sheep studied at a research station by Obst and his colleagues[39] they were fed *ad libitum* on pellets consisting of 50 percent elephant grass an 50 percent concentrate (Beef Kwik)* which constituted a very high plane of nutrition. They reached puberty early, earlier than the probably less well-fed village animals[40].

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* 15% Crude Protein (CP)

RATINGS	1	2	3	4	5	TOTAL
DESCRIPTION	Full adult STANDS FIRM. TAIL-FANNING, HEAD TURNING, SCROTAL NUZZLING, ETC.	Near adult STANDS FIRM. ONE FACET OF FULL RESPONSES MISSING.	Firm standing STANDS. LACKS MORE THAN ONE RESPONSE.	Partial standing GENERALLY STANDS FOR PART OF TEST.	Weak response RARELY STANDS FIRM.	
ADULTS	19	1	-	-	-	20
LAMBS	14	7	15	7	8	51

TAIL-FANNING
(as nudged by ram)

HEAD-TURNING
(towards ram)

SCROTAL-NUZZLING
(ewe to ram)

Fig. 15 Comparison of courtship responses of ewes and lambs[33].

Table 4. Age and bodyweight at puberty of some Indonesian goats and sheep.

				Nutrition		Male		Female	
Sources	Village (V) or research station (R)	Species Goat (G) or Sheep (S)	Breed	Level	Gain	Age (m) g/day	Weight (kg)	Age (m)	Weight (kg)
39*	R	G	K	High				6.3	
		G	EX	High				8.8	
		S	JTT^B	High				7.5	
		S	JTT^B	High				7.4	
		S	JFT^M	High				9.1	
40	V	G	EX	Low		12		10	
		S	JTT	Low		18		9-18	
38**	R	S	STT	0^{**}	37			10	
	R	S	STT	0.6	48			9	
	R	S	STT	1.0	57			8	
	R	S	STT	1.4	64			7	
41	R	S	JTT^G	Low				10-12	
28,29	R	S	JTT	Low	44^a	8.3^c	15.3^e	9.6^g	16.7^i
	R	S	JTT	High	87^b	5.9^d	20.3^f	7.6^h	17.7^i
36	R	G	EX	High		5.3	18.7		

* *ad libitum* 50:50 napier grass + BeefKwik, 15% Crude Protein (CP)
** Supplementation with concentrate at 0, 0.6, 1.0, 1.4% bodyweight
K - Kacang
EX - Etawah cross
JTT - Javanese Thin-tail; G - Garut strain; B - Bogor strain
JFT - Javanese Fat-tail; M - Madura strain
STT - Sumatran Thin-tail
Different superscripts denote statistically significant differences between groups on higher or lower planes of nutrition

In another study no details of nutrition are given, but the multiple-born lambs tended to reach puberty earlier than the singles, although the latter almost certainly must have been heavier. The differences were not statistically significant, but if real, suggest the possibility of a genetic component to the timing of puberty[41]. On the other hand, Sutama (unpublished data) found that singles reached puberty earlier than twins, although at a higher bodyweight.

Puberty was reached at about five months in a study of Etawah cross bucks. No details of nutrition are given but it must have been high for such early onset of puberty[36].

3. *Changes in Ovulation Rate and Litter Size with Age*

Finally, ovulation rates (and also litter sizes) are usually lower at puberty, which together with the asynchrony factors discussed in the previous section, contribute to the lower reproductive efficiency of the young animal. In fact, ovulation rates usually rise until three or four years of age, after which they may fall slightly.

Table 5 shows the effect of age on ovulation rate and litter size. Generally, these increase with age, although not always. For example, they did not rise between the first and second parturition in the experiments of Sutama and his colleagues with JTT, nor in those of Iniguez and his colleagues with Sumatran Thin-tail (STT) sheep[42]. Nevertheless, when evaluating reproductive performance, ages should be given because of the trend to higher fecundity with age. Unfortunately, some workers (see Tables 5 and 6) do not give the ages of their experimental animals. Presumably, they are dealing with mixed-age flocks which include some young animals. Furthermore, some workers call any animal over one year of age 'mature', which they are highly unlikely to be either in size or in reproductive performance.

II. NUTRITION FOR EFFICIENT REPRODUCTION

The effects of nutrition on the onset of puberty have been described in the previous section (Tables 3 and 4). It is obviously uneconomic to feed animals with unlimited high quality feed throughout their lifetime. Therefore, practical and efficient management consists of supplementation during critical periods of high demand: that of the young animal, especially after weaning, as well as for the adult female in late pregnancy and during lactation. In addition, a period of high nutrition or 'flushing' before mating is considered likely to increase ovulation rates and consequently, litter sizes. It is believed by Leng and his group that supplementation during these critical periods should consist of sufficient non-protein nitrogen for the efficient functioning of the rumen microbes plus some by-pass protein. This is because in the tropics, it is non-protein nitrogen (NPN) and protein rather than energy which limit productivity[56].

Constant *ad libitum* nutrition may not be the best apart from being prohibitively expensive. Thus, in Sutama's studies with JTT

Table 5. Effects of age on ovulation rate (O.R.) and litter size (L.S.) in some Indonesian goats and sheep.

Sources, village or research station	Species	Breed	Level of nutrition or gain/ day	O.R.	Age (y)	O.R.	Age (y)	O.R.	Age (y)	L.S.	Age (y)	L.S.	Age (y)	L.S.	Age (y)	L.S.	Age (y)	L.S	Age (y)
43(V)	G	KXE	Low	0.7	1-2.4	1.3	2-3.4	1.9	3+										
	S	JTT	Low	1.4	1-2.4	1.4	2-3	2.0	3+										
44*(R)	S	JTT[G]	?	1.53	1.2	2.04		2.5+			1.43	12***	2.03	2.5					
	S	JTT[G]	?	1.78	1.2	2.21		2.5+[1]			1.43	12	2.03	2.5					
	S	JTT[S]	?	1.00	1.0	1.78	3.0				1.33	10	1.87	3.0					
	S	JTT[S]	?	1.33	1.0	2.00		3.0			1.33	10	1.87	3.0					
	S	JFT[M]	?	1.23	1.2	2.03	2.6			1.38	12	2.08	2.5						
	S	JFT[M]	?	1.46	1.2	2.31	2.6			1.38	12	2.08	2.5						
45**(R)	S	JTT	?							1.6*	1st L	1.9	2nd L		2.2	3rd*L			
	S	JFT	?							1.5	1st L	1.9	2nd L		2.3	3rd L			
46(V)	G	K	? Low	1.40	1.6-2.5	1.71	2.6-3.5	1.75	3.6+	1.20	1.6-2.5	1.85	2.6-3.5		1.75	3.6+			
	S	EX	? Low	1.20	1.6-2.5	1.46	2.6-3.5	1.76	3.6+	1.20	1.6-2.5	1.38	2.6-3.5		1.65	3.6+			
47(R)	G	EX	?							1.17	1 year	1.34	2	1.30	3	1.56	4	1.60	5+
29(R)	S	JTT	44 g/d	1.4	10***	1.5	1.5			1.3	10***	1.5	1.5						
	S	JTT	87 g/d	1.8	7.5	2.0	1.2			1.4	7.5		1.2	1.2					
	S	JTT	87 g/d	2.0	7.5	1.6	1.2			1.5	7.5		1.5	1.2					
	S	JTT	87 g/d	2.0	7.5	2.0	1.2			1.2	7.5		1.8	1.2					
42(R)	S	STT	?							1.54	1.3								

* Within each age category in 2 cycles; [G] Garut strain; [S] Semarang strain; [M] Madura strain

** Age not given, 1st, 2nd, 3rd pregnancies, probably at about 1, 2, 3 years of age

*** Age in months

**** Sumatran Thin-tail breed

Other abbreviations see Table 4

Table 6. Reproductive performance of some Indonesian does and ewes - no information on nutrition.

Sources	Species	Breed	O.R.	L.S	E.M.	M - W	I.P.I (d)	Research Station (R) or Village (V)
43	G	KXE	1.5					V and slaughter house
	S	TT	1.8					
48	S	JTT[G]		1.62		26	691	V
40	G	EX		9		34		V
	S	JTT		1.8		11		
27	S	JTT		1.9		19	699	V
49	G	K		1.76		22	210	R
	G	EX		1.42		22	290	R
	G	KXE		2.00		34	270	V
	G	KXF		1.92		21	400	V
50	G	K		1.77		6	443	V
	G	EX		1.58		4	488	V
	S	JTT		1.52		4	513	V
	S	JFT		1.63		35	443	V
25	G	?		1.2		?	586	V
	S	JTT ?		1.5		?	741	V
51	G	K	1.30	1.29	1	19.6		R
	G	EX	1.34	1.30	2	13.6		R
52,53	S	JTT		1.94		27		R
	S	JTT		1.96		?		V
45	S	JTT	2.05	1.79	13	?	266	R
	S	JFT	1.92	1.84	4	?	266	R
46	S	JTT				35		R
	S	JTT				49		R
47	S	JTT		1.88	21			V
	S	JTT		1.75	14			V
54	G	EX		1.42	33			R
	G	EX		1.36	34			R
55	S	M				15-20		Australian national average

G - Garut strain of JTT
M - Merino
E.M - Embryonic mortality
M-W - Mortality to weaning
I.P.I. - *Interpartum* interval (days)
O.R. - Ovulation rate
L.S. - Litter size

ewes, high levels of nutrition led to earlier puberty and higher ovulation rates during the first breeding season. However, during the second pregnancy there were higher embryonic and perinatal losses in the high plane group and several ewes died. Likewise Obst and his colleagues[39] found that their extremely well-fed does and ewes produced large litters, but perinatal and maternal mortalities were high. The reasons for these adverse effects of constant high planes of nutrition on reproductive efficiency and survival have not yet been elucidated. They may be complex and differ in different circumstances. For example, a very high plane of nutrition during early pregnancy may lead to pregnancy toxaemia in the second half, with the consequent loss of dam and fetus.

1. *Male Performance*

There are no comparable Indonesian data, but work with temperate breeds has shown that the male reproductive organs have a high priority for available nutrients and low requirements (compared with those of a female during late pregnancy and during lactation). Total male infertility and total loss of *libido* with undernutrition are rarely encountered.

Rattray[57] summarizing data from temperate zones and breeds suggested that *libido* is affected before spermatogenesis. When rams were fed on a nitrogen-free diet which led to the death of four rams out of eight and a 40 percent reduction in liveweight in the survivors, there was no difference in *libido* or volume, motility and total sperm count of the semen[58]. When Merino rams were fed at 75 percent and 50 percent maintenance for 15 weeks sexual activity declined progressively as did volume, density and motility of ejaculates, but never stopped completely[59].

It is unlikely that severe underfeeding occurs in Indonesian bucks and rams, but it should be remembered that severe underfeeding reduces testis volume and sperm production and thus reduces the general reproductive capacity of the male. Note that overfeeding of male animals can also have detrimental effects on their fertility because it can decrease their fitness and mating dexterity[60]. There is need for quantitative work in Indonesia on evaluating the response of the underfed and overfed buck or ram especially with frequent mating or sperm collection in terms of sperm production and *libido*.

Libido has been defined as the level of willingness and ability of the male to mate and inseminate females[61]. It is obvious that to fulfil his function of impregnating the requisite number of females, the male must have both adequate *libido* and spermatogenesis.

Libido has been extensively researched in several farm species in developed countries. Lack of *libido* has been found to cause infertility. Data for Indonesia are scarce for all species, but lack of *libido* has been reported often in *Bos indicus* cattle and buffalo. Information is much needed for Indonesian bucks and rams. Under pen conditions (in which many goats and sheep are kept permanently), dominance can be a problem when more than one male is kept in a pen. Thus, the presence of a more dominant male within a pen or even in adjacent pens, will inhibit the subordinate males from mating. Lindsay and his colleagues termed this the 'audience' effect[62].

2. *Female Performance*

The adult life of a doe or a ewe can be separated into different phases each with different nutritional demands: during the perimating period in relation to oestrus and ovulation, during early, mid and late pregnancy and during lactation.

Measurements of reproductive response to nutrition can be in terms of conception rate, fecundity, offspring survival and intervals between parturitions. Fecundity can be expressed in terms of ovulation rate and litter size. Ovulation rate, of course, puts a ceiling on litter size. Litter size is the result of ovulation rate in the cycle that conception occurred in, minus ova, embryonic and fetal loss. When wastage occurs before day 13 a normal cycle usually follows with possible re-mating in the next cycle. Later losses result in extended cycles with conception occurring much later if at all.

Before discussing the effects of nutrition it is worthwhile to look at the reproductive performance in village and research station flocks in Indonesia. Table 6 shows the ovulation rates (where available) and litter sizes of some Indonesian goats and sheep. The planes of nutrition are not given, but in the villages, at any rate, the animals would be in very lean condition. Except for the data of Obst and his colleagues, ages are not given either, presumably they are mixed-age[43]. Yet, ovulation rates and litter sizes are high both at the research stations and in the villages. In other words, Indonesian goats and sheep are

highly fecund. This characteristic of Indonesian small ruminants is also discussed in Chapter IV on Breeding.

a. During the mating period

Submaintenance diets have been reported to cause some females to fail to exhibit oestrus through absence of ovulation or to have ovulation without oestrus in temperate zone animals[63]. This certainly often occurs with buffalo at low feeding levels in Indonesia[64]. There is evidence, however, that Indonesian goats and sheep will keep on reproducing even when thin and underfed although kid/lamb mortalities may be high, probably due to low birthweights, inadequate maternal behaviour with poor bonding and inadequate lactation resulting from maternal undernutrition.

In goats and sheep, good body condition and/or a rising plane of nutrition before mating may increase litter size through increased ovulation rate, a fact which was known in Britain 150 years ago. However, it has to be pointed out that, in spite of many experiments over the years with temperate breeds, the area of 'flushing' has remained confused and controversial, with increases in ovulation rate not always occurring.

Summarizing data from temperate zones, usually, high body-weight and condition (for a given breed and strain) at mating, results in higher ovulation rates than if animals were lighter in weight and in poorer body condition. This has been called the 'static' effect. In addition, many workers believe that a rising plane of nutrition is necessary and this has been called the 'dynamic' effect. Probably, both the static and the dynamic effects can be involved in induction of higher ovulation rates.

Earlier investigations in temperate zones and in Indonesia studied the effects of long-term flushing (at least a month before mating). The reader is directed to many papers in this area from temperate zones[65-68]; or from Indonesia[69-72]. Effects of nutrition on reproductive performance of some Indonesian small ruminants are shown in Table 7.

In more recent years, it was found in Australia in Merino sheep that ovulation rate increased by 20 to 30 percent after only six days of feeding 750 g lupins per head per day (a high protein diet, maybe involving by-pass protein)[73]. However, in another experiment similar

gains in ovulation rate were produced by short-term infusions of energy-yielding substrate (glucose and acetate) for nine days[74]. The supplemented Merino ewes in these two experiments did not have measurably greater bodyweight. It is uncertain whether it is an increase in the energy substrate above a minimum level of protein that is important or an increase in protein intake *per se*.

It is not known either whether these stimulatory effects are through a direct non-hormonal effect or through induction of a hormonal environment conducive to multiple ovulation. It has been suggested that a hypothalamic-pituitary action may be involved because ovariectomized ewes fed high protein diets showed increases in FSH levels[75]. In another experiment, however, when entire ewes were fed with lupins, FSH levels did not rise[76].

Table 7 shows the effects of nutrition on ovulation rates, embryonic mortality, as well as litter size, pre-weaning mortality and *interpartum* intervals in small ruminants in Indonesia. Looking at results from different workers, some fed their animals at what has been called 'supramaintenance' or very high planes of nutrition[29,39,68] In some data[39] there were no control animals fed maintenance diets and litter sizes on high nutrition over the entire experimental period were high. Other workers with a control group on maintenance, found higher ovulation rates and litter sizes in the better- fed animals, but only after ten weeks on the 'supramaintenance' diet with the maximum being reached five weeks after that[68]. This appears to be longer than the periods of high nutrition required for increases in ovulation rates in temperate zone animals.

JTT ewe lambs in the *ad libitum* groups grew faster and reached puberty sooner than those on a lower plane of nutrition, but ovulation rates and litter sizes were not significantly different. In all of these experiments, embryonic mortality was significantly higher in the well-fed groups[29]. In another experiment with JFT ewes the high plane ewes had higher ovulation rates but tended to have similar litter sizes due to higher embryonic mortalities[77].

When different levels of protein were fed, an increase in ovulation rate and litter size was found only at the highest level of protein supplementation during the critical periods (15 percent CP)[71].

Table 7. Effects of nutrition on the reproductive performance of some Indonesian goats and sheep at research stations.

Source	Species	Breed	Age (y)	Nutrition	O.R.	L.S.	E.M.	M-W	I.P.I.
39	G	K	>			2.08		41	197
	G	EX G	>	Very high		1.81		46	201
	S	JTI B	MA >	plane		1.86		39	197
	S	JTI M	>			1.58		24	199
	S	JFT	>			1.67		39	250
52,53	S	JTT	**	S 90%NRC	1.05^{a}				
	S	and	MA	S 120%NRC	1.47^{b}				
	S	JFT		T 90%NRC	1.62^{c}				
	S			T 120%NRC	1.57^{c}				
70	S	JTT		S 90%NRC	1.21^{a}	1.03^{a}	1		
	S	JTT	2-7	S 120%NRC	1.58^{b}	1.08^{a}	32		
	S	JTT		T 90%NRC	1.71^{c}	1.59^{b}	7		
	S	JTT		T 120%NRC	1.79^{c}	1.70^{b}	5		
	S	JTT		HM	2.48^{d}	2.00^{b}			
38									
	S	STT	> 4 m	0 >	1.2^{a}		37^{a}		
	S	STT	> till	0.6 >***	1.3^{a}		11^{b}		
	S	STT	> par-	1.0 >	1.1^{a}		4^{b}		
	S	STT	> turi-	1.4 >	1.4^{a}		9^{b}		
				tion					
71				10% CP(****)	1.95^{a}				
				12% CP		2.01^{a}			
				15% CP		2.45^{b}			
68	G	KXE	>	Mainte-	1.69^{a}	1.29^{a}	23		
	G	KXE	> 2-3	nance +	2.65^{b}	1.78^{b}	33		
	S	JTT	>	6 kg	1.69^{a}	1.50^{a}	11		
	S	JTT	>	Mainte-	2.65^{b}	1.78^{b}	33		
				nance +					
				6 kg					
69	G	K		150 g	1.73^{a}	1.00^{a}	77	50	200
	G	K	2	300g(4+12)	2.43^{b}	1.20^{b}	59	35	202
	G	E		150 g	2.00^{c}	1.14^{c}	41	43	209
	G	E		300g(4+12)	2.25^{d}	1.80^{d}	34	40	198
	S	JTT		150 g	2.09	1.57	23	24	
	S	JTT	< 2	300g(4)	2.33	1.53	32	37	
	S	JTT		300g(4+6)	2.3	1.71	31	30	
	S	JTT		300g(4+12)	2.18	1.53	23	25	
30	S	JTT	7-10	L Restr.	1.4^{a}	1.3	7	31	232
			m	H ad lib	1.8^{a}	1.4	22	33	204
		JTT		L 350 g	1.6^{a}	1.5	6	33	213
				H 700 g	2.1^{a}	1.8	24	55	199
72	S	JFT	1	250 g	1.2^{a}	0.9	25		
			year	500 g	1.8^{b}	1.3	28		
				250 g	1.2^{c}	0.8	33		
				500 g	1.5^{d}	1.0	33		
				500 g	1.9^{d}	1.1	42		

* MA - Mixed-age flock.
** NRC - National Research Council; S - previously had singles; T - twins or HM - more than 2 lambs.
*** Energy supplementation at 0, 0.6, 1.0, 1.4 % of bodyweight
**** C.P.- Crude protein.
Reference 69 (4) - supplementation 4 weeks pre-joining and 4 weeks before parturition
(4+6) - 4 weeks before joining and parturition + 6 weeks after joining
(4+12) - 4 weeks before joiningand parturition + 12 weeks after parturition
Reference 72 39,38,71 flushing for 0, 7, 17 or 35 days before mating
Except for - Beef Kwik used for supplementation
different superscripts for OR, LS and mortality till weaning means are statistically different from each other
Other abbreviations see Table 4

This supports the work of Leng that it is NPN and protein not energy that is lacking in the tropics[56]. Thus, supplementation for diets of low quality (high fibre, low protein, and low digestibility) should be with NPN and by-pass protein feeds only.

The remaining workers used modest increases in levels of nutrition (approximately 120 percent NRC* recommendations compared with about 90 percent for the control groups). Energy supplementation advanced puberty, but did not affect litter size[38]. Another study found an increase in ovulation rate and litter size in goats, but not in sheep[69].

The results of Inounu and his colleagues[52,53,70], are of interest. They separated their JTT ewes into those that produced single lambs in their previous pregnancy (S) and those that had produced twins (T). Modest supplementation increased the fecundity of the S ewes but not that of the T ewes. Similar results were obtained by Chaniago (personal communication). Thus, it appears that in Indonesian sheep, at any rate, multiple ovulators reach their genetic potential on maintenance diets, whereas those that are single ovulators on the maintenance diets will produce multiple ovulations only if well-fed. If it is considered that higher fecundity is desirable, it would appear to be cheaper to apply genetic selection than to feed does/ewes with costly supplements. Probably, if the farmer can afford expensive supplementary feed, it is more efficient to give it to young growing stock or maybe towards the end of pregnancy and in early lactation to does/ewes to increase birthweight as well as perinatal growth and survival.

Recently, Sutama working with Javanese Fat-tail (JFT) ewes tried short-term flushing, by doubling a 15 percent protein supplement (from 250 g to 500 g per day). Flushing for two oestrous cycles (35 days) before mating with a fertile ram, increased ovulation rates (1.2 to 1.8) and litter sizes (0.9 to 1.3). The ovulation rates were significantly higher in the flushed group. He next studied the effects of flushing in three groups for 0, 7 and 17 days. Ovulation rates rose significantly (1.2, 1.5 and 1.9 respectively). Litter sizes followed, but differences between groups were not significant[77].

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* National Research Council

b. Nutrition during pregnancy

It is not necessary to give pregnant females extra feed until the last third of pregnancy. Severe undernutrition lasting three weeks may cause some embryonic mortality, but it seldom exceeds 15 to 20 percent. A great proportion of this loss is due to chromosomal abnormalities of embryos, and thus unavoidable[78]. Thus, normally, undernutrition during this period is not a problem, the female having immense capabilities to sustain the fertilized ova and the small, growing embryo(s). Embryonic mortality and factors affecting it are discussed in the next section.

Studies of progesterone levels in early pregnancy have not yet been done in Indonesian goats and sheep, but in temperate zone sheep, those on submaintenance diets (25 percent maintenance) had progesterone levels which were higher than those on maintenance, which in turn were higher than those on 200 percent maintenance. Thus, low levels of progesterone are unlikely to cause embryonic mortalities in poorly-fed ewes[79,80].

There have been no controlled experiments yet on the effects of undernutrition in mid-pregnancy on fetal size in Indonesian small ruminants. For a review of sheep in temperate zones see McCrabb[81]. In his experiments the effects of undernutrition during this period varied: an increase, a decrease or no change in birthweight being reported. Moreover, the detrimental effects can be overcome by a high plane of nutrition during late pregnancy[82]. McCrabb found in one experiment that undernutrition between 30 and 96 days reduced placental size by 23 percent, but, this did not reduce lamb size[81]. Thus, the plane of nutrition at that time is unlikely to be important and expensive supplementary feed if available, should be saved for the period of late pregnancy and lactation.

It is normal to recommend a higher plane of nutrition during the last third of pregnancy. This is because the gain in mass during this period is equivalent to 85 percent of birthweight. It has been pointed out before that undernutrition during this period will result in low birthweights and hence higher perinatal mortalities, particularly in litters. Conversely, overfeeding will lead to a too big kid/lamb which can be damaged as it tries to squeeze through the cervix. The latter seldom if ever occurs under village conditions. If higher litter size is

desirable under these conditions, does and ewes must be better fed in late pregnancy to increase birthweight as perinatal mortality rises sharply with decreasing birthweight.

The reproductive performance of JTT ewes as well as Kacang and Etawah cross does was compared on a maintenance ration and supplemented at four weeks before joining and parturition and either during the first six or first 12 weeks of lactation. In goats there were no effects of nutrition on survival rates of kids, birthweights and weaning weights. However, in sheep, birthweights and weaning weights were better in the supplemented groups[69].

It is of interest to determine the minimum periods of time during late pregnancy, when re-feeding an animal following earlier undernutrition will enable a fetus to recover or catch-up. Mellor's group, working with the Scottish Blackface have followed fetal growth *in vivo* by measurement of crown to rump length and thoracic circumference. They concluded that birthweight would not be affected if undernutrition was less than 16 days. Conversely, undernutrition for more than 25 days resulted in a stunted fetus[83,84].

Recent work by Lynch and his colleagues in Australia suggests that protein supplementation during the last trimester of pregnancy not only increases birthweights, but also increases the rates of survival of lambs above that expected for the actual birthweights. They supplemented Booroola Merino x Border Leicester ewes with cottonseed pellets: 80 g per head per day for those carrying singles, 150 g for twins and 200 g for those with three fetuses and more[85]. They are now trying to determine the nutritional-physiological reasons for these responses, the minimum duration of supplementation needed and whether separation of litter size groups to provide differential feeding is useful.

Of particular interest is the work of Egan (personal communication). He tried supplementing one group of Merino ewes with 400 g lupin grain per sheep per day only for the final nine days of pregnancy. Table 8 shows his results. By this relatively cheap strategic supplementation he lifted birthweight by 300 g and through that, survival of the lambs so that 33 percent more lambs were weaned. Work needs to be done in Indonesian goats and sheep to see

if an affordable, short-term supplementation regime could be effective in increasing birthweight and post-natal survival.

III. EMBRYONIC MORTALITY

Embryonic mortality in Indonesian goats and sheep can be obtained from some of the data in Tables 6 and 7 where both ovulation rates and litter sizes were measured i.e. at research stations. It can be seen that these losses are extremely variable, ranging from one to two percent in one study with Kacang and Etawah goats,[51] while another found that less than one quarter of the ovulations in Kacang goats resulted in live births[69].

Table 8. Effects of supplementation with 400 g lupin grain per sheep per day for the final nine days of pregnancy in Booroola Merino ewes.

	No lupins	Lupins
No. ewes lambing	45	45
No. lambs born	112	113
Birthweight (kg)	3.2	3.5**
% alive at birth	89	92
% surviving to weaning	64	78**
Weaning-weight (kg)	22.9	22.8
No. lambs weaned/ewe	1.2	1.6**

[From Egan (personal communication)]

** difference between groups significant $P < 0.01$

With the limited information available, one can only speculate on the reasons for some of the high embryonic losses. There has been no work in Indonesia on the effects of high temperatures on embryonic mortality in native goats and sheep. It is true that temperatures in barns rarely exceed 35° C. However, with animals tethered in the sun a high effective heat load will result. It is also possible that multiple ovulators are more sensitive to high temperatures in terms of embryonic losses.

The following brief review of effects of high temperatures on reproduction refers to Merino sheep in Australia or to temperate breeds of British origin in the United States. When pregnant Romney Marsh ewes were subjected to temperatures of 40.5° C dry bulb (DB) and 30.6° C wet bulb (WB) for 6 hours per day fewer lambed and those that did had smaller lambs[86].

Experiments with temperate crossbred ewes in the United States showed that it was high temperatures in the pre-mating and immediate post-mating period that caused embryo loss. Ewes given the heat treatment eight days after mating were relatively unaffected. In these experiments researchers used a temperature of 32° C ambient dry bulb (DB) with 60 percent relative humidity which resulted in fertilization being reduced from 93 percent to 52 percent[87]. Similar embryonic losses were found in Australia with Merinos in climate rooms, but at higher environmental temperatures and humidities.

High temperatures can decrease growth rates in fetuses producing so called "dwarf' lambs[88,89] However, there are great breed differences in susceptibility to heat stress - for example whereas temperatures of 40.5° (DB), (30.6° C wet bulb (WB)) caused resorption of embryos and dwarfing in Romneys, Merinos needed much hotter conditions as well as undernutrition before being affected (44.4° C DB; 33.3° C WB). Romneys originate from cool England while Merinos have been selected in Australia to breed often under hot conditions. It is likely that native Indonesian goats and sheep are very heat tolerant, but heat could contribute to embryonic losses and low birthweights under some conditions in Indonesia, particularly when the animals are tethered in the sun.

Note that embryonic mortalities were also large with very high planes of nutrition[29,39]. This is similar to reports with temperate zone sheep[78].

IV. KID/LAMB MORTALITY

Post-natal mortality of kids and lambs greatly influences both the profitability of an enterprise and the rate of genetic progress possible through its effect on the selection differential. Much of it occurs in the first few days after birth and can be due to a variety of genetic and environmental factors as well as to the interactions between them. Among those are birthweights, litter size, offspring vigour and maternal

ability. Nutrition in late pregnancy, maternal experience and social conditions around the birth site may influence kid/lamb survival by affecting the speed of formation and strength of the maternal-offspring bond and thus whether the neonate can obtain that first essential drink of *colostrum*. There has been no work in these areas in Indonesia. Hence work from Australia, New Zealand and Great Britain is discussed in the ensuing sections.

It is obvious from some of the data presented in Tables 6 and 7 that kid/lamb mortalities are variable and can be very high. Another surprising fact is that they tend to be higher at research stations than in villages. Perhaps perinatal mortality may be underestimated in the villages as some farmers may not report stillborn kids/lambs or those which die within a few days of birth. On the other hand, it could be that farmers manage their does and ewes more efficiently at parturition (because losses decrease their profits) than hired labour at experimental stations who do not gain extra money for increasing the number weaned.

In Australia the national average for deaths of lambs is 15 to 20 percent, for animals kept during their whole lives at pasture outside[55]. Thus, cold kills many, while in Northern Australia, heat stress also kills many newborn animals. But most goats and sheep in Indonesia (and all of those listed in Tables 6 and 7) give birth in barns with no extremes in temperature. Thus, other factors such as too low birthweight, and weak or absent bonding of the young to its (their) mother probably cause these high mortalities. Too high a birthweight causing dystokia is unlikely in the smallholder situation. However, too low birth-weight is often the cause of perinatal losses. It is usually inversely related to litter size. Bigger neonates are, as a rule, more vigorous and more likely to obtain that first crucial drink of *colostrum*. Good nutrition in the last part of pregnancy will increase birthweight. Egan's work with short-term supplementation is of interest with possible applications in Indonesia (see Table 8).

Two studies illustrate the effects of birthweight and litter size on survival[53,90]. In the first study singles averaging 2.6 kg and twins averaging 2.0 kg had 17 percent and 18 percent mortalities respectively, whereas triplets and quadruplets averaging 1.4 kg and 1.3 kg had 36 percent and 43 percent mortalities respectively. Similar

correlations between birthweight and survival were found in the second study.

Note that the figures in Tables 6 and 7 group all postnatal mortalities into one period, the time between birth and weaning (which occurs at three months or more of age), because in most of the work reported, no details are given of when the deaths occur. In fact, numerous data from temperate zones show that most kid/lamb mortalities occur within the first few days of birth and the limited data for Indonesia suggest that this is probably also true here. Thus, Sutama and his colleagues found pre-weaning losses of JTT sheep at the first and second lambing to average 21 and 26 percent respectively, with 14 and 15 percent respectively occurring within three days of birth[29].

1. *Maternal Behaviour and Development of the Maternal-Offspring-Bond*

A review of maternal-offspring behaviour, including the development of the maternal-offspring bond, its endocrine and sensory regulation, as well as factors affecting survival rates of neonates and strategies for improving post-natal survival is given by Wodzicka-Tomaszewska and her colleagues[1].

Initially after birth a doe/ewe will accept any kid/lamb. Later, however, an exclusive bond is established so that the young has (have) sole access to the mother's limited milk supply. The time during which this bonding can take place (called the 'sensitive' or 'critical' period) is limited in length and varies between individuals and breeds. This has been studied extensively in Australia,[91] Britain[92] and New Zealand[93].

The period immediately after birth is a period of intensive reciprocal stimulation, with the mother licking the placental membranes and fluids from the newborn and the neonate trying to stand up and find the teat for that crucial first drink of *colostrum*. Usually, it is during this initial short period that the mother learns to recognize her young, but the young may take several days to recognize its mother and if hungry will approach strangers for weeks trying to suckle them. The action of licking soon after parturition probably stimulates breathing since licking usually starts from the head. A ewe with more than one lamb often licks the first-born more intensely than her second and third lambs[93]. The smell of amniotic fluids attracts a ewe to her lambs and malfunction of olfactory cues in

anosmic ewes depressed their licking of their own lambs. The less long and intensive licking which twins, triplets and quadruplets get, may result in less strong bonds and less adequate maternal care than for singles. Also, the distribution of *colostrum* within litters may be uneven with some kids/lambs not getting any, or at least not enough.

In feral goats, licking or grooming was used by does to 'label' their kids. Thus, alien kids which had eight hours' contact with their own mothers were rejected, whereas those that had no contact with their own mothers were accepted by foster does[94].

At pasture, the parturient females tend to leave the flock before giving birth. This withdrawal from other animals should help to form quickly strong bonds between the offspring and its (their) dam. Good bonding at pasture is related to the length of time spent at the birth-site, and twin survival was increased by ten percent by leaving ewes and their lambs enclosed at the birth-site after parturition compared with control ewes which were not enclosed, and by 30 percent compared with ewes which were drifted away 25 meters from the original birth-site 30 minutes after the birth of the second lamb[95].

In general, primiparous females do not exhibit as good maternal behaviour as do experienced ones[96]. Dystokia depresses maternal behaviour and this is more likely in primiparous females. Both mother and offspring may be weakened by the long labour, the mother may not stand for some time and the young may wander away and fail to get its vital first drink. Also ewes may 'learn' better maternal behaviour with subsequent parturitions.

Conversely, low levels of nutrition in late pregnancy, particularly in growing primiparous ewes or ewes with litters, not only lead to the production of weak young, but also undernourished ewes have little milk and show poor maternal behaviour[97].

2. *Perinatal Problems in Indonesia*

Most Indonesian small ruminants give birth in a pen. Often there are other animals in the pen beside the new mother and her offspring. It could be that under these conditions a strong maternal - offspring bond does not get established. It is possible that the other animals in the pen interfere with its establishment because the dam cannot isolate herself with her newborn offspring. There is no information in this area. Alternately, the high mortality under Indonesian conditions

could also be due to the inability of many Indonesian goats and sheep to care for more than one offspring. Again more data is required on the maternal ability of local goats and sheep.

3. *Strategies for Improving Post-natal Survival*

a. Fostering alien neonates

This technique is useful for newborn which have been deserted by their own mothers or for multiple - born offspring that have mothers with insufficient milk. Under Indonesian conditions fostering is possible so long as more than one female gives birth at about the same time on a farm or within a village, if farmers will cooperate with each other. Bottle-feeding may also be possible if the farmers have been trained in this situation, although the price of milk will probably be too costly to make bottle feeding economic.

Fostering is easy if the young are presented at birth to a dam who has just given birth too, but becomes harder once the exclusive maternal - offspring bonds have been established.

There have been many studies of fostering in sheep in Australia, Great Britain and the USA, but few in goats. The acceptance of foster lambs by alien ewes was increased by washing of the lambs followed by close confinement for at least two days[98], or by using textile lamb coats which had been worn for 24 hours by the ewe's own lamb(s) and then transferred to alien lamb(s)[99]. In the latter case, the acceptance of fostered lambs was 60 percent compared with only 12 percent of lambs without exchanged coats.

Using several kinds of odorant to disguise the smell of an alien lamb for fostering has also been reported[100]. Substances originating from the skin such as neatsfoot oil and wool wax were more effective than other substances such as vanilla, methyl salicylate, butyric and propionic acids, vegetable oil, mercapto - ethanol or eucalyptus oil.

b. Genetic selection for good maternal behaviour

Most of the selection for mothering ability has been indirect in Australia and New Zealand. In Australia, under arid or semi - arid extensive conditions natural selection has favoured a single-bearing ewe, which would desert her lamb if feed became scarce, so that she would survive herself to reproduce again when conditions improved.

Thus, the Australian Merino produces largely single lambs and is not a good mother, often failing to bond adequately to each of a pair of twins. Alexander's group studied the incidence of separation of twins from each other and their mother in several breeds of sheep and found this to differ greatly between breeds and individuals[101]. A twin-separation test has been used to distinguish between ewes that could bond adequately to twins and those that could not[97].

In New Zealand, selection has been carried out by sheep-farmers for 20 to 30 years for the so called 'easy - care' sheep, which do not need assistance with parturition, bonding or care of their young. The National Breeding Scheme in New Zealand places a heavy weighting on total weaning - weight, which favours a twin - bearing animal which gives birth to twins and bonds well to both, unassisted by people.

George Alexander and his group in Australia have been selecting for about ten years for 'good' maternal behaviour using various post-natal indicators of maternal behaviour which should maximize the survival of lambs at pasture[102]. It is too early to evaluate the success of this approach to increasing offspring survival.

What do Indonesian farmers want to select for, in their small ruminants to reduce perinatal losses? Should selection be for litter size with systems for fostering and artificial rearing of the surplus young that the dam cannot bond to and feed? Alternatively, should selection favour a female with capacity to bond to two or more offspring and an adequate milk supply to feed them? Are many Indonesian goats and sheep lacking in adequate maternal behaviour? Do they have sufficient milk to feed two or more offspring? Do the existing husbandry systems fail to provide an environment that favours early, strong bonding and hence post - natal survival? Until we have information on the behaviour of the dams and the neonates as well as of the interactions between them, a sensible plan for increasing the survival of neonates cannot be formulated. Statistics on survival and death do not clarify the causes. We feel that the remedy is not necessarily expensive i.e. requiring expensive feed or drugs. Maybe it lies in a slight change in conditions (such as partitions for the isolation of the dam and her offspring) for great improvements in perinatal survival. Maybe also, genetic selection for maternal behaviour adequate for bonding and

suckling litters is possible and needed. No one knows until we have more facts!

V. *INTERPARTUM* INTERVALS

Interpartum intervals can be seen in some of the data presented in Tables 6 and 7. It is amazing how short the interval between succeeding parturitions can be in Indonesian goats and sheep. The interval between parturition and subsequent conception can be as short as six weeks, shorter than for most breeds of small ruminants anywhere. It is comparable to that of the famous D'man sheep in Morocco, which have an anoestrous period of 45 to 60 days[37]. It can be very short even in animals that kidded/lambed at only 12 months of age[29] and those that are on maintenance rations[69]. Chaniago in fact found no effects of plane of nutrition on lambing intervals. Yet, most of the village data show that animals kid/lamb even less frequently than once a year, in some cases once every two years. The problem is one of mating management, with the doe/ewe not meeting a buck/ram at the time of oestrus, not mating and thus not getting pregnant.

Often a farmer has no buck/ram and has to rely on his ability to detect oestrus before making arrangements for bringing the male to the female(s). Detection of oestrus without the presence of a male is much harder in does or ewes than in cows or sows. Furthermore, the farmer is often too busy with other farm work to spend the time necessary for accurate oestrus detection or for obtaining a buck or ram at the correct time for mating.

Low 'mating efficiency' has been observed on farms studied in Garut[27]. Farmer ignorance of reproductive physiology and behaviour as well as time constraints and difficulties of obtaining a ram could be the factors responsible. For example, it was found in this study that if a farmer finds a ewe in oestrus, he tries to mate all his ewes, even though they are not in oestrus, in fact some of them are already pregnant. Thus, 'each ewe is held in turn for the ram to mate' and the authors reported that rams showed high *libido* and aggressiveness, mating anything that will stand still. It may be a long time before the male is taken to the females again and mating opportunities are lost again and again. Careful daily checking with a male is essential for efficient detection of oestrus.

C. FUTURE TECHNIQUES FOR IMPROVEMENT IN REPRODUCTIVE EFFICIENCY

Some of the techniques described in this section are already being used in developed countries, but are still impractical at present in Indonesia. For a good summary, the reader is directed to reviews of Betteridge[103] and Gardner[104].

L ARTIFICIAL INSEMINATION

This is definitely the most powerful tool for genetic improvement. Artificial Insemination (A I) in goats and sheep is not yet as successful as in cattle, but progress has been made in recent years. A buck and a ram can be trained to mount a so-called dummy or a teaser animal and serve into an artificial vagina. Another alternative is electro-ejaculation which means electrical stimulation with a rectal probe.

AI has the following advantages:

1) The selection differential can be increased, using only a few genetically superior sires;
2) the cost of keeping extra males is reduced;
3) venereal diseases from inseminated flocks can be eliminated.

AI in goats and sheep in Indonesia has not been extensively used, although at least both 1) and 2) could be important in the smallholder situation in the village. Thus, a male is needed for the efficient detection of oestrus and the cost of keeping such a male by each farmer is relatively much higher than under extensive, large flock situations in Australia and New Zealand.

AI is used extensively in the Indonesian dairy industry, but to take-off in small ruminants, synchronization of oestrus would be needed, which is a relatively expensive procedure.

Table 9 shows the differences in semen characteristics among cattle, goats and sheep, in number of females that can be inseminated per ejaculation and per week as well as in conception rates. Initially, AI in cattle was more successful, partly because bull semen could be extended (diluted) further and easily frozen with little damage to sperm survival, and also because with the larger reproductive tracts of cows, intra-uterine insemination was possible without surgery.

Table 9. Fresh semen characteristics of cattle, goats and sheep[105].

Species and type of insemination		No. of females inseminated /ejaculate	/week	% pregnant
Cattle (IU)*		300+	1000	60-70
Goats } Sheep }	cervical	15	150	50

* Intrauterine

Double insemination raises conception rate in goats and sheep (from 58 to 66 percent), as does intra-uterine insemination by laparoscopy (Table 10). Freezing semen extends the use of a selected superior sire and allows the preservation of genetic material for future use, but conception rates per oestrous cycle are lower than with fresh semen. Intra-uterine insemination will raise conception rates with frozen semen to rates similar to single cervical insemination with fresh semen (51 percent). Figures are similar for goats. Because of the relatively small size compared with the cow, intra-uterine insemination has to be surgical in these small ruminants.

Diluents for goat and sheep semen include cow's milk (whole or skimmed) or egg-yolk-phosphate used for the storage of semen at 2 to 5°C or at room temperatures under anaerobic conditions. Polge discovered in 1949 that glycerol protects spermatozoa from the effects of freezing, by accident and by being an observant scientist. He was testing various sugars as cryoprotectors and discovered that the one labelled fructose was effective. This mislabelled fructose bottle was actually Meyer's egg-albumen which contained glycerol as the active agent which protected spermatozoa from damage during freezing. Note that some damage occurs even with bull semen so that larger numbers of spermatozoa are needed for AI with frozen than with fresh semen.

II. DETECTION AND SYNCHRONIZATION OF OESTRUS

A buck or ram (entire or vasectomized) with a raddled brisket or with a harness and crayon will detect oestrus well when there is enough space at pasture or in large yards. The difficulty under

Table 10. Effects of method of insemination and freezing on % lambing.

	Intercervical		Intra-uterine
	Single insemination	Double insemination	
Fresh	58	66	
Frozen (3-11 years)			51

confined conditions is that a non - oestrous female finds it difficult to escape from an enthusiastic male and one can get false tupping marks without mating having taken place.

Detection and synchronization of oestrus are essential for AI and for embryo transfer. The two main methods used for synchronization are outlined below:

1) Vaginal progestagen sponges (such as Repromap, Upjohn Pty. Ltd., Chronogest, Intervet) and subcutaneous silastic compounds (such as Siloestrus Pty. Ltd.) are satisfactory for goats and sheep. These are left *in situ* for ten to 14 days and artificially prolong the luteal phase. When the sponges are removed, oestrus follows and is confined to about two days (see Fig. 16).

2) Prostaglandin analogues destroy the active CL during the second part of the cycle. They are not effective at the beginning of the cycle and it is necessary to have two injections eight to 12 days apart to synchronize the whole flock (see Fig. 16).

There is no clear-cut superiority between the two methods. The first synchronized oestrus is characterized by lower conception rates due to poorer sperm transport. Conception rates are normal in the second cycle, but oestrus is less synchronized (see Fig. 17).

III. INCREASED OVULATION RATES

In Indonesian goats and sheep, a high proportion of females produce twins or more, but the system of husbandry is not efficient enough to ensure high survival rates of multiple-born litters. Perinatal losses have already been discussed in this Chapter. Genetic selection

for higher fecundity is possible and this is described in Chapter IV on Animal Breeding.

For embryo transfer PMSG, HCG and FSH give variable results, either not enough ovulations or too many, which often results in non-viable litters. Two methods to produce greater fecundity under natural mating conditions are 1) active immunization against androstenedione which has been marketed as Fecundin[107] and 2) immunization against inhibin[108]. It appears that genetic selection is a better and cheaper option for the Indonesian smallholder if indeed more than one offspring is required per female under present management conditions.

IV. PREGNANCY DIAGNOSIS

It is reproductively and economically inefficient to keep animals which are not pregnant when they should be. At present in Indonesia, detection of oestrus (and hence non-pregnancy) is all that should be encouraged.

However, there are many sophisticated and expensive methods ranging from ultra-sound to hormonal assays. For example, the presence of placental lactogen in the blood can be used as a reliable indicator of pregnancy at 55 days after mating in sheep[103]. False positives are unlikely because by this time most embryonic mortality would have already occurred.

V. CONTROL OF PARTURITION AND REDUCTION OF PERINATAL LOSSES

It is possible to time kiddings and lambing so that births occur when people are about and can prevent perinatal mortality through dystokia, mismothering etc. Theoretical work initiated by Liggins has elucidated the hormonal cascade which brings about birth and various hormones (or their analogues) from that cascade have been used. Birth has been induced by using prostaglandin, corticosteroid and oestrogen analogues. Other compounds like ACTH analogues will induce parturition, but are not used. In goats and sheep, glucocorticoid analogues are effective five days before term, as are oestrogen and $PGF_{2\alpha}$ analogues. Fig. 18 shows a moderately intensive system of synchronization of oestrus and parturition in France, to save

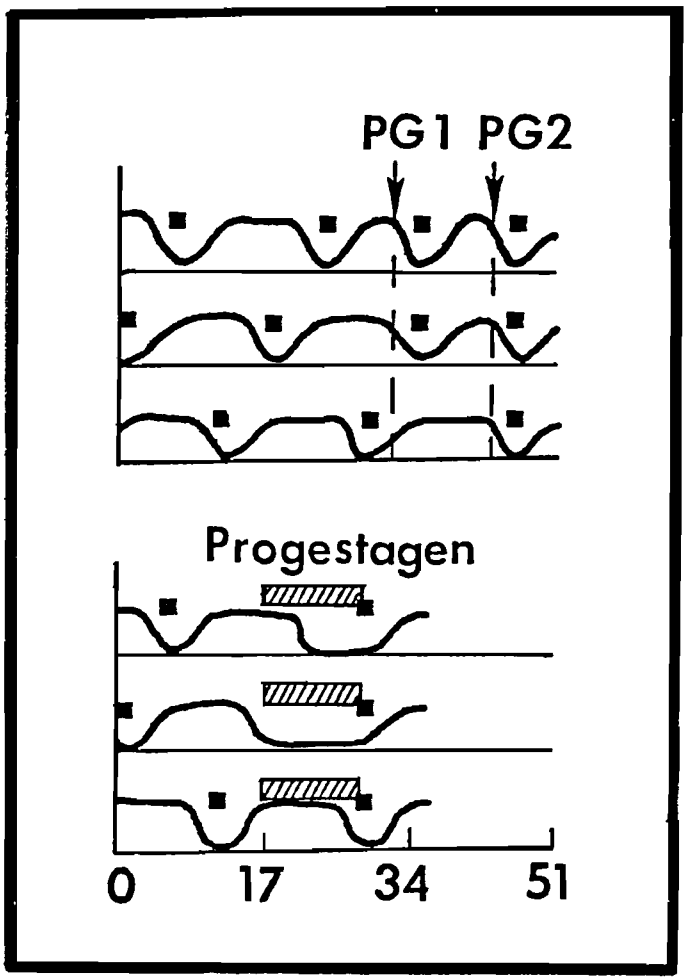

Fig. 16 Methods of oestrus synchronization in sheep; upper panel using prostaglandins; lower panel using progestagens. Oestrous cycles for three animals are schematically illustrated by the lines showing changing levels of blood progesterone and the black dots which indicate oestrus. Before treatment oestrus is asynchronous, whereas after treatment oestrus is synchronous[2].

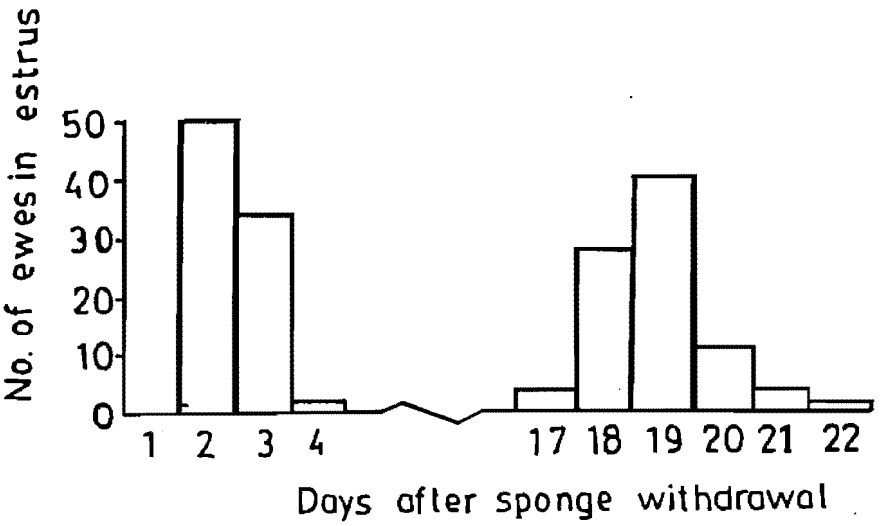

Fig. 17 Patterns of synchronized oestrus at the first and second cycle following treatment with a progestagen impregnated sponge[106].

money on overtime payments to workers during week-ends. This treatment is not recommended for village conditions. Not only is it too expensive, but it needs accurate mating records to avoid kids or lambs being both prematurely and failing to survive.

VI. EMBRYO TRANSFER AND OTHER EMBRYO MANIPULATIONS

Embryo transfer (ET) is a useful research tool and has been used to investigate the extent to which the mother or the offspring control characteristics like birthweight, length of gestation, fleece characteristics, embryonic survival etc. as well as for elucidating the interrelationships between the uterus and the embryo.

However, as far as farming is concerned, it should always be remembered that ET is not only more costly than AI, but that it can never become as effective as AI. This is because the number of progeny per female (even with repeated superovulations) is smaller by

a factor of a thousand at least, usually by a factor of hundreds of thousands.

Nevertheless, the lure of reproducing perfect individuals draws enthusiasts of ET on and already in 1983 in the USA 143,000 cattle embryos were transferred, of which about 20 percent were frozen-thawed[103]. Moreover, embryo-splitting has become common practice in ET programs to produce identical twins, triplets or quadruplets. This procedure is illustrated in Fig. 19.

For successful ET, the oestrous cycles of recipients and donors must be synchronized. Because goats and sheep are smaller than cattle, surgical methods have to be used in embryo collection and transfer. For freezing, carefully controlled rates of cooling are necessary using cryoprotective agents (such as dimethyl sulphoxide, glycerol, propanediol, methanol or ethylene glycol), which allow balanced dehydration of cells without damage to the embryo.

Besides ET of embryos of superior individuals, ET and embryo manipulation have been used as research tools. Cattle and sheep embryos have been successfully sexed and transferred after hatching from the *zona pellucida*, when a piece of trophectoderm can be removed for chromosomal analysis without embryo damage. However, it has proved impossible to freeze hatched embryos, thus limiting the usefulness of this technique.

The production of chimeras has already been carried out, for example by mixing of goat and sheep blastomeres. The pioneer work in chimera production has been in Carole Fehilly's and Steve Willadsen's laboratory in Cambridge. It has enabled an individual of one species to develop in the uterus of another protected by the trophoblast of the same species as the host animal (see Fig. 20). This enables interspecies transfers that would otherwise fail (eg. sheep x goats). This is because it is the trophoblast which determines the acceptability of the conceptus to the mother's uterus.

The potential value of mixing individuals within a species - nuclear transplantation is also being investigated. So already, unproven embryos can be duplicated by existing techniques, but 'cloning' of proven adult animals is still a pipe dream.

Another thrust is at the sub-nuclear level which means production of transgenic stock by microinjection of genes themselves

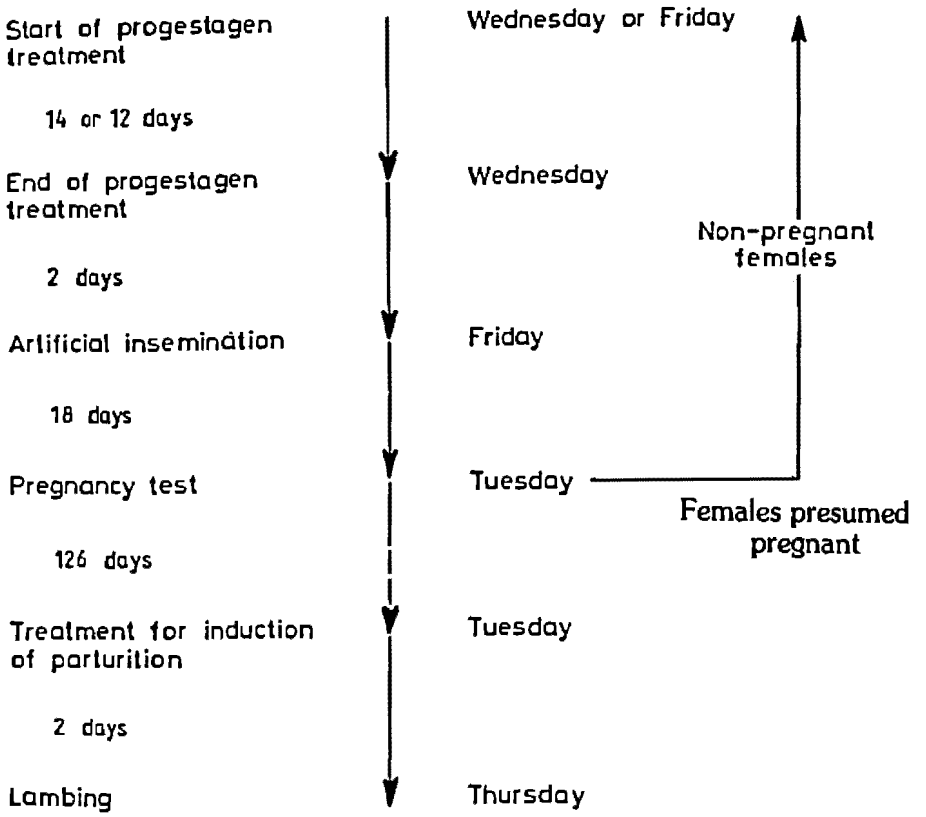

Fig 18. A moderately intensive flock management scheme that produces three lambs per two years. New batches of females are introduced into the scheme at 49-day intervals: interval between lambing and next AI is approximately 52 days[109].

into a pronucleus after fertilization but before the first cleavage. The first successful venture in this area was the introduction of foreign (rat) genes into mouse eggs. The genes were successfully incorporated in a small proportion of mice embryos (0.2 to 0.5 percent) which produced more growth hormone (GH), grew faster, and made more efficient use of food. The creation of transgenic mice showed that it was possible

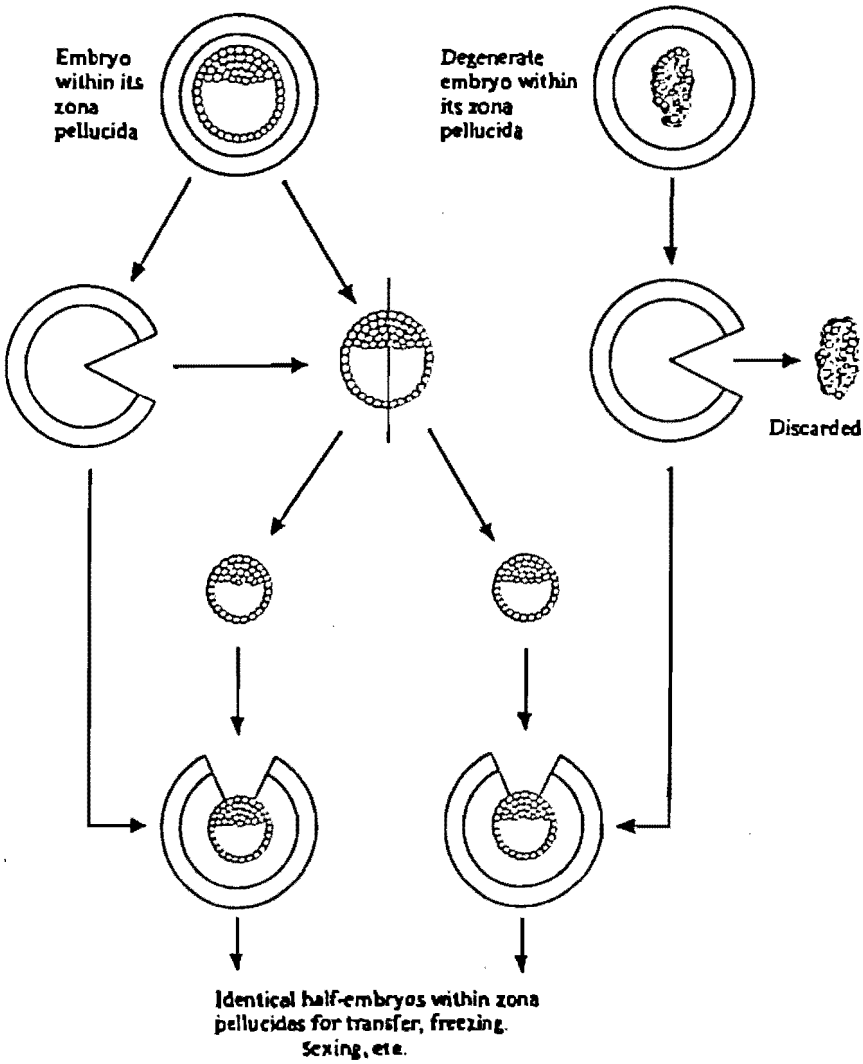

Fig. 19 Diagrammatic representation of the 'embryo splitting' procedure that is now widely used in commercial embryo transfer practice[103].

to transfer DNA between species regardless of the origin of the DNA. For a discussion on prospects for sheep, see a review by Ward and his

colleagues[110]. *In vitro* fertilization (IVF) which has been successful in many species including goats, sheep and our own, offers a medium where this can take place. It should be remembered that this technique is unlikely to replace conventional breeding techniques, not only because of insufficient knowledge of the mapping of genes in farm animals, but also because of the multiple gene interactions in the selection processes for economically important characters. One possibility is the genetic engineering of the inhibin gene, partially or wholly suppressing inhibin gene activity and leading to greater fecundity. This is unlikely to be necessary with the already highly fecund Indonesian goats and sheep.

CONCLUSIONS

1) Indonesian goats and sheep are fertile, fecund animals which moreover have a short *post-partum* anoestrus even when very lean (see also Chapter IV on Breeding).
2) However, losses between birth and weaning are often large.
3) Kid/lamb mortality could probably be reduced by better feeding in the last part of pregnancy, which would increase birthweights and perinatal survival. It is important to determine whether the higher birthweights and survival could be achieved by short-term supplementary feeding. Better management such as separation of the dam and neonate from other animals so that a strong bond is quickly established and the neonate gets its vital first drink of *colostrum*, should also help.
4) A resident buck/ram or careful daily checking of oestrus with a male is necessary to shorten *interpartum* intervals.
5) Supplementary feeding before mating is probably not needed as litter sizes are already high on maintenance feeding. If higher litter size is required, genetic selection is more economic than expensive supplementary feeding. Alternatively, short-term supplementary feeding for under two weeks is worth testing.
6) In deciding optimum litter size for village conditions attainable growth rates of kids and lambs have to be considered as well as total weights of litters weaned. It is obvious that when litters do

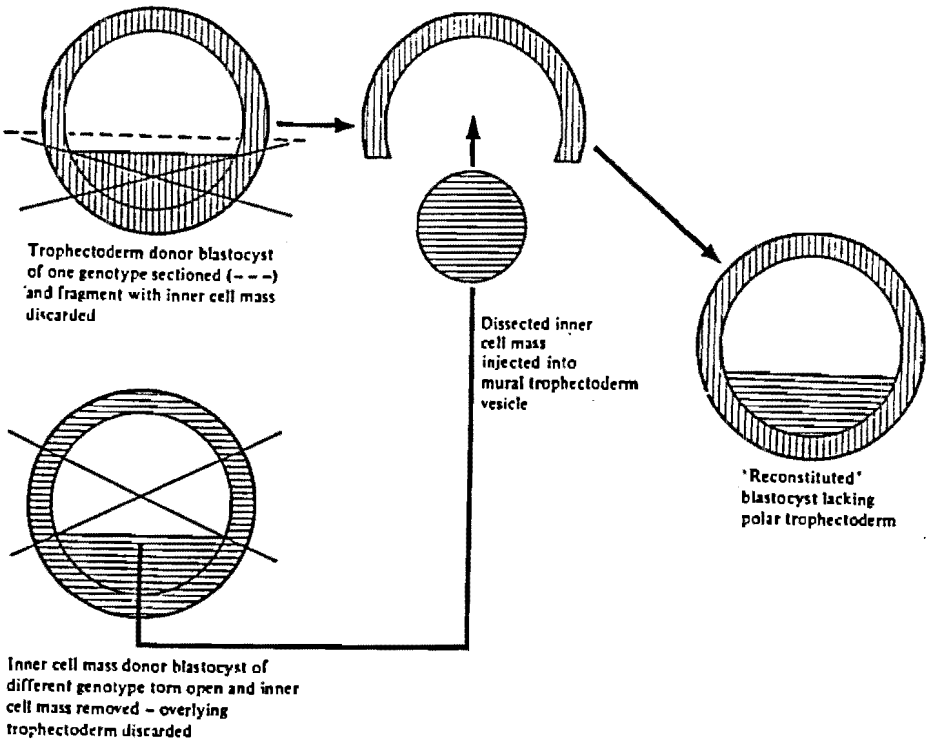

Fig. 20 Scheme of experimental 'reconstitution' of mouse blastocyst from genetically dissimilar trophectoderm and inner cell mass[103].

not survive (or only one or two young do), they are not more economic than single births. One or at most two well-grown offspring reaching puberty and a higher sale price earlier may pay better than three, four or five runts. If this is true, and it should be possible for economists to produce figures from existing data, then, perhaps selection for more than two kids or lambs is not desirable except as an exercise in genetics.

7) The low growth rate of Indonesian goats and sheep is sometimes given as a reason for cross-breeding with a faster growing breed or breeds. Usually the comparison is made between well-fed animals in temperate zones and poorly-fed animals in the village

in the tropics. However, when the growth and reproductive performance of JTT and Border Leicester X Merino lambs, on high planes of nutrition were compared, although mean growth rates of 162 and 216 g/day respectively were obtained, the total weight of lambs weaned was 58 percent higher in the JTT because of their superior reproductive performance[111]. Thus, temperate zone animals showed irregular oestrous lengths because of lack of photoperiodic stimulus and if they did reproduce, their litter sizes were smaller. Selection within the well-adapted native breeds is much more likely to be successful than crossbreeding with breeds from temperate zones.

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CHAPTER VII
HEALTH ASPECTS OF GOAT AND SHEEP PRODUCTION

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INTRODUCTION

One of the factors affecting livestock production in Indonesia is animal health, rendering programs for control of livestock disease very important as such diseases can cause large economic losses[1]. There is little information available about the relative incidence and economic importance of different diseases in Indonesia although a number of reviews[2-5] have been written. These studies indicate that parasitic disease is by far the most important. Significant diseases of small ruminants in Indonesia are discussed in this Chapter with the exception of parasitic disease which is covered by Carmichael in Chapter VIII.

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A. BACTERIAL DISEASES

The most important bacterial disease of small ruminants is pneumonia caused by the *Pasteurella species*. Other diseases include those caused by Escherichia coli, Footrot, Clostridial infections, Anthrax and Pink Eye.

I. PNEUMONIA

Pneumonia is a common cause of loss in sheep and goats[2,4]. Pneumonia was the commonest clinical finding in both sheep and goats, in an abattoir survey on Java[6].

Pneumonia in small ruminants is usually caused by *Pasteurella haemolytica*, but other agents (*Mycoplasma* spp., *Chlamydia* and viruses) may also be involved. *Pasteurella haemolytica* causes disease only in animals whose resistance is low due to adverse environmental conditions, poor nutrition or stress. An outbreak may be precipitated when animals are transported. Young animals are more susceptible than adults. Losses are due to reduced weight gains and deaths.

Animals may die before clinical signs are seen. Other animals in the group usually show laboured breathing, coughing and nasal discharge. Diagnosis is generally possible from clinical signs and history. Lungs of affected animals are fluid-filled at post-mortem. Oxytetracycline is generally highly effective in treating the disease. Vaccines against *P. hemolytica* are available, but their use is unlikely to be justified in Indonesia since they may provide only incomplete protection and are expensive.

II. ESCHERICHIA COLI

The commonest disease causing mortality in very young animals is that caused by *Escherichia coli* infection (a number of viruses may also be involved), and joint-ill, caused by a variety of bacteria which enter via the navel to cause a septicaemia, with purulent arthritis of one or more joints. Improved management practices, aimed at increasing the neonate's resistance to disease and reducing the challenge of infection, are discussed in detail in Chapter VI.

III. FOOTROT

Footrot is associated with wet, dirty conditions. It is a bacterial disease caused by *Bacteroides (Fusobacterium nodosus).* It causes lameness which, in severe cases may prevent animals from grazing or leeding normally.

IV. CLOSTRIDIAL INFECTIONS

Clostridial infections, especially tetanus and enterotoxaemia of lambs, have been recorded in Indonesia[3]. These diseases generally cause sporadic losses. Effective vaccines are available.

V. ANTHRAX

Anthrax is a bacterial disease which is nearly always fatal and is found worldwide. It affects not only ruminants, horses, and pigs, but also wild animals eg deer, rabbits, and swine, and humans[7]. It is one of the important zoonoses in Indonesia.

The cause of anthrax is *Bacillus anthracis*, which is gram-positive, rod-shaped, non-motile, and spore-forming. The centrally formed spores are produced when the oxygen supply is adequate. Spores are not found in the blood, within the affected animal or in undissected cadavers. *Bacillus anthracis* produces a complex toxin. The bacteria are enclosed within a capsule, which protects them from destruction by phagocytosis produced by the infected animal.

Anthrax in animals occurs in three forms, i.e. peracute, acute (rapid death before clinical signs are detected), and chronic. The two former types are usually found in goats and sheep, while the latter is commonly found in pigs. The diagnosis of anthrax is based on history, appearance of the cadaver, succesful isolation and identification of the causal agent in the laboratory. In cases where the above methods cannot be applied, the Ascoli precipitation test may still be used to diagnose anthrax in the laboratory[8].

Anthrax is often too acute for treatment, but where possible, penicillin-G should be given at a rate of 20,000 to 40,000 International Units (IU)/kg body weight intramuscularly daily. Anthrax in goats and sheep can be prevented through vaccination. Mass vaccinations of healthy, susceptible livestock should be undertaken in enzootic areas where anthrax may erupt at least annually.

VI. PINK EYE

This disease affects not only sheep, but also cattle, goats, pigs, and chickens[9]. In sheep the disease is caused by *Colesiota conjunctivae*, while in goats the agent is *Rickettsia conjunctivae.*

Rickettsiae are short or oval rod-shaped microorganisms, truly parasitic, and will only grow when incubated in live media, e.g. in chicken eggs[10]. The organisms are gram-negative however, staining is not commonly applied to examine this organism. Their size is smaller than that of most bacteria, being about 300 nanomoles (nm).

Among the diseases caused by *Rickettsiae*, Pink Eye is the only rickettsiosis which affects a specific organ, i.e. the epithelium of the conjunctiva.The main vector of this disease is a fly (*Musca autumnales*).

In mild cases, the affected eye turns watery, while the white of the eye and the conjunctiva appear reddish. The eyelids appear swollen and the cornea becomes cloudy with distinctly visible blood vessels[11]. The infected eye usually recovers without impairment within a week. Secondary infection may cause a purulent conjunctivitis and in severe cases this may lead to corneal ulceration. Rarely the ulcer bursts and the animal becomes blind.

Clinical signs and the history of the disease alone are sufficient to make a diagnosis of Pink Eye. Most animals recover spontaneously, and herding animals together for treatment may cause spread of infection. Broad spectrum antibiotics normally in the form of ointment, may alleviate the severity of the disease and the incidence of secondary infection. Some workers believe that in addition, daily doses of 15 mg riboflavin are effective.

Immunity after infection in sheep lasts between 100 to 250 days, after which the animals are again susceptible to infection[11].

B. VIRAL DISEASE

CONTAGIOUS ECTHYMA

Contagious ecthyma or Orf, is a viral skin disease which is highly contagious and which affects both goats and sheep. The disease mainly affects the skin around the mouth, but lesions can spread over the face and elsewhere, particularly the legs and axillae. The disease

was first reported in 1919 and at the time referred to as scabby mouth disease, but it can affect other parts of the body. The causal agent is a Pox virus and three types of this disease i.e. the labial, podal, and genital types have been described[12].

The virus is highly resistant to environmental conditions, grows readily on the infected animal, and in pastures. It may survive for months or even years[13]. Infection occurs where the virus comes in direct contact with a susceptible animal, for example from farm equipment, animal attendants, or pastures contaminated with the virus. Transmission through inhalation has so far not been reported, but mechanical factors causing injury to the skin are important in facilitating infection[14]. Cases with lesions on the udders of ewes and the mouths of their lambs can be seen.

The predominant clinical signs are raised and crust - forming lesions on the lips. In goats and sheep, the clinical signs will appear one to three days after infection, and, depending upon the animal's condition, the disease can last for three to four weeks[15] or longer when it is accompanied by bacterial infection. Animals with immunity disorders may suffer for months[16]. The mortality rate is usually low, about two percent, but can be higher in young animals[17].

To the experienced veterinarian, diagnosis of this disease is based on typical clinical signs. Laboratory diagnostic techniques are the Agar Gel Precipitation (AGP) and the Fluorescent Antibody Technique (FAT). When lesions in body parts other than lips are present, the diagnosis should be aided by laboratory examination, since similar clinical signs can be found in several other diseases, for example, suspected blue tongue, foot-and-mouth disease, goat pox, stomatitis, periorbital dermatitis, photosensitization and scabies. At autopsy, lesions may be found in the mucosa in the mouth (lining the gums, tongue, and palate) and in the gastro - intestinal tract[18,19].

Antibiotics can be administered to eradicate bacterial secondary infection. Nutritious feed should be given to help recovery. Vaccination is the best way to prevent orf infection. Animals in infected areas should be vaccinated, but vaccination of animals in known orf - free areas is not recommended. Livestock transferred to infected areas should be vaccinated immediately upon arrival. If orf infection is suspected (e.g. from scars left by lesions on the mouth), animals should

not be transferred or their arrival be postponed until the animal has totally recovered.

C. METABOLIC DISORDERS AND TOXICITY

I. BLOAT/TYMPANY

Bloat or tympany is a condition in which the rumen is distended with gas. It occurs either when there is obstruction of the esophagus which prevents eructation of gas or as a result of over-production of gas or foam. This latter or 'frothy' bloat is due to abnormal fermentation, and is related to the concentration of soluble protein in the rumen. Gas persists in the form of small bubbles which do not stimulate reflex eructation, and the rumen swells.

Bloat is commonly observed in temperate countries when animals feed on large quantities of legumes. Leaves of temperate zone legumes that have a high water and protein content (of the 18-S series) are responsible for bloat. They produce non - volatile acids such as citric, malic, and succinic which with other acids will rapidly (within 30 to 60 minutes) decrease the rumen pH. The rapid production of gases (CO_2 and CH_4) as fermentation end-products accelerate bloat. Frothy bloat should be uncommon in the tropics largely because of the low soluble protein content and the presence of precipitating agents in tropical legumes. Tropical legumes do not normally contain the bloat-inducing 18-S protein. The only tropical legume known to cause bloat at a young and rapidly growing stage is *Lablap purpureus*[20].

The rumen is grossly distended. As a result, the pressure in the abdominal and thoracic cavities increases, causing difficulty in breathing indicated by frequent, shallow and thoracic breathing. In turn, the lungs may collapse as well as the cardiovascular system, leading to blood circulation disorders and death within a few minutes.

Diagnosis is made on clinical signs. Post-mortem diagnosis is difficult, since there may be post - mortem distension of the rumen following death resulting from other causes. Other causes of death must be ruled out before a diagnosis of bloat is given.

Force - feeding about 50 ml of vegetable oil into the rumen through a tube often helps. 'Bloatinol' which consists of silica in one

percent Dimethycone and 5 percent peanut oil is quite effective in overcoming bloat[21]. The use of a trocar inserted in the part of the rumen which has the highest resonance to relieve the pressure in the rumen is the last resort because of the high risk of infection. The diet of remaining animals in the flock should be altered following cases of bloat. They should not be fed a high proportion of bloat-inducing legumes.

II. TOXIC PLANTS AND SUBSTANCES

A very large number of plants contain toxic compounds. Weed-killers, pesticides and other chemicals are also toxic. However, incidence of poisoning is generally sporadic. Plants and other substances most commonly linked with poisoning in animals in Indonesia are discussed here.

1. *Cyanide*

Cyanide is a toxic compound and many sources of cyanide, such as fish poisons, KCN and NaCN, pesticides (containing HCN), $Ca(CN)_2$, fertilizer and plants that contain cyanogenic glucosides can kill both animals and human beings[22,23]. Cyanide intoxication (from cassava) in Indonesia is often not reported although it is frequently experienced in the field.

The toxic plants are not palatable, so under normal conditions animals would not eat these plants. Toxicity problems occur if animals are given these plants when they are hungry and the only available feed is that with high cyanide content, so that they consume large amounts in a relatively short time. Poisoning may also occur when animals drink river water which has been contaminated with 'potas' (NaCN) used to kill fish.

Cassava and sorghum planted at the end of the dry season grow very fast during the wet season and their leaves contain high cyanide levels. Fertilizers with high nitrogen levels will increase the cyanide content in leaves.

Death occurs because of the inability of cells to use oxygen. The lethal dose in sheep and goats is about 2.5 mg/kg body weight, but varies depending on the condition and age of the animal.

Clinical signs of acute cyanide intoxication appear within a few minutes after consumption of feed with a high cyanide content (cyanogenic plants). Breathing becomes more rapid and deeper, tremors occur in the muscles, and failure of muscular coordination (ataxia) sets in. Then the animal struggles, collapses, and gasps for breath, this being accompanied by convulsions. The pupils of the eyes become dilated and the mucous membrane appears bright red. There is salivation and the animal excretes faeces and urine.

Other disorders caused by cyanide poisoning are nervous symptoms called tropical atoxic neuropathy (TAN), lesions in the mucous membrane, spinal cord, and peripheral nerves[22,24]. Chronic cyanide intoxication also causes a continuously high level of thiocyanate in the body which may cause secondary goitre, with enlargement of the thyroid gland, especially when it is accompanied by a low iodine content in the feed[21,25].

Immediate treatment is needed in cases of acute poisoning to prevent death. Combined treatment with Sodium Nitrite (Na_2NO_2) and Thiosulphate ($Na_2S_2O_3$) is the classic therapy for such cases.

The recommended dosage for the two compounds is one ml 20 percent $NaNO_2$ and $Na_2S_2O_3$ given intravenously to animals weighing 45 kg. An alternative is to give one g $NaNO_2$ and 2.4g $Na_2S_2O_3$, dissolved in ten ml distilled water by intravenous injection.

Animals should be prevented from eating solely feeds containing large amounts of cyanide. Such feeds must be mixed with other feeds which do not contain cyanides. Bitter cassava leaves which contain high levels of cyanide should be chopped up and dried in the sun in order to eliminate most of the cyanide. Goats or sheep which have never or rarely been given feeds containing large amounts of cyanide should be given such feeds gradually, in small amounts over a period of several weeks to enable the animals to get used to eating small amounts.

2. *Anamirta coccolus*

This plant, known as 'Oyod Peron' (in Java) is a climbing plant that can reach a height of 15 m and grows well in areas less than 300 m above sea level. The stem can be as thick as an arm and has five to six smaller branches at the end of a big branch. Its fruit, the size of

grapes, are dark purple in color and often used to poison fish and birds in Irian Jaya. The seeds contain picrotoxin which affects the heart and the respiratory system, and is dangerous when consumed by livestock.

3. *Lantana camara*

This plant originated from tropical America and was introduced to Indonesia as a hedge plant. It can grow from sea level to 1700 m above sea level. *Lantana camara* is a shrub that varies in shape, can reach a height of 0.5 to four metres and produces a strong distinctive smell[26]. It grows well in open fields and in areas that are not too shady or too damp. Animals do not like to eat this plant, but poisoning occurs when it is mixed and consumed with other plants, in particular in the dry season when the food supply is limited. It was reported that 990 sheep died out of 1650 sheep poisoned by this plant in 1979[27]. This plant is widespread in Indonesia and has killed great numbers of livestock, especially cattle[28].

The active ingredient that is toxic to cattle and small ruminants is *lantanadene A*. Symptoms of poisoning are liver dysfunction, jaundice, and photosensitivity. (Photosensitization is discussed in detail in the section on Brachiaria). Other disorders may take place in the digestive tract and kidneys.

4. *Leucaena leucocephala (Lam), de Wit*

Leucaena leucocephala (*Lamtoro*) was introduced to Indonesia early in the 20th century from Central America as a shade tree in coffee plantations. It is an excellent fodder and provides fire - wood for cooking[29]. *Lamtoro*, which is now widespread in Indonesia, is believed to be a cross between *Leucaena leucocephala* and *Leucaena pulverulenta*.

The continuous provision of *lamtoro* at rates of more than half the feed eaten may cause poisoning. Stock from temperate zones are more susceptible, since they do not have rumen microbes to metabolize mimosine in the plant to a harmless by product. Instead, mimosine is metabolized in the rumen to 3,4 dihydroxy pyridine (DHP). DHP inhibits the mobilization of thyroxine in the thyroid gland, and eventually the metabolic processes in the body are affected. Tannin in this plant may inhibit the activity of digestive enzymes, i.e. trypsin,

amylase, and lipase. Symptoms in the form of hair loss, retarded growth, and excessive salivation occur[30,31] in temperate zones, but seldom in the tropics.

5. *Brachiaria species*

The special qualities of *brachiaria* grass are its ability to grow well in shady areas and along rivers to produce stock feed as well as to prevent erosion. This plant provides good sites for the growth of *Pithomyces chartarum*, a fungus that causes photosensitization.

Photosensitization in sheep after feeding on *lantana* and *brachiaria* has been reported in various places in Indonesia. Facial eczema was reported in sheep in Bogor and *dermatitis simetrica* in Lombok[32]. Brachiaria sp. grows abundantly in Indonesia. Photosensitization, linked with detection of liver damage and the presence of spores similar to those of *Pithomyces chartarum*, in the Brachiaria wash ingested by the sheep, has been reported in Indonesia[33,34]. Photosensitization appears as dermatitis or skin eczema that commonly affects cows, buffalo, sheep, goats, and horses. It has been reported in pigs, but occurrence in this species is rare. Various forms of photosensitization occur all over the world.

Photosensitization occurs when a photodynamic agent circulates in peripheral areas where ultraviolet (UV) rays of the sun reach the skin, especially around the mouth and nose, around the eyes and ears, around the vulva, and on the inner side of the hind legs: areas which are not adequately protected by hair or wool. The photodynamic agent absorbs energy from the UV rays which is then passed on to the components of the surrounding cells. The cell membrane breaks down and finally the cellular structure, to cause dermatitis. In serious cases crusts are formed which sometimes peel off.

The most common photodynamic agent is phylloerythrin which is a normal metabolite produced by anaerobic fermentation of chlorophyll in the rumen. In healthy animals, phylloerythrin is expelled from the body through the bile ducts. However, the toxin sporidesmin, produced by *Pithomyces chartarum* causes liver damage and constriction of the bile ducts, so that phylloerythrin cannot be excreted through the bile ducts. Instead, it enters the blood circulation so that its quantity in the blood increases.

Other agents may also cause photosensitization by liver damage. For example, plants containing alkaloid pyrrolizidine like Cenecio sp., *Heliotropium* sp., *Crotalaria* sp., and *Eupatorium* sp., and infestation with *Fasciola hepatica* which cause obstruction of the bile ducts.

Other photodynamic agents, for example hypericin and fogopyrin can cause photosensitization directly without previous liver damage. In this case, the photodynamic agents react directly with the UV rays on the skin and cause damage in the skin cells and tissues. Table 1 shows reports of photosensitization in sheep in Indonesia. Unfortunately livers do not appear to have been examined in all cases.

Table 1. Cases of photosensitisation by Lantana camara and Brachiaria species in sheep in Indonesia[27,29,39].

Place and year of incidence	Number of cases	Number of dead animals	Clinical symptoms and post-mortem changes
Lantana camara	1650	990	- photosensitivity, heart, liver, kidney damage
Brachiaria species			
Sawangan (Bogor) 1977	92	29	- eyes: watery; oedema around eyes, nose and lips - liver: swollen, yellowish and degenerated
Cigombong (Sukabumi) 1980	65	19	- oedema around eyes and ears
(Central Lombok) 1981	16	7	- facial *dermatitis simetrica*, oedema around eyes and mouth
Sel Putih (Medan) 1982	22	6	- dermatitis around mouth, eyes, nose and ears
Cicadas, Bogor 1983	10	9	- dermatitis not clearly visible as animals were kept inside - slight oedema around eyes - liver and kidneys: swollen

D. OTHER DISEASES OF GOATS AND SHEEP

Many other diseases may cause clinical disease in goats and sheep in Indonesia. It is beyond the scope of this Chapter to cover them all, and further information is available from, for example, the Goat Health Handbook[11].

Bluetongue is caused by an arbovirus. It affects cattle, buffalo and wild ruminants as well as sheep and goats. Clinical Bluetongue has been observed in Indonesia only in imported Suffolk sheep. The Bluetongue virus has been isolated in Indonesia and serological evidence indicates that the virus is widespread in sheep and goats[35]. Goats and sheep may act as a reservoir for the infection in cattle[2].

Foot-and-Mouth Disease (FMD) has mainly occurred in large ruminants in Indonesia, although the virus has been isolated from infected sheep. Indonesia is now officially free of FMD.

Malignant Catarrhal Fever is a disease which affects cattle and buffalo in many parts of Indonesia[36]. Sheep do not show clinical signs of malignant catarrhal fever (MCF), but it is thought that they act as a reservoir for the causal agent.

Viral agents may also be implicated in pneumonia and neonatal diarrhea. Rabies is endemic in 20 of 27 provinces in Indonesia[37], and may affect goats and sheep[2].

Traditional Methods of Treatment

Small ruminant farmers in Indonesia often cannot afford expensive pharmaceutical drugs to treat sick animals. However, they have been treating their sick animals with natural herbs that are growing in the surrounding areas. This knowledge is generally obtained from the elders in the village and neighbours who have had previous experience. There are a number of recipes that are often used by farmers to treat diseases in animals. For instance, a mixture of sulphur and used engine oil is considered a cure against scabies; ground areca palm (*pinang*) fruit (5 to 10 g/animal) is given to adult goats to reduce the burden of intestinal parasites, (this should not be given to a pregnant animals). A mixture of one litre tobacco sap and 30 g ferro-sulphate or copper sulphate is believed to have the same effect on gastro - intestinal parasites. To improve appetite and prevent bloat, a solution containing tamarind and molasses mixed with water is

force - fed to the suffering animals. Recently, a survey showed that a number of traditional medicines are generally used by farmers in East Java[38]. Unfortunately, no scientific evidence is available that has tested the effectiveness of traditional drugs. There is a need for more information to justify the traditional treatments in order to provide farmers with inexpensive methods to treat their sick animals. This might reduce the high mortality rate encountered in small ruminants in the villages and also limit the need to import expensive pharmaceutical drugs which smallholder farmers cannot afford to buy. Areca palm (*pinang*) and *Cucurbitaceae* species (*Biji labu*) are currently under investigation at the Research Institute for Animal Diseases (Balitvet).

CONCLUSIONS

1) Little information is available in Indonesia about the incidence or economic cost of the diseases discussed above. There is a shortage of trained veterinarians and technicians leading to unsatisfactory reporting and recording of diseases. There is also a need for refresher courses for veterinarians and training courses for technicians in the areas of health disorders of farm animals.
2) Diagnosis, vaccination and treatment with pharmaceutical products is effective for many of those health disorders, but the smallholder farmer cannot afford those medicines. Traditional medicines from local plants are available, but there is little information on their effectiveness, toxicity (if any), dose rates and best extraction procedures.
3) There is a need to train key farmers in methods of detection, prevention and treatment of health disorders of farm animals.
4) There is a need for a larger budget for research and development of accurate methods of detection and treatment of the most important health problems of small ruminants in Indonesia.

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CHAPTER VIII

INTERNAL AND EXTERNAL PARASITES AS CONSTRAINTS TO PRODUCTIVITY OF SMALL RUMINANTS IN THE HUMID TROPICS

I. H. Carmichael*

INTRODUCTION

This review attempts to summarise the state of present knowledge concerning the occurrence, epidemiology, pathogenicity, treatment and control of the important internal and external parasites of small ruminants (goats and sheep) in the humid tropics. Because of the diversity of climatic conditions and farming practices within this geographical zone, the review concentrates mainly on broad principles arising from observations and research findings in the few areas in which systematic work has been done. It also refers to recent fields of research elsewhere which could lead to improved control methods or the development of new management concepts to assist parasite control of small ruminants in the humid tropics. The main sources of

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currently available information do not reflect the overall livestock distribution and density in the humid tropics. More work has been done in some countries with relatively small goat and sheep populations (e.g. Malaysia) than in others with greater animal numbers (e.g. Bangladesh). Nevertheless, this does not reduce the likely benefits from broad application of data generated in one area to larger livestock populations elsewhere. There is, however, no truly satisfactory substitute for local knowledge - our overall understanding of parasitic disease in the humid tropics would doubtless benefit greatly from further specific studies to clarify parasitic problems in countries where little or no work has been done.

I. THE HUMID TROPICS

The humid tropics can be defined as climatic areas where conditions of 'humid tropicality' occur for at least nine months per year. Monthly 'humid tropicality' requires a relative humidity greater than 65 percent at all times, a mean temperature above 20°C and rainfall (usually over 75 mm) which exceeds evaporation during that month[1]. Equatorial rainforest areas which all have heavy rainfall and a uniformly hot and moist climate are included. Monsoon climates with only a short dry season in the winter half year are also included, but those with insufficient total rainfall to compensate for even a few 'dry months' in which precipitation is less than 60 mm, are not. Rainfall and temperature data for a representative humid tropical environment (North Sumatra, Indonesia) are illustrated in Fig. 1.

Livestock populations in humid tropical countries are summarised in Table 1. India is not included, although much of it is monsoonal, little is defined as humid tropical. Likewise some areas of Sri Lanka do not qualify. Much of South-East Asia, the Indonesian archipelago, Philippines, New Guinea, Oceania, parts of central and western Africa, the Carribean and equatorial South America have humid tropical climates. However, for the purposes of this review, attention is focussed on the Asian and Pacific areas.

Approximately 30 percent of goats and 78 percent of sheep in this area are found in Indonesia (Table 1), the majority in Java. Excluding Bangladesh, Indonesia has 72 percent and 89 percent of the total goat and sheep populations of the humid tropics respectively,

hence information from there is an important component of this review.

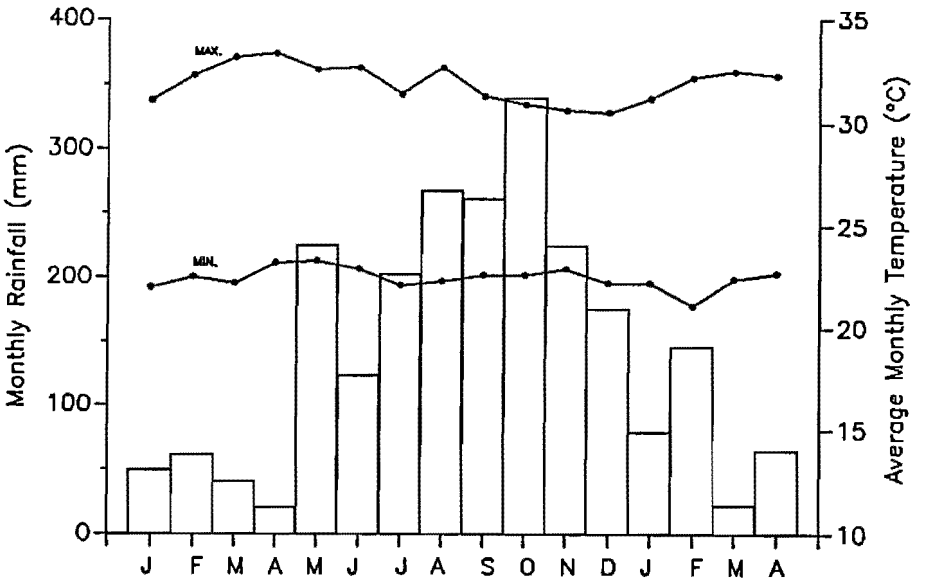

Fig. 1 Representative meteorological data for the humid tropics (North Sumatra Indonesia).

II. PARASITES AND PARASITISM

A parasite is a living organism which survives at the expense of another living organism known as the host. Parasites that live within a host are called endoparasites. They obtain nutrients from the organs or tissues of their host in order to grow and reproduce. The ability of the host to produce normally or even to survive is often decreased as a result of the parasite's presence. Some parasites are much more harmful (pathogenic) than others and commonly lead to illness or death of their host whereas others cause little or no ill effects. Parasites that live or feed on the skin or related tissues of a host animal are called ectoparasites. Some cause itching and irritation of such severity that the animal feeds irregularly and fails to thrive. Others are responsible for serious damage, often with a fatal outcome.

Internal parasites of small ruminants may be divided into three categories: nematodes, or roundworms; cestodes, or tapeworms; and trematodes, or flukes. The roundworms are the most important internal parasites of the humid tropics, but flukes can also be responsible for losses in some areas. Tapeworms are of minor importance in small ruminants in the humid tropics and will not be discussed further in this review. The most important external parasites are certain mites and lice and the larvae (maggots) of some fly species.

Table 1. Livestock populations in the humid tropics ($x10^3$) *

Country	Goat	Sheep
Bangladesh	22000	900
Cook Islands	5	-
Indonesia	11300	5750
Laos	143	-
Malaysia	315	200
Myanmar (Burma)	1040	280
Philippines	2107	30
Sri Lanka	132	31 **
Thailand	140	178
Vietnam	451	-
Fiji	123	-
Papua New Guinea	2	4
Tonga	9	-
Vanuatu	11	-
Total	37778	7373
% of world total	6.4 %	10.65 %

* Source: Food and Agriculture Organisation of the United Nations. Statistical Profile of Livestock Development in Asia-Pacific Region (1981-91). RAPA Publication 1992/21, FAO, Bangkok.

** Approximately 75 percent of the 526,000 goats in Sri Lanka occur in the non-humid tropical areas of the country.

III. SMALL RUMINANT PRODUCTION SYSTEMS AND THEIR RELATIONSHIP TO PARASITES AND PARASITISM

The level of exposure of small ruminants to internal and external parasites in the humid tropics is strongly influenced by management procedures. An understanding of the production system and the biological concepts concerning parasite transmission is important for the design of control programs. The main types of production systems within a wide range are as follows:

1. ***Tethering***

   This usually occurs where smallholders have only a few animals. The animal is tied to a peg or tree and allowed to graze around it. After a couple of hours it is shifted to another location and tied to another peg or tree. Animals are usually housed overnight.

2. ***Intensive***

   This is the 'cut and carry' system, more popular in South-East Asia with goats than with sheep. Animals do not graze but are permanently housed in covered pens, (*kandangs**) usually of bamboo and with raised, slatted floors. Their diet consists entirely of harvested natural or roadside grasses and/or agricultural by-products.

3. ***Semi-intensive***

   The animals are grazed during the day and housed at night. Grazing is either on common land, along roadsides, canals or rice field verges, under plantation crops, or sometimes on planted pastures. Supplementary feed in the form of cut forage may or may not be provided overnight in the *kandang*. This system has been extended and modified on a few rubber, coconut and palm oil estates for sustained production on a moderate to large scale.

Common to all of the above production systems are opportunities for animals to be exposed to infective stages of internal parasites either during periods of grazing or through contamination of forage which is cut and brought to housed animals. Infection with both internal and external parasites can also be acquired within and around the *kandangs* themselves. A fundamental objective of management (and one which can usually be achieved through simple procedures), should be to reduce this exposure to a minimum. The control methods which it is possible to apply in the humid tropics are quite different to many other parts of the world. This is because small ruminants are generally not a major economic part of the farm enterprise and fulfil only secondary roles such as providing a source of meat and manure, a

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* The term '*kandang*' is used for raised covered pens made of local raw materials in which goats and sheep are housed either permanently or overnight. They are a common feature of the humid tropics. '*Kandang*' is a more widely acceptable and descriptive word than alternatives such as 'pen', 'shed', etc.

form of savings, of cultural and religious functions, a means for accumulation of wealth, and in some areas a source of recreation etc. In addition, farms are small, each has only a few (two to five) animals and capital assets are very limited. It follows not only that animal husbandry practices are generally inefficient and not directed towards maximum productivity, but that radical changes in management are unlikely to be widely adopted. Specific recommendations concerning tethering, grazing patterns, forage collection, manure disposal and *kandang* hygiene will be given later in the Chapter.

A. INTERNAL PARASITES

I. LIFE CYCLE OF THE COMMON ROUNDWORMS (NEMATODES)

The important roundworms of small ruminants in the humid tropics live in the gastro-intestinal tract and all have direct life cycles. This means that they are transmitted from animal to animal by means of a free-living phase during which development takes place in the environment external to the animal. There are no intermediate hosts.

Female worms lay thousands of eggs which pass out in the faeces of infected animals. Under optimum conditions (for the worms) eggs hatch into first stage larvae (L1) within 24 hours. Larvae have a tough outer skin or cuticle. Before another animal can be infected the L1 must progress through two moults of its cuticle to reach an infective stage. The life cycle of important nematodes of goats and sheep is shown in Fig. 2.

The L1 feeds actively on bacteria in the faeces then sheds its cuticle one to two days later when it moults into the L2 stage. The L2 feeds for a further two to three days and moults into the L3 or infective larval stage. This time, however, it does not shed its old cuticle and the L3 is enclosed within two cuticles. It is therefore unable to feed and must survive on its stored food reserves until it is taken in by a host and can develop further. Although the L3 is well protected by its double 'skin' and can survive for extended periods in mild environments it remains vulnerable on two counts. First, it requires moisture to survive and, like the L1 and L2 stages, will die if subjected to prolonged

dry conditions. Second, at high temperatures it increases its activity and can rapidly exhaust its stored food supplies. This is because unlike the L1 and L2 stages it is unable to feed and thereby replenish its reserves.

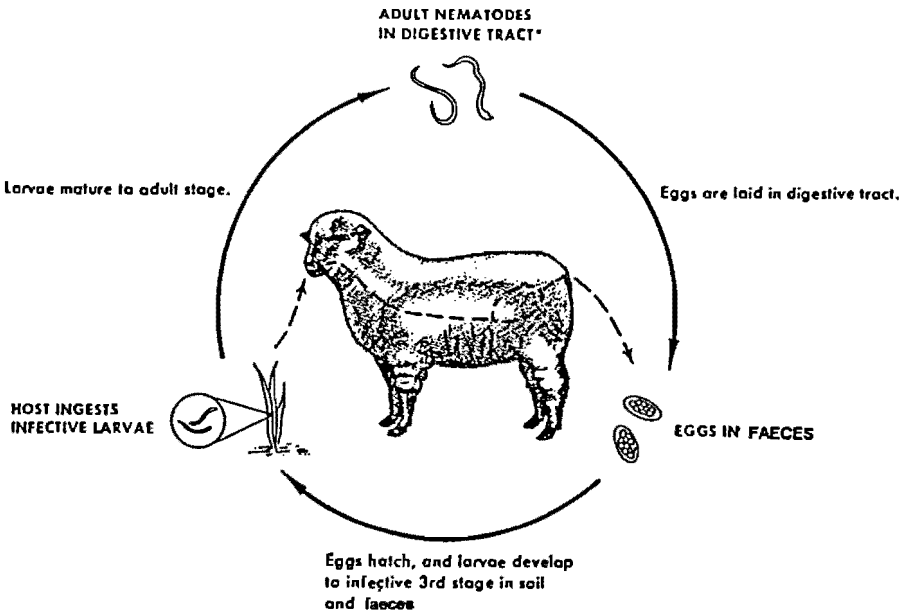

Fig. 2 Life cycle of the important nematodes of goats and sheep.

The free living stages of the various roundworm species have different optimum requirements for temperature and moisture, which are limiting factors in their transmission and ultimately determine the environment and time of the year in which each is most abundant.

The infective larvae migrate on to blades of grass where they survive on drops of moisture. They are taken in with the feed while animals are grazing and develop further to adult worms in the gastro-intestinal tract. In the absence of adverse conditions, the environmental phase can be completed in only six to seven days and the worms can reach maturity in the animal in two to three weeks and start producing eggs. Environmental contamination therefore, can

rapidly build up to extremely high levels, particularly under warm moist conditions which favour the development and survival of the free living stages of several important worm species.

II. LIFE CYCLE OF FLUKES (TREMATODES)

The important flukes live either in the gastro-intestinal tract or organs associated with it such as the liver and pancreas. The life cycle is indirect, which means that development must occur in at least one intermediate host before the fluke can be retransmitted back to its ruminant host. The life cycle of the liver fluke, *Fasciola gigantica* is shown in Fig. 3.

Each adult fluke has both male and female reproductive organs. Adult flukes in the host lay eggs which pass in the faeces. Under suitable conditions of moisture, warmth and light, a larva called a *miracidium* hatches. This penetrates a snail host where it develops into a *sporocyst* which may divide and produce either 'daughter sporocysts' or *redia*. The final stage known as the *cercaria* develops either from a *sporocyst* or *redia*. *Cercariae* leave the intermediate host snail and then may attach to vegetation in a protective cyst called a *metacercaria*, or in the case of some fluke species they may invade a second intermediate host (e.g. an ant or grasshopper) and develop into a *metacercaria* in that host. When the *metacercariae* are eaten by a grazing animal (either on vegetation or within the second intermediate host), the transmission cycle is completed. Because asexual division can occur at various stages through the life cycle, millions of *cercariae* can eventually develop from a single egg which has been passed in the faeces. This contrasts with the roundworm life cycle where one egg gives rise to only a single infective larvae.

Two fluke species to be discussed later (*Fasciola gigantica* and *Gigantocotyle explanatum*) each have a single intermediate host, a water snail, whereas another fluke *Eurytrema pancreaticum* uses a land snail as its first intermediate host and certain grasshopper species as the second intermediate host.

III. THE EFFECTS AND OUTCOMES OF INTERNAL PARASITE INFECTIONS

Internal parasites are responsible for a wide range of effects on small ruminants including reduced appetite and lowered feed intake,

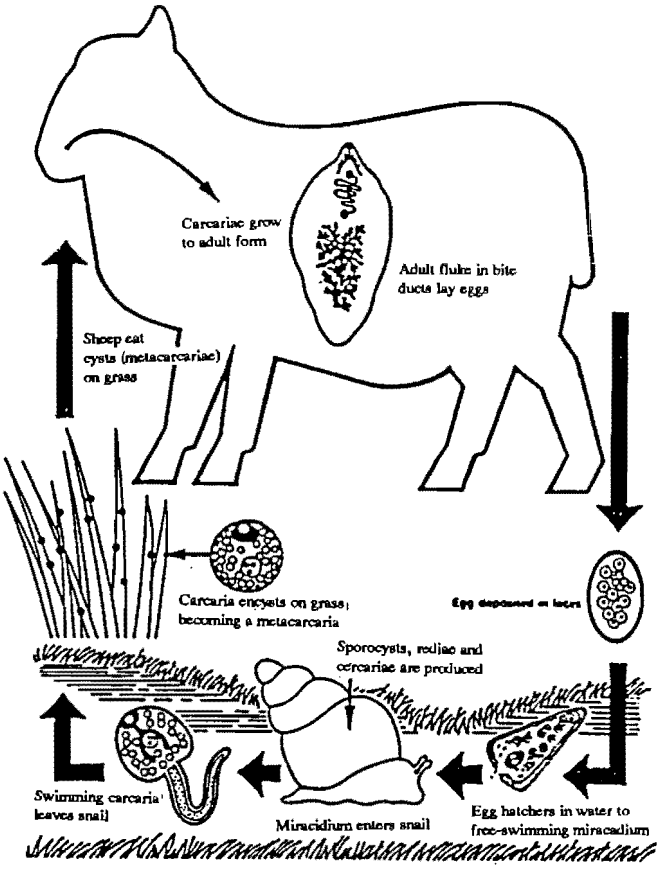

Fig. 3 Life cycle of a trematode, *Fasciola gigantica* (the liver fluke).

loss of blood and plasma proteins into the gastrointestinal tract, disturbances in protein metabolism, depressed levels of minerals and reduced activity of some intestinal enzymes. They cause these effects either by actively sucking blood or by extensively damaging the lining of the gut, or both.

Poor growth rate or outright loss of weight is one of the most common outcomes of internal parasitism. In many animals with low or moderate levels of parasitism or with heavy burdens and a degree of natural immunity, a failure to thrive is all that occurs. Under traditional systems of management in the humid tropics, thin, undernourished-looking animals are usually and understandably accepted as normal,

given that the greatest overall constraint is the availability of feed[2,3]. Moreover, the prices paid when small ruminants are disposed of to provide cash for religious or family needs are generally not related to the body weight or condition of the animals. It follows that, apart from the more commercialised systems, close attention is rarely given to the animals that fail to thrive or grow vigorously, save, on occasions, to increase their supply of food.

Diarrhoea is a prominent clinical sign in some common parasitic infections (e.g. *Trichostrongylus colubriformis*) and contributes to the poor condition of animals and their failure to thrive. However, it is often not linked with parasitism because there can be numerous other causes such as bacterial or viral infections or certain types of feed. Anaemia is the final outcome of infections with the most important parasite of small ruminants in the humid tropics, *Haemonchus contortus*. This parasite not only sucks blood in the fourth stomach (abomasum), but moves around leaving wounds on the lining of the stomach which continue to bleed freely. When animals become extremely heavily infected, severe and rapid development of anaemia can be quickly followed by death. More often, however, the animal is progressively drained of its body reserves as it attempts to replace the iron and protein which are being lost. It gradually becomes weaker, loses body condition until it is emaciated and anaemic and eventually dies if not treated. The milk yield of ewes infected with *H. contortus* is drastically reduced[4]. This has additional important implications for the lamb whose susceptibility to worms is likely to be increased because of a deficient milk supply[5]. Under field conditions many lambs die because their dams simply do not have enough milk to feed them, or because they are exposed to very high levels of infection early in life. ***Ultimately the overall effect of all of the common internal parasites whatever their location in the host, is exhaustion of the body reserves and, if infection is severe enough or sufficiently prolonged, death.***

It is only when deaths occur that the losses due to internal parasites are clearly recognised and documented. For example, in Fiji, the weaning percentage rose by over 20 percent on one government goat station following the use of an effective treatment program and was accompanied by a 69 percent reduction in mortality[6]. In Sri Lanka it was found that approximately 25 percent of kids dying at a

research farm did so at two to three months of age, probably from worm infections[7]. A serious situation was reported in Bangladesh[8] where over a three year period 82 percent of kids less than six months of age and 48 percent of adult goats died; 25 percent and 43 percent of these deaths respectively were ascribed to internal parasitism. Investigations of similar problems in Malaysia[9,10] and Indonesia[11, 12] confirm problems with parasitism in those countries and provide sufficiently representative data which can be related to other countries with similar climates. However, there is no justification for extrapolating data from seasonally tropical countries e.g. Ghana[13]; Nigeria[14]; Sierra Leone[15]; India[16] to the humid tropics even though those countries also consistently identify similar parasite problems. The climates are far too different for meaningful comparisons to be made. Whereas the latter areas are characterised by a distinctly seasonal rainfall, a clearly defined often prolonged arid period and marked temperature variations, the humid tropics have a seasonal rainfall pattern, constant high humidity and only minor temperature fluctuations.

The most important parasites of goats and sheep in the humid tropics, those of lesser importance and those which are probably unimportant or whose presence needs to be reconfirmed are summarised in Tables 2, 3 and 4 respectively together with comments and supporting references.

IV. THE SEASONALITY OF INTERNAL PARASITES IN THE HUMID TROPICS

It was shown by regular monitoring of faecal egg counts and the demonstration of rapid reinfection after successful repeated treatments that transmission of parasites occurred readily throughout the year in a North Sumatran rubber plantation[12]. These results are shown in Fig. 4. These findings were similar to earlier studies in Serdang, Malaysia [17,18] and the humid zone of Fiji[19].

In North Sumatra, *H. contortus* was the predominant parasite recovered in cultures made from the faeces of sheep throughout the year, except that *T. colubriformis* became more prominent in June-July. The period of lowest uptake of worms by grazing tracer sheep was during July-August, a little later in the year than in Malaysia. However for both locations low larval uptake corresponds with the

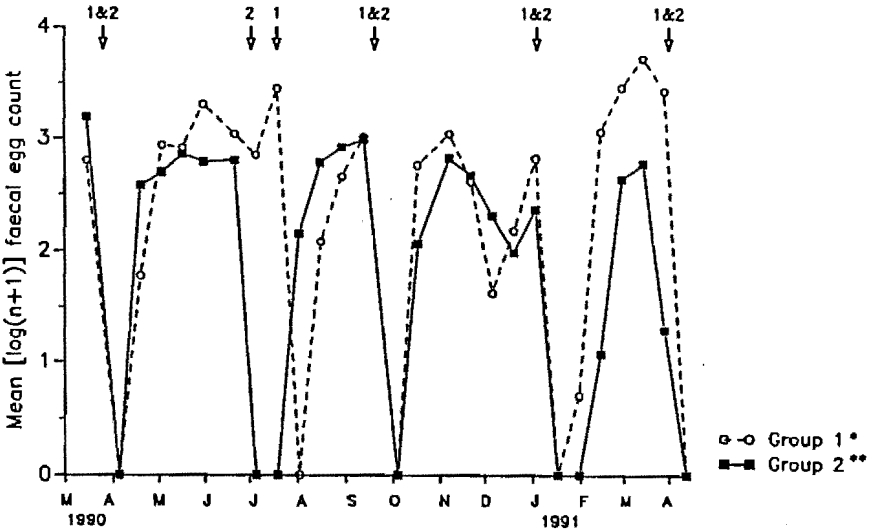

Fig. 4 Mean faecal egg counts in rotationally grazed* and shepherded sheep at Sungai Putih, North Sumatra, March 1990-April 1991[12]. Counts in eggs per gram of sheep faeces (n) transformed to log(n+1) Arrows indicate successful deworming treatment of one or both groups.**

period of greatest rainfall. Ikeme, Fatimah and Lee (1986) raised the important issue of the influence of torrential rain on larval availability[20]. They pointed out that, whilst adequate moisture is essential for development of the preparasitic stages and larval migration onto herbage, excessive rainfall probably physically washes many of them from the pastures, thereby reducing their availability to livestock. Thus, ironically, in the humid tropics the 'drier' months of the year are possibly when the greatest transmission occurs. In general, the findings in North Sumatra by the author and his colleagues suggest an annual peak in overall transmission from December to March, which supports the prediction in Malaysia that parasitic gastroenteritis in grazing goats is likely to be most severe from November to February[17]. These intervals coincide with the periods of lowest rainfall in North Sumatra and Malaysia.

Table 2. The most important parasites of goats and sheep in the humid tropics.

Parasite	References	Comments
Internal		
Haemonchus contortus Barber's Pole Worm)	12, 18, 19, 47	The most important and widely distributed parasite of goats and sheep in the humid tropics. Sucks blood and causes anaemia, poor growth, decreased milk supply in ewes, weakness and death.
Trichostrongyus colubriformis (Black Scour Worm)	9, 11, 18, 19	Causes depression of appetite, poor growth and diarrhoea in goats and sheep throughout the area.
Oesophagostomum columbianum Nodular Worm)	6, 9, 18, 49	Recorded in Indonesia, Malaysia and Fiji. A highly pathogenic species which causes inappetence, diarrhoea and dehydration. Immature stages can cause extensive nodule formation and abscesses in the small intestine. Distribution needs to be confirmed.
Oesophagostomum asperum	12, 49	Causes severe nodule formation and disease similar to *O. columbianum*. Has only been found in the humid tropics and numerous references to *O. columbianum* may refer in error to this parasite.
Fasciola gigantica (Liver Fluke)	18, 48, 72, 73, 74	Widespread in Indonesia. Also occurs in Malaysia and the Philippines. Unpublished reports suggest high infection rates in some areas in Java; published records do not support this and give for several locations a range of 0 %-15 % in small ruminants, with much higher rates in cattle. There is considerable evidence that *F. gigantica* is primarily a problem of large ruminants and much less important in goats and sheep. This may be due in part to routine management practices which reduce the exposure of small ruminants to fluke infections. More important may be the relative resistance to infection of the indigenous sheep breeds[75,81].
(*Eurytrema pancreaticum* (Pancreatic Fluke)	9, 18, 50, 73, 76	May be much more important than currently recognised as a cause of chronic, irreversible ill thrift in adult sheep, especially in integrated plantation grazing systems where it can be a serious problem leading to wasting and death.
External		
Sarcoptes scabiei Sarcoptic Mange Mite)	6, 62, 77	The most commonly reported and devastating disease of goats in Indonesia. Less common in other countries. Highly contagious. Usually fatal if untreated. Treatment attempts frustrated by suspected long survival of mites off the host in housing.
Chrysomya bezziana Screw-worm Fly)	64, 65, 66, 67, 71, 78, 79	Widespread throughout the area as far East as Papua New Guinea. Infestation commonly follows birth - either the vulval area of the dam or the navel of the newborn animal. Injuries caused by insects, wire fences or the spikes of oil palms provide sites for strike. Untreated animals will be repeatedly struck with severe illness, debility or death following.

Table 3. Parasites of lesser importance.

Parasite	References	Comments
Internal		
Cooperia curticei	9, 18, 80	Found together with *Trichostrongylus colubriformis* in the small intestine but appears to play a lesser role than that parasite in causing diarrhoea and ill thrift. This was the only *Cooperia spp* recovered from both goats and sheep (Malaysia)[9,18] and in sheep (Indonesia)[80] which suggests that it is the species most suited to the humid tropics.
Mecistocirrus digitatus (Syn. Haemonchus sheatheri)	72	Reported from small ruminants but is much more important in cattle. No confirmed reports of disease (anaemia) in sheep or goats.
Trichostrongylus axei	6, 9, 18, 72, 76	Shanta considered it to be rare in Malaysia and Sani et al. did not recover it there from either sheep or goats. Its sole identification in Indonesia is in a museum collection. However, it is reported to be 'very common' in Fiji[6]. The importance of this parasite needs to be re-examined
Strongyloides papillosus	6, 9, 11, 18, 47, 76	Has a high prevalence in Malaysia according to Shanta but Sani et al. found only 3 % and 1 % prevalence in goats and sheep respectively in that country. Recorded from a museum specimen in Indonesia[72]. Mentioned as being common in Indonesia[11] without direct reference to data. Was not recorded during systematic field experiments in West Java[47]. Common in goats and sheep in Fiji[6]. More work is required to confirm its distribution, prevalence and contribution to disease or production loss. Currently its listing among the more important parasites is not justified.
External *Damalinia spp.* (Biting Lice) *Linognathus spp.* (Sucking Lice)	6	It is generally recognised that lice are widespread in the humid tropics and cause irritation and possibly direct or indirect losses in small ruminants. However no systematic studies have been done to determine the species present, their abundance, or their influence on the general health of the animals. The effect of *Damalinia* which causes itching and scratching would be restricted in sheep to 'louse worry' because the animals are not raised for wool. In goats any importance that *Linognathus* and *Damalinia* may have is probably overshadowed by the clinical prominence and severity of sarcoptic mange.

Table 4. Parasites which have been recorded, but are either economically unimportant or whose presence needs to be reconfirmed.

Parasite	References	Comments
Internal		
Bunostomum trigonocephalum	6, 44, 72, 76, 77, 82	Records of the presence of this parasite in Indonesia are mostly dated (1915-1920). More recent records usually refer to the early ones. However, Stevenson reports it as being 'frequently present' and 'often contributing to clinical disease'. The writer has been unable to confirm this. Not recovered from sheep or goats in Malaysia[9,18] but Shanta lists it as present there, with a low prevalence mainly in young animals. It is difficult to reconcile conflicting reports concerning *B. trigonocephalum* in Fiji. Severe infections reported[82] whereas Walkden-Brown & Banks do not include it on their list of parasites in goats and sheep in Fiji. Careful observations including the recovery of adult worms are needed to clarify the anomalies in the literature.
Gaigeria pachyscelis	49, 18	An uncommon parasite, morphologically similar to *B. trigonocephalum* (which could possibly account for some of the confusion concerning records of the latter parasite). An active blood sucker which is pathogenic even in small numbers and could be locally important.
Trichuris ovis *Trichuris globulosa*	9, 12, 18, 49, 76	Both species occur occasionally in goats and sheep in low numbers. They are unlikely to cause problems.
Fasciola hepatica	49, 72, 76	It is highly unlikely that *F. hepatica* occurs naturally in the humid tropics. The early Indonesian records refer to reports from 1893-1924 which are most likely incorrect identifications or records from animals imported from Europe. *F. gigantica* was not reported from that country until 1940; there are no confirmed reports of *F. hepatica* since then. Shanta confirms that *F. hepatica* is not indigenous to West Malaysia and notes 'recent findings have confirmed that this liver fluke is found only in animals imported from those countries where the helminth is prevalent'.
Oesophagostomum venulosum	9, 72, 76	Morphologically similar to *O. asperum*, a pathogenic nodule-forming species. The two species could be easily confused in a cursory examination. It would be beneficial to review the records of *O. venulosum* in indigenous sheep in the humid tropics because it is generally associated with the winter rainfall zone of temperate climates [83]. It is not considered to be pathogenic.
Cooperia oncophora *Cooperia punctata*	49, 76	These are generally regarded as parasites of cattle with small ruminants serving only as occasional hosts of low numbers of parasites. They have not been recovered from sheep or goats in recent years.
Moniezia expansa *Moniezia benedeni*	6, 9, 18, 49, 84	Common in Fiji. Sporadic in other areas. Unimportant in terms of disease, but can alarm farmers because detached segments (proglottids) from worms are easily visible in the faeces.
Paramphistomatidae *Conical Flukes)*	48, 49, 76	Several genera, including numerous species are common, although generally this group of parasites is more numerous in cattle and buffalo. Adults occur in the rumen/reticulum and are not considered to be important, but the immature stages cause marked irritation and inflammation as they migrate along the mucosa of the duodenum. Boray stresses that the pathogenic effects of this group of parasites, especially the subclinical outcomes (inappetence, retarded growth), have been grossly underestimated, but firm evidence is not available to confirm this realistic expectation. Moreover, under traditional farming practices slow growth rates do not usually constitute a major impediment to the enterprise.
External		
Chrysomya rufifacies *Calliphora sp.* (Blow Flies)	66	These are secondary invaders of wounds and do not initiate primary strikes. Widely distributed, but their importance greatly overshadowed by that of *C. bezziana*.

In the humid tropical environment arrested development of larval parasitic stages of nematodes in the host (*hypobiosis*) does not appear to be important, whereas in other environments it plays a significant role in ensuring that the parasite bridges adverse external conditions to improve its chances of survival. Only small numbers of arrested *H. contortus* and *Cooperia* larvae were recovered from tracer sheep in Sumatra[12]. Likewise, although arrested *H. contortus* larvae were found throughout the year in Malaysia, they accounted for only a very small proportion of the total *Haemonchus* burden[17].

V. THE SURVIVAL OF NEMATODE LARVAE ON PASTURE

In a review of the control of helminth parasitism in grazing animals in Malaysia[21] it was stated that in humid tropical climates the infective larvae of nematodes develop continuously and survive for long periods. The first assertion is verified by work in Malaysia[20], Fiji[19] and Indonesia[12]. The second is neither supported by field data nor by laboratory studies. Indeed at *low* environmental temperatures third stage larvae survive for long periods presumably due to a slow rate of utilisation of stored energy[22-24], whereas with increasing temperatures metabolic rates rise, there is exhaustion of energy supplies and reduced longevity[23, 25]. This phenomenon was clearly demonstrated under field conditions at Koronivia in Fiji, which is warm with frequent well-distributed rainfall and high relative humidity[19]. During the warmer months of the year, pasture larval counts at Koronivia declined below detectable levels five to nine weeks after the last artificial contamination; the onset of the 'cool' season from May to September was reflected in increased longevity of larvae from 13 to 17 weeks. These survival times are very short when compared with those of larvae in temperate regions, many of which survive several months or longer under cool moist conditions [24, 26, 27].

The author and his colleagues[12] confirmed the findings in Fiji in the slightly different humid tropical environment of a rubber plantation at Sungai Putih, North Sumatra. Unlike in Koronivia, there is no cool season at Sungai Putih. Mean monthly minimum and maximum temperatures remain remarkably constant at 22.0 to 23.5 C and 30.5 to 32.7 C respectively, with an overall average of 25.5 to 27.1 C. Humidity is always high and, with only one or two exceptions early in the year,

there is more than 50 mm of rain monthly. Even in the driest months rain falls on at least four to five days. Conditions are apparently ideal for development of infective larvae and their translation from the faecal pellets and soil to pasture. However, larvae fail to survive for extended periods on pasture in this environment. Mean faecal egg counts of experimental sheep grazed eight to ten and 12 to 14 weeks after pasture contamination were reduced 73 percent and 98 percent respectively compared with those of sheep grazed four to six weeks after pasture contamination. Corresponding reductions in total worm counts were 83 percent and 96 percent.

These authors also noted that the mean faecal egg counts of shepherded sheep were consistently below those of sheep on an approximately 60-day pasture rotation cycle. This was ascribed to the likelihood that, although shepherded sheep would eventually re-graze a particular area on the plantation or part thereof, grazing pressure *per se* was not a critical issue, being overshadowed by grazing quality and palatability. Therefore, sheep would tend to range more widely and cover previously grazed pastures less frequently than an average of every 60 days. Further observations on flock sheep supported these findings. Sheep restricted in their grazing to an area of the plantation which had been absolutely free of animals for at least several weeks had faecal egg counts reduced 78 percent to 97 percent six to 12 weeks later compared with sheep which were rotationally grazed on a flexible 30 to 60 day turnaround.

It is evident that significant reductions in larval numbers can occur on pastures in the humid tropics within a period which is short enough for the economic and practical management of those pastures. This is particularly so in a 'cut-and carry' system but can become more difficult where casual unsupervised grazing occurs along roadside or rice field verges, or close to villages. In these cases the challenge is to educate farmers that the health of their livestock will benefit from a system of rotation in which revisits of a few days to each area are extended to several weeks apart. Sociological interactions and the absence of alternative grazing sites will hamper the uptake of this concept, except in communities where fencing is established and communal grazing limited.

In plantations, several additional management factors apply. The ability of plantation forages to regenerate after grazing depends not only on weather but on many other factors as well, including light penetration through the canopy, extent of grazing (a product of stocking rate and time), composition of forage species etc., hence optimum utilisation will differ from area to area even within the same plantation[28]. The important factor relevant to nematode control in plantations will be the period of time that the pasture can be kept entirely free of stock between episodes of grazing. Although moderate numbers of larvae may persist for eight to ten weeks the survival rate thereafter is negligible. Therefore, an ideal interval between grazing periods appears to be around ten to 12 weeks with the lowest realistic cut-off point at about two and a half months. Intervals less than this are unlikely to produce significant reductions in nematode transmission.

It was estimated that, using grazing to control weeds under rubber tress in Malaysia, four grazing rounds can be achieved annually under immature rubber three to six-years old but only two rounds would be possible in a seven-year old plantation[29]. It was found that either a system of small mobile paddocks controlled by solar-powered portable electric fencing or free grazing flocks under the supervision of shepherds were feasible[28]. In the former system, the fences were moved daily and the sheep were always confined within them, although they sometimes attempted to escape if the amount of palatable species was reduced towards the end of the grazing period. In the latter system, pasture utilisation was less efficient and the animals concentrated on the more palatable species first with considerable time spent on roaming. In both systems flocks returned to the same area after about two to three months depending on the rate of regrowth of forage. Optimistically, minor adjustments in either of these grazing systems should enable 'weed control' to proceed adequately without compromising the health of the flock through parasitism. Success will depend upon the design of various management strategies for pastures under different plantation crops (e.g. rubber, oil palm, coconuts) at different levels of maturity, all with the common objective of providing an interval between grazing periods of preferably 12, but at least ten weeks.

VI. GENETIC VARIATION IN RESISTANCE TO NEMATODE INFECTIONS

Whitlock (1958) first reported genetic variation within breeds of sheep to the Barber's pole worm (*Haemonchus contortus*) using differences in faecal egg counts and packed cell volumes as indicators[30] and later it was clearly established that the resistance has a genetic basis[31]. Within and between breed variation in resistance to *H. contortus* infections in sheep has been reviewed. Resistant breeds or individuals within breeds generally had lower faecal egg counts under similar conditions, which usually reflected lower worm burdens[32]. Other workers showed that differences between lines selected for high and low faecal egg counts following artificial infections persist after sheep graze naturally infected pasture; they also confirmed that selection for resistance to *H. contortus* confers, in addition, a degree of resistance against *Trichostrongylus colubriformis*, another important parasite[33].

There are certain clear risks in attempting to relate directly the above findings (which deal to a large extent with infections of *H. contortus* in the Merino breed) to the indigenous breeds of small ruminants and production systems in the humid tropics. There are great potential benefits, however, should they prove to be relevant and applicable, particularly so because the most important parasites in the humid tropics are *H. contortus* and *T. colubriformis*.

Differences between breeds of sheep in susceptibility to *H. contortus* are well documented. It was found that Florida Native lambs had lower egg counts than Rambouillet lambs in natural infections[34]. The Red Masai is more resistant than European breeds[35] and the St Croix more resistant than Florida Native, Barbados Blackbelly or European breed crosses[36]. Numerous breeds of sheep and nematode species have been examined in studies conducted in different parts of the world with remarkably consistent estimates of heritability of resistance that range from 0.3 to 0.5, values similar in magnitude to heritabilities of production characters such as fleece weights and body weights, for which selection has been demonstrably successful[37]. Encouraging findings are that resistance to *H. contortus* and *T. colubriformis* (at least in Merinos) is not genetically correlated with production characters in the absence of infection[38,39], which means

that selection for resistance to them should not hinder primary selection programs for increased production.

It would seem prudent at this stage to concentrate in the humid tropics on within-breed (or breed cross) selection criteria based on existing productivity expectations, but with the realistic addition to the selection criteria of faecal egg count under conditions of equivalent natural challenge. In this way the author and his colleagues[12] were able to identify three Javanese Thin-tail ewes in North Sumatra which had consistently lower faecal egg counts than other animals in the flock at most of the 16 observations over one year. To generate useful data as a basis for selection guidelines in each country and maintain selection pressure will require thorough, sequential sampling, standardisation and quality control of laboratory techniques as well as long-term maintenance and analysis of comprehensive parasitological records. The entrenchment of efficient administrative structures in development establishments is essential for progress to be made.

The strategy of selection for nematode resistance could prove to be rewarding. However, optimism and enthusiasm need to be tempered by an understanding, first, that many traditional selection criteria applied to small ruminants (eg. the removal of sick animals from the flock and their slaughter for food) will have a similar outcome to formal selection and, second, that whatever developments are forthcoming, flock management will remain the major influence on parasitism in the humid tropics. Finally, it would be quite unrealistic in terms of practical management to attempt to introduce selection schemes at the individual farmer level. To date such schemes have not proceeded much past the experimental stage, even in many developed countries with extensive resources and large flocks of animals. An exception is Fiji, where progeny testing for parasite resistance has commenced on the major government goat and sheep breeding stations[40]. The future of this concept in the humid tropics will depend greatly on the outcome of the pilot project in Fiji.

VII. WORM REMEDIES (ANTHELMINTICS)

There are numerous good quality worm remedies available. Most modern remedies have a wide safety margin, are highly effective and some have activity against the entire range of important parasite

species (broad spectrum remedies). Other, usually less expensive remedies have activity against a single or only a few species (narrow spectrum remedies). Usually small ruminants are dosed orally with worm remedies, although some are available in injectable form, as in-feed preparations or in sustained release formulations. The latter two categories will be given more attention later in this review.

The available remedies are classified according to their chemical structure/mode of action into five main groups:

1) The benzimidazoles and related remedies ('white' remedies) (e.g. Panacur, Valbazen, Systamex, Fasinex). These comprise the largest chemical family. They are generally characterised by a broad spectrum of activity against nematodes and a wide safety margin. Valbazen (albendazole) is also effective against liver fluke. An exception to the general rule is Fasinex (triclabendazole), the activity of which is restricted to liver fluke. Because their lethal effect on nematodes is quite a slow process, repeated doses at low levels can also be effective; they have thus been incorporated into feed supplements and sustained release devices.

2) Levamisole and morantel ('clear' remedies)
(e.g. Ripercol, Nilverm, Banminth). These are readily available broad spectrum nematode remedies without activity against flukes and tapeworms. Overdosage with levamisole can cause toxicity in goats.

3) Salicylanalides and substituted phenols
(e.g. Seponver, Trodax, Ancylo!). These narrow spectrum remedies are active against liver fluke and the important blood sucking nematode *Haemonchus contortus*. They also persist in the body for long periods and provide residual activity against *H. contortus* for several weeks, assuring them of a useful place in planned control programs.

4) Organophosphates
(e.g. Neguvon, Loxon). Narrow spectrum remedies which are not readily available nowadays but are useful for the humid tropics because they are inexpensive, packaged in small quantities and have good activity against *H. contortus* with somewhat reduced activity against *Trichostrongylus* and *Cooperia*. A disadvantage is

that efficacy is sometimes unreliable. They can also be toxic, especially if animals are stressed or in bad condition. Because of the limitations with toxicity and efficacy, care is required in the calculation of dosage volumes and their administration.

5) Avermectins/Milbemycins
(e.g. Ivomec, Cydectin). Potent, safe, broad spectrum remedies. Effective against all important nematodes and some external parasites (ivermectin). The efficacy range of ivermectin includes sucking lice, sarcoptic mange mites and the Screw-worm Fly, *Chrysomya bezziana* (see later). A major disadvantage is that these products are expensive and packaged in multi-dose containers which renders their use prohibitively expensive for individual smallholder farmers. Unfortunately the only application that they are likely to find in the humid tropics is for specific treatment of life-threatening conditions (e.g. sarcoptic mange in goats, *C. bezziana* infestations), or on the larger commercial farming systems where tangible economic benefits are demonstrable.

The major problems a smallholder farmer has with worm remedies are obtaining them, understanding their purpose and having the means of administering them. Calibrated dosage equipment or syringes and needles for injection are simply not available or affordable by smallholders. Local community programs using existing social or administrative networks are the only means by which farmers will obtain access to materials and concepts designed to improve the health of their livestock or prevent losses.

VIII. RESISTANCE OF NEMATODES TO ANTHELMINTIC REMEDIES (WORM REMEDIES)

There are numerous examples in the humid tropics where the increased frequency of anthelmintic use has become alarming and the emergence of resistant strains of parasites inevitable. For example, when the Rubber Research Institute of Malaysia started a small flock of about 100 sheep in 1975, worm burdens were monitored by faecal egg counts; when they rose above 1000 eggs per gram of faeces the sheep were treated. It was believed that in this way endoparasites could be kept at a manageable level at reasonable cost[29]. Within only a few

years the frequency of administration of worm remedies on this specific farm had increased dramatically and it was reported that lambs required monthly drenching between the age of four weeks and six months, whereafter bi-monthly treatments were needed[41]. During the very wet season it was necessary to revert to monthly treatments, even for adult sheep. In other words, within its first two years of life a sheep in this system could receive up to 20 treatments for worms. Management strategies of this nature are recipes for disaster. Ironically, even with monthly treatments sustained control will still not be achieved. Large numbers of nematode eggs continued to be deposited on the pastures because the developmental period of the most important parasites is three weeks or less.

Certain important factors concerning anthelmintic use are directly related to the development of worm resistance:

1) There is a direct correlation between the frequency of anthelmintic use and the prevalence of resistance[42,43]. Selection pressure increases dramatically if treatment intervals approach the prepatent (maturation) period of parasites[24]. Therefore, the overriding priority should always be to reduce the number of treatments to an absolute minimum and try by all means available to avoid spacing treatments at monthly intervals or thereabouts.

2) Underdosing is strongly implicated in the emergence of resistance to worm remedies. On farms in Western Australia where an <u>average</u> sheep weight has been the basis for calculation of a dose rate, resistance has been significantly greater than on farms where sheep were treated according to the weight of the <u>heaviest</u> sheep[44]. This finding emphasises the vital concept that ***the full therapeutic dose of an anthelmintic should be given each time it is administered.*** Some means by which this may be achieved are as follows :

   a. Animals should be dosed according to actual not estimated weight. Where a group or batch are being treated the dose volume should be calculated according to the heaviest animal in that group.

   b. Dosing apparatus should be calibrated, cleaned and checked regularly. The product should be stored and

handled in strict accordance with the manufacturer's recommendations. Out-of-date products should not be used.

c. Careful thought should be given to the quality of the worm remedy which is used. In some countries worm remedies are not formulated precisely the same or subject to the equivalent exacting quality control as the same product manufactured by the parent company. This applies particularly to those products where patent rights have expired for the active ingredients. The formulation of and physical characteristics of the components (e.g. particle size) are critical to their expected performance. Cheap generic products should be avoided if possible because of an increased risk of underdosing due to reduced potency or bio-availability of the formulation. In addition, worm remedies should not be mixed with other medications or diluted in any way, unless specified on the label.

3) For some years anthelmintics have been available in self-medication formulations such as licks, blocks or water additives. Dunsmore (1985) recognised the dangers for the development of resistance in Malaysia through the use of low daily dosage systems. Nevertheless, he felt that the concept of a base feed additive or vehicle which was so attractive to the grazing animals that they would take enough of it every day could be feasible, with the additional benefit that appropriate mineral supplements could be added to the same product[21]. It is strongly recommended that administration methods such as these are not introduced into farming systems where resistance to worm remedies is not yet present. One such example is Indonesia, or parts thereof, where worm remedies have been used so infrequently that resistance to them is absent, and where attention could be more beneficially focussed on preventing its development[12]. There is an ever present risk with self-medication that variation in the amount of drug each animal receives can lead to poor parasite control and the parasite population may be exposed to levels of anthelmintic below the effective dose rate, thereby favouring the development of resistance[45]. It was stated '***It is perhaps fortunate that ...neither the daily dose phenothiazine***

systems nor its more modern counterparts have been adopted widely ...(because of)... the inherent uncertainty that each animal, or even a sufficient number of animals, will take an adequate amount of medicament each day to achieve the desired effect[46]. In countries where anthelmintic resistance is already common (e.g. Fiji[6]) there is little to be lost if/when self medication systems fail to control parasitism. The concept is based on the fact that constant low level administration of benzimidazole - group worm remedies (e.g. Valbazen (albendazole), Panacur (fenbendazole), Systamex (oxfendazole)) kills developing worms in the animal, including those that are resistant to a regular single dose treatment. However, the author is of the opinion that deviations from a 'constant dose' are inevitable in smallholder farming systems and are likely to cause the breakdown of this concept of medication under all but the most stringent management systems.

On the other hand, orally-dosed controlled release devices 'capsules' delivering therapeutic doses of drug constantly or intermittently present less of a threat. Design specifications provide for adequate constant release during the active phase followed by a reasonably rapid decline in levels of the drug after completion of delivery; low dose rates would thus comprise a very small portion of the total exposure time (see Other Treatment Concepts).

4) The selection of anthelmintics for replacement, rotation, or alternation should be based solely on differences in their mode of action not upon trade names of the products. For example it is pointless to rotate treatments with "Valbazen" (albendazole - Smith-Kline) and "Systamex" (oxfendazole-Coopers), both of which are benzimidazole group remedies (see Worm Remedies).

IX. OTHER TREATMENT CONCEPTS

1) The chemically related worm remedies nitroxynil (Trodax - May Baker) and closantel (Flukiver/Seponver-Smith Kline) are narrow-spectrum drugs, less expensive than others, which are highly effective against *H. contortus* but have little or no effect against the other worm species. This means that they can be

used strategically, with economic savings, when the major problem is likely to be *H. contortus* and there is little threat from other parasites. Closantel, specifically, has the additional benefit of providing extended protection for up to seven weeks (residual activity) against developing larvae of *H. contortus* which the sheep may take in. This characteristic can be exploited to protect animals grazing suspected contaminated pastures or to prevent recontamination of pastures for a prolonged period. An extremely useful study in Indonesia[47] demonstrated that a single injection of disophenol, (Ancylol; DNP) another related product, suppressed *H. contortus* to very low levels for up to three months despite the presence of large populations of *H. contortus* infective larvae on the pasture and herbage grasses. Because of its residual effect against *H. contortus* and its cheapness, it showed tremendous potential for use in the tropics. Unfortunately it has been withdrawn from the market and is no longer available.

2) In recent years, orally administered devices 'capsules' have been designed to lodge in the rumen and release anthelmintic drugs at rates which are highly effective and have a sharp cut off point to minimise suboptimal dosing. One such device is a controlled release capsule containing albendazole (Smith Kline) for use in sheep from 20-40 kg body mass. The faecal egg counts of treated sheep remain close to zero for 12 weeks after administration. For commercial ventures in the humid tropics this could provide an opportunity, both to remove existing burdens of worms, and to prevent new egg deposition on pasture for longer than the survival time of infective larvae. In addition, the capsules can be effectively used in animals grazing on pastures which are contaminated with resistant larvae. A practical problem could be that the existing capsules may be too large to administer to the smaller breeds of sheep of the tropics. Another problem is their cost: they are unlikely to be affordable in all but exceptional cases.

X. THE PANCREATIC FLUKE *(EURYTREMA PANCREATICUM)*

Eurytrema pancreaticum has only recently[48] been recorded from sheep in Indonesia, but its presence in both cattle and water buffalo

has been recognised there for many years[49]. It was noted that although the infection rate of goats and sheep was not high the presence of the fluke was occasionally associated with ill thrift[48]. In North Sumatra, however, *E. pancreaticum* infections were found to be a serious flock problem in sheep grazing in rubber plantations[50]. Numerous sheep, usually two years of age and older, developed progressive wasting and eventually died in an emaciated condition despite treatment for other possible causes of ill thrift. Clinical chemistry and histopathological findings supported a diagnosis of *diabetes mellitus* caused by progressive pancreatic damage due to infections with pancreatic fluke. The Indonesian findings confirmed observations in Heilungking Province, China which associated heavy infections of *E. pancreaticum* with a severe, often fatal disease in sheep from two to three years of age onwards[51]. In addition to the obvious emaciation in some animals due to the effects of diabetes, significant subclinical production losses probably occur in many others due to chronic pancreatitis and pancreatic enzyme insufficiency[50].

E. pancreaticum has a complex, indirect life cycle. Eggs which pass out in the faeces of sheep or other herbivores hatch when eaten by certain land snails. Of these, *Bradybaena similaris* is the most widely distributed first intermediate host but other closely related snail species (*Ganesella virgo* and *Cathaica ravida*) are important in some areas[51-53]. Intermediate host snails are common in Indonesia, Malaysia and probably also in other humid, tropical countries. Development in the snail proceeds by division through two generations of sporocysts within a period of about five months. The duration of development is markedly influenced by climate, and it can slow down or even stop for many months if temperatures are low[51]. The mature, second generation (daughter) sporocysts pass out the respiratory aperture of the snail, and are deposited upon vegetation where they are eaten by a second intermediate host, a meadow or long-horned grasshopper *Conocephalus maculatus*. Development to maturity in the grasshopper takes a further three weeks[54]. Sheep become infected by accidentally swallowing the infected grasshoppers while grazing. The fluke takes at least a further seven weeks to mature in the pancreatic ducts and start producing eggs.

The life cycle of *E. pancreaticum*, therefore, covers at least 30 weeks. However, there is not yet sufficient information concerning

infection rates in snails and grasshoppers in the humid tropics to determine whether transmission is seasonal or not. The most likely event is that transmission is seasonal and dependent upon increasing populations of susceptible snails and grasshoppers. This should make it easier to design control programs than it would be if transmission occurred throughout the year.

Clearly, there is a pressing need for a detailed examination of the epidemiology of *E. pancreaticum* in the humid tropics. Factors such as the total number of developmental stages (sporocysts) produced by an infected snail, the time of year that they are released on to the pasture, the association of grasshoppers and snails with certain areas of vegetation, the breeding habits, life history and seasonal abundance of both of the intermediate hosts and the influence of climate on transmission should all receive attention.

In Northeast China, where transmission is seasonal, the integrated control procedures described below reduced infection rates in sheep flocks from 37.4 percent to 1.8 percent in four years, with associated improvement in body condition and production performance[55], using the following program:

1) In the first two years, hexachloroparaxylene (Hetol) was used to treat all animals with fluke eggs in their faeces during March to April. Praziquantel (Biltricide, Droncit) replaced this for the next two years.
2) Although the grasshopper host was widely dispersed, the snail was restricted to certain regions. From May to June every year, snails emerging from their annual resting period were manually collected and destroyed before they had the opportunity to breed.
3) Flocks were denied access to identified infected areas during the period of maximum transmission (July to September).
4) *E. pancreaticum* - free flocks were established by moving lambs at weaning to snail - free areas.

It is unrealistic to expect that these measures could be directly applied in all areas of the humid tropics. Nevertheless, the principles should serve as a useful basis for planning once the epidemiology of the problem is better understood.

Very few compounds have good activity against the group of flukes to which *E. pancreaticum* belongs. Hetol (hexachloroparaxylene) is widely used in the (old) Soviet Union for treatment of a closely related fluke *Dicrocoelium dendriticum* at a dose rate approaching toxic levels and with a relatively low efficacy[56]. Hetol was used initially in efforts to control *E. pancreaticum* in China but was later replaced by praziquantel, administered orally at the very high dose rate of 70 to 80 mg/kg[55]. Unfortunately it is not possible to determine the contribution that praziquantel treatment in itself made to successful control of pancreatic fluke in the Chinese flocks. However, It has been reported that at 50 to 70 mg/kg orally it is more effective than hexachloroparaxylene, easier to handle and suitable for mass deworming[57]. In addition, it is certainly safer. The availability of an effective remedy however, will not automatically resolve all of the problems caused by *E. pancreaticum* in sheep grazing in rubber plantations because treatment alone in the absence of other control efforts is unlikely to interfere with the complex and extended transmission cycle. Moreover, no response can be expected from sheep with terminal pancreatic damage, rapid reinfection may negate or obscure production benefits and incorrectly timed treatments may be wasteful. A knowledge of the epidemiology of pancreatic fluke in the humid tropics is essential for the planning of treatment schedules and their interaction with other control measures. In addition, worm remedies such as praziquantel are expensive, and production benefits would need to be quantified to justify economically their long-term use.

XI. IMPORTANT FACTORS IN INTEGRATED CONTROL OF NEMATODE PARASITES

The following concepts are presented as broad areas for consideration in the development of control strategies by government and other departments servicing the needs of small ruminant producers in the humid tropics. Their acceptance, level of practical relevance and potential for uptake will depend entirely upon local conditions and in all cases will be best evaluated by those with a thorough understanding of the farmers and their systems.

1) The ideal interval between periods of grazing on the same pasture is 12 weeks with a minimum of ten weeks.

2) A constant objective should be to reduce treatments with worm remedies to a minimum.
3) When resistance to worm remedies is known not to be present, the practical dangers associated with their administration in licks, blocks or drinking water potentially outweighs benefits which may arise from their use and they should not be introduced.
4) In general, animals should be treated with a calculated full dose of an effective remedy before being moved to 'clean' pasture. Although there are numerous reasoned arguments against this practice in temperate climates, it is unlikely in the humid tropics that the progeny of worms which survive treatment will contribute markedly to subsequent generations, given the short grazing periods practiced and the rapid decline of larval nematode populations on pasture. Moreover, as argued by Morley and Donald (1980), the longterm reduction in dependence on worm remedies arising from this practice should reduce selection for resistance[58].
5) A 'slow rotation' system is suggested using broad-spectrum drugs from a group with a single chemical action over a period of one year followed by a change for the whole of the following year to another group and so on. Theoretical advantages are that no individual worm would be subjected to multiple selection with anthelmintics from different broad spectrum groups; selection pressure for resistance to any one group of worm remedies would also be less than if that group was used alone, and thus, a resistance problem should not occur as rapidly. Less appealing alternatives are 'rapid alternation' of groups of drugs on a cycle of less than a year or dependence on only one group until it is ineffective. A recommendation for Malaysia that anthelmintics should be changed after three cycles of usage (i.e. often as frequently as every three months)[41] is not supported because this may select rapidly for multiple resistance.
6) Treatments for Barber's pole worm (*H. contortus*) with closantel are potentially extremely valuable tools in control but best restricted to one or at most two per year; their placement should prove to be most beneficial in February and July to August.

7) In cases where *Trichostrongylus* has a peak of activity the use of a broad spectrum remedy is warranted at this time.

8) In the event of a decision to use a slow release albendazole capsule, this treatment would be best given in June, in which case both the June (broad spectrum) and July to August (closantel) treatments would not be used.

9) Because births are non-seasonal in humid tropical breeds, the numbers of dams approaching parturition and young being weaned will be evenly distributed throughout the year. ***Irrespective of other general initiatives to reduce pasture contamination or avoid disease in the flock, it is vital that pregnant ewes and weaners receive special attention.*** The system of indoor housing overnight with individual identifications facilitates this. All young animals should be treated at weaning with a broad spectrum remedy. Unless individual ewes have been included in a flock treatment with either a broad spectrum remedy or closantel in the previous four weeks, they should be routinely treated in the last two weeks of pregnancy or when they give birth. The latter option is probably the most convenient. Many early lamb deaths are due to the fact that their mothers have a greatly reduced supply of milk because of heavy worm burdens.

10) A question for which there is no simple answer is 'using faecal egg counts as a basis, when should the flock be treated?'. In general, the use of faecal egg counts as the sole basis for parasite control will usually give disappointing results. Once substantial numbers of eggs are present in the faeces, production losses and considerable pasture contamination are already well progressed. Nevertheless, the regular monitoring of faecal egg counts throughout the year provides useful information concerning the degree of control which is being achieved and a warning to avoid catastrophe should levels become too high.

The author and his colleagues have suggested the following general monitoring procedures for large scale integrated enterprises in plantations, such as those either already developed or planned in Malaysia and Indonesia[12].

Providing that a system of clean pastures is established and maintained, it should be possible (and is economically

essential) to reduce the eggs per gram of faeces 'cut off point' for flock treatment to a level considerably below the guideline of 1000 (epg) eggs per gram used in Malaysia[29]. It is suggested that at least ten to 15 sheep from each management unit, where appropriate, comprising equal numbers of ewes and lambs (weaning to nine to 12 months of age) are selected and individually identified. Faecal samples should be regularly collected from these animals every two weeks and egg counts done. Once the geometric mean count for any group exceeds 500 epg the entire group should be treated all at the same time, and moved to a clean pasture. With time, clean pastures can be established in a plantation using some of the management strategies described earlier and there should be a reduced requirement to treat regularly. Thereafter it can be realistically expected that the 'cut off point' of 500 epg can be further lowered without increasing the number of treatments which need to be given.

11) A good plane of nutrition reduces both the development and establishment of nematode parasites and the magnitude of their pathogenic effects[59]. Management of pastures should not be modified in parasite control programs to the point where the benefits from decreased parasitism are overshadowed by nutritional problems. Longterm management especially in plantations needs to rationalise interactions between the cost of ensuring adequate sustained grazing or alternative sources of nutrition and the severity of parasitic disease.

XII. *KANDANG* (ANIMAL BARN) HYGIENE

A very important contribution that small ruminants make to farming enterprises in the humid tropics is the supply of manure for horticulture. Faeces which accumulate under pens are collected and distributed on crops, rice paddies or pastures. In many countries sound recommendations have been formulated concerning the production of manure compost from this material[60]; despite this, faeces are frequently distributed over areas on which ruminants graze or from which grasses are cut to feed housed animals, without passing through an adequate composting treatment or with no appreciable retention period under the *kandang* (animal barn). This accounts for the well

documented cases where parasite infections are maintained even in permanently housed animals[11]. Thorough composting of faeces before their redistribution on pastures is an extremely important component of worm control. Small areas near *kandangs* should be fenced off and the faeces processed in protected composting pits within these areas for three months before being used as fertiliser. Through this process, the eggs in the faeces and the larvae which hatch from them will be destroyed. Animals should be completely restricted from such areas of composting because they are potentially serious sources of contamination.

Another problem is that faeces which have fallen or been swept from the edges of raised *kandangs* often collect in small ridges on the ground around the *kandang* perimeter where they have been washed by water falling from the roof. In addition, when first released in the morning, animals commonly gather together and defecate on or beside paths leading from the area. The immediate environs of the *kandang* can thus become rapidly and heavily contaminated. It is in these areas that animals are often grazed for short times. Sometimes they are tethered there when brought home in the evening; during this time, no matter how brief, they tend to nibble at vegetation. Cut grass is sometimes fed to them on the ground. The writer has seen a case where lush grass growth beside a *kandang*, resulting from an abundance of uncollected manure, was cut and fed back to the housed livestock as readily available fodder; serious losses followed from worm infections.

It follows that animals should be quickly moved away from their housing and not left to linger nearby. They should also be denied access to vegetation in the immediate vicinity of the *kandang*. Soetedjo et al. (1980) describe severe clinical haemonchosis in housed sheep which were hand-fed most of the time 'except when they were occasionally allowed to graze on small paddocks adjacent to the pens[47]'. In the wet season these sheep were fed pasture grass harvested alongside ditches or small streams adjacent to paddy fields and in the dry season, when grass was scarce, they received weeds, ferns, cassava leaves and other wild herbage. Theoretically, careful disposal of faeces, avoidance of contamination of harvested pastures, and discontinuation of grazing close to the pens should have played a

large part in helping to resolve the problem. In practice the sheep were repeatedly treated with anthelmintics.

In larger systems such as those in some plantations, a further problem lies in the fate of the water used to wash *kandangs*. If left to simply run off into the area surrounding the facility, it can provide an ideal environment for development of large numbers of land snails, the first intermediate host of *Eurytrema*. Unfortunately, fencing the area is unlikely to influence the transmission of *Eurytrema* because the second intermediate host, a grasshopper, is highly motile. Attention should be given in these cases to providing covered concrete or bamboo drains leading to an isolated vegetation-free sedimentation pit.

In integrated plantation management systems, supplementary pasture is sometimes still cut in the plantation, chopped to a manageable size, mixed with supplements where required, and supplied to the animals in the *kandang*. Apart from the obvious responsibility to ensure that such supplements originate from a livestock-free area of the plantation, attention needs to be given to the area where the collected fodder is processed. An open, concreted area under roof is useful for this purpose. Goats and sheep should not have access to it. Constant educational efforts should be directed to the importance of dedicating a scrupulously clean area to the processing of cut fodder and rations for animals in the *kandangs*, regardless of whether the system is large or small.

Another important requirement is that the *kandang* itself should be well maintained in a clean, dry condition with no crevices or decayed areas where faeces can pack and accumulate. All deposited faeces should pass freely through the slatted floor. To ensure this, the floors should be regularly cleaned, particularly when droppings are moist and not well pelleted. Worm eggs can readily hatch and develop to infective larvae in unhygienic *kandangs*. Animals become infected when feeding, grooming themselves or their young or licking the walls. A source of infection for suckling animals are larvae which have been transfered to the teats of the dam as she rests on a contaminated *kandang* floor.

B. EXTERNAL PARASITES

I. LICE

Lice are small, wingless insects one to two mm long with mouthparts adapted for either chewing (biting lice), or for piercing the skin and sucking blood (sucking lice). Biting lice are active and under good light can usually be seen moving through the wool or hair; they are a pale straw or yellow colour with a broad reddish head. Sucking lice are bluish-grey in colour with a pointed head and tend to remain at one spot with their mouthparts embedded in the skin. Biting lice are commonly found on the neck, topline and down the sides, and sucking lice on the legs, belly and scrotum. Both biting (*Damalinia spp.*) and sucking (*Linognathus spp.*) lice occur on goats and sheep in the humid tropics, but the precise species have not been positively identified in most cases. Those most likely to be present are *Damalinia ovis* and *Linognathus pedalis* on sheep and *D. caprae* and *L. stenopsis* on goats. *L. stenopsis* has been confirmed as a common parasite on goats in Fiji[6]. *L. stenopsis* also readily infests sheep in addition to goats; there are plentiful opportunities for cross transmission of this parasite in mixed grazing flocks or whilst animals are communally or closely housed.

Lice glue their eggs on to wool fibres or hair and the entire life cycle is completed on the host. Transmission from animal to animal is generally through close contact, but some lice (e.g. *L. pedalis*) can survive off the host for several days. Eggs attached to hairs which have been rubbed off on the *kandang* walls can also hatch. The housing can therefore serve as an important source of continued infection.

Small numbers of lice are not uncommon and usually cause no problems. Heavier infestations are usually associated with either young animals or old animals in poor health or those maintained in unhygienic conditions. Heavy populations of biting lice (*Damalinia*) are responsible for 'lice worry', characterised by biting, scratching and rubbing, stamping of the feet and a failure to feed well, leading to poor body condition. In moderate numbers, sucking lice cause loss of condition, in heavy numbers, anaemia.

The presence of lice can often be suspected because of clumps of wool or hair on the walls or floor of the *kandang*, of ill-thrift and signs of 'lice worry'. Careful examination of the animal in good light can confirm the diagnosis. Lice can be seen with the naked eye; however biting lice move away from the light and sucking lice are often in small clusters, so a thorough examination all over the body is required. Precise identification of the louse species involved requires a specialist.

Lice control requires the application of effective insecticides. In many areas of the world, this is done in an area set aside for this purpose where a plunge dip or communal spraying facility is maintained. This is impractical and wasteful in the humid tropics. It is usually more efficient and economical to treat animals individually by applying the insecticide under pressure using a hand sprayer or by carefully sponging the backline and other commonly affected areas with dipwash. It is important that the dipwash should soak the fleece or hair and penetrate right to skin level where the lice are found. To facilitate this, the animal should be shorn before treatment. In fact, regular shearing of the hair is an important component of an external parasite control program because it exposes the parasites to very high temperatures in direct sunlight which is harmful to them. Regular washing of individual animals with soap and a brush every few weeks plays a useful role in reducing the build up of external parasites. Spraying of insecticides should be done on bright sunny days and timed so that animals have plenty of time to dry completely before nightfall. Spraying should be avoided in wet weather.

The organophosphorus insecticides are the most cost effective substances for the treatment of lice and can be applied in sprays at the following concentrations (coumaphos (Asuntol) 0.05 percent; chlorfenvinphos (Supona) 0.05 percent; diazinon (Basudin, Top Clip) 0.2 percent; malathion (Malaspray) 0.5 percent). Providing that thorough wetting is achieved, a single application should be sufficient, however in heavy infestations it may be useful to repeat the treatment after two to three weeks. These products should be used to disinfect the *kandangs* at the same time as the animals are treated.

Recently some highly effective products containing synthetic pyrethroids have been developed for application along the backline as pour-on formulations. However, for humid tropical farming systems,

they are too expensive and are also unlikely to penetrate adequately the matted fleeces of local breeds. Moreover, they are formulated specifically for wool breeds of sheep and it is likely that they will not be retained in the hair or distributed across the body in sufficient concentrations to be effective in goats and hair sheep from the humid tropics.

Because the availability of products will be greatly influenced by local regulations, the current local laws and requirements should be determined. All label precautions should be carefully observed to safeguard the farmer, the livestock and the environment.

II. MANGE MITES (*SCARCOPTES SCABIEI*)

Sarcoptic mange mites are minute ectoparasites which are just visible to the naked eye in good light. In most cases their presence can only be positively confirmed by the microscopical examination of skin scrapings from affected areas on an animal. Female mites burrow tunnels into the skin where they live, feed, and deposit eggs. The entire life cycle takes place on the host and can be completed within 17 days. The mites are very susceptible to dryness but can survive for three weeks off the host in humid conditions.

Sarcoptes (scabies) mites pierce the skin to feed, producing a marked irritation which leads to intense scratching. Fluid oozes from the surface, coagulates and dries to form crusts. The skin initially becomes raw and weeping, but later it is thickened and wrinkled with a general loss of hair. The damaged area increases as mites move to the edge of the lesion seeking fresh skin in which to lay their eggs.

This is the most serious ectoparasite problem of goats in the humid tropics[61,62]. In Indonesia alone over 70,000 cases were reported to local veterinary authorities in 1984. Infestations usually start near the mouth (lips, nostrils and the corner of the mouth) and spread to other parts of the face, neck and ears and finally the whole body. Affected goats do not feed, become severely depressed and usually die within a couple of months if not treated.

Scabies control is similar to lice control in that it relies largely upon the use of effective insecticides. Important general control concepts are detailed in the section concerning lice. However, scabies mites are much more difficult to control than lice and the

consequences of failed control are much more serious - unsuccessfully treated goats usually die.

Certain general procedures should always be followed;

1) Affected goats should be herded and housed separately from 'clean' ones. If it is necessary to handle affected goats the owner should wash himself thoroughly before working with healthy animals. These are critical points which need to be discussed at length with the farmer so that he understands that the whole control program depends upon paying attention to them.
2) Before any treatments are applied, affected animals shouldalways be completely shorn, thoroughly washed with soap and water and left to dry in the sun.
3) Once a week for three weeks the *kandangs* should be thoroughly disinfected with an insecticide such as diazinon, coumaphos or malathion (see lice control) and on each occasion the old bedding grass or leaves in the *kandang* removed and burned. The *kandang* should always be completely dry.
4) Immediately it is noticed that animals are affected, efforts should be made to increase the quality and palatability of the feed supplied.

Scabies has been traditionally treated by smearing a mixture of used engine oil and sulphur over the affected area every three to four days. Generally this has been unsuccessful. Poor results in some cases probably reflect not only inefficacy of the remedy, but a failure to attend concurrently to the numerous other control procedures which have been mentioned. Organophosphorus insecticides can be sprayed on to goats as described for the treatment of lice infestations, but should be applied more frequently (weekly for at least three weeks) for scabies control. It is usually more beneficial to bathe the animal carefully with the solution rather than to spray it on; this ensures that the wash completely wets the scabby areas, enters folds in the thickened skin and gains access to sites such as the ears or under the chin which are often not adequately wetted. Again, it is important to remember that this procedure should be done only on sunny days and that the animals should have plenty of opportunity to dry thoroughly before nightfall.

Recently, Manurung *et al.* (1990) have shown that ivermectin given by subcutaneous injection is successful in substantially reducing the levels of infection of *S.scabiei* in goats[62]. The most efficient treatment schedule was two injections each of 0.2mg/kg given seven days apart. A single treatment had no useful effect. Although complete elimination of mites was not achieved this could have been due to reinfection occurring from mites deposited in the *kandangs*. Given that the only alternative to control is death of affected animals (20 out of 23 untreated control animals died in three experiments reported by the above authors), the cost of treatment with an expensive but effective remedy such as ivermectin is probably justified. This would depend upon the development of a satisfactory system for communal purchase of the product and its local distribution, together with appropriate supervision and local support to ensure that wastage or contamination of the product do not occur and that it is administered at the correct dose and frequency.

III. THE OLD WORLD SCREW-WORM FLY (*CHRYSOMYA BEZZIANA*)

Chrysomya bezziana is a species of fly whose larvae (maggots) must invade and feed on living animal tissue to develop and survive. The fly is widely distributed throughout the humid tropics and constitutes a serious problem in goats and sheep as well as cattle[63-67]. In the areas where it occurs, it accounts for an overwhelming proportion of myiases (maggot infestations) in domestic animals[66, 68]. Approximately 33 percent of all health care treatments given to Malaysian smallholders' sheep in rubber plantations are due to 'maggot wound' [69], most, if not all of which can be ascribed to *C. bezziana*. The adult fly is not often seen, however, because it is usually attracted solely by wound discharges, often only late in the day or evening.

The female screw-worm fly lays eggs on the dry edges of wounds or body orifices. Larvae hatching from these eggs invade the wound or body orifice and aggregate in cavities produced as they feed on body tissues. A large cavernous lesion is formed with a seething, pulsating mass of maggots in its depths, bathed in rotting tissue fluids and blood. The area becomes severely swollen and hot, bleeds easily and emits a foul odour. The lesions are often repeatedly invaded by further larvae leading to extensive necrosis of tissues, severe clinical

disease, debility and even death[68, 70]. The larvae pass through three stages of development over five to seven days. When mature they wriggle from the wound, drop to the ground, burrow into the soil and form a pupa. Under warm conditions adult flies can emerge from the pupa after seven to nine days.

Infestation often follows birth. The navel of the new born and the vulva or perineum of the dam are important sites for infestation. Invasion can also occur at foot abscesses or skin punctures anywhere on the body caused by barbed wire and thorns or spikes on vegetation (e.g. palm oil trees). *C. bezziana* is also able to directly invade the soft skin around the vulva and anus of sheep, even in the absence of injury or haemorrhage.

There are numerous insecticide - containing products which are active against screw-worm strikes. A commonly available one in South-East Asia is Gusanex (dichlorfenthion), an organophosphorus compound which is applied at a concentration of 0.1 percent. Other examples are chlorfenvinphos 0.5 percent smear (Supona), coumaphos aerosol 3 percent (Co-Ral), powder 3 percent (Negasunt) or smear 4 percent (S-Gris), maldison 0.5 percent liquid (Malathion), trichlorphon 0.12 percent liquid (Neguvon) and fenthion methyl 0.2 percent spray (Tiguvon). However, under field conditions the effective use of these remedies is often limited. First, practical problems may arise in delivering a paste, powder or liquid to the site of a deep seated larval infestation. Second, very few remedies provide useful long-term protection from re-strike, because a previously struck wound remains attractive to the female fly until the wound is completely dry [67, 71].

A method of prophylaxis commonly used in the humid tropics is to rub kitchen ash on the navel of the new born and vulva of the dam immediately after parturition to 'clean' them and render them less attractive to fly strike. Traditional treatments have relied upon the application of sump oil or even petrol. Naphthalene flakes or tobacco are sometimes used to plug the wounds to discourage reinfestation until they have healed sufficiently to lose attraction for female flies. Generally accepted treatment regimens involve exposure of the larvae to an insecticide or physical removal of them from the wound (extremely difficult), bandaging the wound where possible, and

repeated applications of insecticide, often as frequently as every second day. These methods consume time and labour and can be expensive in terms of insecticide, therefore in many cases the procedures are not rigorously taken up and maintained, with adverse results.

Based on work done in cattle, one treatment with ivermectin (Ivomec injection) administered by subcutaneous injection at 0.2mg/kg can be expected to cause the elimination of existing infections, kill a large proportion of the developing larvae in them and provide protection during sufficient time for wounds which have been cleared of maggots to dry without being re-struck. It should also be possible to administer it systemically at this dosage rate to protect fresh wounds from being struck*.

In providing treatment of *C. bezziana* strike under the farming systems of the humid tropics, the costs of time and labour in relation to other essential daily activities of the farmer and his/her family must be considered in terms of the expected outcome and the price of the remedy used. The decision on whether to use traditional treatment regimens or the more expensive but effective and efficient remedies will vary in different areas.

CONCLUSIONS

Infestations with internal and external parasites are serious constraints to the productivity of small ruminants in all current management systems in the humid tropics. Common outcomes, which are additive to the effects of poor nutrition but rarely distinguished from them, are ill-thrift and loss of weight in all animal classes and reduced milk supplies in lactating ewes and does. However, large scale mortalities, particularly but not exclusively in young animals, are a recognised feature of parasitism in small ruminants in numerous countries. Contaminated grazing areas or forage harvested from them are a major source for infection with internal parasites, but significant transmission of both internal and external parasites can also occur in

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* Ivomec injection has registered claims against *C. bezziana* only in cattle

or around sheds or pens (*kandangs*) in which animals are housed overnight or for longer periods.

The most important internal parasite is Barber's Pole Worm (*Haemonchus contortus*), a voracious blood sucker. Other roundworms such as the Nodular Worm (*Oesophagostomum spp.*) and Black Scour Worm (*Trichostrongylus colubriformis*) cause depression of appetite, poor growth, diarrhoea, and other digestive and metabolic disturbances. Liver fluke (*Fasciola gigantica*) is probably not as important as it has been perceived to be. The pancreatic fluke (*Eurytrema pancreaticum*) has caused chronic wasting and death in adult sheep grazing in plantations but its impact elsewhere is currently undocumented.

Transmission of internal parasites occurs throughout the year, but is probably reduced during the wettest months due to torrential rain washing infective larvae from pastures. Hypobiosis (arrested development) of immature parasites in the host is not an mportant factor in transmission. The survival time of larvae on pastures is very short (ten to twelve weeks) when compared with that of larvae in temperate regions, where they may survive for several months or longer. It should therefore be possible in many circumstances to adjust grazing practices to bring about reductions in roundworm transmission.

Many indigenous breeds of sheep have an inherent resistance to internal parasites which would be further enhanced by selection of the most resistant individuals to form the basis of breeding flocks. Notwithstanding this, flock management will remain the dominant influence on parasites control in the humid tropics.

In many countries repeated administration of worm remedies at short intervals has led to widespread development of resistant strains of parasites; this is compounded by underdosing and also the poor quality of some of the available generic products. Self-medication formulation (licks or blocks) may be useful for control in areas where resistance is already present but could accelerate the rate of development of resistance elsewhere. Orally-dosed capsules which constantly release therapeutic doses of a drug have promising applications but are too expensive to find regular usage. Remedies which are highly effective against *H. contortus* but with little effect against other roundworm species (e.g. Trodoax, Seponver) can be

strategically used when the main problem is likely to be *H. contortus* and there is little threat from other parasites. In addition, Seponver has residual activity which can protect animals grazing contaminated pastures for several weeks. Pregnant ewes and weaners should receive special attention in any control program.

It is extremely important that hygienic conditions are maintained in and around *kandangs*. Faeces should not be allowed to accumulate or be distributed fresh on pastures but should be thoroughly composted in secure fenced areas. Other important management procedures are: harvesting of forage from uncontaminated areas, restriction of access of animals to areas around *kandangs*, provision of clear or covered drains to take water away from *kandangs*, ongoing maintenance of dry, well-ventilated *kandangs*. All management initiatives require concerted educational and extension efforts.

The clinical importance of lice in the humid tropics is not well documented but they are probably of little importance. The mange mite (*Sarcoptes scabiei*) is a serious cause of mortalities in goats. Disinfections of *kandangs*, isolation of affected animals and treatment of animals are fundamental for successful control. Various topically applied dipwashes are effective against lice but mange control requires a course of treatments with injectable ivermectin. The Old World Screw-Worm Fly (*Chrysomya bezziana*) is widely distributed and accounts for an overwhelming majority of 'fly strikes', commonly in the navel of the new born or the vulva of the dam. Although a number of smears, aerosols or washes are available for treatment, their efficient use is difficult because of the deep-seated nature of wounds and continued reinfestation. Ivermectin injection eliminates existing infections and provides sufficient residual protection for wounds to heal without being re-struck.

Current knowledge of parasitic diseases in small ruminants in the humid tropics is limited and much more work is required. Conclusions based on data derived from other geographical areas are likely to be misleading. In this regard it is important to remember that in some countries with substantial livestock numbers only part of the population is located in a humid tropical environment.

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CHAPTER IX
ECONOMICS OF RAISING SMALL RUMINANTS

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INTRODUCTION

In many regions of Indonesia animals are kept as an important component of farming activities, particularly by smallholders. The year round family needs of these farmers are provided by food crop production, while the primary reasons for keeping animals are for storing capital or accumulating cash. The role of animals within these farming activities has been remarkably well demonstrated by small ruminants, such as goats or sheep, most of which are kept by farmers in the island of Java. Goats and sheep are easy to raise using minimal inputs, with low maintenance costs, and utilization of waste products from cropping activities. Furthermore, they have a high reproductive rate and always find a ready market[1]. However, productivity of small ruminants kept by smallholders is still considered low compared with that obtained at experimental stations. Therefore, increasing the on-farm productivity of small ruminants up to their optimum would enhance national development planning in increasing rural income as well increasing the level of protein consumption. Furthermore, the

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economic implication of increased small ruminant productivity is obvious since small ruminants are nearly equally distributed among smallholders and since potential income generated from them contributes a significant share of the total farm income. The potential is clearly shown by statistics of the population in the West Java, Central Java and East Java provinces in 1970 and 1987 (Table 1). Interestingly, since the three provinces also have the largest human population in the country, small ruminants seem to fit and complement the prevailing farming systems in densely populated areas like Java. Table 1 also shows the distribution of goats and sheep in other provinces in Indonesia.

Table 1. Small ruminant population in Indonesia, by provinces in 1970 and 1987 (by 10^3)[2].

Province	Goats		Sheep	
	1970	1987	1970	1987
D.I. Aceh	209,600	386,830	31,600	168,200
N. Sumatra	368,800	54,220	21,600	60,240
W. Sumatra	70,000	213,870	1,000	3,120
Jambi 32,000	92,020	2,400	39,610	
Riau	43,000	143,670	0	870
Bengkulu	0	135,970	0	33,300
S. Sumatra	104,700	438,250	0	103,430
Lampung	236,300	264,560	0	32,580
D.K.I. Jakarta	20,700	9,490	10,000	4,520
W. Java	1,188,900	1,456,010	1,818,300	2,423,320
C. Java	1,924,500	2,350,730	885,800	1,248,830
D.I. Yogyakarta	242,000	269,870	63,300	74,800
E. Java	1,476,600	2,040,810	278,000	969,620
W. Kalimantan	19,800	49,310	0	0
C. Kalimantan	1,100	16,780	100	460
S. Kalimantan	26,500	83,100	7,900	4,170
E. Kalimantan	29,500	49,770	800	3,770
N. Sulawesi	102,000	92,920	0	0
C. Sulawesi	75,800	201,360	3,400	17,100
S. Sulawesi	189,400	592,440	1,900	13,350
S.E. Sulawesi	34,300	101,830	0	340
Bali	12,400	81,050	500	400
W. Nusa Tenggara	86,900	296,390	56,700	40,120
E. Nusa Tenggara	268,400	390,920	84,700	86,820
Moluccas	22,200	167,050	5,700	5,530
Irian Jaya	6,000	34,610	0	1,200
E. Timor	0	79,050	0	28,310
Indonesia	6,791,400	10,392,870	3,273,700	5,364,000

In general, due to the complexity of the farming enterprises and the limited ability of smallholders to produce farm products, including animals, farmers are required to make decisions that must include some of the basic economic considerations such as: what to produce, how to produce it, how much should be produced and how it should be marketed.

This Chapter deals only with one of the many components of the farming activities, small ruminant production, by presenting its production characteristics and economic role within the farming operation, especially in Indonesia. Information provided in this Chapter is mostly taken from results of studies carried out by the Research Institute for Animal Production (RIAP) and the Small Ruminant-Collaborative Research Support Program (SR-CRSP) working in the lowland coastal, upland and intermediate rubber estate areas of West Java.

A. PRESENT STATUS

Nearly ninety nine percent of small ruminants in Indonesia are found in the hands of smallholders and less than one percent are raised under fully commercial operation[2]. This fact indicates an important role for smallholders, the rearers of the potential stock from which the national small ruminant production will be drawn. Table 2 shows the average flock size of small ruminants kept in farm households in different provinces of Indonesia.

The present national development program for increasing livestock and livestock products, including distribution of livestock into transmigration areas and other potential forage supplying areas outside Java, will allow small ruminants to be even more widely distributed among farm households, especially as keeping of small ruminants is a potential income-generating activity for farm families. Table 3 shows numbers of small ruminants slaughtered in 1987 and volume of meat produced. Prospects for exporting small ruminants and their products particularly to the Middle Eastern countries has further enhanced the possibilities for these animals to become an important export commodity. As an example, Table 4 presents volumes and values of exported small ruminant hides from 1984-1987, indicating the existing

Table 2. Small ruminant distribution among households by provinces, 1983[2].

Province	Households raising goats	Households raising sheep	Flock size per household
D.I. Aceh	66,397	5,574	4.3
N. Sumatra	107,342	6,174	4.5
W. Sumatra	44,780	538	2.5
Jambi	25,878	4,671	3.8
Riau	27,640	205	4.4
Bengkulu	25,951	1,847	2.5
S. Sumatra	39,181	2,520	2.5
Lampung	133,869	6,636	3.3
D.K.I. Jakarta	5,074	910	5.4
W. Java	481,415	841,025	3.5
C. Java	975,883	203,880	3.3
D.I. Yogyakarta	147,394	17,210	2.7
E. Java	892,615	177,725	3.0
W. Kalimantan	14,128	50	3.4
C. Kalimantan	2,504	11	4.4
S. Kalimantan	8,669	374	4.5
E. Kalimantan	5,030	145	4.8
N. Sulawesi	20,914	30	3.0
C. Sulawesi	28,713	653	4.0
S. Sulawesi	112,815	1,949	3.0
S.E. Sulawesi	14,201	6,300	3.3
Bali	14,064	170	3.7
W. Nusa Tenggara	67,330	8,629	3.8
E. Nusa Tenggara	84,208	8,218	4.2
Moluccas	18,117	405	5.3
Irian Jaya	3,734	20,300	4.7
E. Timor	21,026	1,780	4.0
Indonesia	3,388,872	1,317,929	

demand for export of small ruminant products. It has been estimated that there is an annual demand for some 500,000 head of small ruminants by Saudi Arabia to be sacrificed during the period of Idul Adha[3].

However, the economic opportunity for expanding small ruminant production, as a result of increased demand for export, has to be justified to the small ruminant producers. For example, price rises as a result of increase in demand must reach the farmer producers who will later reallocate their resources as a supply response and hence, increase small ruminant production at the farm level.

I. PRODUCTION CHARACTERISTICS

Although the subsistence needs of farm families are met primarily by food crops, raising goats or sheep in many instances, particularly on Java, is the only way for farmers to accumulate cash, to store capital and to provide inputs such as manure for cropping activities. Consequently, levels of production in terms of total product (bodyweight) reached at specific levels of input used and the number of animals kept per flock may be important factors not taken into consideration. The predominant reason for keeping small ruminants is saving. Often animals are sold whenever cash is needed. Thus the determination of the time of selling is neither based on technical nor on economic efficiency criteria, i.e when the marginal physical product is at least close to zero, assuming labour and feed inputs are very cheap, or when the marginal value of the product at least equals input price. Soedjana and Knipscheer, in a study of the economic roles of small ruminants, reported their findings, namely distribution of ownership, reproductive parameters, labour requirements and contribution to total farm incomes in three different geographical areas: lowland, upland and intermediate-rubber estate areas of West Java[4]. The general description of the study areas is presented in Table 5.

About sixty percent of the small ruminant producers in the study areas kept their own animals, a little over ten percent of the farmers shared the animals while about 30 percent raised their own in addition to those under contract agreements in the form of sharing arrangements (Table 6). The distribution of ownership tends to be similar in each area except in the intermediate rubber estate area where the percentage of farmers who raised animals completely under sharing arrangements reaches over 16 percent. Furthermore, Table 6 indicates that animals raised in the rubber estate area show better reproductive parameters, in terms of litter size for both species

Table 3. Numbers of small ruminants slaughtered and tonnes of meat produced (by 10^3), in 1987[2].

Province	Slaughtered		Meat produced	
	goats	sheep	goats	sheep
D.I. Aceh	46,570	14,200	23,300	890
N. Sumatra	88,541	1,201	44,300	80
W. Sumatra	40,215	0	20,100	0
Jambi	18,552	1,088	930	70
Riau	12,285	0	610	0
Bengkulu	22,050	4,194	11,000	260
S. Sumatra	75,904	737	38,000	50
Lampung	9,402	38,728	470	24,200
D.K.I. Jakarta	19,410	10,357	970	650
W. Java	89,465	174,179	44,700	108,90
C. Java	85,626	83,837	92,800	52,400
D.I. Yogyakarta	19,557	25,469	980	15,900
E. Java	380,187	130,060	190,100	81,000
W. Kalimantan	4,476	0	220	0
C. Kalimantan	2,655	94	130	10
S. Kalimantan	3,665	501	180	30
E. Kalimantan	3,138	5	160	0
N. Sulawesi	2,785	0	140	0
C. Sulawesi	9,750	85	490	10
S. Sulawesi	5,128	566	260	40
S. Sulawesi	18,388	0	590	0
Bali	91,780	0	45,900	0
W. Nusa Tenggara	10,674	1,087	530	70
E. Nusa Tenggara	45,352	28	22,700	0
Moluccas	6,693	0	330	0
Irian Jaya	9,439	7	470	0
E. Timor	8,947	1,905	450	2,200
Indonesia	1,230,634	488,328	612,000	306,200

Table 4. Quantity of skin/hide exports (tonnes) and their values (Rp x 10^3), 1984-1987[2].

Year	Goats		Sheep		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1984	2,751.2	14,988.5	791.1	9,954.4	3,542.3	24,942.9
1985	2,751.9	15,042.6	734.1	9,639.9	3,486.0	24,682.5
1986	1,918.7	13,759.6	712.3	11,166.8	2,631.0	24,926.4
1987	2,281.5	15,527.8	472.8	12,195.6	2,754.3	28,453.4

as well as similar lamb mortality rates, compared with those of other areas. The availability of forages due to the proximity and access to rubber plantations contributes to a year round forage supply, which means cheaper input costs in terms of distances travelled and costs of labour.

Table 5. Characteristics of geographical areas where small ruminants are raised in West Java[4].

Description	Upland	Intermediate	Lowland
Elevation (m above sea level)	700	410	4
Topography	hilly	undulating	flat
Rainfall (mm/year)	2,000	4,500	1,128
Temperature (°C)	25	23	28
Forest area (ha)	433	0	0
Rainfed rice (ha)	259	127	755
Dryland (ha)	1,236	13	56
Estate area (ha)	0	46	0
Communal pasture (ha)	0	16	14
Goats (head/farmer)			
Bucks	-	0.34	0.20
Does	-	2.48	1.70
Young male	-	0.36	0.20
Young female	-	0.86	0.40
Kids	-	1.20	0.50
Sheep (head/farmer)			
Rams	0.37	0.38	0.18
Ewes	2.07	2.55	3.33
Young male	0.37	0.64	0.32
Young female	0.58	0.88	0.62
Lambs	0.74	1.22	0.83

The lowland coastal area is characterized by an extensive grazing system, while the upland is dominated by the 'cut-and-carry' system. In the lowland area the amount of forage available for cutting is minimal and most of the household activities are not farm related, e.g. working in fisheries or as labourers in factories. The different systems imply different animal management which is indicated by the amount of labour used. In general, labour is required for grazing, cutting grass, feeding the animals, providing water, cleaning, shearing and health care. The extensive grazing system combined with the small number of

animals kept per household, such as in the lowland coastal area, absorbs more hours of labour per animal and consists mainly of 'watching' activity in which the shepherd spends his/her time on watching the animals rather than doing something physically related to feed collection or feeding. This will not be the case when a group of farmers share time spent on watching grazing animals within a larger flock.

Table 6. Percentage distributions of small ruminant ownership, flock composition and reproductive parameters at three locations in West Java.

Descriptions	Geographical situation		
	Upland	Intermediate	Lowland
Goat or sheep ownership:			
Farmer owned	59.6	60.1	52.1
Fully shared	13.0	16.2	13.0
Combined	27.4	23.6	34.9
Goat flock composition:			
Adult male	-	7.0	8.0
Adult female	-	47.0	55.0
Young animals	-	46.0	37.0
Kidding	-	166.0	150.0
Kid mortality	-	10.0	12.0
Doe mortality	-	1.0	7.0
Sheep flock composition:			
Adult male	9.0	7.0	4.0
Adult female	50.0	45.0	62.0
Young animals	41.0	48.0	34.0
Lambing	96.0	209.0	97.0
Lamb mortality	10.0	10.0	13.0
Ewe mortality	2.5	4.0	12.0

Grazing is also partially practised in both upland and rubber estate areas, but with significantly less labour compared with the hours spent on cutting grass. In this case, feeding is done mainly by letting the animals graze and not providing feed to housed animals.

Small ruminant raising is a family enterprise in which members of the farm family substitute for each other in taking care of the animals. Depending on the location, the role of women and children is

more or less pronounced, for example, child input for the upland areas is substantial (approximately 20 percent), while women provide 40 percent of the labour input in the lowland areas and only 25 percent in the rubber estate area. Table 7 presents average daily labour used for activities related to keeping of small ruminants in the three different areas.

Table 7. Average daily labour used, bytype of labour for keeping small ruminants in three different areas of West Java; (minutes/day)[5].

Description	Type of labour				
	Family				
	Male	Female	Child	Other	Total
Upland:					
Cutting grass	123	4	37	2	166
Hauling of grass	44	1	14	2	61
Feeding	15	-	1	-	16
Providing water	5	-	-	-	5
Grazing	5	1	-	-	6
Total	**192**	**6**	**52**	**4**	**254**
Rubber estate:					
Cutting grass	77	28	7	-	112
Hauling of grass	32	12	4	-	48
Feeding	14	4	3	-	21
Providing water	2	1	-	-	3
Grazing	9	4	1	1	15
Total	**134**	**49**	**15**	**1**	**199**
Lowland:					
Cutting grass	77	1	9	1	88
Hauling of grass	19	1	1	-	21
Feeding	11	-	2	-	13
Providing water	6	3	1	-	10
Grazing	45	112	1	-	158
Total	**158**	**117**	**14**	**1**	**290**

Economic productivity of this enterprise depends upon the reproductive performance of the animals kept in a flock, the age at which the animals are disposed of or marketed and the price received per unit sold, i.e. price paid per kilogram liveweight. By incorporating the values of mature animals into the flock and by knowing the flock

composition, income derived from the flock can be estimated. Table 8 presents estimated annual returns to small ruminant activity as well as contribution of each flock component to this return.

Table 8. Estimated annual returns and percentages of contribution of flock components of small ruminants in three different areas[4].

Location	Value of adult animal	Returns /farmer	Returns /animal sold	Flock contribution* AM	AF	YM	YF	K/L
	.....(Rp x 10^3).....			.....(percent)....				
Upland:								
Goats	-	-	-	-	-	-	-	-
Sheep	27.7	41.5	15.1	20	46	7	15	12
Rubber estate:								
Goats	20.9	40.1	14.2	11	32	9	25	23
Sheep	17.4	53.2	13.5	9	14	19	29	29
Lowland:								
Goats	27.5	36.5	19.2	21	48	14	11	6
Sheep	16.0	39.3	11.2	23	57	10	6	4

* A = adult, Y = young, M = male, F = female, K/L = kid/lamb

Small ruminant enterprises in the rubber estate areas show a better reproductive performance and relatively lower mortality rates than in the other areas. Although the rubber estate area received lower prices for adult sheep than the upland areas, which is indicated by the returns per animal, a better reproductive performance, in terms of higher reproduction and lower mortality rates, still generate higher returns on a per farmer basis (Table 8). Soedjana and Knipscheer calculated the labour requirement for total activities related to small ruminant keeping on a man-hours per day basis (MHD) for the upland, rubber estate and lowland areas and found the average figures of 1.08, 0.44 and 1.94 MHD per head, and 1.85, 0.85 and 2.91 MHD per adult animal, respectively[4]. These imply that the values of labour per man-hour spent on small ruminant activities are Rp23, Rp52 and Rp14 for the respective areas. Again, the figures indicate an advantage of the situation in the rubber estate area. The rubber estates provide a good potential for keeping small ruminants, because grasses grown between the rubber trees are available for animals, such as

small ruminants, kept by rubber estate employees who benefit from easy access to this feed resource.

II. TECHNOLOGIES FOR PROFITABILITY

A technology may be defined in broad terms as a way of doing things[6]. An improved technology for small ruminant production could help farmer producers in generating a better income from the enterprise. In general, technologies identified with most livestock production can be classified into breeding and reproduction, feeds and feeding, management and health care, as well as marketing. Improvement in these technologies can mean better prospects for a livestock enterprise as either technical and/or economic efficiency is being improved. It has been suggested that the main differences between small ruminant technologies practised by the specialized farmer producers and those practised by the smallholders are as follows. Firstly, the majority of smallholders cannot afford to keep a buck or a ram on their farms. Secondly, due to the absence of bucks/rams the kidding/lambing interval is generally much longer than 12 months. This is due probably to poor detection of oestrus as well as to unavailability of the male at the correct time for mating. Thirdly, the smallholders seldom provide feed supplements for their animals. Fourthly, veterinary or health care is also uncommon. As a result of these practices, animals kept by smallholders are generally lighter in bodyweight, compared with those from specialized farms, while a lower price per kilogram liveweight is received, hence, lower total revenue[7].

One important finding in this study was a feeding practice using soybean curd, a waste product of the *tahu* factory, which gives higher marginal productivity and economic efficiency for animals fed soybean curd. Table 9 shows budgets per ewe at different prices of soybean curd for a larger than average farm.

It is assumed that the reproductive rate is two lambs per ewe per year, flock size is 20 ewes, selling weight is 22 kg at the age of one year, labour costs are Rp 30,000 per month, selling price is Rp 1,100 per kg liveweight and animals are offered daily four kg wet soybean curd plus four kg fresh grass per ewe.

Table 9. Budget per ewe for sheep farm feeding soybean curd at different prices of soybean curd (Rp/kg)[7].

Cost or revenue	Price of soybean curd (Rp/kg) 10	15	20
Buildings	2,000	2,000	2,000
Equipment	1,500	1,500	1,500
Feeds	21,900*	32,850*	43,800*
Labour	18,000	18,000	18,000
Opportunity cost	6,000	6,000	6,000
Health care	1,000	1,000	1,000
Total cost	50,400	61,350	72,300
Meat	48,400	48,400	48,400
Manure	6,000	6,000	6,000
Total revenue	54,400	54,400	54,400
Profit or loss	4,000	- 6,950	-17,900

* break-even points

Table 10 presents tradeoffs between production rates and prices of soybean curd in order to obtain positive gross margins. These figures need to be scaled down of course for smallholder farms with two to six small ruminants per household.

Table 10. Gross margins per ewe at various production rates and prices of soybean curd (Rp/kg)[7].

Production rates (lambs/year)	Price of soybean curd (Rp/kg) 10	15	20
1.8	- 840	- 11,790	- 22,740
	------ *		
1.9	1,580	- 9,370	- 20,320
2.0	4,000	- 6,950	- 17,900
2.1	6,420	- 4,530	- 15,480
2.2	8,840	- 2,110	- 13,060
		-------*	
2.3	11,260	310	- 10,640
2.4	13,680	2,730	- 8,220
2.5	16,100	5,150	- 5,800
2.6	18,520	7,570	- 3,380
2.7	20,940	9,990	- 960
			------*
2.8	23,360	12,410	1,460

* break-even points

This Table indicates that a minimum production rate of 1.9 lambs per year must be maintained in order to obtain a profit with soybean curd price of Rp10 per kg. A higher production rate is required for profit as price of the soybean curd rises. However, when soybean curd price can be reduced below Rp 10 per kg, lower production rates would yield profit. This implies that the technology of feeding soybean curd can be very profitable for smallholder small ruminant farmers residing close to the *tahu* factories. For example, this is the case with some upland Garut smallholders.

A cost-benefit analysis of raising small ruminants by farmers receiving ewes bred with imported St. Croix' hair sheep rams has been implemented[8]. This hair sheep has a heavier bodyweight than the Sumatran Thin-tail (STT), but the latter is highly prolific. Each farmer was initially given four pregnant ewes and after one year, the average returns to labour was Rp 312,600 per farmer.

The above results imply that technologies presently adopted by the specialized farms may also be applicable to smallholders. The smallholders' lack of economies of scale could be partly offset by the use of family labour which would maximize the returns on labour resources. However, other practices such as the provision of rams on a continuous basis and regular veterinary services will be required by the smallholders before they can realize the economic benefits of the specialized commercial producers. Moreover, dissemination of appropriate technology packages for smallholders would be necessary to enhance small ruminant production at the national level, recognizing that the majority of small ruminants are kept by smallholders.

B. THE ECONOMICS OF PRODUCTION

In a production process there is a relationship between the level of inputs used and output produced. Generally, given a level of fixed resources, higher levels of output can only be obtained by adding more variable resources. Therefore, it is important for the farmer producers to identify the profitable levels of inputs to combine with a given level of fixed resources. The farmer should select the level of each input, such as grass, concentrate, labour and others that will produce an output to maximize profit. This relationship can be expressed as:

Y = f (feeds, labour, other inputs), where Y denotes quantity of output, such as kg liveweight obtained as a result of using feed, labour and other inputs.

I. PRODUCTION FUNCTIONS

Sabrani and his colleagues showed a production relationship in their study on small ruminant production on small farms in West Java.[9] The relationship is expressed in terms of liveweight achieved by sheep and goats (Y) as a function of time or age of the animals (X). This is very useful, particularly for estimating the production function of traditional small ruminant systems since it is very difficult to record the actual amounts of inputs used at the level of a smallholder farm.

The production function for lowland sheep is expressed by:
$Y = 4.75 + 1.52 X - 0.047 X^2$, while for lowland goats as:
$Y = 4.33 + 1.47 X - 0.033 X^2$ and:
$Y = 2.048 + 2.548 X - 0.0685 X^2$ for upland sheep. Taking the first derivative of the functions with respect to X, the marginal productivity ($\delta Y/\delta X$), implies that the production functions have decreasing marginal productivity.

The maximum liveweight of the animals may be obtained by setting the marginal physical productivity $\delta Y/\delta X = 0$. For example, the maximum liveweight of lowland sheep, based on the first equation where:
$(\delta Y/\delta X) = 1.52 - 0.094 X = 0$, can be obtained at X (age of the animal) = 16.2 months and for the lowland goats, based on the second equation, where marginal physical productivity:
$(\delta Y/\delta X) = 1.47 - 0.066 X = 0$, implies that the maximum liveweight is achieved at X (age of the animal) = 22.3 months. Similarly, based on the third equation for the upland sheep, the marginal physical productivity:
$(\delta Y/\delta X) = 2.548 - 0.137 X = 0$, gives the maximum liveweight achievable at the age of 18.6 months. The maximum kg liveweight achieved at the above age, obtained by substituting the value of X into the equations, is 17.0 kg, 20.7 kg and 25.7 kg for the lowland sheep, lowland goats and upland sheep respectively. These figures suggest that in the lowland area, sheep reach the maximum liveweight of about 17 kg around the age of 16 months while goats reach higher live

weights (about 21 kg) at the age of about 22 months. In the upland area, sheep show higher liveweights (about 26 kg) reachable at the age of around 19 months. However, maximum achievable liveweight in this analysis does not necessarily mean maximum profit for the farmer producers because the value of input used (costs) and the value of output produced (price) have to be incorporated into the analysis. For this purpose, a profit function can be used to find out the levels of input necessary for maximum profit, where profit is revenue minus costs, as expressed in the following equation:

$$\pi = p_0 q_0 - \sum_{i=1}^{n} p_i q_i - F$$

where p_0 denotes the price per kg of bodyweight and q_0 is the quantity of bodyweight produced at a particular period or age of the animal, hence $p_0 q_0$ is the revenue obtained by marketing the animal. Likewise, p_i and q_i represent price and quantity of the ith variable inputs involved in the production process, for instance p_1 and q_1 may represent cost per kg of grass and total kg grass and p_2 and q_2 are for concentrates necessary to reach the market bodyweight, whereas p_3 and q_3 are cost and quantity of labour, respectively and F is a fixed cost, a cost that does not vary as output changes such as barn and equipment in this example. However, in the longer run, all costs are variables. Furthermore, in this model it is assumed that q_0 is a continuous, differentiable production function represented by:

$q_0 = f(q_1, q_2, ..., q_n, T_1, T_2, ..., T_h)$, with T_h representing a vector of h biological variables determining the expression of q_0, for instance, average daily gain (T_1) and weaning weight (T_2). The usual first-order condition for profit maximization as well as the negative-semidefiniteness and symmetricity of the Hessian matrix have to be fulfilled in order to obtain a unique maximum profit from which the value of the animal per average weaning weight as well as the value of average daily gain are calculated.

Soedjana and his colleagues presented the results from this approach using information provided by the SR-CRSP/Balitnak breeding project (Table 11)[10]. The data used to estimate the production function, $q_0 = f(q_4, T_1, T_2)$, were obtained from observations on weaning weights, average daily gains, feed consumption and feed efficiency, days on feed, and bodyweight at the end of the feeding

period. The estimated coefficients of production function are provided in Table 11. Note that q_0 = liveweight of the animals (kg) at the end of feeding period, q_4= days on feed, T_1= average daily gain (kg), and T_2 = weaning weight (kg).

Given p_0 = Rp2,200 per kg of liveweight, feed cost of p_4 = Rp250 per kg of daily feed consumed, average daily gain T_1 = 0.107 kg and weaning weight T_2 = 11.625 kg, the marginal productivity of the feeding days:

$\delta q_0/\delta q_4 = 0.334899 - 1.70585 - 0.00875\ q_4 + 0.043627\ q_4 - 0.03562\ q_4 + 1.299685 + 0.003755\ q_4$ or $\delta q_0/\delta q_4 = -0.07126 + 0.002992\ q_4$, and the value of lengthening the feeding period with respect to the profit was: $\delta\pi/\delta q_4 = p_0\ \{\delta q_0/q_4\} - p_4 = 2{,}200\ (-0.07126 + 0.002992\ q_4) - 250$ or q_4 = 61.78 days.

Table 11. Estimated coefficients of the production function[10].

Variables	Coefficients	SE*	T-statistic
Constant	-16.0232	7.0884	-2.2604
T_2	4.7734	1.6087	2.9671
T_1	219.0500	133.9076	1.6358
q_4	0.3348	0.1954	1.7133
T_1^2	-3288.3894	1217.5984	-2.6514
T_2T_1	-64.1872	20.0338	-3.2039
T_2q_4 5	-0.1471	0.0544	-2.7018
T_1q_4	12.1465	7.6830	1.5809
$T_2^2T_1$	2.6685	0.9416	2.8338
$T_2^2T_1^2$	-12.7416	4.5035	-2.8292
$T_2^2q_4^2$	-0.0003	0.0001	-2.9941
$T_2T_1^2$	333.8217	95.5074	3.4952
$T_2q_4^2$	0.0018	0.0007	2.6133
$T_1^2q_4^2$	0.1639	0.1067	1.5356
$T_1q_4^2$	-0.1664	0.0891	-1.8673

* Standard error

Setting the optimum length for the feeding period for maximum profit at 62 days, the marginal productivity of the average daily gain:

$\delta q_0/\delta T_1$ = - 3228.3894 (2 T_1) - 64.187269 (T_2) + 2.6685908 (T_2^2) - 12.741675 (2 T_1 T_2^2) + 333.8217 (2 T_1 T_2) -0.1664944 (q_4^2) or ($\delta q_0/\delta T_1$ = 0.9782955). Therefore, the value of one kg of average gain with respect to the maximum profit is:

$\delta\pi/\delta T_1 = p_4 \{\delta q_0/\delta T_1\}$ = 2,200 (0.978) = Rp2,152.

Similarly, the marginal productivity of the weaning weight q_0/T_2 = 19.4606, obtained from:

q_0/T_2 = 4.7734569 - 64.187269 (T_1) - 0.1470565 (q_4) + 2.6685908 (2 T_1 T_2) - 12.741675 (2 T_1^2 T_2) - 0.00003255 (2 T_2 q_4^2) + 333.8217 (T_1^2) + 0.0018805 (q_4^2). Therefore, the value per average weaning weight of sheep with respect to maximum profit is Rp 42,813 that is: ($\delta\pi/\delta T_2$) = p_4 {$\delta q_0/\delta T_2$} = 2,200 (19.4606). However, the change in profit is not necessarily an expression of the economic value of the trait. The economic value reflects the number of animals raised, that is, the derivative of the profit function with respect to the trait divided by the number of animals.

II. INPUT-OUTPUT RELATIONSHIPS

The input-output relationship is a factor-product relationship in which output or product is related to a single variable, production input or factor given a set of fixed inputs, hence, one input is varied and the levels of the other inputs are kept constant. In our previous example, the relationship can be expressed as Y = f(feed | labour), that is, feed is the only input that varies, all other are held constant. The nature of the relationship between a single input and output can be constant, increasing, or decreasing marginal productivity. Our production functions show that there is decreasing marginal productivity. This is the most typical factor-product relationship for the range of input levels in animal production; that is, the application of each additional unit of feed yields an increment of liveweight which is less than that from the previous increment of feed input.

III. MEASURING ECONOMIC BENEFITS

Many approaches can be used to measure the economic benefits of operation of an enterprise. The approaches may classified into four groups[11]. Firstly, partial-farm analysis which includes partial-budget analysis, gross-margin analysis, parametric budgeting, break-even

analysis and generalized cost of production. Secondly, input-output budgeting, marginal analysis and cost benefit analysis. Thirdly, production-function analysis which utilizes regression coefficients for estimation of marginal products and optimal input combinations. Fourthly, whole-farm analysis which includes costs and returns as well as financial analysis. Traditionally, farmers make management decisions by intuition and some calculations, however, this method does not guarantee farmers' economic survival. Gross-margin analysis is one technique that can be used by farmers to determine technical feasibility as well as economic profitability of alternative plans.

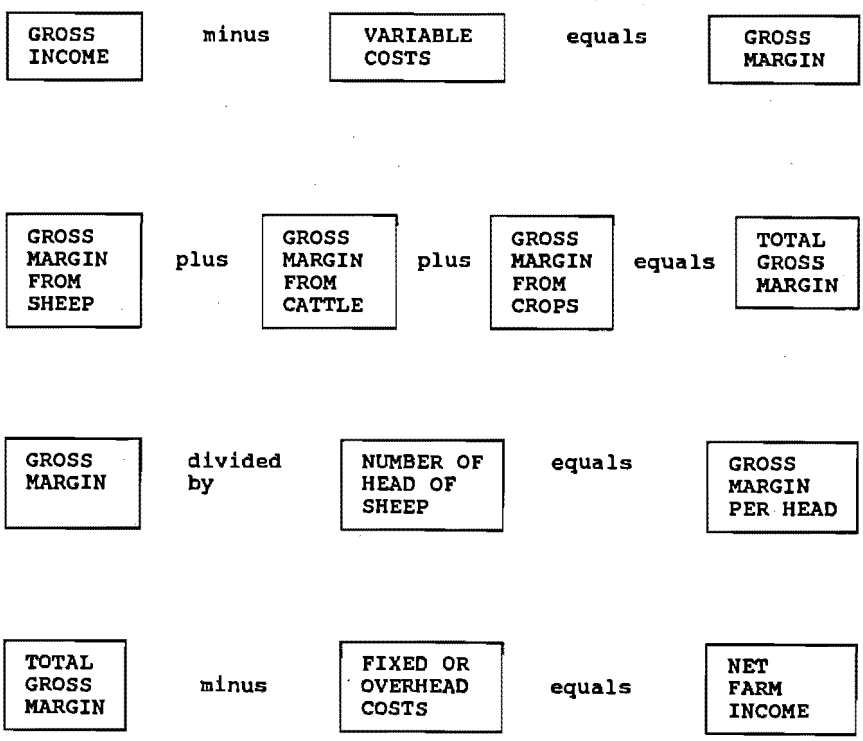

Fig. 1 Steps in gross margin analysis[11].

The gross-margin approach has been used to analyze returns from small ruminant enterprises of some specialized small ruminant farms in West Java[12]. Gross-margin is the difference between the gross income of a farm activity and its variable costs, that is, the

estimate of returns above variable costs for a given activity. The steps in gross margin analysis are illustrated in Fig. 1.

In this particular analysis, the study involved six different farms that were specializing in small ruminant production. The smallest commercial farm consisted of 13 adult animals while the largest farm kept about 400 adult animals. Table 12 shows the results from gross-margin analysis for each farm while Table 13 shows the cost structure in these six specialized farms. In general, the cost structure of a small ruminant enterprise consists of costs of building, equipment, feed and minerals, veterinary services and health care as well as labour. Table 13 presents information on cost items collected from six representative specialized small ruminant farms in West Java.

Table 12. Gross-margin analysis for six specialized small ruminant farms in West Java[12].

Description	Farm					
	I	II	III	IV	V	VI
No. of animals (AU)*	1.05	1.33	1.48	3.24	5.17	24.00
No. of ewes	11	16	15	42	35	200
Farm labour (MED)**	3	1	4	5	14	9
Production rate (%)	173	213	153	205	238	300
Total costs (Rp x 10^3)	802.9	192.4	3557.5	2413.2	4005.1	13738.5
Labour/AU	2.59	0.75	2.70	1.54	2.70	0.38
Gross revenue (Rp x 10^3)	539.8	499.0	4028.8	4121.0	8062.3	30260.0
Gross margin (Rp x 10^3)	-263.0	306.7	471.3	1707.8	4057.2	16521.5
GM***/AU (Rp x 10^3)***	-250.5	230.6	318.4	527.1	784.8	688.4
GM/ewe (Rp x 10^3)	- 23.9	20.4	33.5	40.7	50.7	41.3
GM/MED (Rp x 10^3)	- 87.7	306.7	117.8	341.6	289.8	1835.7

* Animal Units
** Man Equivalent Days
*** Gross Margin

It is clear from Table 12 that the gross margin (GM) and GM/Man Equivalent Days (MED) of labour increases as the number of animals increases, but this is not true on a per animal unit basis (GM/AU) or on a per ewe basis (GM/ewe). This implies that the economic productivity of the animals is different. For example, the highest GM/AU (Rp 784,800) and GM/ewe (Rp 50,700) were obtained by farm V, not farm VI which shows the highest total GM (Rp 16,521,500) and GM/MED (Rp 1,835,700).

Table 13. Cost structure of six specialized small ruminant farms in West Java, (Rp x 10^3)[12].

Cost items	Farm					
	I	II	III	IV	V	VI
Building	80.00	13.30	40.00	300.00	133.30	750.00
Equipment	18.75	19.70	33.00	25.00	30.00	30.00
Feed	459.90	91.25	2,263.00	912.50	985.50	7,300.00
Minerals	0.50	0.30	1.00	0.50	1.00	70.50
Health care	0.00	4.80	20.50	6.00	141.00	30.00
Labour	120.00	0.00	1,095.00	809.20	2,046.80	3,510.00
Opportunity	123.75	63.00	105.00	360.00	667.50	1,920.00
Other	0.00	0.00	0.00	0.00	0.00	128.00

Results of the analysis in Table 12 are ranked and compared by computing Spearman Rank correlation coefficients to measure interdependence between the different parameters[13]. A strong correlation was found between animal numbers and labour, total variable costs, gross returns and gross margins. Also gross margin per animal unit was significantly correlated with the number of animals. Some economies of scale with regard to labour utilization for larger flocks are expected. Reasons for the lack of a statistically significant correlation between flock size (AU) and labour productivity as well as return to labour (GM/MED) may be found in the relatively low share of labour costs in total costs and in substitution of labour for other inputs such as collecting feed instead of buying feed.

C. MARKETING

Small ruminants, as mentioned earlier, play an integral role in smallholder farming systems. This role includes liquidity aspects (that is the capacity of smallholders to produce cash to meet short-term urgent financial needs), cash income generation, supply of manure for high value crops and a form of insurance against risk. Furthermore, all these factors interact to produce the market forces which have an impact upon household production decisions and help to define the marketing systems that have evolved to meet this demand[14]. Likewise, little is known about how the animals are marketed and what the trends are in market volume and market prices, although in general it

is true that small ruminants are easy to transport and have a relatively high turnover rate compared with large ruminants.

A study in a transmigration area, Way Abung, Northern Lampung province, showed that prices farmers received for goats fluctuated seasonally depending on the agricultural and religious calendars[15]. Prices are lowest during the season of scarcity when food stocks are low and the first corn and rice crops of the growing season have yet to be harvested. Evidence of increase in prices received for small ruminants during the religious period of Idul Adha, when the monthly market volume is nearly double, has been observed through a small ruminant market study during Idul Adha in Bandung[16].

The small ruminant market flow in West Java in illustrated in Fig. 2.

Often farmers prefer to sell their animals directly to the local middlemen in the village who are usually resident farmers who buy and sell small ruminants as either their primary or secondary activity. Farmers consider several factors in deciding their marketing strategy such as whether or not they have enough animals to sell to justify a trip to the market, whether they have experience and feel comfortable dealing with strange middlemen in the livestock market and whether they have other work to do, particularly in the fields, on a market day[17].

The usual economic criteria for evaluating market performance include structure, conduct and performance (SCP). Market structure is examined in terms of the number of buyers or sellers operating in the market, conditions or barriers to entry of additional buyers or sellers in the market and the possible dominance of individual buyers or sellers in the market determined usually by their share of purchases or sales. Market conduct is usually evaluated in terms of possible collusion among traders in pricing policy and market performance is usually measured in terms of the difference between market margins and estimated transport, plus handling costs between different market levels for the same product or between the same market levels at different locations.

A market structure composed of only a few buyers does not necessarily imply that the market is not efficient. Other factors should be evaluated, such as volume of sales. The volume of sales may be

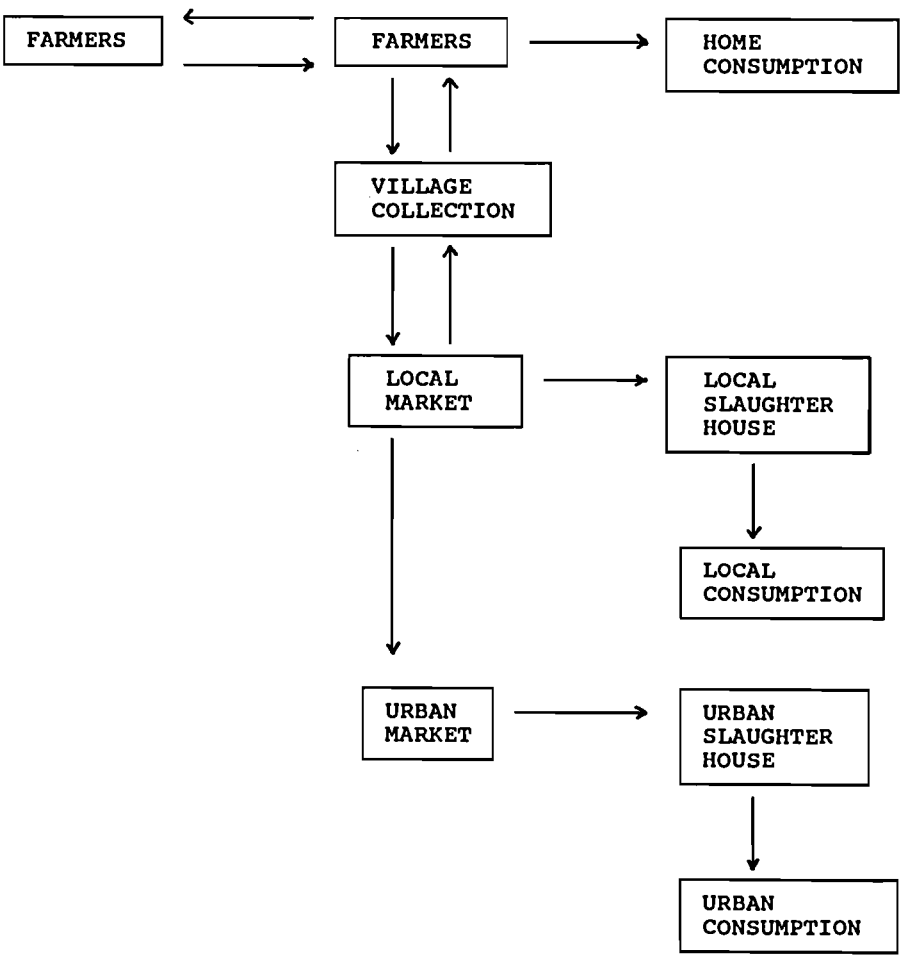

Fig. 2 Generalized market structure for goats and sheep[14].

insufficient to support other buyers in the market. Also, the large investment in operating facilities required for efficient operation may not justify more than a few buyers. For example, a single buyer with a large facility, with significant economies of scale, may operate much more efficiently and at a lower cost margin than a large group of small, less efficient buyers. Market performance, the most important criterion for judging efficiency, is judged particularly unsatisfactory where there is evidence of excessive or dominant concentration of particular

market participants. For example when there are few buyers, high profits for traders, and possible collusion between buyers, then there are strong indications that the market is not operating efficiently for the producers.

I. MARKET CHANNELS AND PARTICIPANTS

In addition to the individuals involved in marketing small ruminants illustrated in Fig. 2, there are other market participants, which also indicates other market channels, such as *makelar* or brokers, sedentary middlemen and itinerant middlemen in addition to village collectors who are intermediate between farmers and the market place. The itinerant middlemen also serve as an intermediate point between a local market place and other market places within the district[14].

The village collector is a key figure in the animal market system. He buys and sells animals, often as a secondary activity, using his skill in examining the animals to estimate the value by sight and touch, while sometimes he keeps the animals for fattening or in anticipation of price increases. The system of estimating the value of an animal by sight and touch is very subjective and, therefore, mostly used for bargaining. The skill is usually based on generations of experience and acquired by learning from other family members. It seems to be not an easy skill to learn. In Aceh there is an arrangement between farmers and middlemen for payment of the transaction where most of the village collectors pay 50 percent of the agreed price and pay off the balance on the next market day. Cash payments between farmers and long-distance traders were usually 100 percent[18].

Farmers who want to sell their animals directly to the market can deal with a variety of middlemen. The broker risks full ownership of animals only occasionally, while the village collector assumes full ownership over the animals with which he trades. The broker operates at the market site, seldom holding animals for any period of time and attempts to sell the animals on the same day. The village collector is well known by the farmers, while the broker is only superficially known at the nearby market place. The sedentary trader is similar to the price-fixing broker who intercepts farmers as they approach a local market. They prefer not to trade between markets, but between farmers and a given local market. In contrast, itinerant

traders operate between markets. These include short and long distance traders. Itinerant traders collect, hold and stock animals. These activities are considered to improve market efficiency, taking advantage of economies of scale, especially in transport.

II. MARKETING MARGINS

A marketing margin is the difference between the price paid by consumers and that obtained by producers, that is the difference between the primary and derived demand curves for a particular product. It represents the price of a collection of livestock marketing services which is the outcome of the demand for and the supply of such services. Under some conditions, marketing margins can be expected to remain constant as the quantity of product marketed is changing, while under other conditions, this could vary. Empirical estimates of primary demand functions are usually based on retail price and quantity data, while derived demand is based on price-quantity relations which exist either at the point where products leave the farm or at intermediate points where they are purchased by wholesalers or processors. Primary demand is determined by the response of the consumers, while the derived demand for the farm product is obtained by subtracting the per unit costs or prices of all marketing components from the primary demand function. Fig. 3 illustrates the marketing margins.

The effect of marketing margins on farm and retail markets is depicted in Fig. 3. The supply or production of small ruminants at the farm level is S_p while the supply S_d of farm inputs at the retail level is the farm supply plus marketing margins. The demand for small ruminant products by consumers at the retail level is D_p while the derived demand D_d at the farm level is D_p less marketing margins.

Marketing margins include transportation, processing, wholesaling and retailing costs. With constant margins, the demand curves (and supply curves) at the farm and retail levels have the same slopes. Then the price elasticity at the farm level will bear the same ratio to the elasticity at the retail level as the farm price to the retail price of a particular quantity. This means that the price elasticity of demand for farm products is lower at the farm level than at the retail level. If margins rise per unit as product quantity expands, this tends to make

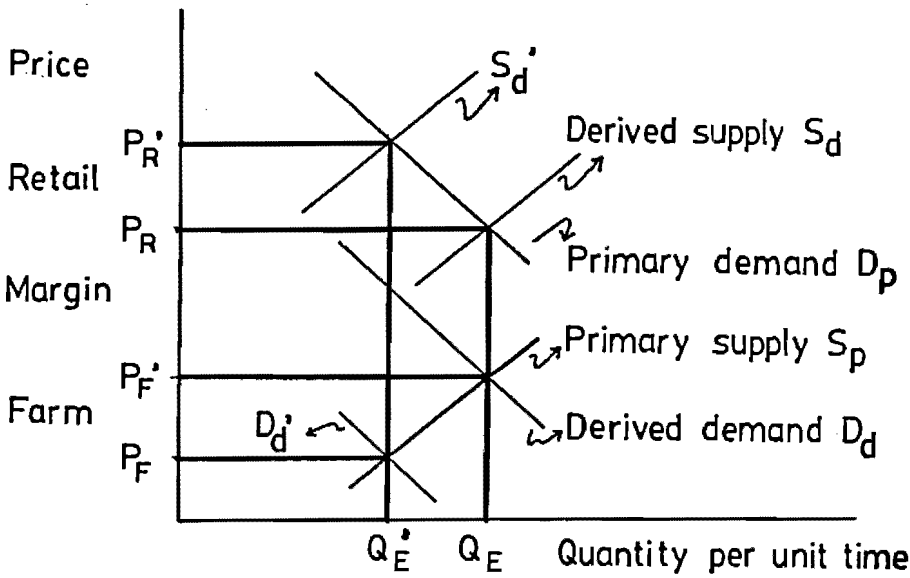

Fig. 3 Illustration of marketing margins.

the demand for farm products even more inelastic. If margins decrease per unit as the quantity of products expands, this tends to make the demand for livestock output less inelastic. In fact, marketing costs tend to remain somewhat stable as livestock output expands.

Furthermore, Fig. 3 shows that the initial market equilibrium is at quantity Q_E, farmgate price P_F and retail livestock price P_R. If we have elements of imperfect competition in the form of excess profits or costs, these costs are assumed to raise marketing margins by a fixed amount for all quantities and therefore to reduce demand at the farm level to D_d' and to reduce supply at the retail level to S_d'. The result is a lower equilibrium farm quantity Q_E', lower price P_F' and a higher consumer price P_R'. Conversely, viewing D_d' and S_d' as an initial position, part of the gains from removing excess profits from the marketing sector are passed on to farmers and part to consumers. The distribution of the benefits depends on the supply and demand elasticities.

With marketing margins reduced by a given amount on all farm quantities as in Fig. 3, the following are the possible resulting distributions of benefits: 1) all benefits go to consumers and quantity is unchanged when demand is perfectly inelastic, but if demand is perfectly elastic the benefits go to farmers and quantity is increased; 2) all benefits go to farmers and quantity is unchanged when supply is perfectly inelastic, but if supply is perfectly elastic the benefits go to consumers and quantity is increased. Thus, it is not possible to say exactly whether farmers or consumers gain the most benefits from increased marketing efficiency, however, in the long run supply of small ruminants tends to be more elastic and benefits eventually pass mostly to consumers.

Some measure of the impact of technological change on the farm and retail sectors is also apparent. As farm resources become more productive, the primary supply increases and the price to farmers is depressed. With a fixed marketing margin, the benefits of the lower farm price are passed on to consumers.

Market price is one of the most important economic factors that influences the allocation of the farmers' resources. In West Java, meat market prices are not subject to any government price control and are therefore determined by the supply and demand of different kinds of meat[17]. Based on the estimated conversion rate multiplied by the sale price, the value of the animal to the butcher can be estimated (Table 14).

Table 14. Estimated revenue components of an 18 kg liveweight goat/sheep (1982)[17].

Component	Weight (kg)	Retail price (Rp/kg)	Total revenue (Rp)
Carcass	9.0	2,200	19,800
Hides/skins	2.0	-	2,000
Inner organs	1.5	2,000	3,000
Head	1.5	1,000	1,000
Lower legs	1.0	1,500	1,500
Waste	3.0	0	0
Total	18.0		27,300

Using a selling price at farm level of Rp1,000 per kg liveweight, the value per animal at the farmgate is Rp18,000. When the animal is slaughtered and each component is multiplied by its price then the total revenue from selling all components is Rp27,300. Therefore, there is a difference in the value of the animal at farmgate and retail of about Rp9,300. The difference has to cover all marketing costs and fees involved in transferring the animal from the farm to the retail place.

D. INVESTMENT ANALYSIS

A procedure for evaluating the effects of a farm manager's investment choices on business profit, risk and liquidity is *capital budgeting or investment analysis* which consists of an orderly sequence of steps that produce information relevant to an investment choice[19]. These steps can be classified as 1) identification of investment alternatives; 2) selection of appropriate choice criteria; 3) the collection of relevant data; 4) the analysis of data and 5) the interpretation of results in terms of the various choice criteria.

The following examples of investment analysis consider only a small ruminant enterprise that is neither subsistence level nor classified as a smallholder enterprise. The analysis attempts to demonstrate a soundly profitable small ruminant business using presently available technical and biological parameters. Therefore, step one will not be followed. Hence, the analysis assumes that a small ruminant enterprise is the alternative already identified. Step two, the choice criteria considered are *net present value* (NPV), *benefit-cost ratio* (B/C), *internal rate of return* (IRR) and *break-even* criterion. The NPV criterion uses the discounting formulas for a series of payments to value the projected cash flows for the investment at one point in time. The NPV criterion therefore, directly accounts for the timing and magnitude of the projected cash flows.

$$NPV = - Inv + P_1/(1+i)^1 + P_2/(1+i)^2 + \ldots + P_n/(1+i)^n + V_n/(1+i)^n$$

where Inv is the initial investment, P_n is the annual net cash flows attributed to the investment that can be withdrawn each year, V_n is

any salvage or terminal investment value, n is the length of the planning horizon and i is the interest rate or required-rate-of-return.

The B/C is the ratio between total discounted benefits over total discounted costs at the end of the planning horizon, while the IRR which is also sometimes called the 'discounted-rate-of return', the 'marginal efficiency of capital', or the 'yield of an investment', is the rate of interest which equates the NPV of the projected series of cash-flow payments to zero. The break-even criteria calculate the minimum output which must be produced, or the minimum price which must be received for the output, in order for the enterprise to break-even, that is, to make zero profit.

Step three, the collection of data, involves 1) information on initial investment usually for barn (*kandang*) or shelter, equipment, animals and land; 2) the length of the planning horizon, usually considered to be ten years; 3) determination of terminal (salvage) values; 4) determination of interest rate used, (18 percent) and 5) construction of *Net Cash Flows*.

Table 15 shows a capital budget for a large specialized small ruminant enterprise with grazing in a rubber plantation. Initial purchase of the animals cost Rp45,000 per ewe and Rp60,000 per ram, modest shelter and equipment cost Rp7,500/m2 and Rp5,000 per unit respectively. Land is neither rented nor purchased since the animals are to graze weeds on the floor of rubber plantations on a rotation basis.

The investment analysis shown in Table 16 indicates that the investment yields a net present value of Rp136,778,600 at the end of a planning horizon (of 10 years). The ratio between total discounted benefits over total discounted costs, Rp445,813,300 over Rp309,034,600, or B/C = 1.44, while the internal rate of return generated by the investment is 67.92 percent. This operation will break-even when about 1,520 head of yearlings are sold each year. Obviously, results of the analysis will be very different when different assumptions are employed in the model.

Table 15. Budget per year for sheep breeding and fattening farm with 1000 ewes and 100 rams as standing stock; (Rp x 10^3).

	Unit	Quantity	Price	Total
Investment				
Land	Ha	0	0	0
Shelter	SqM	1,600	7.5	12,000
Equipment	Unit	1,000	5	5,000
Ewes	Head	1,000	45	45,000
Rams	Head	100	60	6,000
	Total			68,000
Fixed				
Depreciation:				
- Building	%	0.03	12,000	360
- Equipment	%	0.2	50,00	1,000
- Capital Interest	%	0.05	68,000	6,100
- Tax/insurance	%	0.015	68,000	1,830
- Repair/maintenance	%	0.05	68.000	6,100
Labour:				
- Manager	MM	12	200	2,400
- Assistant	MM	60	150	9,000
- Casual	MM	144	75	10,800
	Total			31,380
Operating				
Concentr	Kg	40,150	0.15	6022,5
Medicine	Unit	1,100	0.8	880
Rep.stock	Head	200	45	9,000
Mortality	Head	165	30	4,950
	Total			20,852.5
Sales				
12 months	Head	2,280	40	91,200
Culled	Head	200	40	8,000
	Total			99,200

Table 16. Investment analysis of the sheep breeding and fattening farm with an initial 1000 ewes and 100 rams as standing stock (x 10^3).

Year	Investment cost	Fixed cost	Operating cost	Total cost	Discounted cost	Balance benefit
0	68,000	0	0	68,000	0	-68,000
1	0	26,593.22	17,671.61	44,264.83	84,067.79	39,802.96
2	0	22,536.62	14,975.94	37,512.56	71,243.89	33,731.32
3	0	19,098.83	12,691.47	31,790.31	60,376.18	28,585.87
4	0	16,185.45	10,755.48	26,940.94	51,166.25	24,225.31
5	0	13,716.48	9,114.819	22,831.30	43,361.23	20,529.92
6	6297.336	11,624.14	7,724.423	25,645.90	36,746.80	11,100.90
7	0	9,850.967	6,546.121	16,397.08	31,141.36	14,744.27
8	0	8,348.277	5,547.560	13,895.83	26,390.83	12,495.14
9	0	7,074.11	4,701.322	11,776.13	22,365.24	10,589.10
10	0	5,995.602	3,984.171	9,979.774	18,953.59	89,73.820
				390,034.6	445,813.3	136,778.6

Int. rates = 18 %
B/C Ratio = 1.44
NPV = 136,788.6
IRR = 67.92 %
BEP = 1520 Yearlings

CONCLUSIONS

Small ruminant production in Indonesia plays an important role as an income generating activity, particularly for the smallholders, while being a source of animal protein to support national development programs for increasing *per capita* protein consumption. The involvement of Indonesian rural households in raising small ruminants is large, as indicated by the participation of entire farming family. One out of every five farmers keeps goats or sheep. The contribution of goat and sheep enterprises within the total farming income for small ruminant keepers is substantial. However, the potential for increased productivity in the future, particularly with an increased export demand for small ruminants by Middle Eastern and other Asian countries, still has to be explored, for example, by disseminating new small ruminant technologies to the farmer producers. Improved technologies will help the farmer producers to

increase their incomes and at the same time provide larger supplies of meat for the nation. Supply responses have to receive careful attention since price signals from the market determine reallocation of resources by farmers.

Promoting a larger scale of small ruminant operations through taking advantage of forage availability from estate crops such as the Nucleus Estate Smallholder Project and other forms of integrated operations will benefit both the large scale producers and the consumers. Investment analysis is carried out on this large-scale enterprise. This could be carried out on smallholder farms, although the multipurpose nature of these render calculations less easy and less useful in real life. However, it must be remembered that the large majority of small ruminants are indeed kept in small flocks by smallholders and efforts should be made to make these enterprises more economic.

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CHAPTER X
SOCIAL ASPECTS OF GOAT AND SHEEP PRODUCTION

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INTRODUCTION

Goats and sheep in Indonesia play a complex function in Indonesia's farming systems. Their biological and economic functions have long been recognized. Besides producing animal products, they also provide manure to maintain soil fertility. Most of all, they are one of an Indonesian farmer's sources of cash. Nevertheless, the social functions of both goats and sheep are not well recognized, except for those related to fighting rams in particular areas of the country. Some literature about farming systems and animal production does recognize the close and typical relationship and interaction between goats and sheep and the society of local farmers. Yet, little is known about the typical social roles of these animals in local social affairs.

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A. SUPPLEMENTARY FUNCTION

In Indonesia, goats and sheep are raised as a secondary farm activity. Their function is supplementary as their presence or absence in the farm does not necessarily affect greatly the other farm activities. This situation is true for both Java and the outer islands of Indonesia although, in Java with very limited land ownership and highly intensified rice farming activities, the dependence of goats and sheep on household labour is more obvious[1]. In Java, animal feed is collected from a variety of sources including roadsides, rice fields, gardens and forests. The use of residues and by-products from crops is very common and the collection of animal feed for these cut-and-carry systems depends on a heavy input of unpaid family labour. Goats and sheep in Java complement the crop production enterprise well by utilizing materials which might otherwise be unused and making use of the surplus labour present within most farm families.

Although their function in a general farming system is supplementary, goats and sheep function to absorb hidden family labour, whether unemployed or underemployed, which gives them quite important social functions. They also serve as a source of funds for education for a farmer's family members as well as for use by young adults in a family. Furthermore, with their supplementary function, goats and sheep serve as a 'safety valve' for farmers when a state of financial emergency occurs. In the centres of fighting sheep in West Java, sheep contribute to the social standing of those who raise good fighting sheep. Ram fighting is a common sport in the region and champion animals command a very high price. The phenomenon of sheep fighting blends elements of sociology and economics as it confers on the successful owners a high status within the village in addition to making their animals extremely valuable. Sheep fights are well attended community affairs[2].

B. FINANCIAL CONTRIBUTION

The importance of a 'saving' function of goat and sheep production in Indonesia is well known. It is true that goats and sheep are an asset for providing cash when farmers are in urgent need.

Goats and sheep serve as a living bank account for farmers. Farmers 'save' when extra income is available, then they 'withdraw' their 'savings' when other cash sources disappear and needs arise. 'Saving' through buying or loaning animals occurs also during the harvest periods and 'withdrawing' through selling them occurs during the nonharvest months when cash is low.

The financial contribution of goats and sheep to the total farmer's income is not as high as one might expect. Yet, it is an important source when farmers are in great need. For example, cash proceeds from selling animals are usually used to pay for immediate urgent needs that cannot be covered by the relatively sporadic farm income from other parts of the farming enterprise to pay school fees, for weddings, for circumcisions, for funerals and for many other occasions related to religious and local customs. In such a situation, the regularity of cash contribution from goats and sheep is not of primary importance. Its liquidity to provide immediately a relatively large amount of cash is more important than possibilities provided by the very limited cash sources in the other existing parts of the farm enterprise. The importance of goats or sheep as a capital resource is reaffirmed by the role of the household head as the decision maker in selling them[2].

C. GOAT AND SHEEP OWNERSHIP PATTERNS

Goats and sheep are concentrated in the island of Java with West Java having the largest population[3]. The average ownership and ownership patterns are similar. With the average ownership of approximately 3.5 head per farm family, the ownership pattern often follows the local or traditional share system.

Farmers who raise goats or sheep either own them or look after them for another individual. In the second case, one farmer raises another villager's animals and they share the resulting offspring. A traditional lending institution in which farmers share the offspring is called *gaduhan* or *paroan*. In this system, farmers who want to raise goats or sheep, but cannot afford to purchase the initial breeding stock, frequently begin by borrowing an animal from a relative, neighbour, or even people from another village. Animals are loaned in return for a share of the offspring. The specific conditions regarding the number of

kids or lambs to be returned and the time of pay-offs differ from location to location. The extent of sharing is difficult to estimate, but without a doubt shared animals comprise an important part of the flock of landless and subsistence farmers[4,5]. Traditionally, sharing-in rates and sharing-out rates are virtually equal, indicating that at least part of the received animals are shared 'forward' to other farmers.

There are several reasons why a better-off farmer may decide to give his goats or sheep to another individual through *paroan*. He might choose to reduce the risk of theft or disease by dispersing his herd, or loan animals to help a neighbouring family having a hard time to make ends meet. Or he might decide his time is better spent on other activities, while still ensuring himself of some income from an investment in goats or sheep.

Under the *paroan* or *gaduhan* system, the owner usually loans a female but retains its ownership, plus one-half of its offspring. He also has the right to reclaim and sell the original animal at any time. In practice this is rarely done without some forewarning to the caretaker. Most often, if the owner needs cash he will first sell one of the animals he keeps on his own farm.

The caretaker is responsible for ail care and makes all feeding and breeding decisions. In return, he gets one-half of the kids or lambs from the leased female and is usually given first choice in the case of multiple births. If there is a single kid or lamb, it will either go to the caretaker or upon sale its cash value will be divided with the owner. The owner usually claims his half of the offspring when they are considered to be adult.

If the animal given as *paroan* dies, the caretaker is not liable for restitution. If a kid or lamb designated as part of the owner's share dies before it is claimed, it is simply not counted in the balance and the next kid/lamb produced takes its place.

Risk in the *paroan* or *gaduhan* system is very low, as animal loss through disease or theft is minimal and in any case, compensation to the owner is not necessary. *Gaduhan* provides a means to begin sheep or goat production without having to make a cash investment. Farmers feel comfortable with this kind of loan as they are generally neighbours with the animals' owner. They accept the animals as part of a broader and more familiar relationship than that which exists with formal bank loans.

D. CONSUMPTION PATTERNS

Food habits are one of the most significant and deeply held aspects of man's cultural patterns all over the world. The term 'food habits' can include different methods of obtaining foods or their production and can also involve the various methods of harvesting, storing, preparing and cooking food as well as the very act of eating food, including the implements used.

Food habits among Indonesian peasants in relation to goat and sheep products, are related to many factors which are in turn interrelated with each other. Although goats and sheep contribute significantly to the total meat production and consumption in Indonesia, annual average consumption within peasant households is low. The average consumption of goat meat and mutton among farmers' households during the year 1987 averaged 3.7 kg/household. This is a slight increase from the average consumption in 1983 which was 3.0 kg/household[3].

The consumption of goat and sheep meat is normally assumed to be related to the consumption of other non-animal farm products or animal protein substitutes. The economic state of a household often acts as the decisive factor either in increasing or in decreasing the consumption of goat and sheep meat in terms of frequency and quantity. In many cases, the consumption of goat and sheep meat, as well as other meat produced by four-legged animals, is during festivals, religious holidays, or special occasions such as wedding parties and circumcision ceremonies. Indonesian farmers rarely consume meat produced by their own animals[6,7]. They usually obtain meat from other sources. The primary reason is that the quantity of meat produced from a goat or sheep is too much for a family to consume within a two or three day period. Refrigeration to keep meat fresh is not available in most villages in Indonesia and meat spoils quickly in the tropics without refrigeration.

Other factors that might either hamper or promote the consumption of goat and/or sheep meat are the economic and social status of the family[8]. The family's prosperity plays a significant role in the family's consumption pattern. Often consumption of animal products, including goat and sheep meat, appears to be an indicator of the family's standard of living. The consumption of goat or sheep meat

among rural families is not dictated by trying to obtain a balanced diet, but, it emphasizes the well-being of a family which can afford to eat meat.

E. THE HUMAN COMPONENT

Since goats and sheep are an important source of cash, care has to be taken in managing them. Goat and sheep raising are not seasonal activities; most tasks do not require special skills or strength. Herding and watering animals can be performed by children under ten years of age; they can even herd the animals while playing. According to one study, Philippino villagers actively engaged in crop and livestock production range from 13 to 65 years of age[9]. Another study found that Javanese children aged ten to 13 often participate in such economic activities[10]. The proximity of animal barns to houses and the flexible amount of time and/or effort needed for most tasks in goat and sheep production make it possible for all family members to contribute to this activity[8]. Feeding and watering goats or sheep are the easiest tasks and can be performed by nearly every age group, regardless of sex, while cutting grass, shearing and washing animals demand more strength. Table 1 shows the participation level in raising goats and sheep in West Java by different age groups.

Table 1. Division of labour: relationship of age to percentage participating in goat and sheep production in West Java[1].

Age group	Upland	Lowland
	Percentage	
1. Less than 10	4	19
2. 10 - 19	63	56
3. 20 - 29	92	67
4. 30 - 39	84	75
5. 40 - 49	100	86
6. 50 - 59	95	81
7. Over 59	84	75

The most important activities in goat and sheep production are herding, cutting and carrying grass, feeding and watering, as well as bathing and shearing. For example in one study about 50 per cent of the total time was spent on cutting grass[11].

Tables 1 and 2 show that all age groups participate in goat and sheep production activities. In the upland areas of West Java where sheep are raised in confinement, the husband is the one who bears the greater responsibility in sheep production activities. A son's participation level is second to that of the household head while the roles of a wife and a daughter are not as prominent as that of a husband. A similar situation is also true among goat farmers in the lowland areas where goats are also raised in confinement.

Table 2. Division of labour: responsibility for primary tasks[1].

Relationship in household	Herding	Cutting grass	Feeding	Watering	Washing	Shearing
			Percentage			
Lowland area (goats)						
1. Husband	100	57	57	56	53	100
2. Wife	0	10	12	14	8	0
3. Son	0	22	22	21	29	0
4. Others	0	11	9	9	10	0
Sample sizes	23	58	58	57	38	57
Upland area (sheep)						
1. Husband	65	66	74	81	79	78
2. Wife	3	6	7	3	0	0
3. Son	29	20	13	13	16	14
4. Daughter	3	2	1	0	0	0
5. Others	0	6	5	3	5	8
Sample sizes	31	133	133	31	123	131
Lowland area (sheep)						
1. Husband	9	53	41	29	24	45
2. Wife	3	5	9	8	0	11
3. Son	53	26	32	47	50	22
4. Others	35	16	18	16	26	22
Sample sizes	34	19	22	38	38	9

The roles of a son and other members of the family are more important among farmers who combine confined cut-and-carry and

grazing methods for raising of small ruminants. As previously mentioned, children can herd animals while playing and in a situation where sheep are grazing, sons are given the responsibility to watch them since almost all tasks related to small ruminant production are performed in the grazing area around the village.

While husbands and wives share unequal responsibility in small ruminant raising activities in West Java, that is also true in other areas of small ruminant production activities. Husbands tend to dominate the decision-making in terms of sale of farm products and the decision on how to spend the money if something is sold. This is true for goats and sheep in Java, but is not so for poultry raised in the villages. Women are primarily responsible for raising poultry and they are also responsible for selling them. The percentage of housewives who play key roles in the decision-making of buying and selling goats and sheep, is particularly low (Table 3).

Table 3. Women's involvement as decision makers[12].

Decision	Upland	Lowland
	Percentage	
Buying sheep	9	5
Selling sheep	12	8
Managing money	57	63
Sample size	(56)	(49)

Usually males are engaged in such activities more frequently than are females. The contribution of females in sheep and goat raising is more complementary. Women assume males' work if the latter cannot perform such activities, but they can constitute up to 40 per cent of the total labour input[13].

The significance of female household members in goat and sheep production depends on how they are perceived. In more recent research, it has been found that women in different areas in West Java do participate in physical activities concerned with sheep raising[12]. The percentage of women who participate in particular physical tasks varies from 0 to 38 per cent. Women, in fact, contribute 17 to 19 per cent of time spent in sheep production. A wife in a farm

family spends an average of 32 minutes a day tending the family's sheep.

The dominance of the husband as the household head and the prominent roles of a wife are seen in various tasks related to decision-making. Neither sons nor daughters are deeply involved in the decision-making process related to small ruminant production or, if there is any involvement it is limited to non-marketing policy matters[6]. In relation to selecting breeding animals, sheep farmers rely on their experience as well as on their aesthetic perceptions. This is particularly true for the owners of fighting sheep in the area of Garut, West Java. Since fighting rams contribute to the farmer's social standing, the household head is the one who decides whether to select a sheep for breeding purposes, or for slaughter, as well as for deciding how to raise the animals.

Among sheep farmers without fighting rams, and goat farmers, the role of a husband in the process of decision making is not as strong as among sheep farmers with fighting sheep. Yet, a husband is still the dominant figure in such a process. Selling farm animals is still largely decided by the husbands as the household heads.

Goats and sheep are most valued as income earners and manure producers. Families with goats and sheep commonly receive more cash income from their sales than they do from marketing any other single farm product, particularly among farmers who own very limited land and farm only to fulfil their daily needs (subsistence farmers).

Selling goats or sheep usually occurs if a family is prompted by an emergency or a need for 'big money' such as capital during the planting season, school fees, a wedding, circumcision, or other ceremonial occasions. This situation is largely true for all rural farmers in Indonesia where farm animals also constitute a major form of asset holding and security against unforeseen cash requirements[5].

The same pattern is also seen in the decision-making process related to killing sheep and goats for special occasions related to religious feasts. Idhul Adha is an important religious affair for most villagers in Indonesia where Islamic traditions mandate the sacrifice of a four-legged animal to commemorate Abraham's obedience to God's command that he sacrifice his son. On such an occasion, the decision

whether to sacrifice a goat or a sheep or not to do so is taken by the head of the household[6,7].

F. EXTENSION AND MASS-MEDIA

For many villagers, including goat and sheep farmers, asking a neighbour is far easier than waiting for an extension worker who rarely visits their hamlet because of its relative isolation and because of the transportation problems. In Central Java it has been found that the neighbour is the primary source of information regarding goat and sheep production, while local government officials are viewed as resource persons[14]. Nevertheless, the role of neighbours as sources of information, though important, is limited by the extent of their knowledge. Their roles drop dramatically when farmers need to discuss a technical problem of goat or sheep production before they make a decision. In such a case, farmers consider extension personnel as the second most important source of information. When these are present in the village, farmers normally use this chance to discuss technical problems of animal production with them. Virtually all small ruminant farmers appreciate the extension worker's advice, the only problem is the infrequency of his/her visits to isolated villages.

Besides the material presented in an extension program, the personnel's capability to communicate is a crucial factor to be considered. Since Indonesia consists of more than 250 ethnic groups with more than 300 languages, it is important to consider the efficiency of using a local language or dialect for communication between extension personnel and local farmers. This helps to reduce both social and intellectual gaps between farmers and extension personnel. A poorly educated farmer is not likely to be able to interpret information given by a person from a higher socio-economic status with a strikingly different way of speaking or speaking in Indonesian rather than in the local language. Furthermore, regularity is also important in the process of transferring information to small ruminant farmers. Regularity and frequency in extension visits enable farmers to be more comfortable with the extension personnel and enables them to accept more ideas about goat and sheep production.

G. MARKET ISSUES

Price is as one of several important factors in selling animals. Although many goat and sheep centres in Indonesia are isolated, the distance to the market and the expenses for transportation are not perceived as significant problems so long as the price received satisfies the farmers. The proximity of local markets, availability of transportation and facilities, as well as flow of information shape the marketing system of goats and sheep. Table 4 shows various aspects of the market issues for goat and sheep farmers in the upland and lowland areas of West Java.

Table 4. Market issues[1].

Issues	Upland	Lowland
	Percentage	
1. Market distance, km:		
less than 1	0	16
1 – 5	56	64
6 – 10	44	19
More than 10	0	1
2. Transportation means:		
Walk	32	79
Public transportation	24	0
Other	43	21
3. Price information	46	97
4. Satisfaction about price	94	96
5. Who influence price:		
Farmers in the hamlet	34	88
Farmers out of the village	7	11
Outsiders	59	1

Marketing channels for goats and sheep in Java and in the transmigration areas vary considerably. However, a similar pattern exists in the process of marketing in such areas. The most common market structure for small ruminants in Indonesia is that farmers sell their animals either in the nearest local markets or at the farm-gate to

a local middleman, usually a neighbour. If a farmer takes his own animals to the market, it usually requires a morning off work. Consequently, this activity reduces the farmer's productivity in terms of working on his farm. Often farmers prefer to sell directly to local middlemen in the village who are usually resident farmers who buy and sell goats and/or sheep as a secondary activity. Less frequently, local middlemen buy goats or sheep and hold them for fattening. In such a case, they might sell the animals to another middleman, to a local restaurant, or to the local market.

A goat or sheep farmer considers several factors in deciding his marketing strategy, such as whether or not he has enough animals to sell to justify the trip; whether he has experience and feels comfortable dealing with strange middlemen in the local market; and whether he has other work to do on the market day.

Except for the fighting sheep raised in West Java, prices farmers receive for their sheep or goats fluctuate seasonally depending on the agricultural and religious calendars. Prices are lowest during the season of scarcity (*paceklik*) when food stocks are low and the first corn or rice crops of the growing season have yet to be harvested. Demand is low and farmers forced to sell to raise cash must accept reduced prices. This situation is also true for several transmigration areas[15]. Market demands start to strengthen with the beginning of the harvest season. With food and cash from selling farm products more readily available as well as feed for small ruminants and demand for goats or sheep stronger, prices rise at this time.

CONCLUSIONS

Goat and sheep production in Indonesia may appear to be little more than a hobby if people look at factors such as marginal labour allocation, capital investment, amount of product consumed, and numbers of animals kept. However, goats and sheep play important roles in the peasant's social and economic life. They provide a highly liquid source of capital in villages where banks are non-existent. Since goats and sheep can be raised by gathering forage from roadsides, plantations or communal lands, they are especially attractive

commodities for landless peasants. Many small ruminant producers in Indonesia are landless or near landless peasants.

The importance of goats and sheep among farmers is clearly exemplified by the fact that nearly all of the major management decisions are apparently made by the head of household while the role of a wife, although significant, is not as prominent as that of the husband. Yet, women do contribute significantly to the tasks of goat and sheep raising that are not too heavy physically.

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CHAPTER XI
THE FARMING SYSTEMS APPROACH TO SMALL RUMINANT PRODUCTION

M. Sabrani* and J.M. Levine**

INTRODUCTION

An important question that often comes to the forefront in discussing livestock development, especially small ruminant livestock development, is whether small ruminant production can continue to increase under conditions of high population densities and fragmented landholdings where there is no land set aside specifically for small ruminant production. This is especially true of the overcrowded areas of Java and Bali.

It has been observed that increases in small ruminant populations have been occurring in tandem with increases in human population[1]. Furthermore, marginal drylands with high population densities have seen the greatest proportional increases[2]. This indicates that there are supporting factors for potential development which we must discover, research and develop. These supporting factors interact with farming activities in order to achieve a subsistence equilibrium for

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a given set of production conditions where natural resources are very limited. This is known as an ecological system whereby the farmers interact with and are connected to their surrounding environment.

With an understanding of a specific ecological system which determines the farmer's behaviour, it is easier to define a given small ruminant production system. Small ruminants in a smallholder farming system have an effect on employment and time allocation, a role in providing savings and cash needs, in improvement of soil fertility by recycling of manure, creating a sense of security provided by small ruminant ownership, as well as playing a part in religious and cultural activities. These are all factors supporting production which are very important[3]. This is because a given smallholder small ruminant production system has evolved as part of a complex equilibrium of these interacting factors to form a given ecology, an equilibrium among physical, social and economic characteristics of a given production zone. Because of this interdependence of variables, an interruption or change in any of these, whether by introduction of new technology or by cessation of existing production activities, disturbs the equilibrium of a given ecological system. This is because traditional smallholders are highly dependent upon their surrounding environment. Their behaviour towards changes in their production system such as the introduction of new technology is not neutral because their dominant mode of behaviour is that of risk avoidance[4]. From this type of farmer behaviour we have developed a concept of appropriate technology which consists of a combination of technological and socio-economic interventions which can be applied to provide benefits to smallholders under a given set of production conditions.

Under conditions of limited natural resources and risk avoidance, the traditional farmer hopes to receive a positive return from each new investment by means of this appropriate socio-technology. The higher the positive return the greater the incentive for farmers to participate in this new activity. In addition, before undertaking a new type of production, the traditional farmer also looks at how this increased production will affect the overall stability of the production system so that new factors do not arise which cannot be controlled. For example, it frequently happens that a new technology (e.g. feeding a concentrate supplement to small ruminants) can dramatically increase production and profits, yet this new system is not adopted

because increased cash needs to purchase this improved input conflict with cash needs for other agricultural activities and with those of the household. This requirement for production stability and the ability to predict production outcome (low risk, low gain instead of high risk, high gain) is always weighed up against the prospects of increased gain from a new production technology. This process of weighing up increased risk against possible increased gain often determines the level of participation of traditional smallholders in development programs[5]. Based upon these concepts of an ecological system, of complementary activities within this system, of recycling, of the need for stability and predictability of outcome interacting with the desire for increased profits, a small ruminant development program within a concept of a farming systems approach is defined. Individual small ruminant production activities (feeding, marketing, management) are therefore studied within the whole farm production system where they take place instead of in isolation.

A. THE ROLE OF SMALL RUMINANTS IN A MIXED FARMING SYSTEM

In general, livestock production in Indonesia may be grouped into three main categories: commercial, semi-commercial and traditional. Commercial production systems take advantage of economies of scale, high capital investment and advanced technology that is oriented towards increasing production efficiency as well as maximizing financial returns. Semi-commercial production systems are less able to afford high levels of investment and technology but are still oriented primarily toward profit. Traditional production systems, on the other hand, are characterized by low levels of investment and technology, with the goals of meeting the needs of the farm family, of risk avoidance and of increasing the utilization of farm family labour as well as complementing other farm activities which have low levels of production. In this Chapter, the role of small ruminants is seen from the point of view of development of traditional livestock production which is seen as complex, diversified and interacting in important aspects with a smallholder farming system. Viewed from this aspect, small ruminant production may be seen as a component in income

diversification as well as income stabilization in its complementary role both as a type of farm activity and as an investment in living savings. Seen from the aspect of efficiency and productivity, small ruminant production is highly prized by smallholders with limited natural resources or those who are traditional producers partly because of the recycling of biomass between small ruminants and crop production.

B. ECOLOGICAL ZONES

It is possible to identify ecological zones within which we can classify systems of cropping, climate and altitude as factors which will affect development. Levine has defined nine ecological zones in Indonesia which can be seen in Table 1. The ecological zone of Java-Bali has been further divided on the basis of length of dry season and altitude (low, medium and high). The outer islands have been grouped together in one large ecological zone which is further subdivided again on the basis of length of dry season and altitude. In addition, a semi-arid ecological zone comprised of East Timor, Nusa Tenggara Timur (NTT) and Nusa Tenggara Barat (NTB) is also distinguished in Indonesia.

In each so-defined ecological zone, the cropping system and therefore feed available for small ruminants is very different. It is also possible to see from Table 1 that small ruminants are found in greater numbers in the ecological zones defined by medium and high altitudes in Java-Bali, Sumatra, Kalimantan, Sulawesi and Maluku. In the semi-arid ecological zone this small ruminant distribution generally follows population distribution. In each ecological zone the relative importance of the major livestock production systems is indicated. These systems are determined by complex equilibrium conditions from the physical environment as well as social and economic conditions. Because these production systems are specific to each ecological zone it is important to be able to differentiate among these different types of ecological zones in Indonesia in order to understand the reasons for the observed differences in types and numbers of livestock throughout the archipelago.

Table 1. Major agroclimatic zones of Indonesia[6].

Islands:	Weather	Altitude	Crops	Livestock species
Inner Islands:				
Java	short	lowland	rice,	buffalo and a
Bali	dry season		*palawija**	few sheep/goats
Madura				
		upland	estate crops: coffee, tea, cloves, rubber, tree fruits, *palawija*	many sheep/goats
	long dry season	lowland	rice, *palawija*, sugarcane, tobacco	cattle, buffalo, goats
		upland	estate crops: coffee, rubber, cloves, chocolate, tobacco, *palawija*	many sheep/goats, Fat-tail sheep
Outer Islands:				
Sumatra, Kalimantan	short dry season	lowland	rice, *palawija*, coconuts	buffalo, ducks
		upland	estate crops: rubber, palm oil, forest tree fruits	cattle, sheep/goats
Sulawesi, Moluccas, etc	long dry season	lowland	rice, *palawija*	buffalo, cattle
		upland	estate crops: coffee, cloves	cattle, goats
Nusa Tenggara Barat and Timur	Semi arid/arid	lowland and upland	coconuts	cattle, horses, sheep/goats

* Secondary food crops: cassava, corn, soybeans, etc

Fig. 1 is a model of decision making in choice of livestock species in production systems in Java.

The first factor in deciding which livestock species to raise is the requirements of capital and market price structure. After this, there

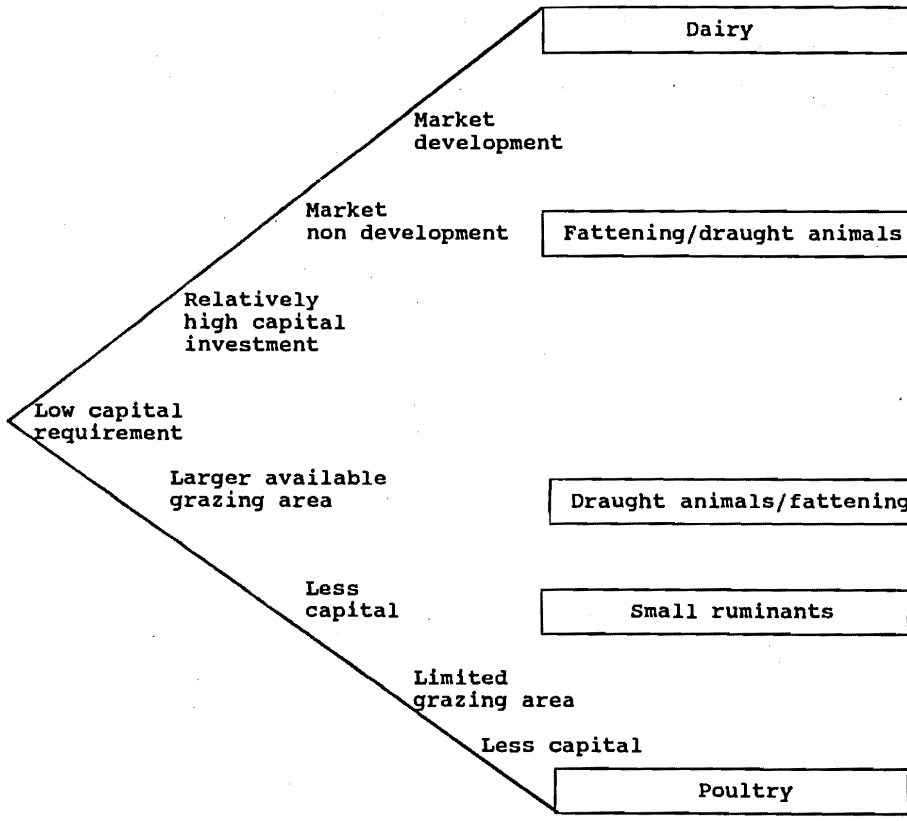

Fig. 1 Flow of decision-making in selection of livestock, showing the effects of size of capital investment, market development, size of area for feed production for livestock kept by farmer[7].

are factors of availability of feed which consists of local grasses for browse and crop by-products from the cropping system specific to each ecological zone. Ruminant livestock are among those products which do not require much capital investment and which can be raised with a simple system of feeding local grasses for browse and a wide variety of crop by-products. From the above picture, it can be seen why smallholders on marginal lands or without land readily select

small ruminants. This type of traditional livestock production is also not heavily dependent on market conditions.

C. INTERACTIONS AND RECYCLING

The interaction of smallholders and their environment (physical, social and economic) in determining mixed farming systems in Indonesia has resulted in what may be termed equilibrium conditions within each ecological zone. On a small-scale basis, we may see an example of this equilibrium in the smallholder's use of his *pekarangan* or houseplot. On this small scale one can trace relatively easily the interactions among the farm family's crops, livestock and the surrounding environment. This system makes intensive use of available light by a layered system of plants: an upper canopy of trees which make use of solar energy and provide shade for an understorey of other crops which are shade tolerant. In this intensive system, livestock make use of crop by-products and provide manure for the continued growth of the crop and tree components. This whole system is one of complementary activities among the farmers, their farm production activities and the household needs of their families[8]. This picture of a houseplot farming system can be developed to study other systems on a larger scale.

Often a disruption occurs in this ecological equilibrium when a new activity is introduced in an attempt to increase the efficiency and productivity of an existing system. This activity may be the introduction of imported livestock, medicines, or a new feeding system which disturbs an existing equilibrium because it has been introduced without consideration of its effect on other farm activities which are taking place simultaneously in a given production system. Changes in livestock populations in a given area of land, the introduction of new breeding stock which increases the cost of purchased inputs, the adaptability of this introduced stock to a new environment, increased need for cash for expenses, the influence of markets and the increased importance of market prices in a more commercial orientation can have drastic effects on the interactions among the farmers, their livestock, their crops and their environment. If the importance of these above-mentioned factors is not considered before

the introduction of a new technology, the new technology does not last and the farmers return to their old method of production where an ecological equilibrium had been achieved. Under conditions of an ecological equilibrium the farmer is able to carry out a wide variety of farm activities which are complementary and supplementary to each other and these activities are integrated into an ecological system where biomass is recycled from one system to another.

In the case of traditional livestock production, this kind of recycling of biomass forms an inexpensive type of technology which requires almost no cash funds. The most successful form of livestock development of traditional production is one which develops a technology which builds on the recycling process so that the interactions among the farmers and their household needs, livestock, crops and their surrounding environment are more efficient. This is why the problem of developing a new system to improve traditional livestock production is very well suited to a whole systems approach[9]. For example, in the case of determining breeding policy or management, it is necessary to take production levels into account and also to consider the sustainability and adaptability of a proposed breeding system to a given ecology. In this respect, all aspects of breed improvement must be examined from the viewpoint of their effects on the surrounding ecological system. It is also important to be aware of farmers' needs and preferences, whether farmers, for example, need/want larger breeds with higher liveweights and faster growth rates, or smaller breeds with higher fertility and fecundity. It is also necessary to take into account the social aspects of new breed selection to avoid any social or cultural problems. After this, it is necessary to determine if the specific environment where this new breed will be produced has sufficient natural resources to support this new level of production. This required ecological equilibrium is graphically shown in Fig. 2. Circle A shows the area of complementary or supplementary relationship of small ruminants with the physical environment (including the natural resource base). Circle B is the area of interaction of social and cultural factors with small ruminants and circle C shows their interactions with economic factors. The shaded area representing the area of overlap of all three circles represents the interactions of small ruminants with physical, social and economic factors. As long as small ruminant production remains within

the area where these three types of factors interact in a positive way, it will form an equilibrium with its surrounding environment or ecological zone and will be sustainable. It can even be increased within this zone of complementarity.

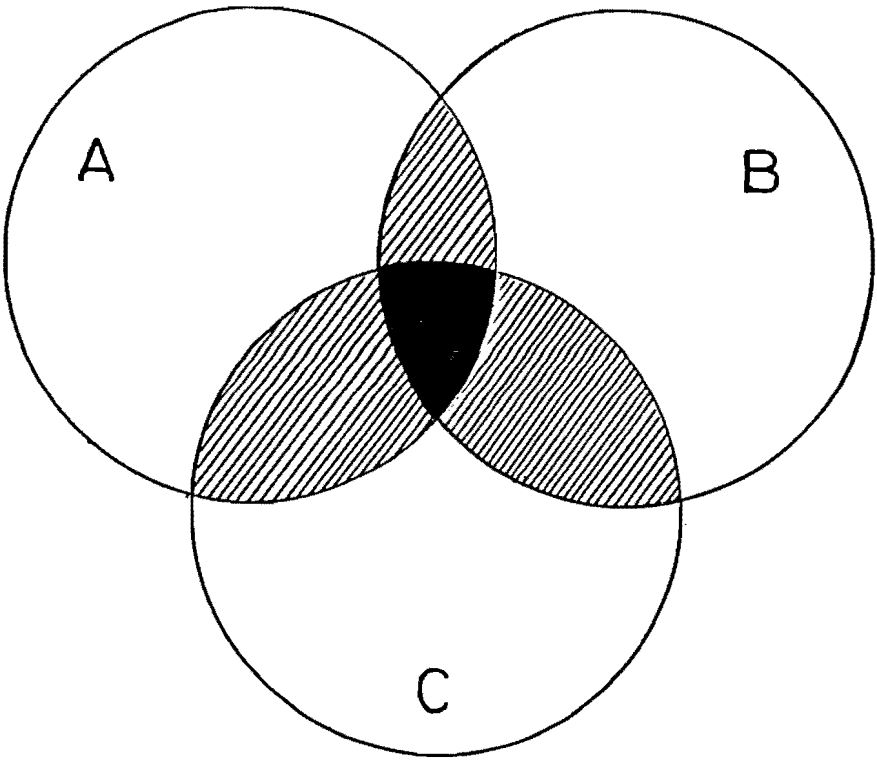

Fig. 2 Ecological equilibrium of a smallholder farming system, showing supplementary or complementary relationship of small ruminants: circle A - physical environment; circle B-social and cultural factors; circle C - social and economic factors. Thus the shaded area represents interactions of small ruminants with physical, social, cultural and economic factors.

The shaded area where physical, social and economic factors complement each other, changes in size depending on the interactions

among these three types of factors in a given environment. In order to enlarge this area of complementary interaction, it is necessary to increase the efficiency of recycling of biomass among activities within the whole farming system and to reduce risk by reducing cycles of irregularity such as disease or crop failures which might disturb the equilibrium of a given production system. For example, one source of instability might be an uneven supply of animal feed due to the irregular pattern of rainfall over the year. This source of instability may be reduced by a change in the cropping system which is better able to supply grasses and browse during the dry season. Introduction of a method of conserving feed over the dry season is another method for reducing this instability in the system. Another method of overcoming the problem of feed supply is to manage breeding activity so that the maximum number of offspring is raised during the time of the year when there is a surplus of feed. The problem of internal parasite infestation may be reduced by improved sanitation in animal housing so that it does not serve as a breeding ground for parasites. This may be achieved by better management of manure produced for organic fertilizer.

From the above description, the equilibrium conditions for small ruminant production may be written in mathematical form as follows:

$$Y = (X_{i}, X_{j}, X_{l})_{i=1}^{n} \; {}_{j=1}^{k} \; {}_{l=1}^{m}$$

where Y = livestock productivity,

X_i = physical factors such as cropping system, climate and soil fertility,

X_j = social factors, such as cultural activities (*adat*), religious activities, farmers' education, family size, institutions,

X_l = economic factors, such as capital, prices, income, technology, risk, family cash needs.

From the analysis of this function it is possible to determine which variable is the most important in determining the level of productivity. Also, in a matrix table of values which shows the relationships (correlations) among the variables it is possible to see which one is most important. These correlation coefficients are very

important in developing a small ruminant livestock development model within a systems approach.

D. A SMALL RUMINANT LIVESTOCK DEVELOPMENT MODEL WITHIN A SYSTEMS APPROACH

The starting points for developing a small ruminant livestock production model are the farmers themselves with their families along with their needs and behaviour as the subject of development. The farmers, as the central point of farming systems analysis, must be first identified, studied and linked to their physical, biological, social and economic environment. For this reason a survey of the farmers' activities (activity analysis) is undertaken in order to determine the flow of interactions among their various activities and the farmers themselves. Then, each activity requires an analysis of inputs and outputs which often comprises diverse activities themselves. There may be purchased inputs, by-products of other farm activities, use of public lands as well as outputs which are sold, consumed within the farm family, or given away. This type of input-output analysis is essential in developing a production model under conditions of mixed farming. The ability to illustrate one set of real production conditions is very much dependent on these preliminary steps in the descriptive stage of describing the production environment, the flow or connecting activities and their interactions. In order to carry this out, farm based-research is often required which consists of farm record keeping and construction of flow-diagrams with the help of the farmer himself/herself. An outline of activities is developed and these are also discussed with the farmer. By this process, it is possible to discover some important key farm activities (centres of association) which are supported by other farm activities.

After this qualitative descriptive phase is completed, some quantitative data are collected. This type of on-farm data collection must be carried out carefully and with a good understanding of the types of activities undertaken by the farmers under study. Production parameters such as productivity, reproductive rate, mortality, costs, income and marketing all require quantitative technical and economic

data which must be analyzed before recommendations can be made for improving the existing system. Construction of such a production performance model requires considerable time, but is necessary because it defines clearly the constraints to this system and the new technology needed to improve the existing system.

In order to formulate this strategy for livestock development, the following are needed:

1) quantitative data concerning key or problematical factors of the existing production system;
2) identification of which parts of the system are poorly integrated or connected to the overall system;
3) information or research on the reasons for the weak integration of a given part of the existing production system so that this may be corrected.

In order to be able to carry out this process, it is necessary to obtain mathematical means, variances and distributions of each major component of the existing production system. These data must also be analyzed for differences among specific locations.

Following this, these relationships among different components of the production system under study can be further analyzed. For example, productivity of small ruminants (Y), can be analyzed as a function of available labour (X_1), availability of local grass and/or other feed (X_2), cash expenses (X_3), age or experience of the farmer (X_4), level of education (X_5), family size (X_6), amount of land (X_7), number and type of diversified farm activities (X_8), type of livestock management (X_9), type of share-system (*gaduhan*) (X_{10}). Y will be the dependent variable while X_1 to X_{10} are explanatory or independent variables.

This relationship may be written as follows:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \ldots \beta_{10} X_{10} + \mu$$

where $\beta_1 \ldots \beta_{10}$ are the regression coefficients between Y and $X_1 \ldots X_{10}$ respectively and _ is the random error term.

This estimation process may be carried out both as simple and as logarithmic regressions. With the use of t-tests it is possible to determine whether any of the coefficients $\beta_1 \ldots \beta_{10}$ are statistically significant with respect to Y. By looking closely at which independent

variables (X_i) are most significant statistically with respect to small ruminant productivity (Y), this information can be used to focus our research on gaining further information on these important variables and in strengthening the relationships among independent variables which are currently contributing only weakly to a given level of productivity (Y) by means of intervention and improvement. By using techniques of stepwise analysis, it is possible, however, to determine the extent of variation in productivity (Y), caused by each independent variable considered separately. If the analysis of variance of Y caused by X_1.....X_{10} shows the relationship to be very weak, this can mean that μ, or the sampling error, is very large and that our model is not correctly constructed (or not enough data have been collected to obtain accurate estimates of each variable under test). Assuming that enough data have been collected, this means our model has not taken into account a major source of variation in the production system under study. This means we must return to our study of this production system and find which variable(s) need(s) to be included in our improved mathematical model of the system. In conducting this analysis we are looking at the relationship between output (Y) and input (X_1.....X_{10}). After we have corrected our model for a given output Y, it is then necessary to look at the combination of activities which support or are complementary to our output of main interest (small ruminant productivity). By means of the farm level survey carried out in the descriptive stage, it can be seen that farmers are engaged in a number of different activities as sources of total farm productivity in addition to small ruminant production (Y_1). These include foodcrop production (Y_2), perennial crop production (Y_3) and off-farm activities such as small-scale trading (*dagang*), (Y_4). The relationship among outputs from farm activities as described above (Y_1...Y_4) can be analyzed by means of a regression equation as follows:

$$Y_1 = \alpha_1 + \alpha_2 Y_2 + \alpha_3 Y_3 + \alpha_4 Y_4 + \mu$$

where μ is the sampling error term and α_2...α_4 are the regression coefficients. If the coefficients α_2...α_4 are positive, then the relationship is complementary. If the coefficients are close to zero, this means the relationship is supplementary, while if the coefficients are negative, the relationship is competitive. With respect to the development of a small ruminant production system by means of an

analysis of the relationships among components of the system, complementary relationships among farm activities are very desirable as they form a profitable system for use of natural resources. Traditional production systems always maintain complementary or supplementary activities. If activities become competitive in nature, often one of the competing activities is reduced in scale. Fig. 3 shows this relationship graphically. The graph ABCD (Fig. 3) shows the relationship between farm activities Y_1 and Y_2. The part of the graph represented by the area under the arc AB shows the area of complementary relationship between these two activities, BC shows the supplementary area and CD shows the competitive area. By using a stepwise analysis of variance, R^2 values can be calculated for each level of **Y**. Activities with a high R^2 represent those activities which are important in the development of the livestock production system under study.

An outline of this system may be seen graphically in Fig. 4. The first level of this system consists of the elements of the farmers, their families and their technology of production. The second level of this system consists of the elements of ecology as well as endogenous and exogenous factors which affect the farmers' response to their production environment. The third level of this system are the inputs into this system such as labour use, capital, land area, level of management in using supporting resources from the surrounding environment and technology. The fourth level of the system are the various production activities which comprise the production system. The fifth level are the outputs from these production activities that supply the requirements of the farmers and their families.

In the following sections two examples of the interrelationships between small ruminants and a mixed farming system are described. These examples of small ruminant production systems are:

1) a small ruminant production system within an estate crop-based mixed farming system in North Sumatra;
2) a small ruminant production system within a mixed farming system of the uplands of Central Java.

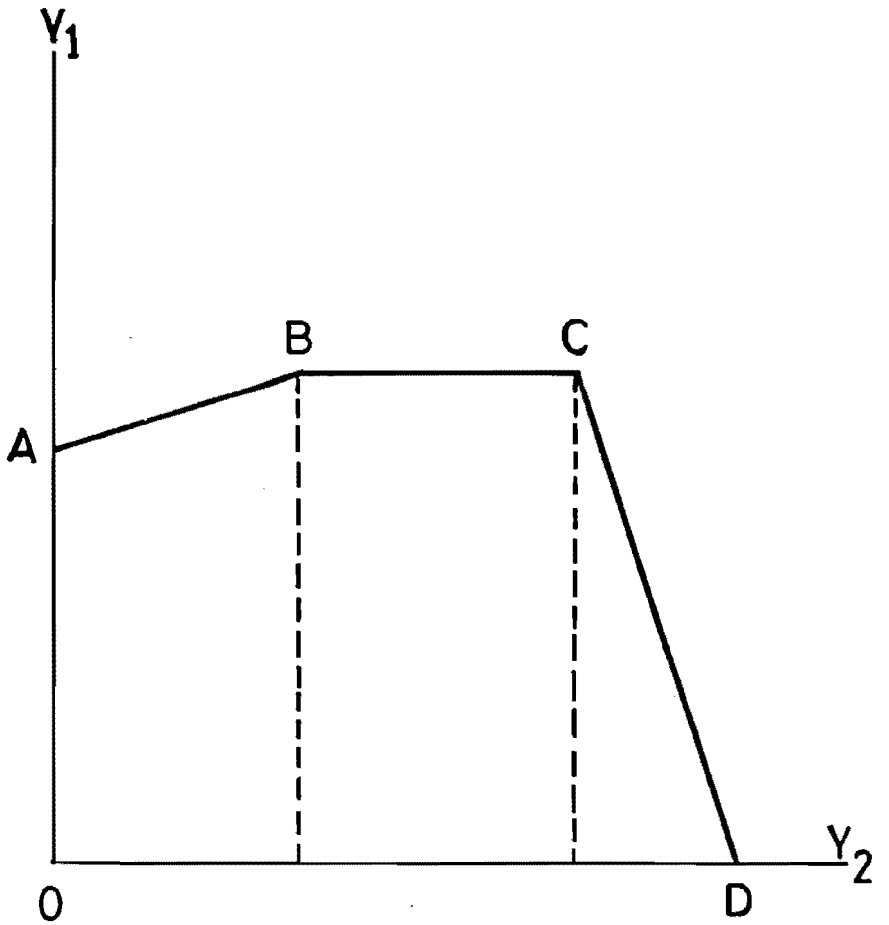

Fig. 3 Relationship curve between activities Y1 and Y2. Area under arc AB shows area of complementary relationship, BC-supplementary; CD-competitive area.

E. A SMALL RUMINANT PRODUCTION SYSTEM IN AN ESTATE CROP- BASED MIXED FARMING SYSTEM IN NORTH SUMATRA

In this example, techniques of collecting and analyzing secondary village data from a representative sample of villages in three sub-

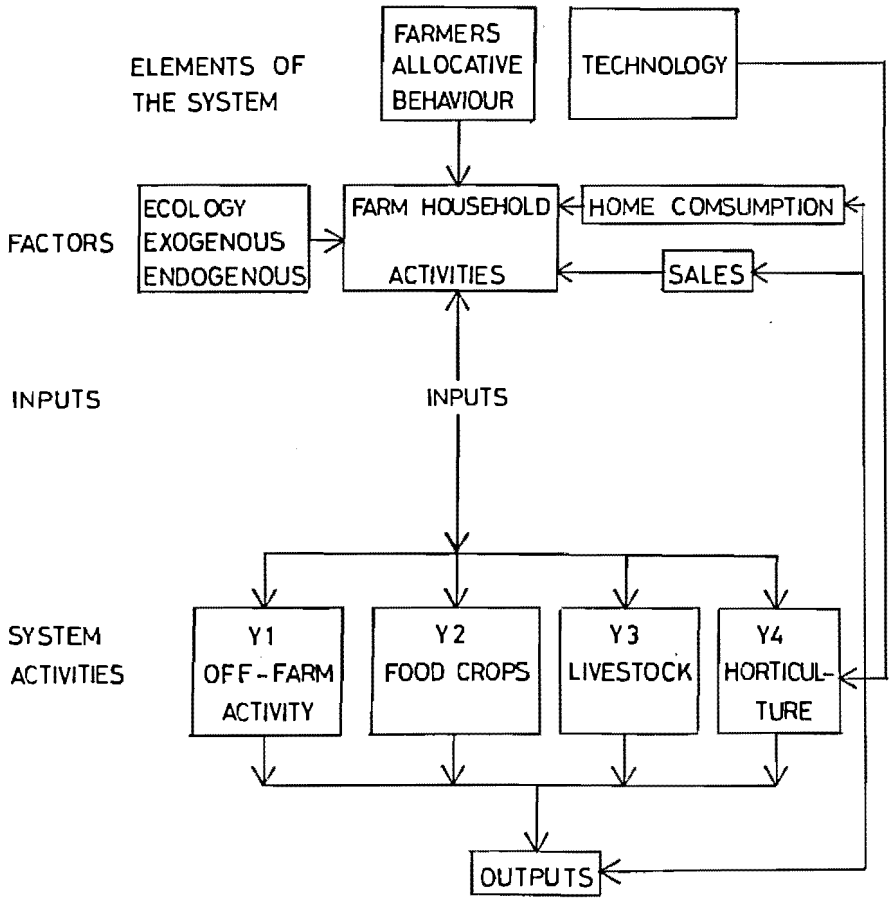

Fig. 4 Diagram of a smallholder farming system.

districts (*kecamatan*) of the Serdang district (*kabupaten*) were used to describe small ruminant production systems within these two ecosystems (low and high altitude) in North Sumatra[10]. It was possible to carry out only two weeks of field-work. The purpose of this study was to provide information on existing production systems to the Livestock Research Centre Branch (*Sub-Balai Penelitian Ternak, Sungai Putih*) of the Agency for Agricultural Research Development (AARD) located in the Serdang district, so that it could formulate a

small ruminant research program suitable for the surrounding area. One sub-district, Sibolangit, is highland, about 40 km northwest of Medan (the provincial capital), has high rainfall, low population density, no large estates and cropped land composed mostly of rainfed rice fields (*sawah)* and dryland farming (*tegalan*). This sub-district has few cattle or goats, no sheep, some buffalo and many chickens and pigs. The second sub-district, Galang, is the sub-district where the Livestock Research Centre is located. It is lowland, about 50 km southwest of Medan, has a higher population density than Sibolangit, lower rainfall and has more than 60 percent of its total area covered in large estates, especially rubber, with the cropland containing irrigated and rainfed *sawah* and some dryland cropping. Galang has many cattle and chickens, some buffalo, sheep and goats, and few pigs. The third subdistrict, Perbaungan, located on the coast northeast of Galang and 40 km east of Medan, has the highest population density of the three subdistricts, 25 percent of its area covered by large estates, especially rubber and more than 30 percent of its area developed into irrigated rice-fields. Perbaungan has large numbers of cattle and chickens, some buffalo, goats and sheep and few pigs. Table 2 shows the area, population and land use of the three subdistricts. Table 3 shows the qualitative descriptors for the same area.

Table 2. Area, population and land use, subdistrict level data, Deli Serdang district, North Sumatra[11].

	Subdistrict:		
	Sibolangit	Galang	Perbaungan
Area (km^2)	232	169	187
Elevation (m)	>500	<50	<50
Rainfall (mm/yr)	3000	2000	2000
Population density (per km^2)	67	371	477
Area of large plantations (ha):			
Rubber	0	7983	3843
Palm oil	0	2022	611
Chocolate	0	27	0
Area of *sawah* (ha)			
Artificial irrigation	0	2605	5513
Semi-artificial irrigation	210	0	400
Raifed	761	645	822
Swamp	0	95	0
Area of cropped dryland (*tegalan*)(ha)	360	1013	387

These data are useful in giving an overall picture of the three subdistricts but are still too general in nature to develop precise ideas of the types of smallholder farming activities that take place in the villages and how livestock production interacts with other farm activities. For this reason, additional secondary village level data were collected by means of interviewing village officials and farmers selected at random using a standard questionnaire. Seven villages were surveyed in Sibolangit and four each in Galang and Perbaungan.

Table 3. Qualitative descriptors, subdistrict level, Deli Serdang, North Sumatra.

	Kecamatan	
Sibolangit	Galang	Perbaungan
Upland	Lowland	Lowland
Batak	Javanese/Mixed	Javanese/Mixed
Christian	Moslem	Moslem
Little *sawah*	*Some sawah*	Large amount *sawah*
Smallholder rubber	Large estate rubber	Large estate rubber
	Large estate palm oil	Large estate palm oil
Tree fruits	Tree fruits	-
Horticultural crops	-	-
Livestock:	Livestock:	Livestock:
Few local cattle	Some local cattle	Many local cattle
Buffalo	Buffalo	Buffalo
Many pigs	Some pigs	No pigs
Many *kampung* chickens	Many *kampung* chickens	Many *kampung chickens*
Few goats	Goats	Goats
No sheep	Few sheep	Few sheep

ON-FARM GROSS INCOME AND INCOME COMPONENTS

Food crops were the most important source of agricultural income for all three subdistricts, accounting for 43 percent of gross income for Sibolangit and two-thirds each in Galang and Perbaungan. The higher percentages for the two lowland subdistricts reflect the greater importance of rice cultivation there compared with the upland subdistrict. Estate and perennial crop production was the next most important category for all three subdistricts and accounted for 29 percent of gross on-farm income for Sibolangit, 26 percent for Galang

and 23 percent for Perbaungan. Livestock and fish-raising were more important for the upland Sibolangit than for the lowland subdistricts and accounted for 28 percent of gross income in Sibolangit. This income came mainly from fish pond harvests, poultry and pigs. For Sibolangit, livestock accounted for 18 percent of gross income, for Galang seven percent and for Perbaungan nine percent. For both lowland subdistricts, income from poultry was the most important, followed by that from cattle and buffalo. This is shown in Table 4.

Table 4. On-farm gross income and income components subdistrict level data, Deli Serdang, North Sumatra.

	Subdistrict:					
	Sibolangit		Galang		Perbaungan	
	Amount (000s Rp)	(%)	Amount (000s Rp)	(%)	Amount (000s Rp)	(%)
Food crops:						
rice	22,489	39	238,055	66	223,123	66
Secondary food crops	2,200	4	2,323	1	3,450	1
Total food crops:	**24,689**	**43**	**240,378**	**67**	**226,573**	**67**
Estate and perennial crops:						
Rubber	10,368	18	22,697	7	0	0
Palm oil	0	0	821	< 0.5	0	0
Coffee	218	< 0.5	0	0	0	0
True fruits	970	2	41,069	11	79,507	23
Other	5,231	9	26,798	8	650	< 0.5
Total estate and perennial crops:	**15,787**	**29**	**953,85**	**26**	**80,157**	**23**
Livestock:						
Cattle	983	2	5,288	2	2,277	1
Buffalo	600	1	2,170	< 1	3451	1
Poultry	3,842	7	11,882	3	22,700	7
Pigs	4,816	8	2,429	1	0	0
Goats	147	< 0.5	1,722	< 1	2,339	1
Sheep	0	0	416	< 0.5	1,121	< 0.5
Total livestock	**10,388**	**18**	**23,907**	**7**	**31,888**	**10**
Fish raising Total	**60,00**	**10**	**0**	**0**	**2,000**	**1**
Grand total gross on-farm income	**56,894**	**100**	**359,670**	**100**	**340,618**	**100**

Several interesting kinds of information with respect to the potential for small ruminant development have emerged as a result of this brief study of 15 villages in North Sumatra. Firstly, data on livestock populations showed that no sheep and very few goats are found in the upland areas of Deli Serdang district. This is very different from Java where large concentrations of sheep are found in the uplands of West and East Java. Instead, in the uplands of Sibolangit, there are many pigs and these animals appear to take on some of the functions of savings and use in cultural festivals that characterize sheep and goats in Java. Small ruminants are found in Deli Serdang district in the more densely populated lowland rice growing areas but not in the uplands. The upland villages of Sibolangit are all Christian and Karo-Batak and carry out a traditional mixed farming system centered around tree crops and upland rice as well as pig, chicken and buffalo husbandry, while all the lowland villages surveyed were predominantly Moslem and Javanese speaking. This means no pigs are raised. The lowland villagers, descendants of workers brought from Java in the nineteenth century to work on the estates, practise their irrigated rice-based farming system on land granted to them by the Sultans of Deli-Serdang. This farming system requires cattle for draught-power. Goats and sheep are raised for the same economic and cultural reasons as in villages in Java. In conversations with villagers in Perbaungan, where there are no pigs and the largest number of sheep, villagers claimed that the sheep were brought from Central Java for food with the nineteenth century recruitments of contract estate labour. These villagers believe there were no sheep in North Sumatra before that time, but there were goats (*kambing Kacang*). *Kambing Kacang* are to be found throughout North Sumatra but sheep are found only in small numbers and in the Javanese speaking villages. Phenotypically, the sheep resemble the Javanese Thin-tail sheep of Central Java, but they are smaller and are believed to be a separate breed (Sumatran Thin-tail sheep) by Iniguez and Gunawan (see Chapter IV on Breeding). It is definitely possible, however that the small number of sheep in North Sumatra are, in fact, descendants of sheep brought from Central Java in the nineteenth century.

It is possible to form a rough idea of the type of farming system practised in each subdistrict from the data in Table 4. The relative values of the gross income components rather than raw data on

production totals are essential for understanding how farmers perceive their farming systems and how important different agricultural activities are to them. Food-crop production is the major agricultural activity in all three subdistricts although *sawah* cultivation is more important in the lowlands. This means that applied livestock research in Deli Serdang must take into account the fact that much capital and family labour will be absorbed by food-crop activities and other on-farm activities will be adjusted around this central activity. In the lowlands, many large ruminants are kept as draught animals in *sawah* cultivation and some fattening takes place using crop by-products, especially rice bran. Sibolangit and Galang have large areas of their villages planted with estate and perennial crops. These villages have the potential to produce animal feed by grazing and/or cut-and-carry systems under these trees, while Perbaungan has less area available for these activities. Analysis of the livestock populations and gross income components per type of livestock indicate the importance of *kampung* chickens in all locations surveyed. This animal tends to be neglected in setting research priorities but overall, in terms of income generation, it is the most important class of livestock in many regions of Indonesia. As mentioned above, pigs in the upland area have taken on many of the economic and cultural functions associated with small ruminants on Java and this class of livestock is very important in this upland farming system. There are very few sheep in Deli Serdang and these appear to be confined to lowland areas with Javanese speaking inhabitants while goats are more widespread, but also found in greater numbers in lowland areas. Cattle and buffalo are kept primarily for draught-power and any research or development programs planned for these species should be focussed on their primary use. Based on these preliminary production-oriented data, research and development priorities may be tentatively established with respect to livestock species and location. As far as the potential for small ruminant development, sheep are not economically important in this area of North Sumatra while goats are found as part of a lowland mixed farming system where the potential for development lies in better use of crop by-products in the rice growing areas and development of grazing or cut-and-carry systems in the villages with large areas of estate and perennial crop production.

F. A SMALL RUMINANT PRODUCTION SYSTEM IN A MIXED UPLAND FARMING SYSTEM IN CENTRAL JAVA

The example of a small ruminant production system in an estate crop-based farming system of North Sumatra, described in the preceding section, showed how collection and analysis of secondary data can be used to describe a given farming system and set priorities for research. In this example of a small ruminant production system in a mixed upland farming system in Central Java, descriptive data were also collected to define a given farming system and to diagnose or prescribe an intervention to improve the productivity of that system[12,13]. More time and resources were available for research than in the North Sumatra example, so the farming systems process has been carried further in this Central Java example. A new feeding system was introduced and the results were studied in two upland villages. Additional livestock were also provided to participating farmers in this research. This goat and sheep production research was carried out in *desa* Kandangan (*kecamatan* Bawen, *kabupaten* Semarang) and *desa* Klari (*kecamatan* Karanggede, *kabupaten* Boyolali) with 19 participating farmers. These farmers each received a package of one male and four female goats or sheep as part of the ongoing activities of the Farming Systems Research (FSR) component of the Upland Agriculture and Conservation Project which has been working in these two villages since 1985. These animals were raised by the participating farmers in addition to the goats and sheep which they already owned. The goats were predominantly of the *kambing Kacang* breed and the sheep were considered to be *domba lokal* or Javanese Thin-tail. A total of 40 goats and 90 sheep were raised by these 19 farmers. In addition, the four participating farmers from Klari and five farmers from Kandangan were also participants in FSR cropping systems research. This meant that they had received *setaria* cuttings to plant on the risers of terraces they had constructed during the project. This *setaria* grass became an important part of the feeding system of those farmers participating in the FSR cropping systems research. Data were available based on monthly visits to each farmer from October 1986 until April 1987, or about six months, which

corresponded to the 1986/87 rainy season. Additional data have been collected but are not yet analyzed.

I. VILLAGE LEVEL DATA

Secondary village level data are presented in Table 5. These data were collected in January 1986.

II. SAMPLE SIZE

Data were collected from four farmers in Klari and 15 farmers in Kandangan. The four Klari farmers owned a total of 17 goats and 14 sheep while the 15 farmers from Kandangan owned 23 goats and 76 sheep. A total of 490 bodyweights were obtained from all 130 animals during a six-month period from October 1986 to April 1987, or the 1986/87 rainy season.

III. GOAT AND SHEEP BODYWEIGHTS ACCORDING TO SPECIES, AGE AND SEX

Figs. 5 and 6 show growth rates of goats and sheep. Because the sample size especially for goats is small and data are only for the six-month period of the 1986-87 rainy season, these data must be interpreted with caution. Still they provide some interesting information on size and growth potentials of small ruminants under village smallholder conditions. Results for male goats show a steep increase in bodyweight from birth until ten months of age when the male goats reached an average size of 22.5 kg. Thereafter, between eleven and 15 months, these goats did not gain any additional weight and weighed about the same at 15 months as they had at ten months. Additional data are needed to verify this phenomenon, but these data indicate that *Kacang* male goats raised under Central Java upland village conditions reach a maximum weight before one year of age and then tend to level off. This means that marketing strategies should aim at selling these goats at ten to eleven months of age and use feed saved for females in the last part of pregnancy and during lactation as well as for weaners. Results for female *Kacang* goats (not counting pregnant animals) show an interestingly different growth pattern. They gained weight very rapidly until seven months of age, but then continued to gain slowly as they became older. The heaviest female goats in the sample (31 kg) were also the oldest. Further information is

Table 5. Village level data, Kandangan and Klari, Central Java.

Village	Kandangan	Klari
Subdistrict	Bawen	Karanggede
District	Semarang	Boyolali
Annual rainfall (mm/yr)	2340	2480
Elevation (m)	540	300
Number of families:	1163	381
Total population	5418	1838
Village area (ha)	946	274
Land use (ha):		
Rainfed *sawah*:		
Cropped dryland	256	90
Orchard:	388	116
Houseplot:	156	n.a
Others	102	57
	44	11
Main crops:		
Crop:	Rice	Rice
Area (ha):	245	171
Yield:	280 tonnes	188 tonnes
Crop:	Corn	Corn
Area (ha):	261	89
Yield:	483 tonnes	72 tonnes
Crop:	Cassava	Cassava
Area (ha)	200	72
Yield:	400 tonnes	300 tonnes
Crop:	Coffee	Peanuts
Area (ha)	5	5
Yield:	26.4 tonnes	7 tonnes
Crop:	Kapok	Soybean
Area (ha):	30	4
Yield:	30 tonnes	3.4 tonnes
Crop:	Cloves	Coconut
Area (ha):	20	6
Yield:	1 ton	1 ton
Livestock populations:		
Cattle:	740	146
Buffalo:	22	10
Goats:	180	367
Sheep:	20	n.a*
Local chickens:	4500	1755
Ducks:	220	215

* not applicable

required to explain this difference in growth patterns, but one preliminary conclusion is that male goats require better feed than female goats if they are to continue gaining weight in a steady and economic manner after ten or eleven months.

Results for male and female local sheep are strikingly similar to those for goats. Male sheep gained rapidly until eight months of age when they reached an average bodyweight of 23 kg. After eight months of age bodyweights declined and did not reach 23 kg again until 17 months of age. This again is strong evidence for marketing male sheep soon after weaning and using the extra feed to increase the performance of the remaining breeding flock by better feeding of weaners and ewes in late pregnancy and during lactation. Female sheep, on the other hand, gained weight steadily until two years of age. There are some weight fluctuations between 22 and 24 months of age which were probably due to the stress of pregnancy and lactation, but female sheep weighed the same (about 23 kg) at 22, 24 and 48 months of age. This result suggests that about 23 kg is the largest weight for female local sheep under these conditions of village smallholder production.

IV. GOAT AND SHEEP INVENTORY CHANGES

Data were available on births, deaths and sales for sheep and goats over a six-month period in Kandangan and Klari. A total of 12 lambs was born to 61 female sheep and three kids born to 32 female goats during this period. Three goats and eight sheep were sold while 17 sheep and eight goats died. Death included newly born lambs (4), female sheep dying during lambing (4), attributed to bloat in goats (3) and due to poisoning in sheep (2). Because these limited data were available for only six months, no conclusions could be made concerning the productivity of either type of small ruminant, especially reproductive performance (*angka kelahiran*). A minimum of one full year's data are required before the productivity of these production systems can be evaluated.

V. LABOUR USE

A mean of 3.6 family members in Kandangan and 2.8 family members in Klari were employed in family farm and off-farm

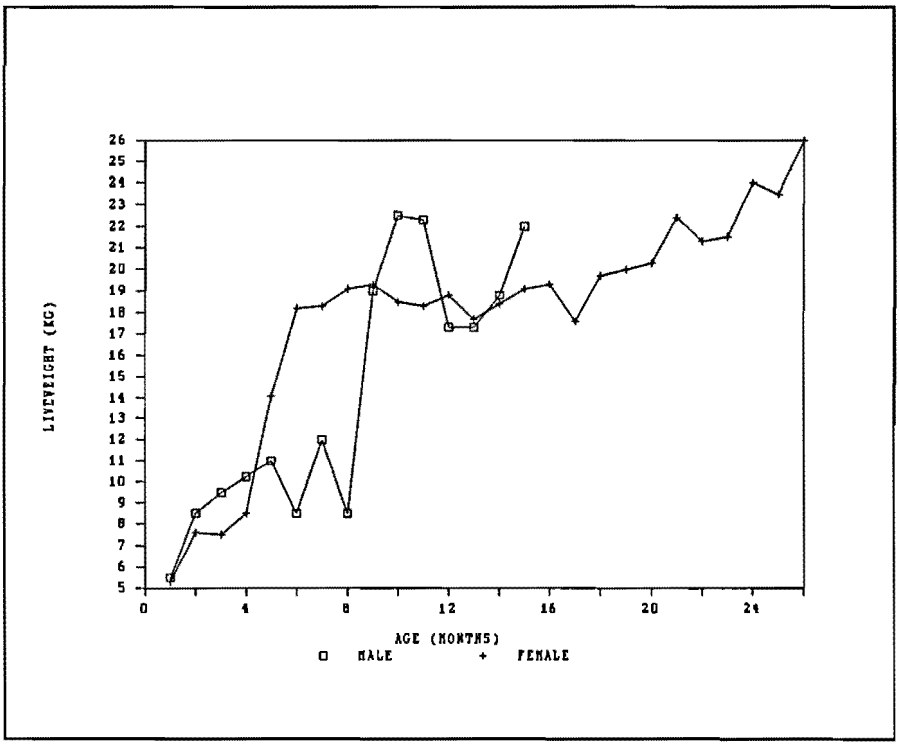

Fig. 5 Growth of male and female goats.

employment. For Kandangan total monthly family employment was an equivalent of 27.5 man-days. Fifty-one per cent of this employment was devoted to off-farm activities, 24 percent devoted to raising goats and sheep and 25 percent to food crop activities. For Klari farmers, a total of 27 man-days of labour was available per month. Thirty percent of this labour went to off-farm activities, 21 percent to raising goats and sheep and 48 percent to annual crops. While data are available only for six months, they show an interesting pattern of labour use where food crop activities account for less than half of total labour (even during the rainy season when these data were collected), while off-farm and livestock activities account for 75 percent of total labour use in Kandangan and 51 percent in Klari. This pattern of labour use is confirmed by a more complete baseline survey conducted in 1986 which showed livestock (including cattle) and off-farm income to be the

two most important activities for farmers in these two villages[13]. Small ruminant production alone has absorbed more than 20 percent of family labour in both sampled villages and is therefore a significant social and economic activity.

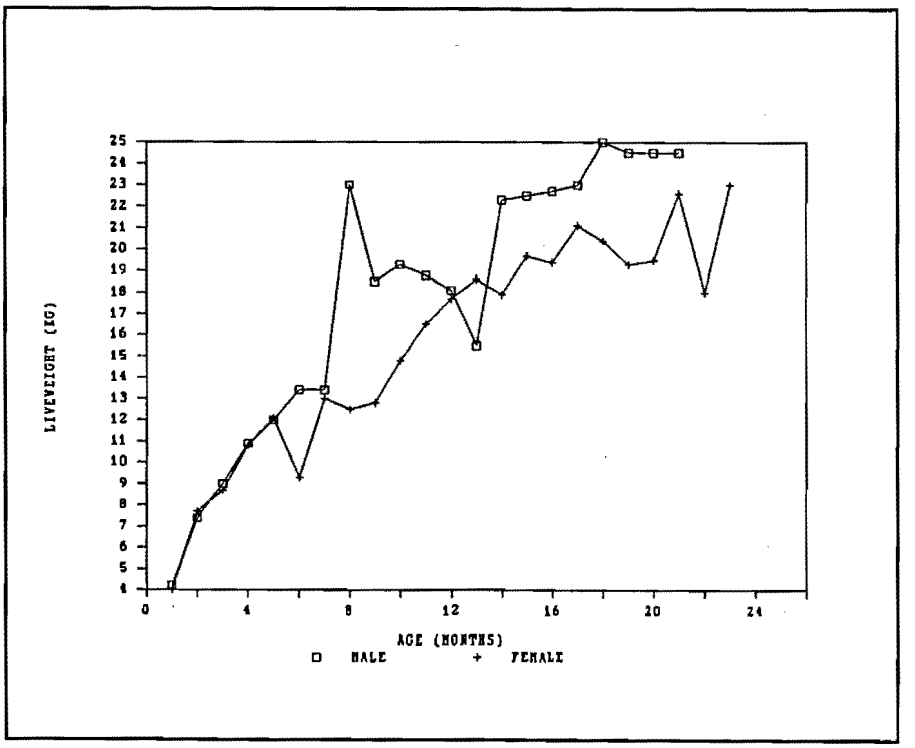

Fig. 6 Growth of male and female sheep.

VI. ESTIMATED INCOMES OF FARMERS

This pattern of labour use is further confirmed by estimates of income from both villages. For Kandangan slightly more than half of total income earned was from off-farm activities while 78 percent of total income in Klari was off-farm. Again, since data were not yet available for one full year of crop and livestock activities, caution must be used in drawing final conclusions. But, from the available data a pattern has emerged of upland farmers being engaged in a diversity of activities with off-farm activities being very important. Livestock

income reported by respondents in both villages was still small, because only eleven young stock had been sold during the initial six-month phase of this study. As the many females who were pregnant during this period produce offspring, income from small ruminant activities will increase sharply.

VII. GOAT AND SHEEP FEEDING SYSTEMS

Two feeding systems were observed in Kandangan and Klari. One was the traditional smallholder system and the other was that system modified by the introduction of *setaria* grass (see Table 6). For both systems the actual amount consumed was measured by weighing the feed on offer and weighing feed which was left uneaten. It was estimated that goats and sheep consumed an average of 2.8 kg of feed per head per day under the traditional system and 2.4 kg with the traditional system modified by the introduction of *setaria* grass. There was no obvious difference between feed on offer to and eaten by goats and sheep in either system, so data for both species have been pooled. Farmers fed their animals that feed which was most readily available in both villages. For goats and sheep fed under the traditional system during the 1986-87 rainy season, 43 percent of feed was local grasses, 22 percent was tree leaves, 21 percent was corn leaves and 11 percent was *rhimosa*, a local legume found under estate crops. For the system modified by the introduction of *setaria* grass, 42 percent of feed was local grasses and 42 percent was *setaria*. The remainder of the feed consisted of tree leaves.

Table 6. Goat and sheep feeding system at Kandangan and Klari, Central Java.

Type of feed	Traditional system		System with setaria	
	(kg/head/day)	(%)	(kg/head/day)	(%)
Local grass	1.2	43	1.0	42
Setaria grass	0.0	0	1.0	42
Rhimosa	0.3	11	0.0	0
Browse	0.6	22	0.4	16
Corn leaves	0.6	21	0.0	0
Shrubs	0.1	3	0.0	0
Total	2.8	100	2.4	100

VIII. BODYWEIGHT GAINS ACCORDING TO FEEDING SYSTEM

The average daily gain of goats and sheep was also analyzed on the basis of age of each species and type of feeding system as described above. A significant difference was found between the response of sheep and goats to the use of *setaria* grass. The average daily gain for sheep was higher with *setaria* grass. Adult sheep gained 4 g/day on the traditional system and 19 g/day when fed with the system modified with *setaria* while lambs gained 52 g/day on the traditional system and 70 g/day on the *setaria* modified system. The response of goats, however, was quite different. Adult goats fed on the *setaria* system lost 11 g/day while kids gained only 9 g/day, on the other hand adult goats gained 5 g/day and kids gained 37 g/day on the traditional system. This result is quite interesting. It points out the need for better management of small ruminants within these smallholder production systems. Without special instructions, farmers tend to feed whatever is available without regard to a suitable ration. During the 1986/87 rainy season when these data were collected the *setaria* was growing vigorously and supplied more than 40 percent of the feed. In the case of sheep which is predominantly a grass-eating animal, there was an increase in growth rates. But for goats, which are predominantly browsing animals, the increased use of *setaria* led to decreased use of leaves, especially *rhimosa* and corn leaves. Goats fed on the *setaria* system received 84 percent of their feed in the form of grasses while goats on the traditional system received only 43 percent of their feed as grass. This increase in the level of grass in goat feed from 43 to 84 percent is believed to be the main reason for the poor performance of goats under the traditional system modified by the use of *setaria*. This means that a greater extension effort is required so that farmers understand the different nutritional needs of goats and sheep and feed different rations accordingly to each species. For good performance goats should not be fed more than about 40 percent of their ration in the form of grasses. For goats, the traditional system was superior to the modified feeding system because the new system contained too much grass.

Because data were not yet available for one full production cycle, caution must be used in evaluating these smallholder production systems. One of the most important parameters to evaluate in animal

production systems is the reproductive performance of the breeding flock. In order to measure this parameter for goats and sheep it is necessary to know the litter sizes, *interpartum* intervals and kg weight of kids/lambs weaned per breeding female per year. These data were not yet available. However, the data analyzed so far still provide some interesting information on the growth and feeding management within these smallholder production systems.

CONCLUSIONS

The two examples of village-based farming systems research from North Sumatra and from Central Java illustrate some of the steps in the complete farming systems process as described at the beginning of the Chapter. The two examples differ in the amount of time and funding available for research and data collection.

The North Sumatra example illustrates the beginning exploratory step of farming systems research, sometimes called the descriptive stage. With limited time and funds some useful data have been collected in a short time. These data are particularly useful in understanding and describing local production conditions of the upland and lowland areas of *kabupaten* Deli Serdang but are only the beginning of a longer-term process of on-farm data collection, introduction of improvements into the existing production system and monitoring of the effects of these changes on levels of production and profitability. The main value of the North Sumatra data presented above is that it defines the existing production conditions and shows where some interesting interventions in small ruminant production, especially in feeding and management, could fit into the existing systems.

The data from Central Java provide a more complete example of the farming systems approach as applied to small ruminant production. An extensive effort of data collection was undertaken as part of the descriptive stage of this farming systems research. Data at the village level were collected as in North Sumatra, but they were supplemented with a family level baseline survey. This farm level survey pinpointed the specific farming activities carried out by each family (landholdings and use, crops, fertilizer, labour use, animal populations and productivity, tree crops and forestry production) as well as off-farm

employment. With these specific on-farm data the existing kinds of small ruminant production could be more accurately quantified and interventions determined. For Central Java, lack of breeding stock and some seasonal feed shortages were initially identified as main constraints to increased sheep and goat production. Participating farmers were provided with breeding stock and advice on use of *setaria* grass which was introduced as part of conservation farming practices in these upland villages. Farmers' responses to these interventions were then monitored (and continue to be monitored). Probably the most interesting response to the introduction of new technology (the use of *setaria* grass) into these upland farming systems was that farmers fed both goats and sheep similarly despite the different requirements for the relative amounts of grass and browse for these two species. In other words, upland farmers, seeking to reduce the labour required to feed their animals, fed whatever was most readily available. The *setaria* grass grown on terrace risers was harvested to free labour otherwise spent in travelling longer distances to gather small ruminant feed. In the case of sheep production, increased bodyweight gains were observed, but goat production suffered from the large increase in the relative proportion of grass in their rations. This response of farmers to the introduction of an improved grass led in turn to research on feed management for small ruminants under village conditions. Monitoring and technology testing are still continuing at these two sites in Central Java.

This follow-on research of feed management illustrates a key element of farming systems methodology, that of problem solving. As described above, the first step in the farming systems methodology is the descriptive stage where data are collected to describe an existing production system. During this descriptive stage an experienced farming systems researcher identifies constraints to increased production in this system and, as part of the second stage, formulates hypotheses to decrease or eliminate the constraints identified during the descriptive stage. This second stage of the farming systems methodology is often called the diagnostic or prescriptive stage where various hypotheses are formulated to improve the described system. Since it is usually not possible to test all these hypotheses at once, some method must be used to select those that should produce the greatest increase in production in the existing system. This ordering or

ranking of prescriptive hypotheses is often called *ex-ante* analysis. This means that a given increase in production is estimated from the application of a given prescriptive set of activities as described in an hypothesis. This estimation or *ex-ante* analysis may be based on the researcher's experience with this kind of production system under other conditions, on information available in the scientific literature, or on the opinions of other researchers. For example, if one prescriptive hypothesis to increase small ruminant production is to increase the feed supply, an *ex-ante* analysis may be performed on increased production of this system such as faster liveweight gains and higher fertility-fecundity based on different hypothetical levels of increased feed introduced into the system. Similar analyses may be performed for hypotheses based upon improving breeding, management or health. This type of analysis usually takes the form of an input-output analysis. The costs of a given amount of proposed inputs are calculated as well as the estimated increased output. This may be done for several proposed inputs. Then the researcher, using his/her experience and the results of this analysis, decides before (or *ex-ante*) he/she introduces his/her new input into the system which is the one most likely (sometimes called best-bet technology) to produce the desired result.

In the next step of the farming systems research methodology this best-bet technology is introduced and the results are monitored over time. In the case of the Central Java example above, the best-bet decision was to plant *setaria* grass and provide additional breeding stock. It should be pointed out that this decision was made after an analysis of the entire upland farming system, not just its small ruminant component. Conservation and natural resource stabilization were identified as the major constraints to long-term production of this farming system and *setaria* grass was identified as an input that could best solve the problem of terrace stabilization (along with other shrubs and trees) and also provide additional animal feed, so that farmers would have an increased incentive to use it. In monitoring the results of the introduction of *setaria* grass, it was found to increase sheep production but to decrease goat production, when 84 percent of the new diet fed consisted of grasses. This led to the formulation of a new hypothesis and new research on to how to manage this feed for goat or for sheep production. This problem solving or iterative aspect of

farming systems research is ideally suited to village-based research. Its methodology is the only one which systematically analyzes all components of a given farming system. When properly carried out, it imitates how smallholder farmers themselves make production decisions among their varied activities of food and perennial crop production, livestock and forestry and off-farm activities and is ideally suited to working under village smallholder conditions of nonspecialized and diverse farming activities.

While this methodology is believed to be the best one for village conditions, several problems in its use should also be pointed out. One problem is the time required to obtain results. This is a problem endemic to all ruminant research. With a generation interval of at least a year for many goats and sheep (actually closer to two years under village conditions) a minimum of three years' research is usually necessary to obtain reliable results for changes in a given production system where levels of reproductive rate are expected to change. The second problem, related to the first, is the cost of conducting village research. While flocks of experimental animals are not maintained on an experimental station, transportation and *per diem* costs for staff to visit village sites, payment in animals or other assistance to cooperating farmers, costs of data management, or of stationing of junior staff in villages (as was done in the Central Java example) all add to a considerable budget. While a research institute may readily support its own activities on its experimental station, it may be much less willing to support off-station work which it may not see as contributing to its development as an institution. This latter problem is the most serious one. Many researchers consider village-based research to be unscientific and the results thus obtained questionable. In the case of small ruminants they point to small flock size, uncontrolled breeding, buying and selling of animals which disrupt data collection with extreme environmental variations from one flock to another due to diverse feeding and health management. How can scientific results, especially statistically significant results, be obtained under such chaotic conditions, these critics ask? The answer to this problem is to remember the purpose of village based farming systems research and the purpose of experimental station research. The latter is usually engaged in testing one specific treatment - a feeding trial, a health treatment, or breeding management - in isolation in a highly controlled

and artificial environment. Specific statistically significant results can be obtained under these conditions and the experimental station is the proper place to conduct such research. But what is the use or significance of such an experimental station result? This often cannot be answered at the experiment station. Almost all small ruminants in Indonesia are raised under smallholder village conditions. Ultimately, the purpose of small ruminant research in Indonesia should be to increase the production and profitability of small ruminants in the thousands of villages where they are raised. The farming systems methodology provides a systematic framework to test the usefulness of research results under the actual production conditions of the villages. This methodology is not meant to replace on-station research. Under Indonesian smallholder conditions, it is meant to be the essential link to transform research results to production gains and to feed back information to researchers on real problems that need to be solved. For this reason alone, village-based farming systems research should be supported as an essential component of any applied agricultural research program in Indonesia and indeed throughout South-East Asia.

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CHAPTER XII
THE ROLE OF COMMUNICATION IN EFFECTIVE FARMER-EXTENSION-RESEARCH LINKAGES

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INTRODUCTION

This Chapter provides an overview of the communication linkages between farmers, extension agents and researchers, along with the methods for stimulating effective collaboration between them. These linkages are required to facilitate the development of appropriate technologies for small ruminant production that can contribute to increased production levels as well as to the welfare of the farm families. Recognition is also given to the interdependent nature of agricultural research and extension systems which require functional and structural linkages with other components of the process of agricultural development. This suggests that a large group of organizations and agencies is focussed on agricultural development. Furthermore, along with the extensive linkages implied in the

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organizational structures, there are socio-economic, political and policy factors to be considered in the larger context of agricultural development through contributions from research and extension programs.

The focus of attention is on Indonesia's research and extension systems related to small ruminant production, however, the larger issues of effective farmer-extension agent-researcher interactions presented are also evident in most developing countries.

Over the past several years there has been worldwide attention directed towards improving farmer, extension and research efficiency. This has taken the form of a continuing series of international and national conferences, workshops and evaluations focussed on effective structures and policies for research and extension systems which are intended to strengthen the interactions between farmers, extension agents and researchers. This recognition is also evident in Indonesia and it has come about due to two important factors. The first is the national development planning directives of the PELITA programs. The agricultural component of the present PELITA V (1989-1993) is designed to promote agricultural export, by optimizing the productivity of the agricultural resource base of Indonesia. The second factor is the realization that researchers need to communicate research results more effectively to extension services and smallholder farmers in order to realize sustainable productivity increases.

The Government of Indonesia (GOI) through the Ministry of Agriculture (MOA) is promoting increased productivity and production of the entire agricultural sector. It has met with success and achieved some of its targets particularly in relation to self-sufficiency in rice production. Success is also evident in increased production of food crops, estate crops and several other agricultural export commodities. The contributing factors to this success hinged on applying new production technologies and marketing mechanisms to large scale production operations. What is needed now is a sustained effort to reach the smallholder farmers with innovative production techniques which take into account the general resource characteristics of the average Indonesian farmer, for example, small landholdings, limited investment resources and low commodity prices.

A point of departure should be noted from previous agricultural research during the 'green revolution' wherein a limited number of farmers participated, and the current emphasis on small-scale farmer participation in interactive research methodologies. The crucial difference is that emphasis worldwide is now focussed on resource-poor/smallholder farmers, not on commercial larger size farmers, as was previously the case. In the past, smallholder farmers did not have access to the research information generated through the national research networks and therefore did not have any effective influence on the direction of research. The present debate is designed to bring the resource-poor farmers into clear perspective through an understanding of their objectives of family welfare and production constraints within the context of national agricultural development and agricultural policy formulation.

A. THE ROLE OF SMALL RUMINANTS

Nearly 80 percent of Indonesia's population live in rural areas with agriculture providing the primary source of income for nearly two-thirds of all rural households[1]. Livestock are particularly important in the rural economy, since most rural households farm small areas of land and livestock provide an additional source of income as well as other benefits. Small ruminants can make a marked contribution to the welfare of these households. In West Java it is estimated that 30 percent of farming families raise small ruminants. Sales of livestock products in this category represent 14 percent of family income in the upland regions, 17 percent in the lowlands and as high as 25 percent near rubber plantations[2]. More importantly, income from small ruminant enterprises, as a percentage of total family income, increases as the amount of land a farmer owns decreases. Small ruminants also offer landless labourers the means for increasing family income by using community land and harvested rice paddies from which to collect forages, or to graze sheep and goats on these during the dry season as well as collecting forages from them during the rainy crop-growing season.

Research studies have indicated that traditional methods of raising small ruminants are difficult to justify from a purely economic

standpoint[3-5]. Even with the low input levels used, such as native grasses, family labour, locally available breeds and traditional management, the profit margins are very small. Typically, small ruminant farmers in Indonesia do not assess their inputs, such as time, labour and management skills, at their true market values, resulting in undervaluation of the end-products of the production system. Nevertheless, small ruminants have traditionally provided a means for family savings and are a ready source of cash. Due to these two qualities and the lack of market information, the animals are usually sold either before or after they have reached their optimum market age. Furthermore, farmers have to accept the prices offered by middlemen or perhaps seasonally low prices due to excess of supply prior to the rice planting season when many mechanisms place farmers with small ruminants in an inferior bargaining position, which has contributed to keeping the national population of small ruminants essentially stagnant. Without an attractive price incentive for improving small ruminant production, farmers will continue to rely on their main priority commodities, predominantly rice and other cash crops, as their means for achieving the objectives of family welfare.

Microeconomic theory suggests that farmers and small ruminant producers will respond to attractive prices for their products by increasing their production to ensure maximum family welfare and profits. Appropriate marketing margins (the difference between sale price received by the farmers and their production costs) can make an important difference in the farmers' response. But, what often occurs is that the farmers do not benefit proportionally from the high marketing margins due, in part, to a lack of information concerning the market pricing mechanisms i.e. mark-up on the animals sold and actual returns for services received by the various middlemen between the farmers and the consumers. This situation yields less response from the farmers because the price transmission process is hampered by the distance between the farm-gate and the markets, resulting in low prices received by the farmers and a high share of the marketing margin for the middlemen. Thus, low prices received by the farmers discourage them from producing efficiently and reduce a farmer's responsiveness to new production technologies developed through the research and extension networks.

B. THE ROLE OF RESEARCH AND EXTENSION IN INCREASED AGRICULTURAL PRODUCTIVITY

As countries such as Indonesia continue to develop economically, the contribution of agriculture to the gross domestic product declines. If the productivity of crop and livestock farmers' resources can be increased, then the share of the country's resources required to produce agricultural products and food for the rest of the population will decline[6]. These 'resource savings', as they are called, are either re-invested in the agricultural sector to encourage further increases in farm productivity, possibly for export, or invested in another sector of the economy.

Agricultural research and extension networks have a central role in this aspect of agricultural development. Extensive analysis of the functions of agricultural productivity and investment trade-offs in developing economies suggests that agricultural production can be greatly increased by investments in education, agricultural research and extension and by applying modern technological inputs[7].

Increasing goat and sheep productivity and farmers' incomes from small ruminant production can be achieved by improving farmers' access to new technologies, production inputs, markets and information. Research programs focussed on increasing animal production and improving marketing methods can be particularly effective if the recommendations provided to the farmers have been tested through a farmer-oriented, on-farm research program. Within this on-farm methodology, the extension agent has the crucial responsibility of conveying these production recommendations as well as marketing information to the farmers.

The extension agent should play a dual role in this process of technology development by training and learning from farmers as well as by informing the researchers of the farmers' production constraints and their evaluations of suggested technologies. The farmers need to understand fully the new production technologies and how to operate within the broader agroeconomic environment. The extension agents and researchers can provide an important mechanism for communication with the farmers by channelling advice and suggestions to them about the optimal utilization of their land,

resources, capital and labour, given the welfare objectives, resource base and production targets of the farm family.

C. THE AGRICULTURAL EXTENSION MODEL IN INDONESIA

Indonesia has made significant institutional developments in its research and extension systems that have contributed to increased productivity overall. The Agency for Agricultural Research and Development (AARD) was initiated in 1979 and part of its mandate is to coordinate the activities in research and information dissemination of several central research institutes including for animal production, the Central Research Institute for Animal Science (CRIAS). Under CRIAS, the Research Institute for Animal Production (RIAP) and the Research Institute for Animal Disease (RIAD) are responsible for research and development of alternative technologies in animal production, as well as for treatment and prevention of disease. These institutes have already made important contributions to increased animal production and productivity in Indonesia.

The dissemination of the research recommendations and information from these two institutes lies predominantly with the Agency for Agricultural Education, Training and Extension (AAETE) and the Directorate General for Livestock Services (DGLS). Research results are channelled to the AAETE and DGLS through the Division for Distribution of Research Results within CRIAS. This division provides feedback from the DGLS and MOA offices relating to the research areas needing immediate attention and also provides policy recommendations to AARD. The research and extension organizations in Indonesia are linked by the common goals of increasing national food supply and improving the welfare of farm families, thereby contributing to national, regional and local development.

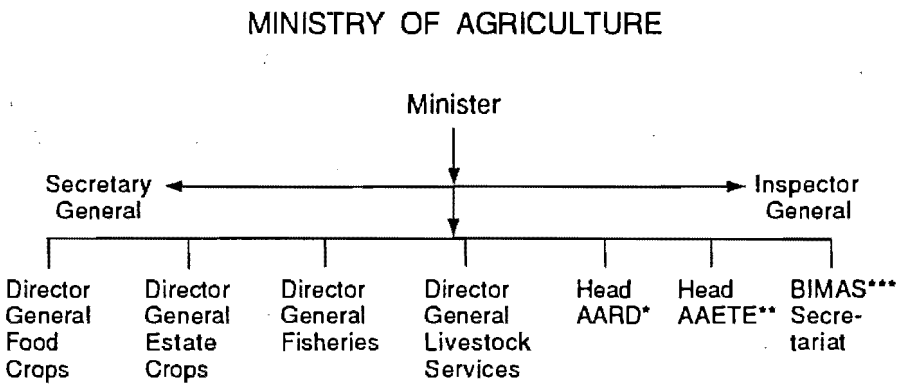
The extension system has been the key mode for providing farmers with information about new techniques and tools they can use to increase productivity. Ideally, the extension system functions as a link between the MOA, the research centres and the farmers. In this manner, new technologies are developed collaboratively with the

farmers and information about farmers' production problems are conveyed back to the researchers.

Indonesia is similar to many other countries where the extension system is organized under the MOA and receives most of its extension agents from specialized agricultural schools. The role of these extension officers may be to promote agricultural innovations, provide administrative oversight for the Ministry, or both. A number of these agents possess limited technical expertise or practical experience in production agriculture. Moreover, although the majority of the technologies and the inputs provided by the extension services are directed toward increasing agricultural productivity in general, functions of the extension service have been expanded to include services that are more regulatory in nature than promoting direct agricultural production technologies and disseminating marketing information. These additional responsibilities reduce the ability of the extension services to concentrate their manpower resources specifically on dissemination of agricultural production technology, for example, that related to small ruminants.

Indonesia, along with other South-East Asian nations, is providing institutional support, extension personnel and a variety of consultants, emphasizing the need for farm planning, management, credit and marketing to train and manage various levels of resources of extension manpower. Indonesia's MOA has recognized the importance of livestock in mixed, smallholder agricultural production systems. Consequently, considerable emphasis has been placed on improving and increasing small ruminant research and training extension officers to disseminate results and recommendations from the research activities.

The MOA links four Directorate Generals (DGs) each of which oversees a specific area of agricultural production: Food Crops, Estate Crops, Fisheries and Livestock. These four DGs are linked to AARD, Guidance for Society - Bimbingan Masyarakat (BIMAS) Secretariat and AAETE. Each DG has specific regulatory functions along with promoting increased production in its area. The organizational scheme illustrating the Ministry's links with the DGs, AARD, AAETE and BIMAS is presented in Fig. 1.



* Agency for Agricultural Research and Development
** Agency for Agricultural Education, Training and Extention
*** Bimbingan Masyarakat

Fig. 1 MOA linkages with DGs, research and extension.

Agricultural information is channelled from the extension directorates of the four DG offices through the AAETE and then to the Agricultural Information Centres (AIC), which are located in each of the 27 provinces. AICs are also responsible for disseminating agricultural information to the district level extension agents.

Extension at the provincial and district level, is carried out by the Agricultural Extension Coordination Forums. The members of these forums consist of representatives from the AIC, regional offices for the Ministry and the Provincial Agriculture Services.

At the district level, extension activities are conducted by the agricultural service officers through the field extension agents at the Agricultural Extension Centers (AEC). The AECs function as the base of operations for extension supervisors who each manage 15 to 20 extension agents who operate within the villages. The AECs also serve as meeting places for agriculturally-related village activities. Agricultural extension training and information exchange with the farmers takes place at the AEC through their contacts with farmer groups and selected key farmers. There are three levels of extension agents that participate in organizing and conducting the farmers' training activities at the AECs. Firstly, the field extension agents who live and work in a particular village. These agents must provide advice on practically all activities of agricultural production in the village.

Secondly, the extension program officers who help the field agents carry out their responsibilities. Thirdly, the subject matter specialists, who are responsible for providing specialized advice to both the field extension agents and the program officers. These specialists cover resource management in the four major areas for agricultural production (Food Crops, Livestock, Estate Crops and Fisheries).

All the research and extension effort is ideally focussed on the family resource base, labour and time constraints as well as welfare objectives of the smallholder farmers. Therefore, the village is the actual frontier of agricultural development. This is where national agricultural policies, research recommendations and marketing information are used by individual farm families to help them make their resource allocations for agricultural production based on maximizing the welfare of the farm family.

D. FARMERS, RESEARCHERS AND EXTENSION COMMUNICATION LINKAGES

The importance of organization and communication linkages between research and extension networks cannot be over-emphasized. This theme has received considerable attention in the literature of agricultural research and development worldwide due to its central role in efforts to increase agricultural productivity. Viable research and extension communication linkages are a pre-condition for effective interactions among farmers, extension agents and researchers. Without these interactions, other efforts to relieve technical, institutional, market policy and economic constraints will be severely restricted or ineffective. Fig.2 presents a simplified diagram of this dynamic interactive linkage process.

Understanding the importance of the communication processes with smallholder farmers in the development of research recommendations for improving the productivity of their goat and sheep enterprises is a challenging task for on-farm researchers. An awareness of this communication process for conducting field research to provide technically and socio-economically acceptable techniques of small ruminant production management, contributes decisive information in the overall s trategy for technology development and

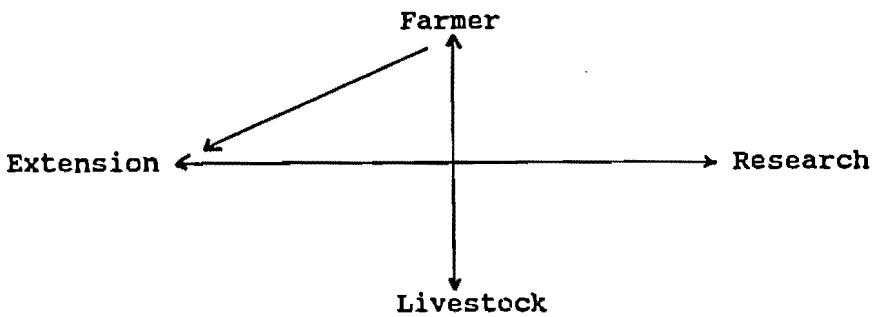


Fig. 2 Farmer-extension-livestock and research linkages.

transfer. Additional benefits accrue when farmers, extension agents/ trainers and researchers are able to collaborate in the research process, thereby improving the extent and rate of transfer of the new technologies. The chances of improvement in the efficiency of research will increase as well.

Presently, no comprehensive communication model has been developed that is applicable to all research programs and projects involving small ruminants. Nevertheless, current literature provides many examples of effective agricultural communication strategies that suggest a basic appreciation of the communication process between farmers and agricultural researchers[8-11].

An example of a communication model is provided by the research efforts of the Research Institute for Animal Production/Small Ruminant-Collaborative Research Support Program (RIAP/SR-CRSP). The primary objective of the Outreach Pilot Project (OPP) is to develop technologies of small ruminant production derived from combining on-station and on-farm research with indigenous farmer knowledge and production objectives. The goal of this village-level research program has been: 1) to increase the economic viability of goat and sheep production systems of small-scale farmers through innovative production technologies and economic/marketing information; 2) to establish a dialogue with a number of farmer groups in order to develop and test production technologies that are socially acceptable and economically profitable. This perspective was taken in order to

increase the farmers' awareness of improved management techniques as opposed to merely increasing animal numbers. The objectives of this United States Agency for International Development (USAID)-funded program are being pursued through three program components: 1) on-station research; 2) on-farm technology development and testing; and 3) dissemination of research results to the extension/training network in Indonesia and other humid and semi-humid tropical countries.

A variety of management recommendations for increasing small ruminant productivity were suggested by the RIAP/SR-CRSP on-farm research program. These recommendations were derived from several years of on-station research, field surveys and on-farm research activities in Java and North Sumatra. This technological package consisted of recommendations in several areas supported by subsidies as well as data collection and evaluation. For example, as far as breeding was concerned, the aim was to reduce *interpartum* intervals. The team also monitored litter sizes of RIAP's established high prolificacy lines. Each farmer was given one ram and five ewes from the high prolificacy lines. The farmers were also given a subsidized loan for the construction of a barn. In the area of nutrition, mineral supplementation was provided and feed was analyzed. Drenching with anthelmintics followed faeces sampling and worm egg counts. Animals were weighed and measured to evaluate the growth, health and nutrition of the animals under study. Temperatures and humidities inside and outside barns were recorded during farm visits as were animal groupings within barns. In the socio-economic area, agro-economic profiles were built up as well as data on perceptions and opinions of OPP and non-cooperating farmers with small ruminants. As a means of repayment, each group of farmers would return eleven animals over a five-year monitoring program.

Originally, it was believed that the suggested modifications to methods of traditional animal management of the smallholder farmers' would be accepted in a relatively straightforward manner by the participant farmers simply accepting the advice and recommendations of the research team. Unfortunately, this assumption, commonly accepted by many agricultural researchers and extension personnel, is not correct due to constraints and production objectives of most farmers not perceived by research and extension workers. It is overly

optimistic to expect farmers to invest more labour and/or capital and to accept new production methods with higher perceived levels of risk. This erroneous assumption was partially derived from the incomplete understanding of the production constraints of the smallholder farmers and their objectives of maximizing family welfare through diverse production systems.

Initially, the OPP began with 19 groups of farmers, later expanded to 29 groups, representing the three climatic zones in West Java, namely, highland or upland, middle, and lowland areas. Each group of farmers consisted of two or three farmers who were selected and grouped by the researchers. The OPP has been underway for five years in 14 villages within the Bogor district of West Java. There are 46 small ruminant farmers directly involved in the OPP on-farm research program.

The on-farm research team was composed of scientists who specialized in various disciplines related to small ruminant production which included breeding/reproduction, health, nutrition, economics/ marketing, sociology and management. The farmers were visited monthly by the on-farm researchers to collect production data and assess the level of acceptance of the various packages of technology information that were proposed.

Data on animal performance collected during the first three years of the project confirmed that the animal productivity of most of the farmers was falling short of known animal production potentials[12]. Improving this situation required a methodology which encouraged the exchange of information between farmers and researchers concerning production problems, constraints on farmers' resources, proposed technological improvements and marketing alternatives. To strengthen the OPP's information collection, dissemination network and technology testing format, a more intensive communication program was developed and incorporated in the OPP in March 1988. A concurrent technology development and testing program in Brazil confirmed that animals perform better when their owners have regular contact with scientists and extension agents[13]. Effective communication linkages with farmers, therefore, have turned out to be the key to on-farm animal research and extension.

The OPP program emphasized an agricultural systems approach to ensure that research recommendations would be relevant to the needs and resources of smallholder farmers. The program was designed to provide farmers with the opportunity to participate in the development of production technologies as partners in the project rather than as passive recipients of information and advice.

I. THE COMMUNICATION GAP

There is a large amount of literature that underscores the communication gap that agricultural extension agents and researchers often fall into. It is therefore important that they familiarize themselves with the major constraints of the farmers which are impeding the implementation of new technologies in animal production. Moreover, the extension service and researchers should be aware of current communication and education/training practices pertaining to how people learn and which methodologies can improve the reception and acceptance of research recommendations for on-farm technology development and testing. This information, combined with consideration of the specific behavioural objectives of the research program as well as encouragement of the adoption of improved practices of small ruminant management can improve the efficiency and effectiveness of both the research and extension expenditures in terms of time and manpower resources.

A brief outline of the communication between farmers, extension staff and research personnel as well as their information sources and networks illustrates the need for increasing the interactions among these groups. This discussion is taken up in the following section.

II. CONVENTIONAL COMMUNICATION NETWORKS

Researchers have traditionally relied on research publications and annual reports, written in a scientific manner, as well as workshops and seminars to convey research results and recommendations to an audience predominantly composed of their fellow scientists and of research directors. Copies of these publications and seminar proceedings are often sent to the extension/ communication sections for dissemination to farmers and/or on-farm testing. All too often, these formal avenues of scientific information flow are one-way, not understood by, and therefore not responsive to,

the informational needs of the 'user groups' represented, in this case, by the extension/training staff and the small ruminant farmers.

Traditionally, agricultural information networks of smallholder farmers have relied upon older family members, village leaders, other farmers, village discussion groups, itinerant extension staff and scanty information packages from television and radio programs. Farmers do not follow formal research methodologies in determining which crop or animal production modifications are most effective. Nevertheless, they do have an inherent propensity for small-scale, low-risk trials for improving some aspects of animal management. Therefore, they are generally willing to consider suggestions and to participate in discussions related to relaxing various production constraints. It is important that the overall production objectives of the farmers and researchers be understood by both groups.

The extension training and field staff have their own media sources and communication networks for disseminating agricultural information that are often, at least partially, derived from research results and recommendations. But, with the research-extension communication gap being as wide as it is, there is little evidence to suggest that farmer-identified production problems are channelled through the extension staff and passed on to the researchers for intensive investigation. Therefore, 'research derived' recommendations are all too often not based on 'farmer identified' production constraints. This situation is true in many countries and is the result of farmer-extension-researcher communication channels being ineffective in promoting and facilitating the development of new or revised animal production techniques. Therefore, an understanding of the overall communication and learning process among these three groups is crucial for optimizing the returns to on-farm technology development and testing.

III. TECHNOLOGY AND TECHNOLOGICAL CHANGE

Smallholder farmers are integrated into a complex and multifaceted system of activities of agricultural production. In Indonesia, the common practice of cropping is primarily rice-based, in which farmers attempt to meet their families' basic needs for rice and other staple foods. The traditional cropping patterns retain a heavy

emphasis on rice and staple foods because family food production is the dominant enterprise of the farming system even in regions which produce perennial estate crops. However, livestock may be raised for draught power, for manure, as a savings mechanism, for social prestige and for a cash income, thus retaining their importance as a part of the traditional farming systems. This is especially true for the small-scale farmers who attempt to minimize risk and maximize returns to resources used with variations in activities of farm production throughout the year.

As populations expand, land area per farmer decreases, while the industrial sector lags behind in its ability to absorb the excess manpower, particularly in the rural areas. With small-scale farming, characteristic of the densely populated island of Java, all efforts and family resources are directed towards increasing the productivity of the land. The small-scale of farming units may be one reason why, in the past, the farming systems research approaches have emphasized cropping systems. Furthermore, considering that farmers have only limited capital for establishing specialized farms, a livestock-based farming system would be limited, especially in regions where food production is the centre of the farming enterprise[5]. Therefore, establishing a highly specific resource enterprise, such as livestock, may result in attempts to focus on improving welfare through the livestock components unlikely to succeed[11].

It has been suggested that institutional and cultural environments, within which small-farm agriculture operates, may limit growth. In small-farming systems with a high level of family ownership, the income earned is largely retained. This generally results in slow adoption of new high-cost and high-return investments. In addition, traditional views and practices related to familiar patterns of allocation of family resources constrain changes required for the incorporation of new agricultural technologies[14].

An extensive amount of literature has been devoted to the discussion of the stages of farming systems research, technology testing and transfer procedures. However, although innovations can often be demonstrated objectively in research station situations to result in higher profitability, the critical factor in ascertaining their potential for adoption are farmers' subjective evaluations of these characteristics,

in particular if extra time and labour are required. Furthermore, the small-scale farmers are usually hampered by their inability to bear the additional risk often imposed by new production technologies.

Adoption of new technology may be more rapid if, in addition to demonstrated increased profitability, the risks associated with the improved technology remain the same or preferably less than those in using the traditional technology[14]. Moreover, it has been suggested that farmers and researchers in the development of new technologies should integrate the complementary domains of indigenous knowledge (IK) and formal knowledge (FK) in order to increase farmers' risk bearing abilities. The IK reflects the experiences of the local community and places them on an equal footing with the researchers involved in the process of technology development. In fact it is the key to participation[15]. Developing appropriate agricultural technologies based on the experience of smallholder farmers is one of the most challenging tasks facing agricultural research and extension efforts in economically less developed countries.

The interrelationships between crops and livestock have been recognized by farmers for many centuries. These imply that improving the incomes of small farms through increased livestock production should be undertaken in-line with the cropping system (see also Chapter XI on Farming Systems). Furthermore, the relatively higher risks involved in livestock enterprises provide an important incentive for participatory research where farmers, extension agents and researchers are all technology developers.

There is no theory to explain or predict the diffusion of new technology throughout a given farming system. Many of the agricultural technologies used in many developing countries have been borrowed from economically more developed countries and are presently being adapted to meet local constraints on inputs. However, when considering interactions between farmers, extension-officers and researchers, two important considerations should be kept in mind when constructing a methodological model for interaction and technology development among these groups.

The first consideration is that technological change can be one of the most significant factors in *per capita* growth in developing countries[16]. In the context of this discussion, agricultural research

institutes have technological development as a primary goal while the extension system has the implementation thereof as its objective. Both these institutions have increased agricultural production as their shared focal point. At this juncture, the second consideration arises as to the interrelation of the shared objectives of the researchers and extension agents with those of the smallholder farmers. The farmers' terminal objective revolves around maximizing family welfare while concurrently minimizing risk. This divergence between the objectives of the two groups is commonly missed or undervalued by research and extension personnel, thus reducing the efficiency of the communication process.

What determines the rate of development of new agricultural technology and its diffusion throughout a farming system? What combinations of farmer-extension-researcher interaction, information exchange and technology adoption are most likely to yield increases in agricultural production and improvements in the welfare of the farm family? These are two pertinent questions that are combined with many factors which can contribute to technological change in the agricultural sector relating to farming systems of smallholders.

IV. UNDERSTANDING FARMERS' RISK ACCEPTANCE LEVEL AS A BASIS FOR A MODEL FOR INTERACTION

There is an extensive body of literature that explains changes in an individual's economic activities in relation to various degrees of risk assumption or avoidance. Economists use risk-income indifference curves to describe this behaviour. In the context of this Chapter, we are concerned with smallholder farmers. The question presented to those farmers in various socioeconomic research studies solicits information concerning, how much increased risk are they willing to accept on the average, given the probability of earning more income?

In Fig.3 a series of trade-offs or risk-income indifference curves are illustrated. The slopes of these curves vary with income as they move out from the origin, indicating higher tolerance levels of risk. Indifference curve A shows that, as long as income does not drop below level M (subsistence level) using one technology or level of inputs, then the farmer will accept the associated level of risk. There will be some variance of acceptable changes in a production technology or

input use and these are indicated as movement along indifference curve A. As the farmers' choice of technology 1 or 2 shifts along the curve, choices are made as to which technology to utilize or what combinations of each technology best satisfy their needs. At higher income levels indicated by curves B and C, there is an increasing range of combinations of technologies and input use for increasing income levels with various combinations of technologies 1 or 2.

Smallholder farming systems are usually considered low-risk enterprises and farmers are not in a position to make a wide range of choices in terms of their allocation of scarce resources. Farmers at point (e) on the curve in Fig. 3 would not choose to move to point (f) even though their income would increase, due to their inability or unwillingness to assume a higher level of risk. They would usually prefer a lower level of income with its associated lower level of risk and increased certainty for their families' welfare (a safety-first strategy). This is a critical point of focus for meaningful farmer, extension agent and scientist understanding, communication and interaction.

The on-farm researcher and extension agent should understand and accommodate the smallholder farmers' ability to accept varying levels of risk for different farming systems enterprises. It is possible that a farmer is willing to assume different amounts of risk among a variety of farm enterprises. For example, a smallholder farmer whose main source of income is from rice production is not likely to accept higher levels of risk for that production enterprise due to the increased possibility of failure (maybe due to less information about a new technology) associated with the potential of increased yield of a proposed technology of that all important enterprise. But, a farmer-extension-research integrated methodology designed to provide farmers with more complete information about the new technology at all levels of development and testing, can encourage smallholder exchange of information, resulting in knowledge that actually lessens the risks that are faced. Therefore, close communication in on-farm research will encourage understanding by the farmers, extension agents and researchers of what level of risk (and level of information) and interactions between them are most effective at a given stage of the implementation of a research and/or extension program.

During the initial stages of a research-extension-farmer interaction model, the farmer is most likely to be averse to risk, not willing to

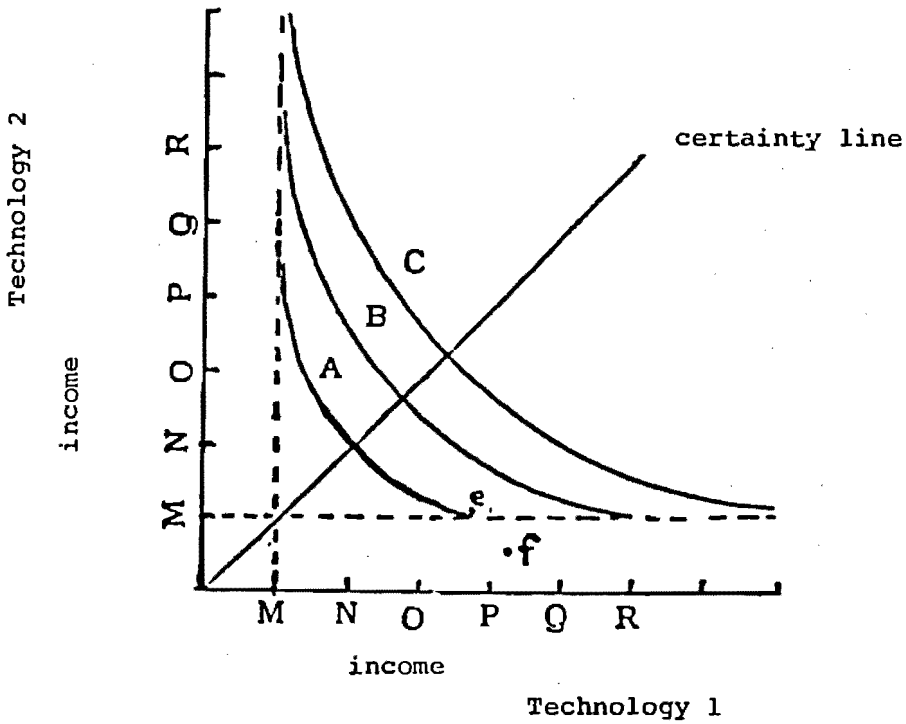


Fig. 3 Farmers' risk-income indifference curves[16].

assume more risk in a particular activity of agricultural production. At this point, a large amount of researcher/extension involvement is required to provide the farmer with technical support, advice and perhaps some initial subsidy to reduce the risk assumption by the farmer. As the participants in the research and development project acquire confidence in each other through effective communication, the researchers and extension agents will be able to provide the farmer with sufficient technical support and advice wherein the farmer, researcher and extension agent will be on a relatively equal basis in terms of sharing risks and responsibilities toward the successful outcome of their joint efforts.

The important intermediate role of the extension agent as a messenger link in information transfer is shown in Fig. 4. The

extension agent can also provide a valuable service in the interpretation of formal knowledge provided by the researchers to be transferred to the farmers and indigenous knowledge from the farmers to be conveyed to the researchers. A suggested role for farmers, researchers and extension agents in the development of new technologies should be to integrate the complementary domains of indigenous knowledge and formal knowledge in order to increase the farmers' ability to bear risk. Indigenous knowledge reflects the expertise of the local farming community and places the farmer on an equal basis with the extension officers and researchers involved in the process of technology development[17]. Developing appropriate small ruminant production technologies based at least partly on the experience of the smallholder farmers, is one of the most challenging tasks facing agricultural research and extension personnel in Indonesia.

V. IMPLEMENTING EFFECTIVE COMMUNICATION STRATEGIES

A basic component in organizing strategies of on-farm research and technology development is to accept and apply the concept that communication is a continually developing process. This perspective takes into account the wide range of socioeconomic and psychological variables present in any interpersonal communication and exchange of ideas. For example, the image that the farmers and researchers have of each other, social status and agricultural experience all impinge on the effectiveness of the communication process. An initial understanding or assumption needs to be reached, wherein the farmers and researchers accept each other as viable sources of agricultural information. In order that this assumption is accepted, the on-farm researchers need to recognize the interactive or feedback mechanisms that are operative in any viable communication strategy or model. Therefore, communication strategies should be selected that optimize the interactions between farmers, researchers and extension staff. These strategies must be carefully designed according to the objectives of a specific program.

The process of agricultural communication involving the exchange and transfer of ideas and knowledge can be facilitated through the use of multiple media resources. These resources include

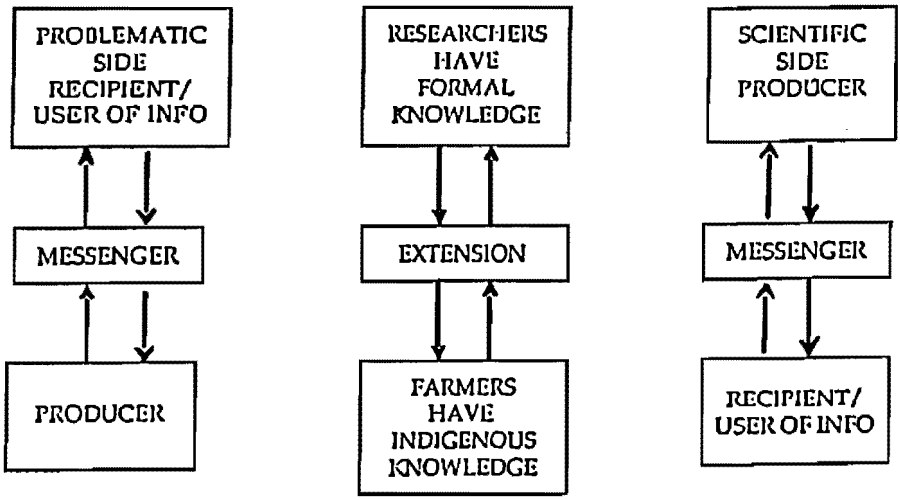


Fig. 4 The role of extension agent/messenger in the process of integrating formal and indigenous knowledge[18].

not only recently developed communication technologies, for example video-cameras and desk-top publishing, but also the most recent information on how people learn, methods for communicating with farmers possessing relatively low literacy levels and between cross-cultural or ethnic groups. Furthermore, adult education, extension and marketing specialists have provided many interesting concepts and low-cost methodologies for reaching specific audiences, such as women farmers, youth groups and low-resource farmers.

A testing program for on-farm technology can use numerous extension-farmer-researcher communication methodologies and media to promote interaction for the exchange of ideas and information. These strategies may include three levels of discussion sessions: 1) general meetings of farmers; 2) meetings at the village level and 3) on-farm visits. Discussion sessions serve to organize and manage farmer participation effectively and efficiently and to exchange information with the farmers. Major topics, reviews of accomplishments and brief introductions of new information could be provided during an annual general farmers' meeting. Village meetings, held bimonthly, provide a forum for discussing region-specific production problems as well as

more complete explanations of suggested technologies and marketing information. A monthly on-farm visit provides an opportunity for individual farmers to identify their specific production problems, to discuss further new procedures for animal management and to provide the research team with feedback on the level of acceptance of each technology package. The research team also collects data on animal production and during the monthly visits conducts an evaluation of the farmers' implementation of the suggested management practices.

As an integral component of the technology development and testing program, numerous farmer training aids should be designed, edited and produced. The primary purposes for producing these training materials follow four lines of reasoning: 1) to summarize the information and management techniques suggested by specific discipline scientists; 2) to provide a means for the extension agents and scientists to work in an interdisciplinary mode by discussing animal production constraints in terms of the entire smallholder farming systems; 3) to convey this information to the farmers using pictures and simplified explanations; and 4) to serve as a reminder for the farm families about suggested procedures of animal management.

As an example of a research program for on-farm technology development and testing, the Outreach Pilot Project, (OPP) within the Research Institute for Animal Production (RIAP), highlights several aspects of effective communication strategies that may be implemented in the national goat and sheep extension programs. This has been briefly described earlier in this section. The OPP farmers obtained information regularly from the on-farm research team related to several aspects of goat and sheep production and marketing technologies. This information was exchanged with the OPP farmers and the livestock service through the various farmer meetings described above. To help stimulate the discussions as well as to test the production technologies with a larger group of farmers, several non-OPP farmers attended regularly and often participated in the discussions. They also received copies of the technology training packages presented to the OPP farmers during these meetings. Research conducted regarding the acceptance rate and level of implementation of the proposed technologies indicated the socio-economic acceptability of these production technologies.

The training materials developed during the two years of on-farm technology development and testing were compiled into a 185 page book[19] with numerous pictures written for farmers to read and for extension agents to use for an intensive training program for small ruminant farmers in other areas.

Other training publications included bimonthly farmers' newsletters and 25-minute videos on various procedures of animal production and management. These practical training support publications were produced primarily to enhance the efforts of the on-farm research team toward strengthening their communication links with farmers, extension training specialists, field extension staff, information staff and the government livestock service.

VI. IMPLICATIONS FOR RESEARCHERS

In an effective agricultural communication process, information among farmers, researchers and the extension service staff is exchanged through a wide variety of communication strategies designed to optimize this interchange. An appreciation of various communication processes involved, as well as of innovative methodologies to promote their effectiveness in the development, testing and transfer of technologies appropriate to the farmers' needs, is required to attain this goal.

A necessary condition for this information exchange is a strong commitment from the on-farm researchers to understand the constraints and production objectives of the smallholder farmers. The next step is for the research team to plan and implement innovative methodologies to encourage farmers' participation in the development process of research and technology. Different methods may be more effective with one group of farmers than with another, even within the same project. Nevertheless, there is significant potential for more effective farmer-researcher communication strategies.

VII. ISSUES RELATING TO RESEARCH-EXTENSION INTEGRATION

For the most part, literature comparing the various methods of organization for research and extension points towards the theme of weak or nonexistent linkages between the two components of an

agricultural development program[20-23]. It must be emphasized that, without effective links of communication between research and extension, the dilemmas faced by small ruminant farmers will continue to be unresolved, resulting in low productivity or perhaps even in its overall decline. As a result of the weak links between research and extension, research efforts are often not focussed on developing technologies that are technically feasible and economically profitable to small ruminant farmers. Furthermore, production technologies and valuable feedback concerning the variety of production constraints, especially those facing smallholder farmers, are not communicated back to the researchers[24].

Although research and extension share the common goal of increased agricultural production, these entities generally do not have a reinforcing structure between them. Crucial institutional, sociological and political factors both within and between them contribute to the problem of effectively integrating research and extension to achieve higher farm productivity. Literature in this area provides little evidence that any one system in a particular country has more effective linkages between research and extension than any other. Therefore, there is a need to implement innovations that support the particular strengths and reduce the number of weaknesses in farming systems in Indonesia and other developing countries.

There are several reasons cited for the lack of communication between research and extension staff. Recent research in this area indicates that the research staff are usually more elitist than extension agents due to their increased opportunities for study for advanced degrees, which often result in promotions[25]. Living closer to the cities is also usually viewed as an advantage for the research staff. This advantage allows researchers a wider range of social activities, better housing, improved education for their children and closer proximity to the Ministry of Agriculture where promotion and posting decisions are made[24]. Furthermore, research staff often have numerous opportunities to meet with visiting researchers to exchange information and discuss research priorities. Limited contact with local extension staff encourages the researcher to look toward fellow researchers instead of consulting with the extension staff, who would be more familiar with the problems of agricultural production and marketing of local farmers.

Many extension agents are often unfamiliar with the ability of research divisions to offer solutions to the farmers' production problems. They often have limited contact with their supervisors and other extension staff who may have more access to recent research studies and perhaps have more direct contact with the research branch. Regular meetings of extension and research staff as well as their supervisors can promote communication within the continuum of farmer, extension, research and thereby reduce the isolation often felt by extension agents as well as increasing their effectiveness.

A constraint on human resource development that requires considerable attention is the agricultural training and educational needs of women farmers. Women make a substantial contribution toward agricultural production in Indonesia and in developing countries worldwide. Women's contributions to agricultural decision-making are well documented[26]. Several recent studies illustrate women's significant contribution to small ruminant production in Indonesia[27,28]. Women are proportionally under-represented in extension training and on-farm research activities. This situation results in women being under-represented on the extension staffs in developing countries, with some possible exceptions. If female small ruminant farmers are not consulted concerning their agricultural production problems, then a major human resource segment of the agricultural production sector will be missed out.

Extension agent density is another critical methodological issue in promoting effective on-farm research. Data in Table 1 indicate that the number of extension staff increased substantially during the 1970's. But, even with this increase in staff the number of farmers per extension agent remains considerable.

The ability of the extension system to provide linkages between farmers and researchers depends on several factors. In a recent World Bank study, it was postulated that the following were the major problems in terms of manpower resources[30]:

- insufficient extension manpower;
- inadequate budget allocations for transportation;
- too many non-extension duties;
- lack of in-service training;
- improper scheduling of contacts with farmers.

Table 1. Agricultural extension staff density in Asian countries around 1980[29].

Country	Farmers per extension agent	Increase in extension staff in 10 years (%)
Asia		
Bangladesh	1,500 - 2,000	+20
Indonesia	1,500 - 1,600	+100
Malaysia	1,500 - 2,000	+ 40 - 50
Rep. of Korea	500	*
Nepal	1,500	+50
Philippines	1,500	+50
Sri Lanka	750	+20
Thailand	3,000	+100

* data unavailable

In most countries, few attempts are being made to address these issues. Actually they deal with in-service training issues only by raising the qualifications of new entrants and increasing budget allocations for extension agent induction and in-service training. Presently, many countries have in-service training institutes that offer regular courses in many areas of agricultural production. Most of these courses last for only one to four weeks, not enough time for a comprehensive course, particularly given the diverse educational backgrounds of the extension agents. Complicating the instructional constraints of the various training institutes are the problems of insufficient instructors, instructional materials, teaching aids and equipment to enable these training institutions to improve the overall quality of the training presently provided[24].

The preceding discussion indicates there are significant constraints in the structure, organization and promotion of agricultural extension in developing countries. These constraints have a definite impact on the methodologies selected for research in farming systems. Constraints within the extension system directly affect the ability of researchers to conduct on-farm research and these constraints may vary considerably from country to country. Moreover, as researchers recognize the problems as well as the important role that extension staff have in furthering the on-farm research projects, the necessity to

incorporate the extension agents into the main stream of research projects becomes obvious.

E. INCREASING THE IMPACT OF RESEARCH AND EXTENSION

I. AGRICULTURAL POLICY ISSUES

A separate but related area influencing the effectiveness of research and extension in increasing small ruminant production in Indonesia is the national agricultural policy, which can adversely affect agricultural production and lower the rate of return on investments in research and extension for livestock production. Agricultural policy planners and decision-makers are often reluctant to recognize the important spill-over effects that distorted agricultural policies can have on extension related services[7]. Many of these policies have as the main aim the provision of inexpensive food and agricultural commodities to urban consumers at the expense of rural producers who are forced to accept low profits[31]. When the price received by the farmers for a given agricultural commodity, such as small ruminants, is relatively low compared to its market value, as is commonly found, then the input costs from a given set of resources such as family labour and capital, are undervalued by agricultural policy makers and planners. As a result, all the costs of agricultural inputs are undervalued, which causes the rate of return to investments in research and extension also to be undervalued[7]. Consequently, research and extension programs are criticized for not being effective. Specialists in policy development and agricultural planners often have not recognized that agricultural price and policy environments discriminate severely against investments in research and extension[32]. This debate remains in the forefront as an issue in agricultural development and investment in Indonesia, as indeed in most developing countries.

II. RURAL INSTITUTIONAL DEVELOPMENT

In order to improve the impact of research and extension activities, rural institutions should place greater emphasis on providing improved services to small farmers, who constitute the majority of farmers in Indonesia. These services may take the form of providing

farm loans to smallholder farmers, including women, who do not possess the title to the land which they are farming or on which they are pasturing small ruminants. These farmers can repay loans from profits on the production derived from their efforts. These developments should be determined by field research directed towards identifying changes and focussed on increasing the returns to institutional innovations at the community level. Small ruminant farmers can be better organized through rural institutional development to discuss their animal production needs, for example, access to credit and to other production inputs. They can also improve their ability to communicate their constraints and reactions to suggested technological innovations by the extension service.

III. ACCOUNTABILITY

Another issue in agricultural research and extension networks in relation to the need for rural institutional development, is accountability. Extension agents and researchers have not been held directly responsible for the recommendations and technical innovations they promote to small farmers[33]. Instead, researchers are usually held accountable to research coordinators, domestic and international funding agencies and various administrative levels within an agricultural ministry or within a research institute. Similarly extension officers are accountable to their supervisors in the central, provincial and district administrative structures. Therefore, farmers have no effective influence on the interactions of management in research and extension in terms of identifying the most urgent problems of animal production confronting them.

An extensive amount of literature has been devoted to discussions of the stages of development of research and agricultural technology, of testing and of transfer procedures. Innovations can often be demonstrated objectively at a research station or under limited farm trials to result in higher animal productivity. However, the crucial factor in ascertaining its potential for adoption is the farmers' subjective evaluations of new technologies in relation to their objectives of family welfare and their level of acceptable risk.

IV. CROP-LIVESTOCK INTERACTIONS

The interrelationships between food crops and livestock have been recognized by farmers for many centuries and have already been discussed in this Chapter. These imply that new technologies focussed on improving incomes of smallholder farmers through increased small ruminant production must fit the farmers' existing cropping systems[34]. The reduction of risks that small ruminant farmers must take should be an incentive for researchers and extension agents to encourage farmers involved in the process of technology development.

F. EMERGING PRIORITIES: INNOVATIVE CHANGES

The interactions among researchers, extension agents and farmers have been a topic of debate over the past several years. This debate has been a sub-issue in discussions concerned with the overall effectiveness for agricultural research and extension systems. Several of the major issues constraining the effectiveness of the extension system and its relation with research have been outlined. Three priorities have emerged as the most critical for improving small ruminant research and extension interactions. These topics include: 1) accountability and integration of related research areas; 2) women's participation both as extension agents and as recipients of extension services; 3) improvements in the applicability of and dissemination of technology of the packages and research recommendations that are derived through the agricultural research process.

I. ACCOUNTABILITY

The primary focus required for improving accountability within the agricultural research and extension systems is a learning process approach. The assumption made for this approach is that farmers, extension agents and researchers expect certain benefits and costs relating to their participation in a program of development of animal production technology and/or extension programs. The organizational structures for the research and extension units often impede this approach. Extensive references in the literature within this area do not support any one model of extension organization over another but basically they all offer some services to farmers. Therefore, the focal

question of this discussion has been: how can the small ruminant researchers and extension service personnel increase their effectiveness in promoting their shared objectives to the small ruminant farmers in Indonesia?

Farmers usually expect extension officers to provide a wide range of agricultural services and information including information on optimum planting times, seeds, fertilizers, pesticides, diagnosis of animal and plant diseases as well as new techniques in animal production. The extension agents often have considerable difficulty in providing all these diverse services due to limited training and organizational support as well as to time constraints and the associated problems discussed earlier regarding the environment of internal and external national agricultural policies.

Field researchers need to consider the difficult situation of extension agents. Agricultural researchers often have more access to decision-making authorities and outside information than extension agents. On the other hand, extension agents can provide important inside information on resource constraints and other social and agro-economic problems confronting small ruminant farmers.

II. WOMEN'S PARTICIPATION IN AGRICULTURAL EXTENSION

Women constitute 66 percent of the agricultural labour force in developing countries with even higher labour contribution levels reported in South and South-East Asia[35]. Along with the well-documented contribution of women to the agricultural labour force, there is considerable evidence to support women's prominent role in the agricultural supervision and family decision-making processes[27]. Altering the extension and research systems to accommodate more women would offer considerable benefits to women farmers, other small ruminant farmers, national agricultural production and on-farm technology development, testing and extension.

The benefits to on-farm research and extension can be highlighted by focussing on on-farm research and an extension philosophy which incorporates extension assistance in organizing technological impact surveys. The present low participation rate of female, small ruminant farmers and their subsequent limited access to

accurate and timely agricultural information as well as to new small ruminant production technologies, limits severely the effectiveness of development and testing of the production technology of extension/ research interactive processes[26]. If women farmers continue to be under-represented in research and extension efforts, both as extension agents and as recipients of extension services, the effectiveness of small ruminant research will be constrained.

Recently, limited restructuring of agricultural development projects has occurred, focussing specifically on women's access to agricultural information and improved production technologies[36]. Agricultural researchers and extension officers need to be more aware of the importance of incorporating women into agricultural research projects in the design, implementation and evaluation phases[37]. In this context, a successful technology development/extension project will probably be the one that provides women with access to resources and inputs thus enabling them to improve the productivity of their small ruminants.

III. TECHNOLOGY PACKAGE DEVELOPMENT

The products of agricultural research, extension and development are technical information, research recommendations and procedures for applying agricultural technologies to attain a specified objective such as reducing lamb mortalities or using crop residues as a feed resource for small ruminants. The processes of determining this information can be derived through several research methodologies but, in the final analysis, the technology package that results must effectively reduce or remove the production constraints for which it was designed. In other words, the technology package should identify clearly a production problem and provide a series of recommendations or innovations that will lead to predictable results[38]. If the technology packages are tested on the farm, then they are more likely to result in higher profits than the traditional technologies and be at a reduced level of risk. Packaging research makes the extension agents' work easier because the small ruminant farmers will probably recognize the value of the technology package more rapidly[39].

In order to carry out this exhaustive research procedure, an on-farm testing methodology should be used. Unfortunately, these

procedures are not always followed. What researchers present as complete technology packages are often individual components of an animal management system. These components, for example growing legumes for a high quality feed supply, are not complete technology packages nor have they been tested on-farm to determine their technical feasibility and economic profitability for the identified group of farmers within a specific farming system.

If these incomplete technology packages are offered to the extension personnel for dissemination as the latest research recommendations, then the credibility of both the researchers and the extension officers will be questioned by the target farmers. This is a major reason why farmer-extension-researcher collaboration is crucial for technology development directed toward improvements in productivity of small ruminants in Indonesia and other developing countries.

CONCLUSIONS

The final test of an effective research and extension system is whether it yields effective production technologies. Research and extension agencies should be organized to serve the farmer. In order to accomplish this goal, all three groups need to work together on an equal basis. Unless this objective is reached, agricultural production cannot increase. Small ruminant farmers, extension agents and researchers need to support each other's efforts.

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THE FUTURE ...

There are solutions to many problems which decrease the productivity and profitability of goats and sheep in the humid tropics. Some are expensive or require unsuitable high technology. Others are either not costly or could contribute greatly to the profitability of small ruminant production. The editors have discussed those below in order of appearance in this book rather than in order of importance.

1. Subdivision of the shed or *kandang* with cheap local materials (e.g. bamboo) is important. Thus, male(s); females during the perinatal period; weaners; females in the last month of pregnancy and during lactation and other females can be separated to enable controlled feeding and breeding.
2. Breeding plans for small flocks both for selection within local breeds and for crossbreeding are necessary and have been discussed in Chapter IV. It should be reiterated that useful genes can be lost by indiscriminate crossbreeding. Candidates for crossbreeding should be wisely chosen from similar environments and latitudes. Note, that most breeding plans are for large flocks and need modification for the smallholder situations. The three authors of this Chapter have made useful contributions in the areas of breeding for smallholder farming systems.
3. More information is needed on nutritional requirements of small ruminants in the humid tropics during pregnancy and during lactation. Most of the existing figures are on growing animals or

from temperate zones with temperate breeds. There is need for more work on goats. There are twice as many goats as sheep in Indonesia, yet much more work has been carried out on sheep.

4. The provision of a set of simple platform scales for each village and the development of tapes to measure condition and weight should be encouraged to evaluate various nutritional regimes. Maybe extension and research workers could develop such tapes and introduce them, plus simple scales initially in a few villages, in pilot schemes.
5. Use of more agricultural and agro-industrial products for strategic supplementation should be investigated in pilot trials, taking into account costs and profitability.
6. *Interpartum* intervals are at least a year, often two years in villages. Yet, research has shown that intervals between births are about 200 days even when nutrition of the does and ewes is at maintenance or below it, when males and females meet at oestrus. The problem lies in the male not meeting oestrous females, due to farmer ignorance of reproduction, lack of time or unavailability of a buck or ram. We suggest, for the cut-and-carry systems, that a couple of males be kept by a group of smallholder farmers with several farmers being trained to detect oestrus by leading the male each day to each group of females. After a short period of training this checking of oestrus will take only a few minutes per group of does or ewes each day.

   If there is a period of grazing, then the male or males can be run with the females during that time. It is interesting that when the males and females are grazed together during the day and kept in one yard at night, the *interpartum* intervals drop to about 200 days.
7. Perinatal mortalities are often high especially with twins or triplets. If twins (or bigger litters) are to be produced and to survive and grow, their dams need better nutrition during late pregnancy and lactation. This is unfortunately expensive and the economics of meeting these feed requirements need to be investigated.

   On the other hand, the subdivision of the *kandang*; enabling the parturient female to be separated with her newborn and to form quickly a strong maternal-offspring bond, is cheap and easy with local bamboo materials and could save many neonates. Also,

farmers could be trained to help a weak neonate to get that crucial first drink of *colostrum.*

8. *Kandang* design and hygiene within and around it can reduce markedly parasite burdens. This has been dealt with in the excellent Chapter VIII. Possibly, subsidy on strategic drenching with anthelmintics, would have great pay-offs. For example, drenching twice with Ivomec plus *kandang* hygiene, would get rid of the important internal and external parasites like *Haemonchus* and scabies.
9. As the survival of larvae on pastures in the humid tropics (including those under tree plantations) is short (ten to twelve weeks), it should be possible to adjust grazing practices to bring about reductions in roundworn transmission.
10. Since farmers already use cheap traditional remedies, studies of the efficacy of traditional medicines could be useful.
11. Improvement of productivity and profitability of small ruminant flocks, lends itself to a farming systems approach taking into account the fact that smallholders have little capital and cannot afford high risk options.
12. Communications need to be improved among farmers, extension personnel and researchers - to identify problems of importance and to find affordable solutions.

    Using extension workers from that part of the country is important as many middle-aged and older farmers speak fluently only the local language.
13. There is need for better communication with women farmers - more women extension officers are needed and women farmers need to be consulted in allocation of resources. Otherwise, an important part of human resources is neglected to the detriment of productivity, profitability and welfare of farming families.

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