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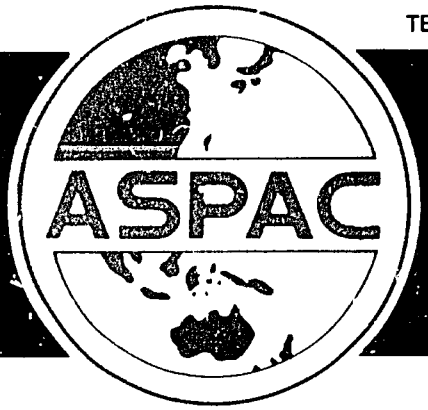

FOOD & FERTILIZER TECHNOLOGY CENTER

SMALL FARM ANIMAL PRODUCTION AND SUSTAINABLE AGRICULTURE

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FOREWORD

This Bulletin discusses livestock production on small farms in less developed countries (LDCs). Although the world's population is becoming increasingly urbanized, the absolute number of people in rural areas of LDCs is still increasing as populations rise. The Bulletin discusses the role of livestock in the small farm economy, and points out that this may not primarily be the production of food. There are other important reasons why farmers keep livestock: as an insurance against a poor crop, for example, or for draft or to meet traditional obligations, or to give status. Small farm animal production is characteristically a low-risk activity which involves a great deal of family labor, including that of children, women and old people.

The various types of small farm economy are reviewed, and the need for sustainable agriculture in the face of population growth and a limited land area. The author points out that in spite of the tremendous volume of information from animal science, the productivity of livestock raised on small farms remains low. He suggests that this is largely because animal scientists are not aware of the needs and concerns of small-scale farmers. Even where they are aware of the gap between their world and that of the farmer, they lack any means of bridging it. The Farming Systems Research Approach is recommended. The author also suggests that farmers should be offered a range of technologies from which they can choose, rather than a "package of technologies" recommended from above. Research priorities are outlined, particularly those supported by international funding.

Dr. Chantalakhana is the author of eight FFTC Extension Bulletins, and has wide experience of animal production on small-scale farms. He first presented the paper on which this Bulletin is based at the 5th Animal Science Congress of the Asian-Australian Association of Animal Production Societies. FFTC was one of the co-sponsors of this major international meeting, which was held in Taipei, ROC on Taiwan, on May 27-June 1, 1990.

SMALL FARM ANIMAL PRODUCTION AND SUSTAINABLE AGRICULTURE

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(Chinese Abstract) 摘　　要

不論都市化比例快速增加，在西元二千年前，農村人口預期可增加至三十億。大多數的農村人民仍將直接地或間接地以小農制爲骨幹的傳統式農業賴以生存。在開發中國家，小農場動物生產在農業生產中佔有相當重要的地位。作物、牲畜、魚類飼養，林木等通常形成關係密切的農場制度。小農場動物不僅生產食物，賺取收入而且具有社會文化的價值，這些角色通常被科學家及政府決策人員所疏忽。在小農場進行動物生產也能以不同方式維持農業生產，但是如何增加小農場動物生產的潛能常被疏忽。在過去往往對農民及農場制度的不了解；科學家疏忽對小農場動物生產改進。爲了生產足夠牲畜以應付衆多的人口，及在考慮維持環境品質及自然資源之時，每人應該在開發中國家致力於改善小農場動物生產實爲急迫及需要。

(Japanese Abstract) 摘　　要

都市化が世界的に進行しているにもかかわらず、農村人口は西暦2000年には30億に達すると予想されている。その大部分は生計を伝統的小農型農業に直接あるいは間接的に依存している。開発途上国の農業形態は、穀物栽培、家畜飼育、漁業、林業が一体化しており、家畜の飼育は小農経営にとって重要な要素である。それはたんに食糧や現金収入をもたらすということに留まらず、社会文化的価値をも持っている。後者の重要性についてこれまで学者や政治家は十分な注意を払ってこなかった。またこれは持続的な農業システムを支える上でも重要である。従来までは農民とその農業形態について理解が欠けていたために、小農型家畜生産の生産性向上については殆ど注意が払われてこなかった。環境と自然資源を保護しながら増加する世界の人口を養うだけの食糧を生産するためには、開発途上国での小農型家畜生産の生産性向上を図ることが緊急に必要である。

(Korean Abstract) 초　　록

전세계적으로 도시화가 증대되고 있음에도 불구하고 2000년까지 농업인구는 3,000백만명으로 증가할 것으로 예측되고 있다. 이들 인구의 대부분은 전통적인 농업을 근간으로 하는 소규모 영농체계하에 그들의 생존과 생활을 농업에 직간접으로 의존하게 될 것이다. 작물, 축산, 어류 및 산림을 종합한 복합영농 체계로 이루어진 개발도상국가에서 소농의 축산물 생산은 농업의 중요한 부분이 된다. 소규모 농가의 축산물 생산은 식량과 소득원으로서 중요할 뿐 아니라, 과학자들이나 정책입안자들에 의해서 종종 간과되고 있으나 또 다른 사회적이나 문화적인 가치까지도 지니고 있다. 소농의 축산물 생산은 개발도상국에서는 농업생산체계 유지에 있어서 여러가지 각도에서 기여하기도 한다. 그러나 소농의 축산물 생산증가에 대한 잠재성이 무시되어 오고 있으나, 아직도 그의 충분한 개발 필요성은 요구되고 있다. 지난날 과학은 소농의 축산물 생산의 개량목표를 상실하거나 소홀해 왔던 것이다. 이는 농민들 스스로나 그들의 영농체계에 대한 이해의 결여 때문이었다. 매년 증가하고 있는 세계인구에게 충분한 식량을 공급하는 한편 천연자원뿐 아니라 환경의 본질을 유지하기 위해서도 개발도상국에서 소농의 축산물 생산 개량에 대해 더욱 집중적인 노력이 시급하게 경주되어야 할 것이다.

SMALL FARM ANIMAL PRODUCTION AND SUSTAINABLE AGRICULTURE

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ABSTRACT

In spite of increasing global rates of urbanization, the rural population is expected to increase to 3,000 million by the year 2,000. Most of these people will depend directly or indirectly on agriculture for their subsistence and survival, with small farm systems forming the backbone of traditional agriculture. Small farm animal production is an important component of rural agriculture in developing countries, where crops, livestock, as well as fish and forestry usually form integrated farming systems. Small farm animal production produces not only food and income, but also has other social and cultural values which are often overlooked by scientists and policy makers. Animal production on small farms also contributes in many ways to the sustainability of agricultural production systems in developing countries. However, the potential for increasing small farm animal production has been ignored, and still needs to be fully exploited. In the past, science has either neglected or missed the target concerning the improvement of small farm animal production, due to a lack of understanding of both farmers and their farming systems. In order to produce enough to feed the annual increases in world population, while maintaining the quality of the environment as well as natural resources, more concerted efforts are urgently needed to improve small farm animal production in developing countries.

INTRODUCTION

During the past 30 years, animal production on small farms has been a very popular topic for discussion in international meetings and seminars, but relatively little effective research has been done to improve it. Research results concerning various aspects of small farm animal production, which have been published in different publications, have not had much impact at a farm or village level. While small farm agriculture continues to provide support for the subsistence of rural people, small farm animal production has remained an integral part of the agricultural system. In spite of the development of commercial production in certain livestock sectors, such as commercial broiler production in some developing countries, the small farm production of most animal species in developing countries continues in its traditional forms. It is obvious that existing science and technology have not been able to transform most small farm animal production into modern systems under the prevailing socio-economic and administrative conditions in developing countries.

The figures in Table 1 indicate that in 1985, more than 2,500 million people lived in rural areas of the less developed countries (LDC's). The majority of these people depended on agriculture – namely crops, animals, fisheries, and forestry – for their livelihood. Despite the fact that the world's population is becoming more and more urbanized as time passes, the actual number of people in rural areas of the LDC's is still increasing. By the year 2,000, it is expected that approximately 3,000 million people, especially the rural poor, will be living in rural areas and will be depending directly or indirectly on agriculture for their survival.

Due to limited land area and growing populations, most rural farms are relatively small in size. More than 90% of all tropical farms are less than 5 ha in size (Harwood 1979). National averages for farm size in Asia are often less than 3 ha. Small farmers generally practice mixed farming, with crops

Table 1. World population

Population	Year			
	1950	1985	2000	2025
World population (billions)	2.5	4.8	6.1	8.2
Rural population (%)	71	59	53	
Less developed countries	83	69	61	
Rural population (billions)				
Less developed countries	1.39	2.53	2.93	3.28
As % of world population	55.6	52.7	48.0	(40?)

Source: Adapted from World Commission on Environment and Development. 1987. pp. 100-101

as a major component and livestock to provide draught power and manure, as well as food and cash income. Subsistence farmers usually produce several varieties of crops, both annual and tree crops, and a number of different animal species (see Appendix, Tables 1, 2 and 3, from McDowell and Hildebrand 1980). Fish in natural waters and products from trees in forests also form part of their subsistence diet.

Rural farmers are characterized by a lack of formal education, and are greatly influenced by traditional cultural beliefs. They lack cash inputs in farming: commercial inputs are often not appropriate and not economically profitable under existing local conditions. A shortage of water and poor soil are common problems on rural farms. Food production is always the top priority for these farmers. The rural poor have to worry about what to eat and what to feed their family today, rather than what to eat or where to live the good life tomorrow.

Prevailing systems of agriculture on small farms in different continents have been well summarized by McDowell and Hildebrand (1980) as shown in the Appendix (Tables 1, 2 and 3). It is clear that animals are always included in all farming systems listed. Cattle, buffalo, small ruminants, swine and poultry, as well as horses, mules, donkeys and fish, were the most common animals found in small farm systems. Small farm animal production is generally well integrated with crop production. Crop residues and by-products are a major source of animal feed, while animals provide draught power and manure for cropping. The purposes of raising animals on small farms are multiple, but they are not primarily raised only for foods such as meat, milk or eggs (Chantalakhana 1988; Devendra 1983). Traditionally, some important purposes of keeping animals on small farm, from the farmers' points of view, are as follows:

- For draft, manure, fuel and other services,
- As an accumulation of capital or heritance,
- Reduction of risks from cropping,
- To generate income,
- To provide food,
- To meet cultural and traditional needs, and
- To give status or prestige.

On small farms, animals utilize non-marketable farm by-products and wastes as well as grasses grown on marginal lands. Small farm animal production is generally subject to a low degree of risk. It offers job opportunities as well as an improved economic role for certain members of the family, particularly children, women and the aged. In many countries, animal production, especially cattle and buffalo raising, appears to prevent, to some degree, the migration of rural people to big cities.

With continuing world population growth, in spite of greater rates of urbanization in all continents, an increasing number of people will depend on subsistence farming for their survival in rural areas. While small farms in many countries will get smaller, the growing population will cause land now under forest or perennial crops to come into use for the production of annual food crops. Sustainable ag-

ricultural production and environmental preservation have thus become major global concerns, both in developed and the less developed countries. Ways of increasing agricultural productivity to meet the demands of an increasing human population, while conserving natural resources and enhancing the quality of the environment, have recently received international attention and support.

In order to increase agricultural production on small farms, animal production offers great potential as a means to produce more food and energy, as well as income, to improve the well-being of people in rural areas of LDC's. In addition, small farm animal production, if appropriately managed, can contribute significantly, both directly and indirectly, to sustainable agriculture systems.

The objectives of this paper are

- To outline the roles of small farm animal production on rural farms in LDC's, especially with respect to sustainable agricultural production,
- To discuss the potential for improvement of small farm animal production, and
- To elaborate some of the reasons why science and technology have not been effective in improving small farm animal production in the past.

SMALL FARM ANIMAL PRODUCTION SYSTEMS

Small farm animal production systems are, with few exceptions, traditionally a part of crop production systems, although geographical variation and climatic factors, as well as socio-economic and cultural conditions, significantly contribute to the existence of different farming systems. Harwood (1979) identified four stages of small farm development:

Stage I: Primitive hunting-gathering,
Stage II: Subsistence-level crop and animal husbandry,
Stage III: Early consumer, and
Stage IV: Primary mechanization.

Hunting-gathering is the most primitive stage, at which food production is based on the harvesting of natural resources. This type of subsistence economy is still found in certain parts of different continents, although hunting-gathering as a sole means of livelihood is becoming less common. Partial hunting-gathering systems are still found in many countries in the world, especially among hill tribes or people in highland regions. Subsistence farming is still common today in the LDC's, especially in rural areas under rainfed conditions. At this stage, more than 90% of farm production is consumed directly on the farm. These systems are very common in Asia.

In the early consumer stage of development, the farmer markets between 10 and 30% of his production (Harwood 1979) for cash income. Earning cash income enables farmers to invest in production inputs to increase farm production, as long as market incentives outweigh the risks. The next stage of small farm development is signified by the use of some mechanization, first for transportation and then for primary tillage. The use of two-wheel tractors in irrigated areas in Southeast Asian countries is a good example. However in rainfed regions, when some farmers tried to shift from draught cattle and buffalo to the use of small tractors, mechanization was found to be uneconomical due to the high cost of gasoline and the variable rainwater supply.

Animal production systems on small farms are more or less related to these stages of development. According to Camoens (1985), livestock production systems in Asia can be classified into ten categories. These are livestock production in: (1) swidden agriculture, (2) shifting cultivation, (3) nomadic herding, (4) transhumant agriculture, (5) rainfed agriculture, (6) irrigated agriculture, (7) plantation agriculture, (8) contract farming, (9) commercial production, and (10) non-traditional livestock enterprises (see Appendix, Table 4).

The first four systems of livestock production are related to the early stages of small farm development, while the next three systems are in the next stages of development i.e. subsistence and early consumer stages. Some small-scale contract farming can also be classified as at a more advanced stage of development than subsistence livestock production. The last two systems in the list above are not small farm systems, but are regarded as commercial or large-scale animal production.

In general, the first eight systems of animal production in Asia cover most of the prevalent small farm animal production

systems in other continents as well. Most of the ranch-type beef production in Latin American countries cannot be classified as small farm production, since the ranches are relatively large.

It is proposed here that the small farm animal production systems as classified by Camoens (1985) may be further grouped into three categories according to their stages of development as follows:

Group I: More Primitive Stage, i.e.
1) Livestock in shifting agriculture,
2) Nomadic livestock production, and
3) Livestock in transhumant agriculture.

Group II: Livestock in Integrated Farming, i.e.
4) Livestock in rainfed agriculture,
5) Livestock in irrigated agriculture, and
6) Livestock in plantation agriculture.

Group III: Livestock in Monoculture, i.e.
7) Contract farming of livestock,
8) Small-scale specialized livestock production.

The first group of small-scale animal production systems represents those still at a primitive age. **Shifting Agriculture** harvests some natural resources, but farmers cultivate most of the staples required for subsistence. The objective of the system is some cultivation supplemented by hunting, fishing, and gathering. Animal rearing is an important part of this system, usually of small ruminants, pigs, or poultry. Feeding, partial confinement, and protection against predators are provided for animals, according to local conditions. **Nomadic Livestock Production** is primarily livestock raising. Rangelands are the main source of feed, supplemented by grasses in forests or by-products from farming. The management of stock mainly consists of herding them from place to place, from one feed source and water point to another. **Transhumant Agriculture** is a mixture of nomadic livestock production and crop cultivation. Such a system develops around permanent sources of water. Animals are herded to rangelands and may remain there for the period of feed availability. Transhumant farmers use large ruminants for meat and milk as well as for farm power. Here, the beginnings of crop livestock integration can be observed.

The second group of small farm animal production systems is characterized clearly by some degree of integration of crops and livestock, as well as often fishery and forestry, in the production system. **Rainfed Agriculture** is very common in most LDC's, especially in Asia. Rainfed agricultural systems are sedentary in nature, situated in areas of seasonal rainfall (more than 1,000 mm per year). Crop production is in general the major source of income, while livestock provides draft power, manure and food as well as additional cash income. Many animal management systems are employed, including the grazing of animals in crop fields after harvest or before planting, tethering of animals during the cropping season, confinement of animals in pens or backyard production. Livestock feeding largely depends on locally available resources, such as grasses and straw, as well as other farm by-products. Health care and other external inputs for animal production are generally minimal. The sale of animals is generally on a small scale: less than 10% of the total stock for large ruminants, while the proportion of poultry and pigs marketed depends on market conditions and prices. **Irrigated Agriculture** is characterized by the availability of water outside the rainy season, which enables farmers to grow crops in more than one season. Farmers in irrigated areas commonly use two-wheeled tractors instead of animal draft power for land preparation. In other words, these small farm production systems have reached the Stage of Primary Mechanization described by Harwood (1979). Animals such as poultry and pigs (and fish in some areas) are integrated with crop production. Some cash inputs such as feed are provided. Animal production in these systems is more market oriented than that found in rainfed agriculture. The use of external inputs depend mainly on the market prices for livestock. **Plantation Agriculture** focuses on the production of any kind of industrial crop, such as rubber, oil palm, coconut and fruit trees. Livestock production is usually aimed at utilizing feeds, especially grasses or legumes, grown between rows of

trees. Ruminants are common under fully grown plantation crops such as coconut. Poultry or pig production is sometimes found in rubber plantations, to maximize the use of land. Livestock provide a supplementary income to the producer, which is particularly important when the plantation crop has not yet reached its productive stage. By-products from plantation crops, such as coconut meal, oil palm cake and rubber seed, can be used as animal feeds. External inputs such as pig or poultry feed are sometimes used when production is market oriented and livestock prices are good.

The third group is characterized as monoculture production. This does not imply that livestock provide the sole source of income and subsistence for farmers. Animal production under this category is more specialized, in terms of technical inputs and managerial skills, although the scale remains relatively small. **Contract Farming of Livestock** refers to a system where one species of livestock is raised to provide mainly cash income, in addition to other sources of income. These systems remain small-scale operations carried out by the farm household. Land and labor are the assets contributed by farmers, while technical and management inputs are provided by outside sources such as city merchants or commercial livestock companies. Pig or poultry farming under contract is quite common in Southeast Asian countries. **Small-Scale Specialized Livestock Production** is becoming more common in many advanced developing countries, as some farmers find themselves able to earn the greater part of their income from livestock. Dairy farming and small-scale pig or poultry raising as an independent and specialized farm enterprise has become a profitable and dependable career, as consumers become more educated and achieve higher standard of living, especially those living in big cities or urban areas. Specialized livestock production is mostly situated near urban centers or markets. External production inputs, such as feed, veterinary supplies, farm tools and equipment, as well as other husbandry supplies, are provided in order to achieve high productivity. Some specialized livestock farms may later develop into large-scale commercial enterprises if market demand and prices for livestock products become attractive.

It can be summarized that most small-scale farmers depend mainly on crop production, while animal production is commonly integrated with crop farming to provide farm power, manure, food and income, as well as reflecting other social and cultural values. There are many small farm animal production systems in the developing world. Most of these systems can be characterized by the use of few or no external inputs, simple and appropriate technology, and locally available resources such as feeds or animal breeding stock. Animal production of this kind is mostly non-market oriented and carries relatively few risks: these are mainly from natural causes such as animal disease outbreaks, rather than economic factors such as a fall in market prices.

SUSTAINABLE AGRICULTURE

The world today is faced with two major problems: population growth, and the limited availability of land. It is estimated that world population will increase by about 80-100 million each year over the next three or four decades (see Table 1). Ninety percent of this increase in population is occurring in the developing world. Agriculture must produce enough to feed these additional people each year. Expanding the area of cultivated land is already difficult in many LDC's: much of Asia, in particular, already has a high ratio of population to arable land. Of the other continents, only central Africa, and temperate and tropical South America, still have large areas that can be brought into more productive use. The question is therefore how the world will sufficiently accommodate and feed its human population without destroying the environment and depleting natural resources.

In recent years, issues of sustainability concerning agricultural production have received world attention. Sustainable agriculture, within the context of the TAC/CGIAR definition, involves the successful management of resources for agriculture to satisfy changing human needs, while maintaining or enhancing the quality of the environment and conserving natural resources (TAC/CGIAR 1989). The determinants of sustainability cover biological, physical, and socio-economic and legal determinants. Biological determinants cover, for instance, preservation of crop varieties and

animal breeds, methods of protection against crop pests and animal diseases and parasites, and improved animal nutrition. The physical determinants include enhancement of the quality of the soil, water, and atmosphere; efficient use, and a long-term supply, of energy, particularly renewable energy sources; and prevention of contamination by hazardous chemicals due to modern inputs in agriculture such as pesticides and fertilizer. The socio-economic and legal determinants involve vigorous agricultural development, economic policies in agriculture, improvement of the infrastructure and markets, availability of inputs and credit, effective agricultural research, extension, and education programs, a favorable land tenure system, and adequate laws and regulations in agriculture. Table 5 in the Appendix gives a broad analysis of sustainability at four levels of complexity, each with its main characteristics and determinants.

SUSTAINABILITY PERSPECTIVES OF SMALL FARM ANIMAL PRODUCTION

Small Farm Animal Production and the Environment

When animals are found grazing on land unsuited for crop production, or on degraded land such as deserts or eroded slopes, one usually relates animals with environmental degradation and deterioration of natural resources. It should not be forgotten that most of the world was once upon a time covered with trees and forest. Man cut down the trees and cleared the land in order to produce food. Crop production came first, and only then did animals follow. It should be recognized that both crops and animals, especially human beings, are all contributing factors to the degradation of lands. Heavy pressure of livestock without appropriate management on grazing land will of course lead to overgrazing. On the other hand, animal production under good management will not degrade the environment and natural resources, but will enhance their quality while generating food and income.

In many developing countries, the use of animal manure to maintain and increase soil fertility is regarded as a national policy. In some countries such as Thailand, where the rice yield in rainfed areas has averaged 1.5-2.0 mt/ha over the last four or five decades without the use of chemical fertilizer, animal manure has been the only major source of fertilizer to which farmers have access and which they can afford. The use of draft animal power also enhances the quality of the environment. It has been estimated that approximately 300 million draft animals are being used each year on small farms for cropping, while 30 million tractors would be needed to supply the same draft power (Ramaswamy 1985). The use of draft animal power saves fossil fuels, and reduces CO_2 emissions into the atmosphere. It is true that ruminants are believed to account for about 15% of total methane emission into the atmosphere, but they also consume forage that absorbs CO_2 from the atmosphere during its growth. Improved husbandry practices and biogas utilization can minimize methane emissions per unit of ruminant product.

As mentioned above, animal production offers an opportunity for the appropriate use of land unsuited for crop production. Forest areas can be saved and become more productive if integrated with animal production. Highly acid soil, saline soil, or arid and semi-arid rangelands, can be used for livestock production.

Small farm animal production helps conserve animal genetic diversity, since most domesticated indigenous animal species in existence today are raised under small farm conditions. There are, for instances, numerous breeds of native cattle, buffalo, native pigs, small ruminants, and poultry as well as camels, donkeys, yaks etc. Commercial livestock production generally use exotic stock or crossbreds, in order to obtain the maximum yield. However, the preservation of biodiversity is an important part of conserving the environment. It is considered to be essential for sustaining and improving agricultural production in the future.

Small Farm Animal Production and Rural People

As mentioned above, animal production is regarded by small-scale farmers as risk aversion in the event of crop failure, and as a savings and inheritance. Animals are part of social, cultural or religious functions in many societies. For example, in many Southeast

Asian societies, pigs are cooked during ceremonies to pay respect to ancestors. Sheep and goats are used as food in religious functions by Muslims; bull fighting and buffalo raising are very popular in some countries. In addition, meat, milk and eggs are an excellent source of protein which is greatly needed by rural people.

It is quite clear that women, children and old people have a role in animal rearing. Small dairies are commonly operated by women, especially housewives, in India and Southeast Asian countries. Children in villages in Southeast Asian countries usually spend their weekends tending and playing with buffalo or cattle. They also feed chickens and pigs in the evening after they return home from school. Psychologically, most old people never feel that they are being left out, because they can take care of family animals as well as grandchildren.

The impact of animal production in terms of preventing migration by rural people to cities has not yet been investigated, but it is well known among scientists that one of the major reasons why people in northeast Thailand do not leave their villages is because they have to take care of their animals, especially large ruminants i.e. cattle and buffalo. Rural migration to cities, especially during the dry season when people in rainfed regions are free from crop activities, has been a social and political problems in some developing countries.

Integration of Animal Production with Crops etc.

Integrated farming systems are characterized by complementary and supplementary relationships between two or more commodities in the system, the combined result of which is higher total returns. Large ruminants provide draft power as well as manure to be used as fertilizer in crop production, while crops provide wastes such as straw and by-products such as bran for animal feed. Fodder trees such as leucaena provide leaves for animal feed and firewood for household use, and preserve soil fertility in the ley-farming system. Wherever water sources are available, ducks, pigs, and chickens can be integrated with fish and vegetable production in order to obtain higher returns than monoculture production can give. Diversification of crops and livestock with appropriate management practices can also reduce crop losses due to pests. Furthermore, diversification of agricultural commodities can also help reduce problems of market fluctuations and economic uncertainty.

In recent years, many farmers, especially in irrigated areas, have increased their use of small two-wheel tractors. This trend raises questions concerning the future demand for draft animal power. However, it has been estimated that to replace 300 million draft animals in developing countries would cost US$200-300 billion, plus $5 billion annually for petroleum fuel (Ramaswamy 1985). In addition it has been shown that the benefits of farm mechanization on crop yield are realized only if other production factors such as fertilizer, insecticides, and particularly irrigation water, are available. At present, under prevailing rainfed conditions and subsistence farming such as that found in Asia, farm mechanization cannot replace draft animal power in crop production. In fact, various indicators have shown that there is a real shortage of draft animals in many developing countries at present, due to rising demand.

Table 2 presents an analysis of sustainability perspectives of small farm animal production, according to the guidelines given by TAC/CGIAR (shown in the Appendix, Table 5).

POTENTIAL FOR IMPROVEMENT

Small-scale animal production has been part of traditional farming systems in the LDC's for a very long time, but its yield levels have been static in most countries, in spite of the fact that great potential remains to be exploited. Devendra (1983) pointed out that the present level of productivity from ruminants and non-ruminants in small farm systems is low. Calving percentages of bovine animals are usually around 40-50%, with a long calving interval of 2 to 3 years, and low milk yields of 300-500 liters per year. Likewise for small ruminants, low kidding or lambing rates of approximately 80 to 100% and high mortalities of about 40 to 60% in young animals up to six months of age, and 20 to 40% in adults, are not uncommon. There is much evidence to indicate that this low level of productivity of animals on small farms can be

Table 2. Analysis of sustainable small farm animal production

Level of analysis	Typical characteristics of sustainability	Typical determinants
Field/production unit	Higher yield from livestock, improved soil fertility; control of animal diseases and parasites, control of pollution from animal wastes	Use of locally available feed resources; vaccination against diseases; disease resistant and heat tolerant breeds; use of marginal lands
Farm	Integrated crop/forestry/livestock farming systems; insurance in case of crop failure; high regard for social and cultural value of livestock; utilization of surplus labor	Farmer training; increased interest in new technologies; use of manure and draught animal power; production of biogas; use of crop by-products; household consumption of animal products
Country	Preservation of indigenous breeds; maintenance of social stability; use of exotic breeds	Disease-free zone; economic role for women, children and old people; use of land not suited for crops; reduced rural migration to cities; expansion of domestic/export livestock markets; increased research and extension activities; breed improvement programs
Region/continent/world	Better nutrition; higher income for farmers, improved soil fertility; reduction in soil erosion and salinity due to cropping	More food, fiber, skins, traction, fertilizer, fuel; favorable effect on the environment; use of animal traction reduces CO_2 emissions

significantly improved by various means. For example, indigenous chickens in Thailand produce only 50-60 eggs per year, while the same kind of poultry produce up to 120 eggs per year with improved feeding. It has also been shown in many areas that mortality rates in village chickens can be reduced from more than 80% to less than 30%, by vaccinating chickens against infectious diseases such as Newcastle Disease, cholera, and infectious bronchitis. For dairy production under small farm conditions, cows of the same breed may produce from 5 to 25 kg of milk per day, depending on genotype and feeding methods as well as milking techniques. Some cows require 3 to 8 breeding services by artificial insemination to conceive, while others need only 1 or 2 services per conception. In beef production, it has been shown that indigenous genotypes which gain only 300 to 400 grams of body weight per day can be upgraded to cattle which gain more than 1,000 grams (1 kg) per day on the same nutritional regime, by crossing them with exotic breeds. The beef quality of the crossbreds is very satisfactory, and the meat can be sold to expensive restaurants for a price which is 200-300% higher than usual. All this evidence points to the fact that there is great potential in small farm animal production still to be tapped, but science and technology must play an appropriate role.

Considering all the knowledge about animal science and technology which exists in the world today, we may wonder why the productivity of animals on small farms remains at such a low level. Large numbers of scientists from developing countries have been trained in world-famous institutions, and many research institutes have been established, both national and international. However, small farm animal production has remained largely untouched, and continues to play its role in traditional farming systems with the same level of productivity that it had a century ago.

SCIENCE WITH NO EYES AND NO EARS

In order to improve small farm production, the first thing a scientist must do is to learn to understand farmers, their existing farming systems, their resources and limitations. This prerequisite has long been accepted in principle among scientific communities dealing with small farm problems, but not much success has been realized until now. The majority of scientists in the LDC's still have "no eyes to see" small farm animal production, and "no ears to listen" to the small-scale farmer's problems.

Today, it is widely recognized that a lack of understanding of small farm systems among scientists is still prevalent, for the following reasons.

- Most animal scientists have been trained in conventional commercial production.
- Most of them have no chance of, as well as no interest in, being exposed to small farm production and problems.
- They usually quick to become involved in large-scale commercial production.
- National planners and policy makers do not understand rural social and cultural values, as well as the economic importance of small farm production at a micro level.
- Most international experts and aid agencies, though recognizing small farm problems, do not have real in-depth, long-term experience with small-scale farmers in specific localities.

These are only some of the reasons why most of the animal science technology available today cannot be adopted by small-scale farmers. Advanced production methods are either economically not viable, or technically not feasible, or socially and culturally not acceptable. Table 3 shows a case study of the extent of adoption of different animal science technology by small-scale farmers in Thailand. The most common

Table 3. Use of some well-known animal production technology by small-scale farmers in Thailand

Animal production technology	Practiced by small-scale farmers raising bovine animals			
	0-1%	1-10%	11-50%	>50%
Nutrition				
• Straw chemical treatment	x			
• Mineral blocks	x			
• Pasture	x			
• Fodder/forage			x	
• Concentrated supplements	x			
Breeding				
• Crossbreeding			x	
• Selection			x	
• Maintain breeding bulls	x			
Physiology and A.I.				
• Estrous synchronization	x			
• Estrous detection techniques	x			
• Pregnancy test	x			
• Artificial insemination (A.I.)		x		
• Embryo transfer	x			
Management				
• Castration (traditional)				x
• Dehorning	x			
• Hoof trimming	x			
• Burdizzo	x			
• Branding	x			
• Record keeping	x			
• Calf weaning	x			
Health cares				
• Vaccination			x	
• Deworming	x			
• Dipping or spraying	x			

rates of adoption by the small-scale farmers who raise bovine animals in Thailand were 0 to 1%, although crossbreeding and selection of draft animals were in the range of 11 to 50%, as was the use of fodder and forage crops and vaccination against certain infectious diseases. Castration, mostly by traditional methods, of animals used for draft was widely practiced. Artificial insemination has become a general breeding method in dairy production, but has only been adopted to a limited extent for beef cattle (1%) and buffalo. Embryo transfer has been a favorite research subject, mainly due to the availability of external funding, but only a few dairy calves have been produced in this way during the last five years, since the cost and the technical requirements are both too high in relation to any possible benefit.

> Colin McClung has accurately noted: "...Science has much to contribute to these farming systems. But to do so, researchers must be unusually adept at seeing the world from the farmer's vantage point." (Foreword in Harwood 1979)

Today, serious problems arise from the fact that most researchers have not yet developed "eyes" to be able to recognize, and "ears" to be able to listen to and understand, the situation as it appears from the farmer's point of view.

Certainly, many animal scientists have realized the gap between themselves and farmers, but there is a lack of acceptable systematic processes and linkages which scientists can use to bridge this gap. In other words, animal scientists need good, systematic and relatively quick methods of learning about existing farming systems and the farmers who used them. Up till the present time, there has not been any quick and easy way for scientists to learn to understand farmers and their practices. The only general recommendation for scientists is that they should go to villages and learn from farmers. This recommendation is logical, but very few scientists have followed it, because they find that farmers and their villages are too far away, and that visiting them for long periods is too inconvenient. Besides, it is very difficult and time-consuming for any one scientist to learn to really understand farmers and their farming systems, as well as all the bio-physical and socio-economic factors affecting them. The real limitation is a lack of any means by which animal scientists might learn to understand and appreciate the farmer's conditions and constraints relatively quickly. One cannot expect a scientist who has a Ph.D. in animal nutrition to spend two or three years in a rural village to learn about small-scale farmers, but on the other hand there must be some suitable way in which an animal nutritionist can learn about farmers' problems, and plan his research so that it produces solutions which are directly relevant and useful to farmers.

One approach which is generally known to offer scientists a good understanding of farmers' perspectives in planning and conducting research is the **Farming Systems Research (FSR) Approach**. The aims of FSR are to generate appropriate technology for small-scale farmers, and where possible, to improve policies and support services for farm production, in order to improve farm family welfare, and to enhance society's goals (Patanothai 1985). This approach views each farm in a holistic manner, and considers the farm as a total system, taking into account the physical biological, and socio-economic factors affecting the farm, and recognizing the interactions between these factors.

FARMER SCIENCE

In general, small-scale farmers in developing countries possess many important features in common, such as limited resources, a lack of cash, subsistence production, limited formal education, etc. On the other hand, they are very diverse in many ways, in terms of e.g. culture, traditions, beliefs, farming practices, soils, rainfall, marketing conditions, etc. Therefore, it is often found that a certain technology is successful in one location, but may not be accepted by farmers in another location or even by different farmers in the same location. It is also often found that a certain technology which was not adopted by farmers over a period of time then became widely used, due to changes in economic or other conditions.

Patanothai (1985) observed that a farmer will adopt a certain technology only when it fits his natural and socio-economic environments, and that these vary from

location to location and from family to family. Analyses of various small farm situations have led me to believe that a **package of technologies** is of limited use. Farmers should be provided with several alternatives or technologies to choose from, and scientists should let farmers decide which technology or combination of technologies fit their resources and circumstances. In other words, as proposed by Patanothai (1985), farmers need a "**basket of technologies**" rather than a "package of technologies".

In order to serve farmers in developing countries better, animal scientists must free themselves from the greatest barrier, i.e. adherence to commercial concepts and styles of research. They must broaden their technical horizons, readjust or rebuild systems and concepts in animal science, from conventional monocultural to small farm integrated production perspectives, and reorient the search from animal science to farmer science, if they are to achieve any improvement of animal production on small farms in LDC's.

RESEARCH PRIORITIES FOR INTERNATIONAL SUPPORT

In the past, international support for research into small farm animal production has been relatively limited compared to that given to research into crop production. In 1987, the Technical Advisory Committee (TAC) of the CGIAR (Consultative Group on International Agricultural Research) recommended that resource allocation to research and research related activities in ruminant production should be increased by the CGIAR System, with the allocation for disease control remaining constant (TAC/CGIAR 1987). Most international resources given to animal research and development in the past were allocated to the prevention and control of animal diseases, which in effect has resulted in a distortion of national policies of the LDC's in relation to their animal research and development programs. Hence, most resources allocated to livestock production in developing countries have focussed on disease control, while production has been mostly neglected. Since an impact has already been achieved in animal disease control and prevention, more resources for research and development in the neglected field of animal production must now be allocated. It is also well recognized that certain animal species, such as small ruminants and buffalo, have been greatly neglected by international support in research and development, in spite of their significant contribution to the production of food and income, as well as to the well-being, of people in the LDC's.

Cattle and buffalo are the two most important bovine animals on small farms in developing countries all over the world. The importance of large ruminants cannot be judged only by their economic contribution from meat and milk, since social, culture and other values such as draft power and manure are even more important at a village level. Cattle and buffalo as a component of small farm agriculture systems should receive higher international research priority. In the past, buffalo were often claimed to be Asian animals, but nowadays it is accepted that they are present on all continents of the world. Buffalo production has become very important in Brazil and Egypt, as well as in Eastern European countries such as Bulgaria. Buffalo have been largely neglected by international research in the past.

Small ruminants, especially goats and sheep, are among the most important animals on small farms, but have received little international support for research in the past. Special attention concerning research and development through international support must be given to these species, in order to promote increased food production and incomes for small-scale farmers in rural areas. Smallholder goat and sheep production is very important in Asia and on the other continents. In North Africa, the Near East and sub-Saharan Africa, small ruminants are an important part of the economy. In the near future, it is anticipated that some intensive systems of production such as sheep fattening might be developed in some developing countries, in order to meet the rising consumer demand.

Pigs and poultry are also important economic animals in the LDC's, but past trends have shown that as consumer demand increases, their production becomes intensive. Technology for intensive pig and poultry production is more readily transferable from developed to developing countries than is that

for ruminants. However, some poultry species such as ducks, geese, and indigenous chickens require special international attention to promote collaboration among developed and developing countries, in order to preserve and enhance genetic resources as well as improving productivity.

In order to increase the productivity of small farm animal production in developing countries, strong support for research and development in animal feed resources, nutrition, management, and health must be given high priority. In addition, improving animal genetic resources and reproduction can also increase the level of animal productivity significantly.

Feed resources, such as forage and fodder crops, crop residues and by-products, as well as other non-conventional feeds which are commonly available on small farms, should receive greater research support. Most areas of animal nutrition directly applicable to small farm problems have yet to be studied. Mineral nutrition has been recognized as one of the most critical factors in feeding animals on small farms. Suitable techniques for improving the feed quality of crop residues, through the use of supplements or various treatments, have yet to be found. Improvement of the germplasm of forage to enable it to grow under marginal and rangeland conditions would make a great contribution to small farm animal production systems. It is accepted that proper nutrition and feeding of animals used for draft power on small farm is almost totally unknown at the present time. It is very important to understand the requirements of draft animals, both buffalo and cattle, in order to be able to utilize them more fully and efficiently.

Improving the management of animals on small farms has been shown to have a significant effect on yield levels, but appropriate techniques for small farm use are still lacking. A simple castration tool which small farmers can afford, for example, would reduce many of the losses caused by traditional methods of castration. Suitable measures for effective vaccination that can be implemented under village conditions must be developed, in order to prevent infectious diseases such as Foot-and-Mouth disease (FMD). Today, while FMD vaccines are available, outbreaks of FMD resulting in heavy economic loss are still common in developing countries. Reproductive losses can also be significantly reduced through various improved methods of feeding and management, such as the deworming of ruminants.

STRENGTHENING OF NATIONAL RESEARCH AND INTERNATIONAL COLLABORATION

While international research is a vital part of the total package for the improvement of small farm animal production, it is national efforts in research which must provide the location-specific perspective. An effective 'critical mass' of researchers in national systems must be trained or retrained by research institutions so that their activities are oriented toward small farm development. Both scientists and technicians who are well trained in research procedures and understand small farm systems are greatly needed in developing countries. Research facilities and infrastructure also have to be made available to national systems. International support to develop manpower for research on small farm animal production will in the long run have a significant impact in terms of increased food production and incomes in rural areas of the Third World.

Another way of strengthening national research systems is better information exchange, through the collection and dissemination of research information, technical meetings and seminars, networking of research staff in various countries, and training in specific research methods. Collection and dissemination of research information in animal production relevant to small farms in the LDC's requires committed and continuing support. The International Buffalo Information Center (IBIC), supported by IDRC of Canada and operated by Kasetsart University in Thailand, has been a very valuable source of information on buffalo production to scientists, especially those in developing countries. When the IBIC began to function, it was discovered that much information which was available in developing countries had not been available to any world source of information, for various reasons. Some information was available only in national or local publications, some of them published in national languages. In the case of Thailand alone, 80% of buffalo information was not accessible for international

readers before the formation of IBIC.

Recent developments in the field of biotechnology has aroused much interest in scientific communities in developing countries. Some biotechnologies may be used as tools by scientists to enhance or accelerate the improvement of small farm animal production, as in the fields of vaccine production, nutritional improvement, and genetic conservation and improvement. It is not justifiable economically for developing countries to begin research into biotechnology without clear and specific research priorities for results which will be of immediate use for the well-being of their people. However, it is necessary for scientists in developing countries to be kept well informed of new developments in this field. They should also be trained to use certain aspects of biotechnology in their research. Hence, some kind of international mechanism should be organized to provide this kind of service for the LDC's. There are also many other research tools and methodologies about which scientists dealing with small farm animal production must be informed. The development of Farming Systems Research methodologies by international or regional research centers is useful for research in agriculture with a farming systems perspective at the national level. Scientists in the LDC's need some monitoring mechanism, to provide them with access to modern science and technology.

Another approach to strengthen national research is through collaborative activities. The conservation and improvement of animal genetic resources is a good example whereby the national research could be strengthened through collaboration. Identification and evaluation of indigenous breeds of animals can best be done at a national level. The evaluation of crossbreds and exotic breeds in different environments can be done efficiently by national scientists, their efforts being coordinated by international organizations. There are also other international research activities which can best be carried out through collaborative efforts involving both national and international systems.

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APPENDIX

Table 1. Prevailing systems of agriculture on small farms, main regions of use, major crops and animal species, and feed sources for animals of Asia

Farming system	Major crops	Major animals	Main regions*	Feed sources
1. Coastal fishing and farming complexes, livestock relatively important	Coconuts, cassava, cacao, rice	Swine	P, T	Coconut by-products, rice bran
		Ducks	TW, T, M, P, I	Marine products, rice bran
		Cattle and goats	SL, P, M, I	Pastured with coconuts
2. Low elevation, intensive vegetable and swine, livestock important	Vegetables	Swine	C, TW, HK	Sweet potato residues rice bran, fermented residues from vegetable crops
3. Highland vegetables and mixed cropping (intensive), livestock important	Vegetables, rice, sugarcane, sweet potatoes, Irish potatoes	Buffalo, cattle	P, T	Crop residues, rice bran, cut forage, sugarcane tops
		Sheep, goats	I	
	Vegetables	Swine	P	Crop residues, waste vegetables
	Rice	Cattle, buffalo	Asia	Crop residues
4. Upland crops of semiarid tropics, livestock important	Maize, cassava, sorghum, kenaf, wheat, millet, pulses, oilseeds, peanuts, etc.	Cattle, buffalo goats, sheep, poultry, swine	IN, T	Bran, oilseed cake straw, stovers vines, hulls, hay
5. Humid uplands, livestock important	Rice, maize, cassava, wheat, kenaf, sorghum, beans	Swine, poultry, cattle, buffalo	Asia (>1000 mm rain)	Stover, weed by-products, sugarcane tops
	Sugarcane	Cattle, buffalo	T, P, I	Sugarcane tops, crop residues
6. Lowland rice, intensive livestock	Rice, vegetables, pulses, chick-peas, mung-bean, sugarcane	Cattle, buffalo, swine, ducks, fish	Asia	Crop residues, weeds, by-products, sugarcane, tops
7. Multistory (perennial mixtures) livestock some importance	Coconuts, cassava, bananas, mangoes coffee	Cattle, goats, sheep	P, IN	Cut and carry feeds from croplands
	Pineapple	Cattle	P, I	Crop residue, by-products
8. Tree crops (mixed orchard and rubber), livestock some importance	Orchard, trees, rubber oil palm	Cattle; goats, swine South	P, M, T	Grazing or cut and carry
9. Swidden, livestock important	Maize, rice, beans, peanuts, vegetables	Swine, poultry, goats, sheep	Asia	Animals scavenge
10. Animal-based	Fodder crops	Cattle, buffalo, goats, sheep	I, M, IN	Cut and carry fodder, crop residue

* C: Mainland China; HK: Hong Kong; IN: India; I: Indonesia; M: Malaysia; P: Philippines; SL: Sri Lanka; TW: ROC on Taiwan; T: Thailand

Source: McDowell and Hildebrand 1980

Table 2. Prevailing systems of agriculture on small farms, main regions of use, major crops and animal species, and feed sources for animals of Africa

Farming system	Major crops	Major animals	Main regions*	Feed sources
1. Pastoral herding (Phase I, L = >10[2])* animals very important (symbiotic relationships)	**Vegetables** (compound)[+]	Cattle, goats sheep	Savanna (Southern Guinea)	Natural rangelands, tree forage
	Millet, vegetables	Cattle, goats, sheep	Savanna (Northern Guinea and Sahel)	Natural rangelands, tree forage, crop residues
2. Bush fallow (shifting cultivation, Phase II, L = 5-10), animals not important	**Rice/Yams/Plaintains** maize, cassava vegetables, tree crops, cocoyams, yams	Goats, sheep	Humid tropics	Fallow, crop residues
	Sorghum/Millet maize, sesame soybeans, cassava sugarcane, tree crops, cowpeas, vegetables yams	Cattle, goats, sheep, poultry horses	Transition forest/savanna Southern Guine and Sahel	Fallow, straws, stover, vines, cull roots, sesame cake
3. Rudimentary sedentary agriculture (shifting cultivation, Phase III, L = 2-4) animals important	**Rice/Yams/Plantains** maize, cassava, vegetables, tree crops, cocoyams	Goats, sheep, poultry, swine	Humid tropics	Rice bran, cull roots, straws, crop residues, vines, stover
	Sorghum/Millet maize, sesame, cotton, sugarcane, tree crops, cowpeas, yams, tobacco, groundnuts, vegetables	Cattle, goats, sheep, poultry	Transition forest/ savanna Savanna (Guinea and Sahel)	Stover, vines, sugarcane tops, cull roots, or tubers, tree forage, groundnut cake, brans
4. Compound farming and intensive subsistence agriculture (shifting cultivation, Phase IV, L = <2), animals important	**Rice/Yams/Plaintains** maize, cassava, vegetables, tree crops, cocoyams, yams	Goats, sheep, swine, poultry	Humid tropics	Rice straw, rice bran, vegetable waste, fallow, vines, cull tubers or roots, stover, tree-crop by-products, palm oil cake
	Vegetables sugarcane, tobacco, sesame, maize, tree crops, groundnuts	Goats, sheep, poultry, swine	Transition forest/ savanna	Vines, stover, tree-crop by-products, groundnut cake
	Vegetables/Millet cassava, cowpeas, tobacco, cotton, groundnuts, tree crops[++]	Cattle	Savanna (Guinea and Sahel	Vines, tree-crop by-products, cassava leaves, fallow
5. Highland agriculture, animals important	**Rice/Yams/Plaintains** maize, cassava, vegetables, plantain, cocoyams	Goats, sheep, poultry, swine	Humid tropics	Fallow, leaves, stover, rice by-products cull tubers, cassava leaves, vegetables residues

(Continued)

(Con't from p. 15)

	Sorghum soybeans, cowpeas cassava, maize, millet, groundnut	Cattle, goats, sheep, poultry	Transition forest/ savanna	Stover, vines, groundnut cake
	Millet/Sorghum maize, groundnuts, cowpeas, sesame, tobacco, cotton, vegetables, cassava, yams	Cattle, goats, sheep, poultry, horses, donkeys	Savanna (Guinea and Sahel	Crop residues, some oil cake brans, stover, vines, cull tubers
6. Flood land and valley bottom agriculture, animals of some importance	**Rice/Yams/Plantains** maize vegetable sugarcane, rice yams, cocoyams, millet, groundnuts	Goats, poultry	Humid tropics	Crop residues, vines, grazing
	Rice vegetables, maize millet, groundnuts plantain, sugarcane, cocoyams	Cattle, goats, sheep, poultry, swine, horses donkeys	Transition forest/ savanna	Straw, stover, molasses, brans, groundnut cake
	Yams/Sugarcane maize, cowpeas, cocoyams, ground-nuts, vegetables, plantains, rice, yams	Cattle, goats sheep, poultry, swine, horses, donkeys	Savanna (Guinea and Sahel)	Vines, brans, cull tubers, molasses sugarcane tops
7. Mixed farming (farm size variable; animals important)	**Rice/Yams/Plantains**	2 or more species (widely variable)	Humid tropics	Fallow, straw, brans, vines
	Rice/Vegetables yams, cocoyams	Some cattle	Transition forest/savanna	Fallow, vines, straw
	Sorghum/Millet groundnuts, cotton, tobacco, maize, cowpeas, vegetables	Cattle, goats, sheep, poultry, horses, donkeys, camels	Savanna (Guinea and Sahel)	Stover, vines, fallow
8. Plantation crops, East Africa (small holdings), animals of some importance	Coconuts vegetables, maize, plantains cocoyams, cassava	Cattle, horses, donkeys	Humid tropics Transition forest/savanna	Grazings or cut and carry
9. Plantation crops, (compound farms, etc.), animals of some importance	Cacao vegetables, maize, plantains	Goats, sheep, poultry, swine	Humid tropics	Grazing or cut and carry, stover
	Tree crops sugarcane, plantains	Goats, sheep, poultry, swine	Transition forest/ savanna	Grazings or cut and carry, sugarcane tops
10. Market gardening (animals may or may not be present	**Vegetables**++	Variable	Humid tropics Transition forest/savanna	Natural rangelands, crop residues, browse plants range forbs

* L = C + F/C; L: land-use factor; C: area of cultivation; F: area in fallow
\+ Enclosed areas around household or village
++ Present or absent, depends on area
Source: McDowell and Hildebrand 1980

Table 3. Prevailing systems of agriculture on small farms, main regions of use, major crops and animal species, and feed sources for animals of Latin America

Farming system	Major crops	Major animals	Main regions*	Feed sources
1. Perennial mixtures (large farms; livestock relatively unimportant)	Coconuts, coffee, cacao, plantains, bananas, oil palm sugarcane, rubber	Cattle, swine	All	Natural pastures, by-products, cull material
2. Commercial annual crops (medium to large farms livestock moderately important)	Rice, maize, sorghum, soybeans, small grains	Swine, cattle, poultry	All except CI	Pasture, crop residues, grain
3. Commercial livestock				
a. **Extensive** Large to very large, livestock dominant	None are important	Cattle (beef)	C, V, Br, Bo, G, CA	Natural grasslands,
b. **Intensive** Medium to large, livestock dominant	Improved pasture, some grains	Cattle (dairy), swine, poultry	All	Natural and improved pasture, feed grains, by-products
4. Mixed cropping Small size in settled areas Medium size in frontier areas Subsistence or monetized economy Livestock relatively important	Rice, maize, sorghum, beans, wheat, cacao plantains, coffee, tobacco	Cattle, poultry, goats, sheep, donkeys, horses mules, swine	All	Natural pastures, crop residues, cut feed

* All: all countries; Bo: Bolivia; Br: Brazil; C: Colombia; CA: Central America; CI: Caribbean Islands; E: Ecuador; G: Guyanas; P: Peru; V: Venezuela

Source: McDowell and Hildebrand 1980

Table 4. Analysis of sustainability

Level of analysis	Typical characteristics of sustainability (cumulative)	Typical determinants
Field/production unit	Productive crops and animals: conservation of soil and water, low levels of crop pests and animal diseases	Soil and water management: biological control of pests; use of organic manure, fertilizers, pesticides, crop varieties and animal breeds
Farm	Awareness by farmers; economic and social needs satisfied; viable production systems	Access to knowledge, external inputs and markets
Country	Public awareness; sound development of agro-ecological potential; conservation of resources	Policies for agricultural development; population pressure; agricultural education, research and extension
Region/continent/ world	Quality of the natural environment; human welfare and equity mechanisms; international agricultural research and development	Control of pollution; climatic stability; terms of trade; distribution

Source: TAC/CGIAR 1989