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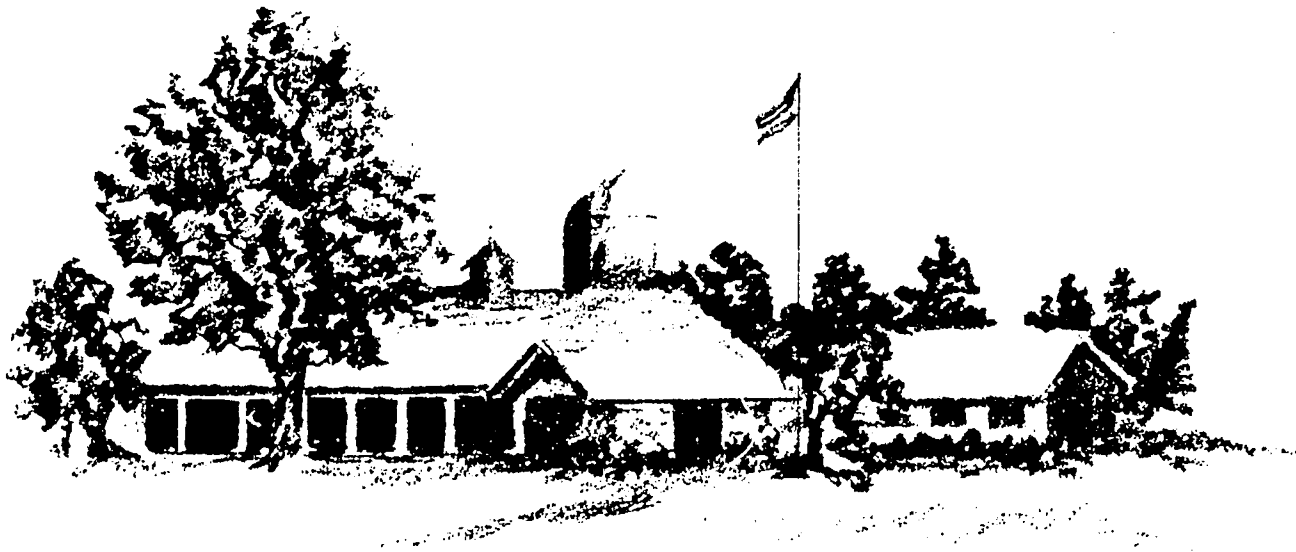

Winrock International
Livestock Research & Training Center

Winrock International's basic mission is to support programs for the advancement of animal agriculture for the benefit of humans.

Winrock has its headquarters on Petit Jean Mountain in Arkansas (about seventy miles west of Little Rock). Extensive livestock facilities surrounding its offices were built by the late Winthrop Rockefeller, Governor of Arkansas from 1967 until 1971. It was Mr. Rockefeller's wish that the experimental operations he had begun would continue. Support was received from the Winthrop Rockefeller charitable trust to enable Winrock International to begin its operations in 1975.

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THE ROLE OF RUMINANTS IN SUPPORT OF MAN

WINROCK INTERNATIONAL LIVESTOCK RESEARCH AND TRAINING CENTER
Petit Jean Mountain, Morrilton, Arkansas U.S.A. 72110

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PREFACE

IN late fall of 1975, three of the authors of this publication — O. J. Scoville, H. J. Hodgson and H. A. Fitzhugh — arrived at the Winrock International headquarters on Petit Jean Mountain, Arkansas to begin working on Winrock's major research effort, "The Role of Ruminants in Support of Man."

Winrock International was itself a new institution just started in September, 1975. Its avowed mission was to improve animal agricultural production systems in meeting the challenge of a hungry world. We began the assignment with enthusiastic aspirations to thoroughly analyze the problems and to effectively communicate findings which we hoped would be of lasting significance.

The broad objectives of this project were first defined in a planning conference held at Winrock in November, 1975. Those attending included: A. S. Rojko, T. C. Byerly, L. N. Hazel, John Lee, R. E. Hodgson, T.C. Cartwright, Glen Beck, W. F. Wedin, Don Stoops, Jan Rendel, R. E. Greep.

There were four broad objectives:

1. To inventory on a regional basis the world population of ruminants, their output and productivity (food, fiber, work, fuel, hides, fertilizer), their feed requirements (grain, oilseeds, pasture crop, harvested forage, crop residues and byproducts); to inventory the world's total feed resources for these ruminants; and to project some of these values to 2000 A.D.

2. To identify the extent of the resources and the constraints to improving level of efficiency of ruminant production, including feed resources, health problems, genetic potentials, capital, market and institutional inefficiencies.

3. To develop priorities for research, training and development programs for ruminant livestock not only for consideration of Winrock International Livestock Center, but also for other institutions engaged in similar endeavor.

4. To provide an information base for use in developing private and public investment policies for ruminant livestock and related agriculture.

We realized that available data bases and documentation were tenuous at best. Therefore, we agreed to rely principally on data bases of the Food and Agricultural Organization (FAO) and the grain-oilseed-livestock (GOL) model of USDA's Economic Research Service, filling in gaps where possible with data from other sources.

Reference years chosen were 1972 and 2000; 1972 FAO statistics were the latest available in complete form, and were compatible with the GOL statistics based on the 1969-71 period. Those statements which we made about production and trade statistics were, of course, tempered by the knowledge of events transpiring from 1972 to the mid and late 1970's; for example, the major reversal in the trend of increasing beef herds.

As the months passed, a need for broadening the scope of "Role of Ruminants" became more apparent. As one result of this, two additional animal scientists joined the ranks of authors: Thanh Nguyen and T. C. Byerly.

In addition, a number of other experienced scientists assisted in the efforts. These included Hudson Glimp, Dennis Child, Mohamed Sarhan and Richard Wheeler of the Winrock International staff — also Howard Ream of the University of Wisconsin who, through service with USAID, had extensive experience in forage-livestock production, particularly in the tropics. Anthony Rojko and Don Regier of the Foreign Demand and Competition Division, ERS, USDA generously supplied commentary as well as data. Don Stoops, livestock advisor, International Bank for Reconstruction and Development (World Bank) made the results of his organization's studies available.

To assist in developing the major project document for "Role of Ruminants," nine viewpoint papers were commissioned from authors noted for their experience and knowledge in specific subject matter areas. These viewpoint papers include the following:

Potential of Temperate Zone Cultivated Forages by R. J. Bula, V. L. Lechtenberg and D. A. Holt

Potential of Humid and Subhumid Rangelands by L. R. Humphrey

Potential of Tropical Zone Cultivated Forages by Loy V. Crowder

Potential of Arid and Semi-Arid Rangelands by Thadis W. Box

Marketing Ruminant Animal Products in Developing Countries by A. Schumacher and D. B. Dorsey

World Human Population Projections in Light of the Potential for Population Control by R. O. Greep

Ruminant Livestock Research and Development by T. C. Byerly

These Are the Animals You May Eat by J. R. Harlan

Ruminant Products: More Than Meat and Milk by R. E. McDowell

In addition, two conferences were held at Winrock International Center: (a) Improving Ruminant Livestock Production on Small Holdings, which was co-sponsored by the Agricultural Development Council, Inc., and (b) The Role of Sheep and Goats in Agricultural Development, which was co-sponsored by the United States Agency for International Development. Information from the viewpoint papers and conferences contributed directly and indirectly as background material and thought stimulators in the evolution of this report.

The authors express much appreciation to those persons who provided the time, attention and skills that helped to bring this project and its documentation to a successful completion. Johnny Thompson of the Winrock International staff coordinated details of printing the final document. Ward W. Konkle, former editor of *Agricultural Science Review*, brought his considerable skills to bear on the problem of coordinating style and format and continuity of thought from section to section. His close working association with our research team helped to contribute unity to the varied components as they were drawn together in the final manuscript.

Charles Bebee of the National Agricultural Library assisted with advice on bibliographic searches. While Imogene Byerly struggled with the beginning of a library for the Center, the library at the University of Arkansas and the National Agricultural Library were always ready to help us.

Many technicians and secretaries spent many hours processing data and typing long tables and pages of text. Special thanks go to Shirlie Glimp, Margaret Sarhan, Mary Marks, Peggy Humphrey and Libby Fowler for their patience and perseverance.

We began our study in the belief that ruminant livestock and the forages and coarse feedstuffs so especially suited to them were being neglected worldwide in research and development efforts. Our inquiry has convinced us that there is neglect, and even prejudice. Moreover, we are impressed and excited by development potentials to be tapped through research, training, investment and changes in policies and institutions. In one sense, we feel that the "Role of Ruminants" project served as a worthy and fruitful vantage ground in the initiation of Winrock International programs. The project really developed into an educational process not only for the authors but also for the Center itself. We trust that there will be an educational carry-over to others as well.

In summary, we hope that our study will stimulate interest, action and further research to the end that within feasible limits, ruminant animals will fully contribute to the support of mankind to the widest extent possible.

SUMMARY AND CONCLUSIONS

FOR nearly 100 centuries, mankind has depended substantially on ruminant livestock not only for food but also for a wide variety of byproducts and services. Ruminants supply almost all the milk and nearly half the meat consumed by people of the world. The estimated value of ruminant products throughout the world amounts to well over US $100,000 million annually, which really is a conservative estimate because it does not include values for work done by cattle and buffalo, the manures they produce as fertilizers, and other byproducts and services. Actually 12 percent of the world population derive their support almost entirely from ruminants because they live in areas where food crops cannot be grown.

The basis of the importance of ruminants to mankind lies in the fact that these animals can obtain their nourishment from grasses and other fibrous forage which people cannot directly utilize. In turn, they provide humans with an adequate supply and proper balance of energy, minerals, vitamins and essential amino acids which human metabolism cannot do without. The nonfood contributions of ruminants — many of which cannot be precisely estimated — are also substantial.

Ruminant Resources

TOTAL population of ruminants making some contribution of food and nonfood uses to man approaches 2800 million head. Cattle and sheep are the most numerous; each includes more than 1000 million head. Other domesticated ruminants include 400 million goats, 125 million buffalo and a combined total of 30 million camel, yak, llama and reindeer. World population of wild ruminants is several hundred million.

About 30 percent of the world human population and 32 percent of the ruminant population live in the developed regions. But ruminants of these same regions produce two-thirds of the world's meat and 80 percent of the world's milk. Chief reason for the difference is the better nutrition provided in developed regions.

Products — Of all the ruminant products utilized by humans, milk and meat rank first, not only in quantity but in value. In 1972, world ruminants produced 47 million metric tons of meat and 408 million metric tons of milk.

A liter of milk a day provides the average person with daily requirements of fat, calcium, phosphorus, riboflavin, one-half the needed protein, one-fourth the energy (calories), one-third the vitamin A and considerable amounts of other vitamins and minerals. The biological value of meat protein is about 80 percent of that of milk.

The relative importance of meat and milk in the human diet varies considerably from region to region. About 10 percent of the protein in the Indian diet comes from milk; in other parts of Asia and much of Africa, few adults consume milk — often because of milk protein allergies or lactose intolerance.

Other products from ruminants include wool, hair, hides and pelts. Although synthetic materials have made some inroads into markets for these products, world wool production has remained relatively stable over the past 15 years. It is important to note that in more than 100 countries, ruminant fibers are used in domestic production and cottage industries for clothing, bedding, housing and carpets.

The annual production of animal wastes from ruminants contains millions of tons of nitrogen, phosphorus and potassium. Of that which is effectively utilized, the value is estimated at $1 billion.

Early history of the developed world abounds with examples of the importance of ruminants as a source of work energy. Today, in the developing world, animals provide as much as 99 percent of the power for agriculture. It is estimated that India alone would have to spend $1 billion annually for gasoline to replace the animal energy used in agriculture.

Species Distribution — The species distribution of domestic ruminant livestock varies widely among the regions of the world. About 40 percent of the cattle and 50 percent of the sheep are in the developed countries, but more than 90 percent of the goats and 99 percent of the buffalo are in the developing countries. These figures reflect differences in climate, food preferences, native customs and animal utility. Goats, for example, are especially important as providers of milk and meat to the millions of subsistence farmers in these countries. Among Asian farmers, buffalo plow their fields as well as feed their families.

Genetic Variation — The tremendous genetic variation among ruminant species is obvious. Compare the stolid bodies of cattle and buffalo to the svelte frames of fleet-footed gazelle. Llamas in the Andes, reindeer in the Arctic, buffalo in Asian rice paddies, goats on the desert, cattle on the grasslands and in the big feedlots . . . all this adaptive variation greatly increases the environmental range over which ruminants can be productive.

Much variation within species, especially in their productive capacities under different environments, is available for molding by animal breeders. For example, genetic capacity for milk production in cattle varies from a few hundred kg to record productions of 20,000 kg. Genetic variation provides the material which has been used in the past to increase genetic capacity for quality and quantity of production, environmental adaptation, resistance to disease. Full genetic potentials for ruminants are yet to be realized.

Nutrient Resources for Ruminant Production

FEED is the first limiting variable in ruminant production. More than 90 percent of the feed available to ruminants of the world consists of roughage — grass, browse, legumes, hay, straw. The remainder of their diet consists of grains, oilseed meals, millings and industrial byproducts; the amount fed varies from one country to another and from year to year, according to availability and price. In the USA where grain surpluses are frequent, grain and concentrates provide about 30 percent of the energy used by cattle, sheep and goats.

Considerable effort was expended in this Winrock study to determine (a) the extent of the nutrient resources presently available to ruminants throughout the world and (b) the potential available for year 2000. Tabular data, which appear in the Appendix section of this publication, show that forages and crop residues will remain high on the list of available nutrient sources. And of these two sources, permanent pasture and meadow will continue to rank first -- at least on a world basis. Despite the fact that total area of permanent pasture and meadow will be only slightly higher in 2000 than it is at present, production of metabolizable energy from that source will be about 16 percent greater than at present. Most of the increase will be due to wider use of applied technology. Since advanced technology has been applied to less than 8 percent of total permanent pasture and meadow, it is clear that a tremendous reservoir of untapped ruminant feed production potential exists.

Overseeding grasslands with legumes, establishment of grass-legume mixtures and use of improved grasses with nitrogen fertilizers on only modest areas of permanent pasture could increase offtake of ruminant products immensely. The amount of grain fed to ruminants will be determined on economic grounds. It is interesting to note that in 1972 less than one percent of the feed energy requirements for India and other developing regions came from grain concentrates. Little change in these feeding patterns is expected by 2000.

The obvious conclusion is that, except for India, there are abundant supplies of noncompetitive feed resources available to support expansion of ruminant populations and production.

Constraints on Production

THE degree of progress that ruminant livestock producers of the world will make in the next two decades will depend to some extent on how ably they meet the constraints that inevitably face animal agriculturists — diseases, parasites and certain nonbiological or socio-economic factors that can impede progress unless they receive serious attention.

Diseases and Parasites — Each year, more than 50 million head of cattle and buffalo and 100 million sheep and goats are killed by diseases and parasites. Production losses in both quality and quantity of meat and milk from ailing and unthrifty animals represent an even greater loss.

The main disease problems of ruminants are in the developing countries, and, although some progress is being made, improvement is slow. Reasons are lack of sufficient financial resources, inadequate administrative backing, insufficient numbers of veterinarians and the fact that some disease pathogens have a way of developing resistance to new control measures. The costs of fighting tick-borne diseases in Africa and South America are staggering. Millions of cattle have to be dipped up to 50 times a year. Such measures merely hold down the incidence; the real problem remains latent. More breakthroughs are needed, such as the successful rinderpest vaccination program in Africa and biological control of screw worms.

The animal health picture in the developed countries is somewhat brighter. In Western Europe, the brucellosis eradication program is moving ahead; in Australia, a vaccination program and good management procedures largely eliminated bovine contagious pleuro-pneumonia. Progress in other areas will require more research, more funds, more knowledge on the location and incidence of disease and public understanding of the measures that need to be taken.

Nonbiological Constraints — Some of the nonbiological constraints that inhibit expansion of ruminant production are associated with land tenure, markets and transportation, credit, human resources and government policies.

The success of ruminant production systems can be visibly affected by attitudes and policies of both local and national governments on land tenure, income transfer, research and extension. Poorly functioning transportation, marketing, processing and preservation of ruminant products can lower productivity, increase costs to consumers and lower returns to producers.

Mores and prejudices against some ruminant products occur in both developed and developing regions. Their basis may be mystical, whimsical or trivial; yet to the people concerned the reasons for certain actions may have well-grounded rationale.

The problem with many of these nonbiological or socio-economic constraints is partly one of benign neglect. Broadened and enlightened viewpoints accepted by all agencies and persons involved would do much to bring about understanding in attitudes and favorable changes in socio-economic environments.

Future Economic Demand

ON a percentage basis, the projected rates of increase in ruminant livestock products are modest. For the world as a whole, compound annual growth rate to the year 2000 for dairy products is 1.9 percent; for beef and veal, 2.2 percent. These increases, however, conceal some rather large increases that will be required in less developed countries. World averages are strongly influenced by the high proportion of livestock numbers in the developed regions where population is growing slowly and demand elasticities are moderate to low. Rates of increase in consumption for developing regions, except China, are considerably above the world averages.

One factor that should be kept in mind because it may alter projected increases is the swift growth of the middle class, whose individual members consume five times as much as members of the poor class. This vast middle class is beginning to exert far more pressure against scarce resources than the growth of the poor population.

Strong consumer demand for livestock products means that production can be pushed vigorously without fear of saturating the domestic market, provided suitable steps are taken to develop an effective market structure.

Meeting the Demand

INCREASED world population and increased consumer buying power will create a demand for 74 percent more milk, 82 percent more beef and 90 percent more sheep and goatmeat in the year 2000 than was consumed in 1970. This increased demand can be met by (a) increasing the numbers of ruminant animals without appreciably increasing per-animal productivity, and (b) increasing the per-animal productivity by improving fertility, health, nutrition and genetic potential. It seems likely that a mix of these strategies will be followed.

Most authorities agree that in order to meet the demands of the future much more emphasis will have to be placed on research, technology application and training of both professionals and producers. This effort should be directed toward minimizing nonrenewable resources (land, water, energy, etc.) and maximizing output of ruminant products.

Along with the recognized need for more research is the realization that governments must do something to maintain the viability of the world's 100 million small farmers, because it is in this group where the majority of the world's domesticated ruminants are found. Although smallholders are generally slow to accept better resource management and technology, it has been proved that unfavorable policies, ignorance and prejudice will change or dissipate when the people concerned are exposed to accurate information as to the true effects of constraints and are given a chance to become involved in working out solutions.

* * * * * * * *

This study by Winrock International has led to some succinct conclusions as to the questions and concerns about the current value and future importance of ruminants in the support of man.

Humans do not want to give up ruminants.

- The majority of the world population has consistently shown a marked preference for ruminant products -- both food and fiber.

- The emotional relationship between man and his most important domesticates have deep social, cultural and religious meanings and values.

Humans need not give up ruminants.

- Noncompetitive feed resources are available and the potential for increases is sufficient to nourish the required ruminant population and allow a high rate of productivity.

Humans should not give up ruminants.

- The many millenia of evolution have made ruminants an integral and critical part of the natural ecosystem which must be preserved if man is to survive.

The Role of Ruminants In Support of Man

H. A. FITZHUGH, H. J. HODGSON, O. J. SCOVILLE
THANH D. NGUYEN and T. C. BYERLY

Ruminants provide humans with food, fiber, work, fuel, fertilizer and recreation.

MANKIND has experienced a long and favorable relationship with ruminant animals (cattle, sheep, goats, water buffalo, camels). The earliest fossil records of man indicate that he was associated with animals for millions of years, presumably as a hunter during much of that period. Domestication of ruminants, however, is of comparatively recent origin. An excavation site in Iraq shows archaeological evidence that both sheep and goats were raised as domesticates as early as 8500 B.C. The earliest domestication date for cattle appears to be about 6500 B.C. in Greece (*1*).[1] Today, most countries of the world depend to a considerable degree upon ruminant livestock not only for food but also for a host of byproducts and services. The role of ruminants in support of man has, over the centuries, grown to become one of great significance. That role is neither generally understood nor fully appreciated.

Ruminants and the World's Food and Energy Problems

BECAUSE they are physiologically adapted to obtain their nourishment from grass and other fibrous forage which man cannot directly utilize, ruminant livestock have always been an important source of food for humans. The reason for this is that they convert these low quality, high fiber foodstuffs to meat and milk which are highly desired by man. Ruminants supply foods rich in high-quality protein, minerals, fats and vitamins. It has been suggested (*2*) that the nature of this food supply, consumed by man for thousands of generations of natural selection, has had a significant impact on modern man's nutritional requirement and status. And because of their ability to subsist wholly on high-fiber rations, ruminants normally have not been regarded as competitors of man for foodstuffs.

[1] Italicized numbers in parentheses refer to References and Notes.

Since World War II, however, a series of events occurred in the developed countries that led producers to substantially increase quantities of feed grains in ruminant livestock rations. This practice resulted from a rapidly accelerating application of production technology and greatly increased grain production. Grain became cheap and economical to feed in large quantities and as a result, meat and milk production increased accordingly. This situation continued to the early 1970's when the combination of rapidly increasing human populations and serious crop failures in the developing world sharply increased the export demand for feed grains produced in countries such as the U.S. and Canada. Public awareness and concern for the world hunger problem have caused many people to question the morality of continued grain feeding to ruminants. Instead, it was argued, these grain supplies should be left available for direct consumption by humans. The reasoning offered for not feeding so much grain to ruminants was that ruminants represent an inefficient system for synthesizing protein to a form suitable for human food. To a certain extent, this argument is valid because nonruminants such as poultry and hogs — also man — are considerably more efficient than ruminants in converting high quality, low fiber foodstuffs (grains, oilseeds and tubers) to food energy and protein.

The issues concerning the merits and the disadvantages of sharing with ruminants certain foods suitable for direct consumption by humans are not as complex and difficult to solve as one might suppose. To begin with, certain hard facts must be recognized and accepted.

In the first place, the amount of potential human food consumed by ruminants on a worldwide basis amounts to no more than 5 to 10 percent of the total annual output. This occurs only when such feeds are available in excess of human demand and hence available for ruminants at relatively low prices.

Data for the United States indicate that grain and byproduct feeds constitute about 30 percent of the nutrients fed to cattle and sheep, about 92 percent of the nutrients fed to pigs and 97 percent of the nutrients fed to poultry. These percentages of grain and concentrates are higher than those fed in most regions; however, the ratio of percent concentrate to roughage in pig and poultry diets (as compared with that of ruminants) is much higher. In the United States, incidentally, about 1 percent of all feed consumed by domestic animals is pet food — about 3 million tons annually. In the world as a whole, grain and byproduct feeds contribute less than 10 percent of the metabolizable energy consumed by ruminants.

In 1974, the amount of grain fed to livestock declined sharply in response to grain scarcity and consequent price increases. These checks caused serious dislocations of livestock industries, especially in North America, Western Europe and Oceania. But despite these checks, total production of ruminant and nonruminant meat and of milk and eggs was greater in 1974 and 1975 than in any previous year.

Actually, about 75 percent of the world's agricultural land produces forage of one kind or another that can be utilized only by ruminants. Cultivated crops are produced on only about 25 percent of the 4500 million hectares of agricultural land. Furthermore, most cultivated crops used as human food are first processed to some degree before coming to the consumer marketplace. This processing results in sizable tonnages of agri-industrial byproducts — grain milling offal, molasses, cannery wastes, oilmeals and many others — which are sold to farmers and fed to ruminants or other livestock, thereby helping to lower the costs of processed human foods. If these byproducts were not used by livestock, they would accumulate and create serious disposal problems. There are at present no indications of any alternative methods of economically converting the immense tonnages of these byproduct feeds to human food except through the livestock-human food chain.

A second fact that must be reckoned with is that about 85 percent of the world's population desires foods of animal origin in their diet (*3*). Their preferences, traditions and buying power guide their choices among kinds of meat and their consumption of milk and milk products. As their incomes increase, they consume even more meat and milk. Nutritionists agree that these ruminant food products contain high quality protein, minerals and vitamins necessary to man's well-being. Because of the worldwide preference for meat and milk and because these foods are so important to human diet, the scope of ruminant agriculture needs to be broadened and its output increased. An approach to accomplishing this goal is by increasing the productivity of the world's grasslands and forage resources and of the ruminant livestock which use them.

A third important fact in assessing the importance of ruminant livestock is that their contributions to man encompass a wide array of products in addition to meat and milk. These include leather, wool and other fibers, pharmaceutical chemicals, fuel, fertilizer, draft power and many more. This subject is fully covered in an earlier Winrock publication (*4*), yet it seems worthy of mention here that the draft power, or work energy supplied by ruminants in developing countries is so extensive that it could hardly be supplanted by fossil fuel energy — at least without staggering costs to the economy of these countries.

And finally, there is the significant economic attitude common among subsistence farmers in developing countries which might well be adopted on a worldwide basis — namely, that ruminant animals really represent a capital reserve which can be drawn upon in times of need or emergency, and then built upon when the emergency passes. Many low-income, subsistence farmers in developing countries who own only one or two cattle or goats have proved that this tenet is valid in times of crop failure. Milk from the animal — or meat from its carcass — can often mean the difference between subsistence and starvation.

Characteristics and Habitats of Ruminants

A ruminant animal is a cloven-footed, cud-chewing mammal which has a multicompartment stomach — a feature that distinguishes it from simple stomached herbivores such as pigs, horses, poultry. It is the largest of these stomach compartments — the rumen — that sets ruminants apart from other animals and makes them the most efficient in converting otherwise unusable plant materials into nutritious food for humans. The rumen is really a large fermentation vat, the contents of which may amount to about seven percent of the weight of the animal itself. Within the rumen are literally billions of microorganisms that break down plant materials into relatively simple compounds that ruminants can utilize. The interior temperature of the rumen is warm and nearly constant; saliva and digestive juices keep the fluids neutral or slightly alkaline and well buffered; conditions are anaerobic or nearly so, and the microbial byproducts are constantly removed by secondary fermentations as the plant material passes through the gut. The microbes, consisting mostly of bacteria, protozoa and yeasts, flourish under these conditions. It is a superbly designed feed processing system.

Feed materials entering the rumen are first attacked by enzymes produced by the rumen microflora. Plant cell walls and fibers are degraded into sugars. Sugars containing six carbon atoms (like glucose) are the most common. These in turn are attacked by more enzymes that convert them into volatile fatty acids, which are the ruminant's principal source of energy.

The rumen flora is remarkably abundant and diverse. The number of microorganisms is on the order of 10 billion bacteria and 1 million protozoa per gram of rumen contents. At least 30 species of protozoa have been identified and the kinds of bacteria can probably be numbered in the thousands. With proper adjustment of flora and adequate mineral and nitrogen balance, the rumen fermentation tank can be marvelously efficient. All kinds of cellulosic wastes can be utilized. In fact, it has been calculated (*5*) that the protein requirements of the world population could be met by ruminants fed five percent of the world's cellulosic wastes.

Protein — or actually a balanced supply of the essential amino acids which make up protein — must be available in the diet of non-ruminants, such as man. Ruminants, however, can utilize non-protein nitrogen sources, such as urea, which the rumen microflora then use to synthesize the protein for their own body building (*6*). Subsequently, these microbes pass through the ruminant's stomach where the digestive juices break down the microbial cells to yield amino acids. These amino acids are absorbed through the gut wall to form the amino acids pool for protein metabolism by the ruminant itself.

Within an hour or so after a mature ruminant animal has eaten its fill of forage, the rumen microorganisms will have partially broken down the plant fibers. At this point in the digestive process, the esophagus of the animal contracts and a bolus, or cud, is propelled up to the mouth cavity at great speed. The animal then begins chewing its cud to further break down the fibers. After it swallows the cud, the whole process may be repeated several times until all the rumen contents are ready to pass along to the next stomach compartment, the reticulum, for further digestion.

Ruminants are noted for their frequent belching but not vomiting. Belching is required to release the copious quantities of gas produced by fermentation. Vomiting, however, would cause a critical loss of rumen microflora and rumen liquors. Failure or inability to vomit, on the other hand, makes ruminants more susceptible to poisoning and disease, such as enterotoxemia and bloat.

The rumen of a newly born ruminant animal is undeveloped. Hence, it is at first dependent on its mother's milk, which requires a radically different digestion arrangement. While the calf is suckling, its esophageal groove bypasses the rumen, thereby allowing its daily diet of high energy milk to be digested efficiently, as in a nonruminant. Close bodily association of the young ruminant with its dam is largely responsible for the introduction of microflora into its rumen, so that within a few weeks it can begin adding forage to its diet.

A ruminant mammal is well named. The Latin root of the word, *ruminare*, carries a number of connotations that fit ruminant characteristics. Thus, *rumination* is a process for extracting maximum value out of a crude resource, whether it is a high cellulose leaf or stem or an embryonic idea. Likewise, *to ruminate* is to rechew or rethink basic materials before products of final digestion or thinking are possible.

The place of ruminants in the animal kingdom is shown in Figure 1-1. Ruminants are widely distributed in all continents except Antarctica and in many islands. Of the six families in the suborder ruminantia, the three that have been domesticated are camelidae, cervidae and bovidae. Three kinds of bovidae — cattle, sheep and goats — are found in all 15 regions of the world (*7*).

Cattle and sheep are the most numerous of the ruminants; each family includes over 1,000 million head. There are nearly 400 million goats and 125 million domesticated buffalo in the world. An additional 30 million domesticated

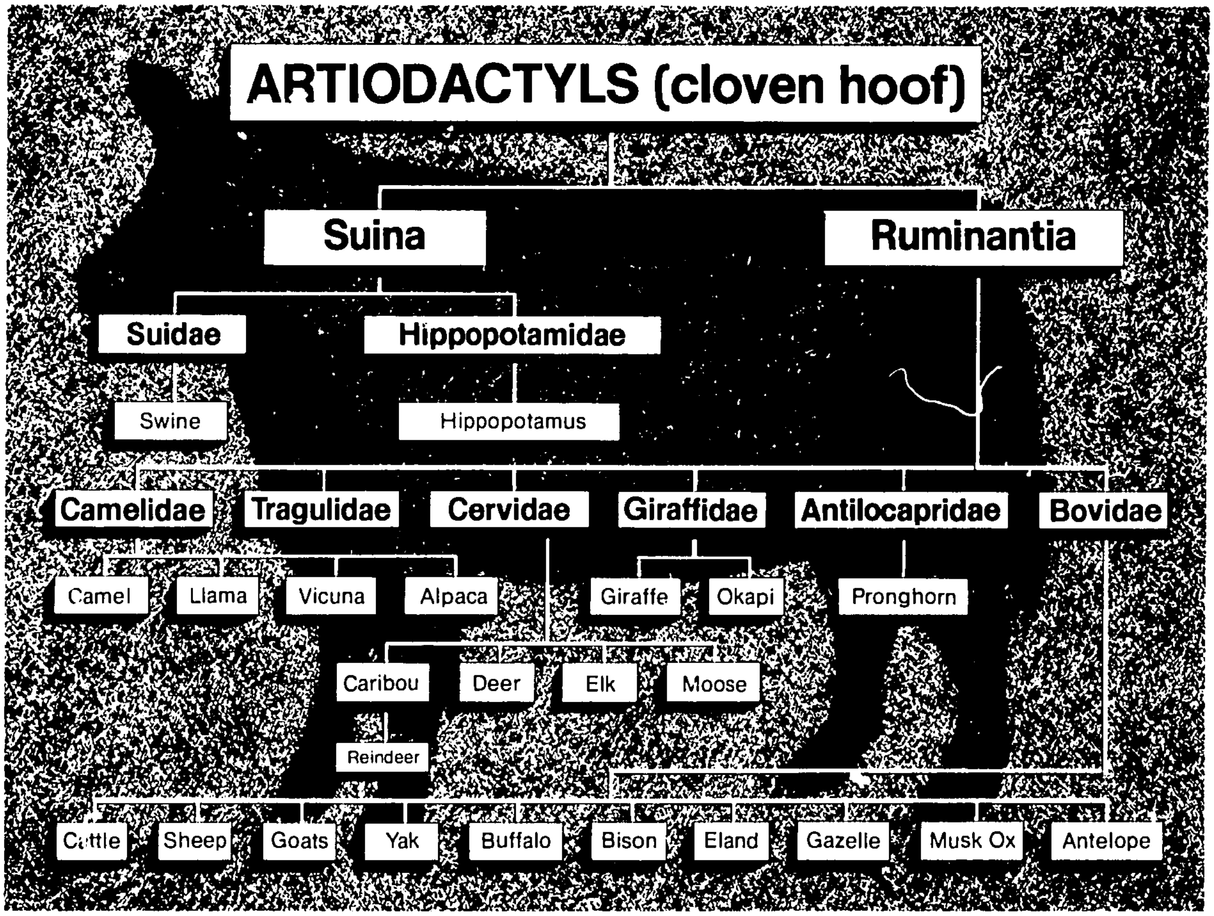

Figure 1-1

ruminants (camel, yak, llama, reindeer) serve man in various ways. An uncounted but substantial number of wild ruminants — at least several hundred million — also contribute to the food, fiber and recreational needs of man. The total population of ruminants making some contribution of food and nonfood uses to man approaches 2800 million head (*4*).

Domestic cattle, sheep and goats have moved from Asia to Europe, Americas, Australia, Africa and many islands. Camels have ranged with man — and carried him with his baggage — from subSaharan Africa to Mongolia. Introduction of camels into the United States more than a hundred years ago failed to establish commercial herds.

Man-Ruminant Relationships

THROUGHOUT the many millenia of man's association with ruminant animals, the relationship has taken many forms. Ruminants have been companions of man; they have been revered, worshipped, ritually sacrificed and considered holy. There is also an ecological involvement more fundamental and far-reaching than most people realize. Furthermore, ruminants play a vital role in the managed ecosystems of agriculture and convert resources that otherwise could not be used into nourishing food products. To a certain extent, the man-ruminant relationship is a symbiotic one, because the vast numbers that have been domesticated depend upon man for their very existence, having long since lost their ability to thrive in the wild without man's husbandry.

In some cases, man's dependence upon ruminants continued for thousands of years without any efforts leading to domestication (*1*). One example was the dependence of many North American Indians on the wild bison. In addition to sustaining themselves on the meat of bison, Indians used the skins of these ruminants to make tents, clothing and shoes. With the sinews they made thread, from the hide hair they made robes, and from the bones they shaped awls. The dung they used for fuel; the bladders served as jugs and drinking containers (*8*).

Such intimate association and dependence may evolve for some millenia without leading to domestication, but it is likely to be out of such an arrangement that taming, selection, protection and breeding will develop. A somewhat similar association or dependence on the red deer occurred in Europe throughout the mesolithic period. In that case, however, there was more of mutual interaction, because it appears that red deer herds may have been tended and selectively culled much as in a managed deer park (*9*).

It is thought that the reindeer cultures of the Eurasian North may have first used domesticated reindeer as decoys to better enable hunters to harvest animals from the wild reindeer herds. People of the Asian tundra and Lapps of northern Europe have evolved a migratory pastoralism suited to the ecosystems of the areas. Reindeer and wild caribou have long been a principal source of food for arctic peoples. Several times in Alaska, Canada and on Baffin Island, natives tried to establish reindeer enterprises on a large scale. They have failed.

Hahn (*10*) suggested that animals, and especially cattle, might have been first domesticated for ritual and ceremonial purposes. Wild cattle, he argued, were fierce and dangerous beasts. There was no way of knowing their utility for work and milk until they had been tamed. What would have induced man to start the process of domestication? Hahn felt that requirements for ritual sacrifice might have been the primary motive.

One example of such a domestication development is that of the mithan, a ceremonial ox cherished by the hill tribes of Burma, Assam and Bhutan from the Arakan Hills to Sikkim (*11*). It is sometimes referred to as *Bos frontalis* although it was probably derived from the wild gaur, *B. gaurus* and the two are fully compatible genetically. Mithan are often allowed to roam over the hill pastures and woodlands without confinement, but they are individually owned and usually tame. They are not used for work or milk and are eaten only after ceremonial sacrifice. The animal is an integral part of the culture of the tribal peoples.

Most of us have difficulty in accepting or even understanding the relationship between man and cattle in the sub-continent of Asia. Over the past eight to ten centuries, human attitudes have developed to the point where the social importance of cattle has a significant impact on the customs and eating habits of the people, particularly in India.

Although the cow is considered sacred by millions of Asians, historical reasons for this status are not clear. It is known, however, that centuries ago the bovine population was reduced by natural forces to near extinction levels and a government decree to stop slaughter was never rescinded. Ruling classes found it socially unacceptable to eat meat at specific times and later at any time (*12*). Of course, a vegetarian diet undoubtedly carries less risk in climates where meat can spoil quickly. Furthermore, in a land where cattle provide fuel, fertilizer, draft power and milk, a bovine may be more valuable on the hoof than on a slaughterhouse hook.

> **Animal Sacrifice**
>
> Historical evidence indicates that human sacrifice was rather widely practiced by early tribes in the Mid-East. The substitution of ruminants for humans in ritual sacrifice reflects in some degree the intimacy of the association between man and beast. The most valuable and the most loved animals were singled out as suitable substitutes for human sacrifice. By the time of Josephus (1st century A.D.) the number of animals needed for scheduled sacrifice had increased significantly. During the eight-day Feast of the Tabernacles in the seventh month, Josephus recorded that 15 rams were sacrificed each day. Another special observance required the sacrifice of three bullochs, two rams, 14 lambs and two "sin" goats (*1*).

Ruminant Production Systems

RUMINANT production systems in the world as a whole may be broadly classified as nomadic, transhumant, and sedentary; variations occur within each type. Nomadic pastoralists move their stock from place to place as seasonal feed and water are available. Transhumants move their stock seasonally or altitudinally in a more defined pattern, for example, grazing alpine or mountain lands in summer and lowland or desert areas in the winter season. In sedentary

A Marchigiana cow and calves are seen on a hillside pasture in central Italy. Formerly used for draft purposes, the Marchigiana is today utilized for beef production. *Winrock International Photo.*

systems, both the herds and those who tend them remain in one location, either because adequate water and feed supplies are available at that location or because supplies are brought in to the herd.

Some nomads operate yearlong in moving their animals over the landscape. They may have (or once had) vast ranges in which to operate. Full-time nomads do little or no farming and depend entirely on livestock for subsistence. The far-ranging tribes have been increasingly confined in recent decades, and many of them have been forced to modify their ancient ways of seeking a livelihood. Truly nomadic patterns are followed in Eastern African countries and in Asian countries. Some Eskimo peoples have followed the caribou herds in their migrations.

In the transhumant pattern, the primary ecological advantage is the utilization of pasture when available, supplemented by forage and crop residues available near the base village. Mountain meadows can be grazed only in summer. But they cannot be exploited at all without movement of stock both in and out again. In the western United States, most of this movement is now done by truck; however, the expense involved can limit the scope of such operations. In the Sahelian countries of Africa, transhumant pastoralists walk their herds north in wet seasons and retreat southward as the dry season sets in.

In the drier parts of Asia and Africa and in some Mediterranean countries, the range resources have been abused to an extraordinary degree. The quality and quantity of vegetation has degenerated, in many cases, beyond recovery. Soil erosion by both wind and water is enormously destructive over vast areas. Animals are seldom in good condition and are often near starvation. A calf may require four to seven years to reach a normal slaughter weight. The yearly round of searching for pastures becomes counter-productive. Animals are moved to new pastures before the forage is ready to be grazed because the old pasture has been grazed out and there is nothing left.

Pastoral nomadism and some types of transhumance exploit grassland resources that cannot be used in any other way. From a broad viewpoint, however, one cannot overlook the devastation of rangeland that often occurs — to say nothing of the poor quality of the livestock product. The systems could be improved, but this will require radical changes in an ancient way of life (*13*).

Sedentary systems of livestock production vary all the way from the subsistence level — producing milk for the family — to the large, integrated feedlot systems and large confinement dairies which produce vast quantities of ruminant food products.

A number of decades ago, cattle in the eastern United States were largely dual-purpose; that is, kept for milk and meat. Similar patterns have existed in European countries and are general in some developing countries, especially in Asia and Africa.

Grazing systems, supplemented by harvested forage are basic to ruminant production in areas with limited winter grazing. Such systems may be modified to include zero grazing in which animals are completely confined and fed harvested forage the year-round.

Throughout history, the needs and activities of the crop producer and the pastoralist have been in conflict. The enmity between cattlemen and sheepmen on the western U.S. range paled in the bitterness generated by "sod busters" protecting their fields and water sources with barbed wire against the invasion of cattle grazing the open range. But grazing livestock can be, and often is, a practice complementary to crop production. Witness the arrangements between African livestock herders and crop producers. Migrating herds graze crop residues during those seasons when pasture forage is in short supply. While grazing, they manure the fields, improving soil fertility and structure to the benefit of the next crop.

Large scale confinement systems for dairy, beef and lamb feeding — widespread in the U.S. — are increasing in Europe, U.S.S.R. and Japan. Such systems generally include use of grain and byproduct feeds in addition to harvested forages. Confinement dairies operating near urban markets are found in many developing regions as well.

Production systems may be independent or integrated. Integration may be achieved in many different ways. Ruminants belonging to many different owners may graze on common or public land together. Governments may stipulate and enforce conditions of such grazing use.

Individual enterprises may integrate all production stages on a single premise or on several premises. For example, a large scale confinement dairy may rear its replacement females on a farm distant from the dairy or it may contract for such rearing with farmers or smallholders or it may simply purchase replacement females. Feedlot operators may purchase or produce feeders or they may feed animals belonging to many owners. Integration provides a means for orderly flow of ruminants or their products through production stages to market and to consumer. It also facilitates provision of services and supplies to producers.

In some regions of Africa and Asia, village herding is a common practice. Cattle, sheep or goats are taken to grazing grounds outside the village. Animals are customarily owned by a number of villagers, but the herd is treated as a unit for the daily grazing exercise. The grazing area may include roadsides, lanes and rough terrain not in cultivation.

Women and children gather manure, which is mixed with straw, formed into cakes and dried in the sun. The resulting product is used as fuel for heating and cooking. In areas where dried dung is the only fuel available, manures cannot be spared for fertilizing cropland.

The small village or urban dairy herd is a system that dates back several centuries when supplying fresh milk to urban areas without refrigeration or rapid transport required special arrangements. It still operates effectively (*1*), although modern techniques such as pasteurization and refrigeration are now being adopted.

India has more cattle and buffaloes than any other country — over 240 million head. She has often been criticized for not making better use of these animals for purposes of human nutrition. People starve while cattle walk the streets. Closer examination suggests that competition between man and cattle for food resources is not as severe as the critics state. The traditional small Indian dairy is a case in point. The feeds and fodders purchased are not materials usable by humans, but the products provided are highly nutritious and especially important for people

Camels being used as draft animals on a land reclamation project near Lake Chad, Africa. *FAO Photo.*

whose caloric and protein intake may otherwise be rather low. The cattle of India are mostly scavengers that compete little with the human population for food. They do contribute enormously by providing work energy for the fields and milk for the people. Admittedly, they could be even more useful in the absence of the cultural prohibition against slaughter, which would not only provide beef but also, by decreasing total numbers, conserve feed for use in raising the productivity of the cattle which remain (*1*).

Male calves born in Indian dairies present a special problem. Cattle are holy and not to be slaughtered. However, dairymen cannot afford to feed useless males. In practice, most male calves starve. Heifers fare better.

Ranching has some features in common with nomadic herding, but the distribution and origin are entirely different. Except for a few parts of the Iberian peninsula where it originated in medieval times (*13*), ranching is rare in the Old World. It is practiced most frequently in the Americas, Oceania and parts of Africa.

Ranching tends to be confined to regions too dry or on terrain too rough for dependable farming. Enterprises tend to be large. Units of several thousand hectares are the rule and a few operations deal in hundreds of thousands of hectares. Productivity of the land is low per unit of area. Since ranches are most often found in regions of limited rainfall, watersheds occupied by ranches are a matter of public concern.

In several of the western states of the U.S., the bulk of the grazing land is controlled by the federal government. Public lands may be leased for grazing while at the same time used for camping, hiking, fishing, hunting, timber production and water catchment. Further, the rough terrain of mountain regions provides possibilities for high dams, hydraulic power, impounding for irrigation and lakes for recreation. Multiple land use can cause intense conflicts of interest.

Ranching is, in many ways, a product of the industrial revolution. As people left the land to take jobs in the cities, they ceased to produce their own food and were forced to purchase it. As incomes rose, demand for meat increased. Ranching in Australia, New Zealand and parts of South America was supported in the beginning by demand for livestock products in industrial Europe, especially England. In the U.S., cattle drives to the rail heads had much of the same character because beef was then shipped to the eastern industrial cities. The trend has continued and ranches today supply many of the animals for American feedlots which, in turn, provide meat for an urban society (*1*).

In contrast with nomadism, the wealth of a rancher is not measured in the number of animals he owns but in the profits he can generate from his enterprise. The rancher is more likely to adjust the number of animals to the carrying capacity of his unit. In a declining market he may keep more animals than he wants, but he cannot afford to ruin the grazing land on which his future income depends. Heavy use may be more common than desirable but the destructive overgrazing so common in Asia and Africa is much less likely to occur. Ownership of the land is an important incentive. A need for more feed is met by improving pasture or by producing hay and feed.

World Basis for Ruminant Emphasis

ONE can evaluate the merits of ruminant agriculture in a number of ways. Two of them deserve a measure of emphasis and discussion at this point: (1) the contribution of ruminants to the food energy and protein requirements of the world, and (2) the value of ruminants as a percentage of the gross national product (GNP).

Food Energy — Malnutrition is a widespread health problem. Too many people are on starvation rations even in "good" years. Inadequate protein is common, especially among the young. As many as 30 percent of the children in the developing world suffer from kwashiorkor (protein deficiency) to the extent that they die before their fifth birthday (*14*). Actually, humans do not require animal protein. What is needed is an adequate supply and proper balance of ten essential amino acids. Both the supply and the balance are most easily obtained from animal sources such as meat and milk. Animal products are also good sources of structural lipids, iron, niacin and vitamin B_{12} (*15*).

For maintenance, an adult human requires a ratio of 20 gms of perfect protein for each Mcal of metabolizable energy. In evaluating other proteins, the protein of mother's milk or the protein in a hen's egg is used as a reference standard; that is, "perfect protein." If we assume a value of 100 for milk or egg protein, ruminant meat proteins have a value of about 80.

Plant proteins are also sources of amino acids, and vegetarians can be perfectly healthy. However, nutritional deficiencies or imbalances are much more common in diets lacking animal protein. Cereals, in general, tend to be deficient in lysine, tryptophan and sometimes threonine, while pulses (soybeans, peanuts) are likely to be deficient in methionine. Pulses have traditionally been the primary sources of protein to supplement the deficiencies in cereals. But pulses do not yield as much as cereals and can be expensive. Tuber crops are high yielding energy sources but generally low in protein (*1*).

Leaf proteins have an array of essential amino acids similar to those in milk; however, man, pigs and chickens can obtain only a small portion of their protein needs from this source because the high fibrous content of leaves limits intake. Estimated protein from all vegetables and fruits amounts to only about five percent of the total protein intake in the low-calorie countries. Concentration of leaf proteins by physico-chemical methods may eventually produce protein concentrate of high biological value, but it is doubtful if such methods will result in a product that can economically replace milk and meat. Recent research with concentrated alfalfa proteins indicates a protein efficiency ratio of only about half that of milk (*16*).

Milk is not only an excellent source of good quality protein, but also of calcium, essential minerals and vitamin A. Actually, milk is an excellent complement to cereals.

The relative food value of ruminant products (meat and milk) as compared with that from pigs, poultry and eggs, is shown in Table 1-1. These figures are also projected to the requirements in year 2000. The projected demand for ruminant products could be met with only a modest increase in numbers of cattle, sheep and goats (*17*). Such a plan would cost least in terms of added feed energy and protein to support ruminant populations.

Table 1-1 — Food energy and protein values for man from ruminant, pig and poultry — annual production for 1970 and projected for year 2000.

Product	Livestock units[1]		Food energy[2]		Food protein[3]	
	Millions		Billion Mcal		Million metric tons	
	1970	2000	1970	2000	1970	2000
Ruminants	1195	1540	373	638	16	28
Pigs	154	190	144	215	2	3
Poultry	55	68	57	100	4	7
Total or average	1404	1798	574	953	22	38

[1] Livestock unit — cattle = .8; buffalo = 1.0; sheep and goats = 0.1; poultry = 0.01; swine = .5.

[2] Physiological fuel values (PFV), expressed as average Mcal/kg carcass weight; cattle and buffalo meat 2.31; sheep and goat meat, 2.0; pig meat, 4.2; poultry meat, 1.4. PFV, Mcal/kg milk: cattle, .62; buffalo, 1.0; sheep, 1.12; goats, .75. PFV, in eggs Mcal/kg, 1.5.

[3] Net protein value (NPV), expressed as gm/kg carcass weight: cattle and buffalo meat, 105; sheep and goat meat, 89; pig meat, 60; poultry meat, 126. NPV, gm/kg milk: cattle, 28· buffalo, 32; sheep, 48; goat, 28. NPV in eggs, gm/kg, 115.

Increasing per head productivity is the most efficient way to meet increased future demand for ruminant products. Simply stated, doubling milk yield per cow requires less feed than doubling the number of milk cows. This strategy is especially critical to regions such as North Africa, India and Japan where feed for ruminants is already in short supply.

The future food value of ruminant products also largely depends on improved processing and timely distribution. In countries with inadequate facilities for pasteurization or sterilization and with little or no refrigeration facilities, contaminated milk and meat may be a health hazard. Some of the sanitation and preservation problems, however, can be minimized or overcome by converting milk to cheese and fermented milk products.

Much of the milk protein of the world — in the form of whey as a byproduct of cheese manufacturing — is either fed to animals or wasted by discharging it into streams and sewers. Research teams are working on ways to better utilize whey.

Ruminant Contribution to GNP — The calculated farm-gate value for ruminant products produced in 1972 throughout the world amounted to about US$107 billion. The total World Gross Product (goods and services) for the same year was approximately US$4,131 billion. The estimate for the value of ruminant products includes values of milk, meat, hides, skins and wool utilized by consumers as well as amounts traded. Among the 15 regions, the contribution of ruminant products ranged from 0.3 percent to 6.8 percent with an average of 2.6 percent (*18*).

The top three ranking regions for ruminant production are North America, Western Europe and the USSR. As might be expected, these three regions follow the same order in a rating of Gross National Product.

Although gross national product may be an appropriate means of measuring the economic value of a country's productive enterprises, the percentage contribution by ruminants is hardly a fair assessment of their true value to man. The reason has been alluded to earlier; namely, that not all ruminant contributions to man can be documented by numerical and monetary data. Indeed, the relationships between and among land, man and ruminants are complex, interdependent and highly productive in ways that can never be fully measured by economic yardsticks (Fig. 1-2).

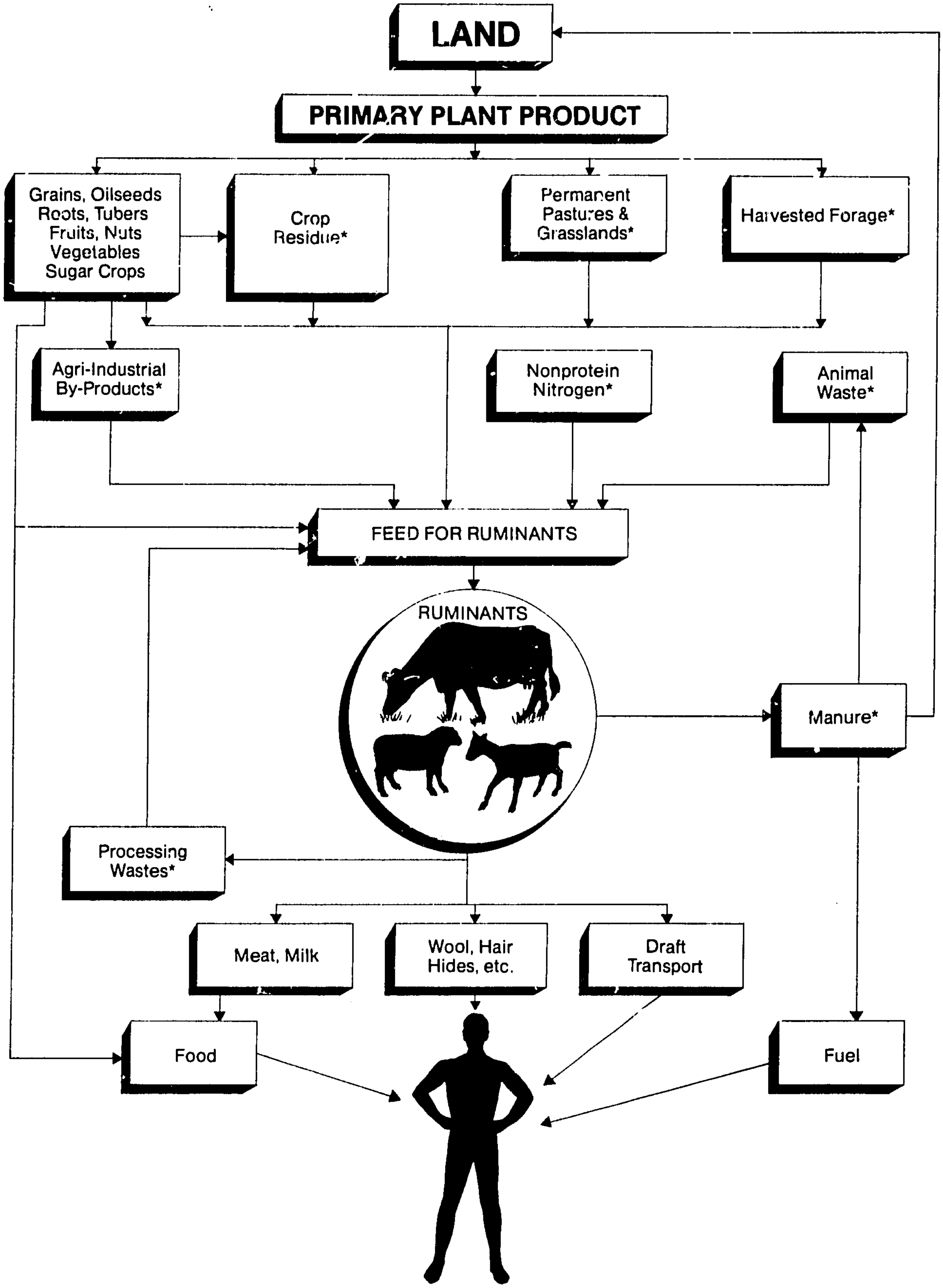

Figure 1-2. — A graphic representation of land-ruminant-man relationships. Products that are starred (*) are not normally consumed by man.

Barbados Black Belly Sheep are found throughout the Caribbean. This hair sheep breed is adapted to the humid tropics and is noted for its prolificacy. *Winrock International Photo.*

This introductory chapter has presented a rather broad overview of the basis and extent of the importance of ruminants to mankind. But to fully appreciate the significance of ruminants and the role they will assume in the next two decades, it is necessary to systematically consider all factors that affect ruminant agriculture and the availability of products and services to humans. Thus, succeeding chapters review world ruminant resources — both their numbers and the products and services they provide — together with feed resources now available and the potentials for year 2000. Critical examinations of the various constraints to production (biological and economic) point to needed research and training programs vital to meeting consumer demands. Closing chapters focus attention on the future economic demands for ruminant products and the likelihood of meeting those demands. In keeping with the mission of Winrock International and the goals of this study, our projections reflect what we feel is a fair degree of accuracy and — as might be expected — a goodly measure of optimism for the future of ruminant agriculture.

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Reindeer are uniquely adapted to serving human needs in temperate areas. This herd was photographed in Norway. *FAO Photo.*

7. Following is a listing of the 15 world regions used in this study:

(FOR MAP, SEE APPENDIX FIG. 1)

Name of Region	*Region No.*	*Countries*
North America	1	United States, Canada
Middle America	2	Mexico, Bahamas, Bermuda, Costa Rica, Dominican Rep., El Salvador, Guatemala, Haiti, Honduras, Brit. Honduras, Jamaica, Nicaragua, Panama, Trinidad & Tobago, Other Caribbean
South America	3	Argentina, Brazil, Colombia, Venezuela, Chile, Bolivia, Ecuador, French Guiana, Paraguay, Peru, Surinam, Uruguay, Guyana
Western Europe	4	Belgium, Luxembourg, Netherlands, France, Germany, Italy, Denmark, Ireland, United Kingdom, Austria, Finland, Greece, Iceland, Malta, Norway, Portugal, Spain, Sweden, Switzerland

Name of Region	Region No.	Countries
Eastern Europe	5	Albania, Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Romania, Yugoslavia
USSR	6	Soviet Union
China	7	China
North Africa - Mid East	8	Algeria, Bahrain, Cyprus, Iran, Iraq, Israel, Kuwait, Libya, Oman, Qatar, Saudi Arabia, United Arab Emirates, Egypt, Jordan, Lebanon, Morocco, Sudan, Syria, Tunisia, Turkey, Yemen (Sana), Yemen (Aden)
Central Africa	9	Kenya, Malagasy Rep., Malawi, Mozambique, Rhodesia, Tanzania, Uganda, Zambia, Angola, Burundi, Cameroon, Central African Rep., Chad, Congo, Dahomey, Ethiopia, French Territory of Afars & Issas, Gabon, Gambia, Ghana, Guinea, Equatorial Guinea, Portuguese Guinea, Ivory Coast, Liberia, Mali, Mauritania, Mauritius, Niger, Nigeria, Reunion, Rwanda, Senegal, Sierre Leone, Somalia, Spanish Sahara, Togo, Upper Volta, Zaire
Southern Africa	10	Rep. of South Africa, Botswana, Lesotho, Namibia, Swaziland
India	11	India
South & Southeast Asia except India	12	Afghanistan, Bangladesh, Bhutan, Nepal, Pakistan, Sri Lanka, Thailand, Burma, Khmer, Laos, South Vietnam, Indonesia, Malaysia, Philippine Islands, Hong Kong, Singapore, South Korea, Taiwan, Brunei
Japan	13	Japan
Oceania	14	Australia, New Zealand
Rest of World	15	North Korea, North Vietnam, Mongolia, Cuba, Pacific Islands, Papua-New Guinea—but also serving as a residual comprised of those regions not yet explicitly modeled.

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RUMINANT RESOURCES

Only one-third of the world's ruminant population lives in the developed regions; yet they produce two-thirds of the world's meat and four-fifths of the world's milk.

THERE are approximately 2800 million domesticated ruminants. On a biomass basis, ruminants exceed swine by nearly 400 percent and poultry by over 2000 percent. Ruminants provide man with food, fiber, and other valuable products. In general, these products result from conversion of feed resources for which man has little other use. This chapter reviews the genealogy of the ruminant families, describes their production and presents estimates of their feed energy requirements.

Ruminant Families

FAMILIES of ruminants include those which have one or more domesticated genera — *Bovidae*, *Camilidae* and *Cervidae* — and those with only wild genera — *Giraffidae* (giraffe and okapi), *Antilocapridae* (pronghorn antelope), and *Tragulidae* (chevrotains, the smallest of all ruminants).

Bovidae — The family *Bovidae* includes the principal domesticated ruminants — cattle, sheep, goats, buffalo — and many wild species including gazelles, antelope and the musk ox.

Cattle belong to the genus *Bos*. There are five major species: (1) *B. primigenus*, the now extinct wild ox of Europe and Asia, and two living domesticated subspecies, *B. taurus*, European cattle, and *B. indicus*, the humped zebu; (2) *B. mutus*, the yak of the Central Asian highlands; (3) *B. javanicus*, the wild Banteng and domesticated Bali; (4) *B. gaurus*, the wild gaur and domesticated mithan; and (5) *B. sauveli*, the wild kouprey. The latter three species, sometimes classified in the genus *Bibos*, are all found in Southeastern Asia.

Records of humpless domesticated cattle are known from the fifth millennium BC in Mesopotamia; those of humped cattle in the Indus valley date from the third millennium BC. Both were longhorned (*primigenus*) cattle. A shorthorned, humpless type (*bracheros*) was developed about 3000 BC in Mesopotamia, probably with emphasis on milk production. The humpless cattle — both longhorn, shorthorn and crosses of the two — predominated in Europe but also migrated into Africa. They were later the first cattle to be introduced by European settlers into the Americas and Oceania. Humped zebu cattle — better adapted than most humpless cattle to the stresses of high temperature, poor nutrition and health problems of the tropics — first migrated from Asia to Africa and in the 19th century were brought to the Americas, and in this century were introduced into Australia (*1*).

Mason (*2*) lists 274 major breeds of cattle. *B. taurus* include European beef breeds (Shorthorn, Angus, Hereford, Charolais), dairy breeds (Holstein, Jersey, Ayshire), dual or triple purpose breeds (Simmental, Gelbvieh, Chianina), plus the Spanish "brave" cattle, the Criollo types of Latin American and many others. Examples of

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"So, Bos . . . So-o-o, Bos"

Those generations of dairy people who knew not the convenience and pleasures of an automated milking system sometimes had to quiet a nervous cow when drawing up a stool at milking time.

"So, bos . . . so-o-o, bos," spoken to the animal in a soothing tone, generally had the proper effect of putting her at ease and inducing the flow of milk. Some cows could be trained — and may still be trained — to respond to the command, "Come, bos; here, bos; here, bossy."

One farmer, when asked why he had used the expression, "So, bos," said he thought he remembered his father and perhaps his grandfather using it years earlier. He had no further reason.

Actually, the Latin term, *Bos taurus primigenus*, gives a logical clue. One can reasonably suppose, therefore, that the origin dates back nearly 1300 years to an era when Old Latin was spoken by European herders. Somehow, the expression continued from generation to generation.

B. indicus breeds include the Indian Sindhi and Sahiwal, African Boran and American Brahman. Breeds formed from crosses of *B. taurus* and *indicus* include the American Santa Gertrudis and Brangus, the Australian Droughtmaster and the South African Africander.

Approximately 1.7 million yak make life possible for man in the highlands of central Asia at altitudes of 3000 meters or more where temperature is below freezing eight months of the year. They provide food, fiber, skins and cartage. Yak and cattle (*taurus* and *indicus*) intermate. Female hybrids (chauri) are fertile, but males usually are not (3).

The genus *Bison* includes two species, the European, *B. bonasus*, and the North American, *B. bison*, often called "buffalo." Intermatings of cattle and bison generally produce fertile females and infertile males. Claims for highly productive and fertile males, "Beefalo," have received much publicity in recent years; however, these claims are still in dispute.

Sheep belong to the genus *Ovis*. The 1043 million domestic sheep, *O. aries*, are thought to be descendents of crosses between *O. ammon*, the argalis of Asia, and *O. musimon*, the mouflon of Corsica and Sardinia. Other species include wild sheep, such as the Bighorn of North America, the Snow Sheep of Siberia and the Red Sheep of Turkestan.

Mason (2) lists over 800 sheep breeds. Some breeds such as the Spanish Merino (especially, those imported to Australia and North America) are noted for producing extremely fine apparel grade wool. Others, such as the Scottish Blackface, the Navajo and many Asian breeds, are noted for coarser carpet grade wool from which floor coverings are woven, including famous Persian carpets and Navajo blankets. Still others in the humid tropics, such as the Barbados Black Belly, the Indian Nellore, the Somali Blackhead and the West African Dwarf, have little or no wool. Breeds such as the East Fresian and Lacaune of Europe and the Middle Eastern Awassi are noted for milk production. Tail type distinguishes many breeds: the fat tail and fat rump types of the Middle East; the long, thin-tailed types (including most European breeds, such as the Merino and Down breeds); and the short, thin-tailed breeds, such as the prolific Finnish Landrace.

Sheep tend to be seasonal breeders, especially those away from the equator. Breeding seems to coincide with shortening of daylight hours (fall months in Northern Hemisphere). Some twinning occurs in most breeds. Others such as the Finnish Landrace, eastern Mediterranean Chios, Morroccan D'man and Chinese Huyang are noted for litters of 3 to 4 lambs.

Goats belong to the genus *Capra*. Domestic goats are thought to have descended from the Asian wild goat, *C. aegagrus*. Ibex is a common name shared by several species of wild goats in Europe, Asia and Africa. The Rocky Mountain "goat" is of another genus, *Oreamos*.

Mason (2) lists 69 breeds of goats and many minor varieties. These include breeds noted for milk production: European — Saanan, Toggenburg, Alpine, Granada; African — Nubian; Asian — Damacus, Barbari, Beetal. Others noted for fine fiber production include the Angora (mohair) and the Indian-Tibetian Kashmiri (cashmere wool). Goats kept primarily for meat include the Brazilian Bhuj (probably descended from importations of Indian breeds such as Jamnapari and Bengal), the Spanish Criollo goats of Northern Mexico, West African dwarf goats and similar types of small goats herded in the arid areas of much of the developing world.

The damage caused by overgrazing fragile, arid rangelands has raised cries for goat eradication. Goats are often able to survive where other ruminants cannot. This has led to the often erroneous conclusion that goats were the primary cause of devastation. Instead, however, goats continue to be raised because they are able to produce some food for man from the few remaining grasses and shrubs in areas where other animals cannot do so.

Buffalo belong to the genus *Bubalus*. There are three species: the Indian *B. arnee*, from which all domesticated buffalo are derived; *B. depressicornis*, the small anoa found on the Indonesian island of Celebes; and *B. mindorenis*, the tamaroa found on the Phillipine island of Mindoro. The wild African Cape and Congo buffalo belong to another genus, *Syncerus* and have not been domesticated.

Records of domesticated buffalo in the Indus valley and Mesopotamia date from the third millennium BC and in China from the second millennium BC. Buffalo were probably taken to North Africa during the Arab conquests of the ninth century and into Europe by returning Crusaders in the twelfth century. Much later, small numbers were imported into Australia (mid 19th century), Brazil and the Caribbean area (early 20th century).

As fuel supplies dwindle, animals become more important for transportation. Here oxen are used for draft purposes in Honduras. *Winrock International Photo.*

Domestic buffalo are commonly grouped in two major categories: the Swamp buffalo of Southeast Asia, including the Phillipine carabao; the larger River buffalo of India, Pakistan, the Middle East, North Africa and Europe, including breeds such as the Murrah, Surti, and Nagpuri. Swamp buffalo are used primarily for cultivating rice paddies; they provide some milk for family use. River buffalo are also used for draft; however, many breeds are milked commercially, producing 1500+ kg per 300-day lactation. Both types suffer from high temperature, particularly when exposed to direct solar radiation. Swamp buffalo compensate by mid-day mud baths, but River buffalo prefer lolling in clear water. Both types are noted for their ability to utilize low quality, high fiber forages.

Camilidae — The two genera (Camelus and Lama) of the *Camilidae* family are widely separated geographically and in the type of environments to which they are adapted. Camels are known as "ships of the desert;" while llamas, alpaca and their wild relatives — vicuna and guanaco — live in the high Andes.

There are two species of camels: the single-humped dromedary of Northern Africa and the Middle East and the two-humped bactrian of central Asia. Camels were the principal means of transport on the desert trading routes. Today, however, their primary contributions are meat, milk, fiber and, to a lesser extent, as work animals. They are noted for their low water requirements and ability to survive on very poor quality grazing and browse. Under reasonably good feeding conditions, females foal every 18 months and yield 2000 to 3000 kg of milk in 365-day lactation. Adult body weight apparently varies considerably. Knoess (*4*) cited carcass weights for male dromedaries of 300-400 kg and 650 kg for male bactrian. Dressing percentages of 50 percent would mean liveweights of double these values. The meat is similar to beef.

Llama and alpaca were probably first domesticated by the Incas. The llama is the larger of the two; males weigh up to 120 kg. Llama produce coarse black, white or gray fibers and serve as beasts of burden; their meat is well-liked. Alpaca weigh about 70 kg when mature and produce finer fibers (both hair and wool) than llamas (5). Their fiber clip weighs approximately 2 kg. The wild adult guanaco is similar in size

Table 2-1. — Production coefficients for principal domesticated ruminants

Ruminant	Male adult wt, kg	Age at puberty, mo.	Gestation length, mo.	Litter no.
Cattle	300-1500	10-24	9-10	1
Sheep	25-125	4-8	4.5-5	1-4
Goats	20-100	4-8	4.5-5	1-3
Buffalo	300-700	20-36	10-11	1

to the llama; wild vicuna weigh 35-40 kg.

Cervidae — This large, diverse family includes deer (American white-tail and mule deer and European red deer), elk and moose. It also includes the caribou and its domesticated type, the reindeer, of the genus *Rangifer*. In the arctic areas of regions 4 and 6, approximately 3.5 million reindeer forage on lichens in the winter; grasses, forbs, browse and even mushrooms in the summer (*6*). They provide meat and hides and have even been trained to pull sleds (leading to one of the better known Christmas stories).

Wild Ruminants — Apart from domesticated ruminants, there are uncounted numbers of wild ruminants grazing the range, forest and mountain lands of the world. These animals have generally evolved so that they efficiently fit within specialized niches of the natural environment. They provide man with much pleasure in watching them roam free, considerable sport in the hunt for meat and trophies and not an inconsiderable amount of protein supplementation to the diets of some peoples, especially in Africa. On the negative side, wild ruminants occasionally compete with their domesticated cousins for scarce feed resources and, worse, may serve as living reservoirs for diseases and parasites which also afflict the domesticates.

On balance, however, wild ruminants play a positive role in the support of man. And there is increasing interest, especially in Africa, in further augmenting this role by harvesting game meat resources on a regular basis either through game cropping or ranching. Projected offtakes of meat from herds of wild ruminants generally exceed offtake of beef, sheep or goat meat — especially where there are serious water, disease or drought constraints. Consumer acceptance of the meat products varies. There is a good, but limited, tourist demand for fresh or frozen meat, especially from species such as the oryx whose flesh is quite tender. The principal problem in utilizing wild ruminants is the harvesting process itself; they must be shot on the open range — generally a long distance from any processing facility. "Domesticated" game tend to become highly excited if loaded on a truck to the point of hurting themselves or their handlers. Nor are long treks to central markets likely to be practical (*7, 8, 9*).

Work on these and other problems continues. And it seems likely that wild ruminants will play an increasingly important role in feeding man.

Ruminant Products

Meat — Meat includes the muscle, fat and edible organs of the ruminant carcass. Variation in taste and custom sometimes determines which organs are considered edible. The saying, "hungry enough to eat the whole steer — hide, hooves and all," is not just idle chatter. Many peoples of the world do boil the hide and hooves to extract what nutrients they can. Bones are cracked and the marrow extracted. Cattle blood provides a valuable supplement to the diet of Central African nomads. Even wool and hair can be mechanically and chemically processed to produce a high protein flour (*10*). But it is the muscular flesh of ruminants that is relished by most humans, whether it is a loin-steak barbecued on the backyard grill, a roast leg of lamb with mint sauce or even a piece of dried venison.

After slaughter, 40 to 60 percent of the ruminant liveweight remains as the carcass. The lost weight includes the head, hide or pelt, shanks and offal (gastrointestinal tract and contents, lungs, heart, liver, and other organs). Depending on the species, age, stage of maturity and degree of fatness, bone may account for 15 to 25 per-

Table 2-2. — Approximate composition of selected ruminant boneless meat products

Meat Product	Tissues, %		Chemical composition, %				Energy
	Lean	Fat	Water	Protein	Fat	Ash	kcal/kg
Beef[1]							
Choice[2]	60	40	49	15	35	1	3790
Good[2]	66	34	55	16	28	1	3230
Utility[2]	76	24	62	19	18	1	2420
Sheep meat							
Lamb[1,3]	79	21	63	17	19	1	2470
Goat meat[4]	85	15	66	17	16	1	2100
Buffalo[5]							
Fat	—	—	64	19	15	1	2556
Thin	—	—	73	22	1	1	1386

[1] Source: Composition of foods, USDA Handbook 8, 1963.
[2] Total edible carcass, including kidney and kidney fat USDA carcass grades in 1963.
[3] Composite of retail trimmed leg, loin, rib and shoulder from USDA good grade lamb.
[4] Adapted from R. R. Mishra and D. S. Chawla. 1976. Annual Report. National Dairy Res. Inst., Karnal, India.
[5] Source: Ognjanovic, A. 1974. Meat and meat production. *In* W. R. Cockrill (*ed.*) *The Husbandry and Health of the Domestic Buffalo.* FAO, Rome.

cent of the carcass weight. Therefore, muscle and fat account for approximately 40 percent of the original liveweight. Separable lean tissue is composed of approximately 70 percent water, 20 to 25 percent protein, 5 to 10 percent fat and 1 percent ash.

Carcass fat includes four categories: subcutaneous fat covering the outside of the carcass, kidney and pelvic fat in the body cavity, intermuscular fat and intramuscular fat (marbling). Fat is the primary storage depot for excess energy. Fat stored in times of nutrient excess stands the ruminant in good stead when feed is scarce.

The location of these fat deposits varies considerably; man has augmented some of them by selection. Fat tail and fat rump sheep, humped camels and cattle are obvious examples. British "beef" breeds of cattle are noted for depositing much of their body fat intramuscularly. The resulting highly marbled beef from these breeds is favored in some countries such as U.S., Great Britain and Japan but not in France, Italy and most other European countries. Few people in the developing world can afford enough beef to argue the point one way or the other.

Tenderness is the most important meat quality trait. Claims are often made that well marbled meat is more tender. These claims probably stem from people having eaten beef from older, thinner animals which had rarely had enough excess energy in their diet to cause the meat to marble. The Texas Longhorn was a hardy beast known for his toughness — both in braving the elements and the beef he produced. But today's better managed and better fed cattle can easily reach market weight at 18 to 24 months of age, even if raised on high forage rations. And research has shown no appreciable effect of fatness on the tenderness of such cattle.

Tenderness can be achieved in many ways. Meat is pounded, punctured, flaked and fabricated. Ground beef has become a staple of the American diet. Longterm or high temperature aging of carcasses is a standard tenderizing technique. Enzymes injected intravenously just before slaughter increase tenderness as does stretching the carcass to inhibit muscle fiber contraction during rigor mortis (*11*).

Ruminants are commonly slaughtered at 60 to 70 percent of mature weight. Meat from mature breeding animals is frequently processed and sold as hamburger, sausage and other such products.

Veal, Easter lamb and cabrito (goat) are examples of highly favored meats from very young ruminants still being fed all milk or mostly milk diets. Slaughter of ruminants at such early ages does not take advantage of their meat production potential but may fit well in dairy production systems, where most of the mother's milk is harvested for human use.

Most meat is eaten fresh, often the day of slaughter. Preservation is a necessity for shipment long distances or for longterm storage. Salted beef was a staple on long ocean voyages, some of which were made expressly to obtain aromatic spices of the Orient which in turn were used for meat preservation and, incidentally, to mask any lingering odors of early decay. Dried meat — jerky or biltong — lasts well in arid lands and in its chipped form became famous to many servicemen as SOS. Large quantities of meat are frozen or canned, especially for international trade.

Milk — Mother's milk is often cited as an example of the perfect food — rich in high quality protein, energy (calories), minerals and vitamins. The milk from mothers of many young ruminants is diverted directly to human consumption.

The major nutrients supplied by milk are fats, carbohydrates, protein and calcium. The fat fraction forms an emulsion with the water in milk; however after sitting, much of the fat rises to the top as cream. Small fat globules rise more slowly than large ones so homogenization, which reduces the size of fat globules, prevents the formation of the cream layer. Goat milk has naturally small fat globules and generally does not require homogenization. Conversely, to thoroughly break the fat emulsion and completely separate fat requires considerable agitation, such as churning, a process used to make butter.

Lactose (milk sugar) is the primary carbohydrate in milk. It gives milk its slightly sweet flavor. Humans who lack the enzyme lactase, which hydrolyzes lactose, suffer severe intestinal upset when they drink milk. Fortunately, commercial preparations of lactase can be added to produce "acidophilus" milk which relieves this problem.

Milk is an ideal medium for microbial growth. Therein lies both an advantage and a serious problem. The problem is that disease organisms causing tuberculosis, undulant fever, typhoid, food poisoning and others thrive in milk. The problem is resolved by high temperature processing — pasteurization — which kills the disease organisms. The advantage is that other microorganisms ferment milk to produce such popular items as yogurt and cheese (Table 2-4).

The many milk products — butter, yogurt, cheese, ice cream — make substantial contributions to the human diet. Aromatic yak butter and Mexican goat milk candy are special delicacies. Condensed and dried milk may be stored for long periods. New techniques include use of antibiotics and irradiation to preserve whole milk for long periods without refrigeration. By-products of cheese and butter manufacture, whey and buttermilk, are fed to both animals and man; however, both require supplementation because certain essential nutrients are removed during manufacture.

Table 2-3. — Approximate composition of fresh milk from several species of ruminants

Specie	Water	Fat	Protein	Lactose	Calcium	Energy
	Percent					*kcal*/100g
Cattle	87.8	3.5	3.3	4.6	0.12	62
Buffalo	83.2	7.5	3.8	4.9	0.19	100
Sheep	81.6	7.5	5.6	4.4	0.20	105
Goat	86.8	4.5	3.3	4.4	0.13	71
Camel	87.1	4.2	3.7	4.1	—	70
Yak	82.1	7.0	5.2	4.6	—	100
Llama	86.5	3.2	3.9	5.3	—	65
Reindeer	63.3	22.5	10.3	2.4	—	250

Source: Kon, S. K., *Milk and Milk Products in Human Nutrition*. 1972. FAO Nutritional Studies No. 27. Food and Agriculture Organization of the United Nations, Rome.

Table 2-4. — Milk sources for some popular cheeses

Milk source	Name of cheese
Cattle	cheddar, feta, stilton, gorgonzola, blue, mozzarella, edam, gouda
Sheep	cheddar, feta, lightvan, manchego, brinza, roquefort
Goat	cheddar, feta, le pyramide, gjetost, myosost, fontino
Buffalo	cheddar, mozzarella

Source: Kosikowski, Frank. 1977. *Cheese and Fermented Milk Foods.* Edwards Brothers, Inc. Ann Arbor, Michigan.
Source: Le Jaouen, Jean-Claude. 1977. *La Fabrication du Fromage de Chevre Fermier.* 2nd Edition. ITOVIC, Paris.

Dairy production systems produce both milk and meat from slaughter males and culled females. At similar fertility levels, diary herds are 5 to 6 times more efficient in converting feed energy to human food energy than are strictly beef herds (*12*). However, dairy systems tend to be labor, capital and technology intensive relative to meat production systems and often are impractical under extensive range systems.

Once produced in the mammary gland, milk must be quickly harvested, processed and preserved. Milk harvested in excess of immediate demand for either family use or commercial markets may be wasted. Meat production in excess of immediate demand does not have to be harvested immediately. Meat animals may be held at weight maintenance levels until needed. While not a feed energy efficient process, this practice does provide marketing flexibility not easily available to the dairy producer.

Many variations of meat and milk (dual purpose) production systems are found throughout the world. Calves in most large commercial dairies are generally weaned within days of birth and raised on milk replacer; in fact, many never suckle their mother. Artificially raised dairy calves make a substantial contribution to beef supplies. Many cows milked in the developing world will not release their milk unless their calf is near at hand. The calf and milker then compete for her milk, but the milker usually manages to get 50 to 75 percent.

Considerable variation occurs from region to region in the relative importance of meat and milk in the human diet. Approximately 10 percent of the protein in the Indian diet (Region 11) is from milk. In other parts of Asia and much of Africa, few adults consume milk — often because of milk protein allergies or lactose intolerance.

Meat, Milk and Human Health — Ruminants are herbivores. Lions and coyotes are carnivores. Man is an omnivore, drawing sustenance from both the plant and animal kingdoms. While some Hindus and Eskimos are proof that man can do well on either an all-plant or all-animal product diet, a balance of both types is the easiest way to insure good health. Human diets must be balanced with respect to energy, amino acids, minerals and vitamins. A deficiency of any of these will likely limit utilization of the others and lead to poor health.

Milk is a highly digestible, well-balanced nutrient source. A liter of milk a day provides the average man with daily requirements for fat, calcium, phosphorus, riboflavin, one-half the needed protein, one-fourth the energy, one-third the vitamin A, considerable amounts of the other required vitamins and minerals. Only iron, copper, manganese and magnesium are in short supply. Milk and eggs are the usual standards against which other proteins are measured for biological value; that is, the mix of essential amino acids required for body protein synthesis. Milk may be used as the exclusive diet for short periods, but is especially valuable as a supplement to high cereal diets. Without milk, less than 30 percent of cereal protein is used for growth; with milk over 60 percent is used. The extra calcium in milk is also important to growing children and their mothers.

The biological value of meat protein is approximately 80 percent of milk protein. Meat is,

Indigenous cattle being milked in Tanzania. To induce milk let down calves are present at milking. Yields from such cows are about one to three liters per day. *FAO Photo.*

however, one of the best food sources of iron.

Small quantities of meat and milk added to cereal and root diets eliminate protein-calorie malnutrition diseases, such as marasmus and kwashiorkor, which have major impact on small children. Supplements with vegetable proteins — soy and peanuts, for example — are also effective but may be less readily available or economical as milk from a goat tethered in the backyard.

The effect of ruminant products — meat and milk — on incidence of arteriosclerosis has been the subject of much debate in recent years. The debate centers around cholesterol. High blood levels of cholesterol have been associated with higher probability of coronary disease. Cholesterol in the blood comes from two sources: that consumed and that made by various body organs. Meat contains very little cholesterol and milk only slightly more. But meat and milk — particularly high-fat meat and milk — are the primary dietary sources of saturated fats. And saturated fats stimulate the manufacture of cholesterol in the tissues of people who are overweight or rapidly gaining weight.

The relationship between cholesterol and coronary problems is still in dispute. But, regardless, the solution does not require eliminating any milk from the diet. Rather, the effort should be to avoid becoming overweight in the first place. Moreover, the trend seems to be away from preference for high fat meat so that selection and management of ruminants to produce lean carcasses will further resolve the problem. Similarly, low fat milk is readily available.

Wool and Hair — Wool and hair are a special, complex protein called keratin. The helical structure of keratin especially suits it to the bending involved in weaving and wearing fabrics.

Almost half the world production of sheep wool comes from Oceania. Wool from camels, alpacas and Kashmiri goats is available in much smaller quantities than sheep wool and usually at higher prices. Mohair production from Angora goats amounts to about 30,000 metric tons annually. Most of this smooth lustrous fiber is produced in Turkey, South Africa, Lesotho and Texas.

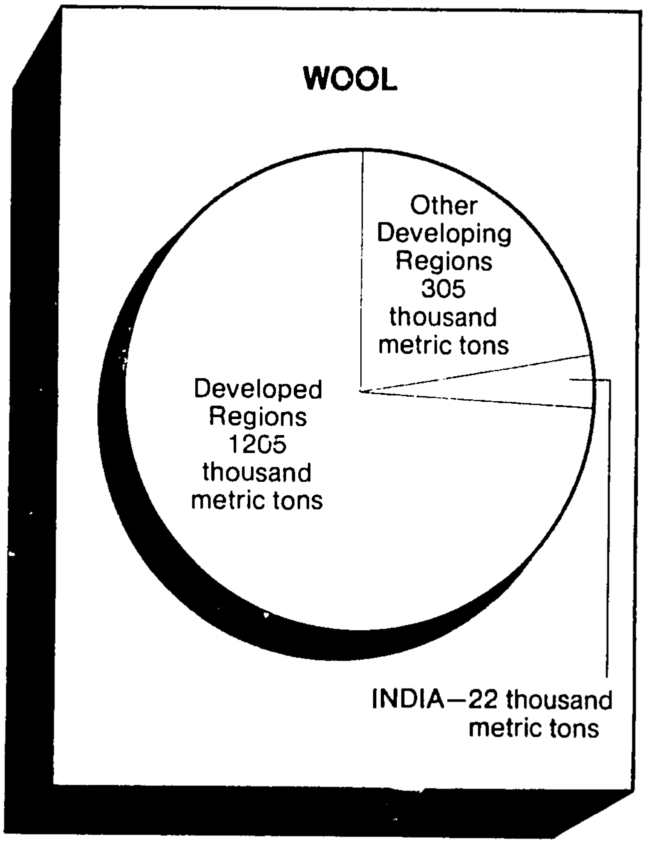
Synthetic fibers compete directly with wool and hair. Recently, there has been a trend in preference for the natural fibers because of their durability, absorbency, drying characteristics and general comfortability. This trend may be accentuated by the increased cost of petroleum derived synthetic fibers. The petroleum energy cost of producing one kg scoured wool is only 18 Mcal compared to 45 Mcal per kg of synthetic fiber (*14*).

Skins — Ruminant skins provide the hides (hair removed) and pelts (hair and wool left on) from which a variety of products are made. These range from the lowly shoe sole to the elegant Persian lamb coat.

Skins make up 7 to 10 percent of the liveweight of ruminants. Pelts from Karakul sheep (Persian lamb) and Alpaca constitute the major market value of the slaughtered animal; in general, pelts make up 25 percent of the market value. Hides account for 5 to 10 percent of the slaughter value at slaughter of ruminants such as cattle, buffalo and goats (*15*).

Hide exports are among the first 10 commodities earning foreign exchange for about 30 countries (*13*). Market values for hides have increased by several hundred percent in the past few years as costs of synthetics have increased and as many synthetics proved less suitable for such goods as shoe uppers.

Fertilizer — Historically, animal wastes have been a principal source of fertilizer for crop



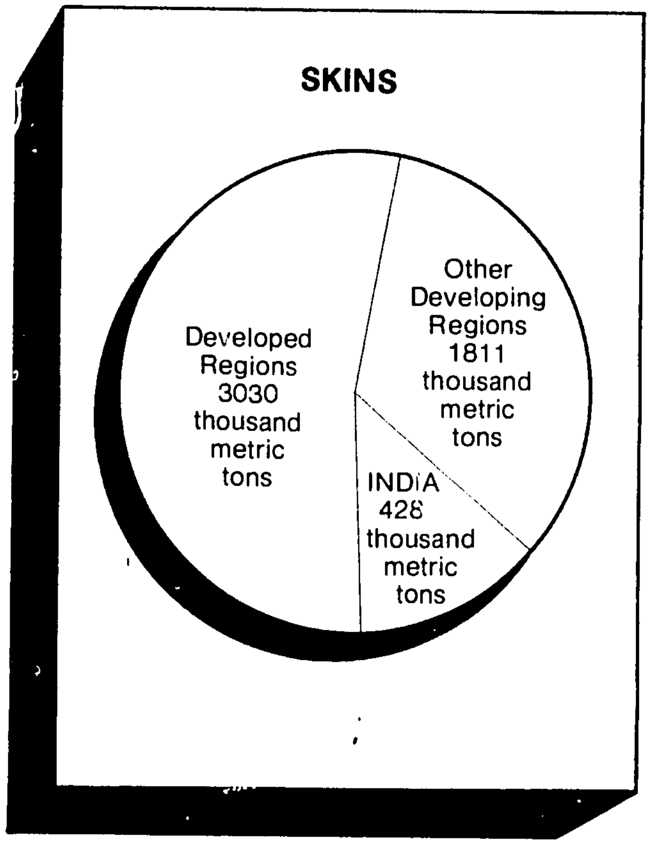


Fig. 2-1 — World production of scoured wool and cattle skins by region, 1972

and pasture land. Recent shifts to chemical fertilizer have caused some problems. The fuel energy requirement for one kg of nitrogen fertilizer is 18 to 20 Mcal, and energy costs have increased dramatically. Chemical fertilizers often lack essential micronutrients and provide no organic material to improve soil structure and permeability.

The annual production of feces and urine from ruminants contains approximately 80 million metric tons each of nitrogen and potassium and 25 million metric tons each of phosphorus and potassium. Most of this manure falls on the grazing lands. Perhaps 25 percent is voided in barns and pens from which it can be collected and spread on croplands. Under the usual conditions of storage and application of collected manure, about half the nitrogen is volatilized or leached from the land. Thus, only about 5 million MT of nitrogen is effectively utilized. Nevertheless, even this amount is valued in excess of U.S. $2 billion. Improved systems of collecting and processing ruminants manures can substantially improve the economic contribution.

Fuel — Pioneers crossing the Great Plains heated their coffee and beans over burning buffalo (bison) chips. Nomadic herders still depend on dung for their fires. Yak and llama dung are principal fuel sources in the treeless highlands. India uses 60 to 80 million tons of buffalo and cattle dung for fuel each year at a savings of $3 billion in foreign exchange which would be needed to purchase coal and oil (*13*).

Methane gas from manure has 71 percent of the energy value of natural gas. Digesters were extensively used in Europe to produce methane gas until oil became cheap in the 1950's. Today, digesters are again becoming popular where petroleum is in short supply. Estimates for the U.S. indicate manure from 40 cows could yield the energy needed by the average farm family, excluding requirements for operating trucks, tractors and automobiles (*13*).

Manure may also be recycled through the

Table 2-5. — Production of wool and fresh skins from ruminants in 1972

Product	Developed regions	Developing regions: India	Developing regions: Others	World
	1000 metric tons			
Scoured wool	1205	22	305	1532
Skins				
Cattle	3030	428	1811	5269
Buffalo	2	294	210	506
Sheep	570	32	363	965
Goats	22	65	194	281

FOR ADDITIONAL INFORMATION REFER TO APPENDIX TABLE 5.

food chain (see chapter on Feed Resources). Mixtures of dung and soil serve as building blocks. Dung and mixtures of urine and clay serve as wall and floor plaster.

Work — The history of the developed world abounds with examples of the importance of ruminants as a source of work energy. Slow but steady oxen proved the beas's of choice in pulling the great Conestoga wagons across mid-America; on arrival the same oxen pulled plows to break the virgin soil. American and Canadian loggers still spin tales about the exploits of Paul Bunyan and Big Babe, the Blue Ox.

What is history for the developed world remains the present and future for much of the developing world where up to 99 percent of the power for agriculture is provided by animals. The rice countries of Asia particularly depend on buffalo for paddy cultivation. Ruminants pull plows, power irrigation pumps, thresh the grain and transport it to the market.

Replacement of animal power with tractors and other petroleum powered mechanization will be expensive and subject to unexpected difficulties. McDowell (*13*) estimated that (a) the initial capital investment for a mechanized Tanzanian farm would be $10,300 vs. $565 for an animal-based operation, and (b) India would have to spend approximately $1 billion for gasoline to replace the animal energy used in agriculture.

Lack of wide roads through the tropical forests, across deserts or in the rugged highlands makes mechanized transport of goods and people difficult, if not impossible. Even where roads are available, there is real advantage to the poor farmer in pulling a cart or wagon with an ox that is energized by grass from the roadside rather than a petrol pump.

Recreation — Hunting wild ruminants is big business. During 1970, nearly 8 million big game hunters in the U.S. spent $953 million to kill 2 million wild ruminants, some bear and — by mistake — a few cows, sheep and goats. The African safari is a longstanding tradition, although now many hunt with cameras rather than rifles.

Ruminants are not ordinarily thought of as pets but the 4-H Club calf or lamb project and the two or three sheep and goats kept by many affluent Americans on their small acreages serve much the same purposes. Certainly, a lamb grazing in the backyard competes less with hungry man than dogs and cats eating canned meat products.

Prize breeding stock are paraded at local fairs and national exhibitions. Camels, cattle and buffalo are raced with much money gambled on the results.

Bulls are fought in the Plaza de Toros, thrown by their tail in the Venezuelan Coleaderos de Toros, ridden in the rodeo arena. The tables are turned each year when young men run before the bulls in the streets of Pamplona, Spain.

Inedible Byproducts — An earlier Winrock Report (*13*) described the multitude of other products yielded by ruminant carcasses. These include pharmaceuticals such as insulin, cortisone, estrogen and thromboplastin; buttons, glue and inedible fat products such as soap, candles, plastics and toothpaste.

Current Population and Productivity

THE 15 regions were reclassified into three major categories for presentation of ruminant productivity (Table 2-6). The "developed regions" include 1, 4, 5, 6, 10, 13 and 14; "developing regions" include 2, 3, 7, 8, 9, 12 and 15. Developing Region 11, India, is presented separately primarily because turnoff of meat from the large cattle population (16 percent of the world total) is so low. The developed regions tend to be more industrialized and located in temperate climates. Developing regions tend to be tropical, at least a substantial portion of each region. Population and production statistics for the 15 regions are presented in Appendix Tables 1 to 4.

In 1972 South America had 17 percent of the world's cattle, India 16 percent and North America 11.5 percent. India had 46 percent of world's buffaloes and 23 percent of the goats. Only Central Africa with 24 percent had more goats. Oceania had 21.4 percent of the sheep, over half again as many as the next top ranking regions of North Africa-Middle East and U.S.S.R.

Cattle were the most numerous ruminant livestock species in 10 regions; sheep numbers exceeded cattle numbers in Regions 6, 7, 10, 14 and 15. Sheep, goats and camels tended to be relatively more numerous in arid and semi-arid areas. Sheep and goats are found in other areas, but parasitism is often a limiting factor in their production on humid grazing lands. Goats outnumber sheep in Regions 2, 7, 9 and 11 but are greatly outnumbered by sheep in most other regions.

Table 2-6. — Ruminant meat and milk production, 1972

	Percent of world totals			
	Developed regions	Developing regions: India	Developing regions: Others	World totals
Cattle				
Number	36	16	48	1131[1]
Meat	72	—	28	39[2]
Milk	86	2	12	372[2]
Buffalo				
Number	1	46	53	127[1]
Meat	1	11	88	1[2]
Milk	—	69	31	22[2]
Sheep				
Number	52	4	44	1043[1]
Meat	67	2	31	6[2]
Milk	48	—	52	7[2]
Goats				
Number	7	17	76	391[1]
Meat	11	19	70	1[2]
Milk	28	10	68	7[2]
Total				
Number	32	18	50	2692[1]
Meat	67	1	32	47[2]
Milk	80	6	14	408[2]

[1] Million head.
[2] Million metric tons.

FOR ADDITIONAL INFORMATION REFER TO APPENDIX TABLES 1, 2, 3, 4.

The Sardinian sheep of Italy are a triple-purpose breed (wool, milk and meat). This breed is more important for the production of milk for use in cheese manufacturing. *Winrock International Photo.*

Approximately 30 percent of the world human population and 32 percent of the ruminant population live in the developed regions. But two-thirds of the meat and 80 percent of the milk is produced by the ruminants in the developed regions. One reason for the much greater productivity in developed regions is the lower stocking rate as shown in Table 2-7. Also, the developed regions have about 50 percent more arable and permanent pasture land available to produce feed for ruminants than in the developing regions. This contrast is even greater for India where there is less than one hectare of agricultural land available per ruminant livestock unit (*16*). Numerous ruminants in India must scavenge deserts, marshes and even urban streets in order to survive.

Although available land resources and the number of people to be served are major factors determining density of ruminant livestock distribution, other important factors are tradition, environmental adaptability, preferences and taboos. Not all of the developing regions are so densely populated and heavily stocked as those in Asia.

Nutrient Requirements and Efficiency

THE ruminant populations in each region include breeding males, breeding females, newborn, recently weaned and those ready for slaughter. Herd composition is rarely known, certainly not on a regional basis. However, 40 to 60 percent are usually breeding females (*12*). Nutrient requirements are proportional to physiological body size, $W^{.75}$, and to level of production. Approximate estimates for each type of ruminant in each region were obtained from the Winrock Ruminant System Simulation Model (17). These estimates take into account regional differences in meat and milk turnoff as well as production coefficients for fertility, survivability, activity, growth rate and mature weight drawn from the literature.

Estimated daily requirements for metabolizable energy (ME) for the "average" animal in each region were as follows:

Cattle — World average was 10.6 Mcal; values ranged from 7 Mcal in India to 14.9 in Japan.

Buffalo — World average was 13.6 Mcal; values ranged from 11.6 Mcal in India to 17.3 in Eastern Europe.

Sheep — World average was 1.8 Mcal; values ranged from 1.5 in South America to 2.4 in North America.

Goats — World average was 1.3; values ranged from 1.2 Mcal in South America to 2 in Western Europe.

These daily requirements were multiplied by the respective population numbers and aggregated across species for each region (Appendix Table 6). Although these estimates are not very precise, the ME requirements may be compared to estimates of ME availability in each region. (Appendix Table 9).

Annual ME requirement for the average ruminant livestock unit in the developed regions exceeded that for most of the developing regions by 30 percent (Table 2-7). This small difference in ME was associated with a several hundred percent increase in production of meat and milk. The average human food energy value of meat and milk per ruminant livestock unit in the developed regions was 714 Mcal *vs.* 100 and 123 for India and the other developing regions, respectively. The efficiency of utilization of ruminant feed ME for producing human food energy was nearly five times greater in the developed regions.

Feed energy requirements, food energy productions and energetic efficiencies are presented in Table 2-8 for the four principal domesticated ruminant species. No claim of precision is made for these necessarily approximate estimates; however, they appear reasonable when compared to previously reported values estimated with more precisely specified production coefficients using the same model (12).

Per head values for production and efficiency (Table 2-8) are weighted averages of country

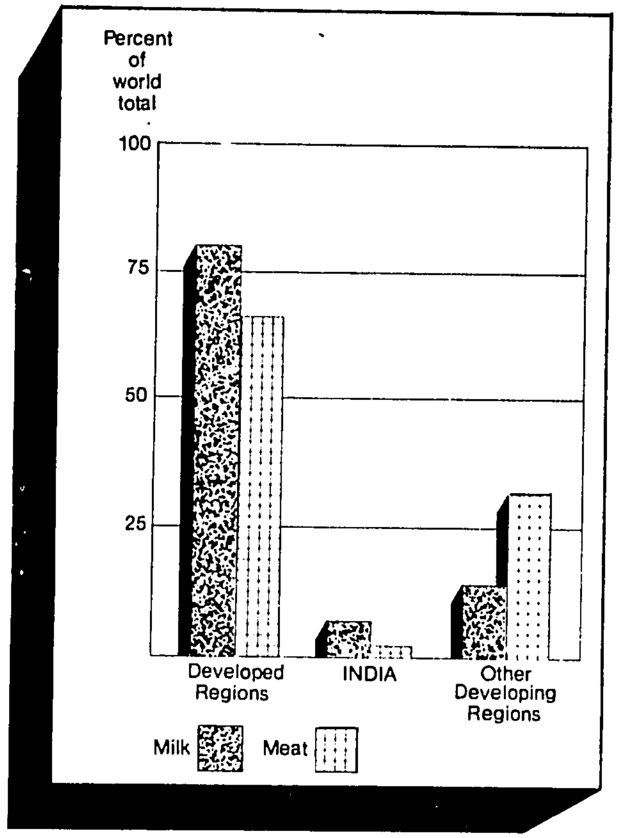


Fig. 2-2 — World ruminant meat and milk production by region, 1972

statistics. Thus, those countries with most animals have most effect on the average. For example, the efficiency values for goats exceed those for cattle in both developed and developing regions but not the world. Since 93 percent of the world's goats, but only 64 percent of the cattle, are in developing regions where productivity and efficiency are relatively low, the average for efficiency of the world population of cattle exceeds that for goats.

Estimates of human food energy values (PFV) were made from the turnoffs of meat and milk given in Table 2-6. Species in regions which produced a relatively high turnoff of milk (cattle and goats in the developed regions and buffalo in India) were noticeably more efficient in converting feed energy to food energy. Relatively fewer sheep are milked than are cattle, buffalo and goats, which is a principal reason for the lower efficiency values for sheep. Conclusions from a previous study (12) also hold here " . . . dairy systems were considerably more efficient . . . However, dairy systems tend to be both labor and capital intensive relative to meat productions . . . the problems of milk processing and preservation limit potential for commercial dairy production under extensive range conditions."

These efficiency statistics do not credit ruminant systems with the value of wool, skins and work. Work performed by ruminants in cultivation, irrigation and transport is especially important in the developing regions. Account was taken of the feed energy required to support these work activities when estimating annual ME requirements. This tends to further decrease the *apparent* energetic efficiency of ruminants in these regions.

These statistics illustrate a point which has been made many times. Highly productive ruminant systems are much more efficient converters of feed energy than lowly productive systems.

Productivity of food and fiber is commonly measured as the average yield of turnoff per head in the national or regional herd. Herds with low fertility, high disease losses, slow growth and late maturity will have low turnoff of product.

Regional turnoff of beef ranged from a low of 9 kg in Central Africa (ignoring the special case of India) to high values of 95 kg in Japan and North America — regions noted for large cattle, good management and concentrate feeding.

Beef cattle in the wet/dry tropics of Asia, Africa and South America often grow in a feast or famine environment. During the dry season, which often lasts six months or more, there are often severe feed shortages and substantial weight losses are common. Generally, cattle gain well during the rainy season although inadequate dry matter intake from the high moisture tropical vegetation is often a problem. This alternating pattern of weight gain and loss often means that it takes 4 to 5 years for an animal to reach desired slaughter weight, which is reflected in the low beef turnoffs.

Excepting North America, a high proportion of the cows in the developed world in 1972 were milked. And these cows produced 4 to 5 times more milk per lactation than cows in the developing world. Milk yields *per cow milked* ranged from 275 kg in Central Africa to over 4,000 kg in Japan and North America.

Ninety-nine percent of the buffalo were reported in the developing regions. They are a major source of work energy. Milk yields were higher than those reported for cattle, especially in India.

The production efficiency of the smaller ruminants is high and their full potential has not been realized. Shorter gestation periods (approximately, five months) and higher fre-

Table 2-7. — Productivity and efficiency of ruminant livestock units, 1972

	Developed regions	Developing regions		World
		India	Others	
Ruminant livestock units, millions[1]	389	213	594	1196
Stocking rate, ha/LU[2]				
Arable land/LU	1.7	.8	1.0	1.2
Perm. pasture/LU	3.6	.1	2.7	2.5
(Arable + PPM)/LU	5.3	.9	3.7	3.7
Total land/LU	14.8	1.5	12.0	11.1
Metabolizable energy/LU, Mcal[2]	6005	3505	4555	4916
Food production, kg[2]				
Carcass meat/LU	82	3	25	39
Milk/LU	837	112	99	341
PFV/LU, Mcal[3]	714	100	123	311
PFV/ME, %	11.9	2.8	2.7	6.3

[1] Livestock unit = 1.0 buffalo, .8 cattle, .1 sheep, .1 goat.
[2] Annual ME requirement per LU.
[3] Physiological fuel value of meat and milk in human diet.

Table 2-8. — Annual per head feed energy requirements, food energy production and efficiency of ruminants, 1972

	Developed regions	Developing regions: India	Developing regions: Others	World
Cattle				
ME[1], Mcal	4690	2525	3550	3800
PFV[2], Mcal	640	30	95	285
PFV/ME, %	13.6	1.2	2.7	7.5
Buffalo				
ME, Mcal	—	4170	5545	4890
PFV, Mcal	—	265	130	190
PFV/ME, %	—	6.3	2.3	3.9
Sheep				
ME, Mcal	710	570	605	655
PFV, Mcal	22	5	16	19
PFV/ME, %	3.1	.9	2.6	2.9
Goats				
ME, Mcal	465	450	470	465
PFV, Mcal	65	14	17	20
PFV/ME, %	14.0	3.1	3.6	4.3

[1] Annual metabolizable energy requirements per head.
[2] Physiological fuel value of annual per head production of meat and milk.

FOR ADDITIONAL INFORMATION REFER TO APPENDIX TABLE 6.

quency of multiple births contribute to the higher annual fertility of sheep and goats compared to cattle. Lambs and kids tend to be earlier maturing than calves, allowing them to reach desired slaughter weights and condition at younger ages, often at less than one year. Feeding trials suggest that sheep are 5 to 6 percent more efficient than cattle in use of energy for maintenance and growth.

The relatively small carcasses and daily milk yields of sheep and goats are an asset in regions where food preservation technology is still primitive. A family can fully utilize these "handy sized" portions of milk and meat the same day they are harvested. Free from most taboos, sheep and goats often provide the major, if not only, source of meat protein in the diet (*18*).

Numbers of ewes and does milked in each region are not known. Dairy sheep are most important in Europe and the Middle East, primarily for cheese manufacture. Few, if any of the 234 million sheep in Oceania are milked, but they do produce almost half the world's wool; most of it is fine apparel grade wool from Australia.

Ninety-three percent of the world goat population is in the developing regions, including India. Browsing low quality arid land vegetation is not conducive to high productivity but even this low productivity may sustain the poor families they serve. With good nutrition and health management, dairy goats produce about the same quantity of milk relative to body weight as high producing dairy cows.

FAO production statistics are not available for the 18 million camels, llamas and alpacas; nor for yak, reindeer and other ruminants which serve man. Generally, these are found in harsh environments, feed is of poor quality and short supply and their productivity is low. Still, the opportunity cost for their feed is also low and their products are often essential to human life where they are located.

Ruminant Resources - Realizing Their Potential

WE have seen that ruminants serve man in many ways. It is no exaggeration to say that their potential remains largely untapped. The

These brave bulls are quietly awaiting their time to fight in a bull ring in central Mexico. *Winrock International Photo.*

chapters which follow describe many of the biological and non-biological inhibitors impacting on ruminant systems. Suggestions are made as to how these inhibitors can and must be removed if the demands for ruminant products projected for the year 2000 are to be met. Failure to meet these demands will condemn the average man and his children at best to a lower quality of life and at worst to increasingly widespread hunger and malnutrition.

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16. Weightings used to convert numbers of buffalo (1.0), cattle (0.8), sheep (0.1) and goats (0.1) to a common livestock unit or biomass basis are the same as those used by FAO. This conversion is primarily useful for combining production and nutrient requirement statistics across species. Their use did yield the peculiar result in Table 2-7 that the "average livestock unit" required more metabolizable energy than did a cattle livestock unit. Inspection of ME requirements by species in Table 2-8 illustrates how this result occurred. For example, in the developed region a "cattle livestock unit" and a "sheep livestock unit" would be 4690/.8 and 710/.1 or 5862 and 7100, respectively.
17. The Winrock ruminant system simulation model was used to estimate the feed energy requirements for ruminant systems at varying stages of productivity. Specified production coefficients include growth rate, birth and mature weight, milk yield and composition, fiber growth, daily activity, conception rate, gestation interval, postpartum interval, longevity, mortality, sales, ration composition and partial efficiencies of feed conversion for maintenance and production. Equilibrium herd composition, dry matter, energy and protein requirements; and turnoff of animals, meat, milk and fiber are evaluated. Additional details on the model are given by T. D. Nguyen, and H. A. Fitzhugh. *Winrock ruminant system simulation model*, Winrock Tech. Report 1, (1977).
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NUTRIENT RESOURCES FOR RUMINANT PRODUCTION

Except perhaps in India, there are abundant world supplies of noncompetitive feed resources to support expansion of ruminant populations and production.

THE productivity of the world's ruminant livestock depends heavily on the quantity and quality of the feed they receive. If the feed supply is ample and if the digestible energy content is satisfactory, the rates of gain and the fertility levels of the animals will in turn favorably affect herd productivity. Although genetic capacity, animal health and the quality of herd management can also affect productivity, feed supply remains the single most important factor among the physical variables in ruminant livestock production.

The feed which ruminants consume is predominantly forage — a term that refers to the vegetative parts of many kinds of plants. Grasses, forbs, legumes, cereals and browse are kinds of forage which ruminants graze; however, grasses, legumes and cereals are also harvested for feeding to ruminants. Grazing and harvested forage supply more than three-fourths of the feed available to ruminants in every region of the world except North America, where it is only slightly below that figure. Ruminant livestock in many developing countries depend almost entirely on grazing supplemented by straw and stover. Ruminants in these countries may graze along roadsides and irrigation ditch banks and in wastelands. Other feeds which ruminants may consume include feed grains, milling by-products, oilseeds and meals, and crop residues.

World Land Use

SUPPLIES of various kinds of feeds for ruminants are influenced by patterns of land use. Land use and its productivity are markedly influenced by climate, topography, soil types and other factors. Major climatic factors of concern are length of growing season, amount and seasonal distribution of rainfall and temperature.

In order to assess the potential levels of ruminant production on a worldwide basis, data from the Food and Agriculture Organization (FAO) were used to establish three categories of land use (*1*). These categories are: (a) arable land, (b) permanent pasture and meadow, and (c) nonagricultural land. Under the FAO scheme, arable land includes land under annual crops; fallow; arable but idle land; temporary meadows for hay, silage, or pasture; and land planted to permanent crops. Permanent pasture and meadow refers to land used permanently (5 years or more) for herbaceous forage crops, either cultivated or growing wild, including rangelands. Nonagricultural land refers to forests (natural or planted) and other lands, including urban areas, parks and wasteland.

In 1967, the President's Science Advisory Committee (PSAC), as a part of a study of the world food problem, estimated world land areas that are (a) potentially arable, (b) nonarable with grazing potential, and (c) nonarable without grazing potential (*2*, *3*).

Land in the three categories is distributed across 33 climate types and 17 agroclimatic regions which are found within the 5 major climate zones of the world (I) polar and subpolar, (II) cold-temperate boreal, (III) cool-temperate, (IV) warm-temperate subtropical, and (V) tropical.

Climate types used are those of Landsberg *et al* (*4*). A climate type is symbolized by a Roman numeral indicating the climate zone, followed by an Arabic numeral indicating a more or less discrete climate within that zone. Agroclimatic region is symbolized by a number, indicating the length of the growing season, followed by the letter T or M indicating whether the restriction is due to temperature or moisture. Thus, the symbol 4T represents a 4-month growing season: production during the other months of the year is limited by low temperature. The symbol 6M represents a 6-month growing season with moisture limitations during the remaining 6 months of the year. There may be one or several climate types per agroclimatic region.

Figure 3-1 illustrates the distribution of climate zones throughout the world. A single climate type may be found on more than one continent and may be located in several of the 15 regions of the current study. For example, climate type IV-7 is found in North America, South America, South Africa, Oceania, China and Japan — indicating that similar climatic conditions, and thus similar production potentials, occur in these areas.

This classification system was used for this study to assess the potential levels of ruminant production from potential permanent pasture and meadow. By using unpublished data provided by USDA's World Soil Geography Unit, potential arable, permanent pasture and meadow, and nonagricultural land area was calculated for each of the 15 regions. These data, together with present land areas so utilized (FAO data), are given in Table 3-1. Potential land area in each category for the climate types occurring in each region was calculated. This was not possible for current areas in each category of land use. Distribution of potential permanent pasture and meadow by regions, agroclimatic regions and climate types is summarized in Table 3-2.

Potential arable land at 3,200 million hectares is a little more than twice the area presently used as arable. Largest increases are projected in tropical South America and Central Africa, followed by North America, North Africa and the Middle East, USSR and Oceania. No region has a projected decrease in potential arable land. Such a large increase implies substantial conversion of present permanent pasture and meadow and nonagricultural land to arable land, increased irrigation, and the use of soil conservation practices in accordance with land capability (5).

The area of potential permanent pasture and meadow is projected at 3,700 million hectares — an increase of about 23 percent, or nearly 700 million hectares. Forty-two percent of this increase — nearly 300 million ha — is in South and Southeast Asia. A sizable increase is also shown for North America; USSR and Oceania show decreases.

Even so-called nonagricultural land produces feed for ruminants: the grazing of roadsides, fence rows, forestlands and even scavenging in cities and villages. The nomadic systems of Africa and Asia developed largely as a means of utilizing the scarce forage resources of the world's deserts. Water is usually the limiting factor and the special adaptations of camels stretch even these limits.

Nonagricultural land is projected to decrease by 28 percent or about 2,500 million hectares. This must mean conversion of forest land which has better soils and suitable topography to arable lands and permanent pasture and meadow.

The magnitude of these changes represents immense shifts in resource allocations. Demand for food must become very high to cause such changes. About 24 percent of the world's land surface would ultimately be arable, 28 percent permanent pasture and meadow, and 48 percent nonagricultural compared to 11, 22, and 67 percent respectively in 1974.

Forage Resources from Permanent Pasture and Meadow

ESTIMATES of annual production potentials of permanent pasture and meadow were made for each climate type in terms of hectares per animal unit and kilograms of liveweight gain per hectare by beef cattle. These estimates were then converted to yields of metabolizable energy (ME) per hectare (Table 3-3). They are based upon research information wherever such data were available. Where research data were lacking, the consensus of a number of experienced forage and animal production specialists was used.

Production values for climate type II and most of III are based on growing and grazing periods of 2, 4, 6 or 8 months. Feed from other sources must be provided for the rest of the year. For climate types IV, V and III 10a, III 12 and III 12a, ruminants remain on the pasture year-round.

The assumption was made that average production potentials within a climate type were similar across the regions in which it occurs. This assumption is supported by research reports. Potentials of two or more climate types may be quite similar, in which case they are grouped together as in Tables 3-2, 3-3. For each climate type, or group of similar climate

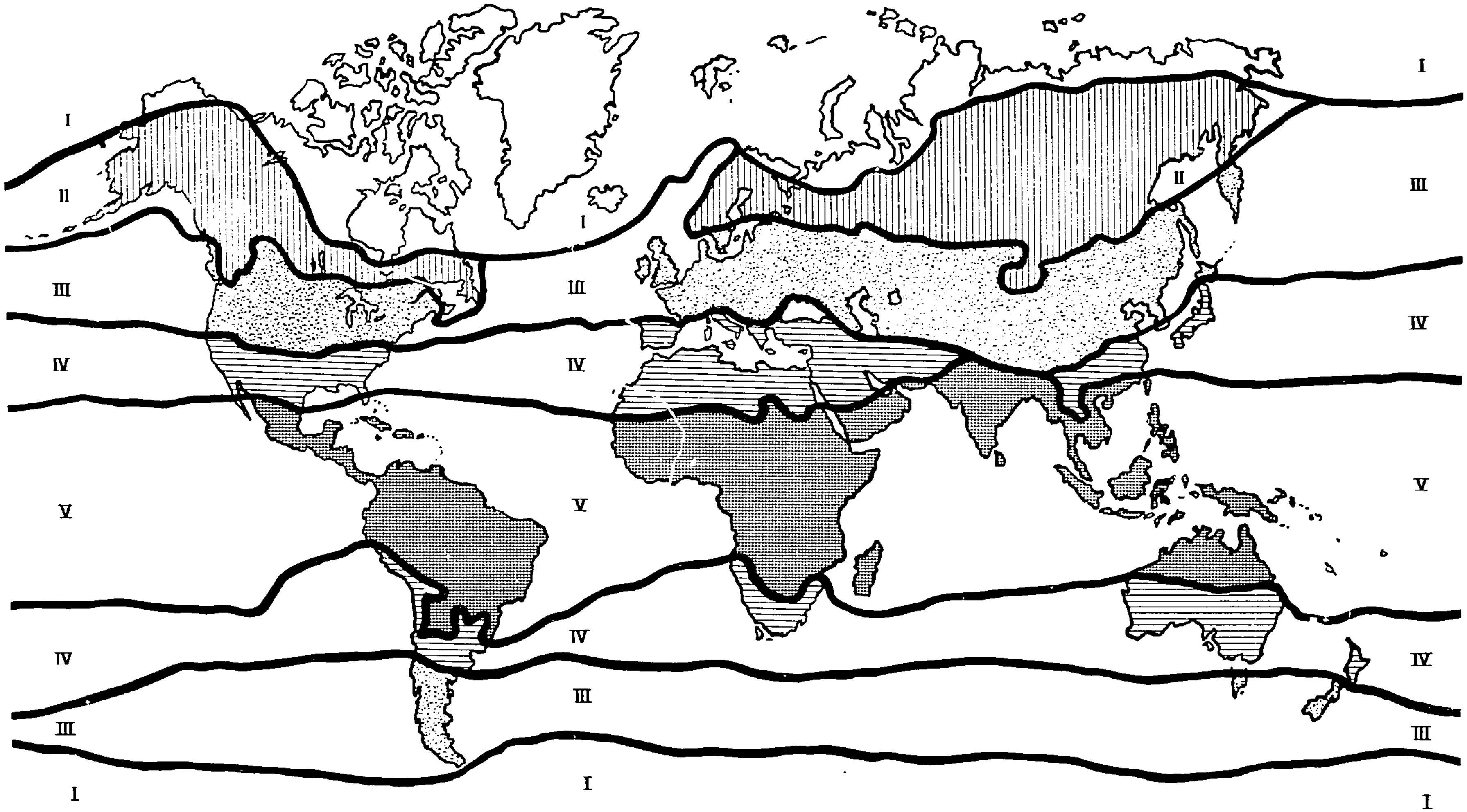


Fig. 3-1 — Distribution of major climate zones. I Polar and Sub-polar, II Cold-temperate Boreal, III Cool-temperate, IV Warm-temperate subtropical, V Tropical

Table 3-1. — Potential arable land, permanent pasture and meadow, and non-agricultural land by regions, million ha

	Developed regions[1]	Developing regions[2]		World
		India	Others	
Arable land				
Present[3]	680	165	624	1469
Potential[4,5]	1126	182	1881	3189
% change	66	10	201	117
Permanent pasture & meadow				
Present[3]	1381	13	1595	2989
Potential[4,5]	1503	53	2132	3688
% change	9	308	34	23
Non-agricultural land				
Present[3]	3713	150	4970	8833
Potential[4,5]	3097	85	3141	6323
% change	-17	-43	-37	-28
Total	5774	328	7189	13291

[1] Includes regions 1, 4, 5, 6, 10, 13, 14; generally temperate, industrialized countries.
[2] Includes regions 2, 3, 7, 8, 9, 11, 12, 15; generally tropical, agriculturally employed countries.
[3] FAO yearbook, 1974
[4] Unpublished data provided by Soil Geography Unit, Soil Conservation Service, USDA.
[5] Differences in present and potential areas due to small differences between data sources in classification and assignments among regions.

FOR ADDITIONAL INFORMATION REFER TO APPENDIX TABLE 7.

types, the production potential of unimproved or natural permanent pasture and meadow was estimated. The potentials of these lands when various levels of technology are applied were also estimated. The technologies are generalized into five levels which represent the range of practical technologies that might be applied. This does not imply that other technologies would not be applied or that all technologies are appropriate to all climate types. Much of the grazing research reviewed was conducted with yearling steers as the experimental animals, and thus 270 kg steers were selected as the reference animal unit in these calculations. These levels of production are used for both potential and current productivity calculations

The technologies in columns 1 through 5 in Table 3-3 are characterized as follows:

1. **Unimproved** — Natural grasslands or rangelands managed with negligible or very minor attempts to regulate grazing or improve productivity.

2. **Improved Management** — Application of management practices appropriate for the region. Includes practices such as the following, either alone or in combination: regulation of stocking rate, control of burning, deferred grazing systems, brush control, tree girdling, water development and similar control practices. It may include seeding or planting of improved grasses with other limited inputs.

3. **Legume oversown** — Overseeding natural grasslands with adapted legumes with limited or minimal soil disturbance and with phosphorus or potassium or other fertilizer where needed for establishment. Continued fertilization as required.

4. **Improved grass-legume** — Generally complete seedbed preparation, liming and fertilizing as needed, and seeding with improved cultivars of grasses and legumes. Continued application of fertilizers and managed grazing are usually practiced.

5. **Improved grass + nitrogen** — Establish-

Table 3-2. — Distribution of potential permanent pasture and meadow by climate type and region.

Agro-climatic region	Climate type	Developed[1] regions	Developing regions India	Developing regions Others[2]	Total
		Million ha			
2T	II 1, 2, 3	171	—	23	194
4M	III 7a	28	—	8	36
4T	III 9	59	—	2	61
4T	III 5, 6, 10, 11	205	—	181	386
6M	III 2	70	—	7	77
6T	III 3, 4, 7, 8	222	—	38	260
6T	III 4 (250-500)	20	—	—	20
6T	III 9a	3	—	—	3
8T	III 1	17	—	3	20
0M	III 10a, 12, 12a	39	—	102	141
0M	IV 5	100	1	40	141
4M	IV 1, 2, 3 (250-500)	140	5	206	351
4M	IV 1, 3 (500-750)	57	—	16	73
6M	IV 4	51	—	32	83
8M	IV 6, 7	68	—	137	205
0M	V 5	38	—	36	74
2M	V 4	127	21	252	400
4M	V 3	83	21	356	460
6M	V 2	8	4	367	379
12	V 1	—	—	332	332
Total		1506	52	2138	3696

[1] Includes regions 1, 4, 5, 6, 10, 13, 14; generally temperate, industrialized countries.
[2] Includes regions 2, 3, 7, 8, 9, 12, 15; generally tropical, agriculturally employed countries.
FOR ADDITIONAL INFORMATION REFER TO APPENDIX TABLE 8.

ment of improved grasses with incremental or annual applications of nitrogen fertilizer plus lime, phosphorus and other fertilizers as required.

Within any climate type, a range of factors — soil, topographic, temperature, exposure, moisture and others — can affect plant and animal productivity. Furthermore, a considerable range of plant species occurs naturally or may be grown. Thus, a generalized productivity average for a large and diverse area represents an integration of many factors. Attempts were made to be conservative in estimating production potentials, while at the same time providing realistic levels of productivity that could be achieved over large areas for each level of technology used.

At technology level 1, metabolizable energy (ME) yield per ha (Table 3-3) varies: in the desert areas (0 months favorable) from about 70 Mcal to about 266 Mcal; in the "2 months favorable" areas from 156 to 293 Mcal; in the "4 months favorable" areas from 195 to 1487 Mcal; in the "6 months favorable" areas from 534 to 2557 Mcal; in the "8 months favorable" areas from 2301 to 4815 Mcal. Application of technology may increase these yields ten-fold.

In order to estimate feed energy production (Table 3-4) from permanent pasture and meadow, it was necessary to estimate for each climate type the fraction of permanent pasture and meadow to which each technology might be applied by the year 2000. Very few guidelines were available to make such judgements

Table 3-3. — Estimated annual production potential of permanent pasture and meadow lands

Agro-climatic region	Months on pasture	Climate type	Technology level 1	2	3	4	5
			Mcal ME per ha				
2T	2	II 1, 2, 3	156	—	—	—	—
4M	4	III 7 a	195	264	—	—	—
4T	4	III 9	1487	1906	—	—	3858
4T	4	III 5, 6, 10, 11	297	396	—	—	2888
6M	6	III 2	2491	—	—	16603	22890
6T	6	III 3, 4, 7, 8	2557	5114	9962	12453	12453
6T	6	III 4 (250-500)[1]	534	763	—	—	—
6T	6	III 9 a	1279	2197	—	—	4823
8T	8	III 1	4815	—	—	20413	28525
0M	12	III 10a, 12, 12a	266	—	—	—	—
0M	12	IV 5	70	—	—	—	—
4M	12	IV 1, 2, 3, (250-500)[1]	492	635	1071	—	—
4M	12	IV 1, 3, (500-750)[1]	797	1181	1683	—	—
6M	12	IV 4	1683	2805	4602	15610	15610
8M	12	IV 6, 7	2301	3204	7251	18127	28045
0M	12	V 5	139	—	—	—	—
2M	12	V 4	293	369	842	—	—
4M	12	V 3	1329	2066	4006	10016	14187
6M	12	V 2	2066	2962	5438	18127	27190
12	12	V 1	3366	4602	10876	21752	36253

[1] Three-digit numbers in parentheses refer to precipitation in millimeters.

and the estimates are admittedly approximate. The fraction of permanent pasture and meadow within a climate type and in a given level of technology is presently unknown for most regions. In some climate types, technological options are very limited for ecological reasons. In others, the full range of technology is possible.

Table 3-4 contains estimates of the potential production in year 2000. These estimates greatly exceed the estimated productivity at "Technology 1". These larger estimates are predicated on the application of Technologies 2, 3, 4 and 5 on selected portions of the potential permanent pasture and meadow land.

Not all the potential permanent pasture and meadow land is suited to Technologies 2, 3, 4 and 5. Indeed, it is assumed that only "Technology 1" is economically feasible in the 2-month and 0-month areas except where irrigation is feasible. In the other agroclimatic types, application of advanced technology will depend on moisture, fertility technology costs, profitable market opportunities for ruminants and ruminant products.

Decisions by farmers to apply any level of technology are influenced by a variety of factors, many of which in some fashion determine profitability. A gross integration of all factors was attempted in arriving at the estimates of the extent to which technology levels would be applied. More detailed analyses for a region or a country than are feasible in this study would produce more accurate estimates and it is hoped that this ultimately will be done. However, these estimates together with those in Table 3-3 provide some basis for estimating reasonable levels of productivity of ruminants from permanent pasture and meadow by regions and for the world. Maximum biological potential was not estimated, as it seems quite unlikely that potential productivity would be

Table 3-4. — Feed energy resources available to ruminants

Land and type of feed	Developed regions		Developing regions: India		Developing regions: Others		World		Energy source as % of world total	
	1970	2000	1970	2000	1970	2000	1970	2000	1970	2000
	Metabolizable energy, billion Mcal									
Permanent pasture and meadow-forage	1970	1990	15	55	2835	3565	4820	5610	38	38
Nonagricultural land-forage	266	206	15	10	738	503	1019	719	8	5
Arable land										
Forage	1720	2090	415	450	980	1235	3115	3775	25	26
Crop residue	1365	1575	270	350	1310	1635	2945	3560	23	24
Grain	408	705	3	15	28	47	439	767	4	5
Oilseeds	69	147	5	5	9	12	83	164	1	1
Agri-industrial byproducts	61	83	30	65	37	67	128	215	1	1
Totals	5859	6796	753	950	5937	7064	12549	14810	100	100
Regional total/world total, %	47	46	6	7	47	48	100	100		

FOR ADDITIONAL INFORMATION REFER TO APPENDIX TABLE 9.

achieved by 2000. Such an estimate could be calculated, however, by applying the most productive technologies on larger fractions of the grazing land areas.

Productivity represents, in broad terms, potential energy offtake which could be converted, in general fashion, to productivity of other kinds, classes, or ages of livestock. In practice it would have to be apportioned to breeding herds, calves, young stock, fattening animals, milking animals or work stock in accordance with the kinds of livestock production involved.

Permanent pasture and meadow may be conveniently classed into four major climatic categories: (1) cold temperate, (2) humid, cool temperate, (3) arid and semi-arid, and (4) humid and sub-humid tropical and sub-tropical.

Cold Temperate Areas — Permanent pasture and meadow is projected to occupy 194 million hectares in climate zone II, the cold-temperate boreal zone. About 60 percent of this is in the USSR, 23 percent is in North America, and the balance distributed across the extreme northern part of Western Europe, China and Mongolia and North Korea (Table 3-2). This represents a very great increase over the area currently utilized by domesticated livestock in cold temperate regions. Most of this land is in the subarctic or taiga region and now is forested. Clearing and permanent pasture establishment costs are high. In much of the area, permafrost prevails. Human population and thus local demands for ruminant products are low, and substantial increases by 2000 are not likely.

These areas might find their best use in food production through the use of wild ruminants such as the moose (known as elk in Europe and USSR) and the caribou, or his domesticated counterpart, the reindeer. These hardy animals are uniquely adapted to converting the browse and herbs of northern areas to meat or milk. Production of these feeds could be increased by management designed to produce maximum browse. Again, the degree to which such development might occur will be determined by world food demand-supply relationships.

Humid, Cool Temperate Areas — Permanent pasture and meadow lands in these areas generally lie between latitudes 30° and 60° and usually receive more than 500 mm annual precipitation. They comprise about 10 percent of the permanent pasture and meadows of the world and are mostly within climate types III-1 through III-9. Growing seasons range from 4 to 8 months. Cool season grasses and legumes occupy these areas in contrast to the warm season grasses and legumes that grow on most tropical and subtropical pastures. Cool season species are capable of high yields with higher dry matter digestibility than most warm season species.

The humid, cool temperate permanent pastures and meadows occupy large areas of North America, Western Europe, Eastern Europe, USSR, Japan, Korea and Oceania, also some significant areas in South America and China. They usually are relegated to land not suitable to cropping, although notable exceptions occur in Oceania and Western Europe.

Soils in the humid, cool temperate zone generally are responsive to good management including application of lime and fertilizer. Rainfall is adequate for good yields. There is a large number of grass and legume species — many with improved cultivars — that are adapted to the variety of ecological niches that exist and which have high yield potential if adequately fertilized and managed. But large segments of these permanent pastures produce much below their potential because of a history of low management inputs which has resulted in a mining of fertility and a resulting take-over by inferior plant species.

Improvement technologies include liming and fertilization, renovation through establishment of improved legumes and grasses, and regulation of grazing to achieve optimum yield and digestibility of forage produced. Once the land is improved, careful grazing management, including recycling of manures on the pastures, can maintain high forage and animal productivity with minimal additional inputs. Bula *et al.* (*6*) have estimated that on some 300 million ha of permanent grazing land, full application of available technology could increase dry matter yields from 2 to 6 MT/ha/yr, dry matter digestibility from 52 to 60 percent and increase liveweight gain from 0.02 to 0.37 MT/ha/yr or milk production from 0.5 to 5.5 MT/ha/yr.

The humid, cool temperate permanent pastures play important roles in world ruminant production. The leading dairy production centers of the world are in the cool temperate zone and produce about 40 percent of the world milk production. About 40 percent of the world beef and veal and 30 percent of the world sheep and goat meat is produced in the cool temperate zone. Feed sources other than permanent pastures contribute to this production.

Most of the humid, cool temperate zone is in developed nations. Land tenure is such that increased demand or government policy can bring a rapid response when needed. Markets, transportation, communications are well developed. Public and private research programs are active. Seed and other input industries are able to supply demands of livestock producers. This infrastructure, together with additional land availability and potential for greatly increased forage production, indicate that sizeable increases in ruminant animal production are possible from humid, cool temperate permanent pastures if increased demand occurs or alternate feed sources decrease or become more expensive.

Arid and Semi-arid Areas — Permanent pastures and meadows in these areas are usually referred to as arid and semi-arid rangelands. They are located on all continents and are found mostly in climate types III 10 through III 12 (temperate zone), IV 1 through IV 5 (subtropical) and part of V 3 and all of V 4 and V 5 (tropical). They occupy significant portions of all regions of this study except Japan (Table 3-2).

These lands are characterized by low and undependable rainfall. Precipitation is erratic, and poorly distributed spatially and temporally. Droughts are common. Biological productivity is low and highly variable within and between years. Plants growing in these lands evolved by surviving under rigorous environmental conditions — a trait not usually associated with great biomass production (*7*).

Successful utilization of such lands by domesticated or wild animals, without deteriorating the resource, demands careful attention to ecological principles. Use should be restricted to capacity of lands to tolerate biomass removal without deterioration. This capacity is affected by a wide array of factors. Principles of sound management have not been recognized or practiced on many of the arid and semi-arid rangelands; in fact, they are not known for some environments.

Many rangelands throughout the world are severely deteriorated as a result of overstocking by livestock and human population. Degradation in many areas seems a relatively recent phenomenon occurring usually within one to three decades of overgrazing. Probably more than three-fourths of the world's rangelands are in fair to poor condition, producing less than half their potential, and in many cases they are still deteriorating.

Lush rainy season growth of tropical pasture provides goats with an abundance of good quality grasses. Goats are also productive under poorer grazing conditions. *Winrock International Photo.*

Because arid and semi-arid rangelands occupy such large areas of the world — about one-third of the potential permanent pasture and meadow — their productive potential is of special interest and importance. Box (7) indicates that the potential productivity in terms of red meat production is difficult to define because of an inadequate base of inventory data but that "estimates of doubling or tripling of productivity are often made and are quite believable." He further indicates that such increases in productivity will require extensive application of sound management based on ecological principles, commitment of resources to acquiring necessary inventory and data bases, research, man-power training, meeting social needs of inhabitants, and integration of these production systems with others.

Productivity from rangelands is inherently low, and investments to improve productivity seem likely to be limited to the optimum sites in most regions. Most developing countries have inadequate resources for wholesale reclamation. Oil rich nations could initiate large scale improvement programs if commitment and incentives become sufficiently strong.

During the balance of this century, significant increases in productivity from arid rangelands are not anticipated. In general, this study indicated rather limited application of improved management to these lands and, consequently, limited increase in ruminant productivity from them.

Humid and Subhumid Tropical and Subtropical Areas — Permanent pastures in this category lie within 30° of the equator and include the tropical climate types V 1, V 2, the more humid portions of V 3 and the subtropical IV 6 and IV 7. The latter grade into humid temperate grasslands nearer to the 30° parallel and have the potential for combining use of tropical pasture species in summer with temperate species in winter to increase ruminant productivity. They are principally located in South America, Middle America, Central Africa, India, Southeast Asia and Oceania, but there are sizeable areas of climate type IV 7 in North America, China and Japan. Most permanent pastures have resulted from man's activity in clearing, cultivation, burning and grazing.

Potential permanent pasture and meadow of the world in this category is estimated to be about 1 billion hectares. About one-third of this is in South and Southeast Asia; South America and Central Africa; each has about 175-200 million ha (Table 3-2). Current pas-

Cattle play an important role in the conversion of grass from arid rangelands to high quality protein (milk and meat) for human consumption. This photo was taken in northern Mexico. *Winrock International Photo.*

ture area in South and Southeast Asia is only about 10 percent of potential; thus, opportunity for expansion is quite high.

The humid and subhumid tropical and subtropical permanent pasture and meadow support about 40 percent of the world's ruminant animals: 40 percent of the cattle, 60 percent of the buffalo, 11 percent of the sheep and 37 percent of the goats (*8*). These animals produce 15 percent of the world's beef, 11 percent of the mutton and 12 percent of the milk. Thus, output per animal is low in comparison with the output from permanent pastures in the temperate zone. But almost all the feed that ruminants consume in these areas comes from permanent pasture and meadowlands.

The potential for increasing productivity on humid and subhumid and tropical and subtropical permanent pasture is very great. Australia, for example, has over 40 million ha suitable for legume establishment, which could support 30 million additional cattle. Significant increases are possible in South and Southeast Asia. Greatest potential is in South and Middle America. Grazing of sizeable areas in Africa is limited by the disease trypanosomiasis which is transmitted by the tsetse fly. Tsetse control or use of trypano-tolerant breeds of cattle could significantly increase useful grazing areas. Except for Oceania, most of the regions containing these grasslands lack marketing, credit, transportation, research and other infrastructure necessary for sizeable increases in productivity.

Forage Production from Nonagricultural Lands

THE name of this category is not borne out by its potential contribution of the ruminant feed supply (Table 3-4). The yield of forage per ha of forest, marsh and wasteland is generally slight, but what is there can be used by both domesticated and wild ruminants. Well-managed forest lands, especially in the initial development stages, are potentially useful grazing lands. Obviously, of course, young seedlings will need some protection. Even urban areas can provide some grazing for livestock along roadsides and in backyards.

Feed Resources from Arable Lands

ALTHOUGH previous studies (2, 5) attempted to define the maximum area of arable land in the world, no attempt was made to predict the rate at which land is likely to be converted to arable status. Certainly, the human population increases expected during the rest of this century would indicate an accelerated rate. On the other hand, conversion costs have risen rapidly, particularly those costs associated with energy. This added cost would tend to slow conversion. It seems likely that increasing the productivity of existing arable land will have first claim on investment capital; nevertheless, considerable conversion to arable land is expected by 2000. A recent study (*10*) projects world arable land to reach 1.6 billion hectares by 1985. If we assume that the rate of growth would continue, arable land in year 2000 would occupy 3.2 billion ha — the upper limit potential of available arable land (Table 3-1). Such a rate of development seems highly unlikely.

Ruminant feed produced on arable land includes forages — hay, silage, soilage, and pasture; cereal crops; tuber crops — potato, sweet potato, beets, cassava and others; oilseed, sugar and other crops; crop residues; byproduct feeds from processing of crops and animals for human food; and other miscellaneous products. Thus, a very wide array of plant materials produced on arable land is utilized by ruminants. Some are also utilizable by humans, but most are not. Many would create disposal problems if not utilized by ruminants.

Forage — Large quantities of hay, silage and pasture are produced on arable land, particularly in temperate climates. For example, about 34 percent of the cropland in the United States produced such forage commodities in 1973 (*11*). Forages are grown on arable land for several reasons: (a) they provide a greater economic return on investment than other crops in certain ruminant livestock systems, (b) they are grown as a cash crop of high value, and (c) they form a part of crop rotation plans for controlling water or wind erosion or to facilitate good soil management.

In areas where cold winter periods require feeding stored forages such as hay and silage, such forages are generally produced on arable land. In some intensive ruminant production systems — notably on dairy farms — animals are fed harvested forage year-round. Harvested forage is rarely used in most subtropical or tropical regions because of difficulties in preservation and storage in hot, humid climates. However, as more intensive production systems develop, including stratified systems, production of forage on arable land is likely to increase. Furthermore, most tropical regions have large areas of potentially arable land. Successful management of some soils in these areas is likely to require that forage grasses and legumes be grown in rotation with other crops. At least during the rest of this century, it appears that considerable areas of arable land will produce forages and these will contribute substantially to the total ruminant feed supply (*12*).

Bula *et al.* (*6*) in a discussion of potentials of temperate zone forages and pastures examine potential production of liveweight gain and whole milk from an estimated 55 million ha of arable land forage in the humid, temperate regions of the world. Under present management, liveweight gain and whole milk production are estimated at 0.19 and 3.6 MT/ha respectively. With adequate soil fertility, improved varieties, timely harvesting, and reduced harvest losses, production of liveweight gain and whole milk could increase to 1.56 and 20.7 MT/ha, respectively. If these practices were applied to all 55 million ha, these authors estimated liveweight gain at 85 million MT or whole milk potential at 1,138 million MT. The largest increases resulted from timely harvest and reducing harvest losses, both of which have direct impacts on forage digestibility.

Holmes (*14*) in the United Kingdom calculated targets for animal production from grazing highly productive grass pastures receiving about 300 kg N per ha at 1.7 MT liveweight gain per ha or 12.5 MT milk per ha with a stocking rate of .22 ha per 500 kg dairy cow and .10 ha per 350 kg beef animal gaining 1 kg per day. Greenhalgh (*15*) reports experimental yields of 14.8 MT milk per ha with .17 ha per cow and about 1.0 MT liveweight gain per acre at .12 ha per 350 kg animal with a

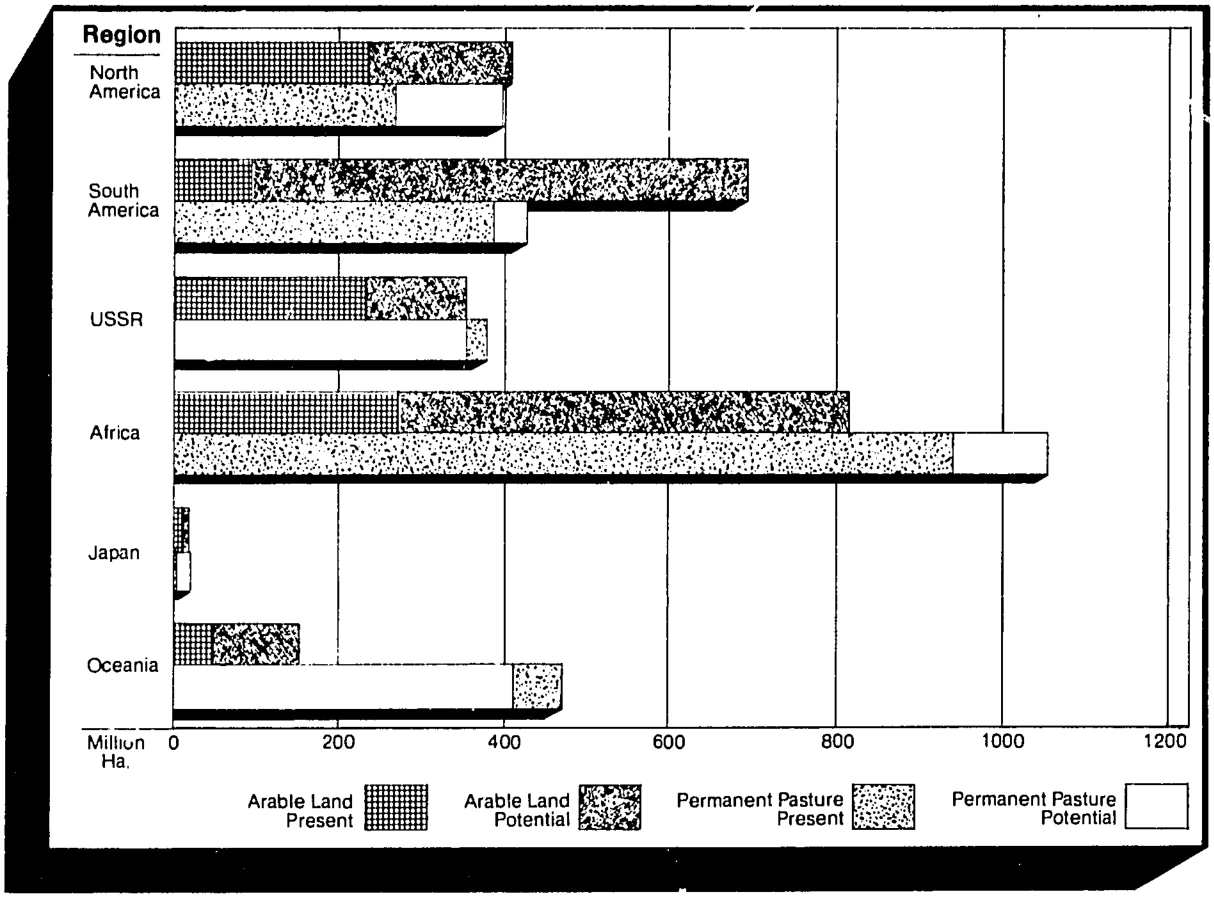


Fig. 3-2 — Present vs. potential arable land area for selected regions, 1970-2000, in millions of hectares and present vs. potential permanent pasture and meadow for selected regions, 1970-2000, in millions of hectares

daily gain of .84 kg. National stocking rates in the UK are only about .6 ha per cow equivalent, thus reflecting either lower than maximum technology use or incomplete utilization of forage or both.

In southeastern United States, Burton reported liveweight gain from an improved bermuda grass variety fertilized with 225 kg N per ha at 1120 kg per ha. If overseeded with winter annual legumes and grasses, beef production could reach 1880 kg/ha.

An extensive review by Crowder (*16*) of the potentials of cultivated forage production in the tropical and subtropical zones shows a very high potential for production of ruminant products. In the humid tropics, improved grasses, well-fertilized with nitrogen, commonly produce over 40 MT per ha of dry matter. Yields of over 100 MT have been obtained. In monsoonal tropics and subtropics, yields of 10-20 MT per ha are more common. Production potential from grass-legume mixtures with phosphate fertilizer is usually well below that of nitrogen fertilized grasses but in many instances may be more economically feasible.

Stobbs and Thompson (*17*) indicate that tropical pastures grazed at immature stages by Jersey cows should produce 1,800-2,200 kg milk per cow per lactation but only 1,000 to 1,400 kg if grazed at semimature stages (*18*). It may be necessary to supplement forage with concentrates and protein supplements to reach genetic production potentials of the better cows. Such supplements are often available as byproducts, molasses, millings.

There is substantial interest in sugarcane as a forage crop for ruminants. Many areas of the humid tropics are highly suited to sugarcane production even though local sugar processing facilities are not available. Feeding programs involving sugarcane do, however, require careful attention to protein and mineral supplementation.

The potentials of conserved forages in the tropics and subtropics have not been well established. There are many problems associated with high rainfall, low feed value of mature forages, etc. However, the potentials to increase production of milk and fattening beef animals by ameliorating the great losses in production during dry seasons are very great. Research should provide answers to many problems.

There are sizeable areas in the tropics and subtropics where elevation contributes environments suitable to production of both tropical and temperate forage species on arable land. Such areas, if adequately watered, have high production potentials for both meat and milk by exploiting forage potentials. Debilitating temperature, disease and insect impacts on livestock are also lessened.

Forage production on arable land in the arid and semi-arid zones is limited mostly to two situations, (a) irrigated land, and (b) in rotation with dry land cereal production. In irrigated production, high yielding crops such as maize, forage sorghum, elephant grass, and alfalfa generally require use of fertilizer or manures. Several crops are possible annually depending on length of growing season. Such production usually is associated with intensive dairy production or feedlot operations. Very high production is possible in such systems. Crowder (*15*) cites actual production by a farmer in Columbia of 75 MT dry matter per ha from elephant grass, enough to feed 15 milking cows also supplemented with 1 kg concentrate per 4 kg of milk, and in Ivory Coast, the same grass feeding 13 head per ha.

In dry land systems, annual reseeding of legumes has potential to produce high quality forage instead of fallow in alternate years in cereal production systems. The practice is widely adopted in Australia and has high potential in other area. with similar climate types, mostly IV 1 and IV 2. Oram (*19*) estimates some 40 million ha in North Africa and the Middle East is suited to such production. Leeuwrick (*20*) estimates production of 4 MT per ha of dry, high quality forage and enhancement of cereal production by 30 percent from such use of reseeding annual legumes in wheat-legume production systems.

High production by most any crop requires a plentiful supply of plant nutrients usually supplied by fertilizers. This is no less true for forages than it is for wheat, rice, maize, or sugar cane (*21*). These nutrients must be replaced for continued productivity. In ruminant systems, many of these nutrients may be returned to the land in manures, but not all are returned. Thus, high ruminant production from forages requires fertilization. Because fertilizer costs have risen, it is often argued that is is uneconomical to use them on forage production. But meat and milk prices have risen too, and use of fertilizers may be more profitable than not using them — provided the livestock operator fully utilizes all the forage produced.

Highly efficient animal production systems, particularly those that use legumes that contribute symbiotically fixed nitrogen to the system, may in fact export fewer nutrients from the land per unit of human food produced than many cereal production systems.

The increased use of legumes in forage-ruminant production systems has immense potential for increasing productivity of such systems. The impacts are several fold. Legumes often increase total yield and almost always increase digestibility and protein content of the forage produced. This improves fertility and increases growth rates — two important methods of increasing offtake from ruminant herds (*22*).

There is great potential to increase ruminant production from forage by using available and anticipated technology. The degree of success achieved will depend on how well forage production packages are formulated for various situations, how well producers are trained to implement those packages and how well profitability is increased.

Among all the feeds available to ruminant livestock, the forages rank as the prime source of energy and, often, of protein. This situation is not expected to change in the year 2000.

Crop Residues — Crop residues rank as the second most important feed source from arable land. In 1970, approximately 24 percent of the world ruminant feed resources consisted of crop residues (Table 3-4); in the year 2000, the percentage is estimated to be about the same.

In the past, potential feed supplies from crop residues have often been neglected, particularly in developing countries where such residues as rice bran, sugarcane tops, cottonseed, straw, and fruit and vegetable culls and wastes are often not fully utilized.

The economic extent of utilization will

depend on the profitability of the livestock industry, the opportunity cost of obtaining the residues, and the costs of processing. The economics of harvesting the primary product must also be considered with respect to availability and value of the residue. Sugar-beet mechanization and field shelling of corn have largely eliminated beet tops and cobs as feed sources in many developed regions. The introduction of short-strawed wheat and rice in Asia has reduced availability of straw for feeding there. There is need for research on crop-harvesting systems that would economically conserve a larger proportion of crop residues as animal feeds.

Research has already established the relative feeding value for ruminants for most crop residues and agricultural byproducts in the temperate developed world. Similarly, we can expect that many, still untested, residues from tropical crops can be used to raise the productivity of local ruminants. Likely prospects include residues from sugar, coffee, citrus and other fruit crops.

Some crop residues may have greater value for other uses. Rice straw in Taiwan may be more valuable in paper-making than as feed. Sorghum stalks in Northern Nigeria find frequent use as thatch and fencing. Stripping all residues from the crop land will adversely affect soil fertility and condition. Manure from ruminants utilizing residues alleviates this possible problem.

Increasing attention is being given to raising the digestibility of crop residues and to feeding them with urea or other nonprotein nitrogen sources. Studies of treatment of straw, stalks and cobs with sodium hydroxide or other chemicals indicate this technology has real potential.

Grain — Concentrated energy sources, such as grain, contain approximately twice the metabolizable energy (ME) per kg of dry matter as does grass, hay or most other forages. Since daily intake of dry matter is physically limited, concentrates can supply substantially more daily energy and protein than forage.

Ruminants with high genetic production potential for growth or milk production must have concentrates as a substantial portion of their diet if they are to perform at the level of their genetic potential. The decision as to whether ruminants will be fed concentrates, and, if so, how much, generally depends on the demand for ruminant products. For example, a considerable portion of the grain imported by Russia in the 1970's was used for their developing cattle industry.

Although the data in Table 3-4 project a small increase in the amount of grain available for ruminant feeding in 2000, the extent to which grain concentrates will be used has been and will probably continue to be an issue in discussions of the future of ruminant livestock production. It is to be expected, however, that ruminants will be fed grain so long as it is profitable to do so.

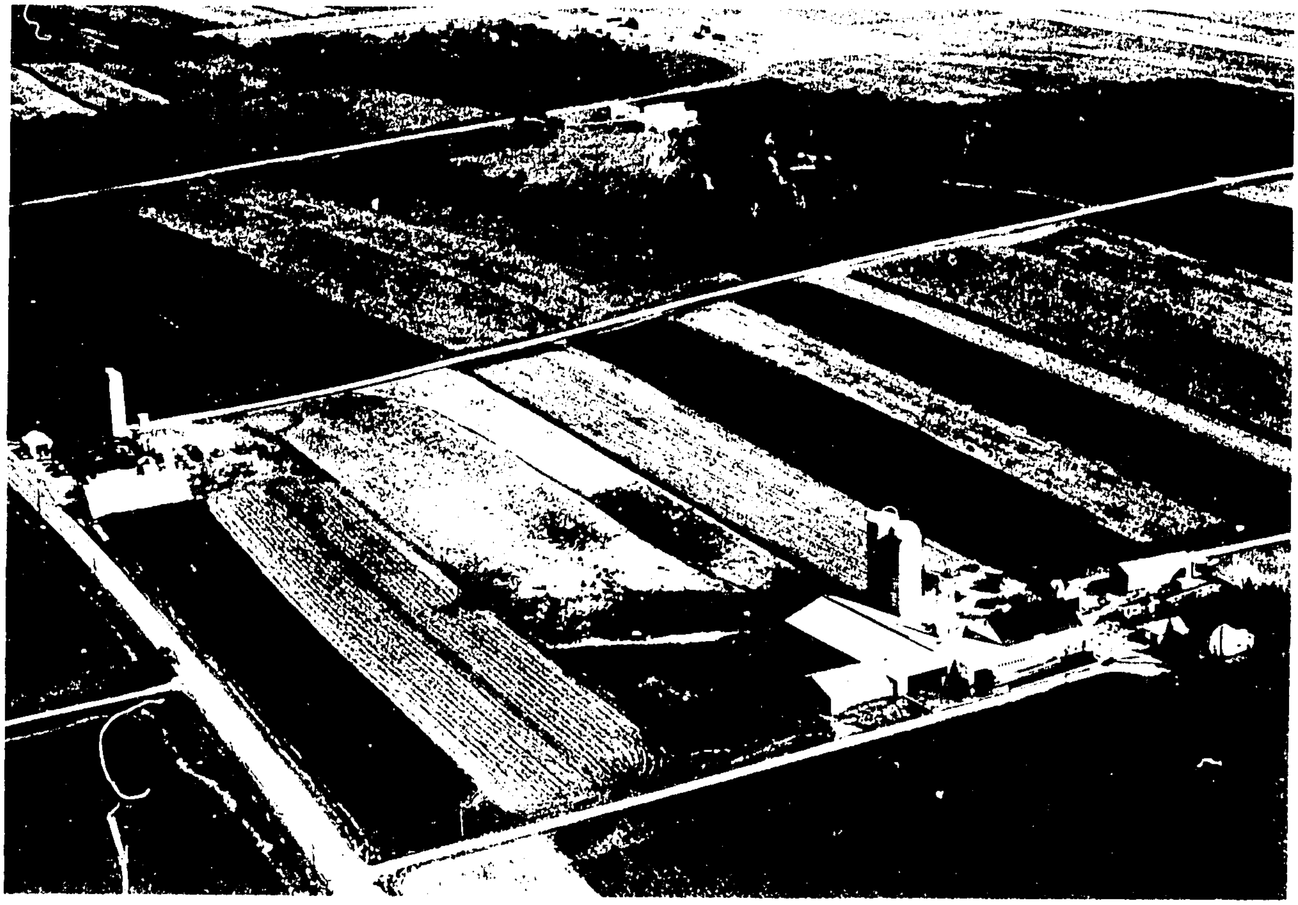
A number of studies have demonstrated favorable marginal returns from adding some grain to beef and dairy rations. Analyses based only on alternative ration costs are inadequate, particularly when applied to meat animal enterprises, because composition of the ration affects daily rate of gain and quality of meat as well as efficiency in use of feed nutrients. Daily rate of gain indirectly affects (a) the investment cost in the animal and in the ranch or feedlot; (b) labor costs; (c) the length of the period in which the animal is exposed to risks.

In countries where there is great pressure on rangeland resources, encouragement of a feedlot industry could help in adjusting stocking rates to range capacity and improve the income of livestock producers (*23*).

Ruminant meat and milk production in mixed farming zones offers much flexibility in choice of rations. Even in the short run, substitutions are possible as prices change. In the U.K. during the cereal price increase of 1973-74, total concentrates fed per milk cow dropped 12 percent from the preceding year, while silage per cow increased 15 percent. Milk production per cow declined only 2 percent (*24*). Changes in pasture and hay consumption were not reported. In the U. S. during the same period, the percentage consumption of all forage-supplied feed units increased from 75 percent to 84 percent.

In the stratified beef industry typical of the U. S., two quite independent sets of decision-makers are often involved in the production and finishing of meat animals: cattle breeders and feedlot operators.

The cattle breeder's principal fixed resource is his grazing land. He has to decide whether it is more profitable for him to use his grass to keep more cows and produce more calves, or to



Soil fertility on these dairy farms near Roaring Spring, Pennsylvania, is at the same high level as it was 200 years ago. Such evidence of good management pays off in increased feed production which ultimately increases the availability of dairy products. *USDA Photo.*

have fewer cows and hold his calves to heavier weights. If calves are high in price, he is likely to sell them early so he can produce as many calves as possible. If calf prices fall, he will be disposed to liquidate some cows and use the grassland thus released to keep his calves longer.

The feeder's main fixed resources are management and feedlot facilities. To the extent that any kind of feeding is profitable, he will vary his feeding program in accordance with changes in the price of concentrates, prices of feeders and prices of finished animals. In reaching decisions, he will keep in mind the variations in feed conversion efficiency associated with age, weight and condition of animals and the premium available for a change in grade. If concentrates are cheap, he will want to buy younger animals and feed them for a long period. If concentrates are expensive, he will reduce the feeding period, perhaps carrying animals just long enough to bring the carcasses to a higher grade or preferred market weight. There is no fixed pattern of specialization between livestock production on grass and on concentrates. With high-priced grain, fewer animals are fed and for a shorter period. With cheap grain the reverse is true, but it is not likely that demands for direct human consumption of grains will bid the price up so high as to preclude all grain feeding in those regions of the world where it is customarily done.

Cassava also is important as a concentrated source of metabolizable energy for ruminants, particularly in some tropical countries. World production of cassava in 1974 was 105 million metric tons (*1*). Somewhere between 10 and 20 percent is estimated to be used as feed. Use of cassava products, mainly for animal feeds, in the European Economic Community grew from 413,000 MT in 1962 to 1,900,000 MT in 1973. Further expansion in production and feed use is anticipated in Europe and other

A variety of plant life existing under arid conditions provides feed for browsing goats. *Winrock International Photo.*

regions as well. By 1980, Latin America and the Far East are expected to have substantial surpluses over human demand for export or domestic use as feed (*25*).

Oilseed Meal — The solids remaining after extraction of vegetable oils from oilseeds — soybean, cottonseed, peanut, linseed, safflower, sunflower, castor, copra and others — are a high energy, high protein food source for animals and man. Soybean products have made some headway as meat and milk substitutes. However, the second major oilseed processed in the U. S., cottonseed, contains gossypol which inhibits vitamin A activity in nonruminants but not ruminants. Of the total soybean and cottonseed meal used in 1968-70 U. S. animal feeds, 28 and 55 percent, respectively, were used for ruminants (*31*). Only in North America and Europe were oilseed meals estimated to be a significant portion of the ruminant diet (Table 3-4).

Cassava and the oil meals are complementary in rations. Cassava serves as a source of starch but provides little protein; oil meals are excellent protein sources. A rise of either cassava or oil meals prices relative to grain will reduce the feed demand for both cassava and oil meal. Similarly, a relative rise in price of grain will depress demand for grain and strengthen demand for cassava and oil meal. Low-priced starch, as from cassava or sugarcane, and a low-cost protein source from oil meals could open new feeding opportunities. Several developing countries are not utilizing their oilseed production fully or are exporting oil meals that might be used in domestic production. But livestock prices must be adequate to bid meals away from the export market or justify the cost of oil meal processing and handling facilities.

Agri-Industrial Byproducts

BYPRODUCTS from processing agricultural crops include molasses, bagasse and pulp from sugar crops; bran and millings from grains; and seeds and bulk from cotton ginning. Molasses is a highly palatable source of readily fermentable energy for use with nonprotein nitrogen. Molasses-urea supplements increase both intake and nitrogen retention of ruminants fed low quality forages.

Even more exotic industrial byproducts have been tested as energy and protein sources for ruminants, including shredded newspaper and sawdust (*28*). Generally, such low quality feeds cause production to drop if they exceed 10 percent of the daily diet. Much more promising is the use of single cell protein, animal waste and byproducts, including manure, garbage, soiled bedding, feathers and tankage (*30*). These wastes are a source of both energy and nitrogen for protein synthesis in the rumen. Disease transmission and toxic buildups of metabolites such as copper are potential problems from recycling human and animal waste; however, waste treatments are being developed to avoid such problems.

Relative Importance of Energy Sources

THE estimates of feed energy resources in Table 3-4 are of two types. Values for forage, crop residues and byproducts are for energy available to, but not necessarily utilized by, ruminants. In fact, comparisons of regional energy requirements (Table 3-5) and availability (Table 3-4) show that less than 50 percent of the estimated available energy in developed and developing regions was required by domesticated ruminants in 1972. Only in India were energy requirements and availability essentially equal.

The other type is the estimated energy from feed grains and oilseed meals fed to ruminants.

Statistics for the U. S. indicated that grains and protein concentrates provided approximately 29 percent of the feed units consumed by cattle, sheep and goats in 1972 (*13*). Our projections suggest that grain and oilseeds provided 20 percent (477 billion Mcal) of the total energy requirements (2336 billion Mcal) of ruminants in the developed regions. Since concentrate feeding is more prevalant in the U. S. than in other countries of the developed regions, these estimates are compatible and supportive of each other. Less than one percent of the feed energy requirements (Table 3-5) for ruminants in India and other developing regions were estimated to be from concentrates. Little change in these feeding patterns is expected by 2000.

The obvious conclusion is that, excepting India, there are abundant supplies of noncompetitive feed resources available to support expansion of ruminant populations and production.

Other Nutrients

WATER requirements vary with species, age, productivity, type of feed and climate. Rapidly growing or heavy milking ruminants consuming dry feed or grass, especially in hot climates, often require water daily in excess of 10 percent of their body weight. On the other hand, ruminants grazing lush pastures may obtain their entire water requirement from the forage. Some wild ruminants, such as Grant's gazelle, rarely visit the watering holes — a definite survival advantage since predators tend to take their prey near such concentration points.

Large quantities of forage go unused each year because adequate supplies of drinking water are not available. As a matter of fact, the opening of much of the western U. S. rangelands to cattle and sheep production was in large part attributable to the use of windmill water pumping systems. In direct contrast, however, the drilling of new water wells in the arid African rangelands has brought mixed results. The resulting expansion of herds and flocks has led to overgrazing in the vicinity of watering points and destruction of the fragile ecological balance. Over time such areas take on desert-like qualities.

Ruminants generally require 3 to 4 units of water for every unit of feed dry matter. Thus, lack of sufficient water of good quality will reduce feed consumption and contribute to a concomitant decrease in productivity.

Minerals — Minerals serve several essential functions, including skeletal development, augmenting enzymatic activity, catalyzing important life functions and regulating osmotic pressure and pH of intestinal and systemic fluid . Fifteen minerals must be provided in the ruminant diet: calcium, phosphorus, sodium, chlorine, potassium, magnesium, sulphur, cobalt, copper, iodine, iron, manganese, zinc, selenium and molybdenum.

Mineral deficiencies may lead to dramatic problems such as rickets (lack of calcium and phosphorus), muscular dystrophy (selenium deficiency), depraved appetite (phosphorus, sodium, sulphur deficiency), hyperirritability (magnesium deficiency) and goiter (iodine

Table 3-5. — Metabolizable energy requirements for ruminants in 1972

Ruminant	Developed regions	Developing regions: India	Developing regions: Others	Species total	% of World
	Billion Mcal				
Cattle	1937	452	1912	4301	74
Buffalo	2	242	377	621	11
Sheep	385	23	277	685	12
Goats	12	31	139	182	3
Regional total	2336	748	2705	5788	100
% of world	40	13	47	100	

FOR ADDITIONAL INFORMATION REFER TO APPENDIX TABLE 6.

deficiency). Deficiencies sharply reduce productivity and usually increase the animal's susceptibility to diseases.

Grazing animals generally obtain adequate amounts of minerals, except where soils — and thus plants growing in them — are deficient in one or more minerals. Soils deficient in phosphorus, iodine, cobalt, iron, copper and zinc have been reported. These minerals must then be provided as supplements, if ruminants are to perform successfully. On the other hand, selenium, cobalt, molybdenum and copper, when consumed in excess, are toxic to ruminants.

Vitamins — In general, ruminants that consume natural feeds do not need vitamin supplementation. Rumen microflora synthesize B-vitamins and vitamin K. Unlike man, ruminants can synthesize their own vitamin C needs. Occasionally, vitamin deficiencies may occur. Green plants provide carotene, a precursor for vitamin A. However, during extended droughts or other conditions where ruminants do not consume adequate carotene, they will become blind and develop other symptoms of vitamin A deficiency. Cobalt deficiency inhibits B_{12} synthesis.

Non-protein Nitrogen — Nitrogen fixation by plants is a major research priority area, primarily because of the increased cost of nitrogen fertilizer. The rumen microflora also "fix" nitrogen to produce valuable food protein; manure is a byproduct. Indeed, a question worth careful analysis is the relative value of using nitrogen directly on the land as a fertilizer or first feeding nitrogen to ruminants to produce food protein and manures for fertilizer. No doubt the answer will vary with the type of production environment, crop and other factors. High technology, capital-intensive monoculture systems in the developed regions will likely continue application of nitrogen fertilizer. It may be the labor intensive, mixed crop-livestock systems of the developing world which can best benefit from feeding nitrogen to ruminants, especially when combined with crop residues treated to improve digestibility and agricultural byproducts, such as molasses, copra and rice bran.

Urea is the nonprotein nitrogen source usually fed. The approximately 800,000 tons fed in the U. S. in 1973 provided the equivalent of 4.5 million tons of 50 percent protein supplement (*27*). On entering the rumen, urea is hydrolyzed to form ammonia which is then incorporated into microbial protein. But the microbes need considerably energy to fuel their own growth. Without a source of highly digestible energy available to the microflora, urea will be poorly utilized and may even accumulate to levels toxic to ruminants. In fact, the usual guideline is that nonprotein nitrogen should supply no more than one-third of total dietary nitrogen.

Feed Additives — Most feed additives are not nutrients but rather they function to enhance productivity — either by stimulating faster growth rate, more efficient digestion, better health or increased appetite. Some additives, such as diethylstilbestrol (DES), a synthetic estrogen, increase growth rates and efficiency as much as 10 to 20 percent. Concern that high doses of DES are carcinogenic has generated much controversy about the continued use of DES in animal feeds. Monensin, a narrow spectrum antibiotic, has been shown to improve feed efficiency by reducing food intake without changing growth rate. Other antibiotics are fed at low levels as a prophylactic measure against diseases such as "shipping fever;" however, there is concern that such usage may lead to strains of bacteria that are resistant to antibiotic treatment. Such resistant bacteria could pose a significant human health threat.

Social, legal and political disputes in the U.S. regarding use of feed additives have probably generated more heated discussions in recent years than any other question involving ruminant agriculture.

The World Outlook

PREDICTIONS or assumptions as to the world outlook for ruminant feed resources in the years ahead must necessarily be predicated on the fact that the forages and crop residues will remain high on the list of available sources. And of these two sources, permanent pasture and meadow will continue to rank first — at least on the world basis, although in some countries production of forages from arable lands will be higher than that from pastures and meadows. Note, however, that total area of permanent pasture and meadows is estimated to be only slightly higher in 2000 than it is at present (Table 3-1). Because total permanent pasture area is only slightly larger, most of the increase will be due to wider use of applied technology. But inasmuch as advanced technology has been applied to less than 8 percent of total permanent pasture and meadow, it is clear that a tremendous reservoir of untapped ruminant production potential exists (*26*).

Overseeding grasslands with legumes, establishment of grass-legume mixtures, and the use of improved grasses with nitrogen fertilizers on only modest areas of the permanent pasture could increase offtake of ruminant products immensely. Proponents of pasture improvement for ruminant production generally agree with Hutton (*9*) who stated: ". . . intensive systems of livestock production based on grasslands are the more efficient, producing greater quantities of animal product per unit of land, labor and capital invested, while prices per unit of milk and meat protein are one-half to one-quarter as expensive as when produced within feedlots."

Feeding grain and other concentrates does improve productivity of meat and milk per ruminant unit. Concentrates also effectively raise the feed value of forages and other lower quality feedstuffs. In actual practice, the amount of grain fed to ruminants will be determined on economic grounds. Regional differences will continue largely because of regional differences in grain supply and local human needs, taste preferences and buying power.

Crop residues, otherwise unusable by humans, are an important source of feed for ruminant animals. Here, sheep are seen eating corn stover. *Winrock International Photo.*

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   In this report, we use the FAO terminology; the present area in each category refers to FAO data and potential area refers to PSAC data. It appears that potentially arable includes some land currently in the permanent pasture and meadow and nonagricultural categories. The areas of each that are potentially arable are undetermined. Similarly, some potential permanent pastures and meadows are currently nonagricultural; the amount is undetermined.The permanent pasture and meadow category carries special significance in this report because of its very great importance as the feed source for ruminant livestock and because very limited data are available on these lands in most of the world.
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   I. *Polar and Subpolar Zones;*
   II. *Cold-temperate Boreal Zone* with: 1) oceanic boreal climates, 2) continental boreal climates, 3) highly continental boreal climates;
   III. *Cool Temperate Zones* with Woodland Climates: 1) highly oceanic climates, 2) oceanic climates, 3) suboceanic climates, 4) subcontinental climates, 5) continental climates, 6) highly continental climates, 7) humid and warm summer climates with humid winters,

and 8) permanently humid warm summer climates, and with Steppe Climates: 9) humid steppe climates with cold winter and with mild winters, 10) dry steppe climates with cold winters and with mild winters, 11) humid-summer steppe climates with cold winters, and 12) semi-desert and desert climates with cold winters and with mild winters;

IV. *Warm-temperate Subtropical Zones* with: 1) dry-summer Mediterranean climates with humid winters, 2) dry-summer steppe climates with humid winters, 3) steppe climates with short summer humidity, 4) dry-winter climates with long summer-humidity, 5) semi-desert and desert climates, 6) permanently humid grassland climates, and 7) permanently humid climates with hot summers;

V. *Tropical Zone* with: 1) tropical rainy climates, 2) tropical humid-summer climates and with humid winters, 2) tropical humid-summer climates and with humid winters, 2) wet and dry tropical climates, 4) tropical dry climates and with humid winters, and 5) tropical semi-desert and desert climates.

5. These 1967 estimates for arable land were 20 percent larger than any previous estimate (2). More recently, Buringh *et al.* of the Netherlands estimated the world's potential arable land at about 3.7 billion hectares. No estimate of the extent of grazing lands, or their production potential, was attempted in that study. Buringh, P., H. D. J. van Hiemst, and G. J. Staring. *Computation of the Absolute Maximum Food Production of the World.* (Agr. Univ., Wageningen, The Netherlands. 1975).
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RUMINANT HEALTH

The burden is on man to provide needed health care to the world's herds.

LOSSES from morbidity and mortality among ruminant livestock are conservatively estimated at $10 billion annually. Or, stated another way, diseases and parasites kill more than 50 million head of cattle and water buffalo and 100 million sheep and goats each year. Production losses in both quality and quantity of meat and milk from sick and unthrifty animals represent an even greater loss. The world can ill afford such losses when so many people are denied the quality of diet required for leading normal, productive lives. The mandate facing agriculture — and world governments — is simply this: Improving animal health must have high priority in every region of the world.

Occasional outbreaks of diseases with very high mortality rates, such as anthrax, generally lead to prompt and effective action. However, diseases that are chronic, slow in action and cause long periods of productivity loss, such as brucellosis and mastitis, often continue untreated or with only token control.

Maintaining an acceptable degree of health and physical normality among the world's ruminant herds requires personnel and action at several levels. The first action should be aimed at the public health level — both human and animal health. Regulation of animal movement within and across national boundaries to prevent spread of disease and parasites is an essential function. Another important function is the inspection of facilities and procedures in the preparation and processing of milk and meat products. In the absence of such a guardian function, humans may become infected with such pathogens as Brucella and Salmonella. Another equally important function is the operation of facilities for processing, storing and distributing supplies of vaccines, drugs, pesticides and disinfectants — and, of course, the diagnosis and identification of diseases and parasites and prescriptions for treatment. Such facilities and services may be public or private. In either case, they require trained, competent veterinary and other professional technicians.

Treatment of animal health problems at the field level includes direct participation with pastoralists, dairy operators, farmers, smallholders and other proprietors of livestock enterprises in such activities as vaccination, parasite control, quarantine, sanitation, and administration of drugs. These services require both veterinary supervision and participation.

More emphasis is needed on preventative action to limit the development and spread of diseases. Undernutrition and malnutrition increase susceptibility and weaken the ability of infected animals to recover.

Successful health programs require supervision and coordination to assure that the correct procedures are used and that the producers actually do what they are supposed to do. Perhaps, what is needed in the developing countries is a system of "para-vets" to carry on either in the absence of veterinarians or until they arrive. Such technicians could assist herdsmen and shepherds in such tasks as vaccination, worming, insect and pest control. Cooperation among animal health and husbandry technicians, including those performing artificial insemination, might save transportation costs and assure more timely herd visits. Technicians could perform a valuable function in observing and reporting sickness in herds and collecting and delivering specimens to laboratories for diagnosis with proper safeguards for preservation of such materials.

Many ruminant health problems go unnoted either because the animals are managed in such large of numbers or have so little individual value that veterinarians do not have an opportunity to observe them. Table 4-1 lists cattle

Table 4-1. — Cattle diseases reported to occur frequently in designated regions

Disease	Region														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Virus															
Foot-and-mouth disease			+			+	+		+		+	+			
Vesicular stomatitis	+														
Bovine viral diarrhea	+														
Infectious bovine rhinotracheitis	+														
Leucosis	+														
Lumpy skin disease										+					
Paralytic rabies		+	+												
Bacteria															
Mastitis	+	+	+	+	+	+		+	+	+	+	+	+	+	+
Brucellosis		+	+			+			+	+	+				+
Salmonellosis	+			+		+				+	+				
Blackleg	+	+	+						+		+				
Pasteurellosis	+	+									+	+			
Tuberculosis		+	+		+						+				
Leptospirosis	+		+												
Anthrax			+						+						
Pleuropneumonia									+						
Vibriosis										+					
Protozoan															
Babesiosis		+	+					+	+	+	+	+			
Anaplasmosis		+	+						+	+	+				
Theileriasis								+	+		+				
Trypanosomiases									+		+				
Trichomoniasis			+												
Helminth															
Liver fluke		+		+	+	+		+	+	+	+	+	+	+	+
Tapeworm			+		+			+	+	+	+			+	
Arthropod															
Warbles	+				+						+				+
Mange								+	+		+				+

Source: *Animal Health Yearbook, 1974.* FAO-WHO-OIE. Italy, 1975.

diseases reported with moderate to high frequency in one or more of the 15 regions of this study (*1*). More details are generally available for cattle than for other ruminants; less detail is available for the frequency of sheep and goat diseases.

The diseases listed in Table 4-1 and those briefly described in the following section actually represent only a sampling of ruminant health problems. As might be expected, the degree and type of problems vary considerably from one country to another. Consumers living in countries where they can avail themselves of a bountiful supply of wholesome ruminant food products may consider themselves fortunate. On a worldwide basis, however, the situation is not so favorable — a fact borne out by the magnitude of the production losses cited earlier in this chapter. On the other hand, when one considers the wide variety of factors contributing to disease and parasite conditions, the picture could be worse. Many diseases are influenced by the environments and climates in which the animals live. Malnourished and undernourished animals are much more susceptible to health problems. Sub-standard management of the herd can also adversely affect animal health.

The importance of the health status of the world's ruminants cannot be easily brushed aside; hence the inclusion of this chapter in Role of Ruminants. For ruminants can contribute to the support of man only to the degree for which they are physically capable. And for the most part, the burden is on man to provide the needed health care to the world herds.

Diseases affecting ruminant livestock can be broadly classified as those caused by viruses, bacteria, protozoa, helminth parasites, arthropod parasites and by metabolic disorders. Some of the major diseases are discussed (2).

Viral Diseases

Foot-and-mouth disease is an extremely contagious disease characterized by high fever and blisters in the mouth and on the feet. These painful eruptions affect movement and eating and, thus, productivity. Although mortality rates are low, morbidity rates approach 100 percent.

The virus remains in milk and meat, even when frozen. It may be spread by wind or rainfall or runoff. Birds may carry the virus over long distances. Movement of infected animals and meat products from infected animals are the usual causes of the spread of the disease. Travelers may also carry the disease organism on their clothing.

Outbreaks of foot-and-mouth disease in countries where the disease is not already entrenched are generally eliminated by slaughter of all infected and exposed animals. This dramatic prophylactic measure has been effective in countries such as the U.S. and Great Britain. Embargoes against imports of animals or meat products from areas where foot-and-mouth disease is endemic usually accompany the slaughter programs. In regions where the disease is well entrenched, vaccination programs are normally followed.

Bovine viral diarrhea is characterized by lesions of the intestinal wall and by severe diarrhea. Young calves, cows in late pregnancy and yearling cattle (especially those in feedlots) are most susceptible. The epidemic form of the disease is associated with severe morbidity rates up to 100 percent but mortality is fairly low (6 to 8 percent). A sporadic form may yield death rates of 80 to 90 percent. Exposure generally leads to lifetime immunity. Vaccination is recommended for calves from herds with low immunity if they are likely to be exposed to the disease; for example, when moved to feedlots and mixed with cattle from other herds.

Infectious Bovine Rhinotracheitis is a highly infectious disease causing fever, nasal discharge and abortion. Mortality is low (2 to 3 percent); however, cattle in feedlots may show morbidity rates up to 30 percent. Isolation of sick animals limits transmission of the disease. Vaccination of heifers prior to breeding is often practical in herds where incidence of disease is high.

Leucosis is the most common form of cancer in cattle. It affects many vital tissues and organs, including lymph nodes, spleen, liver, bone marrow and kidneys. Leucosis is thought to be a viral disease. Treatments used for leukemia in other species may prolong life, but are generally not economically feasible for cattle. Research on bovine leucosis has relevance to control of human cancer.

Paralytic Rabies. Vampire bats in Middle and South America are a principal vector for this viral disease. Estimates of annual cattle deaths due to bat-borne rabies exceed one million head. But the means to resolve this serious problem has been developed through systematic research on the life style of the vampire bat. Whole colonies are being eliminated by coating the fur of captured bats with an anticoagulent drug. When released to rejoin the colony, the habit of mutual grooming leads to ingestion of the drug and subsequent death for many of the colony members. Another control procedure requires injection of the anticoagulent into the blood of potential livestock victims. Bats

Sheep being treated for internal parasites at a demonstration center in central Tunisia. This type of improved herd management is needed in many developing regions of the world. *FAO Photo.*

drinking the blood of treated livestock soon die (*3*).

Pox diseases. Cow pox is a relatively mild viral disease affecting the teats and udders. The cow pox virus is immunologically similar to those used to develop vaccines for smallpox. The effects of sheep and goat pox are relatively more severe, leading to blisters on nostrils, lips and other exposed skin areas; internal lesions may develop. Death losses may exceed 50 percent, especially among sheep.

Contagious Ecthyma is a viral disease of sheep and goats, often called sore mouth or orf. Lesions develop on the lips, especially of young animals. Ewes and does nursing infected young may develop lesions on their udders. Vaccination is often an effective preventative measure. The virus may be transmitted to man, usually causing lesions on the hands and face.

Blue tongue causes serious loss of weight, abortion and breaks in the fleece staple of sheep. It is widespread in Africa, U.S.A. and parts of Europe. Cattle, goats and wild ruminants may also be infected.

Concern about the effect on the Australian sheep industry is a major reason for restriction against importation of breeding stock (cattle as well as sheep) from any country where blue tongue is endemic. This restriction has had special impact on U.S. cattle breeders.

Bacterial Diseases

Mastitis is the most frequently reported ruminant disease. The disease is characterized by inflammation of the mammary gland. In its peracute form, glandular swelling is accompanied by heat, pain and abnormal secretions. If left untreated, the mammary gland may become hard and nonfunctional. Mastitis is a major cause for culling dairy females as well as significantly reducing milk production and quality.

Mastitis is commonly caused by *Streptococcus agalactiae*, a bacterium that must reside in the mammary gland to remain alive. Onset of the disease is stimulated by poor hygiene, poor milking management and teat injury. Calves fed contaminated milk may infect others by suckling their immature teats.

S. agalactiae may be eliminated by treatment with antibiotics. For several days following such treatment, the milk from the treated udder may contain traces of the antibiotic rendering the milk unfit for human use. *S. agalactiae* may cause mastitis in goats as well as cattle. Mastitis in goats was reported in all regions except China and Japan.

Mastitis may be caused by other organisms, such as *Staphylococcus aureus*, which may be more difficult to eliminate than *S. agalactiae.* Strict sanitation of milking procedures and equipment is essential for controlling mastitis in infected herds.

Mastitis in sheep was reported from 90 countries in 13 regions, all except Japan and China. *S. aureus* and *Pasteruella mastitides* may cause gangrene, sometimes called bluebag.

Brucellosis occurs in most ruminant livestock species. The disease is generally acquired by ingestion of infected placental tissues and milk. It is transmissible to man causing undulant or Malta fever. Brucellosis of cattle is generally caused by *Brucella abortus*; brucellosis of goats is caused by *B. melitensis*, the pathogen of Malta fever in man. *B. abortus* in cattle was reported from 128 countries in 14 regions. *B. abortus* in sheep was reported in 29 countries in 11 regions. *B. melitensis* in goats was reported in 39 countries.

The diagnosis of brucellosis is made by the serologic examination of milk or blood. An antigenic test, "the milk ring test", is available for identifying infected dairy herds. Samples of milk from each herd are tested; milk from infected herds reacts positively. In beef herds, screening may be accomplished by randomly sampling animals at auction or slaughter facilities. These screening tests may be followed by blood testing of individual animals in infected herds in order to identify and eliminate infected animals.

Brucellosis may be eliminated by test and slaughter procedures. When infection is general among flocks and herds, vaccination is used to control the disease. A low percentage of vaccinated animals may continue to react to tests for brucellosis. Losses from abortion reduce productivity of infected females and cause substantial reduction in productivity of infected flocks and herds.

Salmonellosis (paratyphoid) is a widespread disease occurring in all ruminants. Its effects include development of gross intestinal lesions, profuse diarrhea, abortion, high death rates up to 100 percent and chronic debilitation. Salmonellosis is a common human disease. Ingestion of water and feedstuffs contaminated by feces from infected animals is the principal method of transmission.

Blackleg, caused by *Clostridium chauvoei*, is an acute febrile disease of cattle and sheep that is worldwide in distribution. Spores of the pathogen persist in soil for years. Transmission is by infection of skin wounds and abrasions or through internal body membranes of mouth, gut and respiratory system. Outbreaks in sheep flocks may follow shearing. The disease causes fever, lameness and gas filled swellings. It is usually fatal. Prophylactic vaccination, especially of young calves, is a useful control measure in infected areas. Blackleg was reported in cattle from 116 countries in 14 regions and in sheep in 72 countries in 12 regions.

Pasteurellosis is a broad term covering two basic types of diseases. A severe form often called hemorrhagic septicemia affects cattle, buffalo, camels and yaks in regions 11 and 12. It occurs in periods of environmental stress and is characterized by high fever (107°F), profuse salivation and mortality rates exceeding 50 percent. An effective vaccine has been developed.

A less severe form affects cattle in Europe North America and other regions. Frequent occurrence following transportation stress has led to the common name of "shipping fever." Control is best obtained by reducing stress during and following shipment. Antibiotics are often helpful. The "shipping fever complex" including the effects of other viral and bacterial infections has been identified as a major research priority in the U.S.A.

Tuberculosis affects cattle, sheep, goats and other animals, including man. Infection of man generally occurs by consumption of raw milk. The development of tuberculin tests and elimination of carriers has been a major factor in reducing the frequency of tuberculosis.

Leptospirosis is primarily spread by ingestion of urine contaminated water. Kidney lesions, anemia and bloody urine (especially of calves) are the major symptoms. Vaccines are available but protection of drinking water from contamination is the most important measure of control.

Anthrax, an acute febrile disease caused by *Bacillus anthracis*, is highly infectious and is worldwide in distribution. Anthrax is usually fatal except in swine. Anthrax in man takes the form of localized cutaneous infection although a fatal septicemia does occur (2). Transmission may be by inhalation of spores of the pathogen, contact — especially in skin abrasions — or by ingestion. The spores live for years on wool, hair or other infected animal materials and in the soil. Ruminants are generally infected by grazing on infected land or through infected feedstuffs. Acute attacks produce high fever collapse and death.

Anthrax can be controlled by annual prophylactic vaccination of all animals on infected premises. Dead infected animals should be burned or deeply buried. Anthrax was reported from 102 countries in all 15 regions in cattle, and in 77 countries in 13 regions in sheep.

Pleuropneumonia is a highly infectious disease causing heavy death losses in cattle and, especially, sheep and goats. The disease is spread by inhalation of infected droplets. Infected animals should be strictly quarantined. A related mycoplasmic disease, *contagious agalactia*, causes abortion, arthritis and severe mastitis in sheep and goats.

Vibriosis. Bovine vibriosis is primarily a venereal disease leading to temporary infertility and abortion. Ovine vibriosis, usually results from ingestion of the disease organism by pregnant ewes. Vaccination is generally effective: however, isolation and elimination of carriers and care taken when introducing new animals to the breeding herd are the most effective control measures.

Footrot is the most commonly reported bacterial disease of sheep. Other ruminants are also affected. Symptoms are inflammation and decay of soft tissues of the feet. Incidence is often highest on improved pastures in warm, moist environments. Lameness may be so severe that sheep walk on their knees. Productivity is sharply reduced.

Treatment with copper sulfate or formalin footbaths and antibiotics is usually effective. Merino sheep are much more susceptible than British breeds, such as the Romney Marsh.

Enterotoxemia (overeating disease) is a clostridial disease. It most seriously affects young sheep nursing heavy milking ewes and feedlot lambs consuming high grain diets. The causative agent occurs naturally in the rumen microflora. The rich diet provides a suitable medium for rapid multiplication of the bacteria (*C. perfringens* Type D) which produces a lethal toxin. Regulation of the diet to lower energy consumption, administration of toxoids and antitoxins or feeding antibiotics are the usual control measures.

Protozoan Diseases

Babesiosis. Ticks, especially of the genus *Boophilus*, transmit this serious protozoan disease which causes widespread damage of red blood cells in affected animals. Red blood cell damage, accompanied by body temperatures as high as 108°F, leads to anemia, liver damage, poor performance and death.

The infamous Texas tick fever was finally eliminated earlier this century from the U.S. by eliminating the tick vectors but only after a long, difficult campaign of frequent dipping of cattle in infested areas. Various types of babesiosis (or piroplasmosis) are widely spread throughout Central and South America, Europe, Asia, Australia and Africa.

Early diagnosis and chemotherapy are often successful. However, tick control programs remain the most successful means of reducing the effects of this disease.

Anaplasmosis. This hemotropic disease is a serious cause of poor productivity and often death of cattle throughout the tropics and in many temperate regions, including most of the U.S. Ticks, mosquitos, biting flies, especially horse flies, contaminated surgical instruments, syringes and needles transmit the disease. Infected cattle, even if they recover from the debilitating effects of the disease, remain carriers for life and must be slaughtered or rendered sterile by treatment to avoid infection of susceptible herdmates.

Theileriosis. This protozoan disease, commonly known as East Coast Fever, is characterized by high fever, emaciation and high mortality. It is primarily transmitted by the brown ear tick of the genus *Rhizocephalus* and is a serious problem for cattle production in East, Central and South Africa. Tick control, often by slaughter of affected or exposed cattle and removal of all cattle from infested areas for 15 or more months, is the most effective, but obviously difficult, means of controlling East Coast Fever.

Trypanosomiasis. Most trypanosomes spend part of their lives in the gut of insects. When an infected insect bites a vertebrate animal, the disease may enter the blood of the animal where the trypanosome develops to the adult stage at which point illness of the animal host may develop.

Of the many species of trypanosomes and the diseases they cause, the most serious animal infestation (nagana) is transmitted by the tsetse fly. Nagana is widespread in the countries of Region 9 (Central Africa), especially in the Guinean and Sudanean ecological zones. The infested area includes 12 million square kilometers of land, estimated to be potentially capable of supporting 125 million cattle (*4*).

Nagana is a debilitating disease that seriously affects production of meat and milk in infected herds of cattle. Sheep, goats and indigenous wild herbivores may be infected, but they appear to be more resistant than cattle.

Control of nagana may be possible. Ecological control includes clearing wooded areas, especially along streams. Certain drugs inhibit development of the adult parasite in the host allowing treated animals to develop a degree of tolerance (*4*). Release of sterile male flies has

Goats being milked in central Mexico. Milk is processed to make cajeta — a type of caramel candy. *Winrock International Photo.*

also been suggested as a control measure. Some ruminants appear to have a genetic resistance to nagana. For example, the N'dama cattle, dwarf goats and sheep of West Africa have greater tolerance to nagana than do exotic breeds imported to the area.

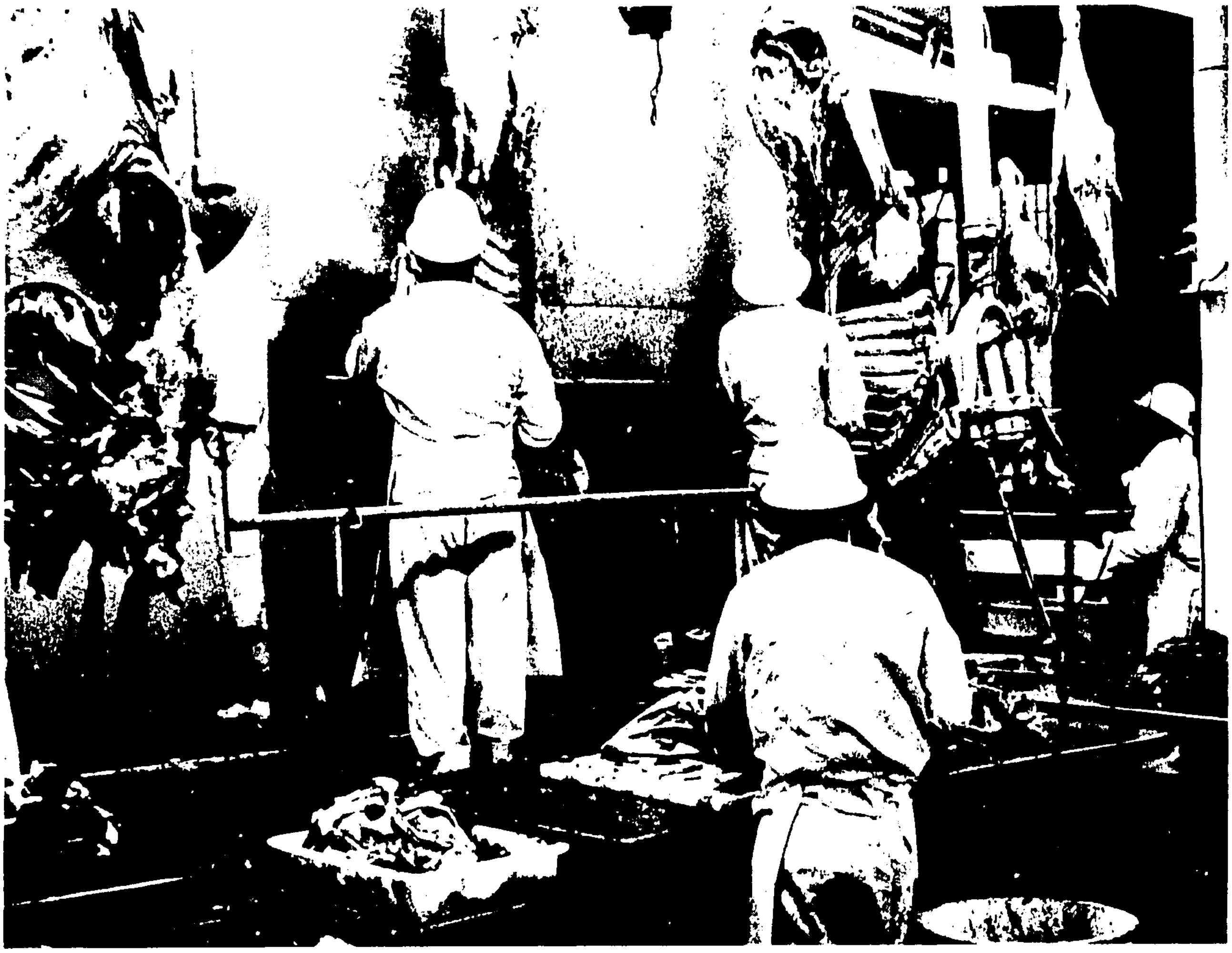
One factor that needs to be reckoned with is that controlling trypanosomiasis may lead to overgrazing. Ormerod (5) postulates that if some measure of control of the disease were achieved, the expanded grazing and resulting loss of vegetation in the Sahel zone on the edge of the Sahara would not only reduce production but bring about climatic changes, such as the recent long period of drought in which several million cattle died. This is not a new problem, however, because overgrazing by wild and domestic animals has occurred in Africa and by domestic animals in other areas. Goodwin (6) points out that despite the overgrazing and its effect on the land, total losses from chronic trypanosomiasis in Africa greatly exceed the potential for drought loss.

Human "sleeping sickness" is caused by *T. rhodesiense* and *T. gambiense*. Wild animals and, sometimes, cattle serve as reservoirs for *T. rhodesiense*.

Trichomoniasis is a venereal disease transmitted during coitus. Cows mated to diseased bulls will generally abort in early gestation and become temporarily sterile; however, the disease organism does not usually persist in the female tract for more than 90 days if reinfection is not permitted. Bulls remain permanently infected. Removal of infected males and use of artificial insemination will usually eliminate the disease from the breeding herd.

Helminth Parasites

Helminth parasites impose a heavy burden on ruminant productivity throughout the



Carcass beef is being deboned in a modern abattoir in Botswana. This meat is destined for export trade and subject to rigorous health inspection. *Winrock International Photo.*

world. However, their worst effects are on ruminants in the poorest, most densely populated regions which can least afford the loss in meat, milk, and work energy. Ubiquitous intestinal worms, such as *Trichostrongyles* and *Hemonchus*, cause heavy losses in cattle and sheep, both in decreased productivity and high mortality, especially of calves and lambs. A warm, wet environment is most conducive to buildup of worm populations. Management practices, such as rotational grazing to break the parasitic life cycle plus treatment with antihelminthics, such as thiabendazole levamisole or phenothiazine, are generally effective in reducing or even eliminating the parasite load. However, the first and most important step is to provide an adequate, balanced nutrient supply. Well nourished animals are little affected by helminthic parasites. In some cases, ruminants apparently develop an immunity to helminthic parasites so that they are less affected after prior exposure. The major danger results from introducing previously unexposed animals into areas with high helminth egg or larval counts; the resulting stress often kills the susceptible animal.

Liver Flukes (Fasciola spp.) are the second most frequently reported disease condition in both cattle and sheep. One hundred twenty-nine countries reported fluke infestations in bovines. In the same 14 regions 103 countries reported infestations in sheep. Goats and other ruminants and wild herbivores also may be infested. The adult fluke infests the host liver. Infected livers may be unfit for human food. Infestation causes debilitation of the host. Flukes are vectors for the clostridial Black

Disease which is fatal to sheep and cattle.

Eggs pass from host in feces. They hatch in water where they infest an intermediate snail host. Infective stages of the parasite *(cercariae)* escape from the snail. Following ingestion by the ruminant host, they infest the host bile-duct where they mature in about three months. Control measures include use of molluscides to eliminate the snail intermediate host, drainage, and treatment of the ruminant host with antihelminthics (*2*).

Tapeworms are a widespread problem to ruminant production even though mortality is not high. The life cycle of tapeworms is fairly complex, generally involving two or more hosts.

Hydatidosis is a tapeworm disease in which dogs are the primary host and sheep (or cattle) are the intermediate host. Man may sometimes become the intermediate host by handling dogs which are shedding eggs. In cysticercosis, man is the primary host and cattle are the intermediate host. The viscera of infected cattle are spotted by cysts which has led to the common name of beef measles. Man is reinfected by eating raw contaminated flesh.

These diseases are easily controlled by breaking the life cycle. Fecal material from the primary host should not be allowed to contaminate the feed sources of the intermediate host. And raw tissue from the intermediate host should not be available for consumption by the primary host.

Arthropod Parasites

THE itching, scratching, loss of blood and general aggravation caused by ectoparasites, such as ticks, lice, flies, mosquitos and mites, are usually the lesser part of the damage suffered by ruminants. Most of these parasites serve as vectors for other diseases. For example, ticks are the principal carriers of previously described diseases, such as babesiosis (tick fever), anaplasmosis and East Coast Fever; the linkage between the tsetse fly and trypanosomiasis is well known. Control of such diseases generally depends on control of the vector by rotational grazing and insecticide use. Some ruminant breeds and lines have developed a degree of immunity to ticks and other parasites. A new technique which shows considerable promise is the use of chemicals, including juvenile growth hormones, which affect insect growth.

A dramatic success story in insect control involves the screw worm fly, which lay eggs in fresh wounds. The larvae burrow deeply into the surrounding tissue causing such extensive damage that the animal may be literally eaten alive. Fortunately, female flies mate only once. Therefore, release of large numbers of sterile male flies increases the probability that this mating will not produce fertile eggs. In this way, the screw worm problem has been virtually eliminated from the U.S.

Warbles, and larvae of *Hypoderma* flies cause extensive damage to hides and tissue. Adult flies lay their eggs on the hairs of the legs. The larvae penetrate the skin and then migrate for 4 to 6 months through body tissues until reaching the skin surface on the back and upper sides of the body. Next, a breathing pore is punctured through the skin. The larvae grow for another 4 to 6 weeks before enlarging this pore and dropping to the ground, followed by a 5-week pupation period. Systemic insecticides, such organophosphates, have been used successfully to destroy the migrating warble and break the life cycle.

Scab or *scabies* are descriptive terms for some of the symptoms of severe mange mite infestation. Infested areas are extremely itchy; hair and wool are lost; and the skin becomes thick and crusty. Quarantine and dipping with chlorinated hydrocarbon compounds or lime sulphur are usually effective in eliminating mites.

Metabolic Diseases

Metabolic imbalances are of major importance to ruminant females under the stress of late pregnancy, parturition or heavy lactation. At these times, the delicate balance of body fluids, salts and organic materials may be upset by factors which abruptly change ingestion, digestion, absorption or excretion of metabolites.

Intensive dairy enterprises that use cows of high genetic capacity for milk production are especially vulnerable to ketosis and to milk fever.

Ketosis usually occurs in cows in early lactation. Highly productive females are particularly

An open air meat market in Kundus, Afghanistan. *FAO Photo by J. H. Hammad.*

susceptible. Appetitie is depressed; blood sugar level drops; milk production declines. The endocrine glands may be affected, resulting in insufficient production of adrenal hormones which induce glucose in the liver. Affected cows generally respond to intramuscular injection of corticosteroids or other glucocorticoid hormones. Incidence of ketosis may be reduced by generous feeding of high-energy feeds a few weeks before and after cal ing.

Milk fever (parturient paresis or hypocalcemia) is characterized by collapse, inability to stand or walk, and death in ruminant females – usually within the first three days after birth of their young. Blood calcium falls to low levels and tetany may occur in affected cows. Injectible calcium gluconate compounds are used to treat milk fever. As with ketosis, generous feeding, protection from stress and administering massive doses of vitamin D prior to giving birth may be helpful prophylactic measures.

Pregnancy disease in ewes is also characterized by ketosis. Ewes in the last weeks of pregnancy, especially those carrying twins, are susceptible. Stress, as caused by storms or undernutrition, may precipitate pregnancy disease. Blood sugar drops; appetite fails; ewes stumble about and may die within three or four days of onset. Generous feeding during the last six weeks of pregnancy and protection from excessive heat or cold may be effective preventive measures.

Grass tetany is a highly fatal disease of cattle and sheep which is associated with a sharp drop in serum magnesium levels. It is characterized by muscular spasms, convulsions and death due to respiratory failure. The disease occurs among lactating cows turned out to lush grass pastures after winter housing and cattle and sheep grazing wheat pastures. Magnesium supplementation is an effective preventive measure.

The Economics of Animal Health Programs

ALTHOUGH animal health programs tend to be concerned with control of diseases, sanitation, or environmental improvement, animal health is ". . . inextricably mixed with nutrition, breeding, management and economics" (*8*). The following example illustrates the economic implications and complexities of animal health programs.

FAO examined the potentials of controlling trypanosomiasis and estimated that control would provide supplementary feed for 120 million head of cattle, which in turn could produce 1.5 million tons of meat, worth $750 million annually. Cost of such a program was estimated to be about $2 to $2.5 billion (*9*). These were rough estimates and no cost-benefit analysis was attempted.

A study in Uganda gives some insight into economic implications of the Trypanosomiasis — tsetse fly problem (*10*). An analysis showed that the cost of fly control with insecticide ranged from U.S. $4.20 to $6.58 per hectare depending on terrain. Control through wild game elimination cost from $4.90 to $7.00 per hectare. The insecticide program would require seven years, compared to 9.5 years for game elimination. The insecticide program appeared to be superior in terms of costs and time required and avoided undesirable aspects of game elimination. However, in time, resistance may develop to the insecticides.

Returns from grazing of tsetse fly-cleared land were examined for nomadic and settled ranching systems. With tsetse fly control costs of $3.50 per ha, stocking rates of 4 ha per head and live slaughter cattle selling for $0.18 to $0.23 a kg, the internal rate of return would be approximately 12 percent for nomadic systems (*11*). Settled ranching gave an 8 percent rate of return, assuming a stocking rate of 2 hectares per unit. Returns to nomadic systems were higher than for ranching systems because of lower overhead, but carried greater risk of adverse environmental effects from overgrazing.

The profitability of clearing tsetse infested areas is very sensitive to delays in land utilization. An increase in the discount rate of 25 percent reduces profitability of control more than does a 100 percent increase in costs per ha. With average clearing costs of about $7.50 per ha, tsetse control for cattle production "may be called an investment of marginal profitability for the Ugandan economy." Livestock prices used in the study were lower than current East African prices, but the treatment and land clearing cost may also be underestimated.

Sheep being treated to control the spread of external parasites. This is another component of management which is necessary to improve productivity. *Winrock International Photo.*

Trypanosomiasis control through use of drugs is generally not financially feasible unless animals are of very high value. Such prophylactic programs may be cheaper per head, but they are difficult to administer and may be advantageous only at low levels of incidence. The lower the stocking rate and the lower the incidence of disease, the more likely it is that control through drugs will be preferable to tsetse fly elimination (*10*). Aside from cost effectiveness, there is a question as to willingness of livestock producers to bear the cost of treatments. Experience has shown that they tend to skip treatments to reduce expenses. As a result, resistance to drugs develop to the detriment of all livestock in the area. Tsetse fly control programs may be preferable to drug programs, not only because of greater assurance of success, but also because the eradication program can be an avenue for achieving land reform.

Disease Control Outlook

DISEASE and parasite problems are major constraints to ruminant productivity in the developing countries. Although some progress is being made toward lowering the incidence of certain diseases, immediate change in the situation is not expected (*6*). Among the constraints are lack of sufficient funding, inadequate administration backing and lack of interdisciplinary teamwork in both research and control activities. Also, disease pathogens may develop resistance to whatever control measures man may devise.

The costs involved in controlling tick-borne diseases in Africa and South America are staggering. Millions of cattle must be dipped weekly. Yet such measures merely hold down the incidence; the real problem remains latent. More breakthroughs such as the successful rinderpest vaccination program in Africa and biological control of screw worms in North America are needed.

In the developed regions, the picture seems somewhat brighter. In Western Europe, the brucellosis eradication program is moving ahead. In Australia, a vaccination program combined with good management largely eliminated bovine contagious pleuro-pneumonia. Further progress will require proper legal authority, funds, trained personnel, knowledge of the location and incidence of specific diseases, and public support for the measures that need to be taken (*7*).

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11. Jahnke, *op cit.* pp. 82-3. Costs are at accounting values, which eliminates income transfers such as taxes and subsidies, and "overvalued" currency and wage rates. Also; p. 99. 1 stocking unit = 1.33 mature cattle, 2 immature cattle, or 5 calves.

GENETIC IMPROVEMENT OF RUMINANTS

Improvement program goals should be determined from thorough analysis of production environment and market requirements . . .

THE ruminant genotype sets the upper limit to productivity. Often, this limit is of little more than theoretical interest because nutritional deficiencies, health problems and inadequate management preclude its realization. Nevertheless, much effort — with a fair degree of success — has gone into genetic improvement of ruminants. This chapter provides insight into the bases for successful breeding programs and suggests goals for future programs (*1*).

When man first domesticated ruminants, he simply took advantage of genetic qualities already available. Soon, however, he began to mold his livestock to meet his special needs and preferences. This was accomplished by regulating the hereditary message transmitted between generations.

The hereditary message is carried by genes — deoxyribonucleic acid (DNA) sequences — primarily found on the chromosomes in the cell nucleus. Chromosomes occur in matched pairs: for example, cattle, 30 pairs; sheep, 27; camel, 37. One member of each pair is contributed by each parent. A sample half of the hereditary material carried by each parent is combined in the union of sperm and egg to form the new zygote. This process provides the genetic communication between generations. By determining which males and females mate, man can exercise some control on the message communicated.

Genetic Diversity

THE original sources of genetic diversity are mutations — small changes — in specific DNA sequences. Generally, mutations yield a nonsense message, just as would an arbitrary change in the spelling of a word. Occasionally, however, a new message results. If this new message is favorable to survival, individuals carrying the favorable message produce more progeny and, thus, increase the frequency of the favorable gene in the population.

Recent breakthroughs in understanding the genetic code and the ways genes function have opened the door to genetic engineering. Already new genetic messages have been introduced into simple organisms, such as bacteria, to induce these single cells to manufacture valuable pharmaceuticals, such as insulin. The next step may be to modify rumen microflora to improve efficiency of fermentation and protein formation.

Many laymen and scientists, too, fear the potential dangers of such tampering; however, it seems only a matter of time until efforts are made to induce changes in the genes of higher organisms, such as ruminants. Still we can expect that genetic improvement programs will continue to depend on the time honored practices of selection and controlled matings.

Selection is the process by which individuals carrying favorable forms of genes leave more progeny than do inferior stock. In time, the genetically superior stock will prevail throughout the population. Nature favors those genes which improve fitness to survive and thrive in the natural environment. This we now understand as the mechanism of natural selection, described by Darwin as "survival of the fittest."

Man may impose a different definition of superiority. His desires may be for high levels of milk production, lean meat or fine fibers. Often these preferences reduce fitness. Housing, nutrient supplements and predator protection are often necessary for highly selected, highly productive ruminants no longer able to fend for themselves in the natural environment.

Genetic diversity is maintained and augmented by isolation. Matings between species are rare. Even when chromosome numbers are the same and progeny result, they are infertile. Examples include yak-cattle and bison-cattle crosses in which the male is usually infertile.

Within species, genetic diversity has resulted from less permanent types of isolation. Sheer distance and the difficulty of travel contributed to development of the distinctly different cattle subspecies — the European *Bos taurus* and the Asian *Bos indicus*.

Often one or more livestock breeders in a region have established particular selection goals and, then, through artificial selection have developed breeds or lines which meet these goals. Their usual procedure is to combine selection with controlled matings so members of the line or breed will be more closely related than average. This "inbreeding" tends to fix type and increase the similarity between parent and progeny but decrease similarity among lines. Often, the sexual isolation among different breeds is maintained by formation of pedigree associations which only register progeny from purebred matings. Males not considered suitable to sire offspring are effectively removed from the breeding population by castration.

Crosses among individuals from discrete populations within species yield fertile progeny. Indeed their fertility and productivity often exceed that of the parental types. These advantages are due to hybrid vigor.

Random chance also contributes to genetic diversity. The results from segregation of members of chromosome pairs and recombination in the union of sperm and egg are not strictly predictable. Progeny may resemble one parent more than the other or, for some traits, resemble neither parent very closely.

Past efforts by man and nature have yielded much useful genetic diversity. There are dairy cows which annually produce 15000 kg of milk, trypano-tolerant goats which survive in tsetse fly infested areas, sheep which produce litters of four to five lambs. The challenge is to apply the scientific principles of genetics to further improve the biological and economic efficiency of our ruminant resources.

Utilizing Genetic Resources

Selection — Selecting superior stock to serve as parents of the next generation leads to lasting genetic improvement by increasing the frequency of desirable genes. Most important traits are influenced by the small, cumulative effects of many genes. Each animal carries tens of thousands of genes — some desirable, some less so. Since the whole individual and all his genes must be either kept or discarded, the challenge is to select those individuals with the best net breeding value.

In the past much attention was given to appearance. Today, however, increasing emphasis is placed on objective measurement of traits with direct economic value — milk yield, weight gains, litter size, wool clip.

The number of males kept for breeding is generally much less than the number of females. For example, even under extensive range conditions one bull can impregnate 15 to 20 cows. With artificial insemination, semen from a single male may be used to breed hundreds of females. Thus, most selection progress may be accomplished through selection of superior sires.

Not all observable differences among animals are genetically mediated. Consider identical twin dairy cows. If one is well fed and the other poorly nourished (or if one is healthy and the other is parasite ridden), the healthy, well fed cow will produce more milk than her unfortunate twin. The portion of observable variation for a trait due to differences in breeding values is called heritability. Values range from 0 to 100 percent. Approximate heritabilities for some important traits include: fertility, 10 percent; milk yield, 25 percent; growth rate, 40 percent; mature size, 70 percent.

Progress from selection depends on the heritability of desired traits and the degree to which the selected parents are superior for these traits. If all animals born must be kept as herd replacements in order to maintain herd numbers, progress will be nil. Thus, the low fertility, high mortality and long delayed sexual maturity characteristic of many domestic ruminant populations in the developing world not only sharply decrease turnoff of meat and milk but drastically reduce the potential for genetic improvement.

One of the most powerful tools available to the breeder of superior animals is the selection index (*2*). This index allows selection pressure to be exerted on all traits which affect the profitability of the production enterprise according to their respective economic values, heritability and correlation with other impor-

Native stock are generally better adapted to the climatic and disease constraints of the local environment than imported breeds. An indigenous cow and calf are shown in Botswana. *Winrock International Photo.*

tant traits. It is even possible to improve performance for traits which cannot be directly observed for the selected individuals. A good example is the improvement of milk production through selection of superior dairy sires based on the measured milk production of their female relatives.

Selection progress is measured in terms of generations. Generations are relatively long for ruminants, ranging from about 1 year for sheep and goats to 5 years for cattle and even longer for water buffalo, camels and others. Several generations of selection toward consistent goals are required for appreciable success. Thus, it is critical to correctly identify the commercial production and market requirements of the future and design effective selection programs to meet them.

Mating Plans — The choice of mating plans is the second major tool at the disposal of animal breeders. There are four, not necessarily mutually exclusive, mating strategies.

Inbreeding — mating of closely related individuals to concentrate their superior genes and promote prepotency.

Outbreeding — mating of unrelated individuals to derive benefits of "hybrid vigor."

Assortative mating — mating individuals that appear or perform more alike than the population average.

Disassortative mating — mating individuals which appear or perform less alike than the population average.

The choice of strategy is one of the most important decisions affecting performance of the target population (*3*).

Inbreeding increases the genetic similarity among members of the inbred population and, thus, improves the accuracy of predicting their breeding value. This practice has some merit in establishing superior foundation stocks, which breed true for desired traits. Inbreeding is a consequence of closing purebred populations to introduction of different genetic stocks. Inbred animals tend to have depressed fertility and productivity -- a characteristic known as inbreeding depression. Thus, inbreeding is not recommended for commercial production, except to develop parent stocks for outbreeding programs.

Outbreeding yields progeny which are often superior in performance to the average of the parental strains. The more genetically diverse the parental lines, the higher is the expected hybrid vigor of the resulting progeny. Experimental results have shown the cummulative impact of hybrid vigor for fertility, survivability, maternal ability, feed efficiency and growth rate to exceed a 25 percent advantage in beef turnoff from crossbred cattle.

Assortative mating — breeding like to like — is a common practice. So is disassortative mating in which males of one type are mated to females of another type to correct deficiencies or to produce an intermediate between the two types.

Crossbreeding is a type of outbreeding in which parents are drawn from different breeds. Commercial livestock production is increasingly taking advantage of the benefits of crossbreeding. In addition to the hybrid vigor shown by crossbred animals, crossbreeding allows for desirable combination of traits. A good example is the cross of exotic breeds noted for high levels of productivity of meat and milk on the native breeds noted for adaptation to local climate, disease and parasite stresses. Often the progeny of such crosses will combine at least a portion of the favorable traits of both parent types.

Crossbreeding also provides an opportunity for complementary matching of parents from different breeds. Sheep producers often mate rams from large, growthy, meat type breeds to fine wool ewes in order to produce good meat type lambs while maintaining a high quality wool clip from the base ewe flock. Dairy cows are often mated to beef bulls to improve the carcass qualities of the slaughter progeny (*4*).

Complementary matching of parent breeds may also resolve genetic antagonisms which adversely affect production efficiency. One such antagonism arises from the positive relationship between mature size and rate and efficiency of growth so important to slaughter produce, that is, large animals grow more rapidly than small animals. Animals of large mature size, however, require much more feed for maintenance than small animals, which increases both feed and financial costs of maintaining the breeding herd. Since relatively few males are needed as parents, mature size of females is the major factor affecting herd maintenance costs. One way of resolving this antagonism is to mate sires from large breeds to dams from small breeds in order to produce rapid growing, efficient offspring from low maintenance cost herds. Special care must be taken to avoid the potentially serious difficulties small cows may have giving birth to large calves (*5*).

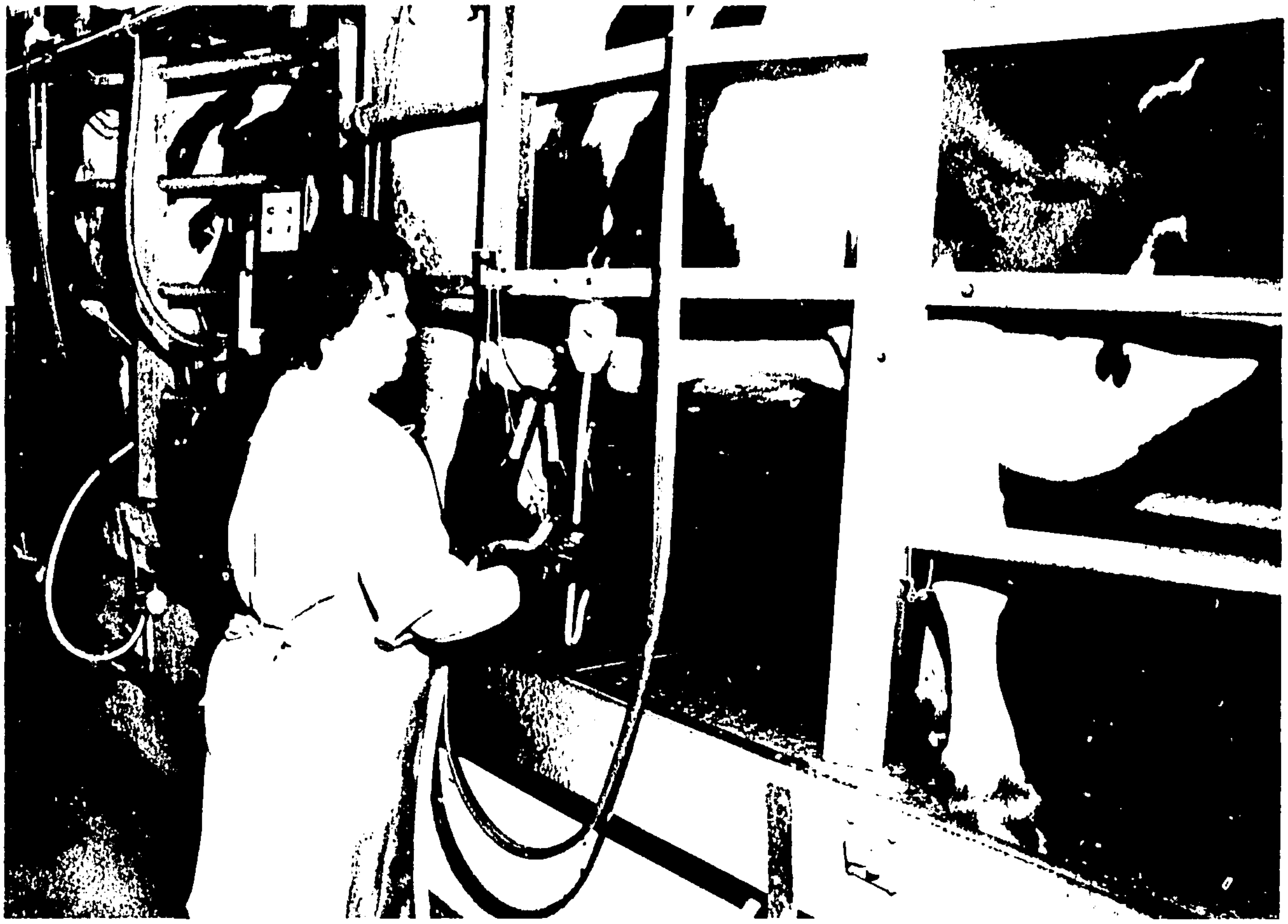
Important Traits

THE many valuable traits of ruminants have been described in previous chapters. Here the emphasis is on consideration of which heritable traits should be emphasized in genetic improvement programs. Economic value is a major criterion. Too often, however, temporary fads and fancies have taken precedence. Ear length, horn shape, coat color and pattern may serve as breed trademarks but rarely make any practical contribution to production efficiency.

The list of traits which follows is not exhaustive by any means. Emphasis will vary with production conditions and marketing options (*6*).

Adaptation — Ruminants poorly adapted to their production environment are slow to conceive and quick to die. Rate and efficiency of production of meat, milk and fiber will be low. This lesson has been learned the hard way where "improved" stocks from the developed world have been introduced into the developing world to raise the productivity of native stock. All too often, productivity dropped and costs increased. High genetic potential for growth rate or milk yield is of little value unless the animals are well-fed and healthy and enough capital is available to keep them in that condition.

Genetic tolerances to stresses caused by harsh climates, feed shortages, diseases and parasites clearly have value in unfavorable environments.



Highly productive cows capable of producing 15,000 kg of milk per year are being milked in a modern milking parlor in central Arkansas, U. S. A. *Winrock International Photo.*

Most wild ruminants, many native goats and the West African Shorthorn and N'dama cattle breeds appear to be relatively tolerant to the disease, trypanosomiasis. *Bos indicus* cattle are generally more tolerant of heat and ticks than *Bos taurus*. Water buffalo have a highly reputed capacity to digest low quality, high fiber roughage more efficiently than cattle. The ability of camels to store extra water and subsist on dry, low quality vegetation allows them to survive in the dry deserts of Northern Africa, but their lack of resistance to trypanosomiasis has prevented their productive use in the tsetse fly zone further south.

Realized Fertility — Females must conceive and their progeny must survive if other production traits are to be expressed. Some components of realized fertility include age at puberty, rebreeding interval following parturition, seasonal anestrus, litter size and progeny survival. Most fertility traits are lowly heritable, with much of the genetic variation eliminated by millenia of natural selection. However, economic value is so great that fertility must be considered in the breeding program, especially where there are opportunities to improve the production environment through nutrient supplementation, health care and other improved management practices.

Male libido and semen qualities also affect fertility. The latter traits are especially important to successful artificial insemination programs where semen collections may be highly diluted and frozen for long term storage.

Feed Efficiency — Efficient feed utilization for maintenance and production (growth, milk, fiber, work) is second only to fertility in biological and economic importance. Individual differences in intrinsic efficiency of feed utilization are generally small so that the major opportunity for improvement is to increase productivity in relation to maintenance requirement. On an individual basis, this may be accomplished by increasing genetic potential for productivity so that all available nutrient intake in excess of maintenance requirements is fully utilized. Good appetite, efficient digestion and high production potential combine to give most efficient feed use.

At the herd level, feed efficiency can be further increased by matching parent lines. Small, well adapted females require relatively less feed for breeding herd maintenance. If mated to large, growthy sires, the progeny will have the potential appetite, growth rate and meat yield to be highly productive. Feed efficiency (lean meat output/feed input) for herd will be high.

Mature Size, Growth and Maturing Rate — Rapid growing ruminants tend to be large; early maturing ruminants tend to be small. These genetic correlations may create difficulties in breeding for net economic value. Earlier this century in the U.S. and some other major beef producing countries, preference for cattle which matured (fattened) at young ages on high forage diets led to emphasis on small cattle. More recently in the U.S., preference for rapid growth, without excessive fattening on high grain rations, has led to emphasis on large size with the attendant problems of increased calving difficulty and higher cow herd maintenance costs.

A general conclusion documented by experimental results is that there are no consistent major differences in metabolic efficiency for maintenance and production among ruminants of different mature size. This conclusion appears to hold for size differences both between and within species (*7*).

The preferred direction and degree of emphasis on growth and maturing rate must be determined by the potential use of selected animals. Sire lines may be selected for rapid growth rate; dam lines, for small mature size. Other alternatives include changing the shape of the growth curve to produce early maturing slaughter stock, which fatten on high roughage rations, without reducing growth rate or even changing mature size (*8*).

Milk Yield — Considerable success has been realized in increasing the milk yield, persistency and lactation length of dairy females, especially cows. At the very highest production levels, dairy cows draw on body fat stores to produce more energy per day than they have capacity to consume. Thus, still further increases require increased appetite and digestive efficiency (*9*).

Among less highly selected dairy populations, further emphasis on yield, persistency and tractability is recommended. Fat and other milk solids for butter, ghee and cheese manufacture are especially important where milk is collected long distances from available markets and preservation is difficult.

Carcass Traits — Increased lean yield has obvious economic merit. Some cattle genotypes, commonly referred to as "double muscled," are noted for especially high lean yields; however, they tend to require special management and are poorly suited to extensive production conditions (*10*). Increased lean yields may be obtained by slaughtering young, rapidly growing ruminants before they have begun to lay on excess fat deposits. Palatability traits — tenderness, flavor, juiciness — can be fairly easily controlled by feeding and management practices. Thus, direct genetic emphasis on carcass traits should be necessary only to avoid the extremes of low yield and poor palatability.

Fiber — Man has imposed his selection skills on the amount and type of fiber (hair and wool) produced by domesticated sheep and — to lesser extent — goats, llamas, camels and yaks. The most spectacular example is the fine wool Merino and derived breeds which originated in the Iberian Peninsula, but which have had their greatest success on the dry rangelands of Australia and the western U.S. The long-stapled fine wool they yield is truly a miracle fiber used as a benchmark for the synthetic fiber manufacturers seeking to emulate its qualities of warmth, softness, texture, color retention and wearability.

Other Traits — Large ruminants still find considerable service in the developing world for draft and transport. Strength and endurance are key factors influencing their value as work animals.

Maternal ability includes providing nutrient requirements, care and protection to her young offspring. A well developed maternal instinct is essential for those conditions where little or no attention is provided by man.

Polledness (lack of horns) is a definite disadvantage when an animal is fighting against predators for its life or against other males for mating priority. This condition is an advantage, how-

Hybrid vigor can result in a 25% improvement in beef cattle productivity. This shows a F_1 Brahman X Hereford heifer. *Winrock International Photo.*

ever, in commercial feeding environments because bruised carcasses are down-graded in marketing.

Fat tails (or rumps) on desert sheep and humps on camels and Zebu cattle serve as energy storage banks for use when nutrients are in short supply and, incidentally, make it easy for the herder to recognize how good or poor is the physical condition of his wards.

Strength, stamina and courage are the hallmarks of "brave" bulls. Their performance in the bullring measures their value.

Conformation and color traits are often used as visual substitutes for knowledge of true genotype for productivity and efficiency. Whenever possible, emphasis should be on direct, objective measurement of the desired production traits.

The choice of traits included in the genetic improvement program obviously must be tailored to the production environment and market requirements. In India, where there is a limited market for beef but a substantial demand for milk, animal power and manure, there is a need for long-lived cattle sufficiently fertile to freshen periodically for lactation and to produce work stock. However, where beef is an important source of human nutrient or earner of foreign exchange, increasing beef turnoff requires increasing the reproductive rate and rapid growth to desired slaughter age.

Economics of Genetic Improvement

ECONOMIC issues which must be considered in any genetic improvement program include (a) the returns expected from the improvements.

A Yak in northern Nepal. This type of ruminant is well adapted to high altitudes. Yaks are adept to foraging for feed on the mountains. In these regions they are used for their abilities to produce meat, milk and hair. *FAO Photo*

(b) the time required to get results, (c) the risks involved, (d) the direct costs of a breeding program, and (e) the required delivery systems to distribute the improved semen or breeding stock.

Even a relatively simple and potentially highly productive procedure like artificial insemination (AI) frequently presents difficult economic and logistic problems. To give one example, the Intensive Cattle Development Program in the Bangalore (India) milkshed has been operating since 1965. It has established a network of laboratories and field units to serve the milkshed. Each AI unit is designed to serve about 1,000 breedable cows. But progress has been slow. It is estimated that each AI unit has averaged about one insemination a day; the conception rate is about 40 percent (*11*).

The problems in India have been related primarily to faulty administration and a low degree of farmer acceptance. However, the Kaira District Cooperative Milk Producer's Union Ltd. at Anand, India has developed an AI program for buffalo that operates effectively at a cost of only U.S. $1.00 per buffalo pregnant (*12*). This has been accomplished by using technical innovation, paraprofessionals, and incentive programs for inseminators. Farmer acceptance has been good.

Artificial insemination tends to be less effective for genetic improvement of beef production in developing countries because of difficulties of inseminating the female at the optimal time during estrus, and lack of breeding stock known to be superior for beef traits best suited to the special stresses of production in the tropics and sub-tropics (*13*).

If there are no limitations of capital or other inputs, returns can be measured by the increased volume of product multiplied by its unit value. Allowances must be made, of course, for any quality changes, less the additional costs. If large increases in output are expected, effects of increased supply on prices will need to be considered. Increased value of product may arise from either greater turnoff, higher yield, or better quality. In the Bangalore milkshed (India), cross-breeding with improved dairy strains greatly increases milk production from cows, but reduces their value as draft animals (*11*). In Thailand, however, farmers gain status by having crossbred oxen from Brahman bulls, so they prefer them (*12*). Costs may be affected directly and indirectly by breeding changes. Cross-bred calves may require more and better feed, but reach maturity sooner, offsetting at least part of the extra cost. An Indian study reported that each day's reduction in the period from birth to first calving saved U.S. $.14 in feed. The average total cost of rearing a calf to maturity was U.S. $275. So a saving of half a year would reduce cost about 10 percent (*14*).

Improving animals by selection offers opportunities to upgrade native stock without the uncertainties and costs of importing exotic stock or developing new crosses. Costs include the establishment of breeding centers, some system of distributing bulls or semen, and operation of a training program. Many years may be required to produce a significant economic impact.

Crossbreeding and introducing new breeds often involve higher costs for health care, more feed, and sometimes better housing structures. Animals of exotic breeds often require protection against diseases or adverse environmental conditions.

Systems Approach

GENETIC improvement programs are time and capital intensive. Program goals — traits to be emphasized — should be determined from thorough analysis of the production environment and market requirements — current and future. Synthesis of an efficacious program depends on knowledge of relevant genetic principles, characterization of the base ruminant resources for both level of productivity and amount of useful genetic diversity. As in most

High quality fleece of the Angora goat finds a ready market in the manufacture of garments. *USDA Photo.*

systems, maximum output does not necessarily insure optimal efficiency.

The smallest unit of selection is the individual. However, genetic improvement of total systems efficiency — biological and economic — requires consideration of the consolidated inputs and outputs for all three components of the production unit — sire, dam and progeny. Figure 5-1 indicates that the dam and progeny have greatest direct impact on system inputs and outputs. However, as previously noted, most permanent genetic improvement is achieved by selection of sires with superior breeding value for the important traits expressed by progeny, including those females which eventually enter the breeding herd.

The heart of the genetic improvement program is the decision: which males and females will be the parents of the next generation. The answers to the following questions will affect this decision.

- Which species or combinations of species are best suited to the production conditions? Feed resources, water availability, predator incidence, disease problems will condition this decision.

- Which breeds or lines within the preferred species should be utilized? Dairy breeds are most efficient food producers but they require special management; fine wooled sheep are more sensitive to tropical humidity than are hair sheep; exotic breeds may

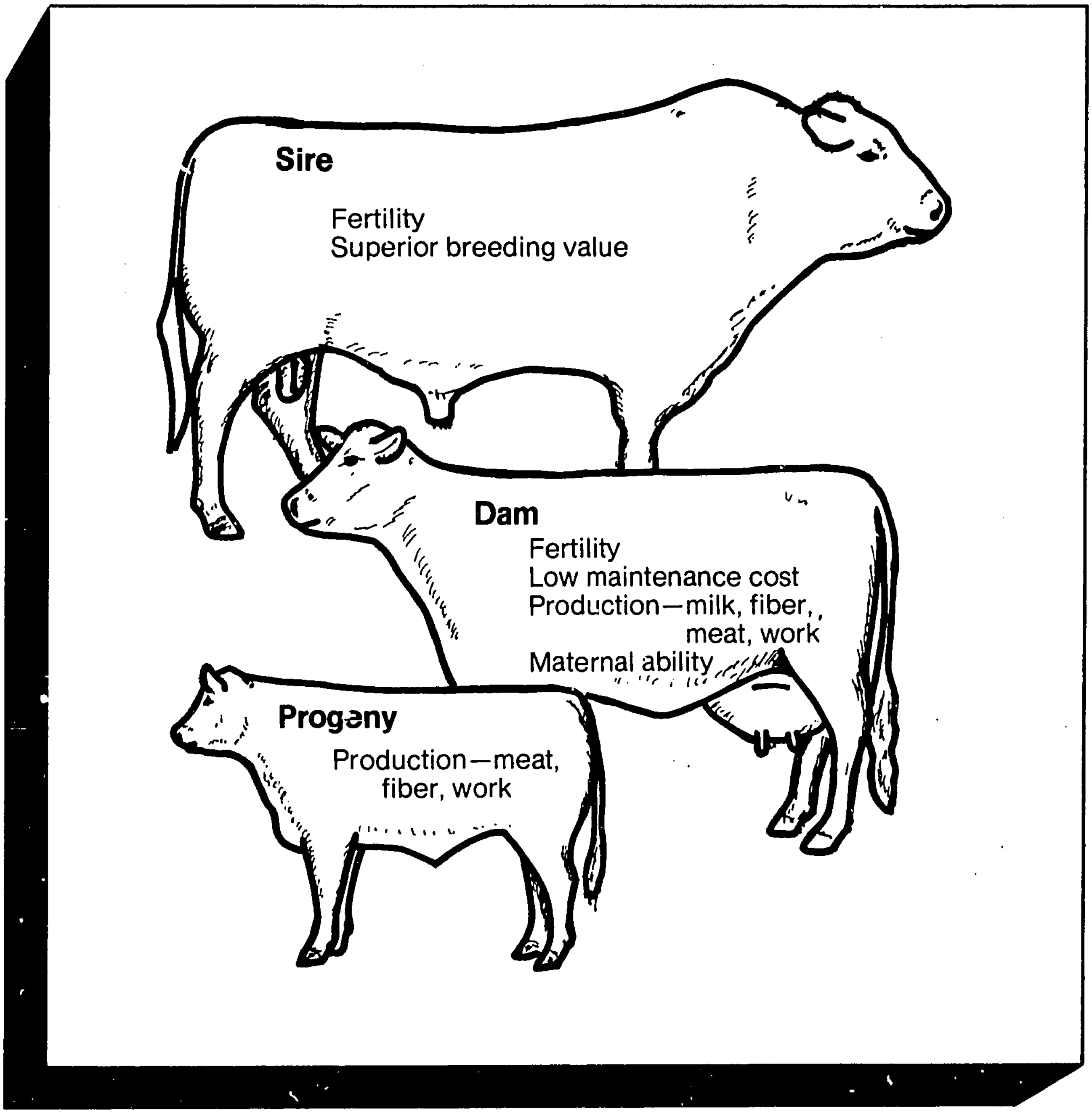


Figure 5-1. Principal contributions of sire, dam and progeny components to productivity and profitability of ruminant production unit.

have higher genetic potential for production traits, but adapted breeds may better tolerate local environmental stresses.

- Which individuals within breeds should be selected as parents of next generations? The cost of the very best may not be justified by expected financial returns under local market or feed conditions which may so limit expression of the superior genotype as to make the acquisition questionable.

- Which mating plan is most appropriate — inbreeding, outbreeding, assortative or disassortative mating? For most commercial production, crossbreeding is recommended. But should the plan be for rotational crosses among breeds of similar performance or for terminal sire-dam line crossing to gain benefits of both hybrid vigor and complementarity?

These are difficult questions. But they should be asked and systematically answered as accurately as possible by every ruminant breeder faced with the decision: which males and which females will be the parents of the next generation.

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A group of nomadic cattlemen watering Zebu-type cattle at a new borehole in the desert area of eastern Niger. *FAO Photo.*

NONBIOLOGICAL CONSTRAINTS ON PRODUCTION

More than 85 percent of ruminant animal production in the developing world comes from the traditional small producers.

SUBSTANTIAL world expansion in livestock production seems technically feasible, particularly in view of the potentials cited elsewhere in this report. Indeed, it is possible that such an expansion will take place. Yet, even if major biological constraints are removed or diminished, actual progress is likely to be slow. The reason is that a number of nonbiological factors most certainly can impede sizable expansion unless they receive serious attention.

According to a review of several World Bank projects: "Livestock development involves a complex interaction of technical, economic and socio-cultural factors leading to considerable uncertainty as to response in innovations" (*1*).

Some of the most important constraints that inhibit expansion of ruminant animal production are associated with: land tenure, markets and transportation, credit, human resources, government policies and socio-cultural values and institutions.

Land Tenure

A particularly serious tenure problem arises because of the separation of decision-making powers of livestock owners and land owners. This is especially prevalent in the Middle East and Africa, wherever the pastures are publicly owned common lands and herds are privately owned (*2*). There also appears to be little community of interest between crop farmers and stockmen. Because the emphasis is on food-and-fiber crops, livestock get only residues from cropland, and these are relatively low in feeding value.

Traditionally, some nomadic pastoral groups have had contractual arrangements with farmers for grazing crop residues, the farmers' compensation being mainly the manure left on the fields. But technological change in such regions as central Tunisia has disrupted this system because of mechanization, introduction of crops that can be injured by post-harvest grazing, and land settlement (*3*).

Somewhat similar conditions are reported for Latin America where large areas of pasture are held in large estates by absentee landlords who show little interest in animal or forage improvement (*4*).

Modern technology in many regions has added to the stresses on range resources by increasing competition for land from settled farmers. A study in Nigeria observes that ". . . in the adjudication of land disputes, authorities have tended to make decisions in favor of the permanent farmers, rather than the nomadic herders" (*5*).

In some regions where livestock herds had traditionally moved on a seasonal basis from one grazing area to another (a practice known as transhumance), the rise of nationalism has broken such patterns, particularly in Africa where they had been established for centuries.

There is a strong pre-disposition of governments to reduce grazing rights in favor of cropping in countries where land is scarce and unemployment exists, because range grazing employs fewer people per 100 hectares than does a cropping system (*6*).

Some studies emphasize the element of increasing pressure of rising population on the land, rather than indifference on the part of migratory grazers, for the plight of range resources (*7*). But, whatever the cause, existing tenure institutions have been inadequate for conserving the range. Looking at measures to improve the range, one expert predicts inevitable failure unless technical programs are combined with "a drastic modification in the management of traditional herds" (*8*).

Land reform cannot be achieved simply by placing constraints on rights to land use in the interests of higher production and soil conservation. In any type of land tenure reform, it is important to plan the organization of new production structures along with an attempt to change the system of property rights (*9*). Where ruminant livestock have a place ecologically and economically, the following aspects of land reform need to be considered:

1. In public-land grazing areas, ways should be devised to control the density and timing of grazing and to implement land improvement practices; for example, grazing associations and self-regulated group ranches (*10*).

In transhumant zones, such schemes are very difficult to establish because of the large area required for normal migratory sequences. Another constraint is the difficulty of finding an adequate management or decision-making unit within the traditional social structures (*11*).

2. Private ownership of land and animals may be a solution to grazing control in some areas. But where transhumance is practiced, private ranches — unless of enormouse size — are not likely to provide year-round forage resources. The establishment of individual ranches has been tried by the Kenya Livestock Development Project, in which individual ranches average 600 ha. These are too small to permit flexible use of dry grazing land (*12*).

3. The concept of range use rights may be more useful in many areas than land ownership and may do much to promote partial settlement of migratory groups (*13*).

4. When arable cropping projects are planned near or in grazing areas, efforts should be made to encourage integration of crop and forage use. This can be assisted through market incentives, educational programs and provision of appropriate facilities. The need for stratification[1] of the livestock industry in areas of overgrazing is emphasized by many authorities (*14*).

5. If land reform is to effectively contribute to livestock development, it must be supported by appropriate price policies, education and development of infrastructure. The Tunisian land reform between 1962 and 1970 emphasized collectivization, modernization and diversification. But the affected people were inadequately educated, and livestock numbers were reduced drastically (*15*). The decline was not offset by increased production per head. By contrast, the land reform in Taiwan in 20 years increased agricultural production by 150 percent and livestock numbers by four-fold (*16*). Since the livestock industry in Taiwan is well managed, production probably rose by the same proportion or more. Increased output was readily absorbed by an efficient marketing system and an expanding economy. It should be noted that a high percentage of Taiwan livestock consists of pigs and poultry. The study (*16*) does not indicate changes by species.

[1] Stratification refers to the practice of feeder stock being produced out on the range by one herdsman and then fattened and finished for market in a more or less confined area by another herdsman.

Markets & Transportation

GOVERNMENTS and international agencies are increasingly recognizing the opportunities that marketing improvements can bring to traditional producers of livestock products. *It is the traditional small producer in developing countries who supplies the bulk of the output. Output generated from large commercial farms, whether beef cattle, dairy units or sheep ranches, accounts for less than 15 percent of ruminant animal production in the developing world* (*17*).

Despite the importance of markets, some governments and financing institutions continue to maintain policies that are often unfavorable to the marketing systems. Many governments in developing countries attempt to control milk and meat prices, especially in urban areas. This policy has often discouraged producers from marketing their output through established channels to urban markets. It has also deterred production. In the case of milk, price controls have often dampened internal production, leading to a major increase in developing countries of outlays of foreign exchange for condensed and powdered milk imports. Also, governments often use the marketing system for tax collection.

Developed country policies have also influenced the shape and pattern of the ruminant marketing system. For example, hygiene and disease restrictions in the European Economic

A beef cattle feedlot near Lubbock, Texas. When prices of grain concentrates are favorable, feeding grain supplements will improve animal productivity and produce more desirable beef. *USDA Photo.*

Community (EEC), Japan and the U.S. influence trading patterns and the structure and cost of the meat processing industries in developing countries.

Pronounced unstable marketing cycles are a normal condition of the international cattle industry. Importing countries that have meat surpluses at the top of their cattle cycle tend to restrict meat imports, thereby forcing a buildup of live cattle inventories in exporting countries. But at the bottom of the cycle, these same countries open up their market at fairly substantial prices. This opening draws considerable quantities of product from exporting countries, up to 60 to 70 percent of beef production in Central America as an example. Since some 80 percent of the meat supply in Latin America and parts of Africa comes from cattle, such policies by importing countries tend to reduce per capita protein supplies in developing countries.

Milk production policies in the EEC have stimulated production of large surpluses of milk powder which are frequently made available to developing countries at subsidized prices. This powder is often reconstituted and sold at fairly low prices in urban areas, further distorting incentive prices for domestic milk production.

Hygienic regulations imposed on slaughter plants by importing countries have effectively created a two-tier meat slaughter/processing industry in developing meat-exporting countries. The export-oriented segment is usually modern, capital intensive and has up-to-date, on-the-line slaughter, chilling and bonine capabilities. Modern freezing and packaging techniques are extensively used. Inspection services in export-certified plants usually meet international standards. However, in plants whose product is designed for local domestic consumption, a very different standard applies. In many countries, animals are slaughtered on a simple slab. Meat is usually sold early in the morning following slaughter the previous night. There is rarely any refrigeration or further processing.

The general disregard for grades and qualities of livestock products in buying and selling markets is a major factor that discourages production in developing countries. As long as buyers were predominately indigenous low-income people, little attention to quality may have been warranted. But with economic growth, a more discriminating market is developing, and both producers and consumers would benefit by purchase and sale on a grade basis. A similar observation can be made for wool and hides. Some of the world's best carpet wool is produced in the Middle East and North Africa. But the absence of sorting and grading results in much poor quality wool. Since payment is not based on quality, good management and selective breeding are discouraged. The same observation applies to Karakul pelts in the Near East (*18*) and sheep and goat hides in Brazil.

Livestock policies in the European Economic Community are moving toward self-sufficiency in meat, especially as high internal meat prices dampen demand. Prospects that the EEC will again be a major market for meat exporters are dim. Because of substantial cattle numbers in Australia, Argentina, the EEC and the U.S., prices for traded beef are unlikely to surpass, in the near future, the halcyon period of the early 1970's. The U.S. is likely to continue to be the largest market for traded beef. Eastern Europe may continue to purchase significant quantities, but usually only when low prices and foreign exchange availabilities in those countries make such purchases attractive.

Imports to the European Economic Community declined substantially in the mid 70's as a result of recession, economic policies, and high livestock numbers in some countries. From 1972 to 1976, imports to the U.S. dropped by 6 percent, but in the European community they declined 69 percent (Fig. 6-1). The Common Agricultural Policy (CAP) of the European Community, coupled with the recession, has very sharply curtailed imports of ruminant meats. The extent of the adjustment is surprising in view of the fact that the strong dairy bias in the CAP has deterred a rapid expansion in beef production. The implications of CAP for market potentials from developing countries outside the common market are obvious. Common Market programs do, however, make some concessions to certain developing countries. In 1975 and 1976, Japan was a more important net importer of ruminant meat than was the European Economic Community.

The inadequacy of livestock processing and marketing facilities is often cited as one of the major marketing problems in developing countries. Lack of veterinary regulation and disease control increases mortality rate and weight loss during the marketing process. Since most animals are marketed on the hoof, often without sufficient feed or water along trekking routes, there are considerable losses in both weight and quality. Because of lack of refrigeration and ineffective local market demand, byproducts are often wasted at the less sophisticated slaughtering sites.

Probably the recommendations given most often as a first step in meeting these problems are the establishment of a network of small local slaughtering plants located near the source of cattle supply, and use of refrigerated trucks or rail cars to carry the meat to market. In more primitive areas, improvement of water and feed sources along trekking routes would greatly increase beef supply.

Poor transportation facilities are often listed as a major obstacle to livestock production. Cattle movements and beef transportation systems vary widely in developing countries. Although a considerable number of cattle continue to be trekked to and between markets, truck transportation is taking a larger share of internal live movements. Generally, beef is moved live to the main consumer markets where it is slaughtered and sold without much further aging, refrigeration or extensive movement. In some countries, there is some movement of slaughter back to producing areas and truck transport of carcasses to consumption centers.

Traditionally, world trade in sheep and goat meat has been primarily between Oceania, Europe and North America. The recent tremendous increase in purchasing power of Middle East and North African oil-exporting countries — combined with their traditional preference for sheep and goat meat — has introduced a major shift in the world market.

Argentina, Brazil and Mexico are examples of countries where much of the slaughter is

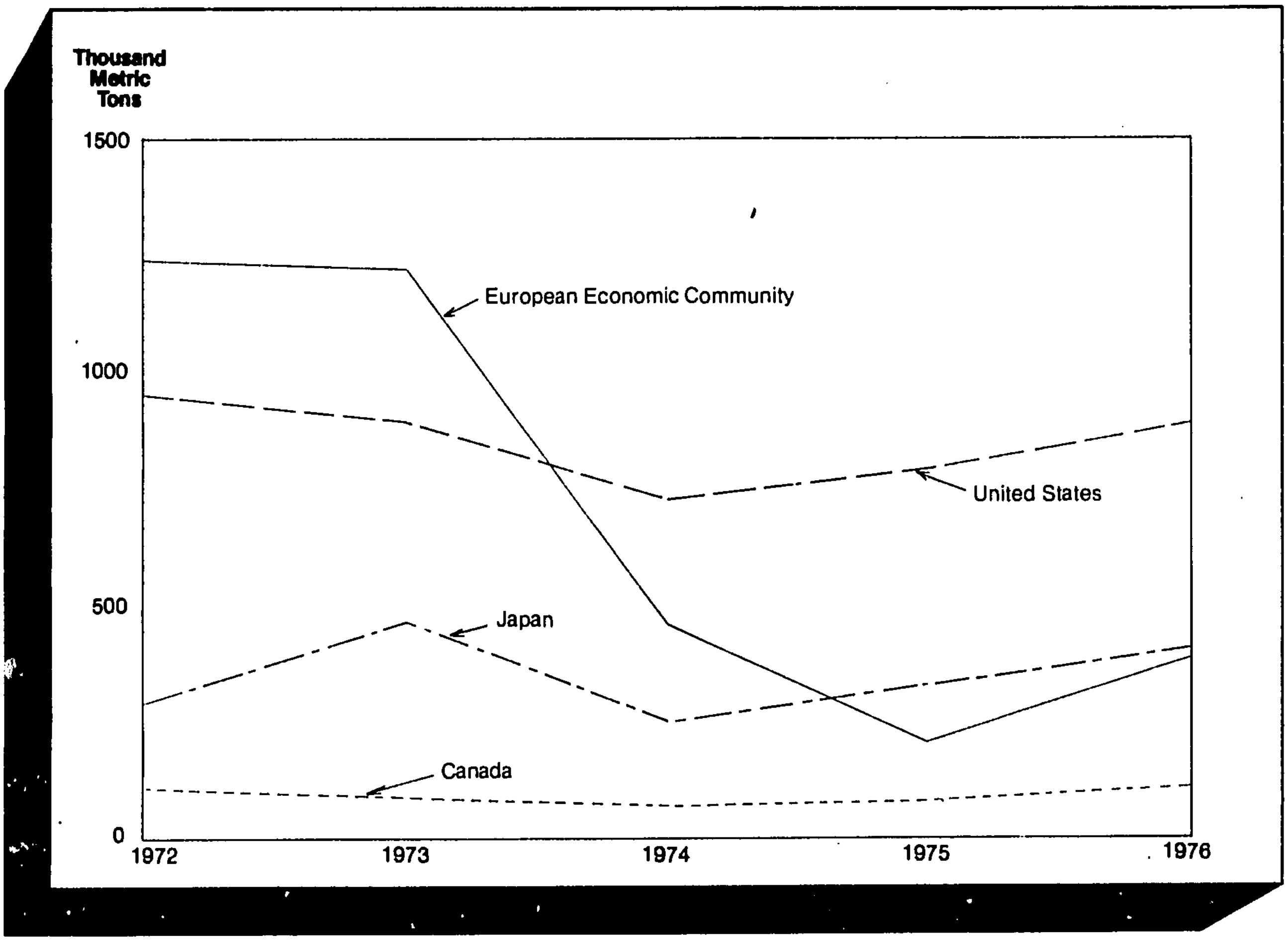

Fig. 6-1 — Net ruminant meat imports of the four largest importers, 1972-1976

done in producing areas. In Africa and Asia, animals are generally slaughtered in consuming areas rather than in producing areas. In a few countries, air transport of carcasses is a factor, especially where producing areas lack road access to consuming centers and retail prices are attractive. In Guyana, some cattle are slaughtered and flown almost 560 km to Georgetown. The Botswana Meat Commission has used jet planes to fly high-value cuts from that country to seasonal high-price markets in Switzerland and Hong Kong.

In the United States, a major feature of the postwar change in structure of the cattle slaughtering business was the shift of plants to the major feeding areas away from both river market and consuming points. There were a number of reasons for this change — the two major ones being the reduction in shrink in movement of live fat cattle and completion of the interstate highway system which enabled carcasses and sub-primal cuts to be shipped to most consuming centers within 48 hours.

This trend is beginning to occur in developing countries. In Latin America, modern plants have been constructed in the interior. In Tanzania and Ethiopia, slaughter plants are currently being constructed in the major cattle areas, therby avoiding the long treks to the capital city for slaughter. These treks often resulted in 30 percent shrinkage and 10 percent mortality.

Credit

To expand and improve the output of ruminant products at the scale projected to 1985 will require large investments in livestock, processing and handling facilities, and forage resources. No recent estimates are available, but the FAO Indicative World Plan estimated that at 1962 prices, the ruminant animal industry would require an investment of about $31 billion of additional capital by 1985. Of this, $16 billion would be in cattle inventory, $8 billion in meat and dairy processing plants and feed mills, and $2 billion in land development (*19*). There would be additional annual outlays to cover increased operating costs. From 1962 to 1974 the FAO index of cattle prices rose by about 50 percent (*20*), and the price index of the gross domestic product (GDP) in OECD countries at market prices rose by about 85 percent (*21*). So, if we increase cattle inventory values by 50 percent and other investment costs by 100 percent, the total investment at today's prices would be about $44 billion.

Sources of agricultural credit are poor in most developing countries, and especially deficient for livestock. Financing of the large sums required for expansion will be difficult. Some of the investment in livestock inventory will accrue through the gradual expansion in herds, and while direct financing may not be required, holding back of additional breeding stock will be a form of forced saving that will present difficulties of its own either through reduced short-run income or added expenditures to expand productivity.

In all Latin American countries, the main factors that limit livestock development are said to be a lack of medium- and long-term funds (8-12 years) for ranch development and the failure to adapt modern technology to local conditions (*22*).

An especially important problem is that of the credit needs of smallholder livestock producers. Because of their limited resources, a workable credit system is imperative (*23*). Unfortunately, institutions in rural areas are not geared to meet the needs of small farmers. Most are reluctant to make loans because administrative costs of small loans are high. As a result, in many countries, 70 to 80 percent of small farmers do not have access to institutional credit. Individual lenders are concerned about high risks and lack of collateral.

One of the deterrents to wider use of credit is the high interest rates that many small farmers are forced to pay. Rates charged by private lenders range from 24 to 200 percent. Although institutional rates are lower — 6 to 16 percent — such loans are not often available to those producers who need them most. Those operators who are fortunate enough to obtain loans generally try conscientiously to repay them; yet the number of loan delinquencies is often very high.

From the standpoint of the small producer, factors that affect the amount of credit a lending institution will deliver are: (a) available technology that can be applied and used properly, (b) number or degree of inputs supplied by the farmer, (c) desire by the farmer to personally invest borrowed money and to pay for the service, and (d) guarantee or collateral.

Factors which will contribute to development of better credit programs for smallholders include:

- Local government should take a larger role in credit development and take steps to avoid political interference and corruption.

- Interest rates should be kept as low as possible without being subsidized. Group credit schemes can help reduce costs. World Bank experience with subsidized credit has been that larger farmers get most of the credit, and private cooperative credit agencies are driven out of the market.

- Farmers must be helped in drawing up realistic repayment plans in line with pricing policies and expected income.

- New loan eligibility criteria need to be developed — perhaps, with less emphasis on security.

- Private banks need to be encouraged to participate in credit programs.

- Credit institutions must become more than sources of credit. Credit should be backstopped by technical assistance and attention to the human factor.

Human Resources

AMONG the most serious nonbiological constraints to achieving livestock production potentials are the shortages of adequately trained and motivated people. This lack of skilled manpower includes producers, processors, distributors and the network of extension advisors and technicians required for teaching, directing and organizing program operations.

 

Labor intensive methods provide control and protection for livestock. Here, herdsmen from Zanzibar (left) and India (right) tend their grazing animals. *Winrock International Photo.*

Management — Quality of management directly affects productivity and value of ruminant products and, thus, the economic returns to producers and processors. Previous chapters have discussed the potentials for better management of nutrient resources, including the benefits of strategic supplementation of nutrients not available in optimal quantity; utilization of quarantine, vaccination, dipping, drenching and other means of eliminating or controlling the ravages of disease and parasites, and the design and implementation of effective selection and breeding programs to raise the genetic ceiling on production.

Management involves additional activities. Housing may be required for protection against predators and the extremes of temperature and moisture. Strong, well designed corrals simplify handling and reduce chance of injury to man or beast. Fences provide the controlled movement of ruminants often necessary for grazing resource management and initiation of effective genetic improvement schemes. Electric fences carrying short impulse, high voltage current are proving an effective protection device against the attack of sheep by dogs and coyotes.

Lost value due to poor processing and preservation of ruminant products is substantial. Poor milking management, is a major cause of mastitis. Unsanitary processing, lack of refrigeration or other preservation techniques hastens spoilage of milk and meat and may cause public health problems. Hides and pelts are damaged by parasites, branding and knife cuts during skinning. Poor shearing technique yields wool of inconsistent staple length.

Knowledge and technology are available to improve management of ruminants and their products. Producers, processors and distributors must be motivated by favorable price differential to manage for higher production and better quality products.

Training — Training and motivation of livestock producers in less-developed areas is often difficult because of low levels of education and deeply-ingrained traditions. This is as true in the neglected low-producing areas of North America and Europe as elsewhere. The needs are for long-run efforts to win confidence, to develop awareness of emerging problems and new potentials, and to teach new technologies. In many instances, extension workers have been ineffectual because they come from a different background, and are over-trained in high-level technology and under-trained in communication, socio-cultural disciplines and practical farming.

Training of those who deal with livestock producers — bankers, buyers, feed suppliers and processors — is almost totally neglected. Hence, there is little attention given to the advantages of better quality grading of livestock products, of possible improvement in feed mixes, of the credit needs of new technologies, the proper handling and use of medicines and vaccines and similar matters.

Well trained extension workers are few and there is inadequate attention to means of extending their effectiveness through recruitment and training of para-professionals (for example, the "animateurs" in Senegal, the "village level" workers in India, and the "vulgarisateurs" in Cameroon) and of "leading" or "contact" farmers. The number of livestock per veterinarian conveys an idea of the scarcity of one kind of animal specialist in developing countries (Table 6-1).

Training specialists and extension workers report that their greatest difficulty is in being able to work effectively with smallholders. Too much emphasis is placed on importing masses of technological facts as applied to production systems in developed countries. Too little emphasis is placed on practical, on-site farm demonstration.

Effective training materials are in short supply. A special challenge is the communication of new technology and superior husbandry skills to illiterate producers. Picture books, slide-cassette programs and videotapes may have real potential but it has yet to be adequately demonstrated.

Organization — Effective utilization of extension staff requires a profitable package of technology, a supply of inputs and good administration. Some common constraints include the following:

- A low-paying technological package, or one that is too complicated for producer implementation.

- Undependable or too-costly supplies of feeds, breeding stock, medicines, fertilizers or other supplies.

- Inadequate communication with research workers for assistance with technical problems.

Table 6-1. — Number of veterinarians and livestock units per veterinarian

Region	Veterinarians[1]	Livestock units per veterinarian[2]
	Numbers	Thousands
1. North America	33,034	3.9
2. Middle America	5,735	8.5
3. South America	11,502	18.2
4. Western Europe	51,392	2.1
5. Eastern Europe	27,043	1.9
6. Soviet Union	80,000	1.5
7. China	n.a.	n.a.
8. North Africa-Mid East	6,231	12.6
9. Central & East Africa	1,260	94.5
10. Southern Africa	930	20.9
11. India	10,800	19.6
12. So. & So. East Asia	6,796	17.1
13. Japan	21,529	.3
14. Oceania	3,736	13.6
15. Rest of World	753	23.1
World Total	260,741	55.7

[1] FAO-WHO-OIE 1974 Animal Health Yearbook. FAO, Rome.
[2] Livestock units: camels, 1.1; buffalo, horses, mules, 1.0; cattle, asses, .8; swine, .5; sheep, goats, .1; poultry, .01.

Consequently, the technical content of extension programs is poor and often obsolete.

• An ineffective development strategy that spreads workers too thinly, or that fails to seek out and concentrate on most responsive sectors of the agricultural population.

A customary time-saving approach is to begin extension work with progressive farmers who are community leaders. While this may improve cooperation, it sometimes alienates both extension workers and leading farmers from the rest of the community. Programs with leading farmers should include companion activities for the rank and file. A project in Rajasthan and Madhya Pradesh, India illustrates an effective approach at the village level. The project involves village level workers, each of whom works with 40 contact farmers. But each contact farmer keeps in touch with 7 followers and encourages them to participate in as much of the extension program as they can (*24*).

A roadside retail meat market is still common in many developing regions. *Winrock International Photo.*

Socio-cultural Constraints

MOST studies of the world food problem give some consideration to the socio-cultural constraints to agricultural development. Usually it is perfunctory; often it is superficial. Of the numerous cultural traits that have a bearing on development, greatest attention is given to the customs and folkways of tenure, family labor utilization, credit and community organization. But few of these have received adequate attention.

The FAO *Indicative World Plan* hardly recognizes socio-cultural problems, except for brief discussion of land tenure and a consideration of Indian beef potentials if Hindu constraints on cow slaughter could be somehow relaxed (*25*). The UN 1974 *Assessment of the World Food Situation*, and the USDA *World Food Situation and Prospects to 1985* do not deal with socio-cultural aspects in their projections. The University of California's *The Hungry World* has a little over one page out of 327 labeled "socio-economic factors." (pp. 155-156) The 3-volume FAO *East African Livestock Survey* of 1967 included no socio-cultural analysis, although it observed that, "In pastoral areas it is often technically feasible to expand meat production rapidly by increasing the percentage offtake of animals. However, the main problem here is sociological." (p. 282). Other studies endorse the significance of cultural obstacles to changing livestock practices with similar lack of critical examination.

The problem is partly one of benign neglect. But it also stems from the nature of the disciplines concerned, and the way they are obscured in government and agency organization (*26*). In nearly all agricultural ministries and bureaus, there are strong departments of range management and animal health, and perhaps even animal science and economics. But sociology and anthropology, if recognized at all, are likely to be represented by a few isolated professionals. Much of the research is focused on narrowly-defined issues of limited geographic scope. For a long time, the body of applied knowledge about human behavior toward livestock management seemed to consist of the well-documented accounts of Hindu aversion to animal slaughter, especially of cows; Muslim and Jewish taboos on pork; a few studies in some depth of economic and social processes found in important societies like the Fulani and the Masai of Africa; and a collection of studies of folkways of small tribes mainly useful in connection with specific projects, but often done in places that had no projects.

The series of studies and projects that are emerging in Africa as a result of the Sahelian drought indicate that applied socio-cultural research is beginning to be appreciated, and that

One necessary, yet labor intensive management practice is the shearing of sheep. *USDA Photo.*

it can become an essential component in development, planning and administration (*27*).

The identification of generalized principles that can be applied safely across many cultural and ecological zones is hazardous with any science or discipline. The plant and animal sciences and economics have all had their notorious failures in transplanting concepts. But scholars are sometimes able and willing to produce useful regional monographs of principles and practices of general applicability with respect to breeding, feeding, disease prophylaxes, credit programs, marketing systems and the like. Anthropology and sociology seem not to have reached that stage. Few anthropologists will advance generalized concepts that they feel are operational beyond a restricted locale.

About the only generalization we can attempt is to suggest a checklist of elements that should be studied in depth. Important items include the following:

1. Ethnic and cultural values relevant to economic development and change are varied and important.

2. Taboos and prejudices in use of animal products or in handling livestock should be identified and dealt with in project planning. It should not be assumed that economically advanced societies will be free of prejudices. Note the irrational American bias against bull beef.

3. There may be mystical, magical or whimsical explanations for some aspects of animal husbandry. But frequently, assertions to that effect are only superficial explanations for actions that really have well-grounded economic or physical rationales. For example, western planners often conclude that the rational "economic" course for a pastoralist is to reduce herd numbers. But the pastoralist may feel that destocking is quite irrational unless the planner can come up with a form of security that is as good as his traditional survival strategy based on numbers (*28*).

4. All cultures have forms of social organization or institutions that can help or hinder economic development. They may offer alternative bases for development of credit, tenure and extension programs for the implementation of exotic forms. Or, they may in some instances be so encrusted with parochialism, nepotism and politicization as to be counter productive. In any event, they should be investigated on the spot in advance of program planning. A serious effort is being made in Tanzania to build development activities around the Uja'maa concept (*29*). Governments in the Near East and North Africa are beginning to recognize the need to preserve the best features of tribal social structure with respect to range utilization, while encouraging full participation of tribal members in the structure of the modern state (*30*). More consideration needs to be given to relating extension, credit and tenure activities to indigenous institutions insofar as they are adaptable.

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Children and pregnant women require sources of high quality protein in their diets. *Winrock International Photo.*

FUTURE ECONOMIC DEMAND FOR RUMINANT PRODUCTS

The vast middle class of the world is beginning to exert far more pressure against scarce resources than the growth of the poor population.

PREDICTING future economic demand is an activity rife with uncertainties. Will economic growth continue in light of increased cost of energy? Will the expanding human population so stress the limits of agricultural and industrial productivity as to generate recession? Can an international balance of trade be reached so that sufficient foreign exchange will be available in Japan, Europe and North America to pay for increased imports of ruminant products? In the present state of constantly changing world conditions, one can never be quite sure what the answers to such questions will be. Within limits, however, it is possible to identify patterns of consumption and demand throughout the world and to draw reasonable conclusions as to probable effects on the basis of supply-demand formulary.

Economic demand is the principal driving variable determining growth of ruminant production enterprises. The determinants of economic demand are (a) population numbers and trends in population, (b) amounts and trends in income, (c) distribution of income, and (d) the responses of people to changes in prices and incomes in relation to the quantities of ruminant products they will buy. Change in the quantity of product purchased due to change in price is called "price elasticity of demand." Change in quantity of product associated with increased consumer income is called "income elasticity of demand." Changes are expressed as percentages. Demand must not be confused with mere wants or desires. Economic demand refers to people's wants backed up by purchasing power.

The principal factors influencing elasticity of demand for a commodity are (a) willingness of consumers to buy more or less of the commodity if prices or incomes change, (b) the availability of other commodities that consumers consider to be good substitutes, and (c) purchasing power. Over time, elasticities of demand can shift as a result of changes in habits, attitudes or taste preferences brought about by education or by experience with substitutable commodities.

Population Factors Affecting Demand

Population Growth — The principal population factor affecting economic demand is, of course, the number of people who make up the potential market. Changes in population numbers in the 15 world regions to the year 2000 are shown in Table 7-1. Projections for the U.S. reflect the recent sharp decline in birth rates.

Projections for nearly all of the developing regions show very rapid rates of population growth to the year 1985; projected growth rates to the year 2000 continue to be quite high. Central Africa, North Africa and the Middle East may actually increase their already high population growth rates to the year 2000. China is projected at a much lower rate than other developing regions, and only a little higher than the more industrialized countries. Developed regions show considerably more moderate rates of population increase than developing countries. In 1970, the less-developed countries had 70 percent of the world's population; by 2000, this proportion is projected to 79 percent. Currently, about 85 percent of all births are in less developed countries.

High population levels are a comparatively recent phenomenon in human history. They followed immunization, sanitation, and a more dependable food supply. Continued high population growth rates are anticipated even though many nations have undertaken family planning programs. Family planning will be effective only in the long run; the extent of its adoption depends upon increased individual income, technology, education and motivation. Even if

Table 7-1. — Human population and per capita private consumption expenditure, 1970, and projections

	Developed regions[1]	Developing regions[2]		World
		India	Others	
Population[3]				
1970, millions	1072	565	1978	3615
1985, millions	1220	814	2792	4826
Annual growth 1970-1985, %	.9	2.5	2.3	1.9
2000, millions	1345	1134	3863	6342
Annual growth 1985-2000, %	.7	2.1	2.2	1.8
Private consumption[4] expenditure				
1970, U.S.$	1564	73	161	564
1985, U.S.$	2600	89	259	840
Annual growth 1970-1985, %	3.7	1.3	3.7	2.7

[1] Includes regions 1, 4, 5, 6, 10, 13, 14; generally temperate, industrialized countries.
[2] Includes regions 2, 3, 7, 8, 9, 11, 12, 15; generally tropical, agriculturally employed countries.
[3] Compound annual growth rates. Projections are United Nations "medium" variant as assessed in 1974 except U.S. which is U.S. Department of Commerce, Series III. U.S. Dept. of Commerce, Bureau of the Census. *Population Estimates and Projections.* Current Population Reports Series p. 25 no. 541, Feb. 1975. U.N. Data from Population Division, U.N. Secretariat, New York.
[4] In 1970 constant prices. Projections from unpublished preliminary estimates supplied by Foreign Demand and Competition Division, ERS, USDA. See Reference No. 3 for basis.

family planning is successful, it will be years before birth rates will decline because of the increasing numbers of young women.

Population Composition — Another characteristic affecting demand is composition of the population, particularly with respect to age and sex. One of the consequences of disease control has been a change in the population age distribution. Fig. 7-1 illustrates the present situation in selected regions. The "population pyramids" show the percent of male and female population in each 5-year age group. The pyramids for less-developed regions are characteristic of population with a high percentage of young people. The diagrams for North America and the USSR have narrowing bases with fewer children in the youngest age groups than in the next older ones. The significance of the pyramids for the less-developed regions is that, for at least the next 15 years, more girls will be maturing into child-bearing ages than there were in the previous generation. Even with increasingly effective family planning programs, birth rates will probably continue to rise for several years. The point has often been made that the rate of growth in population is highest in the regions of greatest stress upon food supplies and least in the regions with abundant food supplies.

Regions with high proportions of children also have high proportions of pregnant and lactating women who require more good quality protein in their diets than other people. Other elements include the kind of work done, especially the extent of manual labor, and the ratio of rural to urban population. Dietary habits of rural people often differ from those of urbanites because of differences in education, availability of home-grown food, differences in competition for the use of money between food and other commodities, and other factors.

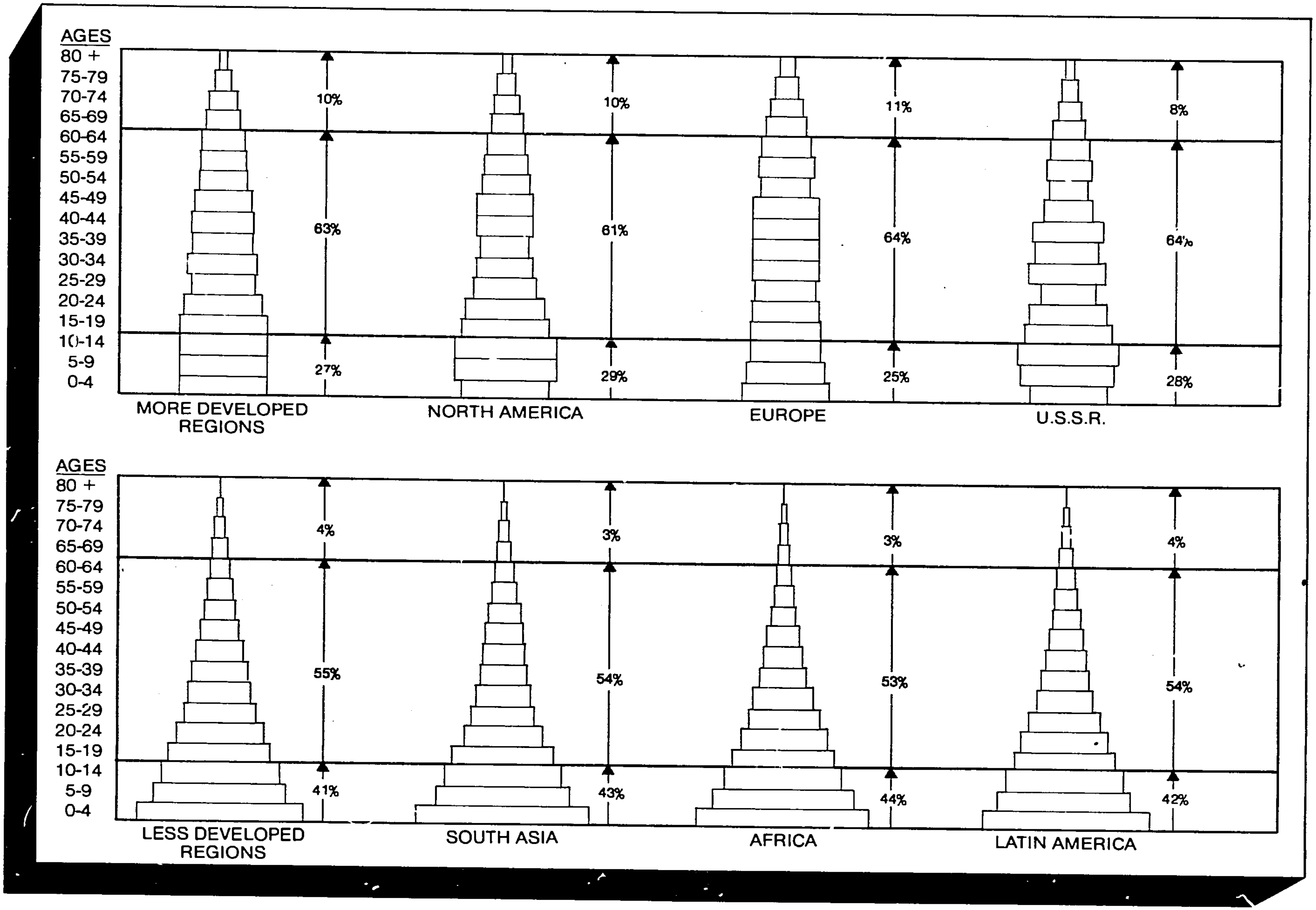
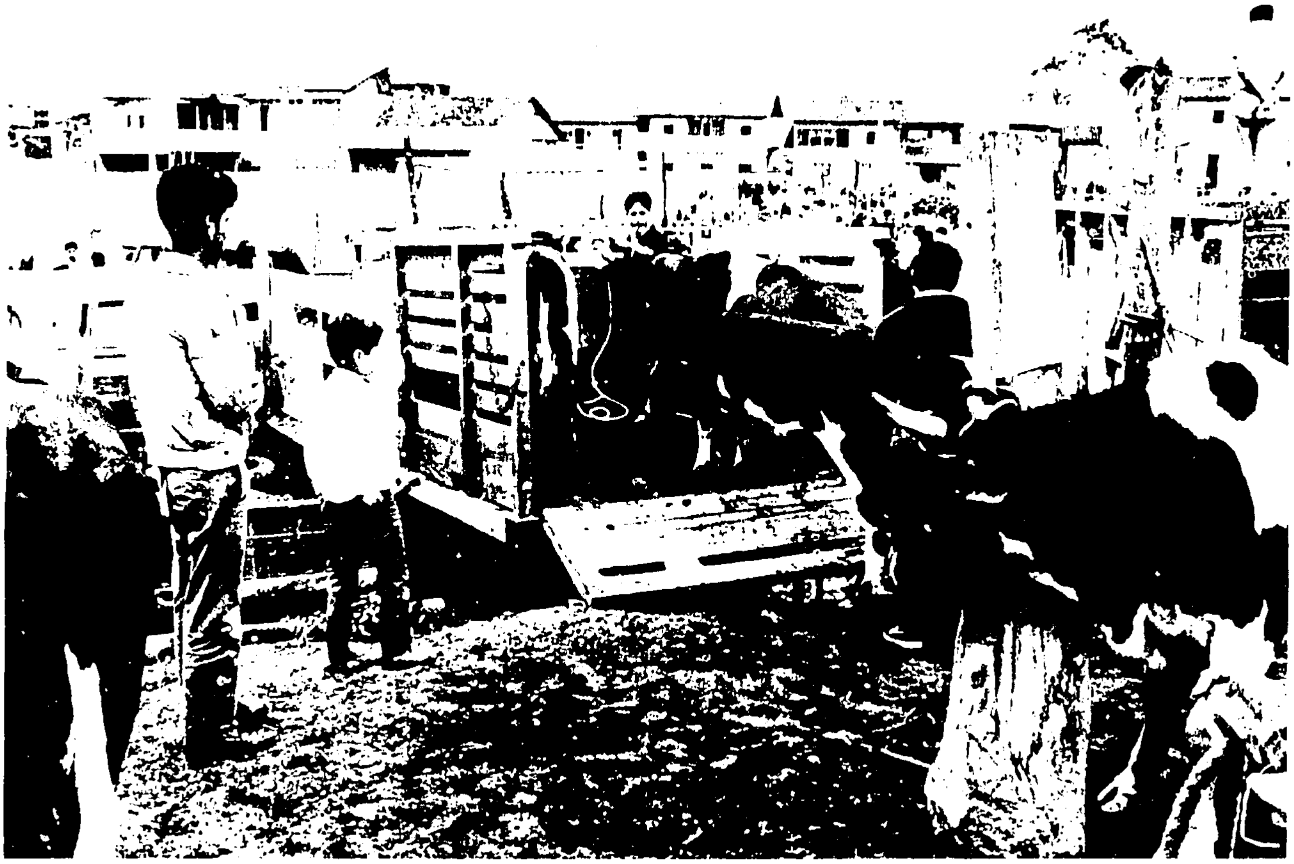


Fig. 7-1 — Age structure of world population by selected regions, 1970. Source: IBRD *Chart Book of Global Indicators*, (1973).



Cattle being loaded at a market at Santo de los Colorados, Ecuador. *World Bank Photo.*

In some areas and among some people, a high frequency of lactose intolerance can limit the amount of milk included in the diet.

Customs and traditions have an important bearing on food choices. Taboos against cattle slaughter among Hindus and against eating pork by Muslims are well known examples. Some societies have a high proportion of vegetarians, some of whom will consume no animal products while others will consume milk and eggs. Customs also affect consumption of food within families. In some cultures, the breadwinners have the first choice of the food available, followed by the male children and the aged, then by the female children and the mother.

Effect of Income on Demand

PER capita levels of income for the various regions as expressed in private consumption expenditures for 1970 and projected to 1985 are shown also in Table 7-1. These figures suggest continuing increases in income per persons in all regions but generally lowest in regions that have relatively low incomes and high population growth rates. Even though quite substantial economic growth is expected in most of the developing regions, the effects of it are so diluted by rapid population growth that only small increases in per capita income can be obtained.

In addition to problems caused by low incomes and very slow rates of growth in per capita income in developing countries, there are serious income distribution problems in many of them. A study of 44 developing countries showed that, on the average, 30 percent of the total income was received by the highest 5 percent of the population, 56 percent by the highest 20 percent and only 14 percent by the poorest 39 percent of the people (*1*). Inequality in income distribution tends to be less in developed countries and in the very least developed countries than it is in countries in the process of development.

Despite much discussion and legislation to make income distribution less unequal, changes in distribution are very slow. In discussing the merits of more income equality, most authorities agree that an increased share of income by low-income families would increase food consumption significantly because of the higher propensity to consume food at low income levels. But there is considerable difference of opinion among economists about the effects on saving and investment and the rate of economic growth. It is also argued that in many societies, limited demand is a greater barrier to growth than capital scarcity and that increased consumer buying power in the hands of the masses would create demand that would attract saving and investment.

A shift in the shares of income from an affluent to a low-income sector would result in an aggregate increase in the demand for food because of the higher income elasticities of demand at low income levels. It would also result in higher *percentage* increases in demand for foods with the highest income elasticities, such as animal products, fruits, and vegetables. But the greatest *quantitative* changes would be for the staple foods, especially cereals.

Estimated income elasticities of demand for selected food products in selected countries and the 1970 per capita income (gross domestic products basis) are shown in Table 7-2. Elasticities for different commodities vary considerably among the countries. But in general, income elasticities tend to be lower in countries with higher income. Elasticities tend to be highest for meats, milk, fruits, vegetables, and sugar; somewhat lower for pulses; still lower for cereals; and lowest of all for root crops. At higher incomes, elasticities for pulses, roots and even cereals are often negative. A negative income elasticity means that the quantity

Table 7-2.— Per capita income and income elasticities of demand for specified food commodities, selected countries, 1970

Country	Per capita income[1]	Demand Elasticities							
		Cereals	Roots	Sugar	Pulses	Fruits	Vegetables	Meat	Milk
	US $								
Nigeria	97	.37	-.13	1.59	.51	.60	.60	1.19	1.20
India	99	.26	.00	.89	.50	.80	.70	1.00	.65
Indonesia	109	.69	.20	1.49	.30	.80	.60	1.37	2.00
Ivory Coast	288	.52	-.36	1.25	.35	.49	.60	.94	1.50
Peru	415	.41	.35	.37	.60	1.00	.60	.77	1.10
Mexico	649	-.18	.27	.32	-.16	.54	.50	.60	.76
Argentina	950	-.08	.07	.19	.12	.44	.30	.21	.10
USSR	1,295	-.30	-.40	.22	.16	.72	.40	.54	.30
Austria	1,825	-.31	-.30	.10	.27	.60	.30	.30	-.20
Japan	1,933	-.07	.09	.45	.00	.59	.60	.89	.50
France	2,552	-.39	-.30	.32	-.10	.50	.30	.41	.10
Australia	3,008	-.09	.00	-.09	.20	.71	.20	.08	.00
Denmark	3,097	-.32	-.42	.00	.20	.69	.50	.19	-.10
Sweden	3,718	-.34	-.30	.01	.00	.59	.50	.18	-.20
USA	4,798	-.23	-.20	.11	.05	.27	.10	.26	-.50

[1] Income in this table is figured as per capita gross domestic product. Gross domestic product is somewhat the same as gross national product except that it includes only domestic inputs and excludes any inputs from foreign transactions accounts.

Source: Adapted from FAO, *Agr. Commodity Projections*, 1970-80, Vol. 11. a/ Section 1, Table 6; b/ Section III, Table 13. "Meat" includes red meats and poultry but not fish.

consumed declines as income increases. An elasticity greater than 1.0 indicates that with a 1 percent increase in income, the percent of a commodity consumed rose by more than 1 percent. Similarly, between 0 and 1.0, a proportionate increase in consumption is positive but less than 1 percent.

Elasticities for meat, fruits and vegetables are positive for all the countries shown in Table 7-2, which reflects a desire to improve quality of the diet even at quite high incomes. Milk elasticities for low income levels are very high but decline sharply and are frequently negative at higher incomes. However, the estimate applies only to whole milk. If butter, cheese and ice cream were included, the elasticities might be somewhat higher.

Regional Patterns in Food Consumption

MORE than half the world's food energy (caloric basis) comes from cereals; only 17 percent of it comes from animal products. Less than 10 percent is supplied from roots and tubers or from sugar and its products. Each of the categories of pulses, fruits and vegetables, vegetable fats and oils provides 5 percent or less of calories consumed (Table 7-3).

Animals supply about 32 percent of the world's protein, cereals supply 47 percent, pulses 12 percent and other foods lesser amounts (Table 7-3).

Sources of nutrients on a calorie basis vary greatly among geographic regions (Fig. 7-2). In Asia, about two-thirds of all calories comes from cereals. Root and tuber crops are an important source in USSR, Central Africa, China and parts of South America and Asia. Roots and sugar crops together supply about 30 percent of the calories in Central Africa and parts of South America, notably Brazil, a fact that is significant because of the low value of these crops in any nutrient except energy and the low quality of overall diets consumed by many people in these regions.

North America obtains more of its proteins from animal sources than does any other region — 75 percent; India ranks lowest in use of animal protein — 11 percent. Dairy products are the most important single source of protein in North America and Western Europe, but are of minor importance in some regions. The major sources of proteins for six countries or regions are shown in Fig. 7-3.

Table 7-3. — Contribution of various food groups to world food supply, 1964-66

Category	Calories	Proteins
	----- *Pct.* -----	
Cereals	52.4	47.4
Roots and tubers	7.8	4.8
Sugar and sugar products	8.8	.2
Pulses, nuts and oilseeds	5.1	12.0
Vegetables and fruits	3.5	4.3
Vegetable fats and oils	5.3	—
All animal products	16.7	31.7
Meat	(7.1)	(14.0)
Milk	(4.9)	(10.8)
Eggs	(.8)	(2.1)
Animal fats	(3.1)	(.2)
Fish	(.8)	(4.6)

Source: Adapted from University of California Task Force: *A Hungry World*, Berkeley, 1974, p. 36. (Original data from FAO food balance sheets.)

Nutritional Adequacy in Relation to Economic Demand

THE United Nations has assessed the world food situation of 1974 in terms of energy and protein supply per person. These data are given in Table 7-4. Note that in Africa and the Far East, energy supplies were less than requirements. Including the suggested margin of 10 percent above requirements to cover expected effects of maldistribution, energy supplies were deficient in all less-developed regions; also for some of the developed market economies, and for the world as a whole.

Protein supplies, on the average, are equal to or above quantity levels often assumed to be necessary. But, as the UN study pointed out, assessments of protein requirements by themselves tend to be meaningless because if the energy supply is not adequate, proteins are burned for energy and are not available as body-builders. Also, one would have to look more carefully into the composition of proteins before making any conclusion about adequacy of the supply. Food nutrition specialists seem

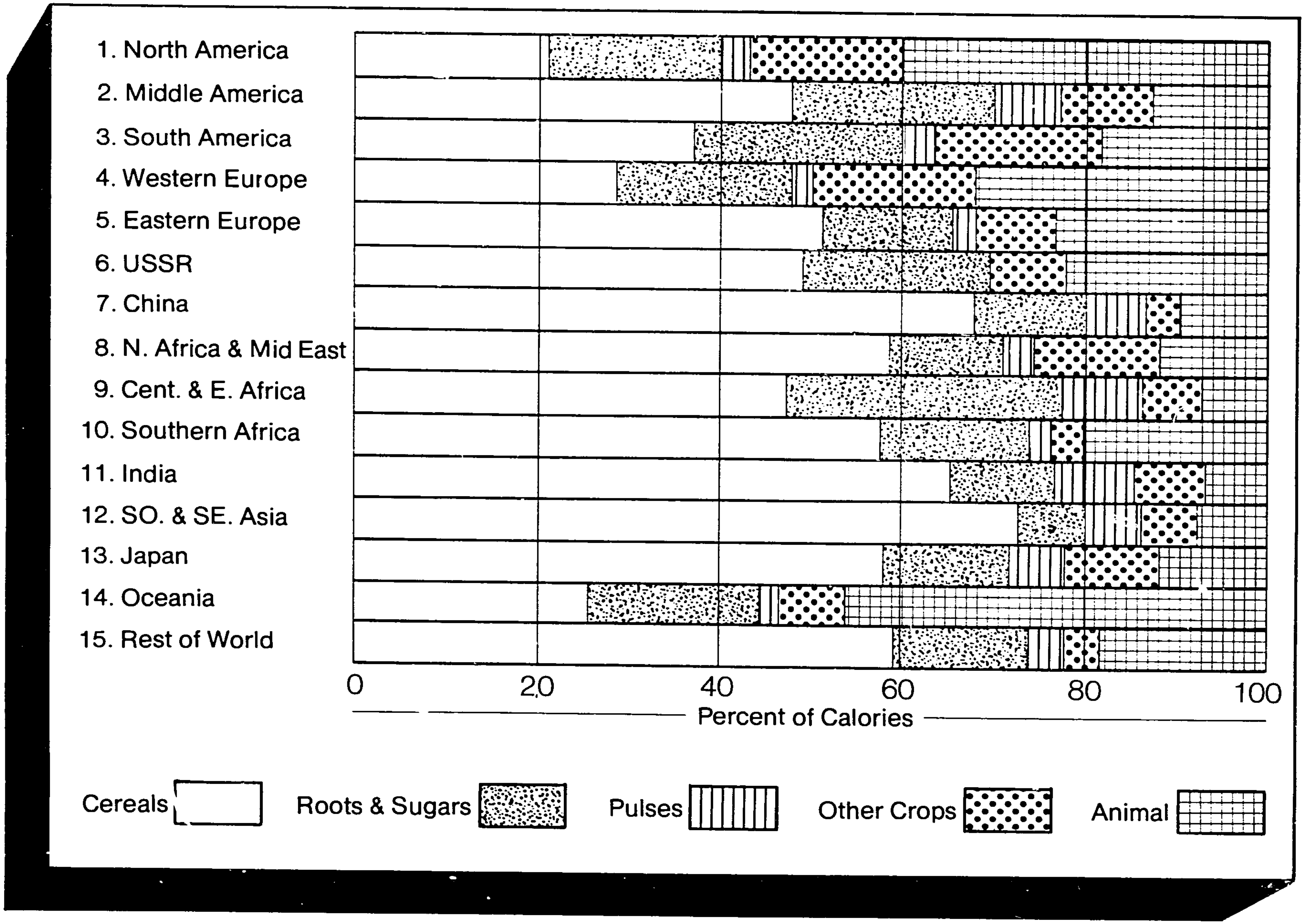


Fig. 7-2 — Principal sources of calories by regions. Source: Adapted from data in FAO *Agricultural Commodity Projections*, 2. (1971). In some instances, individual countries are used to represent regions.

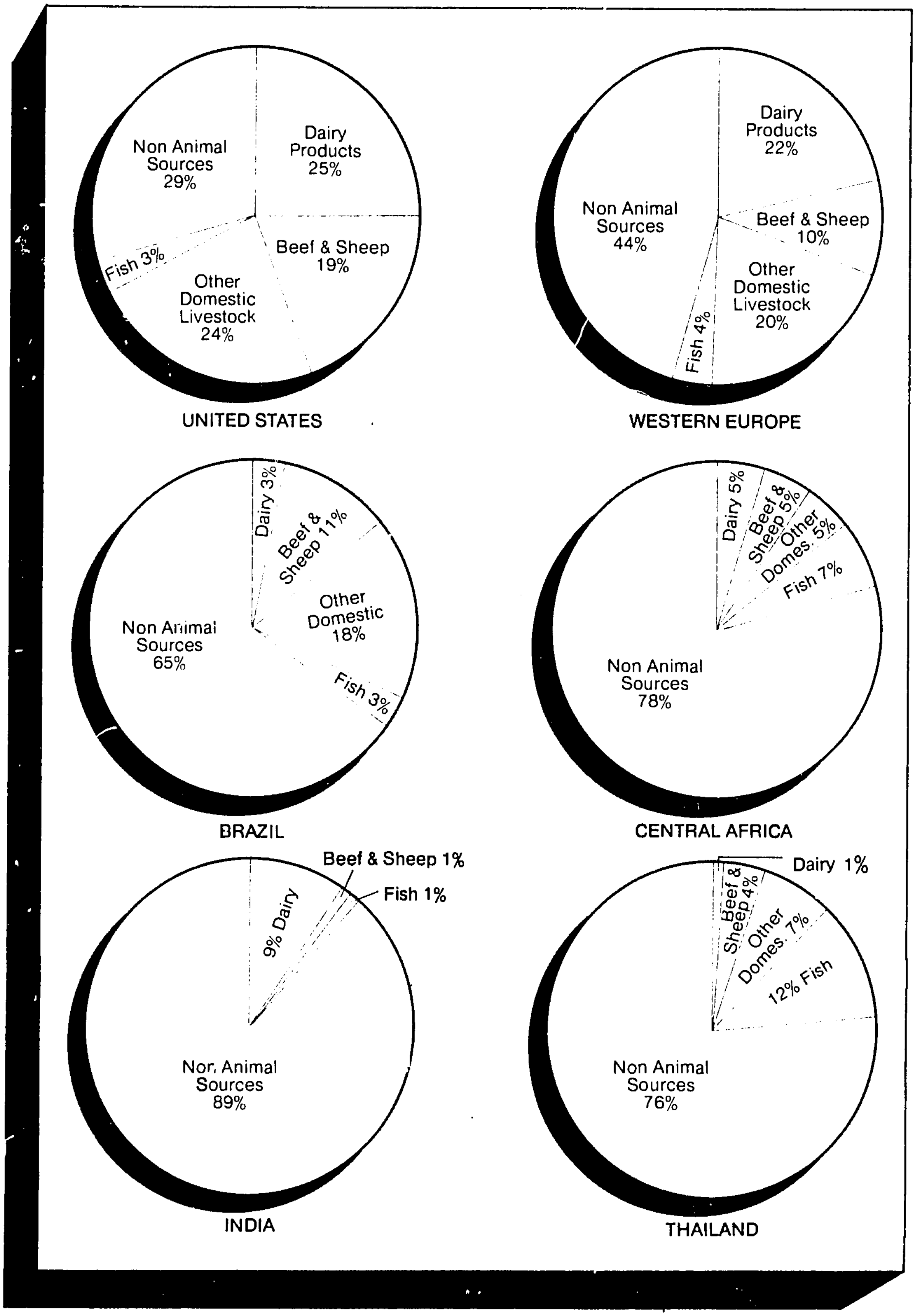


Fig. 7-3 — Proportions of protein supplied from specific sources in selected areas, 1964-66.

Table 7-4. — Average annual energy and protein supply per person by region, 1969-71

Region	Energy		Protein[2]
	Amount	Percent of Requirement[1]	
	Kcal.	Pct.	Grams
Developed market economies:	3,090	121	95
Western Europe	3,130	123	94
North America	3,320	126	105
Oceania	3,260	123	108
Other	2,550	108	79
Eastern Europe & USSR	3,260	127	99
Developing market economies:	2,210	97	56
Africa	2,190	94	58
Far East	2,080	94	51
Latin America	2,530	105	65
Near East	2,500	102	69
Asian centrally planned Economies:	2,170	92	60
World	2,480	104	69

[1] Energy supply should be at least 110 percent of requirement to allow for maldistribution. Requirements are based on needs of a moderately active "reference" man of average body weight for the region.
[2] No requirement is calculated for protein because need depends on an adequate level of energy and quality of protein.
Source: United National World Food Conference. *Assessment of the World Food Situation*, Rome, 1974, p. 58. Availability is after allowance for storage and marketing losses and waste.

to be moving away from an earlier preoccupation with a protein gap. Instead, emphasis is now on adequate energy; the concern for proteins is secondary. There still is concern for the protein needs of those with exceptionally low protein diets as amongst root or plantain eaters, and for vulnerable sectors of the population such as small children, pregnant and lactating women and people who are debilitated or suffering from internal parasites.

Aside from the question of aggregate adequacy of diets by regions, there is a serious problem of maldistribution of purchasing power and food supplies within countries and regions even for the affluent and well-developed areas. It is doubtful if the United Nations 10 percent margin is sufficient to provide adequate food for everyone in most countries if only a minimum supply of food is to be made available to all inhabitants.

The calculation of nutritionally adequate diets does not insure that they will be acceptable to the people whose diets need to be improved. The protein-rich pulses have the disadvantage of causing flatulence and other digestive disturbances and can be consumed only in small quantities by small children. Studies on effective demand and studies of price and income elasticity clearly show that consumers have a very strong desire to eat fewer roots as soon as they can afford something more appetizing and even to move moderately from high cereal diets to livestock products, fruits and vegetables. Some of the assumed cost advantages of cheap cereal diets may be lost through greater plate wastes or avoidances of high intake of unpalatable food.

Meat and milk from ruminant livestock provide about 10 percent of the energy and 15 percent of the protein in the world food supply (Table 7-3). Milk is a major source of calcium in many countries. Meat and milk are principal sources of the essential vitamin B_{12}. Furthermore, these nutrients are supplied in foods preferred by most people. Other equally acceptable alternates are not generally available.

Projected Demand for Food from Ruminants

THE combined effects of income elasticities, income growth and population increase on the rate of growth in meat demand for 6 selected countries are shown in Table 7-5. In poor countries, population growth often has a greater effect on demand than does income. But in the more affluent developed countries, income effect is likely to have the greater influence.

An important point about commodities with high income elasticities is that production can be increased with much less danger of flooding the market and causing disastrous declines in price. However, it is essential that market, storage and processing facilities, and sometimes consumer education, expand along with production.

Per capita levels of consumption of ruminant livestock prod..cts in 1970 and projected levels to 1985 are shown for each of 15 regions in Table 7-6. Projected quantities shown here are not merely extrapolations based on rates of

> **Agriculture's Unfair Burden: Disproving Malthus**
>
> How can we best solve the food/population problem? As a biologist, I cannot bring myself to believe that it is in the best interests of humankind to lead with increased food production rather than decreased fertility. I view with misgivings the proposition that more food must be produced to accommodate an ever expanding population. The question is not whether the world *can* feed 40 billion people but whether it *should*. I hold that population growth must be halted as harmlessly as possible and soon — within the next two decades. Attention could then be given to the elimination of hunger, malnutrition and disease among the impoverished who remain untouched by the capacity for dignity and the productive and creative potential of mankind. The population problem is manmade and will either have to be solved by man or it will be solved by the harsher methods of nature. — *R. O. Greep, Harvard University*

Table 7-5. — Population and income effects on annual rate of growth in meat demand, selected countries

Country	Population growth rate 1970-1985	Income			Rate of increase in demand for meat[2]
		Growth rate 1970-1985	Elasticity	Income effect[1]	
	Percentage				
India	2.5	1.4	1.0	1.4	3.9
Indonesia	2.6	2.5	1.4	3.5	6.1
Venezuela	2.9	2.7	.5	1.4	4.3
USSR	1.0	4.8	.5	2.4	3.4
Japan	1.1	5.4	.9	4.9	6.0
USA	.7	2.9	.3	.9	1.6

[1] Income effect = Income growth rate x Income elasticity.
[2] Rate of increase = Population growth rate + Income effect.
Source: Population and income growth rates from unpublished FDCD/ERS estimates. Elasticities from FAO *Agricultural Commodity Projections*, Vol. II, Part III, Table 13.

Table 7-6. — Per capita consumption of ruminant livestock products 1970, and projected 1985, by region

Region	All dairy products (Milk equivalent)		Beef & veal (Carcass weight)		Mutton & lamb (Carcass weight)	
	1970	1985	1970	1985	1970	1985
	kg					
1. North America	277	296	52	64	2	2
2. Middle America	79	99	9	11	1	1
3. South America	104	119	26	29	2	2
4. Western Europe	374	398	23	29	3	4
5. Eastern Europe	136	159	14	18	2	3
6. USSR	272	343	21	27	4	5
7. China	5	6	2	3	1	1
8. No. Afr. & Mid East	110	129	5	6	5	6
9. Central Africa	27	31	6	6	2	2
10. Southern Africa	139	158	23	24	9	10
11. India	69	82	—	—	1	1
12. So. & S.E. Asia	40	52	2	3	1	1
13. Japan	46	102	3	9	2	2
14. Oceania	489	480	43	41	39	37
15. Rest of World	40	52	3	3	1	2
World Average	111	119	11	12	2	2

Source: Adapted from USDA, ERS. Foreign Demand and Competition Div. unpublished material; FAO. *Agr. Commod. Projections*, Vol. 11, 1971: and University of California, *A Hungry World*, 1974. Figures are generally comparable with those in *Hungry World*, p. 23. Differences in the base period arise from definitions. The FAO study uses 1970 as a "normal trend" estimate (Commod. Proj., Vol. 1, par. 34); We show 1969-71 average. *Hungry World* refers to milk; our figures give all dairy products in milk equivalent. *Hungry World* figures for 1970 and 1985 for world total are: milk, 104.8 and 110.2; beef and veal, 10.7 and 12.2; mutton and lamb, 1.9 and 2.3.

population change and income change adjusted for demand elasticities. Some adjustments have also been made for expected shifts in elasticities as incomes and economic conditions change.

It should be noted here that it is the vast middle class of people that will affect demand to the greatest degree in the future. Writing in *World Agriculture*, R. G. Lewis (*6*) states: "We are right at the point where the swifter growth of the middle class, whose individual members consume five times as much as each of the poor, is beginning to exert far more pressure against scarce resources than the growth of the poor population. . . . It is that phenomenon which is the truly explosive and cultural force in the future of international economics and politics."

Present levels of consumption of ruminant products vary widely among the regions. The quantitatively heavy users are, as would be expected, the developed regions including the USSR. The very low levels in China are related to the fact that the Chinese are traditionally low consumers of dairy products and they generally eat more pork and poultry than beef and mutton. Low meat consumption in India, likewise, is related to not only low incomes but also Hindu aversion to animal slaughter. Indians, however, do consume quite large quantities of milk in comparison with other Asians. Lamb and mutton consumption per capita in Oceania is several times that of any other region.

Table 7-7 shows estimates of total world consumption of specified ruminant products by region in 1970 with projections to 2000. For the

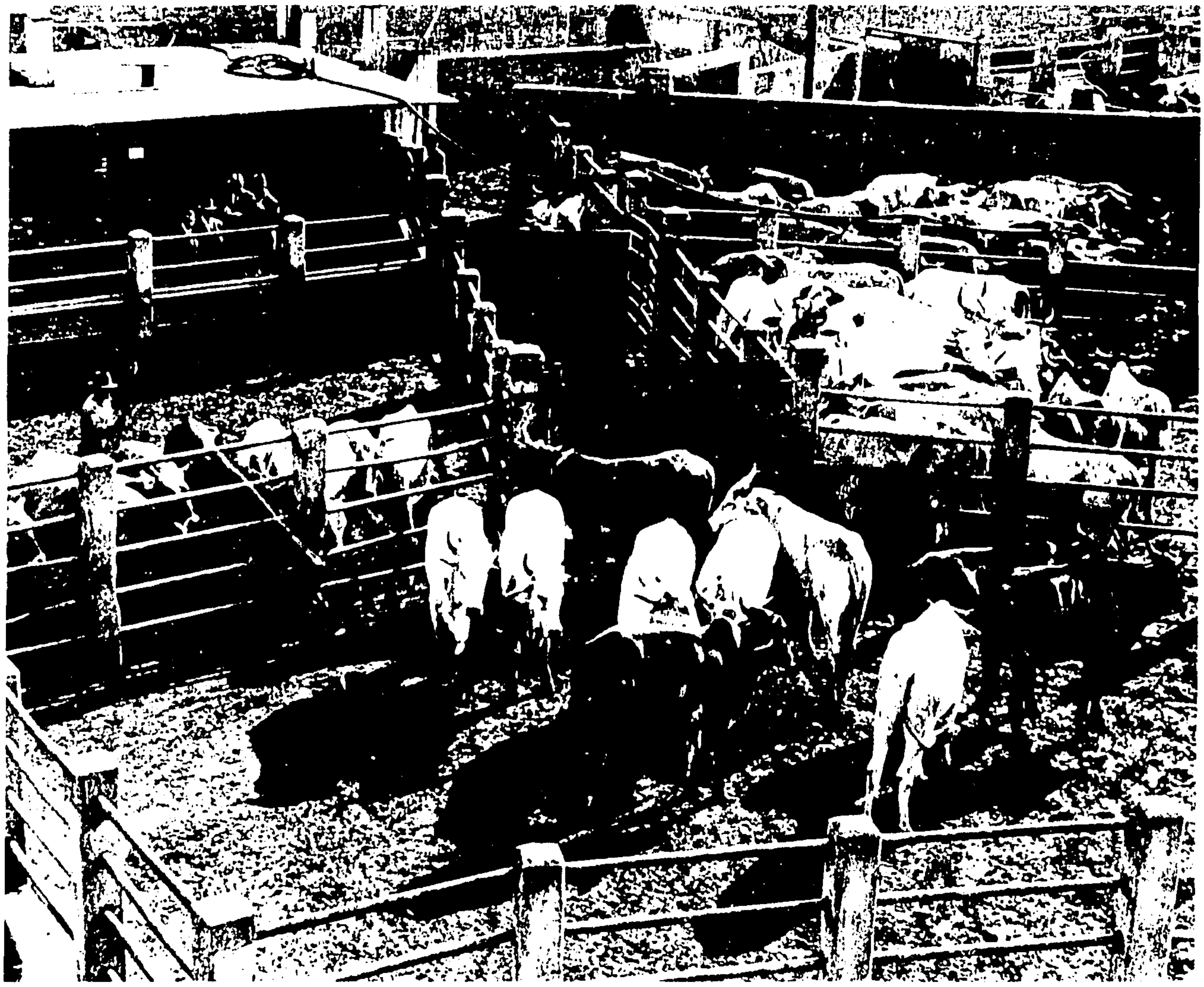
Table 7-7. — Total consumption of ruminant livestock products, 1970 and projected to 2000 by regions

	Developed regions[1]		Developing regions[2]				World	
			India		Others			
	1970	2000	1970	2000	1970	2000	1970	2000
	Million metric tons							
Dairy products (milk equivalent)[3]	286.2	403.7	38.8	91.2	77.5	205.5	402.5	700.3
Beef and veal (carcass weight)[4]	27.6	43.7	.2	.4	10.9	26.3	38.7	70.4
Mutton and lamb (carcass weight)[4]	3.7	5.6	.4	1.0	2.7	6.3	6.8	12.9

[1] Includes regions 1, 4, 5, 6, 10, 13, 14; generally temperate, industrialized countries.
[2] Includes regions 2, 3, 7, 8, 9, 11, 12, 15; generally tropical, agriculturally employed countries.
[3] Conversion factors: 1 kg butter = 21.1 kg milk; 1 kg cheese = 10 kg milk (USDA, Agri. Statistics, 1974) Dairy products include those from cattle, buffalo, sheep, goats and camels.
[4] Beef and veal include cattle and buffalo carcasses; mutton and lamb include sheep and goats.
Source: Adapted from USDA, ERS. For Demand and Competition Div. unpublished material; FAO. *Agr. Commod. Projections,* Vol. II, 1971, and University of California, *A Hungry World,* 1974.

FOR ADDITIONAL INFORMATION REFER TO APPENDIX TABLE 10.

Open-air markets are frequently used to buy and sell goods. Here, wool is displayed for sale in India. *Winrock International Photo.*



Cattle being assembled in a Columbian stockyard for inspection by packers and buyers. *FAO Photo.*

year 2000, estimates are based simply upon projected population multiplied by 1985 per capita levels of consumption. This may understate the future effective demand for these products in regions with rapid growth in per capita income. Note that per-capita levels by 1985 are still very low in nearly all less-developed regions. Consumption projections for milk are especially low in China, Central Africa, East and South Asia, all of Africa except Southern Africa, and for Central America. Even Japan, with its huge percentage increase from 1970, is still low. A slight decline is projected to 1985 in the very high consumption of all meats from cattle and sheep in Oceania.

For the world as a whole, compound annual growth rates for dairy products would be 1.9 percent to the year 2000 (Table 7-7). For beef and veal the figure is 2.2 percent (2). But these modest increases conceal some rather large increases that would be required in less developed countries. World averages are strongly influenced by the high proportion of livestock numbers in the developed regions where population is growing slowly and demand elasticities are moderate to low. Rates of increase in consumption for developing regions except China are considerably above the world averages. Japanese rates of increase (at a compound annual growth rate) are among the world's largest; for dairy products, 3.5 percent; and for beef, 4.9 percent.

Summary

- The wide regional variations in the proportion of animal products in human diets throughout the world reflect varying income levels, relative product prices, differences in tastes, mores and other factors.
- The high income elasticities of demand for livestock products in nearly all countries, and especially the poorer ones, indicate a strong consumer preference for improving the quality of diets and for avoiding the deadly monotony of minimal diets low in animal products, fruits and vegetables.
- A high elasticity of demand for livestock products in a poorer country does not mean that, with moderate income increases, the people will consume large additional quantities of the products. The current consumption base in these countries is very small.
- A high elasticity of demand for livestock products is a step in the direction of good nutrition, but not necessarily toward least-cost nutrition on a per-unit nutrient basis.
- Strong consumer demands for livestock products in poorer countries suggest that if domestic output of these products is not encouraged, there will be growing pressure for importing such products, particularly as income improves, thereby placing serious strains on foreign exchange supplies.
- Strong consumer demand for livestock products means that production can be pushed vigorously without fear of saturating the domestic market, provided suitable steps are taken to develop a marketing structure.
- Greater equality in income distribution would increase aggregate food consumption in most countries. For low income countries, increases would probably be greater for basic starchy foods than for the more expensive sources of foods such as animal products.
- Per capita consumption of ruminant livestock products will quite likely increase modestly in the next 2 or 3 decades on a worldwide basis. In the less-developed countries, percentage increases in consumption will probably be greater than in developed countries.

REFERENCES AND NOTES

1. Erma Adelman and C. T. Morris. "An anatomy of income distribution patterns in developing countries." *Development Digest.* (1971).
2. The FAO *Assessment of the World Food Situation* (1974) uses demand growth rates to 1985 of: beef and veal, 3%; mutton and lamb, 3.6%; milk and its products except cheese, 2.1%; and cheese, 2.8%. Differences arise mainly from different assumptions on income elasticities, and a further assumption of a lower population growth in the U.S.
3. Projections in Table 2-1 are based mainly on the "trend" gross domestic product rates from the FAO, *Assessment of the World Food Situation,* (1974). The term "trend" is somewhat of a misnomer. FAO was guided by the trend of the late 1960's and the first 3 years of the 1970's. But trends were modified to allow for the medium-term depressing effects of energy difficulties in the developed market economies and high growth rates in petroleum exporting countries. Trends were also adjusted upward in the majority of developing countries. In addition to the FAO basis, projections in Table 2-1 assume a modified continuation of recent world economic trends and basic policies, which, in turn, is based on alternative projections by USDA's Economic Research Service.
4. McDowell, R. E. *Ruminant Products: More Than Meat and Milk.* Winrock Report, (1977).
5. Makhajani, A. and A. Poole. *Energy and Agriculture in the Third World.* (Ballinger. 1975).
6. Lewis, R. G. *World Agriculture.* 26, 1. (1977).

MEETING THE DEMAND FOR RUMINANT PRODUCTS

Most of the increased demand for ruminant meat and milk must be met by increased productivity.

INCREASED world population and increased consumer buying power will create a demand for 74 percent more milk, 82 percent more beef and 90 percent more sheep and goatmeat in the year 2000 than was consumed in 1970 (Table 7-1).

Can world agriculture meet these demands? This question is far from being a hypothetical one. Demands can be met by implementation of the proper — and workable — strategies of action for producers, marketers and policy-makers in both the governmental and private sectors.

Two options are open for increasing the supply of ruminant products: (1) increase the numbers of ruminant animals without appreciably increasing per-animal productivity, and (2) improve the fertility, health, nutrition and genotype of ruminants without appreciably increasing numbers. The first strategy will entail the highest total cost in feed energy, but will require relatively little effort toward improving nutrient quality of feed, genetic make-up or herd environment. The second strategy will require capital investment for development and application of new technology, better quality feed, improved disease and parasite control, genetic programs and more effective management tools. In all likelihood, a combination of these two strategies will be followed; the degree of mix will vary from region to region.

Most knowledgeable authorities in agriculture and human nutrition place much emphasis on the larger role that research and new technology will have to assume in the years ahead. Wittwer (*1*) recently noted that "the research challenge will be to minimize the nonrenewable resource inputs (land, water, energy, fertilizers, pesticides, time) and maximize the outputs. . . . Improved technology is the world's only hope of substantially increasing food production."

Projected Ruminant Populations And Productivity

PROJECTIONS for the year 2000 include numbers and productivity per head (Table 8-1); total regional production of meat and milk, expressed as percent of world totals, with percentage increases from 1972 (Table 8-2); estimated average annual feed energy (metabolizable energy) requirements, food energy provided from meat and milk and average energetic efficiencies (Table 8-3) and total metabolizable energy requirements by species (Table 8-4) (*2*).

Developed Regions — Cattle are the principal source of ruminant meat and milk, accounting for an estimated 86 and 99 percent of the respective totals for the developed regions. The projected increase in beef is 49 percent; in cow's milk, 33 percent. These increases result from an anticipated 20 percent increase in cattle numbers, 15 percent increase in turnoff of carcass meat, and 14 percent increase in milk per head. In 1972, approximately 27 percent of the developed region cattle were dairy cows; their average milk yield was 2866 kg per lactation. If dairy cows constitute the same proportion of the regional herds in 2000, their projected yield would have to be 3277 kg in order to meet the projected demand for milk.

Fewer than one million buffalo are in the developed regions, and these are limited to Europe and USSR. Their contributions to milk and meat supplies will be important only at local levels.

Production statistics for sheep and goats are shown in the aggregate for 2000. Although a 30 percent increase in combined numbers is projected, there is no reason to expect any change in the 20 to 1 ratio of sheep to goat numbers reported for 1972 (Table 2-6). Most sheep will be kept for both meat and wool production. Increased labor costs will probably

Table 8-1. -- Projected ruminant numbers and productivity in 2000 with percent change from 1972

	Developed regions		Developing regions: India		Developing regions: Others		World	
	Amount	% Change	Amount	% Change	Amount	% Change	Amount	% Change
Cattle								
Number, million	496	20	179	0	760	41	1435	27
Carcass meat, kg[1]	78	15	1	0	38	90	47	38
Milk, kg[1]	885	14	178	295	229	183	449	36
Buffalo								
Number, million	1	0	75	29	88	29	164	29
Carcass meat, kg[1]	28	12	6	0	15	18	11	37
Milk, kg[1]	54	15	259	0	100	0	173	0
Sheep and Goats								
Number, million	743	30	130	20	1132	50	2005	40
Carcass meat, kg[1]	8	12	8	118	6	48	7	30
Milk, kg[1]	9	2	13	117	16	53	13	38

[1] Average yield per head in regional herds.

FOR ADDITIONAL INFORMATION REFER TO APPENDIX TABLE 11.

decrease the proportion of both sheep and goats which are milked; however, yields per female milked will likely increase because of selection and better feeding and management.

India — Barely enough feed resources are currently available in India to maintain her ruminant populations even at their current low productivity. The 14 percent increase in available metabolizable energy (Table 8-4) will count for little unless the numbers of animals with low or no productivity decline. Thus, no increase in cattle numbers is anticipated. Cultural restrictions against eating beef will likely prevail through this century, so little increase in beef production is predicted.

The required 295 percent increase in milk production can be met only by increasing the proportion of the herd milked and, simultaneously, increasing the yield of cows milked. If 17 percent (the world average in 1972) of the Indian cattle are milked in 2000, their average lactation yield would have to be 1017 kg — over a two-fold increase from the 450 kg yield in 1972. India has the trained manpower, abundant labor, genetic resources and technology to accomplish this ambitious, yet feasible, goal.

Buffalo currently provide most of the milk produced in India, even though there are three times as many cattle as buffalo. A logical alternative to supplying India's milk need in 2000 would be to focus on increasing milk yield per buffalo cow.

Numbers and productivity of India's sheep and goats are projected to increase substantially by 2000. High labor costs which work against small ruminants for milk production in the developed regions are less significant in India. Labor intensive herding, even cut-and-carry forage feeding, are viable alternatives, especially for goats providing milk for rural family use.

Other Developing Regions — Substantial increases — 174 and 289 percent — are projected for beef and milk from cattle in the developing regions. These will be achieved by a 41 percent increase in numbers, a 90 percent increase in beef yield and an 183 percent increase in milk yield. These increases will require substantial

Table 8-2. — Projected ruminant meat and milk production in 2000 with percent change from 1972

	Developed regions		Developing regions				World	
			India		Others			
	% of world total	% change	% of world total	% change	% of world total	% change	Totals	% change
Cattle								
Number	35	20	12	0	53	41	1435[1]	27
Meat	58	49	—	—	42	174	68[2]	75
Milk	68	33	5	295	27	295	645[2]	73
Buffalo								
Number	1	0	46	29	53	29	164[1]	29
Meat	2	100	24	29	74	52	2[2]	77
Milk	—	—	68	29	32	29	28[2]	29
Sheep and Goats								
Number	37	30	6	20	56	50	2005[1]	40
Meat	44	45	8	163	48	123	13[2]	85
Milk	26	40	7	100	67	125	27[2]	93
Total								
Number	34	26	11	11	55	45	3604[1]	34
Meat	55	47	2	180	43	153	8[illegible]	77
Milk	63	33	8	117	29	238	700[2]	72

[1] Millions of head.
[2] Million metric tons.
FOR ADDITIONAL INFORMATION REFER TO APPENDIX TABLE 11.

Table 8-3. — Feed energy requirements, food energy production and efficiency of ruminant populations, 2000

	Developed regions	Developing regions		World
		India	Others	
Cattle				
ME, Mcal[1]	5035	2875	3840	4130
PFV, Mcal[2]	734	107	225	385
PFV/ME, %	14.6	3.7	5.9	9.3
Buffalo				
ME, Mcal[1]	—	4200	5565	4930
PFV, Mcal[2]	—	275	135	200
PFV/ME, %	—	6.5	2.4	4.0
Sheep and Goats				
ME, Mcal[1]	740	700	649	695
PFV, Mcal[2]	26	26	26	26
PFV/ME, %	3.5	3.7	4.0	3.7

[1] Annual feed energy requirement expressed as metabolizable energy (ME) per head.
[2] Annual food energy value of meat and milk expressed as physiological fuel value (PFV).

Table 8-4. — Metabolizable energy requirements for ruminants in 2000

Ruminant	Developed regions	Developing regions India	Developing regions Others	Species totals	% of World
	Billion Mcal				
Cattle	2497	515	2917	5929	73
Buffalo	4	315	490	809	10
Sheep and Goats	550	91	735	1376	17
Regional total	3051	921	4142	8114	100
% of world	38	11	51	100	

FOR ADDITIONAL INFORMATION REFER TO APPENDIX TABLE 12.

improvement in both nutrient quantity and quality and in herd health to reduce both mortality and morbidity. Fertility must necessarily be improved, especially by shortening calving interval.

More work buffalo will be needed as additional lands are put under cultivation in the humid tropics. Buffalo's long gestation interval and generally low fertility and high perinatal mortality will make it difficult to meet the projected 29 percent increase in numbers. Emphasis is still expected, however, to be on increasing numbers rather than per head productivity of meat and milk.

Increases of 123 and 125 percent, respectively, for meat and milk from sheep and goats are projected. These will result from a 50 percent increase in combined numbers and 48 and 53 percent increases in turnoffs of meat and milk. Even these projections may be conservative if more attention is paid to genetic improvement and development of nutrition and health management techniques. The potentially high fertility from early maturity, relatively short gestation intervals and multiple births has not been effectively exploited. More attention may be given to care of lambs and kids to improve survival rates. Sheep and goats are likely to continue primarily as sources of meat and milk for family subsistence; however, the export market for sheep and goats to the oil countries of the Middle East is substantial and growing.

World Totals — Numbers of cattle, buffalo, sheep and goats in 2000 are projected to total 3604 million, an average increase of only 34 percent over 1972. This increase may be compared to the projected 75 percent increase in human population over the same period (Table 7-1). Thus, most of the increased demand for ruminant meat and milk must be met by increased productivity. Cattle will continue to provide most of the needed meat and milk — 82 and 92 percent of world totals, respectively.

The projected average increase of 38 percent in beef turnoff (Table 8-1) may be achieved in several ways. Cattle are commonly slaughtered at approximately 60 to 70 percent of mature weight — roughly equivalent to reaching mature lean body mass. Increasing mature weight or slaughtering at higher degrees of maturity could, therefore, increase beef yield. But both strategies would tend to increase feed requirements and the latter would result in fatter carcasses. Next, the dressing percent which varies between 50 to 60 percent could be increased, but again the probable consequence is fatter beef. Finally, cattle can be fed and managed to grow more rapidly to normal slaughter weights, and losses due to health problems may be decreased by appropriate health measures. The result will be a substantially increased proportion of the herd being slaughtered each year. This course of action should improve both energetic and economic efficiency of meat production.

An example illustrates one important con-

Meat -- a preferred and highly nutritious food. This photo was taken in western Nigeria. *FAO Photo.*

sequence from increasing turnoff. In 1972, world averages were 19 percent turnoff and 34 kg carcass weight yield per head in herd (Table 2-9). Assuming a 50 percent dressing percent and slaughter at 65 percent of mature weight, carcass weight was 179 kg (calculated as 34/.19) with an estimated slaughter liveweight of 358 kg (179/.5) and estimated mature weight of 550 kg (358/.65). The projected per head yield of carcass weight in 2000 is 47 kg (Table 8-1). With the same assumptions for dressing percent and maturity at slaughter, a 19 percent turnoff in 2000 would mean an average carcass weight of 247 kg, an average slaughter liveweight of 495 kg and an average mature weight of 760 kg. However, by increasing turnoff to 26 percent in 2000 with other assumptions remaining constant, average mature weight could remain at 550 kg. Mature cattle weighing 760 kg require 27 percent more feed energy for maintenance alone than do those weighing 550 kg. Increasing turnoff should substantially reduce feed energy requirements and increase energetic efficiency of beef production.

Systems Approach To Improving Ruminant Production

RUMINANT production systems are complex. As noted in previous chapters, these systems are affected by multiple biological, economic and social factors. The relative importance of these factors varies. Breeds, management practices and technology which work well in the temperate, developed regions are rarely directly transferable to tropical, developing regions. At best, such technology requires careful adaptation. In general, ruminant

A Peruvian woman working with wool at a hand loom. *Winrock International Photo.*

production systems have evolved under the pressures of local biological, social and economic constraints to be efficient, even if not highly productive. Changes to functioning systems should not be done casually. Rather, full understanding is necessary of why and how the entire system functions in order to better predict the consequences of the change (*3*).

Genetic Resources — Genetic variation between and within species provides the opportunity for improving production. It is critical that genetic resources be matched to the production environment and to market requirements.

First attention should be given to indigenous populations already adapted by generations of selection — both natural and artificial. Introduction of exotics may be successful; certainly, cattle and sheep have thrived in the Americas, but often unexpected problems arise. Low productivity of indigenous stocks may reflect adaptation to harsh environment rather than genetic inferiority for meat and milk production.

Use of exotics — perhaps, through artificial insemination — as sire lines on local females is one strategy for raising productivity while generally minimizing dangers of poor adaptation to local disease, climatic and nutritional problems. This approach brings benefits of (a) probable hybrid vigor and (b) the complementary combination of genetic advantages. Progeny should inherit a substantial percentage of the sire's genetic superiority for meat, milk, wool or work plus the dam's adaptation to local environment, including possible benefits of immunity against disease and parasites.

Selection may effectively raise the genetic production potential of local breeds or gene pools created from introduction of exotics. However, redefining selection goals also generally requires improving the production environment. In any event, selection should emphasize those traits which have real economic value.

Environmental Resources — As stated earlier, nutrition, or feed supply, is usually the first limiting constraint on a ruminant production system. Undernourished or ailing animals will be poor producers regardless of their genetic potential. Ruminants do, however, have a remarkable ability to survive on high fiber, low quality nutrients that would have little value for other animals. The objective of a ruminant production system, however, is production of a useable product, not just survival of the animal. Competent producers, therefore, will need to keep certain physiological facts in mind as they strive to make their system more profitable. For example, residues from rations that are less than 67 percent digestible literally clog the animal's digestive tract and thus place a physical limit on daily intake (*5*). When digestibility drops below 45 percent, the amount of energy absorbed each day is not even enough for maintenance.

Potential for increasing forage production for ruminant use is greatest where moisture and length of growing season are not limiting factors. The humid and subhumid tropics, as well as some temperate zones, have high potential. Priority should be given to increasing yield of digestible dry matter through grazing management, introduction of superior species, fertilization, harvesting and preservation practices. Much of the required technology is available to accomplish these goals (*5*).

In order for protein and energy intake to be adequate enough to realize genetic production potential, rations will often require some grain or other supplementation in addition to forage, crop residues and other less digestible nutrient sources (*6*). Opportunity costs for these supplements should determine when and how they are used; however, three types of ruminants deserve special consideration: high-producing dairy females, young rapidly growing meat stock and highly fertile females.

Strategic supplementation of these most productive members of the system can be thought of as catalysts to increase rate and efficiency of production. Supplements may consist of relatively small quantities of grains, oilseed meals or other nutrient dense feeds added to the base forage ration to raise digestibility of the total ration to 70 percent or more.

This concept of strategic supplementation may be further expanded from the single animal to the production unit, or herd. Consider cattle herds grazing the arid rangelands of the western U.S. Mature cows utilize the grazed forage more efficiently than young, growing cattle. Even though the opportunity cost for the grazing is low, the opportunity cost for capital invested in the cattle is high and returns will not be realized until the young beef stock are marketed. Not only do these young stock grow slowly on the 50 to 60 percent digestible grazing, but they compete with the cows whose fertility may suffer as a result. Thus, removing the young stock to feedlots where they are fed highly digestible rations of hay, silage and grain will improve productivity of the herd in two ways:

a. Accelerate growth and shorten time to slaughter of beef animals, thereby reducing nonproductive energy costs of maintenance and raising beef turnoff.

b. Conserve pasture resources for cow herd and, thus, increase the number and weight of calves weaned each year

Management — Domesticated ruminants require special care and attention because they have often lost most of their ability to cope with the vagaries of the natural environment. They often must be protected from the elements, from predators and from parasites. Enlightened, informed management of genetic and environmental resources is essential to increasing ruminant production.

Improvement of nutrition through pasture management, grazing control, harvesting practices and strategic supplementation have been discussed. Requirements for water, minerals and vitamins must be provided.

Milk plays an important role in providing healthful nutrition for today's children the world over. *Heifer Project International Photo.*

Control of disease and parasites is a major problem of management. Immunization, selection for resistance, vector control and general sanitation are all procedures available to managers. Mastitis is a good example of a costly disease resulting primarily from poor hygiene and faulty milking techniques — both directly reflecting poor management.

Socio-Economic Factors

THE trend in the developed world has been toward larger, capital intensive production systems. These larger operations can afford skilled management better able to implement improved technology and production practices. Their greater production volume often leads to more efficient marketing and other economics of scale. Nevertheless, the majority of the cattle in the U.S. remain in herds of 50 head or less and similar emphasis on smallholding holds true throughout the developed regions.

With the exception of a relatively few large commercial ranches, ruminant production in the developing world is in the hands of smallholders. The smallholder has been looked on as the "poor" producer whose efforts yield barely enough to feed the family. Even where true, self sufficient rural families relieve the burden placed on world food supplies by the urban multitudes. In fact, the smallholder system tends to be efficient in terms of conversion of increasingly scarce energy resources and in substituting intensive labor (man and animal) inputs for the intensive capital inputs required for so-called modern, large scale agriculture.

Most smallholder systems are generally in balance with nature. Plant and animal resources are chosen for efficiency in the production *environment*, which is not always synonymous with high *productivity*. Any suggested changes or introduction of "modern" practices to such balanced systems must be carefully evaluated under the risk of destroying the balance and provoking disaster.

A common characteristic of successful smallholder systems is the major role played by animals — especially ruminants. They pull plows, concentrate needed plant nutrients in their manure, harvest their own feed, supply food and clothing for the family and, often, serve as a savings bank.

Whether true or not, many accusations directed at the so-called "wasteful" practices of large-scale, commercial ruminant production systems in the developed countries do not apply to the smallholder systems. And this is where the majority of the world's domesticated ruminants are to be found — among the herds of small pastoralists and in the fields of the small farmers.

Much of the responsibility for maintaining the viability of the world's smallholder system rests with governments. Unfortunately, favorable political attitudes are not always apparent. Governments typically establish policies favoring low cost food for the urban masses even though such policies mean poor returns to producers and act as deterrents to increasing food production.

Another constraint among smallholders is that they are sometimes slow to accept improved resource management and technology, either because of ignorance or prejudice. It has been demonstrated, however, that unfavorable policies, ignorances and prejudices can and will change when the people concerned with the situations are exposed to accurate information as to the true effects of the constraints.

Human concern for the plight of the world's 100 million small farmers has sparked numerous efforts to accurately identify the problems and recommend research and action programs which, if adopted, would undoubtedly bring both economic and social rewards. One such effort was a workshop held at Winrock International Center in June, 1976. Recommendations for development programs as published in the proceedings (7) of this workshop included the following:

- People to be served by projects must be involved in the planning.
- Market development must be a part of project development.
- Devise simple, easy-to-use packages of technology adapted to smallholder needs.
- Provide adequate feeds at reasonable cost.
- Improve communication within and among producers.
- Programs should be location-specific; that is, geared to the problems at the site of the action.
- Provide training at all levels.
- Projects must be supported for a sufficient number of years to permit them to become effective.
- More pilot-scale development projects are needed.
- Government commitment and support must be strengthened.

Research, Training and Demonstration Opportunities

IN order to increase the per-capita supplies of meat and milk which we predict will be needed by year 2000, agricultural research and development will most certainly face new and severe challenges in the next two decades. Byerly (*8*) has listed six specific areas of research critical to improving ruminant production systems:

- Improve pasture and range productivity, particularly in the tropics.
- Develop genetic resistance to disease and control parasites and disease vectors, especially arthropods and helminths.
- Improve fertility and decrease fetal and perinatal mortality.
- Develop and evaluate systems — biological, ecological, engineering, economic and social — for resource use, ruminant production and product utilization.

These sheep are being herded to a summer grazing area of mountain meadows in the western United States. *USDA Photo.*

- Develop new products, such as meat protein concentrates, texturized products from trimmings and lactose-hydrolyzed milk.
- Improve genetic resources and feeding programs which will satisfy the energy, protein, mineral and other nutrient requirements of pregnant and lactating ruminants.

Research priorities should be based on results of careful analyses of the local production systems. In the developed world, research on sex control, induced twinning, protected protein, meat tenderization and growth promotants may be appropriate. But for much of the developing world, highest priority should be given to utilization of surplus feedstuffs, forage improvement, parasite and disease control, identification and characterization of locally adapted genetic resources, product preservation and resolution of socio-economic constraints to production and marketing.

There is a desperate need in the developing world for more and better trained research, extension and management personnel. Agricultural graduates in the developing countries are often from an urban background with little or no agricultural experience. Those who travel to the universities of the developed world for advanced training often return with research abilities and interests inappropriate to local needs. Thus, it is important that at some point their training should involve first-hand working experience with the problems of ruminants and their owners in their native environment.

Producers also require training in improved practices of ruminant production. Innovative efforts are required to develop techniques and materials appropriate to training producers with little or no formal education. Testing and demonstration of improved practices is recommended as an effective means of converting producers from their traditional ways of operating.

Research, training and demonstration programs appropriate to the special needs of ruminant production systems will be a good investment. Such programs should increase production and lower production costs. They will, thus, ultimately serve all society and, particularly the consumer, by making more ruminant products available at lower prices while still providing the producer with sufficient returns to his investment, labor and management.

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   The specific combinations of increased numbers and increased productivity required to meet increased production varied from region to region. The mix was based on subjective assessment of the probability of increased investment in pasture improvement, concentrate feeding, disease and parasite control, genetic improvement programs, improved marketing, processing and preservation, etc. Principal emphasis was given to availability and quality of feed resources.
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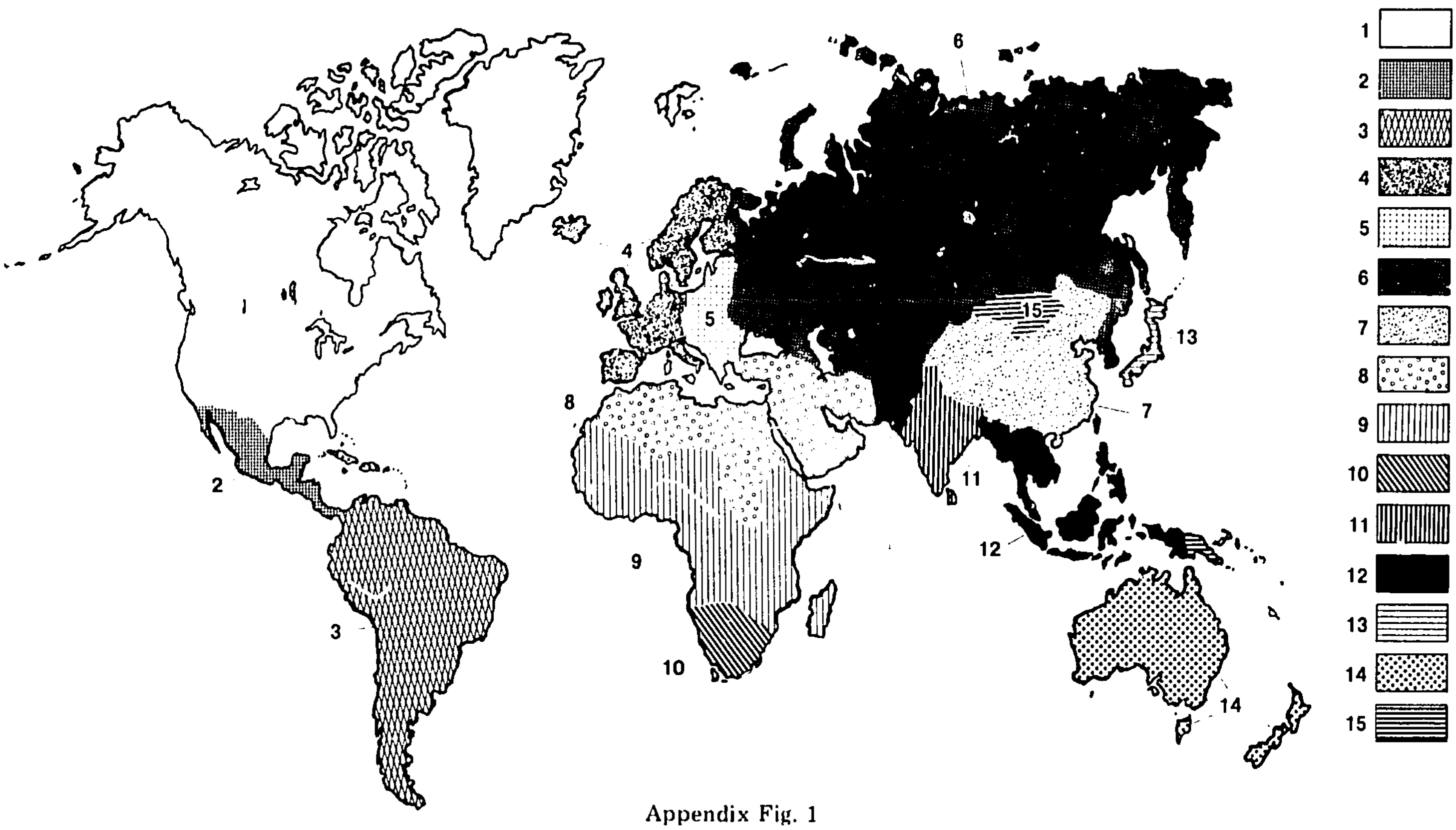
APPENDIX



Appendix Fig. 1

Appendix Table 1 — Cattle population and productivity, 1972

Region	Number	Head Slaughtered[1]	Carcass Meat[1, 2]	Cows Milked	Milk Yield[2]
	(millions)	% total	kg	% total	kg
1. North America	130	37	95	11	480
2. Middle America	39	15	26	13	124
3. South America	190	16	32	11	105
4. Western Europe	89	36	77	38	1289
5. Eastern Europe	35	34	56	46	1090
6. Soviet Union	102	36	60	40	807
7. China	63	15	24	10	53
8. North Africa — Middle East	44	18	20	27	174
9. Central Africa	116	8	9	12	33
10. Southern Africa	16	19	34	11	194
11. India	179	1	1	10	45
12. So. & So. East Asia	75	10	12	10	37
13. Japan	4	36	95	31	1373
14. Oceania	37	31	53	36	361
15. Rest of World	11	17	27	14	112
World	1130	19	37	17	329

[1] Adjusted for annual growth rate in regional inventory.
[2] Yield per head in herd.
Source: FAO Production Yearbook, 1974.

Appendix Table 2 — Buffalo population and productivity, 1972

Region	Number	Head Slaughtered[1]	Carcass Meat[1, 2]	Milk Yield[2]
	(millions)	% total	kg	kg
1. North America	—	—	—	—
2. Middle America	—	—	—	—
3. South America	0.1	—	—	—
4. Western Europe	0.1	17	25	44
5. Eastern Europe	0.3	33	58	110
6. Soviet Union	0.4	—	—	—
7. China	29.7	11	18	34
8. North Africa — Middle East	4.8	29	38	296
9. Central Africa	—	—	—	—
10. Southern Africa	—	—	—	—
11. India	57.9	4	6	259
12. So. & So. East Asia	33.2	7	10	131
13. Japan	—	—	—	—
14. Oceania	—	—	—	—
15. Rest of World	—	—	—	—
World	126.6	7	11	173

[1] Adjusted for annual growth rate in regional inventory.
[2] Yield per head in herd.
Source: FAO Production Yearbook, 1974.

Appendix Table 3 — Sheep population and productivity, 1972

Region	Number	Head Slaughtered[1]	Carcass Yield[1, 2]	Milk Yield[2]	Yield[2]
	(millions)	% total	kg	kg	kg
1. North America	19	51	12	—	2
2. Middle America	6	18	2	—	—
3. South America	115	15	2	—	1
4. Western Europe	84	61	9	24	1
5. Eastern Europe	41	45	6	30	1
6. Soviet Union	140	42	7	1	2
7. China	71	31	5	6	1
8. North Africa — Middle East	145	33	6	18	1
9. Central Africa	68	31	3	2	—
10. Southern Africa	37	40	5	—	1
11. India	40	29	3	—	1
12. So. & So. East Asia	39	34	4	12	1
13. Japan	—	—	—	—	—
14. Oceania	224	36	6	—	3
15. Rest of World	14	30	6	4	1
World	1043	36	5	7	1

[1] Adjusted for annual growth rate in regional inventory.
[2] Yield per head in herd.
Source: FAO Production Yearbook, 1974.

Appendix Table 4 — Goat population and productivity, 1972

Region	Number	Head Slaughtered[1]	Carcass Meat[1,2]	Milk Yield[2]
	(millions)	% total	kg	kg
1. North America	1.5	—	—	—[3]
2. Middle America	10.4	18	2	21
3. South America	27.4	23	2'	5
4. Western Europe	9.7	64	5	133
5. Eastern Europe	2.2	48	7	104
6. Soviet Union	5.4	44	7	73
7. China	58.2	31	5	5
8. North Africa — Middle East	70.5	22	3	28
9. Central Africa	89.2	35	3	7
10. Southern Africa	8.0	29	4	—[3]
11. India	68.0	43	4	10
12. So. & So. East Asia	36.2	40	5	27
13. Japan	0.2	36	5	25
14. Oceania	0.2	43	10	—[3]
15. Rest of World	4.5	26	5	8
World	391.6	33	4	17

[1] Adjusted for annual growth rate in regional inventory.
[2] Yield per head in herd.
[3] Less than 0.5 kg.
Source: FAO Production Yearbook, 1974.

Appendix Table 5 — Production of wool, hides and skins (fresh) from cattle, buffalo, sheep and goats, by regions, 1972

Region	Scoured wool	Cattle hides	Buffalo hides	Sheep skins	Goat skins
	1000 Metric tons				
1. North America	38	1,122	—	33	—
2. Middle America	3	132	—	5	4
3. South America	142	834	—	77	15
4. Western Europe	82	569	—	102	10
5. Eastern Europe	57	388	2	41	3
6. Soviet Union	252	656	—	114	5
7. China	36	242	89	75	40
8. North Africa — Middle East	79	116	16	118	38
9. Central & East Africa	1	231	—	42	62
10. South Africa	56	86	—	33	4
11. India	22	428	294	32	65
12. So. & So. East Asia	32	238	96	35	31
13. Japan	—	26	—	—	—
14. Oceania	720	183	—	247	—
15. Rest of World	12	18	9	11	4
World Total	1,532	5,269	506	965	281

Source: FAO Production Yearbook, 1974.

Appendix Table 6 — Estimated metabolizable energy required by ruminants in 1972, based on population numbers and meat and milk production.[1,2]

Region	Cattle	Buffalo	Sheep	Goat	Camelid	Total	% of World Total
	--------------------	--------------------	----------1000 Million Mcal	----------	--------------------	--------------------	
1. North America	623.7	—	16.9	.7	—	641	11
2. Middle America	142.1	—	3.6	4.8	—	150	3
3. South America	702.5	—	63.8	11.8	19.2	797	14
4. Western Europe	452.6	—	66.3	6.9	—	526	9
5. Eastern Europe	164.4	2.2	28.1	1.4	—	196	3
6. Soviet Union	464.0	—	97.8	3.3	1.3	566	10
7. China	225.3	168.8	44.1	25.8	—	464	8
8. North Africa — Middle East	156.1	27.3	93.9	34.1	25.3	337	6
9. Central & East Africa	389.8	—	39.0	39.2	31.4	499	8
10. Southern Africa	60.2	—	22.8	3.5	—	86	1
11. India	452.0	242.0	22.8	30.6	6.0	753	13
12. So. & So. East Asia	255.5	181.0	23.9	17.6	6.1	484	8
13. Japan	19.3	—	—	—	—	19	—
14. Oceania	152.3	—	153.5	—	—	306	5
15. Rest of World	40.7	—	9.0	2.0	4.3	56	1
World Total	4300.5	621.3	685.5	181.8	93.7	5880	100

[1] Production statistics from FAO Production Yearbook, 1974.

[2] ME requirements estimated using results from Winrock simulation model.

Appendix Table 7 — Potential arable land, permanent pasture and meadow, and nonagricultural land by regions, million ha.

Region	Arable land			Permanent pasture & meadow			Nonagricultural land			
	Present[1]	Potential[2, 3]	% Change	Present[1]	Potential[2, 3]	% Change	Present[1]	Potential[2, 3]	% Change	Total
1. North America	235	402	71	269	398	48	1,430	1,038	-27	1,934
2. Middle America	35	63	80	81	143	77	151	68	-55	267
3. South America	89	692	678	385	427	11	1,309	642	-51	1,738
4. Western Europe	89	109	22	66	87	32	211	143	-32	366
5. Eastern Europe	58	64	10	22	42	99	51	34	-33	131
6. USSR	232	353	52	376	353	-6	1,632	1,531	-6	2,240
7. China	127	176	39	200	296	48	633	505	-20	960
8. North Africa — Middle East	91	223	145	231	294	27	1,119	673	-40	1,441
9. Central Africa	165	550	233	526	557	6	1,245	1,001	-20	1,936
10. Southern Africa	15	38	153	182	200	10	73	71	-3	270
11. India	165	182	10	13	53	308	150	85	-43	328
12. So. & So. East Asia	112	160	43	30	328	993	475	173	-64	617
13. Japan	5	9	80	1	18	1,700	32	9	-72	38
14. Oceania	46	151	228	465	405	-13	284	271	-5	795
15. Rest of World	5	17	240	142	87	-39	38	79	108	185
World Total	1,469	3,189	117	2,989	3,688	23	8,833	6,323	-28	13,291

[1] FAO Production Yearbook, 1974.
[2] Unpublished data provided by Soil Geography Unit, Soil Conservation Service, USDA.
[3] Differences in present and potential areas due to small differences between data sources in classification and assignments among regions.

Appendix Table 8 — Distribution of potential permanent pasture and meadow by climate type and region

Agro-Climatic Region	Climate Type	North America	Middle America	South America	Western Europe	Eastern Europe	USSR
		Million ha					
2 T	II 1, 2, 3	45			10		116
4 M	III 7a	19					9
4 T	III 9	11				1	47
4 T	III 5, 6, 10, 11	102					103
6 M	III 2	12		7	19		
6 T	III 3, 4, 7, 8	86			28	41	56
6 T	III 4 (250-500)	20					
6 T	III 9a	2					
8 T	III 1	5		3			
0 M	III 10a, 12, 12a	19		39			20
0 M	IV 5	5	4	4			
4 M	IV 1, 2, 3 (250-500)	32	19	45			2
4 M	IV 1, 3 (500-750)		16		30	1	
6 M	IV 4	12		6			
8 M	IV 6, 7	28		50			
0 M	V 5		2	8			
2 M	V 4		9	42			
4 M	V 3		45	54			
6 M	V 2	1	24	97			
1 2	V 1		24	74			
TOTAL		399	143	429	87	43	353

Source: Unpublished data from Soil & Geography Unit, Soil Conservation Service, USDA.

China	N. Africa Mid-East	Central Africa	South Africa	India	So. East & So. Asia	Japan	Oceania	Rest of World	TOTAL
					Million ha				
15								8	194
	6				2				36
								2	61
102	24				21			34	386
							39		77
23	5				5	11		5	260
									20
							1		3
							12		20
32	1							30	141
	25		24	1	7		71		141
	128		38	5	14		68		351
							26		73
20			22		4		17	2	83
83			1		1	7	32	3	205
	5	21					38		74
	41	160	68	21			59		400
	42	199	47	21	16		36		460
19	17	136	1	4	70		6	4	379
3		41			190				332
297	294	557	201	52	330	18	405	88	3,696

Appendix Table 9 — Feed resources (as metabolizable energy — Mcal x 10^9) available for ruminants, years 1970 and 2000[1]

Region	Forage Sources: Perm. pasture and meadows 1970	Perm. pasture and meadows 2000	Arable lands 1970	Arable lands 2000	Non-ag lands 1970	Non-ag lands 2000	Grain 1970	Grain 2000
	Billion Mcal							
1. North America	470	515	615	700	175	125	205	335
2. Middle America	215	350	60	70	30	15	3	5
3. South America	1130	1170	230	295	230	110	15	15
4. Western Europe	310	310	220	220	40	30	95	170
5. Eastern Europe	115	145	85	85	10	10	35	65
6. Soviet Union	300	310	575	670	15	15	50	100
7. China	250	360	75	85	20	15	2	5
8. North Africa — Middle East	180	200	150	230	15	10	5	15
9. Central Africa	850	900	240	300	310	300	1	1
10. Southern Africa	190	205	25	30	15	15	3	5
11. India	15	55	415	450	15	10	3	15
12. So. & So. East Asia	70	445	220	245	130	50	1	5
13. Japan	5	10	25	25	1	1	5	15
14. Oceania	580	495	175	360	10	10	15	15
15. Rest of World	140	140	5	10	3	3	1	1
World Total	4820	5610	3115	3775	1019	719	439	767

[1] See Chapter III for information on estimation procedures.

Agri-ind. byproducts		Oilseeds		Crop residues		Total		% World	
1970	2000	1970	2000	1970	2000	1970	2000	1970	2000
Billion Mcal								Percent	
15	20	25	55	440	500	1945	2250	16	15
1	1	1	1	65	80	375	522	3	4
5	10	2	5	195	325	1807	1930	14	13
10	15	25	55	275	280	975	1080	8	7
5	10	5	10	175	180	430	505	3	3
25	30	10	15	370	430	1345	1570	11	11
5	5	1	1	540	595	893	1066	7	7
5	20	2	2	110	135	467	612	4	4
10	10	1	1	130	160	1542	1672	12	11
1	1	1	1	25	35	260	292	2	2
30	65	5	5	270	350	753	950	6	7
10	20	1	1	235	300	667	1066	5	7
2	2	2	10	45	45	85	108	1	1
3	5	1	1	35	105	819	991	6	7
1	1	1	1	35	40	186	196	2	1
128	215	83	164	2945	3560	12549	14810	100	100

Appendix Table 10 — Consumption of ruminant livestock products, 1970, and projected to 2000 by regions.

Region	Dairy products (Milk equivalent)[1] 1970	2000
	-------- *Thousand metric tons* --------	
1. North America	62,584	81,713
2. Middle America	6,273	19,222
3. South America	19,866	47,816
4. Western Europe	124,818	154,548
5. Eastern Europe	17,085	24,101
6. USSR	66,000	110,165
7. China	4,102	6,651
8. North Africa — Middle East	19,697	54,489
9. Central Africa	6,407	17,552
10. Southern Africa	3,351	7,907
11. India	38,802	91,206
12. So. and So. East Asia	19,292	55,039
13. Japan	4,847	13,505
14. Oceania	7,485	11,733
15. Rest of World	1,861	4,602
World Total	402,470	700,249

[1] Conversion factors: 1 kg butter = 21.1 kg milk; 1 kg cheese = 10 kg milk (USDA, *Agri. Statistics*, 1974) Dairy products include those from cattle, buffalo, sheep, goats and camels.

[2] Beef and veal include cattle and buffalo carcasses; mutton and lamb include sheep and goats carcasses.

Source: Adapted from USDA, ERS. For, Demand and Competition Div. unpublished material; FAO. *Agr. Commod. Projections*, vol II, 1971, and University of California, *A Hungry World*, 1974.

Beef & veal (Carcass weight)[2] 1970	Beef & veal (Carcass weight)[2] 2000	Mutton & lamb (Carcass weight)[2] 1970	Mutton & lamb (Carcass weight)[2] 2000
Thousand metric tons			
11,705	17,674	347	414
692	2,213	59	155
4,927	11,642	341	725
7,600	11,222	1,159	1,553
1,761	2,794	263	380
5,058	8,575	960	1,574
1,897	3,269	575	1,014
858	2,408	985	2,619
1,355	3,544	410	1,069
561	1,216	220	495
176	445	366	1,002
1,053	2,981	306	639
293	1,236	165	292
654	994	604	906
118	223	65	134
38,708	70,436	6,825	12,971

Appendix Table 11 — Projected ruminant population and productivity of meat and milk in 2000.

Region	Cattle		
	Numbers (000)	Carcass yield kg/head	Milk yield kg/head
1. North America	156,164	106	523
2. Middle America	58,593	46	315
3. South America	285,740	48	180
4. Western Europe	107,287	83	1,425
5. Eastern Europe	42,293	70	1,182
6. USSR	122,921	71	888
7. China	82,284	31	70
8. North Africa — Middle East	56,653	27	539
9. Central Africa	150,548	44	175
10. Southern Africa	19,108	53	414
11. India	178,865	1	250
12. So. & So. East Asia	112,475	18	325
13. Japan	4,316	102	1,731
14. Oceania	43,868	67	401
15. Rest of World	13,433	24	339
World	1,434,548	50	450

[1] See Chapter VIII for information on projection procedures.

Buffalo			Sheep and Goats			Camels
Numbers (000)	Carcass yield kg/head	Milk yield kg/head	Numbers (000)	Carcass yield kg/head	Milk yield kg/head	Numbers (000)
			25,020	12	5	
			25,190	4	22	
			213,987	4	1	6,154
85	25	44	112,956	9	36	
456	58	110	51,637	7	40	
			218,000	7	3	307
38,556	18	34	194,211	5	6	17
6,239	38	296	322,896	8	36	6,165
			235,060	5	7	7,656
			66,812	7		
75,323	6	259	130,103	8	13	1,464
43,107	10	131	113,127	5	24	1,489
			276	4	18	
			268,832	8		
			27,234	7	6	1,059
163,766	11	173	2,005,341	7	13	24,311

Appendix Table 12 — Estimated metabolizable energy required by ruminants in year 2000, based on projected population, meat and milk production.[1, 2]

Region	Cattle	Buffalo	Sheep & Goat	Camelid	Total	% of World Total
	1000 Million Mcal					
1. North America	774.4	—	21.8	—	796	10
2. Middle America	234.6	—	15.3	—	250	3
3. South America	1124.5	—	125.1	25.0	1275	15
4. Western Europe	647.8	.5	88.9	—	737	9
5. Eastern Europe	207.6	2.9	37.6	—	248	3
6. Soviet Union	573.3	—	153.6	1.7	729	9
7. China	299.9	219.4	122.8	.1	642	8
8. North Africa — Middle East	221.2	35.5	233.2	32.9	523	6
9. Central & East Africa	576.1	—	147.3	40.8	764	9
10. Southern Africa	79.3	—	45.7	—	125	2
11. India	515.3	314.6	91.4	7.8	945	11
12. So. & So. East Asia	410.4	235.3	72.9	7.9	726	9
13. Japan	24.5	—	.2	—	25	—
14. Oceania	189.9	—	202.6	—	392	5
15. Rest of World	50.3	—	18.6	5.6	74	1
World Total	5929.1	808.2	1377.0	121.8	8251	100

[1] Meat and milk production statistics from Appendix Table 11.
[2] ME requirements estimated using results from Winrock simulation model.

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Theodore C. Byerly is currently staff consultant, Winrock International Livestock Research and Training Center, Morrilton, AR, and a retired scientist and science administrator, U.S. Department of Agriculture. He holds three degrees from the University of Iowa, obtaining his Ph.D. in zoology. He has held teaching positions at the University of Michigan, Hunter College and the University of Maryland. He joined the staff of the U.S. Dept. of Agriculture in 1929 and, except for a 4-year period on the Maryland faculty (1937-1941), he served progressively in USDA as poultry scientist, chief of animal and poultry research, assistant director of livestock research, deputy administrator of ARS farm research, administrator of USDA's Cooperative State Research Service, and Ass't. Director of Science and Education. Since retiring from USDA in 1972, he has remained active as a consultant on both national and international food and agricultural problems for USDA and other agencies. Dr. Byerly was recipient of the Borden award, served on key committees of AAAS and the National Research Council and as president of the Poultry Science Association. He is a Fellow, American Association for the Advancement of Science.

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