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9. ABSTRACT

This report examines the theory that there should be greater production of grain for human food rather than for conversion to animal protein, and it argues that the relative non-monetary inefficiency of producing animal protein occurs only when it is produced on cropland suitable for intensive grain crops used as human food. In most cultures cattle or other livestock do not compete with man for agricultural products or lands. More than half the domestic ruminants receive less than five% of their food from cereal grains. Only a small percentage of the world ruminant population of 3 billion competes with man in that they eat food which would be suitable for humans. The vast majority derive their sustenance from plants totally unfit for human consumption - the forages. Ruminants exist symbiotically with man and provide his only means of deriving life-sustaining products from that one-third of the earth's land surface unfit for cultivation. About 12% of the human population lives in areas where food crops cannot possibly be raised. This is possible because of the presence of ruminant animals, from which they derive their support. Not only do ruminants convert inedible products into high quality protein but they provide countless nonfood products. These nonfood resources are not being exploited efficiently. The report describes ruminant contributions under fiber resources, skins, traction, waste resources, conservation, pest control, and recreation. It concludes that ruminants play an important part in the interrelationship between animals, plants, and humans.

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RUMINANT PRODUCTS:
MORE THAN MEAT AND MILK

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RUMINANT PRODUCTS: MORE THAN MEAT AND MILK

R. E. McDOWELL[1]

Throughout the world, domestic ruminants such as cattle, sheep, goats and buffaloes provide man with significant quantities of highly nutritious food in the form of meat, milk and milk products. In addition, these animals are a main source of the hides, skins and fibre used by man for clothing, furnishings and other useful items. In some cultures, ruminants are valued for the motive power, fertilizer and fuel they provide.

Ruminants also provide a variety of inedible products which, when processed, make available to man a wide array of items useful in industry, in the home and by the medical sciences. Production, processing and distribution of both food and nonfood items directly and indirectly provide employment and sustenance for extremely large segments of the world's population.

In certain areas of the world where man has a close symbiotic relationship with ruminants, their important contribution to man's welfare is largely understood and appreciated. But on the whole, the vast size of the ruminant population, their present contributions to man's welfare and their future potential are as yet largely unrecognized

From the research viewpoint, animal scientists have tended in the past to concentrate mainly on ruminants as producers of milk, meat and wool in the context of social or economic situations common to developed and prosperous societies. With the expansion of human population and its need for food, however, many people have come to view some animals as competitors of man and as an inefficient means of providing human food. Some protagonists have argued against ruminant husbandry strictly on these grounds.

Reid (*1*) and others, assuming that (a) human population will inevitably rise and that (b) demand for food grains will rise more rapidly than production have concluded that per-capita use of domestic animal products could be significantly less in the year 2000, which implies that numbers of domestic livestock will decline in the future On the other hand, if one considers the overall contributions of animals and human dependence on them, the populations of some species, particularly ruminants, are likely to increase. Those who tie livestock production to grain production tend to ignore that in most cultures, cattle or other livestock do not compete with man for agricultural products or lands, therefore, nothing is sacrificed in their support. Even where there is competition, more than half the domestic ruminants (buffaloes, camelids, cattle, goats, sheep and yaks) receive less than five percent of their food from cereal grains. If wild ruminants were included, the numbers of non- or low grain-feeding animals would be exceedingly low.

Types and Numbers of Ruminants

The suborder Ruminantia include 6 families (Table 1) with 67 genera. The 67 genera include from 1 to 111 species Altogether there are 159 species. Domesticated ruminants up to the present have primarily belonged to the families Camelidae and Bovidae The genera *Llama* of the Camelidae family are all found in the Andes region of South America and number about 4.8 million (Table 2) The camels (*Camelus dromedarius* and *C bactrianus*) are found in Asia and Africa They number 13 2 million, of which 80 percent are in Ethiopia, Mauritania, Somalia, Sudan, India, Mongolia, Pakistan, and Saudi Arabia. The remainder are in 27 other countries. The Tragulidae and Giraffidae occur principally in the lowlands of Central Africa

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and Asia. The Antilocapidae (*Antilocarpa americana*) is found only in the western part of North America (estimated population 400,000). None of the Tragulidae, Giraffidae or Antilocapidae are as yet domesticated Beyond being hunted for sport, they have had little direct utility to man

Species of Cervidae and Bovidae are found on all continents except Antarctica World census data are not available for many species, especially the non-domesticates, but as will be shown later the wild ruminant species make vital contributions to man and the environment. *Bison bison* occur in the U S. and Canada (population 20,000) European bison (*Bison bonasus*) numbers are few Canada and the U S. are the main habitats of the elk, moose and caribou; estimated numbers are 1 65 million (Table 3). Of the non-domesticated ruminants, deer (30 species) are the most widely distributed. Estimated population for the U.S., USSR, Canada, and 9 countries of central Europe exceed 27 million (Table 3), but world population may number 40 to 50 million (*3*). Population estimates for many species in Africa, South America and Asia are difficult to make because of inadequate census data.

Yak and their crosses with cattle (*Chauris*) are found only in the high elevations of the Himalayan region of Asia Estimated population for the two groups is about 1 million Current estimates of the other domestic species are· buffalo (exclusive of feral buffaloes in Africa) 130 million; goats 398 million, sheep 1,032.7 million, and cattle 1,178 9 million. Cattle and sheep are most numerous, 2,211 6 million, but there are approximately 30 million additional ruminants that man has under full or partial control, that is, on farms, game farms or by pastoral herding (Table 3). The total population of ruminants making some contribution of food and nonfood uses to man approaches 2 8 billion head.

Estimates of African wild ruminant populations are difficult to obtain. Serious proposals have been made for food production based on husbandry of wild ruminants, including the giraffe and many antelope species In the Transvaal province of South Africa alone, over 3,000 farms and ranches are engaged in commercial utilization of large wild mammals, sales of which amount to more than 3 million kg of fresh meat annually (*5*).

Table 1 -- Families of suborder ruminantia, numbers of genera and species with some examples of species

Family	Number of genera	Species: Number	Species: Examples
Camelidae	2	4	Alpaca, llama, camel
Tragulidae	2	4	Chevrotain, mouse deer
Giraffidae	2	2	Giraffe, okapia
Antilocapidae	1	1	Pronghorn
Cervidae	16	37	Caribou, deer, (including reindeer), elk, moose
Bovidae	44	111	Antelope, bison, buffalo cattle, gazelle, eland, goat, sheep, yak

Source· Adapted from (2)

Table 2 — Estimated population and distribution of Camelidae in South America

Species	Peru	Bolivia	Chile	Argentina
	Thousands			
Alpaca	289	300	20	Some
Llama	915	2500	70	500
Vicuna	30	2	—	—
Guanaco	Some	Some	Some	100

Source: Adapted from (2)

Table 3 — Estimated populations of wild ruminants in Canada, Europe, U.S. and USSR

Species	Population	Principal locations
Moose	250,000	Canada, US
Elk	600,000	Canada, US
White-tailed deer	10,000,000	Canada, US
Black-tailed deer	1,800,000	Canada, US
Mule deer	6,250,000	Canada, US
Axis deer[1]	5,000	US
Roe deer	4,000,000	Europe, USSR
Red Deer	610,000	Europe, USSR
Reindeer	2,500,000	Canada, Scandanavia US, USSR
Caribou	800,000	Canada, US
Pronghorn antelope	400,000	Canada, US
Bison	20,000	Canada, US
Mountain goat	17,000	Canada, US
Feral goat[1]	10,000	US
Feral sheep[1]	6,000	US
Bighorn sheep	30,000	Canada, US

[1] Numbers are for Hawaii only, population estimates for Axis, Sanbar deer and other African and Asian species are not available
Source Adapted from (*3, 4*)

To gain a full appreciation of the contributions of ruminants, one must recognize the symbiotic associations between ruminants and man in certain environments. Camels, buffalo and cattle are kept on a high proportion of farms in developing countries — up to 75 percent in a number of countries (*6*) because they represent the lowest possible investment farmers can make to aid them in easing their work load in agricultural production. If the animals could be replaced by an equivalent capital investment and direct cash outlay for producing power, these numbers would likely be reduced markedly.

In the high elevations of the Andes and Himalaya mountains, less than 5 percent of the land can be cultivated. This results in a high dependence on the Camelids in the Andes and the yak in the Himalayas for food, and complete dependence on the fiber harvested from these animals and their skins for cash to fill certain essential needs. If the market for such nonfood products were eliminated by synthetics, fewer humans could survive in these two regions.

Thousands of examples could be cited of the multiple ways in which ruminant pastoralists around the world directly depend on their herds or flocks of domesticated species for a livelihood — and even in some cases on nondomesticated species. With the exception of those who herd goats or sheep, these people almost all use their herds for meat, milk, skins and hair for clothing and shelter, traction and for some personal transportation. Beyond these major categories of usage, which are nearly universal, there are innumerable specific life sustaining and nonessential nonfood uses of herded ruminants.

The many kinds of services and nonfood products provided by ruminants have been sorted into 9 classifications (Table 4). Three of the classifications (fiber, skins and other products) are important in international trade, while the others serve mainly for local, country or regional needs.

Fiber Resources

Wool — The main supply of wool is from sheep. Approximately 58 percent of the world sheep population is in 15 countries. These countries supply 85 percent of the world production (Table 5), but the bulk of wool moving in world trade comes from Australia and New Zealand (75-80 percent) Europe and the U.S. are the major markets for wool used in the commercial manufacture of clothing and carpets. In more than 100 countries, both wool and hair from sheep are used in domestic pro-

duction and cottage industries for clothing, bedding, housing and carpets.

World wool production has remained relatively stable over the past 15 years. In 1960, total production of greasy wool was 2 528 million tons and in 1974, 2 548 million tons. Year-to-year production has varied about 41 thousand tons, or approximately 1.6 percent, from 1960 to 1974 A precipitous decline of 161,000 tons occurred between 1972 and 1973 which caused considerable alarm Production in 1975 declined slightly.

The other source of fiber in commercial trade is from the camelids of Latin America, mainly llama and alpaca. Estimated annual production of this fiber is 10 million kg (*2*). Alpaca and llama fiber usually sells for 2 to 3 times the price of sheep wool. About 50 percent is exported for making sweaters and fine wearing apparel; the remainder is used for local domestic consumption or cottage industry products. More than 250,000 people depend on products of camelids for their main livelihood. Feed sources are from grazing on otherwise unproductive steep mountain slopes or mountain meadows.

Hair — Mohair from Angora goats is the main hair in world trade. About 50 percent of the world production, or 3,000 tons, is produced in the U.S. and 90 percent of this is exported to Europe (*9*) Turkey and the USSR are the other major sources. In recent years demand has risen rapidly, thus, favorably influencing expansion of the Angora goat population. Goat hair other than mohair comes mainly from Angola, Namibia, South Africa and Botswana. Approximately 53,000 tons are sold per year (*10*)

Some hair of buffalo, camel, sheep, yak and reindeer is marketed for brushes, optical items, and the manufacture of felt and stuffing material. Adult yak yield 1.0 to 1.5 kg of hair and 0.5 kg of wool per year, and the camel, 2.0 to 3.5 kg of wool (*11*). In developing countries, hair is used largely in local industries to produce grain sacks or rope, and in homes for blankets and tent coverings. More than half the people in southwestern Africa and in the Himalayas depend heavily on the sale of hair or handicrafts from hair for their livelihood. For instance, U.S. $1.0 million worth of saddle blankets, bed coverings and hair for Santa Claus beards is produced annually from yak and sheep hair in northeastern Afghanistan and northwestern Pakistan (*12*).

Making of Ghasghaei cloth using fiber made from sheep hairs (Iran) In more than 100 countries, wool and hair from sheep are used in domestic production for clothing, bedding, housing, and carpets. *(All Photos by Author unless otherwise specified.)*

Table 4 — Classification of nonfood contributions of ruminants

Classification	Contribution	Main sources[1]
Fiber	Wool	Sheep, camelids
	Hair	Goats, yak, sheep, camel
Skins	Hides	All ruminants
	Pelts	Sheep, camelids
Inedible products	Inedible fats	Cattle, buffalo, sheep
	Horns, hooves, bones	Cattle, buffalo
	Tankage	Cattle, buffalo, sheep
	Endocrine extracts	Cattle, sheep
Traction	Agriculture	Cattle, buffalo, camel
	Cartage	Cattle, buffalo, yak, camel
	Packing	Camel, yak, buffalo, cattle reindeer
	Herding	Buffalo, camel
	Irrigation pumping	Buffalo, cattle, camel
	Threshing grains	Cattle, buffalo
	Passenger conveyance	Buffalo, camel, yak, cattle
Waste	Fertilizer	Domestic ruminants
	Fuel (dung)	Cattle, buffalo, yak, camel sheep
	Methane gas	Cattle, buffalo
	Construction (plaster)	Cattle, buffalo
	Feed (recycled)	Cattle
Storage	Capital	Domestic ruminants
	Grains	Cattle, buffalo, sheep
Conservation	Grazing	All ruminants
	Seed distribution	All ruminants
	Ecological	
	Maintenance	All ruminants
	Restoration	All ruminants
Pest control	Plants in waterways	Buffalo
	Weeds between croppings	Domestic ruminants
	Snails (irrigation canals)	Buffalo
Cultural, including recreation	Exhibitions, including rodeos	Cattle, sheep, goat, buffalo
	Fighting	Cattle, buffalo
	Hunting	Deer, elk, gazelle
	Pet	Goat, sheep, deer
	Racing	Buffalo, cattle
	Riding	Camel, buffalo
	Religious	
	Instruments	Goat, buffalo
	Sacrificial	Buffalo, sheep
	Bride price	Cattle, sheep, goat
	Social status	Cattle, sheep

[1] Species listed in order of importance, if identified

Table 5 — Wool production, number of sheep and estimated yield per head for major wool-producing countries

Country	Greasy wool	Sheep	Yield/head
	Thous. metric tons	*Millions*	*kg*
World	2,548	1,033	—
Australia	703	145	5.1
USSR	461	143	3.0
New Zealand	285	56	5.5
Argentina	156	42	4.6
South Africa	115	31	4.0
US	65	16	4.4
Uruguay	52	15	4.0
China	61	73	1.3
Turkey	52	37	1.3
UK	49	29	1.8
India	36	40	0.8
Spain	32	16	1.8
Afghanistan	24	17	1.3
Brazil	37	26	1.8
Bulgaria	32	10	4.0

Sources (*7, 8*)

Despite competition from synthetic fibers, world wool production has remained relatively stable — about 2.5 million tons in 1974. *Photo by Ohio Agr Research & Dev Center*

Because of seasonal fluctuations in the main wool- and hair-producing areas, production cannot be held constant; therefore, it is difficult to predict future trends. Fluctuation in demand, especially for wool, is affected by competition from synthetic products. Some argue that the use of synthetics will continue to curb the use of wool, and that as taxes and costs of land, labor, pasture improvement and disease control rise, wool will be in an increasingly unfavorable market position While these views have some justification, they are not new and probably are of modest importance in predicting the long range outlook on wool production (*13*). Costs of competing products have soared since 1973, mainly because many synthetic fibers have as their base hydrocarbons from unreplaceable crude oil. There is no evidence that petroleum costs are going to decline in the near future. Relative to other agricultural products, wool has one of the lowest ratios of labor cost to monetary value of output.

Because of rising costs in the U.S., wool production will no doubt continue to decline, unless petro-chemical prices increase at a higher rate. Wool yield per head will be expanded in most countries (Table 5) if prices rise (*14*). The numbers of animals kept in developing countries for wool and hair production will decline somewhat, but this will be largely offset by increased utilization and harvest of what is available. Wool cannot, however, be the major criterion for change in nomadic herding patterns, because of the importance of milk for survival. There is a move to establish a "world pool" to serve as a stabilizer in supply (*15*). When all factors are considered, there will be a modest, but significant, rise in wool production, world trade and consumption (3.0 million metric tons) by 1990 (*13*). Future demand for hair will tend to follow that for wool (*14*).

Skins

Skins of ruminants (outer body covering) are used as sources of many useful, essential products, and they constitute a large commodity in world trade. Including trade in finished products, the commercial value of skins exceeds that of wool and hair (*16*). There is not full agreement on terminology, but in this discussion skins are grouped as hides (skin with hair removed) and pelts (skins with hair or wool intact).

Hides — Cattle and buffalo are the main sources of hides; production amounts to over 6 million tons per year. Of this, about 41 percent comes from the developing countries. Hides represent 7 0 to 7.5 percent of the liveweight of cattle, 7.5 to 8.5 percent for buffalo, 10 to 12 percent for sheep and 7 to 10 percent for most other species, such as yak, camel and deer. Pelts make up to 25 percent of the total market value of animals; hides make up from 5 to 10 percent of total market value (*17*) The main value of hides is to produce leather, but significant uses (Table 6) include foods like *Kerupuk kulit* in Indonesia, *Chicharons* in the Philippines, in Thailand *Khab-kwai* and similar products in Nepal and Afghanistan (*18*). Often in developing countries, the primary processing of hides for leather represents the major labor intensive industry (*17*) In Pakistan, hides are the next most important raw material in the economy after jute and cotton (*18*) Hide exports rank in the first 10 commodities earning foreign exchange for about 30 countries (*16*) Hill (*19*) estimates hides of commercially slaughtered deer at about half the value of meat. Over the past several years, market prices for hides have advanced nearly 300 percent (*17*). This is because (a) the price of synthetics has risen, and (b) synthetics are not found suitable for making the upper parts of good quality shoes. The use of hides for clothing, especially coats and jackets, is increasing rapidly.

An important factor in the leather industry is the quality of the basic raw material. Among the factors affecting hide value are species, breed within species, age, sex and the environmental conditions, especially with respect to disease and parasite exposure The manner in which animals die or are slaughtered also influences quality Great economic losses arise in developing countries because of low quality hides. The United Nations has sponsored programs for producing better quality hides in a number of countries. Until recently, the most technically successful substitute for good quality leather in footwear was corfam It proved to be a commercial failure after costing $100 million to develop This turn of events has markedly increased the interest of shoe manufacturers in leather and should lead to increased utilization and interest in quality (*20*)

Pelts — The value of raw pelts of lambs, goats, and camelids is over U.S. $3 billion per year.

Hide tanners at work in Somalia. Almost three-fourths of Somali's population relies on animal husbandry and its byproducts for a livelihood. *FAO photo.*

These have a market value as finished products of greater than U.S. $20 billion. Persian lamb pelts from Karakul sheep presently have the greatest value. They constitute the total cash income for many pastoralists in parts of southern Asia and southwestern Africa. Even though pelt prices have been reasonably high, the return per herder has been insufficient to stimulate expansion. Production is expected to decline.

Because environmentalists are concerned over the preservation of certain wild species such as leopard, the market for pelts of other ruminants is rising. Fernández-Baca (*2*) states that the pelts of young alpaca (less than 3 months of age) are prized for coats and handicrafts. Heretofore, pelts have been largely from young animals, but the use of skins of adult animals for clothing, handicrafts (purses, bags, etc.) and carpeting is increasing rapidly. Clothing from leather or pelts is warm, durable, and ventilative. Reindeer skins, for example, are impervious to water and the fur has good insulating qualities Projections show that the demand for pelts will rise in the foreseeable future and their use will be encouraged by the meat industry to help defray costs. Game farming and deer herding will no doubt benefit (*21*). The pelt industry has problems of quality similar to that of the hide industry; therefore, effective training programs will need to be developed and put into operation.

Inedible Byproducts

The classification of inedible byproducts (Table 4) is subject to variable definition since byproducts from slaughter not normally consumed in one cultural system may be readily eaten in another. Discussion will deal with products in two groupings, industrialized use and nonindustrial.

Byproducts used in industry are largely the creation of organized slaughtering among affluent societies. A 450 kg steer yields about 200 kg of market meat. The remaining 250 kg yields numerous products, such as those listed in Table 6. Most byproducts used in industry come from cattle; lesser amounts come from sheep and swine (*22*) In developing countries, most carcass parts are used as human food; therefore, there is very little excess fat or other products. Unconsumed carcass fat is used either as household fuel or for making candles.

Inedible fat is a major item in world trade — 2.5 million tons in 1972. Nearly 50 percent came from the U.S , 33 percent from the USSR, Australia, Canada, UK, Argentina, France and New Zealand, the remainder was produced in small amounts in a number of countries. The U.S. normally exports half its production (1.2 million tons, 1974) to 50 or more countries. Presently, the main use of inedible fats in the U.S. is for animal feed, 23 percent, followed by 12 percent each for soaps and fatty acid production. The latter serves as a precursor of numerous products (Table 6)

Production of inedible fat is expected to decline, particularly in the U S , because of rising prices of feed grains. Already, fats have serious competition in the international market from palm oil. The animal feed industry uses fats because they have been relatively cheap Pressure from environmentalists will no doubt continue to reduce the use of phosphate detergents in favor of biodegradable products, such as can be made with tallow This could increase the use of fats or soaps, but palm and other plant oils are equally suitable as biodegradable detergents. New uses for fats are being sought, especially in products from fatty acids, but the demand is not likely to influence feeding practices for livestock.

Prize cattle in India with the traditional ornamentation carried on festive occasions. Note the massive horns, which, in some countries frequently serve as the basis for cottage industries in the making of buttons, combs and other articles. *FAO photo.*

Although several synthetic products have been developed, endocrine gland extracts continue to be important in human health. Thyroid extract is used to treat hypothyroidism in humans, pituitary extract serves as a growth stimulant, pineal extract is used to control growth or retard puberty, adrenal extracts are utilized to treat Addison's disease, and pancreas extract (insulin) is an aid to diabetics. A number of other products are also extracted, among which are cortisone from cattle gall and thromboplastin from cattle brains that is used as a coagulant in surgery. Brisket cartilage from neonatal calves is useful in rebuilding of facial bones in humans, and foetal fluids are widely used as culture media in virology.

Some of the extracted products from animals have been largely replaced by synthetics, and others have been synthesized, but by procedures that are impractical for commercial scale production, thus, animal byproducts represent only the practical sources for several biological products. The need for these materials will undoubtedly continue, and further research will expand their use (*23*). Increased production is anticipated in those developing countries which emphasize better health programs.

Table 6 — Some nonfood products of slaughtered ruminants

Source	Products	Source	Products
Blood	Albumin glue	Hides	Bedding
	Animal feed		Carpeting
			Clothing
Bones	Animal feed		Covers musical instruments
	Buttons		Gelatin
	Fertilizer		Glue
	Glue		Handicrafts
	Jewelry		Housing
Digestive tract	Animal feed		Leather
	Fertilizer		
		Hooves	Animal feed
Endocrine glands	Wide variety of		Gelatine
	pharmaceuticals		Glue
	for human use		Neat's foot oil
		Horns	Animal feed
			Buttons
			Carvings
Inedible fat	Animal feed		Combs
	Fatty acids		Gelatin
	Abrasives		Glue
	Candles		Handles
	Cement Additives		Musical instruments
	Cleansers		Religious symbols
	Cosmetics		
	Lubricants		
	Nitroglycerin	Brisket cartilage	Plastic surgery
	Plastics		materials
	Printing ink	Foetal fluids	Virology culture
			media
	Resins	Cattle gall	Cortisone
	Synthetic rubber	Cattle brains	Thromboplastin
	Toothpaste		Other useful
	Water repellents		byproducts include
	Waxes		estrogen, lanolin,
	Soap		rennet and
	Sacrificial fuel		butter oil (fuel)

Glue from blood, bones, hides, hooves and horns was formerly a major item for commercial furniture manufacturing. General usage has declined because of cost, although animal glue is still used in the construction of the best grades of wood furniture. (*24*). Use of animal base glue for the production of handicrafts is increasing in developing countries (*17, 18, 25*).

Horns of ruminants are generally an insignificant item in the total animal weight but are nevertheless valuable. In many societies, horns are useful and often symbolic. The core, or the horn pith, contains a high percentage of gelatin for glue or food. Horns frequently serve as the basis of cottage industries for buttons, combs, handles, and religious or cultural symbols. Preparation of sets of horns for use as religious symbols is a multimillion dollar industry in Malaysia, Indonesia, Philippines, Burma and Thailand (*18*). In western societies, horns are generally the trophies of the hunter and are largely responsible for interest in hunting pronghorn antelope, deer and other ruminants.

A pair of bullocks pulling a load of forage in Bangladesh. Twenty percent of the world's population depends on animals for cartage. *Photo by Ralph Phillips, Foreign Agriculture Service, USDA.*

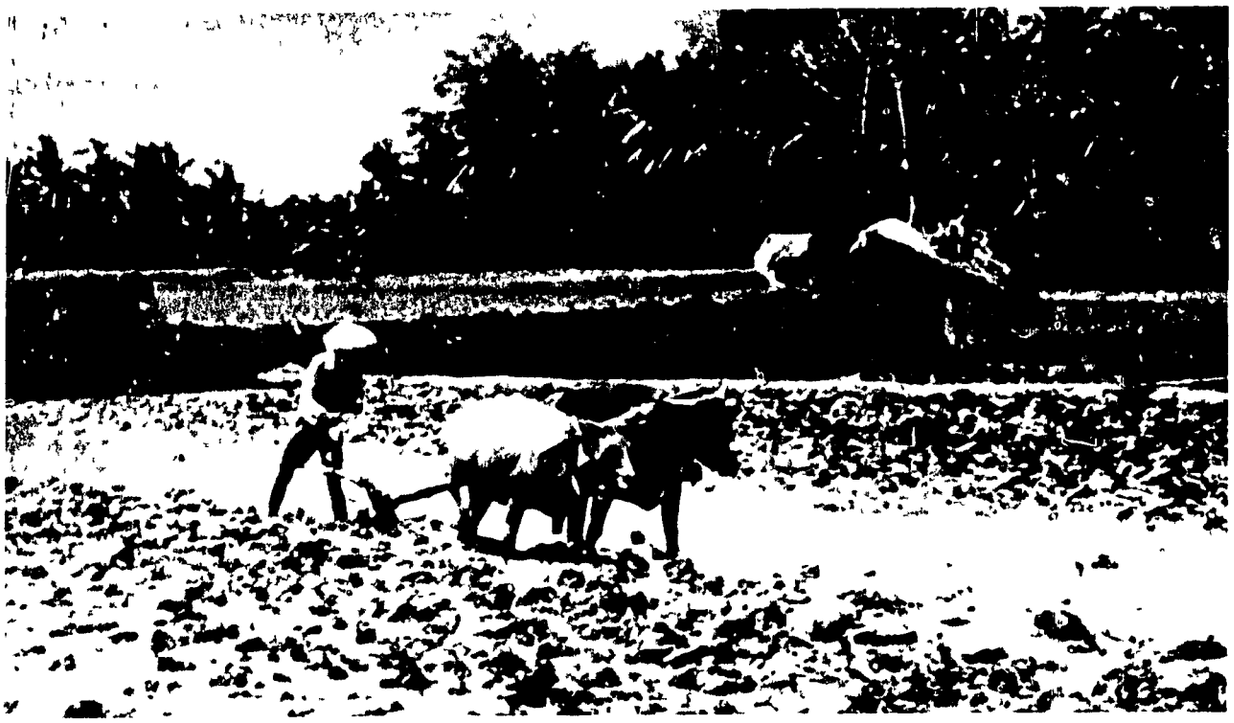
Traction

In past years, the concepts of development and mechanization ignored the essential role of animals for traction services, and this contribution still goes largely unrecognized in the preparation of national income accounts. Yet working animals constitute the most important single part of the livestock sector in more than half of the countries of the world. If petroleum prices continue to rise, the most serious deterrent to meeting food production goals in Southeast Asia for 1985 will be a shortage of buffalo and cattle for farm power (*26*). Ruminants are frequently preferred for power, especially in paddy cultivation, because of their tolerance of mud (*18*). For packing, they are preferable to horses because of higher possible pack loads in proportion to body weight (38 to 40 percent of body weight for yak and camel) and the ease of their management in mountainous terrain or in desert sands (*11*).

A large factor accounting for differences in animal production between Asia and the West is in the proportion of reproducing cows. In most western countries, at least 50 percent of the total cattle populations are females; whereas, in Asia less than 20 percent are females because males are retained for power (*27*). Many countries of Asia have laws prohibiting slaughter of buffalo or cattle under 7 years of age. These laws have been attacked as deterrents to livestock development, but the intent is to protect the primary interests of the majority of the population which are served by animal traction.

Agriculture — The extent of the use of animal versus mechanical power in agriculture for several countries is illustrated by data in Table 7. Although the use of tractors has expanded, there has been no appreciable change from the 75 to over 90 percent contribution by animals in many countries (*6, 26, 29, 30, 31, 32*). Significant change in these proportions is neither likely nor possibly desirable in view of the petroleum situation.

For most of Asia, there is one draft animal per hectare of cultivated land (*33*), except for China and Taiwan which average 1.5 hectares per animal (*34*). Estimates for selected countries (Table 7) indicate that even in developed countries like Japan, South Africa, France and Germany, animal power plays a rather significant role in agriculture. Animal power in the U.S. is provided solely by horses and mules, but in other countries, including Europe, oxen, buffalo, or camel are the main source Banta (*6*) showed that in Thailand and the Philippines, 18 percent of all farms use only hand labor, 72 percent have animal power, 2 percent have mechanical power, and 8 percent use a combination of animal and mechanical power (Table 8).



Indonesian farmer plowing his rice land preparatory to planting Animals provide from 75 to 90 percent of the power for use in agriculture in many countries of the world.

Table 7 — Animal and tractor power used in agriculture in selected regions and countries

Region or country	Type of power			Animal (% of total)
	Animal	Mechanical	Total	
	10^3 Mcal[1]			
Africa	2,095	449	2,544	82
Far East[2]	19,591	282	19,873	99
Near East	3,320	436	3,756	88
Latin America	6,731	2,289	9,020	75
Morocco	231	102	333	69
India	15,481	119	15,600	99
Japan	200	1,466	1,666	12
Turkey	1,480	192	1,672	88
Brazil	2,604	326	2,930	89
Spain	536	520	1,056	51
Greece	293	135	428	69
South Africa	24	535	559	4
Italy	800	1,557	2,357	34
Argentine	671	568	1,339	54
France	902	2,883	3,785	24
Germany (Fed. Rep.)	378	3,453	3,831	10
US	28	21,238	21,266	1

[1] Mechanical power is expressed as animal power divided by five; animal power is converted to Mcal equivalents used directly in agriculture.
[2] Excluding China
Source: (*28*)

Table 8 — Power sources by farm size for Thailand and the Philippines

Farm size	Hand power		Animal power		Mechanical power		Mechanical power + animal power	
	Farms	%	Farms	%	Farms	%	Farms	%
Ha	*Thousand*	*%*	*Thousand*	*%*	*Thousand*	*%*	*Thousand*	*%*
<1	355	40	495	55	19	2	27	3
1-2	263	19	1026	75	23	2	62	4
2-5	267	14	1484	76	40	2	166	8
>5	76	7	852	74	31	3	190	16
Total	961	18	3857	72	113	2	445	8

Source: (*6*)

The general consensus is that a minimum power input of 600 kcal per hour per ha is necessary to achieve sustained agricultural growth in the less developed countries. The current level for the U.S. is 600 kcal and in Japan about 1,800 kcal. But for countries in Southeast Asia, kcal available from all sources averages 333 kcal. The contribution of power by animals ranges from 8 percent in Iran to 70 percent in Pakistan (Table 9). If the Philippines were to import sufficient farm equipment to raise power inputs in agriculture to the current level of Japan, it would be necessary to obtain and allocate for farm machinery the foreign exchange equivalent to that presently allowed for automobiles over the next 100 years (*29*). MacPherson and Jacobson (*36*) estimate the initial capital cost of mechanization per farm in Tanzania at $10,300 versus $565 for an animal-based technology.

At current prices, India would need to expend U.S. $.7 to $1.2 billion per year for gasoline just to replace the equivalent in Mcalories of energy provided by the 1 5 million or so buffalo, cattle and camels used for land preparation or operating irrigation pumps. The lower value is based on 120 work days at an average of 6 hours per day per animal per year; the higher value corresponds to 200 work days. Odend'hal (*37*) found the average number of working days varied from 80 to 300, depending on geographical location, size of farm and crops. Although the exchange rate is 8.60 Indian rupees per U.S. dollar the relative purchasing power of the rupee versus the U.S dollar is approximately 1:1 within the country. On this basis, the replacement of animal power would have an impact on the Indian economy about 8 times greater per year than the mere purchase of gasoline at world market prices, to say nothing of the upkeep and replacement costs of mechanized substitutes. Numerous other countries will be confronted with a similar dilemma.

The uses of animals for agricultural power are so country-and commodity-specific that it is impossible to make more than general predictions on future trends. For mechanization with animal power, the minimum size farm should be 2 ha for an intensive irrigated holding and 4 to 6 ha for drylands (*28*). Ulinski and Berker (*38*) concluded that in the Philippines, work animals are the most economical on holdings of less than 4 ha, whereas four-wheel tractors become viable on holdings greater than 50 ha.

Some reports, like those of FAO (*39*), deGuzman (*40*), and Turk (*41*), project a decline in the use of animal power, while others (*6, 29, 38, 42, 43, 44, 45, 46*) project a necessary increase in animal power even though the number of tractors will rise too. In the most recent writings, scarcity of fossil fuel has been cited as a crucial factor The rate of increase in the number of tractors serves to illustrate. The number of tractors in India increased 19 percent from 1971 to 1972 but slowed to 9 percent from 1973 to 1974. The overall change for Asia was plus 9 4 percent from 1971 to 1972 but declined to 6 6 percent during 1972 to 1973. The same was true for Africa — 4.4 percent versus 2.8 percent. The rate of increase in the two years was about the same for Latin America (*7*).

Changes in agricultural technology to increase crop yields have often been accompanied by mechanization designed to replace human or animal energy. Mechanization may be very helpful; for example, in India it is estimated that each day's delay in planting after the opti-

Table 9 — Average farm size, agricultural workers per hectare and power available from various sources for cultivation in several rice-producing countries of Asia.

Country	Arable land per farm	Agric. workers	Type of power Human	Animal	Mechanical	Total
	Ha	*Number per ha*	*Kcals per ha per hour*			
Sri-Lanka	1.59	1.20	77	95	71	243
Taiwan	1.11	1.95	125	105	105	335
India	2.62	.90	577	131	5	713
Iran	6.17	.37	237	31	99	367
Korea	0.90	1.96	126	151	2	279
Nepal	1.22	2.49	160	308	3	471
Pakistan	2.37	1.09	70	185	8	263
Philippines	3.66	.71	46	67	15	128
Thailand	3.64	1.10	71	118	35	224
Vietnam	1.57	2.10	135	157	15	307

Source: Adapted from (*35*)

mum period brings a reduction of one percent or nearly one million tons in the yield of grains (*47*). But in a large part of Africa where land is not so restricted, agricultural production is limited because of primitive implements; thus, better manual and animal drawn implements could substantially increase agricultural production. Because of fuel prices, policies on mechanization are being scrutinized more closely in many developing countries (*31*).

In attempts to implement land reforms which increase the number of farms and small owners, as well as intensify production and expand employment, it is likely that the use of animal power will rise more rapidly than mechanization. Others, projecting an increase in animal power, cite that prices of off-the-farm produced products and inflation will no doubt continue to rise more rapidly than governments can condone changes in prices for food grains; hence, farmers will resort to continuation or extended use of animals instead of switching to mechanical power. Lele (*44*) holds that for small farms, ox-plow cultivation is preferable because of its relatively greater flexibility, lower cost, and greater growth linkages with other sectors of the rural economy.

Cartage and Packing — Estimates show that about 20 percent of the world's population largely or wholly depends on the movement of goods by animal cartage or packing (*48*). Tea and coffee, for example, owe their availability to animal transport from producing areas. Pastoral herders and the people of the Andes and Himalaya regions almost exclusively depend on ruminants as pack transport (*41*). Heath *et al* (*49*) found that in the high plateau of Bolivia there were 3 animals per 10 households used exclusively for packing. For India, it has been calculated that over 80 percent of the grains are moved from farms to intermediate markets by cartage (*32*). Assuredly, this holds for numerous other countries. Even within many metropolitan areas, up to 50 percent of all goods is moved through cartage, drawn more frequently by buffaloes, camel or cattle than horses or donkeys (*35*)

In villages of India, 49.6 percent of the households own either no land or less than one hectare. These households own 17.9 percent of all bovines and derive more than 95 percent of their income from the sale of milk, cartage, rental of animals for cultivation or some combination of these (*32*). This suggests that a significant sector of the rural population of India depends on ruminants for income.

Other Forms of Traction — As indicated in Table 4, ruminants are employed in various regions for such tasks as riding to herd, providing power for irrigation and the trampling of grains in threshing. In irrigated areas where animals work 200 days or more per year, up to one-third of the work time may be devoted to power for irrigation (*28*). In Egypt and India, farmers use their cattle or buffalo about 6 days per year for the threshing of grains (*35*). No-

Camel caravan moving peanuts to market in Pakistan. About 20 percent of the world's population depend, largely, on the movement of goods by animal cartage or packing.

mads frequently use camels for driving their sheep and goats to market as well as for passenger conveyance in movement from one area to another. In contrast to power for soil cultivation, the magnitude of the use of these forms of service is projected to continue at about the same level in certain situations, but in general, there will be a decline, particularly in irrigation and the threshing of grains (*50*).

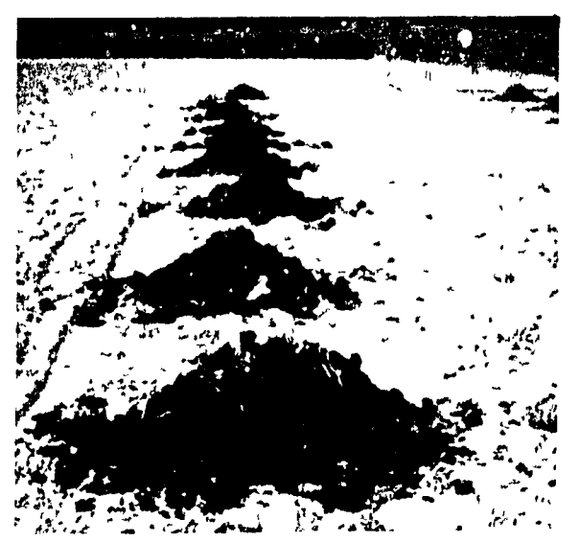
Animal Waste

For large herds or flocks, disposal of animal excreta has become a serious problem, but in some parts of the world animal wastes serve numerous useful purposes, such as indicated in Table 4. In fact, animals are frequently kept beyond their period of usefulness for the production of milk or work so that they can provide dung.

Fertilizer — Approximately 40 percent of the farmers of the world depend wholly or in part on animal wastes to enhance soil fertility (*48*). Generally, manures do not increase short-term crop yields to the extent of equivalent amounts of nutrients supplied in refined chemical form. The differences in yields are, however, less with long-term usage (*51*, *52*). Small farmers who till land by hand or with chisel type plows prefer manures over chemical fertilizer because manure enhances the aggregate crumb structure and soil permeability which aids in cultivation (*30*, *36*). Marginal micronutrient deficiencies, which may occur after repeated cropping with chemical fertilizers, can be prevented with supplementary applications of manure (*51*).

The value of manures for soil fertility can be markedly influenced by handling procedures. At least 50 percent of the nitrogen and 60 to 70 percent of the potassium are found in the urine Frequently, manure has a low fertility value due to failure to incorporate the urine, or the nitrogen is lost through leaching (*53*) Eighteen to 20 Mcal of energy inputs are required to produce one kg of nitrogen fertilizer. Fuel costs to produce nitrogen have already aroused new interest in research on storage and handling of manures Predictions for the future are that animal wastes will again be viewed more favorably as a useful resource.

Fuel — The energy in ruminant manures is rather high (dry cow dung 4 58 to 4.72 kcal per gram) and can be used as efficiently as energy from coal or oil if appropriate equipment is used. In some cases, dry dung cakes are preferred over plant residues because of uniformity of heat (*33*). India annually uses 60 to 80 million tons of dry buffalo and cattle



Manure piled on fields near Jaipur, India preparatory to planting. About 40 percent of the farmers of the world use animal waste to enhance soil fertility.

dung for fuel. In the central plains area where there is no firewood, per-capita use is as much as one ton per year (*54*) In two instances, the sale of dung cakes to urban centers provided up to 60 percent of the total cash income per rural family (*55*) The expected return per animal per day from the sale of dung cakes is 1 03 rupees or $0.12 (*18*) India would need to expend over U S $3 billion per year, exclusive of distribution costs, for coal and oil to replace dung.

Energy in ruminant manures is high and can be used as efficiently as energy from coal or oil if appropriate equipment is used. Dried dung cakes are stored in piles (India).

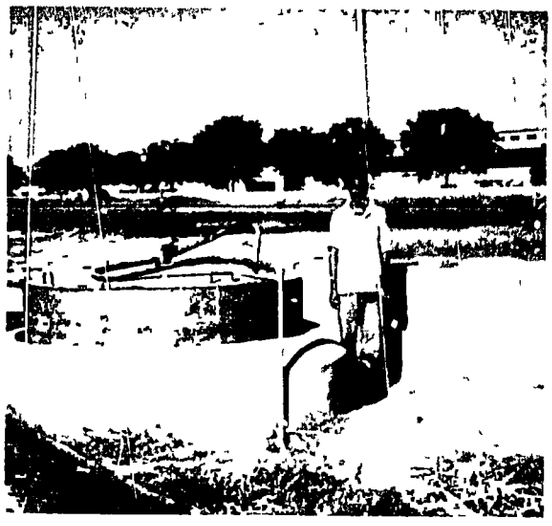
Pastoral herders, especially nomads, largely depend on cattle or sheep manure as fuel for cooking, heating and light (*56*). Estimates are that over 200 million tons of manure are used per year as fuel in developing countries (*33*). Eckholm (*54*) points out that supplies of firewood or charcoal — traditionally the chief sources of fuel in central Africa fringing the Sahara, the Andes region of Latin America, the highlands of Central America and the Caribbean islands -- have become scarce or nonexistent. In many areas nearly 20 percent of the total family labor is expended to gather wood or crop residues for fuel, and the time spent is increasing. Expenditures by salaried workers for firewood or crop residues have risen from 15 to 25 percent of income. In Africa and the Americas, animal manures have not been used extensively as fuel, but usage will probably increase rapidly in the near future (*37, 54*). Over the long run, methane gas from animal wastes will likely make the greatest contribution.

Methane Gas — During the 1930's and 40's digesters were used rather extensively in central and northern Europe for producing methane gas, but production declined to nearly zero when oil became cheap during the 1950's (*57*). Currently there is vast interest in digesters to meet fuel needs. In 1975, South Korea had 29,000 bio-gas plants and planned to build another 50,000. India has about 20,000 plants, two-thirds of which were built since the energy crisis, and plans to build 100,000 more within the next 5 years Taiwan has a large number of plants and there are some in Bangladesh and Nepal (*58*).

The U.S could obtain nearly 1.0 percent of its energy by 1985 from renewable resources, and this could increase to 25 percent by 2020 A.D. Of this, methane production is capable of producing about 5 percent by 1985 and 25 percent in 2020 (*59*). Downing (*60*) estimates Canada has a similar capability.

Fecal material produced by ruminants, particularly buffalo and cattle, is an ideal substrate for anaerobic fermentation because it is already buffered and contains large populations of methanogenic bacteria. Methane from manure has a value of 5 kcal per cubic meter which is 71 percent of the energy value of natural gas. It works well for household use but is difficult to handle in mobile power (*61*). Processing manure through bio-gas plants has the added advantages of better preservation of fertilizer in some areas where dung is burned.

A major handicap for methane production is capital cost for small units. Several countries have extensive research programs underway to reduce construction costs Even so, the use of bio-gas plants is not likely to approach anywhere near the level projected in the reports by FEA (*59*) and the Economic and Social Commission for Asia and the Pacific (*58*) unless prices of fossil fuels rise to extremely high levels. For the U.S., it is estimated that manure from 40 cows will be needed to supply fuel, including electricity, for an average farm family, but will not replace fossil fuel to operate tractors, trucks or automobiles. The average Indian village could potentially accrue high



Digester (Methane production unit from cattle and buffalo manures in India) Digesters are on the increase in much of the world since the oil energy crisis Methane from manure has about 71 percent of the energy value of natural gas.

benefits from the use of digesters, but acceptance will be low because it will deprive individuals of one, if not their major, source of income. In spite of limitations, anaerobic fermentation technology will undoubtedly play a much more significant role in waste management For developed countries, units will be employed mainly on large farms or in conjunction with feedlots where the cost of production will be in line with other fuels In Asia, most units will be found in areas with high density of swine, or as village units to process plant residues or surplus manures not sold as dung cakes.

Other Uses of Manures — Ruminant feces contain substantial proportions of the original nutritive value of the feedstuffs. The feasibility of recycling feces as a feed supplement has been demonstrated (*62, 63, 64*). To recycle manures of poorly fed animals will not pay. Manure from well-fed cattle may be utilized as a partial supplement for dry cows; therefore, from a practical standpoint, recycling will be relegated to feedlots where nutritive level of the rations is high and the units are large enough to afford volume preparation.

In certain low income areas, manures are valued for still other uses. The Masai herders of Africa plaster their huts with cow dung (*65, 66*) Urine mixed with clay is utilized for daubing in walls or floors of houses of India and other Asian countries (*18*). Indian villages also employ a mixture of water and dung to renew floor covering and to serve as a means of controlling insects (*67*). Blocks made of approximately 50 percent cow manure, plus soil and chopped straw, are used for construction of houses and animal housing in the higher elevations of Peru and Uruguay (*68*) Some groups in Africa use fresh manure for poultices in wound healing (*25*) It is fairly common practice to use animal excreta as fertilizer in fish ponds in developing countries (*41*).

In general, animal waste management will become an increasing problem. For developing countries the problems are (a) disposal from sizeable livestock operations close to metropolitan centers and (b) mismanagement of animal wastes in rural areas Overall, the use of manures for improving crop production will continue as the most practical use for animal waste; however, distribution costs will force development of alternative uses

Data derived from village surveys in 5 countries have been used to illustrate the significance of animals for total energy expended in operation of small farms (Table 10) The average size farm varied from 1 0 to 4 8 ha Livestock density per capita indicates all or nearly all households had animals Based on energy use per capita from all sources, including inputs from animals in the form of power or fuel, animals contributed 59 percent in India, China 22 percent, Nigeria 17 percent, Bolivia 17 percent, and Mexico slightly over 2 percent. These results show that exclusive of milk, meat or fiber, rural villages around the world have moderate to very high dependence on animals.

Storage

There are no means of determining the numbers involved or the monetary value of the contribution of ruminants through storage (Table 4); nevertheless, it is a role worthy of investigation. Some surveys indicate (e.g Table 10) rural households have 0 4 to 6.1 ruminants per capita (*33*). If these are not managed to maximize reproductive efficiency nor slaughtered at the most efficient stage of life — in other words if they are maintained as "scavengers" — then a large proportion of such domestic ruminants seem to function as "stored capital." Among the major reasons given by McDowell (*69*) for

man keeping livestock is to "serve as a bank or means of providing reserve food in periods of shortage." This category was justified on the basis that, in proportion to their numbers, such animals contribute only a small fraction of the total animal products marketed. A study of the Near East (*13*) showed farmers often kept their animals primarily to insure a source of capital to resume farming in case adverse weather caused crop failure

In Tanzania and other countries of Central Africa, tribal groups regard an increase in animal numbers as the best insurance against economic and social risk as they afford protection against the uncertainty of rainfall and the destruction of grains by pests. To store large reserves of food is pointless in view of inadequate storage facilities; thus, any surplus from agriculture is converted into cattle which serve as accumulated capital until needed (*70*).

In certain areas of Africa, control of land rests with tribal councils. Such councils require individual families to pay fees for the use of land for tillage, as well as the privilege of grazing. Goats or cattle are kept by each family to insure access to the lands they need.

Although poultry and swine make up the largest group of scavengers, the majority of goats, a sizeable number of sheep and some cattle, buffaloes and camels are maintained for similar "storage of capital."

In 1968 the world stock of grains was 188 million tons but declined to 93 million tons by July, 1975 (*13*). During the period of high surpluses, large quantities of grains were "stored" in livestock. Decreasing reserves of grains are accompanied by rises in prices and much less storage in livestock; nonetheless, livestock continue to represent a tremendous storehouse of food in case of emergency. For example, animals kept for breeding purposes in the U.S. are equivalent in calories to more than one year's total food need for the U.S. (*71*).

Table 10 — Size of farm, livestock numbers per capita, estimated energy use per capita per year (kcal 10^6) and major crops in selected areas of five countries

	India	China	Nigeria	Mexico	Bolivia
Average farm size (ha):	1.5	1.0	3.1	4.8	1.0
	Livestock per capita				
Draft (plow or transport)	.30	.15	.20	.07	.30
Milk production	.10	—	.60	.05	.10
Horses or donkeys	.005	.03	—	.19	—
Goats and sheep	.80	.25	5.30	—	.30
Swine	.008	.50	.30	.05	.20
Poultry	—	.60	—	.83	.70
	Sources and energy use per capita per year (kcal 10^6)				
Animal power	95.8	63.0	63.0	37.8	75.6
Fuel: wood	12.6	25.2	264.6	12.6	252.0
crop residues	12.6	151.2	—	63.0	—
animal manures	25.2	75.6	—	—	—
coal or oil	small	151.2	2.5	151.2	—
Electricity	—	—	—	410.8	—
Human energy	20.2	25.2	25.2	12.6	126.0
Chemical fertilizer	37.8	126.0	25.2	831.6	—
Total	204.2	617.4	380.5	1,519.6	453.6
Major crops	*Kind of crop*				
	Maize	Rice	Maize	Wheat	Cassava
	Cane	Maize	Millet	Maize	Potatoes
	Rice	Wheat	Groundnut	Cotton	Maize

Source: Adapted from (*33*)

Conservation

The usefulness of ruminant excreta in maintaining soil fertility is well recognized, but the role of ruminants in maintaining an overall ecological balance is less well recognized. Many plant species are interdependent with ruminant populations. Also, distribution of seeds of both grasses and legumes through the feces of grazing animals aids in maintaining grass cover and in ecological restoration (*72*).

Good plant coverage is highly desirable to reduce erosion in many areas Ruminants often furnish the incentive for establishing and maintaining plant cover, because the cover can be utilized for their feed. Also, legumes planted for ruminant forage fix nitrogen and enrich soils generally. Prevention of soil erosion and increasing water storage are important. Without returns from livestock, efforts in soil conservation would be substantially impaired (*73*).

In Indonesia (*74*), Brazil (*75*), and Mexico (*76*) plans to open new lands for agriculture in hilly regions allocated 10 to 12 hectares per family of five on the assumption that an average family of five persons could live on food provided from one hectare and acceptable yields could be maintained under a system of shifting cultivation (10 to 12 years fallow). For all the locations, soils were highly susceptible to erosion; hence, yields of grains or tubers were unacceptable. Shifting to grass and cattle grazing reduced erosion and gave higher returns per farm.

Hunters and fishermen of the U.S. have made a major financial contribution to conservation. Over the past 75 years, they have spent over U.S. $100 million per year improving wild habitats on private lands and contributed U.S. $1.5 billion per year to the general economy, much of which is spent on conservation projects. During the last 40 years sportsmen have provided U.S $450 million for game and wildlife development through taxes on arms and ammunition (*77*).

Pest Control

In the paddy rice areas of southeast Asia, buffaloes are used to control grasses in waterways. Buffaloes are driven back and forth through irrigation canals to crush snails that may destroy crops or transmit disease to man (*18*).

Where crop cultivation depends on hand labor or primitive plowing, such as with chisel plow, farmers want the land as free as possible of crop residues and weeds or grasses that may have grown since the previous harvest. To remove the undesirable materials, farmers will utilize their own stock. They may have adequate numbers but more likely they do not, in which case they make arrangements with nonland owners who have animals to graze off the materials It is very common where there is a mixing of pastoral herding and sedentary farming to use the herded ruminants to clear the cropland. It is estimated that in countries such as Mexico and Dominican Republic, up to 30 percent of the feed available for cattle, sheep and goats might be classified as "land clearing" (*78*).

Plant pathologists advise that a buildup of soil microorganisms which attack cereal grains can be arrested most readily by rotation with forage legume crops or grasses. Soil organism control is important in the performance of the newer varieties of wheat and rice in tropical areas. Experiments in India showed continuous planting of an improved variety of rice for 5 years gave only 18 percent higher yields than native varieties By the fourth year, yields from the improved variety were less than for the native. But with a 4-year rotation, yields from the improved variety were 27 percent higher than for the 5 years of continuous planting of the native type. Berseem clover was used in the rotation. Cows grazing and being fed harvested hay produced U S $665 worth of milk per ha. Coupled with higher rice yields, total returns per ha over continuous planting of native rice were 47 percent higher for the rotation system (*79*). In Nigeria, yields of tomatoes following two years of grass for livestock feeding were three times higher than yields from continuous planting of tomatoes (*80*). These experiences illustrate important side roles for ruminants which contribute substantially to both crop and livestock production.

Cultural

Even though ruminants have a vital role in food supplies and for traction, these are secondary to the part some species play for recreation, religion, social custom and as a mark of respectability (Table 4). Some humans derive pleasure from the company or study of animals. Catering to recreational and educational

Sacrificial table in Montgnard village of South Vietnam, post-harvest celebration with rice wine, and buffalo meat. Buffalo head is symbol to God.

needs is contributing to the growth of substantial industries (hunting, racing, natural history societies, etc.) plus supporting services, such as manufacturing of specialized clothing or equipment, feed firms, veterinarians, etc. Because of uncertainties in the world market for several primary products, a number of developing countries are indulging the recreational appetites of overseas visitors to generate foreign exchange (*81*).

Exhibitions — In most countries one or more species of ruminants are assembled for exhibit. Frequently, the main purpose is advertisement by breeders interested in selling stocks. Competition for recognition among the breeders serves for recreation and entertainment. Rodeos provide excitement in the U.S. as do other sporting events with cattle elsewhere. For instance, the Coleaderos de Toros (throwing the bull by the tail) is held annually in each town of Venezuela as a part of the Fiesta Patronales (Patron Saints Day). There may be up to 100 bulls and several hundred horsemen involved in a single day's events.

Fighting — Bull fighting is traditional in Spain and Latin America. About 50,000 animals of a special breed are maintained to supply several hundred bulls per year for fights in the large city arenas. In addition, there are several thousand bulls and some females from local breeds that fight in small towns. Not so renowned, yet very popular, are bull fights with swamp buffaloes in Indonesia and Malaysia. Fights in Spain or Latin America are between man and animal, while in Southeast Asia, fights are between animals (*18*, *26*).

Racing — Equal in history to horse racing are races with buffaloes, camels and cattle. Numbers involved are unknown; nevertheless, camel racing is popular in countries of northern Africa and Central Asia (*82*). Buffalo racing with riders is a great sport in Indonesia, Sabah, Malaysia and the Philippines. Cart racing with teams of buffalo is fashionable in Bali (*18*). During the times of the Maharajas in India, cattle cart racing with a single animal was the largest spectator sporting event of the country. It has declined, but continues in the southern part of the country.

Pets — Ruminants are not ordinarily identified as being kept for pets in the same sense as are cats or dogs. Nonetheless, there are thousands of goats and sheep maintained principally for child and family recreation In New York State, for instance, the number of holdings with less than three goats or sheep far exceeds holdings of larger size. The per-capita consumption of goat meat in New York is less than .5 kg and that of milk is no more than one or two kg; thus, their keeping can be justified mainly on the basis of recreation

Harris (*67*) states that a major reason for keeping sheep or goats on subsistence farms is to occupy the time of young children because of lack of toys and to while away time while parents are laboring in the fields. Sheep or goats are preferred to dogs or cats since they have salvage value or provide a means of storing wealth. Deer are also used in some societies as pets.

Hunting — Sport hunting of ruminants has wide popularity. During 1970 in the U.S. 7.78 million people hunted big game. These hunters had 54.5 million days of recreation and expenditures of U.S. $953 million. Except for a small number of non-ruminants, e.g. bear, the hunters sought ruminants. For 1970, the estimated kill of moose, elk, deer, pronghorn antelope, caribou, bison, feral sheep and goats was 2.06 million (*83*).

Total spending for hunting in the U.S. during 1970 was U.S. $2 billion, of which 26.2 percent was for auxiliary equipment, 28.3 percent for hunting equipment, 21.0 percent for guides and dogs, 17.3 percent for food, lodging and transportation, and 3.6 percent each for licenses and privileges. This breakdown illustrates a very significant indirect contribution from ruminants, namely employment in industries to support hunting. It appears that hunting will continue to increase at least to 1990. Numbers of game animals continue to rise. In 1920, the ratio of livestock to big game animals was 80:1 but fell to 50 1 in 1970 (*71*). During the same period, forests or woodlands not grazed by livestock increased by approximately 47 million ha, indicating U.S land-use policies favor expansion of lands for wild animals for preservation or hunting (*84*). (The per-capita consumption of meat of wild animals in the U.S. is 1.0 to 1.5 kg and is not expected to rise significantly). In some areas of the western U.S., the income from hunting already rivals that from domestic ruminants (*77*)

Hunting ruminants is an extensive activity in Canada, Europe (*85*), and the USSR (*86*) The estimated annual kill of wild ruminants for Canada is 66 million, Europe 1.05 million and the USSR 1 50 million. Several hundred thousand people in the USSR are involved in the handling of reindeer and their products (*19*). The USSR cans more than 0.5 million kg of reindeer meat per year (*87*) West Germany during 1971-72 marketed venison worth DM 83 million. The main source was game preserves for shooting. Revenues for the leasing of shooting rights on these preserves were DM 149.2 million and other expenditures by hunters totalled DM 266.7 million (*3*).

A number of writers (e.g. *88*, *89*) have extolled the potential for hunting such species as gazelle, eland, feral buffaloes, and other wild ungulates through the establishment of government preserves or private game farms in parts of Africa Numerous reports indicate advantages of mixed wild species in animal production from grazing, but Ledger *et al* (*90*) contend a large number of species of ungulates must be kept to reap the full benefit of their combined grazing behavior which is impractical except in closely controlled areas Currently, the economic value of hunting as a sport greatly exceeds the monetary value of food that could be grown. This situation, which is highly dependent on both economic affluence and the fluctuating popularity of hunting as a leisure activity, could change in the future

Because wild species have certain advantages over domestic stock in their adaptation to severe climatic conditions, and the preservation of ecosystems in many regions dictates non-agricultural use, and if man has an inherent desire for challenge by hunting, the sport will increase rather than decrease as the world's human population grows (*91*)

Religious — Trumpets prepared from the horns of rams are blown on Yom Kippur, and have a sacred role in the Jewish religion. On the Hajj (pilgrimage to Mecca for those of Islamic faith), those who are financially able will sacrifice camels, sheep or horned animals to provide the "great feast" to which all pilgrims are invited From 140,000 to 200,000 Moslems make the pilgrimage annually.

A number of societies inaugurate a new house, roadway or bridge in a sacrificial ceremony, using one or more ruminants (*70*). The Montanard tribes of southeast Asia require sacrifice of a buffalo prior to planting their rice and post-harvest (*30*)

Social Status — Animals, particularly ruminants, are often man's legacy to his son(s). They may be used to symbolize formal contracts such as marriage. In some societies, animals are hoarded in order to build a system of human bonds aimed at increasing individual security (*92*).

Marriage contracts frequently involve the exchange of cattle, goats or sheep. Among the Serbi tribe of Africa, the bride price always includes at least one cow. For marriages in 1960, the average number of cattle supplied by the groom's family was 9 1 per contract (*93*). The husband's father pays the bride price for the first wife, whereas the husband meets the costs of subsequent unions Since the Serbi and other tribes practice polygamy, animals are almost continually accumulated to obtain additional wives. Rwanda has passed a law restricting marriage contracts to one cow per marriage as a means of attempting to reduce stock numbers. The government of India endeavored in 1975 to abolish the custom of dowry provided by the bride's family as a means of reducing the number of livestock held for conversion to cash at the time of marriage.

In several areas of Latin America, meat pro-

cessing plants are idle because people will eat only fresh killed beef. U S citizens traditionally eat certain meat dishes on special days. To multiply examples of how cultural practices interfere with economically "rational" production and marketing schemes would distract from the main point — namely, that people continue to give high priority to their culturally defined needs in utilizing animals Although the production of livestock products can be enhanced, plans for changes will need to take into account a delicate balance of economic productivity and cultural preferences.

CONCLUSIONS

More and more people are becoming aware of the fact that many of the world's resources are not only limited but unreplaceable. This awareness has led to a number of theories and plans aimed at solving the problems related to the expanding human population. One such plan advocates greater emphasis on the production of grain for human food rather than for conversion to animal protein. The extremist position even states that intensive animal husbandry is untenable. The truth of the matter is, however, that the relative non-monetary inefficiency of producing animal protein occurs only when it is produced on cropland suitable for intensive grain crops used as human food.

Those who claim that ruminant animals compete with man for the limited resources of the land blind themselves to the fact that animals and man are actually interdependent. Of the currently estimated world ruminant population of 3 billion, only a small percentage actually "competes" with man in that they eat food which would be suitable for humans. The vast majority of these ruminants derive their sustenance from plants totally unfit for human consumption — the forages. Moreover, ruminants exist symbiotically with man and provide his only means of deriving life-sustaining products from that one-third of the earth's land surface unfit for cultivation.

About 1½ percent of the human population lives in areas where food crops cannot possibly be raised. They are able to live there only because of the presence of ruminant animals, from which they derive their support. In addition to the fact that ruminants convert inedible products into high quality protein, they provide countless nonfood products essential to man's existence. Furthermore, these nonfood resources are not being exploited efficiently and their potential remains virtually unexplored.

Just as we have outgrown traditional calculations of cost and benefits which were made in only monetary terms, so too, man's relationships to animals must be understood in broader terms — not just in regard to nonfood uses and products, but in terms of overall placating "ecological" considerations. Animal life, plant life and human life exist in a necessary relationship, and their interdependence is clearer as we cease to regard ruminants as only sources of food.

Aside from their main contributions of meat and milk, cattle such as these yield a host of useful by-products for the welfare of man *Photo by Ohio Agr Research & Dev Center*

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