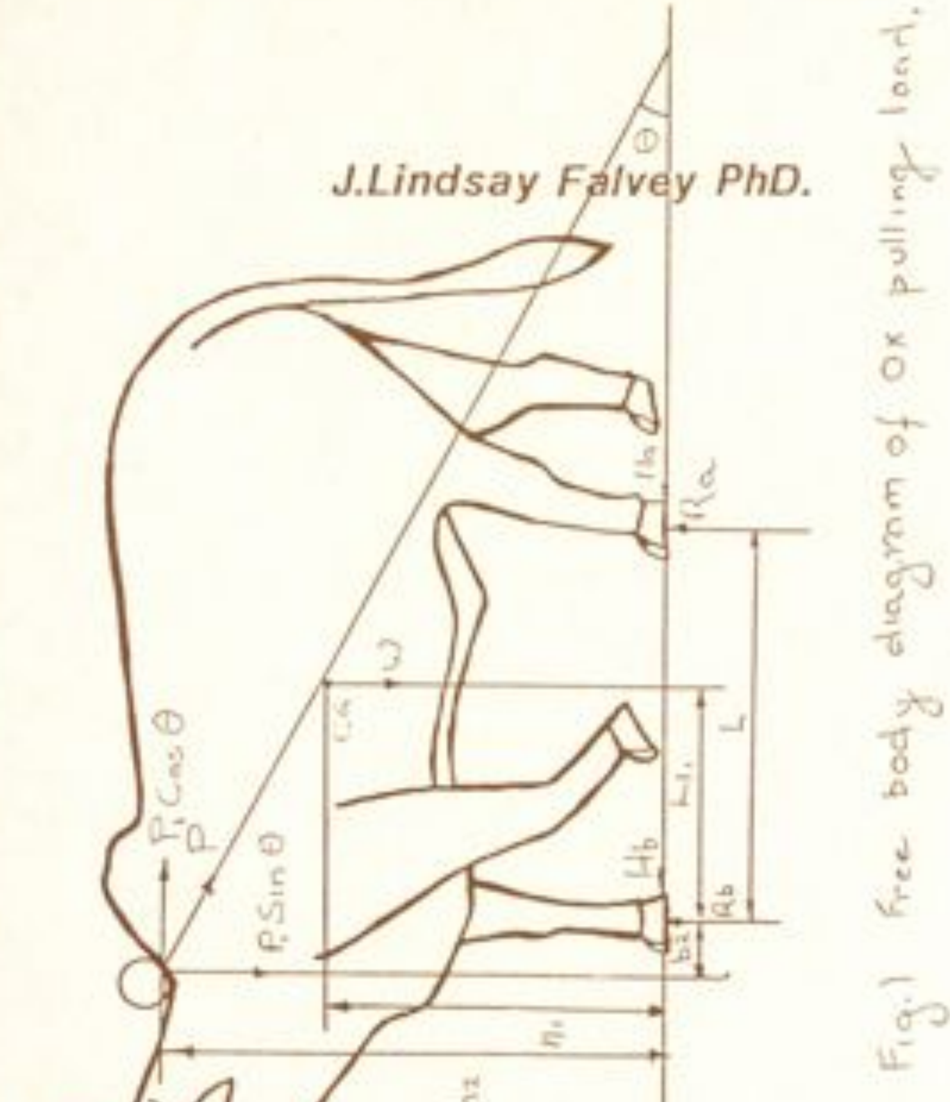
AN INTRODUCTION TO WORKING ANIMALS

J.Lindsay Falvey PhD.



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PREFACE

Emeritus Professor D E Tribe, OBE, FTS, D Agr Sc, Ph D, D Sc (Hon), FASAP, FAIAS.

The most remarkable thing about the working animals of the world (presently estimated to total more than 400 million) is how little we know about them. Therefore, Dr Lindsay Falvey and MPW Australia are to be congratulated on the production of this unpretentious but extremely useful little book which is exactly what it claims to be: "An Introduction to Working Animals".

H.G. Wells pointed out that throughout the history of mankind, until the advent of the industrial revolution and the exploitation of fossil fuels, the development of all civilizations was dependent on the muscle power of humans and animals. Throughout the developing world draught animals are still vitally important parts of highly appropriate and effective systems of food production and transportation. Further, because of the high capital and operating costs of machines, working animals are likely to remain essential power bases of the developing world's small farmers.

Although scientists and technologists in industrialised societies talk increasingly of advances in high technology associated with robotics and automation, most people in the world will remain dependent for a long time on systems of production which rely on the transformation by draught animals of solar energy which has been captured and accumulated by the plants upon which they feed. These production systems, tested and proven through the centuries, are not only based on renewable energy resources, but are also economically and socially appropriate in the communities in which they are used.

However this does not mean that they cannot be made more efficient. On the contrary, there is no doubt that working animals can be greatly improved, just as food producing animals can be, through better breeding, feeding, health and management. In addition their harnesses and equipment, as well as the implements or carts they pull, are similarly capable of improvement.

Indeed, the scope for increasing the efficiency of the management and operating systems which involve working animals is so great that it is surprising that a concerted effort has not already been made to develop the research, education and extension activities that are so urgently needed. Although, in recent year, FAO and some of the international agricultural research centres (e.g. ILCA, IRRI and ICRISAT) have initiated important studies in this field, much more needs to be done before a comprehensive basis of systematic knowledge is available which satisfactorily integrates the necessary technical, economic and social information.

The lack of reliable and factual information has in turn resulted in a paucity of articles, journals and books on the subject. It is this shortage of good resource material that makes the present MPW text particularly welcome. Dr. Falvey and his associates have brought together in a readable and concise form what is now known about the origins, use and management of the world's working animals. The result will be extremely useful to students, teachers and extension workers in many parts of the world. It also serves to highlight the enormous gaps in our knowledge of such an important subject and, hopefully, will stimulate research and extension workers to pay more attention to what is, without doubt, the most ignored aspect of world animal production.

This volume will certainly not be the last word on the subject - but as one of the first words it thoroughly deserves to be widely circulated and studied. If it attracts more attention to this badly neglected field and encourages readers to devote more effort to the investigation and study of working animals, it will more than justify the efforts and hard work of the authors.

ACKNOWLEDGEMENTS

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J. LINDSAY FALVEY

FOREWORD

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There is no doubt that man first used the flesh of animals for food, but it is not clear whether initial efforts at domestication were for packing his household goods as he moved from one hunting area to another, to provide security or to obtain more food in the form of milk. Even so, non-food contributions such as traction have been important linkages between man and animals for a long time in many societies. Although mechanization has replaced animals for farm power in some countries, animal power for agriculture remains vital to a large portion of the world's population. The forecasts are that this will continue in the predictable future.

There is a strong need for those who wish to assist in the expansion of food production on low resource farms to create awareness of the contributions made by animals that were especially vital to the betterment of situations on farms. Generally animals receive low credit in contribution to gross national products, usually in the range of 4 to 12 percent. The value of products is based almost entirely on sales or exchanges in markets recognized by governments. Non-food services are seldom credited and yet these are often the first priority of farmers. In Africa, for example, animals contribute approximately $5 billion per annum in products (meats, milk, fibre and skins). Conservatively, domestic livestock provide an equivalent amount in non-food products and services such as manure for fuel and fertilizer and traction or transport. The game population contributes $3.5 billion from meat, tourism and trophies. An additional $3.4 billion in seafood comes from rivers, lakes and coastal waters. FAO estimates the total value of animal output at $18 billion per annum. This far exceeds Africa's annual cereal output valued at $8.5 billion.

In relation to its importance, animal traction seldom receives focus in policy planning. Agricultural ministries usually focus on crop production with medium to low levels of structure to interact among agencies concerned with animal health and/or production. The ministry/department responsible for livestock is frequently supervised by a veterinarian who normally has limited experience in animal nutrition and other factors associated with farm systems. With structures of government agencies as described, many of the roles of animals, especially traction, tend to receive little or no attention.

High capital costs of machinery, lack of foreign exchange, shortage of spare parts and escalating fuel costs make the prospects for agricultural mechanization poor in the longer term for many of the developing countries. Better use of animal resources is a viable alternative. Investigations focusing on the introduction of modern-type implements are important, but many other changes and inputs also need to be considered if the maximum contribution of animals to agricultural production are to be realized. Topics in need of urgent study include animal nutrition, the crop-yield effects of timely cultivation, cash flow consequences of introducing modifed animal traction practices, better harnesses and implements.

Several of the international agriculture research centres; namely, the International Livestock Centre for Africa (ILCA), the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), and the International Rice Research Institute (IRRI) have shown there are substantial opportunities for increasing the animal draught component of many farming systems where crop and livestock enterprises are in direct competition for local land resources. Investigations conducted by ILCA researchers have shown that modification of the long beam commonly employed for the traditional plough and the use of a single oxen is as effective in land preparation as a traditional pair of oxen. This seems to reduce capital requirements on low resource farms. It has also been determined that with stall feeding, lactating cows may be used without impairing milk yield or breeding efficiency. Crop yields may be increased up to 100 percent with the use of an improved plough in land preparation. With some ten million draught animals being used in sub-Saharan Africa and with the importance of animal traction increasing rapidly in West Africa, ILCA seeks to reinforce its efforts by establishing a pan-African research network. ILCA will be serving as a catalyst and the centre for a research network.

At ICRISAT, a wheel-bar suitable for a mounted operator and attaching several pieces of cultivating equipment has been employed successfully in India and Niger. With cultivation equipment under the control of a riding operator, there is a marked increase in the efficiency of power output from oxen. FAO, the World Bank, other international agencies and certain governments are commencing to give attention and support to investigations on animal traction.

There remain numerous elements technological in nature, as well as social and economic factors, which will need consideration before developing guidelines for full exploitation of animal traction on low resource farms. For example, as efforts are made to increase the efficiency of harness, implements and land preparation, the question of suitability of existing breeds or types will need determination. In general, rather temperamental animals are desired for draught. This may be reflected in the females of these groups to the point that difficulties will arise in obtaining milk. Male cattle which are heavy in the forequarters are preferred as best for draught. This proportioning of the body is not the type sought by animal breeders focusing on improvement for meat production.

Numbers of those making projections on the value of animal traction assume there is little cost. If, for example, a farmer owns one or more head of cattle or buffalo, it is assumed he can commence use of one or more of his stock for draught with only the labour cost of training and the capital for a plough. This may not be the full cost to the farm system. If the best feeds on the farm are mobilized to feed one or more lactating females, the introduction of draught may result in a change of priorities in feed allocation which could offset milk supplies. This may in turn create conflict in objectives between man and wife.

Other factors limiting the use of animal traction include possible cultural constraints as described by Professor M. Barnett:

> 'Pairs of yoked animals at the outset of the growing season pull ploughs. Hours of work and land prepared may be measured and found inefficient, but it is only by living in the community throughout the full agricultural calendar and beyond that one begins to be sensitized to the more integrated role of livestock. They are linked with the life cycle of human beings.To attempt to impose a schedule of higher output through more hours of input by man and his animal may destroy the cultural relation beyond tolerance'.

The main aim of this book is to improve the planning base for the use of animal traction in agriculture. The author *describes how various animal species became a power source for various societies. The use of each major animal species is assessed according to contributions. This analysis leads to a classification of the predominant production systems. The classification is justified by its fulness in identifying some of the possibilities for using animal power. A central theme of the book is that animal traction cannot be viewed as a parallel expansion tool in all existing systems. Priorities must be set. Like other processes of change, animal traction to expand food production is open-ended. Farm systems at different stages in the development path face widely differing constraints on their improvement. Dr Falvey's book should prove valuable in this context.*

Just as we have outgrown traditional calculations of costs and benefits which are made in only monetary terms, so too, man's potential utility of animals must be understood in broader terms.

PART A

USE OF ANIMALS FOR WORK

CHAPTER 1

DRAUGHT ANIMAL POWER IN THE THIRD WORLD

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Progress of mankind has been influenced by technology at the one end and social organization at the other. When miracles of technology in space, electronics, nuclear and innumerable other fields have increased the productivity of man and opened up vistas hitherto not dreamed of, man is going ahead with gay abandon on the assumption that the earth and all creation on it was made for his special benefit and delectation.

But since the people of the world are divided into nations, ethnic groups, religions and races, the benefits or fruits of development are unequally distributed. Thus, in the midst of abundant affluence and high technology, there is mass privation and primitive technology mocking man's inability to make use of nature's gift to man.

A standing example of this is the role of draught animals for mankind. From the beginning of civilization, draught animals have been making significant contributions to society. In fact, there exists a symbiotic relationship between man, animal and nature which, alas, is being ignored.

Two billion people in developing countries depend on draught animal power. For a variety of reasons, these countries may have to continue to depend on draught animal power for many more years to come. Fortunately, draught animal power is complimentary to petroleum-based power and, in fact, there is no real conflict. While mechanization, as a process of industrialization and development, can continue at a pace technically feasible and economically viable, draught animal power need be used only wherever it is inevitable or appropriate.

APPROPRIATE TECHNOLOGY

Draught animal power is an excellent example of mass application of appropriate technology. There are over 100 million small farms in the developing countries, and in hilly terrain, narrow or water-logged fields and in special situations, draught animals are often the only feasible source of power. In India itself, there are more than 50 million farms of less than three hectares. Two-thirds of rural energy for cultivation comes from draught animals. This situation is similar in parts of Africa as well as Indonesia. The estimate is that half the crop area in China (100 million hectares) is prepared with the help of draught animals.

Draught animal power is equally appropriate for hauling vehicles for small scale transportation (about one tonne) over short distances (below 20 km). In fact, wherever the loading and unloading takes time, animal drawn vehicles are economical. Also, over rugged terrain, unpaved roads, and narrow pathways such vehicles are able to negotiate easily. Use of animals for ploughing and transportation during the off-season make draught animal power highly economical. In cities, animal drawn vehicles are utilised better and prove economic solely on transportation work alone.

It is estimated that there are over 25 million animal drawn vehicles in the Third World. India alone has 15 million of them catering for two-thirds of rural transportation. China also has over 5 million.

Donkeys, mules and camels serve as an important source of transportation in many parts of the third world, particularly in deserts and hilly regions and in areas, where there are no roads or even pathways. Elephants are used for logging in India, Burma, Sri Lanka, Philippines and other countries. Specially bred draught horses are used for logging in Western countries. Bullocks are used in South America. Thus, there are situations where draught animal power is a technically and economically viable source of energy. Mechanization can probably make headway only (a) when the income of the farmer goes up substantially; (b) the size of farm land is increased by consolidation; and (c) technical and maintenance facilities become available.

While efforts to mechanize should continue, the existing technological level of animal powered systems also has to be upgraded.

OTHER BENEFITS OF ANIMAL POWER

Working animals make available dung for fuel and fertilizers, fibre, and provide security and companionship. For millions of small farmers, they are the major source of production. At times of emergency, animals can be sold for cash, and are an asset which gives status and allows borrowing.

Over and above their tremendous contribution to man during their life-time, draught animals leave behind for man, a number of useful products after death through meat, skin, bone, hoof, horn, blood and numerous other by-products. Unfortunately, in many parts of the Third World, the systems for slaughter, recovery of by-products and their utilization are so poor that there are colossal losses.

It has been argued working animals compete with man for scarce land. The situation is true only in certain countries, particularly Bangladesh. At the same time, it should be pointed out that working animals live largely on crop residues, grass and such other products which are not really useful for man.

Working animals are a unique form of renewable energy, converting sun's energy through plant life into useful products and services. They are more equitably distributed among poor people than any other assets. Policy-makers, conditioned by urban life-styles and norms, have tended to neglect the role of working animals in society, and in some cases have condemned it.

Unfortunately, the beautiful day when draught animals will no longer have to serve man is far off. In spite of the success of technology the conditions in the Third World are getting worse in many ways. Presently, imports to the Third World total 80 million tonnes of food, which is expected to rise to 100 to 150 million tonnes by 2000 A.D. Increased food production would need more energy for ploughing to which working animals will contribute a share.

This can be illustrated from the case of India where 80 million work animals plough two-thirds of the land and carry two-thirds of rural transportation. It has been estimated that the energy input has to be doubled in order to optimize output. Such vast quantities of energy cannot come from petroleum-based or other sources of energy. Even today, India is short of electrical power and petroleum-based power which has to be imported.

MAGNITUDE OF DRAUGHT ANIMAL POWER

Estimates of draught animal population in different countries and their contribution to agriculture and allied operations are presented in Table 1.1. Figures are gross estimates due to the failure of most countries to record working functions of animals.

Table 1.1.

Estimated Working Animal Population by Country

Countries	*Cattle*	*Buffaloes*	*Horses*	*Mules*	*Donkeys*	*Camelids*
		(millions of head)				
India	*110.0*	*16.0*	*1.0*	*0.1*	*1.0*	*1.7*
China	*53.0*	*17.0*	*11.0*	*4.0*	*7.4*	*1.1*
Bangladesh	*10.0*	*1.0*	–	–	–	–
Thailand	*3.0*	*5.0*	–	–	–	–
Pakistan	*7.0*	*0.5*	*0.5*	*0.1*	*2.3*	*0.8*
Ethiopia	*6.0*	–	*1.5*	*1.4*	*3.9*	*1.0*
Indonesia	*3.5*	*2.0*	–	–	–	–
Burma	*4.0*	*1.2*	–	–	–	–
Nepal	*2.8*	*2.0*	–	–	–	–
Philippines	*0.6*	*3.0*	*0.3*	–	–	–
Mexico	*2.8*	–	*6.5*	*3.2*	*3.2*	–
Brazil	*2.6*	*n.a.*	*2.0*	*1.7*	*1.7*	–
Turkey	*2.5*	–	*0.6*	*0.3*	*1.4*	–
Columbia	*1.3*	–	*1.0*	*0.6*	*0.6*	–
Tanzania	*1.0*	–	–	–	*0.2*	–
Egypt	*1.0*	*n.a.*	–	–	–	–
Chile	*0.3*	–	*0.5*	–	–	–
Peru	*0.1*	–	*0.4*	*0.2*	*0.5*	*1.2*

– Nil/negligible

Draught animals produce between 0.4 to 0.8 horsepower on a sustained basis. The power made available by 300 million animals at work may thus be of the order of 150 million kilowatts horsepower. If it is usually assumed that five pairs of animals can be substituted by one tractor, then about 30 million tillers and tractors will be required to replace the draught animals. This equipment would be worth between 200 and 300 billion dollars with recurring annual costs of around five billion dollars.

An FAO estimate of the share of manual, animal and machine power for soil preparation is presented in Table 1.2; these figures do not include China which cultivates about 100 million hectares, some 50 percent of which is probably cultivated by animal power. It is significant that animals provide over 50 percent of energy for land preparation.

Table 1.2.

Area Cultivated (million hectares) in Developed and Developing Countries in 1975.

	Total		Power Sources					
			Hand-Labour		Animal Power		Tractors	
	Area	%	Area	%	Area	%	Area	%
Developing Countries	479	100	125	26	250	52	104	22
Developed Countries	644	100	44	7	63	11	537	82
World	1,123	100	169	15	313	28	641	57

Source FAO.

For an overall growth of three to four percent of output, FAO estimates that power input has to be increased by two to three percent both for extension of the harvested area as well as for increases in yield from existing areas. They predict that use of tractors will increase rapidly in Latin America and the Near East, with a smaller growth rate for the Asian region while for Africa and the Far East, the share of mechanical power would still be less than 10 percent by 2000 A.D. A deficiency in power requirements which may be filled only by hand labour has also been identified.

NEGLECT OF WORKING ANIMAL SYSTEMS

It is an unfortunate fact that draught animal power has been neglected by policy-makers, governments, scientists and professionals. While programmes for milch and meat cattle are gaining momentum in developing countries there are no corresponding large programmes for upgrading draught animal breeds. It is noteworthy that China even has farms for raising donkeys and mules for draught purposes. However traditional breeders are disappearing and little is known as to whether cross breeding for milch cattle is affecting the draught capability.

Poor nutrition is another factor affecting the quality of draught power. Egypt has considered slaughter of all donkeys, as there is no space for raising feed. However, they have also realised that the work now done by donkeys cannot be easily taken over by other sources of power. Common ownership of land in China has enabled land to be set apart for draught animals. Bangladesh is unable to feed its cattle adequately and their condition is miserable indeed.

Animal health services throughout Asia and Africa, are usually poor. Africa has not yet solved the problem of debilitating and deadly diseases. Animals suffer from poor health, to which is added the burden of overwork.

Agricultural implements being used are outmoded and primitive. Though better designs have been developed in many countries, they are not used in the field. Thus, efficiency of land preparation is low. Harnessing and hitching devices can also be improved substantially. At present, much of the draught power of the animal is wasted due to rough bearings, heavy platforms and crude harnessing devices.

Harnessing devices need much improvement. The head yoke and the neck yoke injure animals' necks and considerably reduce life-span. It is estimated that around a million animal years are lost annually because of neck injuries.

A great deal can also be done to modernise systems of credit, subsidies, insurance, co-operatives for working animals. Today, in many countries, subsidies are given for fertilizer, seeds, water and other inputs to agriculture while working animals are omitted. This may be related to a mistaken feeling that animal power is no longer necessary. Such policies ignore the fact that a major critical input may be the work of the animal.

The total animal power system can be further upgraded if slaughter itself is modernised. In most of the developing countries, slaughter of crude and primitive. Apart from the needless sufferings of the animals, there is enormous wastage of all products of slaughter. Estimates in India show that the export value of leather commodities could be improved ten times, if only hides and skins were recovered and processed properly.

DRAUGHT ANIMAL POWER AND DEVELOPMENT

Agricultural output will largely depend upon increased availability of energy and other inputs such as fertilizer, water and pesticides. Therefore, many low income countries will continue to depend on animal power. As their resources for mechanization are limited, incremental energy requirements can only be met by increased use of animal power. This necessitates upgrading the whole system including better use of by-products.

Arguments in favour of animal power need not be construed as discouragement of the mechanised system. In most situations, there is no competition between these as animal power need be developed only where it is feasible and economic.

No introduction to animal power can be complete without some reference to the miserable plight of animals which go through untold suffering both during their working life and in death. Most of them are kept on starvation diets during the off-season and made to work soon after the monsoon, at a time when they are least fit to do so. In order to goad them to haul or carry loads beyond their normal capacity, they are mercilessly beaten, their tails twisted and their undersides tickled to the point of pain. In some parts of the world, far more cruel practices are followed. Even today, in spite of scientific developments, castration is still done in some parts by muling their testes. They are branded with hot irons and their horn roots burnt. Veterinary facilities are inadequate. Due to the abrasive yoke, their necks become injured, and often, sick and injured animals are made to work. In many parts, they are trekked long distances to the slaughter house. Slaughter itself is carried out without stunning practices, and in the presence of other animals, brutally and in the most crude way. The animals go through such needless suffering, all through their life and in death. Man also loses a great deal, through not looking after the welfare of draught animals.

CHAPTER 2

THE ORIGIN AND USE OF WORKING ANIMALS

The history of animal domestication has been discussed by many authors including Zeuner (1963 a and b) and Cole and Ronning (1974) yet the origins of domestication are unknown. Domestication may have had its origins in the provision of animals for religious sacrifices or it may simply represent a natural phenomenon associated with the domination of one species over another. To animal and behavioural scientists there are certain attractions to the latter alternative.

One explanation which considers man as an integral part of his physical and biological environments is substantiated by examples of one animal species domesticating another species. Such relationships include the symbiotic association of the hermit crab and the sea anemone, and the social parasitism of the Lomechusa strumosa beetle on the ant, Formica sanguinea. In the former case the sea anemone shares the food obtained by the crab and protects the crab by the presence of its tentacles. In the second case the beetle is raised by the ants because they relish a secretion of the beetle. The beetles in turn eat the ant larvae. Parasitism, such as that practised by insects that live off the blood of their hosts, have their parallel in man in the Masai tribe of East Africa who drink the blood of their cattle without killing them. Slavery among insects may also be considered as further evidence of the biological basis of domestication as one form of association between animal species.

Assuming that such associations are natural, it may be stated that man probably found benefits in taming animals such as the dog and the sheep as part of his social evolution. With the development of agriculture from hunting and gathering activities, the advantage of domesticating animals probably became evident to man. During the early stages of domestication, trained animals were probably bred with their wild counterparts with progressive steps toward complete control of the life cycle of animals by man being taken slowly. Egyptian paintings depict many experiments with the domestication of a range of animal species native to the region. The technique of domestication peculiar to the different species of animals domesticated by man have been differentiated by Zeuner (1963a). Reindeer husbandry, for example, is quoted as having been an initial social parasitism while cattle are classified as having originally been crop robbers.

THE ROLE OF WORKING ANIMALS

Traditionally animal scientists have concentrated on the principal products that animals provide to western culture. Other products provided by animals include meat, milk, leather, wool and other fibres, pharmaceutical products, fuel, fertilizer and power. In developing countries, the economic benefit of any one of those products is often difficult to separate from that of other products. This is true of the value of work performed by animals. As has been noted by McDowell (1977), the huge drain on foreign exchange that would result from the introduction of mechanized power to replace animal power in total could not be met by any nations if no other increase in industrial production occurred at the same time. The value of working animals in a socio-economic sense includes their social value, their use as a capital reserve for times of need, their production of offspring, as well as the value of other products introduced above. The value of these additional products over the utility of the animal for working may represent the difference between subsistence and starvation in those countries where up to 90 percent of the power for agriculture is provided by animals in association with man.

One means of comparing the role of animals in developing and western countries is the proportion of the total cattle populations made up by females. In western countries the proportion of females is higher than in Asia where males are retained for working purposes and are not slaughtered for meat until they are quite old. The importance of livestock in these roles is reflected in prohibitive slaughtering regulations of many of these countries. Animals under the ages of seven (McDowell, 1977) or eight to ten years (Falvey, 1977) for those species that are utilized for work, are restricted for reproduction or work. Export quotas are similarly tied to a percentage of the total ownership of cattle. Such regulations are decried as repressive by the few ranchers in these countries but remain a comment on the primary value of livestock. It is encouraging to note that the importance of draught and special purpose animals which includes all of those species we have classified as working animals, has also been recognized by the Food and Agricultural Organization of the United Nations in their programme for the conservation of animal genetic resources (Phillips, 1967).

The role of animals compared to mechanical power in agriculture (Table 2.1) has been reviewed by McDowell (1977). The proportion of animal power in the total varies from one percent in the United States of America to 99 percent in South East Asia.

Table 2.1

Animal and Tractor Power Used in Agriculture in Selected Regions and Countries.

Region / country	Type of Power			
	Animal	Mechanical	Total	(% of total)
	10x3 Mcal a/			
Africa	2,095	449	2,544	82
Asia (excluding China)	19,591	282	19,873	99
Middle 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
Argentina	671	568	1,239	54
France	902	2,883	3,785	24
Germany (Fed. Rep.)	378	3,453	3,831	10
United States of America	23	21,238	21,261	>1

a/ Mechanical power is expressed as animal power divided by five; animal power is converted to Mcal equivalents used directly in agriculture.

Source: Based on data compiled by FAO.

There is approximately one working animal per hectare of cultivated land in Asia except in Taiwan and China where the ratio is approximately 1.5 hectares per animal. Working animals are still employed in western countries to various limited extents, the principal species being horses, mules, cattle, buffalo and camels. In Thailand and the Philippines, McDowell (1977) quotes data (Table 2.2) which indicates animal power to be far more common than either hand power (18 percent) or mechanical power (2 percent).

Table 2.2

Power Sources by Farm Size for Thailand and the Philippines.

Farm size (ha)	Hand Power		Animal Power		Mechanical Power		Mechanical Power and Animal Power	
	Farms '000	%	Farms '000	%	Farms '000	%	Farms '000	%
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: Basta (1973)

Animals are also utilized for work in the roles of carting, packing, herding other animals and hauling of timber and other goods. The availability of various agricultural products is due to animal transport from the areas where these crops are produced and it is estimated that about 20 percent of the population of the world relies largely on animal transportation of goods. This includes the use of llamas in South America, yak in Nepal and surrounding countries and camels in the Middle East. The role of working animals in the world can thus be introduced as one that is largely hidden from western civilization and is one that is often regarded as primitive. However, it is a role upon which some western comforts are based and certainly is one that is of critical importance to the majority of the world's population. Arguments concerning the competition between animals and man for food products are transcended by their interdependence in these cultures.

WORKING ANIMALS IN WESTERN AND INDUSTRIALIZED NATIONS

An upsurge in the use of working animals occurred in the medieval eonomy of western Europe after the year 1000 AD. A new farming system evolved based on a division of large fields into strips held by individual peasant farmers to reduce the variability of land quality between farmers. Heavy work was shared by neighbours such as during the harvest and cultivation periods. Pooling of working animals to form large teams was common and increasing numbers of work animals were pastured on the poorer soils in large herds, thereby reducing further the labour input for animal management. Despite the disadvantages of stifling individual initiative and the rate of work being set by the slowest operator, this system flourished and produced a surplus. One advantage of the system was that heavier ploughs could be drawn; a boon to agriculture in this zone allowed by the pooling of livestock. The heavy plough that originated in Germany had spread through all of that region, northern France and southern and central England within a century. Also during this period, the three-field system of crop rotation that included a fallow and both spring and autumn crop harvests was developed.

By the time of the industrial revolution in England, horse drawn transport was the principal means of travel and the amount of traffic on the roads was sufficiently high to cause frequent accidents (Lewinsohn, 1954). This new limitation to horse drawn transport and the likely drain of horse numbers for use in the Napoleonic wars provided the impetus for the construction of railways. If the three principal products provided by useful animals are considered to be food, clothing and transport, the introduction of other transportation modes in the industrial revolution caused a marked change in the need for horses. For the first time in western history the population of horses failed to keep pace with the increase in human population.

Mechanization in western agriculture did not replace animal power suddenly. In the USA, between about 1850 and 1910, cattle, horses and mules were the main source of power for tillage equipment. Cattle were gradually replaced by horses and mules which can accomplish tasks faster than cattle. Animal power was utilized for threshers and other machinery of increasing size until about the time of the Civil War when machinery powered by steam became more popular. Still at this stage, tasks requiring mobility such as cultivation and harvesting were carried out by animals because steam engines had poor power to weight ratios. At the turn of the century, the internal-combustion engine made its debut in agriculture and with refinements gradually replaced both steam power and animal power in Northern America (Krebs, 1964). Similar development histories apply to most western countries although the degree to which animal power has been displaced by machinery is higher in the countries of the industrial revolution and the new world.

WORKING ANIMALS IN THE DEVELOPING WORLD

Working animals have previously been neglected in national policies possibly because of their association with under-development, a state which national policies ostensibly aim to change. Such neglect is shortsighted for the countries that rely on animal power for agriculture. If a farmer acts as an individual under a condition of high prices for animals, he may sell his surplus animals. The increased demand for meat however, is possibly caused by population expansion which also causes an increase in demand for agricultural crops. This necessitates the extension of agriculture to new areas and higher production levels which will rely on an increased number of working animals. If such animals are not available, the agricultural base of the country may be placed in jeopardy unless mechanization takes place simultaneously.

A problem of this nature was seen to be developing in Thailand (Cockrill,1974). The traditional system whereby a farmer bought a four to five year old buffalo and worked it for five to seven years is changing. Price increases and other factors have led to the situation where working buffalo may only be kept for one year before being sold for slaughter. This has resulted in the population of buffalo in Thailand decreasing rapidly. A similar alarming decline in buffalo numbers exists in Indonesia (Robinson, 1977). Extrapolation of this rate of decline in Indonesia suggests that, if no check is introduced, the buffalo population would be negligible within 30 years.

Variations in the numbers of draught animals in each country are not always an indication of changes in the source of power for agriculture in the short term. However, the short term future use of working animals does seem to be fairly well established for reasons of tradition and economics. The region of South East Asia seems suited to the continued utilization of animals in those situations where double cropping is impossible. These areas support the poorer farmers who, even if there was an economic benefit associated with the introduction of mechanical power, could possibly not afford to make the initial purchase. The unusual case of Burma in which a reversion to animal power is taking place, is related to restrictive trade policies and is an exception to the general trend toward mechanical power in rich paddy lands. Animal power is used in China to a wide and unspecified extent although it may be expected that further mechanization will occur in association with the recent changes in government policy toward agricultural development. In Africa, there will probably be an initial major increase in the numbers of working animals particularly cattle, with mechanization ultimately replacing those working animals to an extent similar to that in South East Asia (Williamson and Payne, 1978). A direct transition from manual to mechanical power is seen to be even more difficult.

It is likely that the uneven distributions of wealth in the world, the increasing costs of machinery operation and the association between population pressure and poor farmers will continue to create a need for working animals. Those species not directly associated with agriculture but employed in other tasks, such as elephants, yak, llamas, equines and the camel will continue to serve the poorer societies or be favoured above machines due to their adaptation to specific working environments.

POWER SOURCES ON SMALL FARMS

One picture of a small farm which relies upon animals for agricultural power is presented in an Indian example (Groenwold and Crossing, 1975). These farms, in the low rainfall regions, average about four hectares in area and utilize a pair of cattle for cultivation. One animal is usually owned by the farmer and the other borrowed from a neighbour. A cow, not utilized for work, may also be kept to provide replacement working male animals. All animals subsist on a diet of crop residues, stubble and wasteland grazing. It was estimated that 3.7 hectares is cultivated each year to produce crops plus about 8.3 tonnes of roughage, the latter being sufficient for the male working animal, the cow and her calf. Calving rates average 60 percent, mortality 15 percent and the yield of milk from the cow may be up to 300 litres per lactation. The farm supports an unspecified number of persons and has a labour availability of three adults. The authors noted that improvement of dryland crop yields or development of irrigation, which lead to large increases in total farm output, increase the reliance on animals as the source of power.

Industrialization is an obvious competitor of working animals. The number of agricultural tractors used in the world has doubled since 1930 although 85 percent of the draught power utilized for agriculture is still provided by animals (Smith, 1979). At the other extreme, hand labour should be considered; while commonly considered as paving the way to the use of working animals and then perhaps mechanization, examples of efficient agricultural industries based on manual labour continue to exist.

An example of a manual labour based system is that of shifting agriculture in the highlands of Thailand and Burma. With the difficult terrain of the area, animal power is as unsuitable as mechanical power. The principal crop of the region is opium, which requires intensive care including the preparation of a fine seedbed. Hand labour is utilized exclusively to produce the crop from small fields. However, opium is a special crop to which the basic economic premises regarding free markets and free trade do not apply. The principal alternative available to these people is the production of subsistence crops, and it is significant that the only new crops that have successfully been introduced to the region have been those of which a high labour input is essential, thereby reducing competition from regions where animal or mechanical power can be utilized. This association between terrain and manual labour has also been documented for part of the island of Mindanao in the Philippines (ADAB, 1978). The proportion of households using hand rather than animal or mechanical power in upland regions was twice that of lowland regions due to the steepness or stoniness of the uplands.

The association between cultivation and livestock production in semi-arid Africa has been documented by McCown et al. (1979). While rare over most of that region, farming along areas of the Nile River is based on animal power for ploughing and water lifting. The first draught implements in West Africa were introduced by the French around 1850 but were not readily accepted until after the second World War.

The size of farms (Table 2.3) indicates the greater areas that can be cultivated by the introduction of animal power. This is ascribed to two main factors, the first being that only larger and more successful farmers can afford draught animals and the associated equipment due to their high cost, and the second being that larger farms are necessary to achieve the increased labour productivity.

Table 2.3

Farm Size and Animal Powered Farm Equipment.

Country	Equipment	Farm size (ha) Without Equipment	Farm size (ha) With Equipment
Senegal	Sowing machine	1.6	3.4
(3 regions)	Sowing machine	3.8	8.6
	Sowing machine	2.8	7.4
Mali (mean)	Ploughs	5.4	11.8

Source: After McCown et al. (1979)

Increases in the area cultivated per active family member varies from between 30 percent to 50 percent in Senegal to between 40 percent and 70 percent in Mali. Table 2.4 indicates the reduction in labour per hectare experienced for groundnuts in Senegal. Draught animals led to a 35 percent reduction in labour requirements while partial mechanization led to a further 42 percent reduction or a total reduction of 62 percent. Complete mechanization led to a total reduction of 94 percent. If labour was limiting and markets were available for produce it could be expected that more farmers would utilize this new system. The relationship between cropping patterns and animal power utilization indicates that subsistence crops decrease in importance with the advent of the ability to cultivate larger areas.

Table 2.4

The Number of Hours Worked per Hectare in the Production of Groundnuts in Senegal.

Practise	*Number of hours per ha*		
	Man	*Draught Animal*	*Tractor*
Manual labour	*480*		
Manual and draught animals	*311*	*53*	
Manual and partial mechanization	*179*		*13*
Complete mechanization	*30**		*12*

* Operation of machines only.
Source: FAO (1972)

The rate of increase in the use of animal power is demonstrated by the increase in the number of animal drawn ploughs in Uganda from 48 in 1914 to 8,300 in 1932 (Wrigley, 1969). Singh (1976) presents figures (Table 2.5) that suggest an increase in labour from large scale mechanization which he accepts as evidence of the total benefit of mechanization.

Table 2.5

Use of Human and Cattle Labour (days) by Farm Size in India.

Farm Size	*Mechanized farms*		*Traditional Farms*	
	Human Labour	*Bullock Labour*	*Human Labour*	*Bullock Labour*
Small	*98.4*	*30.6*	*89.1*	*32.3*
Medium	*88.6*	*26.0*	*70.8*	*24.6*
Large	*87.6*	*21.5*	*54.9*	*18.4*
All Farms	*89.0*	*23.5*	*62.2*	*21.3*

Source: Singh (1976)

Yields per unit area often show an increase with the change from manual to animal power although it is always difficult to separate the cause. If animal power is the only variable, yield per unit area may actually decrease in some cases because weed control can no longer be effected adequately (Ruthenberg, 1971). Nevertheless, statistics often indicate an increase, either as an interaction from the greater variety of implements that can be utilized with animal power, or even as the consequence of the fact that it is the richer farmers who first aspire to new technology and can thus afford to employ labour to cover the additional weeding and other requirements. This apparent increase in land productivity resulting from the introduction of animal power is counter to the apparent decrease that is recorded to the introduction of mechanical power. The general relationship between farm size and therefore power source and per unit area is one that decreases with increasing size as demonstrated in Figure 2.1. Comparisons such as this are never precise because of the social bias of innovative and richer farmers adopting new technology more rapidly. Farmers who do not adopt the technology may therefore be worse farmers than were those who initially adopted the technology.

The relationship between farm size and farm output is described for some countries in Table 2.6. The higher efficiency of small farms, often based on the use of working animals can be related to greater ease of management of a small area and greater need to maximize yield per unit area in a situation where land is the first limiting resource. Exceptions to the trend of higher per unit yields from small farms are largely attributable to plantation farming which benefits greatly from economies of scale.

Table 2.6

The Relationship Between Productivity on Small and Large Farms in Ten Countries.

	1970 output per ha (million kilocalorie equivalent)	1970 output per ha (million kilocalorie equivalent)1/
Brazil	5.9	4.2
Colombia	7.0	3.7
Ghana	5.8	5.6
India	6.1	3.4
Iraq	10.6	2.0
Jamaica	8.0	28.0
Liberia	7.8	3.7
Pakistan	6.6	4.1
Peru	3.9	11.0
Uruguay	3.5	4.5

1/ Non food products converted on basis of wheat price relatives.
Source: World Census of Agriculture, FAO, 1970

A relationship of animal power to agricultural development is evident in work concerning Taiwan over the period of 1903 to 1960 (Yhi-Min Ho, 1966). Water buffalo and cattle are the most important draught animals in Taiwan for the respective purposes of cultivation and pulling carts. A large decrease

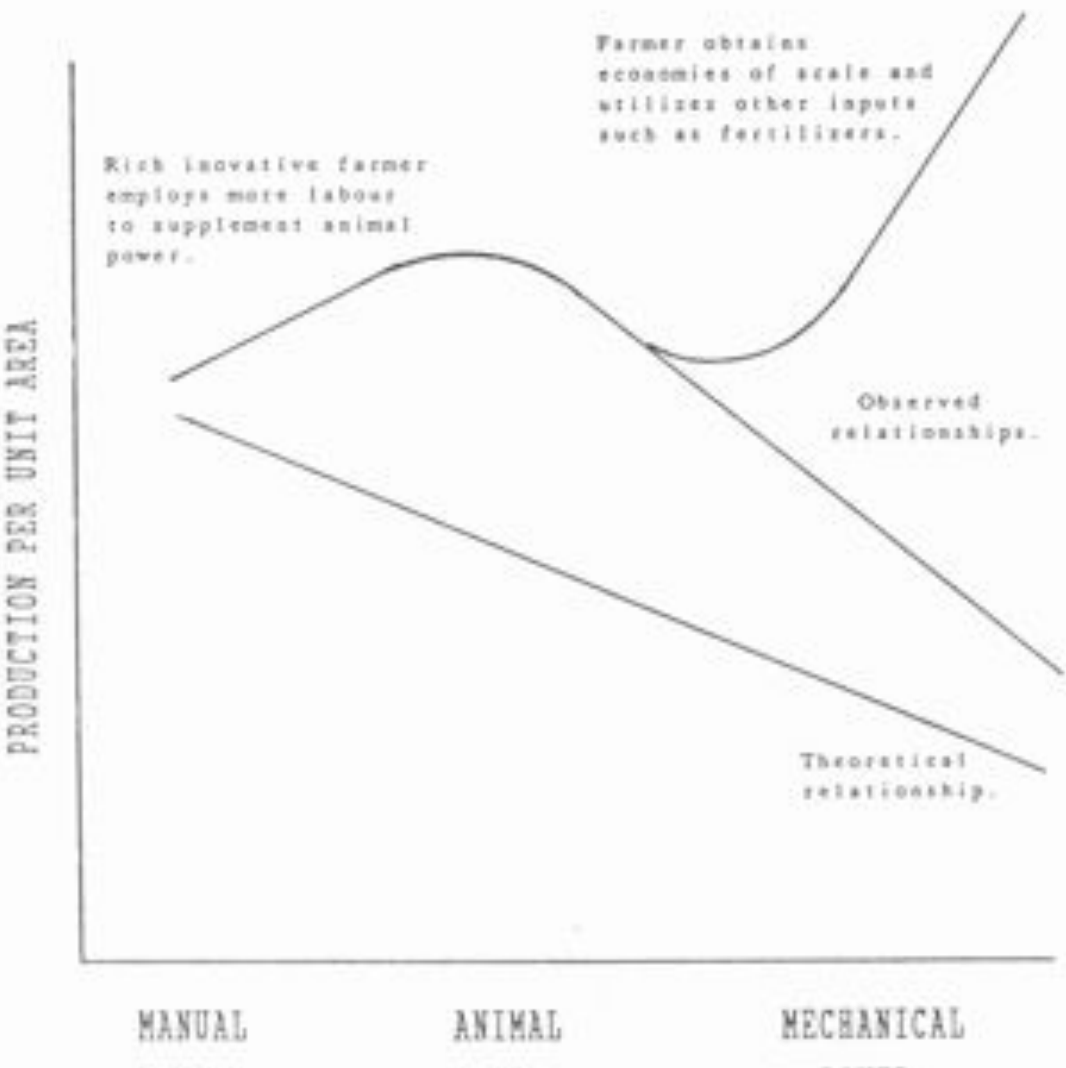

Figure 2.1 Schematic Representation of the Effect of Power Source and Incidentally Farm Size on Productvity Per Unit Area.

in the numbers of cattle over the years 1910 to 1944 while buffalo numbers remained reasonably stable, (Figure 2.2) can be attributed to the development of modern transport facilities which led to the cattle cart becoming virtually obsolete. However, water buffalo were not displaced by machines over the period and an increase in the utilization of water buffalo was precluded by farm size. Very small farms could not economically support a draught animal. Nevertheless, an increase in the buffalo population after 1951 did occur as a consequence of an intensification of land utilization. Replacement of buffalo by machines subsequently proceeded at a rapid rate with the development of small tractors that are suitable for use on small holdings.

MECHANIZATION

Differences between western and third-world farmers are related to use of machinery, fertilizers and farm size. Rice production has been researched in depth and mechanization of that industry may be relevant to other crops and industries using animal power. The objectives of mechanization in rice farming have been listed as follows (Stout, 1966):

- (i) An increase in the output per agricultural worker and farm incomes and a contribution to overall economic development.
- (ii) Maximization of crop yields, increasing output per unit of land by permitting improved cultural practices such as a better seedbed, more uniform planting or chemical distribution and more timely operation (tractors may be able to plough land that is too hard for hand or animal cultivation).
- (iii) Minimization of losses and waste.
- (iv) Permitting of an additional crop each season by more rapid harvesting and seedbed preparation.
- (v) Bringing new land into production and reclaiming land lost to agricultural production.
- (vi) Reducing the amount of land devoted to of feed and forage for livestock.
- (vii) Meeting peak labour requirements such as at transplanting and harvest time.
- (viii) Constructing water control measures.
- (ix) Lifting water.
- (x) Constructing roads.
- (xi) Making rice production less laborious, minimizing energy requirements, and reducing drudgery, thus allowing the grower to look after the crop more effectively.

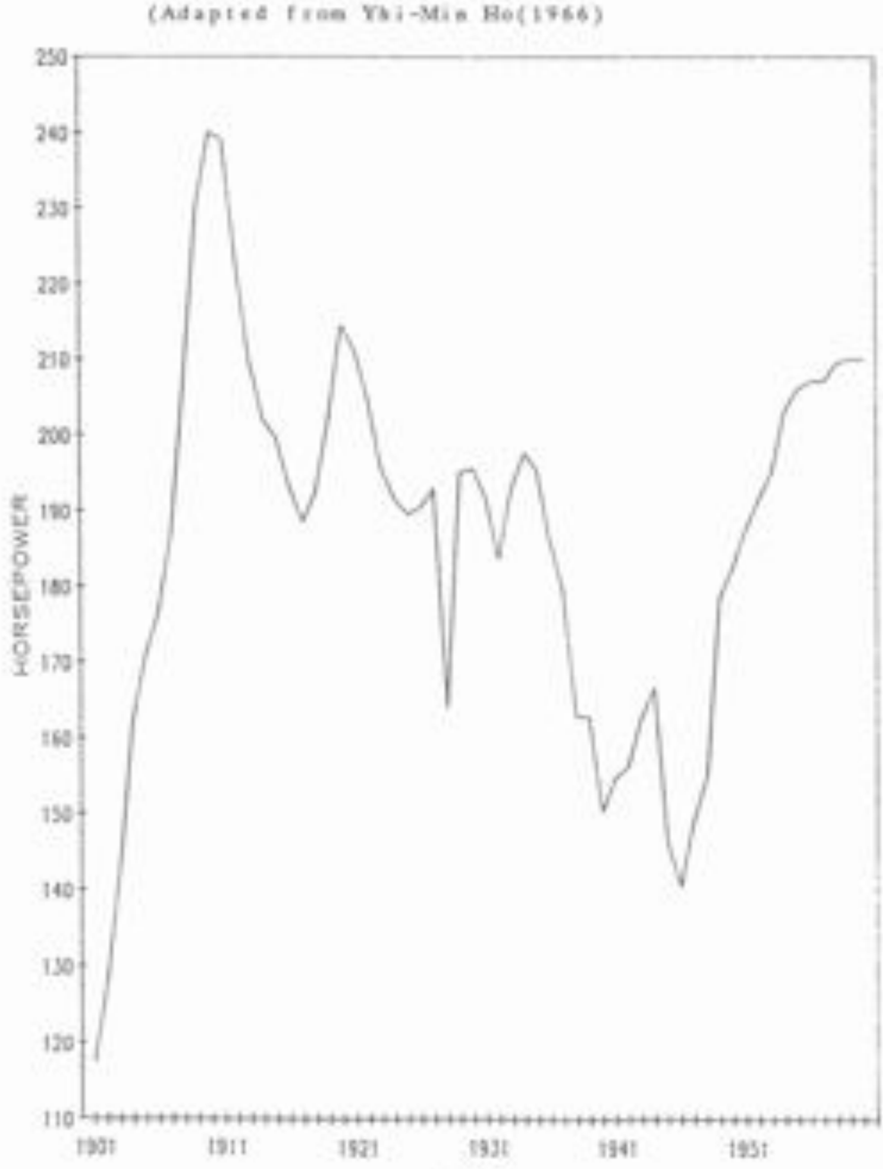

Figure 2.2 Energy Requirements for Farming in Taiwan, 1901-1960

Productivity should increase if one or more of these points is met (Stout, 1966). Tables 2.8 and 2.9 show trends in yields and labour inputs for rice production. While the data cannot be interpreted to be evidence of the benefits of mechanization, a general association between increase in rice yields and mechanization is evident.

Table 2.7.

Percentage Change in Rice Yields in Nine Regions

Decrease		*Increase (50-100%)*		*Increase (over 100%)*	
Madagascar	*-16*	*Philippines*	*+53*	*United States*	*+124*
India/Pakistan	*-11*	*Japan*	*+54*	*Malaya*	*+125*
Thailand	*- 8*	*China, Taiwan*	*+79*	*Ceylon*	*+129*

Source: Stout (1966)

A machine should pay for itself through increased profitability in the medium and long term. Specialist services need to be available for routine maintenance and machinery repairs. Apart from these technical and infrastructural constraints, the problem of divided land holding prohibits rapid changes to mechanization. Inherited blocks of land divided between children have often produced uneconomical units for mechanized farming yet are not so small as to preclude animal cultivation. This reflects the constraints under which the inheritance system has evolved and animal power would be expected to have an advantage over mechanical power within a system that has been developed around the use of animal power. Small tractors of similar capacity to an animal power unit are now providing successful substitutes in some areas.

The distribution of labour over the year is an important determinant of the benefits of mechanization. An analysis of the labour requirements for each of the tasks associated with rice production in Japan indicates a potential benefit from alternatives to existing practices associated with ploughing, transplanting, weeding, harvesting and threshing (Stout, 1966). Information from 88 sources concerning the manual time, animal time and engine power requirements for various systems of rice production is presented in Table 2.9 (Johnson 1963).

The advantage of mechanical power is evident for all operations to which it could be applied at the time of the report, although animal power was apparently also more efficient than manual power alone; this is also evident from

Table 2.4. Areas completely unsuited to mechanization continue to rely on manual power. A comparison of yields from fully mechanized rice production areas and manual or animal powered systems is equally unsatisfactory due to the inherent biases. The latter bias includes the ability to lift water and flood fields more easily which improves both weed control and moisture relations. Opposing this is a bias toward higher plant care in a manual power system.

Table 2.8

Average Labour Time in Various Countries to Produce Rice.

Country	*Hours per 100 kilograms*
Japan	*44.4*
Colombia	*34.0*
Greece	*25.2*
Chile	*14.0*
United States	*1.3*

Source: Stout (1966)

ADVANTAGES AND DISADVANTAGES OF WORKING ANIMALS

It is necessary to determine a basis for comparison in order to discuss the advantages and disadvantages of working animals. Usually the comparison is between working animals and machines, particularly for field cultivation. An equally valid basis for comparison is manual labour.

The commonly recognized advantages of animal power over mechanical or manual power can be listed as follows:

(i) Animals require less capital investment than do machines thereby enabling small farmers to operate their own power source.

(ii) Operating costs are lower for animals than machines.

(iii) Animals are adaptable to a wider variety of environments than are machines.

(iv) Animals produce offspring thereby obviating the need for repurchasing and can also produce a profit.

(v) Under the conditions of adequate labour commonly available in developing countries, the use of working animals can lead to an increase in productivity per person without creating large scale unemployment.

Table 2.9.

Average Labour and Power Requirements for Producing Rice.

Operation	Description	Manual (hour/ha)	Animal (hour/ha)	Engine (HP/hour/ha)
Primary Tillage	Brush and burn	240-630		
	Hand hoe and spade	114-250		
	Trampling, soft soil	40		
	Animal trampling	32-40	160-200	
	Animal drawn plough	40-96	40-96	
	Light disc harrow	8	8	
	Tractor 4-6hp-plough	20-40		100-200
	Tractor 4-6 hp-tynes	16-24		80-150
	Tractor-rotary tiller	10-24		100-160
	Tractor 12-70 hp plough	2-8		75-125
	Tractor 12-70 hp discs	0.8-1.6		30-90
	Rotary spade or tiller	3.3-4.0		66-140
Secondary Tillage	Hand hoe and rake	110-250		
	Hand harrow	250-500		
	Buffalo harrow	64-100	64-100	
	Animal puddler	8-33	16-66	
	Tractor harrow	16-24		80-150
	Tractor rotary tiller	10-20		100-160
Planting	Hand Direct Seeding	160		
	Hand broadcast	3		
	Line by hand planter	20		
	Tractor rotary seeder	0.4-1.0		15-30
	Tractor 15-40 HP drill	1.2-3.1		5.6-35
	Aerial seeding	0.3-0.6		16
Trans-planting	Nursery	120	10	
	Pull and bundle seedlings	30-48		
	Transport to field	8		
	Transport	80-160		
Culti-vation	Handweed once	150		
	Rotary tiller	24		
	Herbicides - manual	30-40		
	Herbicides - power back pack	16-26		3-6
	Herbicides - aerial	0.2-0.4		8-16
Harvest-ing	Hand cutting	80-160		
	Tractor and binder	26-44		400
	Combine	4.4-12.0		175-360
	Threshing-hand	20-69		
	Threshing-buffalo	60-89		150-178
	Powered thresher	20-25		3-5
	Large threshers	12-80		3-180
Cleaning of Grain	Wind throwing	10		
	Hand fan	7		
	Fan mill	1.5-70		
	Chaff sieve	4-8		

Based on rated horsepower of engine.

Source: After Johnson (1963).

Exceptions to most of those points can be presented but they do not detract from the general validity of the statements. For example, small individually owned machines can replace buffalo in paddy field cultivation for an investment that is still within the reach of a paddy rice farmer in many areas. The adapting of machines to a wider range of tasks has been accepted as a challenge by engineers who have achieved notable successes in the production of multi-use machines of low cost. Point (v) could equally well apply to machinery if it was purchasable by farmers and land availability was high. However, operating costs of machines are increasing at a faster rate than those of working animals in many areas, and the ability of working animals to reproduce compares favourably with the depreciation of tractors. It is invalid to regard the use of manual, animal and mechanical power as being mutually exclusive. The requirements and resources of each farmer and each area will determine the ratio between these three sources of power. In the discussion of animals as a power source, the role of manual labour, at the very least in controlling and caring for the animals, must be assumed at all times.

Manual power cannot be fairly compared with other power sources simply on the basis of power output. Man has the ability to perform a great variety of tasks in succession and to devise means of minimising the energy expenditure necessary for a series of tasks. As the mechanical power of a machine is a constant, a direct comparison in terms of power may not be entirely valid. There are some tasks that may remain suited to one particular power source such as cart pulling by cattle under start-stop conditions (Bates, 1957) but a two wheeled tractor equipped to pull a cart, while not as versatile as a cattle cart, may represent a higher total economic efficiency if the tractor has allowed double cropping to be practised where only monocropping was possible using animal power.

The disadvantages of working animals have been accommodated to enable their use in many situations. The working animal requires; capturing in some cases, training, continuous feeding, resting and health care. Efficient systems established from centuries of experience have led to these inputs being minimized, nevertheless they are still drawbacks to the use of animals as a source of power. With regard to the necessity for continuous feeding, the costs may be offset by the sale of the animal for meat at the end of its productive working life. This is particularly so for those animal species whose meat is eaten by the societies in which they are worked, an obvious exception being cattle in India. It is interesting to note however, that the prohibition on eating beef in India may have originally arisen from a need to protect the valuable working animal.

Perhaps the greatest disadvantage of working animals over both manual and mechanical power is the need for rests. It is often claimed that operators also require rests therefore this should not be regarded as a disadvantage of animal power. Nevertheless, rests are often needed by the animal itself, a fact that becomes more obvious when seasonal changes necessitate rapid cultivation of land. Farming systems have evolved around these requirements such that the effect of resting on the efficiency of the system seems minimal. Compensatory mechanisms for this requirement include small farm size and single cropping in areas where double cropping may be possible. The total system as designed around animal power is perhaps the largest single constraint to the introduction of mechanical power and, for that reason, works against any change away from animal power in situations where no immediate economic benefit is obtainable. To introduce more efficient power sources, the social traditions and distribution of labour and wealth may be upset to the end that the national good appears to be directly opposed to the short term good of the common people.

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CHAPTER 3

ECONOMIC AND SOCIAL CONSIDERATIONS OF DRAUGHT POWER

INTRODUCTION

The long association between man and working animals has led to the development of an intricate system of exploitation. Besides providing power for the performance of work, working animals also provide meat, milk, leather, fibre, medicinal chemicals, fertilizer and fuel. Some of the non-food contributions of ruminants are presented in Table 3.1 Even within species, it is very difficult to separate these products although overall economic analyses may be possible for individual socio-economic units.

The primary reason for maintaining working animals is for draught and traction with other benefits being by-products. Loss of some of these by-product benefits by the employment of an alternative power source need to be considered in economic analyses. Other considerations in this context include; the social value of cattle in the provision of status or as capital reserves for times of need; the production of offspring, meat and other products and the ability to recover from minor injuries with little cost.

The milk and meat provided by a draught animal during and after its working lifetime may represent the difference between subsistence and starvation in many lesser developed countries. The nutritional value of animal products while replaceable by skilled mixing of plant products, is important to human nutrition under conditions of scarce food availability of little variability. However, the value of the working animal in pre-mechanized societies is perhaps not as critical as such arguments would indicate provided that replacement of

Table 3.1
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 conveance	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.
Source: McDowell (1977)

the working animal is associated with an increase in productivity that improves the overall lot of the farmer. It has been stated that introduction of mechanized power sources on small farms can be based on a rule of thumb that replacement of working animals provides a five fold increase in productivity or profitability (Wijewardene, 1978).

In macro-economic terms, replacement of working animals leads to a shortage of meat for human consumption and possibly total farm power needs; in South East Asia this situation could be reached before 1990 (McDowell, 1977). The crux of the socio-economic value of working animals through their many products additional to those commonly costed in conventional western economic budgets may be the basis for the five fold increase required by the agricultural engineer before he can be confident of acceptance of mechanization. For example, it has been estimated that importation of farm equipment sufficient to raise the power inputs in Philippines agriculture to the current level of Japan would require foreign exchange equivalent to that allowed for automobiles over the next one hundred years. India would similarly require the expenditure of US$ 0.7 to 1.2 billion per year to provide oil products for the replacement of the one to two million animals used to cultivate land and power irrigation pumps (McDowell, 1977).

AVAILABILITY OF FEED FOR ANIMALS

The ratios of the number of animals to the area of land to be cultivated is low; one cattle beast for example can cultivate up to only three hectares of land per year under monocropping. The total cattle herd necessary to provide work for one hundred average hectares exceeds fifty including breeders (Smith, 1979). Age of slaughter determines the number of breeders necessary, but extended working lives must be balanced against growth rates which largely determine the economics of meat production. In countries where meat production is of less importance as is virtually the case in Hindu India, longer working lives of cattle become more economic by reducing the numbers of less work-efficient breeders. Table 3.2 presents data which indicate the variations in the composition and size of herds according to different ages of slaughter of male and usage of female animals for work. Employment of female cattle as working animals will increase the total economic productivity of the system in situations where meat products are consumed. In any case, breeders and other non-working stock must be raised to provide future working animals and this comprises a cost which must be attributed to the working animal system.

The feeding requirements of animals also represents a cost that varies in economic and social importance with country and locality. It has been suggested that energy requirements

Table 3.2

Variations in Composition and Size of Herd that will Supply Fifty Draught Animals when Changes are Made in Age of Slaughter of Males and when Females are Used for Draught Purposes (Smith, 1979).

Age of slaughter of males	6-7	9-10	12-13	6-7	12-13
Working life of oxen in years	3	6	9	3	9
Number of draught oxen per 100 hectares	50	50	50	16	30
Number of draught cows per 100 hectares	0	0	0	34	20
Calves (0-1 yr.)	27	14	9	11	7
Young Cattle (1-3 yr.)	54	28	18	22	13
Adult Cattle (3 + yr.)	144	97	82	50	50
Total Livestock Units	176	113	93	63	58
Carcasses produced per year.	27	13	9	11	6

ASSUMPTION USED TO PREPARE TABLE

Females start to breed at 4 years of age

Animals start to work at 3 years of age

Females are killed at 9 years of age

Forty five calves survive per 100 breeding cows per year

When oxen are used for work all male calves are kept but only some females.

One adult is assumed to be equivalent to 5 calves or 2 young cattle.

rise by up to five times maintenance levels when animals perform work (Smith, 1979). Using data from Zimbabwe, two estimates of the energy requirements of cattle have been made depending on whether they maintain liveweight during the dry season or whether they lose one hundred kilogrammes in the dry and regain it during the wet season. These are presented in Table 3.3. The total energy requirements are remarkably similar although Smith (1979) reasoned that maintenance of liveweight through the dry season is to be preferred because animals must be in peak condition before the wet season to be of maximum working value. Compensatory weight gain may reduce energy requirements for regaining liveweight and thus make this system seem more efficient. However, it may not provide maximum work output. The feeding requirement of cattle based on liveweight maintenance was estimated to require approximately one hectare of intensively managed maize forage per working animal unit or approximately thirteen hectares of rough grazing.

Table 3.3

Energy Required by a Five Hundred Kilogrammes Draught Animal Working for Three Months Each Year, Maintained at Maintenance or Reduced to Seventy-five per cent Maintenance for Six Months During the Dry Season and then Re-alimented for Three Months. (Adapted from Smith,1979).

Nine months maintenance at 54 Mj day-1	*14500 Mj*
Three months maintenance plus work at 125 Mj day-1	*11250 Mj*
	25830 Mj

Six months (182 days) at 75% maintenance (54 x 0.75 = 40.5 Mj/day)	=	*7371 Mj*
Energy deficit (54 x 0.25 x 182)	=	*2457 Mj*
Weight loss (1 kg body weight loss provides 28 Mj)	=	*88 kg*
Average weight loss per day (88/182)	=	*0.48 kg*
Three months maintenance plus energy required to gain weight at 0.96 kg/day (93.7 Mj/day)	=	*8527*
Three months maintenance and work at 125 Mj/day	=	*11375*
Total energy required	=	*27273*

Feed requirements severely affect the economics of animal utilization through the long period when cattle are not worked. The relative efficiency of intensive utilization of working animals on an irrigated farm provides greater utilization of animals as calculated by Smith (1979). This system would be practised in areas where land was limiting, and assumes that female in addition to male cattle are worked in order to reduce total herd size. However, such intensive farming would require more cattle, up to 1.3 beasts per hectare in Bangladesh and 1.5 to 2.0 in Indonesia. Rough grazing would probably not be available and feeding of farm by-products are sufficient to support 1.5 cattle per hectare in the case of maize stover or 0.7 in the case of rice straw. Nutritionally these by-products would not be sufficient by themselves, but they could provide most of the energy requirements of cattle, especially if supplementary nitrogen and other deficient nutrients were provided. Such calculations should be qualified by practical considerations. Total feed intake may not be sufficient to obtain adequate energy for extended periods of work when the diet is of low digestibility. Total work output is restricted by feed. It is significant that working cattle in the intensively farmed regions of the world are traditionally fed high energy supplements such as oil cakes and rice bran. These practices are more common in those countries where such feedstuffs are not required for the feeding of swine.

It might be concluded from these and other examples that animals are inefficient and that mechanization in some form could be introduced. This is not necessarily the case. In the former example the apparent energetic inefficiency of cattle is largely associated with feeding demands out of the working season. Where by-products or rangeland grazing are the source of this energy, the opportunity cost is low.

However, where productivity is limited by the animal's ability to work on the diets available, mechanization may appear to be an alternative, especially if it allows higher productivity at a cost that is less than the value of the increased productivity minus other benefits supplied by animals.

SOCIAL VALUES AFFECTING UTILIZATION OF ANIMALS

The close association between man and the animals he uses for power and his very reliance on them for his continued well being has led to cultural traditions arising to protect the animals from exploitation or overuse. For example, the sacred position ascribed to cattle in the Hindu religion is a tradition that has apparently evolved to preserve the existing Indian agricultural system.

Animals are also used as sacrifices in animistic religions (eg. Falvey, 1979). Marriage contracts and gifts between and within households may similarly involve livestock in pre-industrial societies because, among other things, the value of the gift is recognized to be more than its current market value and as a symbol of the continuation of the means to sustain existence. Social status can also accrue from having a large number of animals. Sometimes, for example in parts of East Africa, numbers of cattle exceed the environmental capacity to support them. However, individual animals, which lose economic value under these circumstances, are valued in terms of colour, shape of horns, and other non-economic ways. Recent regulations in India recognize the disbenefits of hoarding of cattle against dowries and aim to reduce the number of animals not used for productive work.

Livestock may also be accumulated as insurance against financial stress induced by crop failure, sickness or other unplanned circumstances. Such accumulation may not always involve people who utilise the animals as power sources but does rely on a ready market which is usually based on working animals. The Lisu hilltribe people of Thailand and Burma do not utilize cattle for work but tend to accumulate large herds as insurance against crop failure. In times of need they sell to lowland markets that supply the draught and meat trades of Thailand.

EFFICIENCY OF RUMINANTS VERSUS OTHER WORKING ANIMALS

Energetically ruminants may not be superior to other working animals except in terms of the cost of their feeding through their ability to exist and work while consuming a fibrous diet that has little other value. Economic estimates of the contribution of ruminants to man normally do not include draught power because this cannot be easily quantified. Thus the figure of US$4,131 billion as the total world gross product of which US$107 billion was ascribed to ruminants, may be low by a factor of several fold.

Non ruminants would not be able to compete in economic terms with ruminants as working animals if they did not exhibit some advantage over ruminants. Horses, for example, have superior intelligence and a faster walking pace while other equines exhibit superiority in their adaptability to special tasks. Elephants while energetically inefficient provide a higher power output per animal unit. The relative advantage of ruminants does not usually become evident until supplementary grain feeds are in short supply because non ruminants require additional feeds of high energy content. A confusing issue in discussions about the efficiency of ruminants and non ruminants has been the reliance of western civilization on non ruminants to an extent comparable to that of the reliance of developing countries on ruminants. Reasons for this anomaly are historical and practical. The draught horse of western agriculture was a surplus product from armoured knights when wars subsided and battle techniques changed and the continued use of the horse was enabled by the favourable social and physical environment of the west at that time. Temperate pasture species tend to be of superior nutritional quality to that of tropical species and could therefore sustain working horses more readily than could tropical pastures. Grain surpluses may also have been more common in western agricultural production systems of past centuries than they are in developing countries today. Most working animals are found in tropical countries or in regions where alternative power sources are unavailable. The inherently low quality of tropical pastures and the lack of surplus energy concentrate feeds in densely populated countries make ruminants the working animals of primary importance both now and for the future.

COMPARISONS WITH ALTERNATIVE POWER SOURCES

MANUAL VERSUS ANIMAL POWER

The primary advantage of animal power over manual power is that it allows an individual farmer to cultivate a large area in regions where land is not limiting. In energetic terms, the energy requirements of the animal are usually only slightly less than the increased energy output (Smith 1979). Where the source of this additional energy requirement is by-products or rangeland grazing, the increased productivity of the individual farmer accrues entirely to him and is thus distinctly advantageous. Grain feeding of cattle is not practicable in monocropping areas of Asia and elsewhere where rice straw and grasses are fed to cattle. In economic terms, animal power is likely to be superior to manual power where it can be implemented, primarily because one cattle beast can increase the productivity of a man by up to ten times (Gregoire, 1976). Manual power is likely to be practised only in situations to which animal or mechanical power cannot be readily adapted, such as steep slopes of remote areas. However, in Java, the declining cost of hand labour compared to the cost of maintaining draught animals has led to displacement of animals by hand labour.

MECHANIZED SYSTEMS OF ENERGY TRANSFER

The association between rich countries and the use of tractors has provided a basis for simple advertising to encourage mechanization in developing countries. Pressures for mechanization similarly exist within lesser developed countries where, in economic terms, productivity per unit area and per unit labour has increased. The cost of mechanization may be a factor increasing the disparity between rich and poor, because mechanization is available to the richer farmer first. He can then expand his farm by buying the lots of neighbouring small farmers. Some of the displaced farmers then become labourers on the bigger farm, and the remainder increase the pool of unemployed persons. As unemployment is an increasing political and social problem of many developed countries, innovations that add to it are not often favoured by elected governments. However mechanization promises rewards of improved gross national product which may seem to outweigh the dangers of increased unemployment.

Mechanization in agriculture may refer to tractors, pumps, sprayers, dusters, dryers, processing and storage equipment and a number of other items. In development situations mechanization is usually only one part of a group of high technology inputs such as fertilizer and crop protection chemicals.

At the farm level, in situations where tractors can increase the area of land under cultivation either in space or in time by multi-cropping, labour may not be displaced at all. The technology associated with tractor power can allow increased utilization of land through increased power inputs which allow dry season ploughing and precision planting to name but a few examples. Mechanization can also be of positive value in relieving a labour constraint to productivity; wet season labour demands in many areas of the world are excessive and can be relieved or spread over a wider time period by partial mechanization.

At the national level, labour displaced by mechanization can be utilized in the production and support industries which manufacture the machinery. The adaptability of farmers to factory tasks may be raised as one criticism of this suggestion. Nevertheless, there is a need for an additional type of labour associated with mechanization. If perfect balance of numbers was reached whereby the number of persons displaced by mechanization was equal to the additional jobs created to service the mechanical industry, then mechanized farms would be required to increase productivity by an amount equal to the costs of relocating ex-farmers, transporting of produce to relocated consumers, operational costs of machinery and depreciation of the machine, before any economic advantage could be expected. Such increases in productivity are possible where mechanization allows the exploitation of additional land or the growing of an additional crop per year.

One common criticism of reliance on a mechanized system is the necessity to spend foreign exchange to purchase oil products and that mechanization would be required to produce exportable surpluses that will produce foreign exchange. The poor bargaining position of lesser developed countries exporting agricultural crops may tend to limit the benefits that thereby accrue to agricultural mechanization.

Caution is thus required before mechanization can be recommended; alternatives exist and are often underexploited and little known. It has been concluded from several studies concerning the relative value of animal and tractor power in Thailand that substitution of animal power by mechanical power without other additional inputs in farm operation does not usually effect a significant increase in crop yields (Rijk, 1977). Deeper ploughing by tractors is often invoked as a reason for higher yields but it has been pointed out it may also lead to lower yields in some circumstances. Improvements in the design of equipment utilized with animal power are possible and a valid comparison between the two power sources should logically be based on the maximum output of the existing system.

Rijk (1977) has also stated that :-

'higher yields are not achieved by mechanical power only: fertilizer, insecticides, improved animal-drawn equipment or other new farm practices will result in higher yield, probably against lower social costs'.

The requirements of new varieties of crops for better seedbeds, the higher power requirements of tillage and the excessive seasonal demand for labour are common reasons advanced for the introduction of mechanization. On the other hand, mulch fallow tillage is utilized in East Africa to allow dry season cultivating under animal power (Rijk, 1977). Exotic animal drawn implements such as disc harrows, seed drills and cultivators are virtually unheard of in most areas where animals provide the main source of power. If the increases in productivity that are attributed to mechanization could be partitioned between the source of power and the equipment used, a more realistic comparison could be prepared. It does seem however, that studies comparing equipment suited to animal power should be expanded before mechanical power is accepted as being superior. Then the discussion would be one comparing sources of power rather than the productivity of two systems, one of which represents a current peak of technological development while the other is often based on traditional wooden harnesses and ploughs.

Improvements in the efficiency of utilization of working animals may produce systems as technically efficient as mechanized systems in some circumstances. Examples of improved efficiencies of production in systems based on animal power are documented (eg. Groenwold and Crossing, 1975) although little attention has yet been paid to the development of machinery appropriate for use with animal power. A combination of the two systems should also be studied. An interesting analysis of the relationship between time and energy inputs for agricultural tasks is presented in Figure 3.1 which is adapted from a graph prepared by Wijewardene (1978). It demonstrates the normal relationship in curve A with extremes being high time and low energy inputs from manual farming to low time and high energy inputs from mechanized farming. Curve B represents a more desirable curve where both inputs are reduced. Wijewardene (1978) suggests that this may be possible by the replacement of ploughing with herbicide treatment and direct drill sowing. The economic viability of such a system could be calculated in each case. Divergences from curve A could also be expected from improved efficiencies that may accrue to the use of machinery powered by animals. Such machinery was utilized in the mechanization of western agriculture but was soon replaced by tractor powered machinery. However, technology is further advanced today and is able to produce more efficient designs of equipment that can be used with animal power.

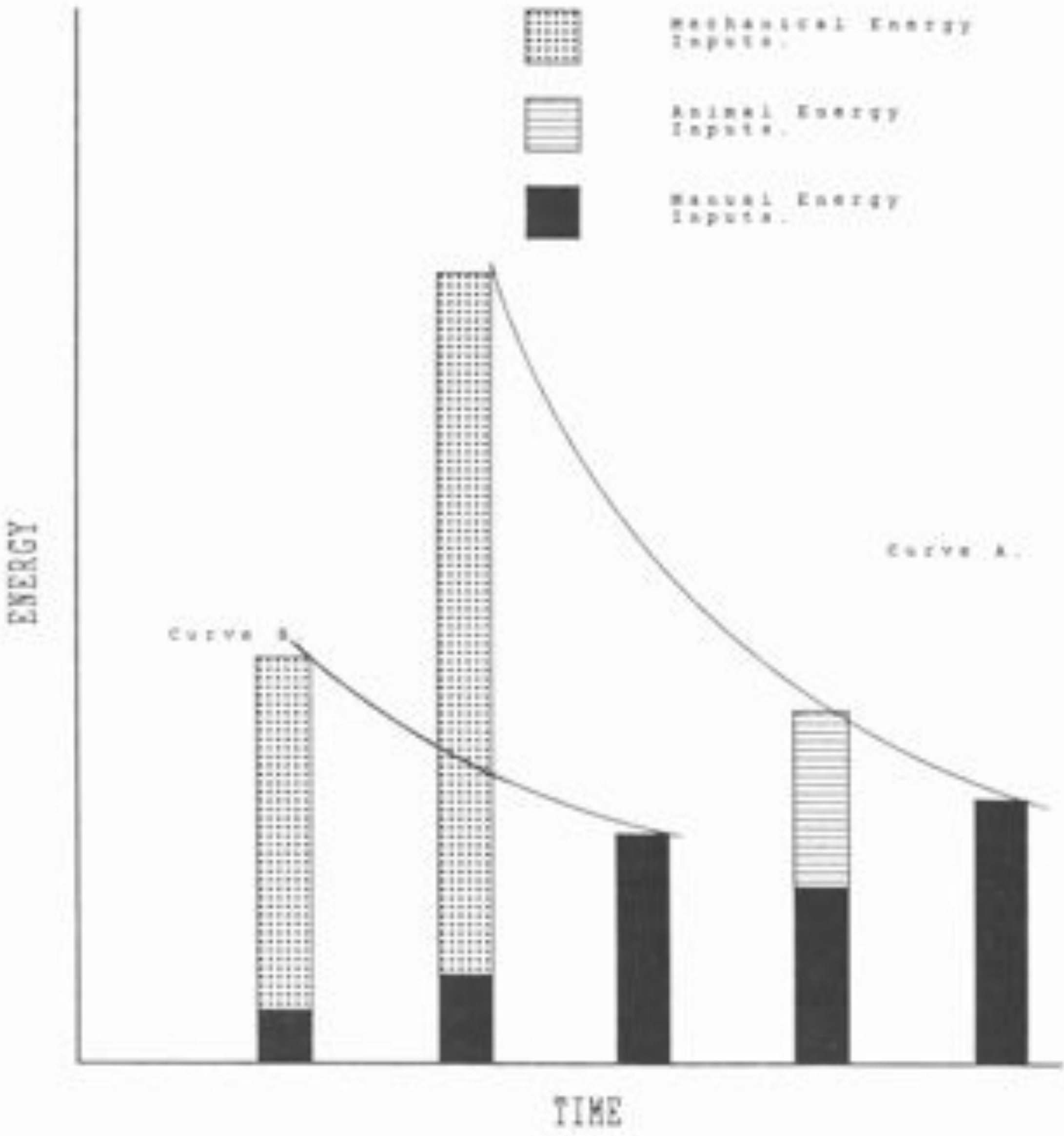

Figure 3.1 Time and Energy Inputs for Agriculture Under Two Systems . (adapted from Wijewardene, 1978)

The corollary to the above argument is the comparison between manual and animal power. The most efficient hand tools should really be the basis of a comparison in order to evaluate the potential of the system. In terms of appropriate technology, tools whether for manual or animal power, can be manufactured within poor countries in many instances without having to rely on foreign exchange. The advantage of such a system is self-reliance which is often a social objective of both individuals and countries. In Burma, where national self-reliance is being pursued, animal power has replaced mechanical power in many sectors because it is more appropriate to the country's current needs and goals.

THE MECHANIZATION OF AGRICULTURE

Mechanization in western agriculture cannot be consistently used as a model for mechanization in the lesser developed countries. While it may be argued that western agriculture of two centuries ago did not vary greatly from that of Asia today, the histories of the two regions and their relative roles in world trade which are largely a function of the industrial revolution, negate any direct comparisons between them today. It is therefore pertinent to examine the history of mechanization in countries not part of the initial industrial revolution in which mechanization has proceeded rapidly during the last few decades.

In Taiwan, the decrease in cattle numbers during the period between the First and Second World Wars can be seen as an indication of their replacement by motorized transport, whereas buffalo numbers did not decline during this period because they were used almost exclusively for cultivation (Yhi-Min Ho, 1966). Three stages in the history of mechanization in post-World War II Taiwan can be recognized viz; the 1960's, the 1970's and post-1970 (Chiang, 1979). During the post-World War II period, draught cattle were in short supply thereby creating a need for additional agricultural power. Thus mechanization of agriculture in Taiwan grew from motorization of transport and from 1953 onwards, small power tillers of two to three horsepower were imported to make up the deficiency in farm power caused by low cattle numbers. By 1956, these power tillers were manufactured within Taiwan in response to local demand as part of the rapid industrialization occurring in Taiwan at that time. In the decade of 1960 to 1970, the effects of industrialization were reaching agricultural labourers which led to increased use of power tillers. The horsepower of the tillers also increased to further minimize labour inputs such that only about ten percent of tillers were less than five horsepower. Pumps, sprayers and dryers also increased in a period of consolidation where the productivity of the agricultural sector was the prime consideration (Chiang, 1979).

The policy for agricultural development in Taiwan is based on mechanization which is promoted by: the provision of loans and subsidies; creation of rice nurseries to provide seedlings suitable for transplanting machinery, and the financing of research to improve farm machinery for local conditions.

In Thailand, where mechanization is proceeding at a pace slower than Taiwan's, specific case studies have been recorded. One such study compares the private cost of using tractors rather than buffaloes in the production of rice (Sriboonchitta, 1975). Some essential differences between the two power sources were noted to be of economic importance such as; buffalo ploughing requires two passes whereas tractor ploughing is deeper and thus requires only one pass; buffaloes can work under a greater variety of conditions than can tractors except in the dry season and maintenance costs vary markedly between the two power sources. In situations where double cropping is to be practised, tractors are essential because they can be worked constantly for short periods whereas buffaloes cannot be. Similarly, if buffaloes are utilized for the threshing of rice from the first crop, they will not be available for paddy preparation for the second crop. It was further calculated that five buffaloes used to thresh paddy by trampling require 11.5 hours per 1,200 kilogrammes of rice while a tractor powered thresher would require only 1.7 hours. Thus the tractor is free to provide the power for ploughings of the second crop sooner than are buffaloes. In India, power threshers were introduced in order to release draught animals for second crop ploughing.

The estimated labour inputs for the care of buffaloes for three periods of the year in a rice cultivation system are presented in Table 3.4 and for tractors in Table 3.5. The huge differences between these figures are a major economic consideration favouring the use of tractors in this situation. The labour requirements for operation similarly favour tractors; tractor speeds for harrowing and puddling in this situation averaged 1.9 and 1.6 hours per hectare while those for buffaloes averaged 5.1 and 4.7 respectively. Total labour costs for preparation of a 6.4 hectare rice field were estimated to be 29.7 hours for a tractor and 104.3 hours for buffaloes. It was also suggested that the quality of land preparation may be better when a tractor rather than a buffalo is used. The total cost of rice production on a 6.4 hectare lot was estimated to be 2,123 baht (US$92) if tractor power was employed, and 3,056 (US$133), 4,435 (US$193) and 6,085 (US$265) baht if two, three or four buffaloes were employed. Buffalo cultivation was not only more labour intensive and thus more costly in the study, but also precluded the planting of a second crop in some circumstances. In such a situation mechanization seems a

Table 3.4

Labour Requirements for Buffalo Care for Three Periods of Each Year in a Rice Production System in Thailand. (Sriboonchitta, 1975).

Labour requirement per four buffalo. *Period and Activities*	*man hours*
Period 1. (February to April)	
1. herding buffaloes	*720*
2. preventing mosquitos (40 minutes per day)	*60*
3. giving water, cleaning and penning	*150*
Sub Total	*930*
Period 2. (from May to the middle of August)	
1. herding after finishing land preparation (five hours a day)	*525*
2. preventing mosquitos	*70*
3. giving water, cleaning and penning	*175*
4. cutting grass to feed four buffaloes for a meal per day in the evening after working	*52*
Sub Total	*822*
Period 3. (from the middle of August to January)	
1. cutting grass to feed buffaloes	*328*
2. feeding four times (15 minutes per day)	*41*
3. preventing mosquito (40 minutes per day)	*110*
4. giving water and cleaning buffaloes. (20 minutes per day per buffalo)	*220*
Sub Total	*699*
Grand Total	*2,451*

logical development.

Other Thai reports suggest that buffaloes may be more economic if only one crop is grown (Inukai, 1970). This indicates the variability of results in such studies which prevents any general statement being made as to the economic feasbility of mechanization even within one crop.

Comparisons of labour inputs may not be of primary importance unless labour is an absolute cash input. Labour inputs for the care of buffalo for example, may be offset against other returns received for the animal including meat, milk, leather, offspring and status. Attempts to compare the relative economic viability of two such power sources should view the animal as an entity rather than attribute all of the costs of animal care and management to the draught output of the animal.

Table 3.5

The Labour Requirement for Tractor Care for Two Periods in a Rice Production System in Thailand (Sriboonchitta, 1975).

Period and Activity	*Labour requirement for tractor care (man hours)*
Period 1 : *The period of land preparation (25 days)*	
- cleaning each day after working (30 minutes a day)	*12.5*
- cleaning after finishing land preparation season and storing	*2.5*
Period 2 : *The period of threshing*	
- cleaning after finishing the threshing and storing.	*2.5*
Total	*17.5*

CASE STUDY: ALTERNATIVE POWER SOURCES IN AFRICAN AGRICULTURE

Labour has been identified as the first limiting resource in an African example (FAO, 1972). The demands of weather and soil conditions allow economic comparisons to be made on the basis of man-hour inputs. However, it must be emphasized that the labour requirements of a subsistence economy are difficult to assess and confounding demands on labour may not be immediately obvious in many cases.

This example compares the production of peanuts by four systems: entirely manual power, animal power, partially mechanized power, and fully mechanized power. The number of hours required per hectare for various tasks under the four systems are presented in Table 3.6. However, the apparent superiority of the fully mechanized system may be misleading if costs could be determined more precisely. The calculations use the simple approach of subtracting the sum of all expenses from the market value of the crop and dividing this by the number of man days invested in that production. In this example it is assumed that:

(i) a price of 20 francs (US$3) and a yield of 800 kg per hectare is appropriate [i.e. 16,000 francs (US$2,700) per hectare],

(ii) that seed cost 1,400 francs (US$230) for 70kg,

(iii) that amortization of hand tools amounts to 100 francs (US$17) per hectare, and

(iv) that a working day equals eight hours.

The mean value of a day's manpower under the manual cultivation system in this example equals 240 francs (US$40). For animal power, higher yields are common due to finer seedbed preparation. Thus at a conservative yield of 1,200 kg per hectare, the market value of the crop is 24,000 francs (US$4000). Depreciation on equipment averages 3,000 francs (US$500) per year per hectare and the hourly cost of draught animals is estimated to be 50 francs per hour. Seed costs are the same and fertilizer costs 2,000 francs (US$330). Thus, calculating a similar labour cost to manual farming, the mean value of a day's manpower under animal power is about 380 francs (US$63).

Partial mechanization does not increase yields above those of the animal power system and the only other variable in this calculation is the cost of the tractor and equipment at 1,250 francs (US$210) per hour. Thus the value of a day's manpower can be equated to about 280 francs (US$47). The fourth system, that of full mechanization was not analyzed because it was considered to be completely unacceptable for sociological and other reasons.

From these figures, it seems that the animal powered system is the most profitable of the three systems analyzed. The total annual income for the three systems would be 72,000 francs (US$12,000), 74,100 francs (US$12,350) and 30,800 francs (US$5,130) respectively; the only advantage of animal power over manual power is the decreased time required to produce the crop. This is of importance, particularly at the stage of soil preparation and while this would conceivably lead to a recommendation for animal power, it is unlikely that this reasoning could be extended sufficiently to recommend the partial mechanization system. Partial mechanization would only become more economic when the machinery costs were distributed over a larger area; considerations of capital as well as time economy are relevant in this instance.

It has been suggested that the additional land required for cultivation before greater capital investment in machinery will be seen does exist. Nevertheless, the availability of this land is limited in most areas and the high rate of population increase and social traditions of small farming restrict opportunities for the introduction of mechanized farming. Likewise, the infrastructural economies of scale of mechanized farming rely on large levels of usage which would necessitate massive restructuring of land utilization.

Table 3.6

The Time Inputs (hours ha-1) Required for the Production of One Crop of Peanuts (adapted from FAO, 1972).

	Manual	Animal		Partially Mechanized		Fully Mechanized	
Task	Man	Man	Animal Pair	Man	Tractor	Man	Tractor
Soil preparation	30	36	8	3	2	3	2
Shelling seed nuts	70	70	–	70	–	0.5	–
Fertilizer application		)	)	)	)	)	)
		)14	)7	)2	)1	)2	)1
Sowing	60	)	)	)	)	)	)
Light surface tillage		5	5	1.5	1.5		
Hoeing-post sowing	35						
- first	50	)	)	)	)	)	)
		)	)	)	)	)	)
- second	50	)48	)24	)2	)2	)	)
		)	)	)	)	)5.5	)3.5
- third	35	)	)	)	)	)	)
						)	)
						)	)
Weeding	20	50	–	50	–	)	)
Lifting	60	18	9	2	2	4	2
Gathering and stacking	20	20	–	20	–		
Threshing and winnowing	50	50	–	12	2	)	)
						)15	)2
Handling of sacs				15	1	)	)
TOTAL	480	311	53	177.5	11.5	30	10.5

DISPLACEMENTS OF THE BY-PRODUCTS OF ANIMAL POWER

The principal by-product of animals kept for working purposes is meat. Obvious exceptions such as the refusal of Hindus to eat beef and the uncommon nature of the meat of some of the less important working animals such as elephants do not detract from the importance of meat consumption in general. In purely economic terms, the value of this by-product to the individual farmer can be assessed. However, in appraisals of the feasibility of mechanization on a national basis, attention is also required to determine whether the market price of meat within the country represents the true price. Meat prices are often regulated by government because meat is seen to be an indicator of the state of the economy . Additionally, the cost of reducing the size of national herds which results from farm mechanization must also be assessed in nutritional terms.

It may be argued that livestock numbers do not need to decrease with mechanization. However, the decrease is usually associated with their redundancy on farms because retention is uneconomic once the primary product of the animal, ie. power is no longer required. On a national basis, continued production of meat requires a transference of these animals to ranches or other smallholders interested in the production of meat. However, the price of meat in these countries is usually low through its association with the other traditional products of the animal. The whole cost of the other animal's production after mechanization must be held against the return from meat and other by-products including milk; thus the price of meat and milk should logically rise to cover the prior value of the animal's power. The lag period when meat prices are low and cattle are not required on cropping farms will not favour investment and will, in all probability, lead to meat shortages. In the longer term, meat prices will probably rise due to shortages and while this may favour investment in meat production, it will be of little benefit to the bulk of the population who will most likely be unable to afford these products at what would then seem to be luxury prices.

Milk is sometimes utilized as a by-product of working animals where females are employed. The work output of females is about thirty percent less for buffaloes in terms of the time required to cultivate a given area while differences for cattle appear to be above five percent (Van Leeuwen, 1952). The yield of milk from a working cow has been estimated in Bangladesh to be greater than one kilogram per day (Odend'hal, 1972). Much higher yields are possible according to German data, however, such investigations are of limited application to lesser developed countries where nutrition of animals limits yields of milk and power (Smith, 1979). Light work does not necessarily reduce milk yields at all (Van Humbert, 1948) and the effects of heavy work on milk yield can be negated by improved nutrition (Torriede, 1939). Where milk is utilized, the economics of the use of working animals is improved proportionally. As with meat, the cost of replacing working animals with machines can lead to a decrease in the quality of human nutrition in milk consuming countries. One technical constraint on the use of female animals for work is the higher incidence of abortions that occur if animals in late pregnancy are worked (Cockrill, 1974). It is suggested that work should not be performed for two months before and one month after calving (Lall, 1940). The most common association between milk production and work is at the herd level; females retained to produce working male cattle may be milked and where milk is a valued product selection for milk production in females may conflict with selection for working ability in males.

The third major by-product of working animals and possibly the most widely utilized is faeces. In India, faeces is dried by slapping it onto walls exposed to the sun to produce pats that are used as fuel for fires in the treeless regions. It is estimated that about two-thirds of the faeces of cattle and buffalo on the Indian subcontinent is utilized for fuel (Odend'hal, 1972). Alternatively faeces may be utilized as fertilizer and if it is assumed that one beast produces 1.2 tonnes of faeces per year, this can be equated to about 20 kg of superphosphate, 12 kg of potassium sulphate and 30 kg of ammonium sulphate (Smith, 1979). Faeces is also being utilized to an increasing extent to produce biogas for use in household cooking. This is particularly appropriate where faeces is otherwise utilized as fuel because it allows the production of a fuel in the form of methane while largely retaining the fertilizer value of the faeces. The cost of the loss of this dung with the advent of mechanization must also be included in economic analyses.

Other by-products of working animals are specific to the needs of different regions and each requires valuing in comparative studies with mechanical power sources. Machines have been designed to replace the power component of animals alone yet their value must be costed in terms of the total of all animal products. As the agricultural and other systems in which animals are utilized have evolved around the use of animals, it is not surprising that mechanization is only appropriate to situations where productivity can be increased several fold by its introduction.

CONCLUSION

The benefits of development projects concerning cattle and buffalo do not usually include attempts to quantify the improvement of draught availability. In the case of a World Bank project in Burma (World Bank, 1971), an attempt to estimate this additional benefit was calculated in the following manner. The shortage of draught power was recognized as a constraint to rice production because draught animals provided around 90 percent of all seedbed preparation energy inputs excluding human inputs. Traditional rice varieties were photosensitive and thus showed decreases in yield if planted late. Accepting that improvements under the livestock development project would not necessarily increase the energy output per animal (one pair of oxen can prepare an average four hectares per day in Burma), the increased number of cattle could lead to an advancement of the average date of planting by 25 percent. This would reliably increase yields of rice planted on the second two hectares of a four hectare plot by up to 300 kg per hectare. In the case of this project, an estimated increase in the number of pairs of oxen by 30,000 was calculated to increase rice production by about 18,000 tonnes per year.

Much of the information available refers to draught and traction. However, draught and traction are only two aspects of the work performed by animals and is the one that has been most studied because mechanization is more readily introduced to replace draught power than it is to other sectors of animal power. Traction power can be provided by machines and it is of interest to note that the most successful machines have been small two-wheeled tractors that provide both traction and draught power by the use of different accessories and thereby replace the two main work functions of cattle and buffalo. Economic evaluations of the use of other animals species such as the yak and the camel can be conducted on the same bases as those employed in the studies for cattle and buffalo but mechanization is less common where these animals are utilized. The adaption of animals to specific conditions such as the yak to high altitudes and the elephant to working in forests, are factors determining their continued use. An additional factor is the limited extent of their utilization which does not constitute a market sufficiently large to produce specialized machines at reasonable cost to replace the animals.

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CHAPTER 4

HEALTH OF WORKING ANIMALS

Dr. E.G. Wells

INTRODUCTION

Health can be defined as the optimal functioning of the animal body. Maintenance of health in working animals differs from domesticated species used for other purposes in that they are subject to a heavy physical stress and are subject to occupation injuries. A literature search reveals several references to injuries but few on the relationship of work stress and diseases. The information available only either catalogues the diseases in general of animal species used for work or describes disease episodes incidentally occurring in working animals.

A wide range of textbooks covers the spectrum of disease in equines and oxen but for other species specific references are more informative. As examples: intensive attempts to collate information on the diseases of water buffalo have occurred just in the last quarter century and have been summarized in recent years, (FAO 1977); Wilson (1978), Feldman et al. (1981) and ILCA (1981) have listed disease of camels in Africa; and diseases of elephants have been discussed by Jainudeen and Scheurmann (1975) in relation to Sri Lanka and in general by Eltringham (1982). Examples of diseases incidentally occurring in working animals are: photosensitive dermatitis in collie working dogs in New Zealand (Fairley), 1982); leptospirosis in working dogs in East Germany (Fuchs et al., 1974); glossitis of military working dogs in Vietnam (Voelker et al., 1975) and chronic fluorosis in draught buffalo in China (Deng et al., 1981). There is no disease information readily available for the yak, reindeer or moose.

The present chapter discusses the relationship of work stress and animal health; reviews the diseases or injuries important specifically to working animals; discusses the principles involved in the maintenance of health; and gives a case study illustrating the problems of the maintenance of health of working oxen in a peasant farming context.

DISEASE AND INJURY IN WORKING ANIMALS

STRESS AND ANIMAL HEALTH

Stress in relation to animal health has been examined in recent decades, but principally in relation to the transport of animals or to those maintained under intensive husbandry systems (Selye, 1955; Klussendorf, 1957; Archer, 1979; Stephens, 1980). The subject has considerable bearing on working animals.

A force causing stress is called a stressor, and stressors include genetic, nutritional, management and disease factors. More than one factor normally operates in any particular situation. The stress syndrome involves the stages of alarm, resistance and exhaustion which reflect complex physiological pathways involving both the central and autonomic nervous systems and the release of hormones. The stages can operate both in the short term and over extended periods of time.

The important result of stress is that an animal has a depressed immune response. Experiments suggest that this is due to the immunosuppressive effects of an increased secretion of corticosteroid hormones (Tizard, 1977; Stephens, 1980). The depressed immune response results in: increased susceptibility to infectious disease; increased susceptibility of animals to normally avirulent bacteria; the activation of latent viruses; and a poor response to vaccines. The effect can be compounded by malnutrition, which, as well as being a stressor, can impair immunoglobulin production if proteins are deficient (Tizard, 1977; Kelley, 1980).

WORK AS A STRESSOR

Overwork in an animal can be a potent stressor. In those tropical and subtropical countries where cattle and buffalo are important draught animals, their hardest work most commonly is ploughing at the beginning of the rainy season. This may also be the time of greatest nutritional stress. This combination of stressors is believed to be the reason for an increased incidence at that time of the year of haemorrhagic septicaemia in Asian cattle and buffalo (Centre for Tropical Veterinary Medicine, 1976). The same stressors are believed to be a root cause of an important trypanosomiasis problem in working buffalo in northern Vietnam (Wells, 1982). The water buffalo in the Red River delta are known to have been infected with Trypanosoma evansi for many decades but with little economic impact. The shortage of working buffalo after the Vietnam war put an extra work load on those remaining. The additional stress disturbed the equilibrium between host and trypanosome and clinical episodes with significant mortality have occurred. The same phenomenon occurs with tsetse transmitted trypanosomes in Africa. Where trypanosomes are being transmitted by forest or riverine species of tsetse; an equilibrium can develop between cattle, the tsetse and the trypanosomes. When the cattle are worked, the equilibrium can again be disturbed. However, the equilibrium can be maintained by careful management and the judicial use of drugs as has been demonstrated in Ethiopia (Bourn and Scott, 1978). In West Africa, the problem can be alleviated by the use of a trypanotolerant breed but even these may die of trypanosomiasis with bad management and overwork. The same animals may also break down to streptothricosis against which they are normally highly resistant (Starkey, 1982).

Owners of working animals may prevent them from breeding during times of heaviest employment. However, the stress of work may in itself interfere with reproductive efficiency. The effect of work on reproduction is also of importance. In Bangladesh, a mean of only 1.2 calves per cow used for draught has been attributed to the continued effects of work and lactation as a stress, and poor nutrition. Replacement of stock by migration from India reduces the impact of these factors and does not provide stimulus for improving reproductive rates.

The examples cited are derived from the practical experience of farmers and field extension workers and many other measurable situations may well exist but are unrecorded. Surprisingly few reports exist of controlled experiments determining the relationship between stressors in general and animal disease. Experiments on the effect of work as a stressor in working animals are the most limited with a rare example being a study of heat and work stress in horses by Carlson et al. (1976).

DISEASES WHICH AFFECT FUNCTION

Diseases of the foot are those most directly affecting function. A major transmissible disease of cattle and buffalo inhibiting their use for draught is foot and mouth, which is endemic in most of Asia, many parts of Africa and many South American countries. In subsistence farming areas, the lameness resulting from foot lesions at times when land needs to be prepared can create an emergency situation for an individual farmer. All causes of lameness in buffalo in Malaya have been described by Hill and Rajagopal (1962), and diseases of the feet of elephants have been described extensively by Ruthe (1961).

Transmissible diseases which cause important mortality obviously reduce the number of animals available for work, for example, rinderpest of cattle and African horse sickness which is endemic in Africa south of the Sahara. Other diseases may temporarily affect availability such as those causing febrile episodes or temporary lack of mobility. A prime example is ephemeral fever of cattle and buffalo in the tropics and sub-tropics of Africa, Asia and Australia, but also in temperate South Africa and Japan. However, the diseases which are probably most significant in relation to draught animals are the chronic debilitating infections and parasitisms. These conditions are themselves stressors affecting an animal's capability to work. Of likely greatest importance are helminth diseases (endoparasites including liver-fluke) and heavy tick infestation.

Recorded non transmissible diseases affecting function are many and miscellaneous, of which the following is a selection. Stringhalt is a spasmodic lifting of the leg during progression commonly reported in cattle, buffalo and horses. Dhablania et al. (1971) reported, for the first time in the literature, two cases in the camel. Lemmer (1982) described an excessive curvature of the sole often found in Sicilian mules which has to be corrected, if necessary, by orthopaedic shoeing. Harden (1981) described rotation of the coffin bone in the horse as a common sequel of acute laminitis. Lastly, a retinal disease of the New Zealand working dog has been described by Hughes and Joyce (1981) as possibly an inherited characteristic.

INJURIES

The types of injury to which equine and bovine working animals are subject have been described by FAO (1972) and by Williamson and Payne (1978). They can be summarized as:

- bruising or open wounds caused by the needless hitting of animals or undue pulling on the nose ring;

- injury caused by faulty action, "over-reach" and "brushing" in horses;

- sores caused by badly fitting harness or hobbles, or by roughness or projections on such equipment;

- muscle, joint and tendon strains from being required to perform a task which is too heavy;

- discomfort from stones and earth becoming stuck or caked in the cloven hoof (oxen) or hoof (horse);

- chronic irritation from head ropes predisposing to horn cancer, principally in India (Centre for Tropical Veterinary Medicine, 1976); and

- the highly specialized situation of sledge dogs in the Antarctic has been described by Bostelmann 91976) and Leach (1978). Injuries include wounds from fighting, cut pads, mild keratitis and mild frost bite associated with any skin lesion involving loss of hair.

THE MAINTENANCE OF HEALTH IN WORKING ANIMALS

The common sense and compassion of a good stockman will cover many requirements. The underlying principle in the management of working animals is to limit stress to a level which animals can accommodate. As previously outlined, stressors are many and varied. The major points to be considered are:

- adequate feeding, with higher energy feeds during periods of work;

- adequate housing providing protection without over-crowding;

- a"oidance of extremes of temperature;

- limiting size of loads;

- regulating hours of work;

- giving adequate time for animals to feed, and , in bovines, to ruminate;

- avoidance of change in the working environment including change of locality, change of human contact and changes in a working team of animals;

- removing stress of chronic parasitisms by controlling ecto- and endo-parasites following the advice of the local veterinary authorities;

- the prompt treatment of wounds or sores and their protection from flies, and the repair of equipment which may have caused the lesions;

- the prompt treatment of skin diseases, principally ringworm, and

- the vaccination or prophylactic treatment of animals following the advice of local veterinary authorities and at the time of the year when the work load is least.

A CASE STUDY FROM ETHIOPIA

A list of requirements to maintain health is easily compiled. The realities of a situation may provide serious obstacles to implementation. The peasant farmers in the Ethiopian Highlands are dependent on the draught oxen to cultivate their grain crops. However, the grazing resource is never adequate at any time of the year; there is climatic stress at the cool times of the year and there is stress from enzootic disease. Liver-fluke infestation of adult animals in some areas can reach a prevalence of 90 percent and infestations with pathogenic species of intestinal worms can be over 70 percent. Apart from improving the food resource, a strategy for treatments and vaccinations must be evolved.

Figure 4.1 gives a diagrammatic representation of the seasonal occurrence of cattle diseases in relation to the climate, grazing quality and the periods of activity for draught oxen in the farming calendar. Figure 4.2 shows a possible strategy for the routine treatment and vaccination of the draught oxen, but there are inherent problems. A characteristic of the farming pattern is the time required for repeated weeding of the grain crops. This means that the farmer is not available to assist at the optimal time for cattle vaccinations, which is the time of maximal feed resource, and a compromise has to be reached. Moreover, the simple drugs needed by the farmer are in short supply, and beyond the financial resource of Government to supply free of charge.

The Ethiopian predicament, although extreme, demonstrates the type of problems facing developing countries. In addition, it demonstrates that the development of an adequate veterinary service is one prerequisite for the optimal utilization of draught animals (FAO, 1982).

CONCLUSIONS

Information on health and disease in working animals is currently scattered and incomplete. This situation needs to be rectified if research is to be properly supported.

A priority research need can be argued as being a study of the interaction of work stress and chronic diseases and parasitisms (Smith, 1981). This has to be related to peasant farming systems world-wide where animal draught power has present and future importance. Goe (1983) reviews the limited research on animal traction and gives an apposite warning. Traditional management systems may already be using available resources to maximum efficiency and the integration of new technology has to be made with the minimum of inputs.

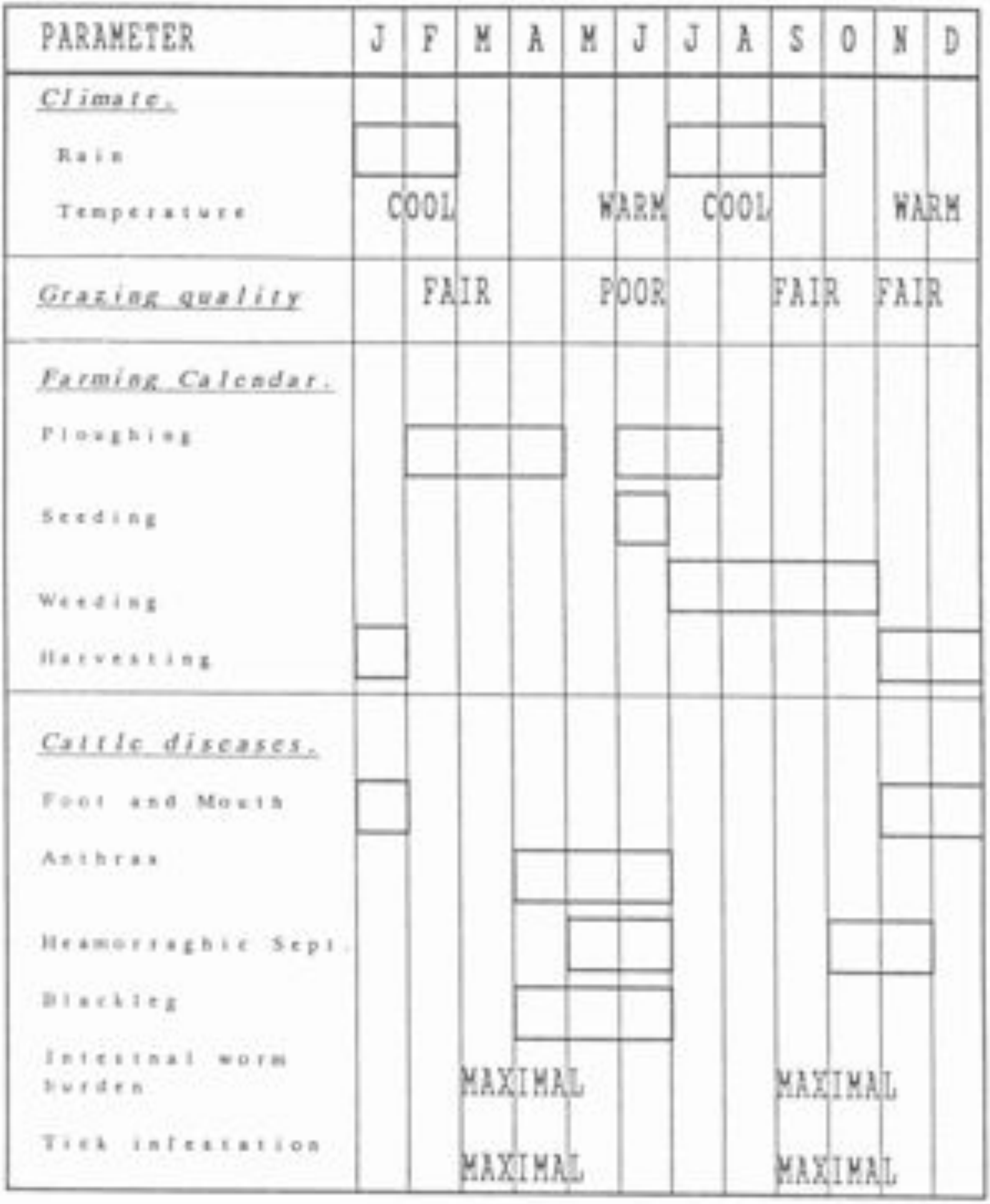

Figure 4.1 The Reported Seasonal Occurrence of Some Cattle Diseases in the Ethiopian Highlands in Relation to Climate, Grazing the Farming Calender, and Work Stress in Draught Animals.(with Acknowledgement to Dr Solomon Haile Mariam, Leader, Veterinary Team, Ministry of Agriculture, Addis Ababa).

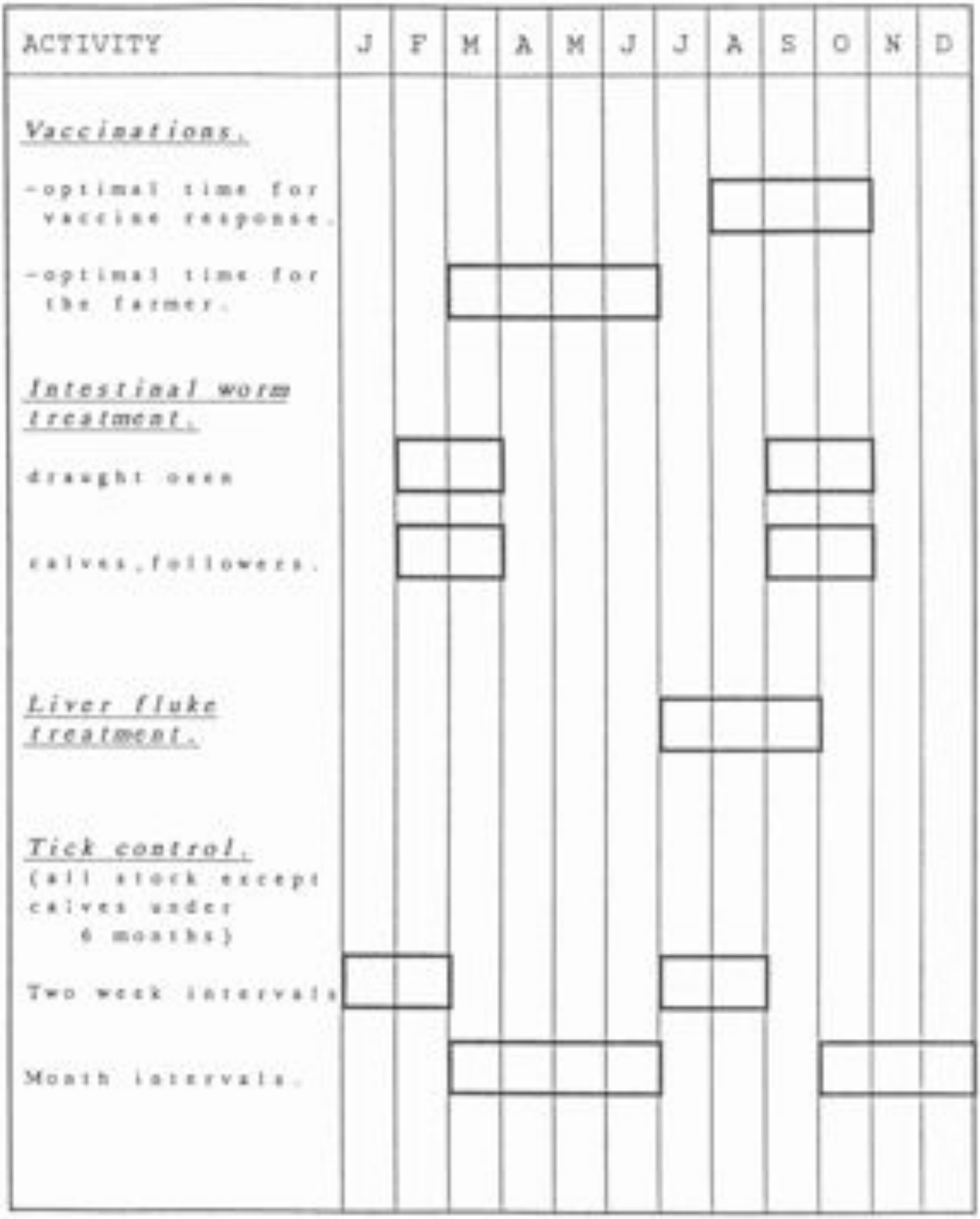

Figure 4.2 <u>A Possible Stratagy for the Treatment and Vaccination of Cattle under Traditional Management in the Ethiopian Highlands Against some Endemic Diseases.(With Acknowledgement to Dr Solomon Haile Mariam, Leader, Veterinary Team, Ministry of Agriculture, Addis Ababa).</u>

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CHAPTER 5

NUTRIENT REQUIREMENTS OF WORKING RUMINANTS

Dr. Peter R. Lawrence

Nutrients for any class of livestock are generally divided into four classes; vitamins, minerals, proteins and energy giving nutrients. The requirements for these nutrients have been extensively investigated in beef and dairy cattle and tables drawn up in the form of feeding standards which tell one the amount of each type of nutrient required per animal according to its type, sex, age and physiological state.

For most nutrients it is customary to divide requirements into those for maintenance and those for production, i.e. growth, pregnancy and lactation. Since there is no reason to believe that the maintenance requirements of draught oxen differ from those of cattle kept for other purposes (see eg., MAFF, 1975 or ARC, 1980); the rationing of such animals becomes simply a question of determining the extra nutrients needed for work.

VITAMINS AND MINERALS

There seems to be no significant extra requirement for vitamins and minerals in working animals over and above those contained in the extra food needed to supply the animals' increased energy needs. In very hot climates animals may need extra salt to replace that lost in sweat; there is seldom any lack of chloride ions in most diets, but forage crops in some tropical areas tend to contain very little sodium.

PROTEIN

As in the case of vitamins and minerals, protein requirements seem to be minimal. Exercise seems to have little effect on urinary nitrogen excretion in man (Rennie et al., 1981) or sheep (Clapperton, 1964). No work appears to have been done on draught animals, so the matter was investigated as part of a project carried out at the Eseuela Centro Americana de Ganaderia in Costa Rica.

Six oxen were fed six kg of hay and three kg of concentrate daily and nitrogen excretion in both urine and faeces were measured for one week while the oxen were at rest, one week when they used an amount of energy calculated to be 1.5 times maintenance followed by a further week at rest. The results (Table 5.1) show a small and statistically insignificant increase in urinary nitrogen excretion in the weeks during and after work compared with the week prior to work. The corresponding decrease in nitrogen balance is not large enough to be of any nutritional importance.

Thus there seems to be very little requirement for extra protein during work. If a working animal is not to lose weight, it must consume more energy-giving foods and this will almost certainly involve taking in enough extra protein as well. In the case of an underfed animal, the release of body reserves to meet the animal's need for energy will also involve the release of sufficient extra protein.

Although draught animals appear to need very little extra protein for work, they often have to survive on very fibrous diets such as poor quality grass or straw. In these cases, supplementation of the diet with such things as Leucaena, oil seed residues or urea is often beneficial since it provides the rumen microflora with nitrogenous compounds for their own optimal growth and hence increases the intake and digestibility of the food by their ruminant host (Moran et al., 1983). Calculations by Leng (1982) show that the nutrients available from a diet of rice straw may be almost doubled by the judicious addition of urea and essential minerals.

ENERGY

THE NEED FOR ENERGY

The most obvious extra requirements for draught animals is for energy. In general, a ruminant may need energy for any one of the following purposes; maintenance, pregnancy, growth, fattening, lactation and work. These are known as net energy requirements because in addition, an animal has to expend energy on the nutrients it absorbs in order to use them for any of the above processes. This extra energy is called a heat increment and can have different values according to the use to which the absorbed nutrient energy is put e.g., an animal fed on medium quality hay would use about an extra 30 kJ of energy to provide 100 kJ for maintenance but about 50 kJ to produce 100 kJ of fat (MAFF, 1975).

Table 5.1

Nitrogen Intake and Average Nitrogen Excretion and Balance of 6 oxen fed 6 kg of hay + 3 kg of Concentrate Daily.

	INTAKE	EXCRETION		BALANCE
		Faeces	Urine	
	g/day	g/day ± S.D.	g/day ± S.D.	g/day
WEEK 1 - at rest	70.4	54.6 ± 3.1	14.0 ± 3.5	+1.8
WEEK 2 - working at 1.5 x maintenance	67.3	50.7 ± 4.9	17.8 ± 3.4	-1.2
WEEK 3 - at rest	67.6	52.2 ± 7.3	18.1 ± 3.0	-2.7

THE CLASSIFICATION OF ENERGY GIVING FOODS

Foods for ruminants can be classified according to how much net energy they contain and this forms the basis of the Net Energy (N.E.) system. The main drawback is that any particular food will have two or more net energy values according to what it is used for and up until now comparatively few foods have had their various net energy values measured.

A more flexible system is that based on the absorbed or Metabolizable Energy (M.E.) system (MAFF, 1975). The M.E. value of a food is rather easier to determine than the N.E. since it involves simply subtracting energy losses in the forms of faeces, urine and methane gas from the gross energy or heat of combustion of the food. A further advantage is that the M.E. value of a particular food tends to be fairly constant under most conditions. Standard values for the heat increments are then used to calculate the N.E. available for maintenance, growth etc.

FITTING WORKING ANIMALS INTO THE M.E. SYSTEM

To do this we need to know (a) how much energy will be needed for work and (b) the heat increment associated with work which can then be translated into quantities of food.

The energy used by a working animal in the field cannot be determined directly. However, the amount and type of work can and this, along with the liveweight of the animals, enables an estimate to be made of the energy used for work.

The information necessary to make these estimates can be summarized as:-

energy used for work = energy for walking
+ energy for carrying loads
+ energy for pulling loads
+ energy for walking uphill

This formula may be expressed quantitatively as

$$E = A\,F\,M + B\,F\,L + \frac{W}{C} + \frac{9.81\,H\,M}{D}$$

where E = *extra energy used for work (kJ)*
F = *distance travelled (km)*
M = *liveweight (kg)*
L = *load carried (kg)*
W = *work done whilst pulling loads (kJ)*
H = *distance moved vertically upwards (km)*
A = *energy used to move 1 kg of body weight 1 m horizontally (J)*
B = *energy used to move 1 kg of applied load 1 m horizontally (J)*
C = *efficiency of doing mechanical work* $\frac{\text{(work done)}}{\text{(energy used)}}$
D = *efficiency of raising body weight or* $\frac{\text{(work done raising body weight)}}{\text{(energy used)}}$

Quantities F, M, L, W and H can be determined routinely. The two weights M and L present no problem and F and W can be measured throughout the working day using apparatus developed at the Centre for Tropical Veterinary Medicine (CTVM) in Edinburgh (Lawrence and Pearson, 1985). The distance moved upwards, H, may be estimated from a knowledge of the animals' itinerary and a good large scale map.

Factors A, B, C and D have all been investigated intensively at CTVM and elsewhere and the results are summarized in Table 5.2 . Table 5.3 shows the application of this formula using appropriate values of A, B, C and D to two days' work done by a 620 kg ox.

The heat increment associated with work should be the same as that for maintenance since in both cases, it is produced mainly as a result of converting the M.E. in the diet to the correct form for fueling muscle tissue albeit at a much greater rate in the working than the non-working animal. Some support for this supposition came from a study at CTVM in which two Brahman cattle performed a standard amount of work both at maintenance level of feeding and after a 48 hour

Table 5.2

Values for Factors Used to Calculate the Extra Energy Consumption of Draught Animals for Work.

Factor and units	Numerical value + S.E.	Number of observations	Type of animal	Authors	Comments
(A) Joules per kg live-weight per m travelled	2.09 ± 0.062	61	Brahman cattle and swamp water buffalo	Lawrence and Stibbards (1985)	Walking speed range 0.4 - 1.6 m.s.-1
"	2.0		Cattle	A.R.C. (1980)	Preferred value derived from several authors.
(B) Joules per kg carried per m Travelled	4.24 ± 0.24	24	Buffalo	Lawrence and Stibbards (1985)	Load placed in saddle over the middle of the animal's back.
"	2.60 ± 0.19	24	Brahman cattle	"	Load placed in saddle over the animal's shoulders.
(C) Ratio work done pulling energy used	0.389 ± 0.010	30	Buffalo	Lawrence (1985)	Most data for animals in single harness wearing collars
"	0.289 ± 0.0006	80	Brahman cattle	"	Data for animals in double and single yokes + a few for single animals with collars
(D) Ratio work done raising body wt/ energy used.	0.356 ± 0.011	24	Brahman and Brahman x Friesian	Thomas and Pearson (1985)	Results taken at ambient temperatures of 15 and 33oC
"	0.35		Cattle	A.R.C. (1980)	Preferred value derived from two authors.

fast. In both cases, the energy used to do the work was almost the same. Had the use of dietary M.E. for work involved any metabolic activity over and above that required for its use in maintenance, then the animals would have used more energy to do the work at maintenance than when they were starving.

It is practically very difficult to do this kind of experiment since the animals were, not surprisingly, reluctant to work after a prolonged fast. Furthermore, short experiments of this type do not preclude the possibility that prolonged work throughout the day may result in an overall increase in basal metabolic rate during rest periods. In order to clarify the situation, experiments need to be done in which the energy expenditure of animals is measured for 24 hours both while at rest and when doing a normal days work.

PROVIDING ENERGY REQUIREMENTS FOR WORK

Work carried out at the Eseuela Centro Americana de Ganaderia in Costa Rica shows that the extra energy used by oxen during a normal working day is not large. Table 5.4 shows the daily energy expenditure calculated in the manner previously described and expressed as a multiple of maintenance of six oxen on different diets and under different conditions of management. Even under optimum conditions of feeding and management, the oxen only used energy equivalent to 1.67 times maintenance when working a 5.5 hour day.

Theoretical calculations for beef and dairy cattle producing at rates typical of developing countries show that draught animals generally need less energy than dairy cows of similar size and the difference becomes even greater when it is considered that oxen seldom work every day in a week and maybe only 100 to 200 days a year.

In practice, the main constraint to providing this energy when only poor quality food is available is the voluntary dry matter intake (VDMI) of the animal. Another part of the Costa Rican study (Table 5.5) showed that on a diet consisting of 22 g of concentrate/kg 0.75 /day plus very poor quality hay ad lib the average VDMI of six oxen was virtually the same during weeks when they worked as when they were idle. On a poorer diet (11 g concentrate/kg0.75 /day plus hay ad lib) work was associated with a slight decrease in VDMI. These results also illustrate another important point which is that tropical forages are often too poor in quality to supply maintenance let alone the extra energy required for work. In this case, although the animals worked on average only one day in three, they only just maintained body weight on the better diet and made substantial average losses on the poorer one.

If therefore an animal at or near maintenance and feeding to appetite is required to work then the extra energy for work must be supplied by increasing the quality of the diet i.e., by giving a concentrate supplement. In poorer countries this may mean that draught animals then become direct competitors for food with human beings.

Table 5.3

Estimates of the Energy Expenditure (E) of a 620 kg Ox

using the formula:

$$E = AFM + BFL + \frac{W}{C} + \frac{9.81\ HM}{D}$$

where *F = distance travelled (km)*
M = liveweight (kg)
L = load carried (kg)
W = work done whilst pulling (kJ)
H = distance moved vertically upwards (km)

A, B, C and D are empirical factors listed in Table 5.2. The values chosen for this table were

A = 2.0 J.kg-1.m-1
B = 2.6 J.kg-1.m-1
C = 0.30
D = 0.35

Job	Ploughing medium soil	Pulling 500kg cart on tarmac road
Time spent working (h)	5.5	5.5
Distance travelled (km)	11.59	19.52
Work done (kJ)	6,400	1,955
Average load carried* (kg)	10.7	1.9
Distance raised (km)	0.030	0.310
Energy used for walking (kJ)	14,372	24,205
Energy used for carrying (kJ)	322	96
Energy used for doing work(kJ)	21,333	6,517
Energy used for raising body weight (kg)	521	5,387
Total energy used (kJ)	36,548	36,205
Energy used for walking (%)	39.3	66.9
Energy used for carrying (%)	0.9	0.3
Energy used for doing work (%)	58.4	18.0
Energy used for raising body weight (%)	1.4	14.8

*Vertical component of load

Table 5.4

<u>Energy Expenditure Expressed as a Multiple of Maintenance (± S.D. where applicable) of Various Types of Cattle.</u>

TYPE OF ANIMAL	ENERGY EXPENDITURE
6 working oxen, diet 1, management 1	1.42 ± 0.10 (n = 50)
6 working oxen, diet 2, management 1	1.51 ± 0.08 (n = 60)
6 working oxen, diet 3, management 2	1.67 ± 0.18 (n = 90)
Beef steer* 500 kg gaining 0.25 kg/day	1.18
Beef steer* 500 kg gaining 0.75 kg/day	1.67
Dairy cow* 500 kg milk yield 5 l/day	1.50
Dairy cow* 500 kg milk yield 10 l/day	1.98

* Theoretical calculation

diet 1 = 11g/kg 0.75/day concentrate + poor hay <u>ad lib</u>

diet 2 = 22g/kg 0.75/day concentrate and poor hay <u>ad lib</u>

diet 3 = medium quality pasture <u>ad lib</u>

management 1 = general farm work, 5.5 h/day, all setting up and adjustments to implements included. Animals worked 5 days consecutively at a time.

management 2 = animals worked continuously and as hard as humanely possible for 5.5 h/day all setting and adjustments to implements excluded. Animals never worked more than one day at a time.

Table 5.5

Voluntary Dry Matter Intake (VDMI) of Six Oxen Fed Two Different Diets when Working and Resting.

	DIET 1	*DIET 2*
Average VDMI during resting weeks (kg/day)	*8.3 (n=30)*	*9.8 (n=14)*
Average VDMI during working weeks (kg/day)	*8.1 (n=10)*	*10.0 (n=12)*
Average change in liveweight (kg/animal)	*-19*	*+1*

NOTES:

1. Diet 1 = 11 g concentrate/kg0.75/day + poor hay ad lib.
2. Diet 2 = 22 g concentrate/kg 0.75/day + poor hay ad lib.
3. n = number of weeks during which measurements were taken.
4. Changes in liveweight occurred during 8 weeks on diet 1 and during 6 weeks on diet 2.
5. Liveweights of oxen ranged from 680 - 385 kg.

SOME EXAMPLES OF THE M.E. SYSTEM FOR DRAUGHT OXEN

The following examples show how the existing M.E. system may be applied to draught animals. It should be borne in mind however that the system evolved mainly for use with high-yielding animals in temperate climates and that much work still needs to be done to test its applicability to tropical animals especially those eating very fibrous foods.

Perhaps the biggest problem is in estimating the dry matter intake of grazing animals or those fed ad lib. A.R.C (1980) suggests that the dry matter intake (D.M.I.) of non-lactating cattle on good or medium quality diets should be estimated as 2.5 percent of body weight and that intake of fibrous diets be estimated as:-

$$D.M.I. = 10.6.5q + 37P + 24.1$$

where

D.M.I. = dry matter intake (g/kg 0.75/day)

$$q = \text{the ration } \frac{\text{metabolizable energy}}{\text{gross energy}}$$

for the roughage component and

p = proportion of concentrate feed (if any) in the dry matter of the diet.

This formula can often underestimate the intake of animals accustomed to high roughage diets. For example in the case of diet 1 (Table 5.5) the average D.M.I was 1.62 percent of body weight whereas the formula predicted an intake of only 1.28 percent. Furthermore dry matter intakes of diets may often be substantially increased by the addition of urea or mineral supplements.

In the following examples, the D.M.I.'s are all estimates. In practice D.M.I.'s should be measured experimentally for any particular diet if at all possible.

In cases where animals are not only working but also trying to grow and/or produce milk, the energy needs for all these processes should be calculated separately and added together to give the total needs of the animal.

The most straight-forward application of the M.E. system occurs in cases where the animal is given a fixed amount of food of known nutritive value. After allowing for maintenance needs, it is then possible to calculate how much energy is available for meat or milk production, or in this case, of work. When doing such calculations it is always important to check that the animal's capacity for dry matter intake will not be exceeded and that it is capable of producing work, milk etc. at the rate that the diet is designed to produce.

EXAMPLE 1.

An ox is fed on grass cut and carried to his stall.

(a) How much net energy is available for work per day?
(b) If the ox pulls a cart over level ground for five days each week how far could he be expected to travel each day without losing weight?
(c) How long would the ox spend working each day?

Data

Weight of ox	*500kg*
Amount of grass fed	*25kg/day*
Dry matter content of grass	*40%*
M value for grass i.e. the number D of MJ of M.E. per kg. dry matter	*7.4 MJ/kg*
Average draught force to pull cart	*200 N*
Average speed	*1.0m/s*
Energy cost of moving 1 kg bodyweight 1m	*2.0 J*
Mechanical efficiency of doing work	*0.3*

Dry matter intake = 25 x 0.4 = 10 kg

M.E. intake = 20 x 7.4 = 74 MJ/day

Fasting metabolic rate (F.M.R.) + activity allowance

$= 0.53 \left(\frac{W}{1.08}\right)^{0.67} + 0.0043\,W$ (A.R.C 1980) = 34.5 MJ/day

where W = liveweight in kg.

Efficiency of utilization of M.E. for maintenance/work

$Km = 0.019 \frac{M}{D} + 0.503$ (MAFF 1975) = 0.644

Net energy available for maintenance and work

= 74 x 0.644 = 47.6 MJ/day

Average net energy available for work = 13.1 MJ/day

But ox works only 5 days in 7

Therefore net energy available per working day

$= 13.1 \times \frac{7}{5}$ = 18.4 MJ/day

Let distance travelled per day = X km

Then total net energy expenditure for work

according to formula on pg 67

$= (500 \times 2 \times X) + \frac{200x}{0.3}$ = 1670x kJ

Thus distance travelled (X) per day $= \frac{18.4 \times 1000}{1670}$ = <u>11.0 km</u>

Thus distance could be travelled in $\frac{11 \times 1000}{0.8 \times 3600}$ = about <u>4 hours</u>

<u>CHECKS.</u>

D.M.I. = 10 kg i.e. 2% of body weight therefore probably O.K.

Work output on working days $= \frac{34.5 + 18.4}{24.5}$ = 153 x maintenance which should be within the animal's capability.

EXAMPLE 2.

Two 500kg oxen are fed two kg/day of maize each and as much maize stover as they can eat. What area can they be expected to plough in a five day week?

Data

Dry matter content of maize grain	*90%*
$\frac{M}{D}$ *maize grain*	*14.0 MJ/kg DM*
$\frac{M}{D}$ *maize stover*	*6.2 MJ/kg DM*
Dry matter intake of oxen	*11.0 kg/ox/day*
Force required to move plough	*1200 N*
Average distance between furrows	*300 mm*

Dry matter intake of maize grain $= 2 \times 0.9 = 1.8$ *kg/ox/day*

Amount of maize stover eaten $= 11.0 - 1.8 = 9.2$ *kg/ox/day*

$\frac{M}{D}$ *of whole diet* $= \left(\frac{1.8}{11} \times 14.0\right) + \left(\frac{9.2}{11.0} \times 6.2\right) = 7.47$ *MJ/kg D.M.*

M.E. intake $= 7.47 \times 11.0 = 82.2$ *MJ/ox/day*

$Km = 0.019 \times 7.47 + 0.503y = 0.645$

Net energy for maintenance and work $= 0.645 \times 82.2 = 53.0$ *MJ/ox/day*

Net energy available for work per working day
$= (53.0 - 35.4)\frac{7}{5} = 24.7$ *MJ/ox/day*

If distance travelled $= x$ *km/d and each ox provides half the force necessary to move the plough then the net energy for work* $= (500 \times 2 \times X) + \frac{600x}{0.3} = 3000x$ *kJ*

Distance travelled $(x) = \frac{24.7 \times 1000}{3000} = 8.2$ *km/day*

and area ploughed $= \frac{8.2 \times 1000 \times 0.3 \times 5}{10000} =$ *1.25 ha /5 day week*

Very often, animals are fed on a fixed amount of concentrate and then allowed to fill up on crop residues or grazing. This makes estimation of costs and quantities easier for the farmer since the concentrate is the expensive item. The calculation of energy available for work may be more difficult though since assumptions as to the animal's dry matter intake have to be made. However in most cases, inaccuracies in the estimation of D.M.I. make little difference to the final answer since there are inaccuracies in the estimation of the quantity of the poor quality component of the diet only.

The two previous examples show the M.E. system used in the classical manner, where one starts with a particular diet and then calculates how much production is likely to result from a fixed number of animals. The system is, however, very flexible and can be used in reverse to calculate the quality of diet and number of animals required to do a given amount of work (Example 3a). In the final section (Example 3b) it is shown that the system can also be applied in cases where the animals are losing bodyweight although in this case it must be remembered that the animal's capacity for doing work will be lessened as it will probably not be willing to expend an amount of energy more than about 1.5 times maintenance in 24 hours. Also the lost weight usually has to be put back eventually which, energetically if not economically, is less efficient than not allowing the animal to lose weight in the first place.

EXAMPLE 3

(a) In an agricultural project it is essential that 200 hectares of land be ploughed within 20 days.

(i) How many pairs of 500 kg oxen are going to be needed to do the work assuming each one works at 1.17 times maintenance averaged over 24 hours? and

(ii) What is the minimum quality of the diet which must be provided?

(b) If the only food available has an $\frac{M}{D}$ of 7.0 M/kg D.M. how many pairs of oxen will be needed?

(i) if they are not to lose weight

(ii) if each animal loses 0.5 kg body weight per day

In all cases calculate the total amount of food required.

Force needed to move plough	*1200 N*
D.M. intake in part (a)	*11 kg/ox/day*
D.M. intake in part (b)	*9 kg/ox/day*
Net energy available from 1 kg of liveweight	*20 MJ*
Distance between furrows	*300 mm*

Example 3 a

i)

Area ploughed per day $= \frac{200}{20}$ $= 10$ *ha*

Distance travelled by plough $= \frac{10 \times 10000}{0.3 \times 1000}$ $= 333$ *km/day*

Number of ox km per day $= 333 \times 2$ $= 666$ *km/day*

Net energy input required for work

$= (666 \times 2 \times 500) + \frac{1200 \times 333}{0.3}$ $= 2000$ *MJ/day*

but this represents only $\frac{0.7}{}$ $= 0.142$ *of the 1.7 net energy required both for work and maintenance.*

Therefore net energy for work and maintenance

$= \frac{2000}{0.412}$ $= 4854$ *MJ/day*

Net energy per ox $= 1.7 \times 34.5$ $= 58.7$ *MJ/day*

therefore number of pairs of oxen $= \frac{4854}{58.7 \times 2}$ $=$ *41 pairs*

and total food requirement for the duration of the project

$= \frac{41 \times 2 \times 11 \times 20}{1000}$ $=$ *18 tonnes* ii)

Let quality of diet be x MJ/kg D.M.

Then Km of diet = $(0.019x + 0.503)$

M.E. in diet = 11.0x MJ/day

Net energy in diet = $11.0x\,(0.019x + 0.503) = 58.7$ MJ/day

from which $x^2 + 26.47x - 280 = 0$

the positive root for which is $x = 8.1$ MJ/kg D.M

Example 3 b

i)

M.E. available per ox per day = 7.0×9 = 63 MJ

Km = $0.019 \times 7.0 + 0.503$ = 0.636

Net energy available per ox per day
= 0.636×63 = 40.1 MJ

Net energy available for work
= $40.1 - 34.5$ = 5.6 MJ/day

Number of pairs of oxen required = $\frac{2000}{5.6 \times 2}$ = 178 pairs

Total food required = $\frac{9 \times 178 \times 20 \times 2}{1000}$ = 64 tonnes dry matter

This is quite a considerable amount of feed and number of oxen. A more likely ploy would be to work the oxen so they all lost weight.

ii)

Net energy available for work per ox per day

= $5.6 + 0.5 \times 20$ = 15.6 MJ

This gives a total net energy used equivalent to 1.45 x maintenance over 24 hours which is reasonable providing the animals were in good condition to start with.

Number of pairs of oxen required = $\frac{2000}{15.6 \times 2}$ = 64 pairs

Total food required = $\frac{9 \times 64 \times 20 \times 2}{1000}$ = 23 tonnes dry matter

This is a considerable saving in oxen and at first sight a considerable saving in feed also. But at this level of feeding it can be calculated that the animals would require 31 days of rest in order to regain the weight lost which would require another 36 tonnes of food.

In all cases considered, it is possible to estimate total food requirements using the M.E. system as follows; a) estimate the total amount and type of work which needs to be done, b) calculate the M.E. necessary to do the work, c) decide on the basis of the quality of food available how many animals are needed to do the work and d) calculate total food requirements for maintenance and work. Providing the food available provided a balanced diet for maintenance and sufficient extra energy for the level of work required, then the nutritional needs of the animal should be satisfied.

CONCLUSIONS

From the previous sections it can be seen that the strategy for draught animal use in a particular area may well depend largely on the amount and type of food available.

In places blessed with grass containing more than about 9 MJ of M.E./kg dry matter, the feeding of draught oxen should be no problem since food of this quality will allow an animal to work at what appears to be the optimum level of energy expenditure (1.7 x maintenance) during most of the week without losing body weight. Supplementary feed would only be needed for such animals if they are also expected to perform some other function such as producing meat or milk.

If grazing is plentiful but of poor quality, it is probably better to have more animals doing what little work they can rather than to have fewer animals attempting to do more work than the quality of the food permits. Other advantages to be gained from having larger numbers of animals is that the farmer is protected to some extent against the consequences of accidental loss or injury of animals. He can also afford to use animals in pairs which provides greater maximum draught force for heavy jobs and facilitates the training of young animals who can be teamed up with more experience ones.

In cases where land is scarce and/or grazing is very seasonal the appropriate strategy is to use fewer animals and to get as much work out of each of them as possible. Thus although some of the farmer's time and land are used merely to grow forage or concentrates for oxen so that they can support the higher work levels, the amounts required are kept to a minimum. An alternative to growing crops exclusively for oxen is to grow a cash crop which has some by-product which the animals can eat e.g. the tops of sugar cane.

A COMPARISON OF TWO DIETS USING

a) THE "FERMENTATION BALANCE" APPROACH and

b) THE "METABOLIZABLE ENERGY SYSTEM"

(Data on diets from Leng, 1982)

Type	*Diet A* Rice straw	*Diet B* Rice straw, urea and minerals
(1) *Digestible energy intake (MJ/day)*	70	123
(2) *Digestibility of diets*	0.40	0.50
(3) *Energy available for metabolism according to fermentation balance (MJ/day)*	48	98

Derived and additional data

(4) *B.M.R. of 500 kg ox* $= 0.53 \left(\frac{W}{1.08}\right)^{0.67}$ *(A.R.C. 1980)* 32.4 Mj/day

(5) *F.M.R. of 500 kg ox* = B.M.R. + 0.0043 W *(MJ/day)* 34.5 MJ/day

(6) D.E. = M.E. x 0.81 (MAFF 1975)

(7) $'q' = \frac{M.E.}{G.E.} = \frac{D.E.}{G.E. \times 0.81}$

(8) *Efficiency of utilization of M.E. for maintenance (and, it is assumed, for work)* Km = 0.351 + 0.503 (A.R.C., 1980).

(9) *Maintenance energy expenditure* = B.M.R x 1.5 (Leng, 1985) (personal communication)

Calculation of diets by Fermentation Balance

		Diet A	Diet B
(10)	Energy available for metabolism (MJ/day) (see 3)	48	98
(11)	M.E. intake at maintenance (MJ/day) (see (9))	48.6	48.6
(12)	Level of nutrition as a multiple of maintenance	0.99	2.02

Calculation of diets by M.E. system

		Diet A	Diet B
(13)	M.E. intake (MJ/day) (see (6))	56.7	99.6
(14)	G.E. intake (MJ/day) (see (1) and (2))	175	246
(15)	'q' (see (7))	0.324	0.405
(16)	Km (see (8))	0.616	0.645
(17)	Net energy for maintenance (MJ/day) (see (13) and (16))	34.9	64.2
(18)	F.M.R. (see (4))	34.5	34.5
(19)	Level of nutrition as a multiple of maintenance	1.01	1.86

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CHAPTER 6

ENGINEERING CONSIDERATIONS

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WORKING CAPACITY OF ANIMALS

The work performance of animals is measured by quantifying their capacity to generate power. An animal, like any other power source generates a little more power than what is actually measured as tractive power because part of it is used in self propulsion. The tractive power measured in watts (W) is the rate at which work is performed and is calculated from the formula given below:

Tractive power (W) = draught (N) x speed (m/s)

The work output is represented by the total amount of energy delivered by the animals to accomplish a particular task. It is expressed in terms of kilowatt-hours (kw.h). The above equation indicates that the factors responsible for work output are draught and speed.

DRAUGHT

The term "draught", sometimes denoted as tractive effort or tractive pull, refers to the force, required to pull an object for a given distance. The draught component of pull is of most interest to persons concerned with animal traction because it determines the design of the implements and the feasibility of using them in a given condition.

The application of draught from an animal for pulling a particular implement depends on several factors. The important factors are animal breed, health and body weight, method of harness, training, and field working conditions. The relationship between some of the above factors can be

Then substituting

$$Ra = P.(Cos\ \theta)/u \qquad (5)$$
$$Rb = W = P.Sin\theta - P.(Cos\theta)/u \qquad (6)$$

$$L.Rb + P(h2.Cos\theta - L.Sin\theta - L2.Sin\theta) = W9L\text{-}L1 \qquad (7)$$

Solving equations (5), (6) and (7), we obtain

$$P = \frac{W.L1.u}{(L - h2.u)\ Cos\theta + L2.u.Sin\theta} \qquad (8)$$

Terms L, L1, L2 and h2 depend upon physical measurement and are constant for a given ox. The value for angle θ can vary considerably depending upon the hitching arrangement between implement and the yoke. Since the useful work is done by the horizontal component (P.Cosθ) of the pull, the least possible value for θ is preferred. Under optimum conditions the term L2.u.Sinθ becomes very small and thus can be neglected as θ approaches zero.

$$P = \frac{W.L1.u}{L - h2.u} \qquad (9)$$

It is clear from the above equation that the body weight and the coefficient of friction between the ground and the hoof of the ox directly influence his pulling capacity. Sinkage and soilsheer strength are also important in field conditions. Many researchers have correlated the draught developed by the bullocks with their body weights. The findings of Swamy Rao (1964) showed that bullocks developed draughts varying from 14.5 to 24.5 percent of their body weight. On level hard road surfaces Premi (1979) recorded draught capacity of bullocks to be between 13 and 16 percent of body weight.

The draught capacity of bullocks is generally taken as one-sixth or one-fifth of their body weight. However, the actual value can be more depending upon ground condition. Bansal and Srivastava (1981) reported 220 to 240 kg pull obtained from a pair of bullocks weighing about 450 kg each for a continuous ploughing operation. Apparently the value of the coefficient of friction was more favourable due to a better grip.

A further study of equations (6) and (8) will reveal that any increment in angle θ will make a relatively small difference in the draught. On the other hand, the vertical load on the neck determined by the factor P.Sinθ will go up steeply. Evidently, it is the neck load factor which can cause premature tiring of the bullocks if the hitching of the understood from the following theoretical model developed by Devnani (1982) for an ox working with a neck yoke.

Figure 6.1 shows the free body diagram of an ox used for pulling an implement through a neck yoke. The pressure of the yoke acts on the neck just ahead of the hump. If the line of pull does not pass through the centre of gravity (CG), a rotating torque, proportional to the perpendicular distance between the two, is exerted to destabilize the body of the ox. The animal then readjusts its body to overcome the torque and maintain a working posture while stepping forward. The value of draught can be calculated by applying the condition of equilibrium of forces.

Referring to Figure 6.1, the forces acting on a single bullock are as follows:

W = Weight of the animal acting at the CG.
Ra = Vertical reaction at the rear foot.
Rb = Vertical reaction at the front foot.
Ha = Horizontal reaction at the rear foot.
Hb = Horizontal reaction at the front foot.
P = Pull force.
θ = Angle of line of pull from horizontal.
L = Horizontal distance between front and rear feet.
L1 = Horizontal distance between front foot and centre of gravity.
L2 = Horizontal distance of the neck load point from the front foot.
H1 = Height of CG from ground.
H2 = Height of the neck load point from ground.
u = Coefficient of friction between hoof and ground surface.

To simplify the analysis Devnani (1982) assumed that (i) the bullock is moving on a plain hard surface at a uniform speed, (ii) the net reaction is available from only two feet at a time during motion because the other two are either off the ground or providing only limited benefit, (iii) the inertia forces are negligible because of low speed, (iv) the position of the CG of the body is the same during walking, and (v) the tractive effort is developed only by the rear foot. However, the validity of above assumptions needs to be established with experimental data.

Under the condition of equilibrium we have

$$Ha + Hb - P.\cos\theta = 0 \quad (2)$$
$$Ra + Rb - P.\sin\theta - W = 0 \quad (3)$$
$$P.h2.\cos\theta + Rb.L - P.(L + L2).\sin\theta - W(L - L1) = 0 \quad (4)$$
$$Ha = Ra.u \text{ and } Hb = 0$$

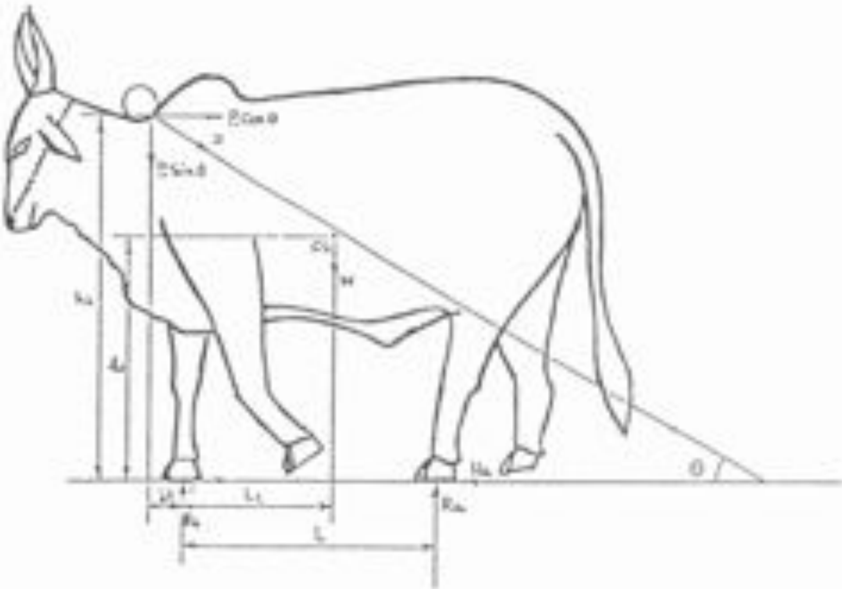

Figure 6.1 Free Body Diagram of an Ox Pulling Load.

Figure 6.2 A Double Neck Yoke for Well Trained Oxen.

implement is not proper. Breed characteristics, good health and good conditioning will help in an animal's ability to sustain fatigue and maintain a normal walking speed over a longer period of time. Use of a suitable harness and proper training will improve efficiency and ease of working with animals.

HARNESS

The design of the harness influences the power output from the animals in many ways. The most important factors are the suitability of the harness to the type and breed of the animal and the job to be accomplished. All animals do not behave the same way when pulling a load. This is largely due to the differences in their temperaments and physical characteristics. Thus the harness should suit the particular type of animals and be comfortable on them. It should also be cheap and simple in construction.

The various types of harness commonly used can be divided into four groups; double yoke, single yoke, collar harness and breastband harness (Hopfen, 1969). The double yoke harness is by far the most commonly used especially with oxen in Central America, Africa, Middle East and the Indian subcontinent. The double yoke harness is of two types: neck yoke and head yoke.

The double neck yoke is commonly used on oxen and buffalo in Asia, Africa and the Mediterranean. These animals have a relatively long and weak neck and good hump. The yoke consists of a wooden pole of 120 to 200 cm long or more (Figure 6.2). It rests on the neck and presses at a region just ahead of the hump when in action. The animals are hitched side by side and restrained in their respective positions by wooden sticks on either side of the neck. A leather strap or rope is normally tied around the throat of each ox. The implement is generally pulled through a chain or rigid beam attached to the centre of the yoke. In the latter case the beam is fastened to the yoke leaving enough flexibility to facilitate turning and working with small differences in the height and pulling capacity of the animals.

The design of the yoke varies considerably from place to place. Most of these designs have some curvature to make the yoke fit better on the animals and presumably increase the area under contact. However, if the curvature does not fit well on individual animals, it can easily produce sores on the skin. The use of a straight round pole as a yoke is quite common in India. Whereas it is cheap and simple to make a round yoke, it has the disadvantage of having a small contact area which is uncomfortable to the animal and impairs efficiency (Howard, 1980). Yoke design can be further improved by lining the portions that sit on the neck with cushioning material covered with leather.

The head yoke is considered to be efficient and suitable for animals with a short neck that do not possess a hump. Some animals pull more with this type of yoke than any other as they tend to lower their heads (Howard, 1980). Lowering of the head helps to bring the line of pull near to the horizontal plane. This type of yoke has a disadvantage of being uncomfortable to the animals by restricting the movement of their head although the better control achieved by positive location of the head may lead to improved performance and less overall stress.

There are wide variations in the designs of single yoke harnesses used for different types of animals and applications. The yoke may be fitted to the head or neck. The single neck yoke appears to be more common in China and South East Asian countries for farm operations. In India, a single neck yoke is mostly used for pulling carts. When an animal is harnessed to pull a cart the pulling force from the yoke is transmitted through two solid beams. In field operations, a rope or chain fastened on both sides of the animal and a swingletree is preferred because it provides the desired flexibility. The same general arrangement can also be used for hitching two animals in tandem by using an additional component called an evener.

The collar and breastband harnesses are most common for horses, mules and donkeys because the main strength of these animals is in their shoulders and breast (Inns, 1980). A three pad collar harness combining the advantages of a conventional neck yoke and collar harness developed in Germany is still used in Central Europe (Hopfen, 1969). Swamy Rao (1964) developed a three pad single and double harness for oxen. When oxen were used with this harness they generated 28 percent more power and reduced the time required for ploughing a given area by 23 percent when compared to using neck yokes. However, this design of collar harness has not been accepted by the farmers probably because it is expensive and difficult to make. Furthermore, in order to get good performance a collar harness has to fit the individual animal.

A belly harness with or without a breast strap has been used very successfully with donkeys and horses for cart pulling (Figure 6.3). This type of harness is suitable for pulling a moderate load when flexibility for animal movement is important, especially for turning. The belly harness protects the animal from impact when the cart encounters an obstacle or jerks.

TRAINING

The accuracy and quality of work performed by an animal depends upon training, regular practice, and an effective guidance system. Oxen often work in a pair side by side. In such cases, it is important that they are trained and used together as far as possible.

The method of training is very simple when the animals are owned by the farmers as they are on the Indian sub-continent, as compared to being owned by a separate community of herdsmen. In the former case there is excellent rapport between the animals and their master; the animals are invariably roped together and learn verbal commands at a very young age. The calves are gradually trained from the age of two years by making them walk together. For the next six months to one year they are yoked and taken around without any load. They are also made to walk in line with several pairs of working animals, first without a load and then with a gradually increasing load. This exercise provides training to the young pairs for walking in a straight line and responding to work related commands. The bulls are generally castrated to make them docile at the age of two and a half to four years when their muscles are well developed and they are almost ready to take up normal duty.

In the case where no tradition of owning and harnessing of animals for farm work exists and farmers do not maintain cattle themselves, training for both animals and farmers follows more defined steps. This has to be closely linked with the implements that the farmers will ultimately use. Difficulties encountered during the early training stage in controlling animals and making them walk straight are two main problems which need patience and extra care. However, incorrect practices such as excessive punishment and guiding the oxen from the front should never be adopted because such practices are likely to make the oxen stubborn and difficult to guide from the rear at a later stage. One way to train animals to walk straight is to put rows of stakes in a straight line to simulate a crop and have the animals walk between the stakes.

ANIMAL DRAWN IMPLEMENTS

PRIMARY TILLAGE

Ploughs, or tillage tools, were the first implement used after man domesticated animals. Breaking or disturbing the soil before planting seeds has always been a time consuming task requiring a large amount of energy. The first tillage tools were made from wood and even today wooden ploughs are still used in some countries such as the Ard in North Africa and the Maresha of Ethiopia.

Figure 6.3 Belly Harness for Donkey Cart Upper Volta. (West Africa)

Figure 6.4 Operation of a Country Plough.

Ploughs used today are of two basic types: the breaking type, referred to as country plough or wooden plough and also known by its ancient name as Ard and the turning or moldboard plough (Hopfen, 1969).

BREAKING PLOUGH.

The main feature of the country plough (Figure 6.4) is that it breaks open the soil and leaves the vegetation on the surface. Hopfen (1969) has given a detailed description of many variations in the construction of a country plough. In general the country plough consists of a beam, body, and handle all made from hard wood. An iron share is attached to the soil engaging portion of the plough body. This implement is simple in construction and is made mainly of locally available materials by village artisans. As a result there is a very wide variation in the shape and size of this type of plough. For example, within India, the Indian Council of Agricultural Research (ICAR, 1960) reported 37 models of country ploughs used in different regions of the country.

Breaking ploughs are essentially shallow working implements. They cut a triangular furrow having a width of 10 to 15 cm at the soil surface. The ploughing rate varies from 0.08 to 0.12 hectares per day (ICAR, 1969). Farmers may have to cross plough up to five times in order to till the unploughed strips left in between the successive passes of first ploughing. The depth of ploughing is varied by changing the hitching position of the yoke on the beam which in effect varies the working angle of the share with respect to the ground. It can also be varied by using wedges of different angles between the beam and plough body. The operator guides the plough with the handle.

MOLDBOARD PLOUGH.

The moldboard plough was first devised in Europe and has been a standard primary tillage implement in many countries since iron became commonly available. It is generally more efficient for destroying weeds by inverting the soil and burying them in the process. But a moldboard plough requires more pulling effort than a country plough because it cuts a bigger furrow slice.

Animal drawn moldboard ploughs (Figure 6.5) are mostly fabricated entirely of steel. In countries where horses or mules are the common draught animals, these usually have a short beam of about 1.5 m. A small gauge wheel in the front of the beam is used to regulate the depth. A swingletree is fastened to the beam and attached to the harness of the animals.

With oxen, moldboard ploughs are usually pulled through

Figure 6.5 An Animal Drawn Mouldboard Plough.

Figure 6.6 Blade Harrow and its Method of use in Light Soil.

chains or ropes fastened to the beam at one end and at the centre of the double yoke at the other end. Sometimes a large plough requires more than one pair of oxen.

The moldboard plough consists of a share, moldboard, land side and a frog. Assembly of the first three components bolted to a frog is called a plough bottom. The plough bottom is fitted to a frame which has handles at the rear and a hitching arrangement at the front. The cutting width of a moldboard plough drawn by pair of oxen varies from 15 cm to 25 cm and it works 3 to 20 cm deep. Right hand moldboard ploughs which move the soil to the right are commonly used. However, reversible moldboard ploughs are also used by farmers to minimise the formation of dead furrows.

CULTIVATION EQUIPMENT

There is a wide range of implements both traditional and improved, for preparing the soil for sowing. The actual choice of a particular implement depends upon the soil type and its surface condition at the time of cultivation.

Figure 6.8 shows a blade harrow made from wood except for the mild steel blade. It is a widely used implement in semi-arid regions in India in both light and heavy soils. It works five to eight cm deep and effectively cuts the weeds without too much disturbance in the soil thereby conserving moisture. Spike tooth harrow, five or seven tyne expandable cultivators and disc harrows are other implements more popular on alluvial soils in northern India.

Cultivation of many crops requires the formation of ridges and furrows for irrigation drainage or soil conservation purposes. To construct these, a ridger which digs a triangular furrow and throws soil both sides is used. The ridger body can be forged as a single piece or made with adjustable wings, and a replaceable point attached to a central member. The body is supported on a frame which is sometimes interchangeable with a moldboard plough.

SEEDING AND FERTILIZER APPLICATION EQUIPMENT

Seeding techniques depend upon the crops, soil condition, and the technological advancement of a particular region. Prevailing practices vary from manual broadcasting of seeds to the use of fairly advanced seeders. In many African countries seeding in hills at 1m x 1m spacing with hand tools is a traditional practice. For row crops hand drilling of seeds through two or three row country made implements is an accepted practice in semi-arid regions of India. An implement called a Tiphan (three row unit, refer to Figure 6.7) or Dhuphan (two row unit) has a bowl which divides the seed into tubes leading to the respective furrow openers. Modified designs of this equipment have another bowl for hand metering

Figure 6.7 Three Row Hand Drilling Equipment. (Tippen)

Figure 6.8 Traditional Inter-row Cultivation in India.

fertilizer simultaneously. This is a labour intensive operation requiring three persons; one each for metering seed and fertilizer and one to drive oxen. In many countries one or two row unit planters pulled by oxen or horses are commonly used. The seed is metered through a horizontal plate or an inclined plate which is easy to change from one crop to the other.

For close growing crops such as wheat in India, animal drawn three to five row combined seed and fertilizer drills have been widely accepted by Indian farmers. These machines have one fluted feed roll for seed metering for each row. The seeding rate is varied by exposing more or less of the feed roll to the seed inside the feed cup. Fertilizer is metered by gravity feed through a variable opening at the bottom of the hopper. Hand metering of seeds behind a country plough or through a multirow implement to the Tiphan is also a common practice in India.

INTERROW CULTIVATION

Weeding is one of the most important operations directly influencing yield. It is also a labour intensive operation since it has to be repeated two to four times depending upon the crop and weed intensity. A large number of indigenous animal drawn hoe designs which cover up to three rows in a pass are available in India. Many of these are narrower models of the blade harrow described earlier with little or no variation in construction. However, the methods of their use differ; usually the yoke for this operation is wider than for the rest and the implement is attached at the proper place to cover alternate rows in a pass (Figure 6.8).

Tyne cultivators and ridgers are also used for controlling inter-row weeds. Tyne cultivators have the facility of adjusting working width to suit row width.

HARVESTING AND THRESHING

The use of animals for harvesting crops is very limited due to lack of suitable equipment. Horse drawn reapers once used in some countries have not been accepted in developing countries. A generally acceptable application of animals for harvesting is for digging groundnuts, potatoes and other similar root and tuber crops which are then picked up manually.

Threshing is a tedious operation when done manually by beating cut earheads with sticks. In India animals are widely used for threshing wheat and paddy by moving in a circle and trampling on the cut grain that is spread on a compacted floor. An olpad thresher consisting of three gangs of serrated discs and pulled by a pair of oxen is also used sometimes by Indian farmers.

TRANSPORT

One of the oldest applications of draught animals is for transportation of man and material. All types of domesticated animals are used for this purpose. However, oxen, donkeys and horses probably constitute the largest proportion. In urban areas of some countries animals are frequently used for transporting water, agricultural produce and industrial goods. In India it has been estimated that over 60 percent of the transportation needs of the agricultural sector are met by some 15 million bullock carts (Ramaswamy, 1979).

The cart can be pulled either by a single animal or by a pair of animals. Single animal carts are popular in China (buffalo cart) and in West African countries (donkey cart). Carts pulled by a pair of oxen or buffalo are more common in South Asia (Figure 6.9). These carts are made of hardwood fitted with mild steel axles. The diameter of the wooden wheels varies from 90 cm to 180 cm and they are fitted with mild steel hub inserts. The weight of the cart varies from 400 to 700 kg and the loading capacity is below one tonne.

A major improvement in the wooden cart which has been accepted by farmers in India and elsewhere is to fit antifriction bearings and pneumatic wheels. This change has reduced rolling resistance thus enabling the transportation of a bigger payload without straining the oxen. In order to minimise the cost of this improvement, used automotive components are frequently employed.

MULTIPURPOSE EQUIPMENT

Animal drawn multipurpose equipment has been introduced to several countries during the last 25 years. These implements are designed for several operations such as ploughing, cultivation, seeding and fertilizer application, intercultivation, and digging of root crops for harvesting. There are broadly two categories of multipurpose equipment, i.e., simple toolbar and wheeled tool carrier. A toolbar is commonly a simple T-shape frame fitted with handles and small wheels or skids for easy manoeuvering of the implement and depth control by the pedestrian operator. The toolbar can be pulled either through a chain or a draw pole depending upon its design and cultivation practices.

A tool carrier which is also known as a multipurpose wheeled tool carrier (WTC) because it has car size pneumatic wheels is a much more versatile machine than a simple toolbar. Wheel tool carriers (Figure 6.10) are pulled by a pair of animals through a rigid beam or draw pole connecting the yoke and frame. The implements are attached to a toolbar at the rear end of the frame and can be raised or lowered with the help of a lifting mechanism. The superior features

Figure 6.9 A bullock cart.

Figure 6.10 Animal Drawn Multipurpose Wheeled Tool Carrier.

of these machines are the possibility of converting them into a cart, precise lateral and vertical adjustments of the implements, wheel track adjustment and a seat for the operator. It is also possible in most of the designs to adjust the lift angle (angle between the face of the cutting tool and the horizontal plane) to suit the height of animals pulling the WTC.

Wheeled tool carriers have great potential in animal power based farming systems through enhancement of human and animal productivity. The WTC is a most useful machine when integrated into an improved farming system because of its high field capacity and better quality of work. It also has the comparative disadvantage of being more expensive which is a constraint to its wider acceptability.

ECONOMIC CONSIDERATIONS

The economics of animal traction depend upon three main factors, i.e., maintenance cost of animals, the availability and cost of suitable implements and the opportunity to make productive use of them. In animal power based agricultural systems these factors are partially interdependent. For example, proper utilization of available power to cultivate a good crop also produces more fodder which is a major component of the cost of maintaining the draught animals.

In situations where animal traction is a part of agricultural activities, the economy has probably stabilized at the present level. The rural system provides traditional implements and service at a very low cost; oxen are bred and trained as a normal routine; farmers harvest and keep the fodder for use in the dry season. In brief the system is self supporting and very few external inputs are required for maintenance and utilization of draught animals. However, change is now required to increase yields from the same farmlands which calls for costly inputs and efficient management of available resources. The rural economy, particularly in semi-arid regions is under strain because of crop failures during deficient rainfall years. It is now necessary to reduce the total number of draught animals in any village and to cover more area with each pair, through the use of improved equipment and managerial techniques which will allow greater animals feed availability and at the same time release some land from fodder cultivation to other crops.

In many African countries where animal traction has been introduced recently, the economics of animal power are more variable from one farmer to another sometimes with negative results on net household income (McIntire, 1983). This is due in part to the limited use of draught animals while crop yields are low due to lack of inputs and proper management.

The prospects of a successful animal traction programme in such situations depends upon the integration of animals into an appropriate farming system based upon crop related innovations. Similarly, livestock must be integrated into rural life so that feed management, recycling of manure and veterinary care are provided.

CONCLUSIONS

Work animals mainly oxen, horses, donkeys, and buffaloes played a crucial role in the agricultural scene of most countries for many centuries. With the invention of motorized equipment the role of draught animals has diminished greatly in Europe and North America. However, they continue to be a major source of farm power for the developing countries.

Farmers have themselves developed techniques of harnessing and suitable equipment for farm operations. Animal traction is expanding into countries where farming depends largely on human power. Traditional implements are now passing through a phase of modernization to make systems more efficient to meet the requirements of more intensive agriculture. Modern equipment is capable of doing virtually all types of field work and its economic viability is often dependent on the degree of integration with productive farming systems.

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PART B

WORKING ANIMAL SPECIES

CHAPTER 7

CATTLE

ORIGINS

From the early Pleistoncene era, the origin of cattle can be traced to the now extinct Auroch (Bis primigenius) through the gaur and banteng of Asia. The centre of origin of cattle was probably in Asia according to Zeuner's (1963a) analysis of archaeological evidence. Much confusion exists concerning the history of the development of domestic cattle, particularly with regard to the Auroch (Zeuner, 1963a). It seems likely that the two predominant large ruminants of prehistory were the forebears of the bison and cattle respectively. The forebears of the cattle, called Aurochs, died out during the sixteenth or seventeenth century and gradually the name Auroch came to mean any wild large ruminant.

Aurochs are believed to have been about 150 cm tall at the shoulder, to have possessed very strong necks, to have been black in colour for males and reddish for females and immature stock, and to have possessed a stripe along the backbone. Modern day Aurochs have been bred according to these and other criteria based on the assumption that the genetic make-up of the Auroch is scattered among the various breeds represented today. Three subgroups of Bos primigenius can be distinguished. However, the aspect of major importance with respect to working animals is the contentious issue of the site of origination of humped cattle.

Some authors have suggested Africa as the continent of origin, because of the abundance of humped breed types represented there today. However, archaeological and ontological evidence to support this suggestion are lacking in Africa while they are present on the Indian subcontinent where Zeuner (1963a) believes Bos namadicus was a subspecies of Bos primigenius (thus B. p. namadicus).

DOMESTICATION

Cattle are known to have been domesticated by at least 3000 B.C. when distinct breeds existed. The beginning of the domestication of cattle is believed to have occurred with humped cattle in Mesopotamia and India. Art work from earlier archaeological levels suggest that domestication most probably took place during the Halafiam period (4000 B.C.). A stone vase dated at about 3200 B.C. from Al Ubaid is decorated with art work which depicts cattle working in a field. Evidence from the subcontinent of India suggests that by 2500 B.C., both Bos primigenius and the zebu had been domesticated. During the fourth millennium B.C., art work suggests that cattle were domesticated in Egypt and third millennium tomb scenes similarly depict working cattle and suggest that their use was common by this time. Thus domestication probably first occurred between 6000 and 4000 B.C. for Bos primigenius and the Indian subspecies Bos namadicus.

Evidence from China suggests cattle were first domesticated at about the same time as were sheep and goats, which was about the middle of the third millennium B.C. (early Neolithic period). The civilization of Hwang Ho from which this evidence was obtained appears to have migrated from elsewhere because no evidence of the evolution of a civilization has yet been uncovered (Epstein, 1971).

Simultaneous development of civilizations in the Fertile Crescent of the Middle East and China is considered to be untenable by Watson (1940) although recent archaeological evidence from Ban Chiang in north-eastern Thailand and other places, suggests that such social evolution may indeed have occurred in Asia. No evidence of cattle domestication has yet been established from Ban Chiang and it has been speculated that the Neolithic cultures in China evolved from a mixture of cultures from different parts of China, the persons of which have been designated as the rice growers, pig raisers, cattle raisers, horse raisers or sheep raisers.

The domestication of cattle is recognized as being the most important part of man's dominance and exploitation of animals with the possible exception of domestication of the dog. Initially the large size of wild cattle must have seemed formidable to primitive man and required co-ordination of many individuals. Upon domestication, feeding of cattle must also have provided some problems and it has been suggested that village settlement was a necessary prelude to cattle domestication; a theory that is interesting when compared to the cattle keeping nomads of Africa. Initially domestication was probably associated with increased and reliable meat supply, and the provision of hides for clothing and other everyday purposes. The role of cattle as beasts of work and burden was soon established with the use of cattle as working animals preceding that of the horse.

That village settlement was a requirement for cattle domestication is open to challenge. The early civilizations of Mesopotamia, the Indus valley and Egypt probably provided agricultural crop residues that served as the basis of the diet of the recently domesticated cattle (Zeuner, 1963a). However, it is equally possible that the crops of those civilizations attracted hungry cattle thereby confronting man with their continued and undesired presence which culminated in domestication as a means of control, a similar speculation to that of Cockrill (1974) concerning the domestication of the buffalo.

However, it is of interest to note that cattle are not usually utilized for working purposes in tropical Africa except in those areas to which they have been introduced by Europeans (Williamson and Payne, 1978). This has now been recognized in the creation of the International Livestock Centre for Africa (Whalley and Astatke, 1979).

WORKING CATTLE

Cattle provide the primary motive power for agriculture in India and neighbouring countries as introduced by many authors. The farmer in these countries commonly sees his cattle to be his most important possession after his land, both for religious reasons and because the farming systems utilized rely heavily on animals in place of manual power (Singh, 1966). Approximately 12,000 million hours per year are worked by draught cattle and buffalo in India (Singh, 1966). Of the some twenty-six breeds of cattle in India, at least fourteen are classified as draught breeds. Different physical attributes, particularly size, are recognized to suit breeds for different work purposes.

The various draught cattle breeds present on the Indian subcontinent have been described by Kelley (1959). The Kankrej breed, which is considered to be the largest and most powerful draught animal on the Indian subcontinent, weighs up to 750 kg and stands up to 155 cm tall at the shoulder. Another breed, the Chhoradi, indicates some of the selection pressures placed on draught cattle which have included such characters as the rate of walking and ensuring overstep of the hind hoof beyond the front hoof when walking. Hariana cattle, the forebears of the American Brahman breed, are categorized as the best medium-sized draught cattle on the Indian subcontinent. A common theme among breeders within

India seems to be that future selection for draught cattle should concentrate on speed and strength in a medium-size animal that can also rear a calf and produce some milk. Medium size is regarded as superior because of the associated lower feeding requirement while retaining sufficient strength to work. The speed of some working cattle breeds in India may be inherited from cattle used in ancient military invasions of India where speed of movement was a major determinant of success and thus selected for in cattle employed to remove guns and equipment (Kelley, 1959). Selection for multi-purpose draught animals reflects the common role of working cattle in the poor countries where they are found; the farmer relies heavily on the cattle for protein through meat and milk, for self replacement and income through reasonable reproductive rates and for work.

India supports the largest population of cattle of any one country in the world. In 1966 this figure stood at 176 million (25 percent of the world's total) of which it is estimated that of cattle over three years of age, more than 69 million are used primarily for work and approximately another four million for both breeding and work (Brattacharya, 1972). The area under crops in India has risen at a rate less than that of the increase in cattle numbers such that the ratio of 0.75 hectares per beast is probably now an underestimate. The role of cattle as power sources for pulling carts is possibly declining as road development proceeds but little impression has been made on the number of cattle used for agricultural production.

Dual purpose animals are deliberately bred particularly within the Hindu and Moslem cultures of the Indian subcontinent. Consumption of milk products is an established practice, thus dual purpose usually refers to milk production, albeit at low levels, and draught capacity. The aspect of meat production is not considered both for religious reasons in the Hindu culture and because deliberate raising of cattle for meat in most of the poorer countries is extremely limited. Meat is regarded as a by-product of working animals. It should also be noted however, that consumption of milk products is not common to all of Asia and consequently draught breeds developed in those areas are not usually considered to be dual purpose.

In China, cattle are the most widely spread domestic animal and are represented by many breeds that vary in terms of size and hump characteristics (Epstein, 1971). In Japan, livestock products, with the exceptions of the fowl and the rabbit, were traditionally not used due to the largely vegetarian eating habits of the Japanese and the abundance of fish. Until the end of last century, cattle and horses were used to transport young grass from the mountains to the lowlands where it served as a fertilizer. Today the population of cattle in Japan has fallen rapidly in response to pressure on land and replacement of draught cattle by machines.

In the Philippines, cattle are yoked singly and utilized to cultivate upland areas (Samson *et al*, 1975). Cattle provide the most common power source, sometimes in conjunction with tractors. Local reasons for preferring cattle over buffalo are that cattle consume less feed of a greater variety, are more tolerant of heat than are buffaloes, do not create wallows and can be sold for a higher price. However, cattle are said to be weaker than buffalo and within the cattle species, the native Philippines' breed is said to be more suited to draught than imported Zebu breeds from Australia. The cattle of Indonesia are raised primarily for land preparation and transport although recently large ranches have been developed specifically for breeding on some of the outer islands where population density is low. It has been estimated that 45 percent of the large ruminants in Indonesia are utilized for farm traction. Burma, with land reform and international trade restriction policies, has experienced an increasing demand for working cattle with increases in prices due to insufficient supply of cattle to replace some functions once carried out by machines.

Asia represents the most concentrated area of working cattle. The large cattle populations of Africa do not reflect a reliance on cattle as working animals as is generally the case within Asia. Historically, the use of working animals may have originated on the African continent and produced those civilizations which are generally traced forward to the civilizations of Persia, Greece and Rome, which make up the basis of western culture. The lower degree of utilization of cattle for agricultural and transport purposes within Africa is apparently not related solely to technical constraints such as terrain and climate as it has been determined recently that a major constraint to the introduction or development and extension of this technology will be sociological (McCown *et al*, 1979). This means that agricultural systems have evolved around the traditional inputs, which exclude cattle in many parts of Africa. While working cattle may appear to be of lesser importance in Africa than in Asia, there is potential for expansion of cattle powered technology in Africa.

Introduction of animal power to Africa will not be easy. Cattle have traditionally been worked in the Nile delta area and highlands of Kenya and Ethiopia and technology has been available for wider adoption for centuries. Two major reasons why draught has not spread more widely are that land pressures in Africa have been lower than those in Asia and that tse-tse fly infestations have excluded cattle from large areas of soil types that are probably suited to animal powered cultivation. Sixty percent of the African cattle population is concentrated in areas receiving less than 700 mm rainfall per year, and soils in these areas are mainly of low fertility. Deep ploughing leads to a decline in fertility because surface layer accumulations of organic matter are diluted by mixing with subsoil. Added to this is an erosion risk which has led to the evolution of local minimal tillage technologies. Thus animal powered cultivation may not be appropriate to the areas of Africa with higher cattle populations.

ATTRIBUTES OF DRAUGHT CATTLE

Cattle share with buffalo the attributes of stamina, ease of handling and ease of feeding. Milk may be collected and meat is the end product of an animal's working life. Females can be worked for up to four hours per day while pregnant or lactating assuming they are receiving an adequate plane of nutrition, although such work reduces milk yields (Williamson and Payne, 1978). In conditions of scarce feed animals may expend up to 40 percent of energy intake in obtaining feed. Thus, under many conditions milk production represents a trade-off with work output. Current studies at the International Livestock Centre for Africa indicate that lactating cows must be stall fed if reasonable work output is also required. It is of interest to note in this context that in areas of higher feed quality, such as in the oil seed production areas of Burma, a division of function is observed with males being used primarily for working purposes.

Opinions of the characteristics necessary in good draught cattle are varied. Vague terms such as good carriage and the holding of the head erect and the tail high are perhaps not of great importance and are certainly not quantifiable attributes. Size is often mentioned to be of primary interest because this determines the number of animals required for a particular task. Length of body, height, speed of walking, thickness of neck, and conformation of the hooves are all of importance.

Temperament is obviously of importance in the selection of working cattle. The differences in temperament of highly bred, fast cattle compared to that of slower, heavy work cattle can be likened to the differences in temperament between the Arab and draught horse breeds. Most working cattle fall into the category of medium to heavy draught rather than speed. Their temperament is usually calm and manageable; those that prove difficult to manage may be castrated to render them more tractable, thus providing an active selection pressure against unmanagability in the breed. This action is sometimes taken to the extreme of castrating larger animals to a greater extent than smaller ones on the assumption that if they did prove to be intractable, the problem would be greater with a larger animal. The perpetuation of a smaller breed is the obvious outcome of this unconscious selection pressure. The temperament of a cattle beast is only determined after some period of contact and a spirited animal may initially appear to be of unfavourable temperament but eventually be trained to become a superior working animal (Williamson and Payne, 1978).

Within western countries, zebu (Bos indicus) cattle are often considered to be more difficult to handle than are European (Bos taurus) breeds. Such observations, while probably valid, overlook the different conditions of domestication of the two breed groups. Under conditions of daily physical contact with humans as is common in Asia, zebu cattle appear docile and tractable. On the other hand, zebu cattle introduced to western countries are often raised under extensive conditions. Under conditions of not experiencing regular human contact the zebu appear wilder than do their European counterparts. Differences in temperament cannot easily be compared in absolute terms as they are related to conditions of management.

The hump of zebu cattle is of interest in the folklore surrounding draught cattle. It is likely that the hump is a product of domestication and it is impossible to determine if this is true or otherwise from osteological evidence because the bifidity of vertebral spines is the only skeletal variation associated with the hump and this association is not absolute. Humps similar to those of zebu cattle are not found in wild animals; other species may have humps such as the moose or the camel but their composition is quite different. The hump of the moose is composed of meat and bone while that of the camel is composed of connective tissue and fat but not meat. It may also be true that the dewlap and horn shapes of zebu animals trace their origin to this cause. Even today, many cattle owners in Asia will not readily consider the use of cattle with poorly developed humps as working animals. The reason often presented is that the harness design requires a humped animal. However, as the bar of the harness in fact rests low on the neck with the hump protruding up to 25 cm above it, excessive hump development is unnecessary. A sex linked gene for hump formation in zebu cattle leads to males possessing humps far larger than females. Castration is therefore delayed to promote hump development although the benefit of delayed castration may actually be an increase in general muscular development rather hump size.

TRAINING

Initially, young working cattle should be applied only to light tasks to avoid the development of skeletal abnormalities. Training may begin at an age of two years which allows such cattle to be fully employed as early as three years. Under harsher conditions, training may not be commenced until cattle are four years old thereby delaying full employment until six years of age.

Techniques for the training of working cattle vary widely. In some instances, work tasks may be learnt from association with a working dam. In other cases, such as that described by Samson et al. (1975) in the Philippines, training is a deliberate process that begins when cattle are at least two years of age. Farmers conduct training by yoking a pole on either side of the animal and progressively applying weights such as tree trunks to the poles. Approximately four and one-half days are required for the initial period with unloaded poles, followed by a further three days with a load applied. The animal is then introduced to light ploughing or harrowing and gradually used for heavier work. While quite simple and quickly achieved, training must be followed by regular work to avoid having to retrain the animal. Training methods all involve the removing of the animal's apprehension and accustoming it to contact with humans. The skin of newly trained cattle is usually sensitive to harnesses and yokes, thus close attention is required to prevent injury.

CARE OF WORKING CATTLE

Division of work among working cattle is of primary importance in the care (Singh, 1966). Under the constraints of the agricultural system, optimal resting periods may not always be practicable, thus sharing of the total work burden becomes the only alternative.

The provision of shoes for cattle used for threshing purposes or required to work on hard ground is critical. Oxen teams as utilized in the pioneering days of Australia and the United States of America required the regular shoeing of cattle utilized to haul heavy wagons along stony tracks. The techniques of shoeing are similar to those practised for horses and are based on the premise of preparing the hoof and then fitting the shoe to the hoof rather than the hoof to the shoe. Shoes may require replacement as frequently as once per month if utilized for road work (Singh, 1966). There is variation both between and within breeds in terms of hardness of hoofs.

During the period of the year that cattle are not required to work due to seasonal cropping systems or other factors, they should be maintained in good condition. Provision of feed and water is essential year round especially during the growing season of paddy rice when cattle may be tied up to prevent their damaging crops. The time expended in the care of working cattle is as great as the management inputs commonly expended on beef and dairy cattle. This labour input must be calculated as an input necessary to the use of working cattle although in many countries, agricultural systems have evolved with such activities being restricted largely to periods of low labour demands, thereby reducing the opportunity cost of these actions considerably. Feeding requirements can be supplied by daily grazing which can often provide a diet of reasonable quality during the working season in much of the humid tropics. In some other situations, however, supplementary feeding may be essential. Supplements such as legume hay and sorghum bran are common in parts of the dry tropics in Africa (Williamson and Payne, 1978) while oil cake is used in South Asia. Disease resistance is lowered by overworking and care is also necessary to avoid wounds from ill-fitting harnesses which can, in the extreme case, lead to loss of the animal. Severe effects of disease such as trypanosomiasis must also be acknowledged although possibilities for greater use of trypanotolerant cattle have been identified (Reh and Horst, 1982).

WORKING ABILITY

Cattle have played a major role in the development of the New World. They were the preferred beasts for hauling the heavy Conestoga wagons of early America and equivalent vehicles in pioneering Australia. Later they were utilized in pulling ploughs. In other western countries the role of cattle was of far longer duration prior to the industrial revolution despite quite large replacements of cattle by horses (Hyams, 1972). In some parts of Europe, draught cattle are still important today.

Within the developing world today, the majority of power needed for agriculture is provided by cattle and buffalo. This situation is unlikely to change in the immediate future as high oil prices and other factors restrict the industrial development of poor countries. Buffaloes may be superior to cattle in some circumstances. The relative advantage of cattle and buffaloes in different situations are discussed in the chapter concerning buffaloes.

Work output is related to breed, sex, size, management and training. Under conditions of similar management and training, larger cattle have a higher working capacity than smaller cattle of the same breed and sex. The generality that cattle develop maximum power at high speeds would suggest that they are more suitable for light cultivation and traction tasks. Work output varies with the frequency of resting as does the level of maximum short term output, such as is required in the ploughing of rocky soil. Similar to other species, harnessing cattle in tandem, triplets or larger groupings, decreases the efficiency of the individual animal by a greater proportion for each additional beast. This decrease in efficiency is approximately 7.5 percent for each animal when cattle are harnessed in tandem (Williamson and Payne, 1978).

In the Philippines, cattle can cultivate up to two hectares per head in a cropping sequence of corn and rice (Samson et al, 1975). They work for seven or eight hours per day with a midday rest period of up to five hours when at their prime working age of about eight years.

Cattle can pull similar loads to horses of similar liveweight, but walk at only about two-thirds of the speed of the horse (Cole and Ronning, 1974). In dryland regions of India, a pair of cattle can lift sufficient water to irrigate one half of one hectare (Groenewold and Crossing, 1975). The Harijana bullocks of India can draw loads of 310 to 540 percent of their liveweight during a working day of six hours.

Chinese breeds of cattle vary greatly in their working ability according to their breeding. Mongolian trek oxen are capable of hauling a 1,300 kg cart for 30 km per day. Manchurian humpless cattle are used as ploughing teams of four head utilizing two large animals in a single yoke and two smaller animals in separate yokes. The Chinchwan is ranked as one of the best draught breeds in China; it possesses a deep and broad chest, high withers and well developed loins, thereby providing a somewhat assymetric conformation that encourages strong forequarter pulling power. A similar breed, the Nanyang, is recorded to be capable of hauling a load of 450 kg over 30 to 40 km per day. Other breeds utilized for draught in China are the Szechwan (also in Hunan and Sweichow provinces) and the zebu of south China. A subgroup of the latter breed, the Hainan cattle, have been noted to be capable of ploughing 0.1 hectare in four to six hours or to carry a load of 150 kg over a distance of 30 km in one day (Epstein, 1971).

The working cattle of Indonesia till dry land at the rate of 300 to 350 square metres per hour and while they are less frequently used for paddy land, their output is estimated to be 20 percent lower than it is for dryland cultivation. The economic efficiency of cattle in this Indonesian system is said to be only 70 percent of that of an alternative system which utilizes a tractor and hand cultivation, yet cattle are preferred by farmers for the convenience of working to a schedule of their own and following familiar patterns.

Williamson and Payne (1978) present examples of the work output of cattle in varying situations. Work outputs for paired oxen include; haulage of carts of a gross weight of 1.02 tonne over a distance of 32 km at a speed of 3.2 km per hour, cultivation of eight hectares in one year or provision of all power associated with a six hectare farm, ploughing of 0.4 hectare in 6.5 hours with a moldboard plough at a constant speed of 3.2 km per hour, and haulage of 30 square metres of round timber 2.4 metres in length over 60 metres for nine hours per day for 250 days per year. Such figures, as with those reported in the earlier discussion, are interesting and valuable but not readily comparable due to differences in climate, soil, terrain and cattle breeds.

BREED TYPES

The apparently superior ability of zebu (Bos indicus) cattle to work in tropical conditions over European (Bos taurus) cattle is well documented. Zebu cattle are often to be observed trotting while hauling carts at temperatures up to 40 degrees C, a difficult task for European breeds to sustain.

Significant differences in the rectal temperatures of different cattle species after work have been demonstrated (Moran, 1973). Bos taurus cattle, naturalized in a humid tropical environment for many generations showed significantly higher rectal temperatures after exercise than did Bos indicus x Bos taurus or Bos taurus cattle. The effect of high temperatures on the Bos indicus x Bos taurus and Bos banteng cattle was similar in stationary experiments, but the latter species appeared less able to stand forced exercise and showed higher cutaneous evaporation rates. The reasons for variations in reaction to high temperatures between species have been attributed to the relative ability of animals to sweat although respiration losses of moisture and resistance to heat uptake by hair covering may also be an important difference between tropical breeds of different origins such as Bos banteng and Bos indicus x Bos taurus.

High temperatures may also affect the nutrition of cattle and a study by Vercoe et al. (1972) indicated depressions of feed intake and nitrogen balance with rising temperature. Dry matter digestibility and nitrogen digestibility were higher in Bos indicus x Bos taurus cattle and may be further complicated by decreased feed intake and digestibility which would place the animal under even greater stress if high temperature or work was a constant possibility.

The ability of zebu cattle to withstand higher temperatures may not be of as much importance to draught animals as it first appears to be, because the adaptation is probably primarily related to the environment in which the species evolved. In other words, zebu cattle are common in the developing countries where working animals are of importance, and these countries tend to be, in the main, located in the tropics. Thus heat fatigue may be as large a problem to zebu cattle working in the tropics as it is to European cattle working in the environment in which they have evolved, the temperate zone.

Many studies have confused the effects of wider appetite of Bos taurus species (and buffaloes) than Bos indicus species with physiological differences between breeds. Bos indicus cattle select more nutritious feeds under foraging conditions and thus can improve their working performance compared to Bos taurus cattle. Bos taurus animals are less selective and consume a lower quality diet which produces a higher heat of digestion. Thus differences between breeds is due to selectivity in foraging as well as to external temperature effects. In situations where feed quality is sufficiently high to ensure that Bos taurus animals receive a high quality feed intake, differences between breeds disappear, such as the demonstrated superiority of Crillo cattle in South America.

The effects of high temperature on the two species is of importance in instances where crossbreeding has occurred, such as in dairy promotion schemes which have been located primarily on the Indian subcontinent. European cattle are crossed with zebu to introduce genes associated with higher milk production while hopefully retaining the adaptation to the environment inherent in the native zebu. Male progeny of the cross are expected to be utilized as working animals in place of the native zebu but they are less adapted to the environment than pure-bred zebu. Thus a potential problem is introduced where it may not have previously occurred. It has been argued however that the lower ability of crossbreeds to withstand high temperatures only necessitates a rest period of five minutes every hour and that most farmers prefer to rest at this interval in any case, for their own comfort. If this is true, deleterious effects of high temperatures may only be observed under conditions that necessitate maximum work output, such as a short wet season or the introduction of a double cropping system.

THE FUTURE FOR WORKING CATTLE

Replacement of working cattle by machinery in the Asian region has been associated with richer farmers and those areas where production potential is higher than average. Mechanization has proved popular with small farmers who are willing to accept debts greater than they have ever before envisaged. The economic advantage has been well demonstrated, particularly as use of machinery allows double cropping when the employment of working cattle would only have allowed single cropping. However, higher operational costs and inflation in developing countries has curtailed this demand during recent times. This may in fact contribute to a widening difference between rich and poor farmers, with the rich becoming richer through access to mechanization and the poor farmer being unable to improve his lot through lack of surplus capital. This unfortunate conclusion is perhaps the major determinant of the continuing use of working cattle.

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CHAPTER 8

BUFFALO

ORIGINS

Buffalo belong to the genus Bubalus in which there are three species; the Indian B. arnee which have evolved into the domesticated buffalo of today, B. depressicornis found only in the island of Sulawesi, and B. mindorenis found only in the Philippines. Neither the African Cape buffalo nor the Congo buffalo have been domesticated to a significant degree. Zeuner (1963a) presents the history of the buffalo from Neolithic times when hunters carved forms of the North African buffalo on rocks. However, north-western Africa is not believed to have ever supported the Indian buffalo while Europe most probably did during the Great and Last Interglacial periods. The Indian buffalo, the species of interest to the study of working animals, appears to have originally been confined to the Indian subcontinent.

The Indian buffalo of antiquity and that seen today in many countries of the world differ only slightly. Domestication probably followed the role of the buffalo as a pest to crop production although archaeological evidence relating to their early domestication is scanty. It is not certain whether the buffalo was utilized in a domesticated state in the Indus Valley civilization although seals from the Harappan culture of what is now Pakistan, indicate that domestication had occurred prior to 2500 B.C. Evidence of a similar age has been obtained from Mesopotamia. Several examples of references to domesticated buffalo have been recovered from the Akkation period (2500 - 2100 BC). The question of whether wild buffalo occurred in Mesopotamia and were then domesticated, or whether domesticated buffalo were introduced from the Indian subcontinent to Mesopotamia remains open to speculation by archaeologists. Nevertheless, the domesticated buffalo does not appear to have spread rapidly. As Zeuner (1963a) points out, the presence of the beast in Mesopotamia from early times seems to conflict with the experience of Egypt where it was not introduced until the Middle Ages despite its apparent suitability to the region. The slow rate of transfer of the domesticated buffalo technology may have been related to its preference for wet areas or to its reputation as a ferocious beast. In the case of the latter suggestion however, one would expect that the wild buffalo would have been featured in the Roman circus through the extensive Roman trade links; it was not.

Saint Willibald, a visitor to Palestine in AD 723, recorded his surprised observation of domesticated buffalo in the Jordan Valley. As Saint Willibald journeyed through Italy and Sicily prior to reaching the Jordan Valley, his surprise at seeing them in the latter region is taken by Kelley (1959) as an indication that they were not then present in Italy and Sicily. The spread of domesticated buffalo technology seems to have been associated, in part, with the spread of the Moslem religion although in the Balkan Peninsula it seems to have preceded Moslem conquest.

The slow progress of the domesticated buffalo to the west from the Indian subcontinent contrasts with its ready spread to the east. The buffalo spread to Indo-China and China itself and thence to Japan; no doubt in association with the cultivation of paddy rice. This has led to speculation that domestication of the buffalo was tied to rice production which was extensive in South East Asia and China. There is no definite evidence however, that the domesticated buffalo evolved in South East Asia or China rather than India despite some inconclusive osteological evidence from China. There have been many breeds developed during the domestication of the buffalo which are distinguished by body size, horn size, horn conformation and hair characteristics. The introduction of buffalo to other countries including Australia, Brazil and the Caribbean countries has occurred during comparatively recent history (mid nineteenth and early twentieth centuries).

The buffalo has featured strongly in the wars between the ancient Kingdoms of Siam and Burma during the sixteenth, seventeenth and eighteenth centuries. Employed both as transport animals, and in a cavalry mounted by Siamese warriors, buffalo are remembered as reliable beasts that fulfilled some purposes that the traditional war animal, the elephant, could not. Turkish history also includes references to the buffalo as a transport animal in the fifteenth century and up until the year 1918. The requirement of the buffalo for wallowing or bathing to avoid heat stress caused it to be considered an unreliable animal in this role in Turkey.

Buffalo of today are categorized as Swamp Buffalo or River Buffalo. The former group which includes the Carabao of the Philippines is found through South East Asia and is utilized mainly for the cultivation of rice paddies. The River type is larger than the Swamp type and is found in areas that include India, Pakistan, the Middle East, North Africa and Europe and includes breeds such as the Murrah, Surti and Nagpuri. Although used for draught to some extent, the primary role of the River Buffalo is milk production.

The distribution of buffalo in the world today is presented in Table 8.1 (Mahadevan, 1978). The total

Table 8.1

World Distribution of Buffalo

	(Thousand Head)
ASIA	
Burma	*1,883*
China	*30,110*
India	*60,767*
Indonesia	*2,823*
Lao	*1,072*
Malaysia	*285*
Nepal	*3,860*
Philippines	*5,050*
Sri Lanka	*736*
Thailand	*5,784*
Viet Nam	*2,330*
Others	*2,238*
OCEANIA	
Australia	*200*
EUROPE	
Bulgaria	*68*
Italy	*81*
Romania	*206*
Others	*78*
NEAR EAST	
Egypt	*2,280*
Iran	*130*
Pakistan	*10,563*
Turkey	*1,022*
USSR	*427*
SOUTH AMERICA	*166*
CARIBBEAN	*7*
WORLD TOTAL	*132,498*

Source: Mahadevan (1978)

population of over 130 million is divided between more than 20 countries, with India supporting almost 50 percent of the population, China more than 20 percent and Pakistan something less than 10 percent. Ninety-seven percent of the world's total population of buffalo are found in Asia. Within these figures however, the distribution of buffalo utilized for work purposes are not evident as the bulk of those buffalo found in the Indian subcontinent are of the River type. Similarly, the ratio of cattle to buffalo numbers is of importance on a country basis. In the Philippines and Thailand, there are more buffalo than cattle, and they are a major source of both farm power and meat.

Mahadevan (1978) has noted that despite the acknowledged importance of the buffalo in the agricultural economies of some countries, techniques to utilize this resource have not varied significantly for centuries. Far from indicating a self-evolved high level of efficiency, this points to the need for consideration of means of further exploiting an existing resource.

THE BUFFALO AS A WORKING ANIMAL

The buffalo is recognized as an efficient working animal in situations where speed is unimportant. It is utilized predominantly to puddle the soil of wet rice paddies and to provide the motive force for cultivation implements such as ploughs and harrows. Economical and efficient movement in muddy conditions is facilitated by the flexible nature of the fetlock and pastern joints peculiar to the buffalo. Other tasks performed by buffalo to which cattle are apparently less well adapted include the powering of irrigation water lifts and the threshing of rice by trampling, the latter of which is related to conformation of the foot (McDowell, 1972).

However, buffalo do appear to be inferior to cattle on hard surfaces due to their slower rate of walking, which is said to average 3.2 km per hour, and a lower degree of heat tolerance. Nevertheless, buffalo teams are capable of pulling loads on carts that are up to twice the weight than can be pulled by cattle teams (McDowell, 1972). It also seems true that female buffalo can be worked to a greater extent than female cattle without effects on reproduction or milk yield. The selection of the buffalo as a draught animal has presumably produced an animal that is well adapted to intensive smallholder farming which includes the provision of milk in some cases. Preferences for cattle over buffalo in the Philippines have been related to cattle consuming less feed of greater variety, not requiring wallows or baths and commanding higher resale values due to market preference for cattle meat (Samson et al., 1975). Comparisons with cattle in such general terms can be misleading. Selection of cattle in many regions has been based on parameters other than draught alone and the frequency of calving, which is necessarily affected by gestation period, possibly places a greater stress on cattle than on buffalo. Thus, while buffalo are most probably superior to cattle in the performance of certain tasks, no sweeping statements of the superiority of buffalo over cattle can be made.

One important difference between buffalo and cattle is their different abilities to withstand heat stress. Australian research (Moran, 1973) has demonstrated this difference in comparisons between Brahman cross, banteng cattle, shorthorn cattle and swamp buffalo, in terms of rectal temperatures, respiration rates, cutaneous evaporation rates and skin temperatures. Under conditions of exposure to natural heat and exercise, buffalo were shown to be the least heat tolerant; even less heat tolerant than the temperate cattle breed, shorthorn. It seems most probable that, in the feral state which is the normal condition of buffalo in Australia, or in the smallholder farms in South East Asia, wallowing serves as a means of reducing heat stress. Under constant working conditions however, heat stress becomes a real problem with all animals and buffalo succumb to this more easily than do cattle. Apparent exceptions to this general rule are usually associated with the relative adaptation of the animal species to the task being performed. Increasing ambient temperature can also have an effect on feed intake which will further affect performance. Measurable effects of increasing temperature such as speed of movement are useful means for the comparison of species when also compared to their performance under different conditions. Other considerations such as the heat of digestion associated with fibrous feedstuffs further complicate the issue. It is suggested that further comparisons between species should aim to isolate all feasible contributory variables if realistic discussions of the relative merits of draught species are to be made. Such isolation of variables would include equivalent training of both species to perform the work which is to be measured.

The buffalo is noted for is longevity and ability to continue working until late in life. Buffalo in Thailand have worked for an average of 13.9 years although in recent times demand for meat has induced the sale of younger animals thereby reducing this figure (Chantalakhana 1979). Instances of buffalo continuing to work up until the age of 40 years have been recorded by Cockrill (1974) who further notes that the farmer and the buffalo grow old together in the common South East Asian situation and "develop a high degree of responsiveness to each other". Such a relationship allows the best work performance of an individual beast, as the farmer will appreciate the effect of heat stress and easily, perhaps unconsciously, note its onset and therefore postpone work for a short period. In many situations it may be the farmers who also require a rest from work. Perhaps the only deficiencies in this system are a certain ignorance of the role of nutrition and implement designs in draught animal efficiency. This deficiency contrasts strongly with the voluminous qualitative literature on this subject for draught horses in the latter part of the last century and the early part of this century.

Buffalo are sometimes said to be unsuited to working in pairs and this is presented as a reason for the more common use of a single buffalo (Samson et al., 1975) and the virtual absence of large teams of buffalo anywhere in the world. Nevertheless, examples of buffalo pairs are plentiful in South East Asia as Cockrill (1974) points out.

The buffalo is utilized for puddling, ploughing, harrowing, threshing, carting, pack purposes, riding, drawing canoes along rivers as well as in sport and in war. It is utilized in the domesticated state in most of South East Asia although in parts of Indonesia, buffalo may spend half of each year in the feral state and be utilized during the remainder of the year for soil puddling, including the trampling down of weeds into the paddy, a system of proven value on swampy soils.

TRAINING

Cockrill (1974) attributes the short duration and ease of training buffalo to their quiet nature. Calves may serve their apprenticeship by walking beside their working mothers such that little conscious training by the operator is necessary. Otherwise training may begin at the age of four years with buffalo reaching prime working age at around eight years. In instances where wild animals are to be trained, buffalo of less than three years of age are preferred. After capture, wild buffalo are quietened by handling and restraining often in a village or road situation to accustom them to humans.

Even in the northern Australian situation of mass herding of wild buffalo, domestication sufficient for the easy handling of these animals can be effected within a few weeks. Their fundamentally quiet nature and subsequent ready acceptance of man is testified to by these experiences although the buffalo of Egypt appears to be an aberration.

Whips are seldom used with trained buffalo. Blunt goads are used occasionally and then only with care to guide gently along the desired route. Reins are similarly utilized to guide animals and a simple flick of the rein from one side of the beast to the other is sufficient for executing the turning of corners. Rough handling of buffalo is seldom practiced by buffalo owners because it is unnecessary and does not promote an even temperament.

The principal work performed by the buffalo is associated with the production of paddy rice. It is suited to the paddy field environment and has not only been called the 'living tractor' of Asia but has also been granted the dubious honour of having small, two wheeled tractors named after it in such forms as the "Iron Buffalo".

Buffalo and the equipment utilized by them are well suited to intensive rice production as practiced in wide river valleys of Asia. With little road access, buffalo can move along narrow walking tracks or step over paddy banks with ease and care. Similarly the ploughs and harrows utilized from China through most of South East Asia are constructed of wood and therefore sufficiently light that they can be carried to the work site by the operator alone. Buffalo are sometimes worked in pairs although it is more usual for single harness systems to be utilized and these harnesses are simply constructed and simple to repair. Nevertheless, improvements in both harness and implement design could lead to large increases in mechanical efficiency.

Harrowing is performed after ploughing and flooding of the paddy, a function that perhaps illustrates the adaptability of the buffalo to this environment more than does any other single step. Wading through an average of 60 cm of mud, the buffalo responds to the operator's instructions, his large feet assisting in the crushing of clods as he draws the harrow through the mud. Harrows other than the common comb harrows are also utilized with buffalo such as the shallow seed harrow used in Bangladesh, which is constructed from bamboo. The final preparation process is one of grading the surface by use of a flat piece of timber or bamboo drawn by the buffalo which moves the upper layer of mud across the paddy.

During harvest, buffalo may again be utilized to pull heavy carts loaded with rice sheaves. Sleds are also utilized for this purpose in the Philippines, Thailand and Northern India for everyday transportation of goods. Control of the buffalo appears to be easily effected by means of a single or occasionally a double rein attached to a rope through the pierced nasal septum or attached to a horn.

Buffalo are also commonly utilized in the rice threshing process. From preparation of the threshing floor itself by trampling after wetting and sweeping, to trampling of the sheaves of rice on rattan mats spread over the prepared floor, buffalo are ever present and well utilized. The buffalo are forced to walk in a circle on top of the rice sheaves to separate grain from the stalks. Grain damage is minimized by the presence of the straw and the process involves periodic rest periods for the buffalo while straw is collected. This system of threshing can usually produce around 500 kg of grain per hour. Hand threshing and small scale hand or motor driven threshers are increasing in popularity in many regions of South East Asia and may well replace this function of the buffalo which, while reasonably efficient is more difficult to organize and requires more assistance than does a simple wooden hand powered thresher. An alternative system is employed in Egypt for rice and other crops where metal discs drawn on a circular route by buffalo crush the sheaves after which a winnowing process separates the grain from the straw.

While the buffalo is considered to be an important component of the agricultural system, management of crops take precedence over management of the buffalo. In cultures where rice is grown extensively, fencing is uncommon and animal control is effected by tethering. This is an efficient process for animal production if managed correctly, however, this is not always the case. Due to the presence of other agricultural activities and traditions of long standing, buffalo and other draught animals may enter periods of peak work requirements after a period of poor nutrition. In rice growing areas, this period of poor nutrition is not necessarily the dry season because, during the main rice growing period in the wet season, buffalo are often tethered near houses and fed on rice straw from the previous crop and some green fodder from roadsides. During the dry season, in the common situation of insufficient irrigation water for a dry season rice crop, buffalo may be allowed to graze rice stubble and seek out other species.

It is likely that, under the nutritional condition enforced by the rice production system, buffalo may seldom be consuming a diet of optimum quality for work. An interesting economic system that possibly allows buffalo to be in better condition for the onset of the rice season and is mutually beneficial to both of the parties involved occurs in northern Thailand (Falvey, 1977). Buffalo utilized in the lowland paddies are agisted to or rented from, neighbouring mountainous areas where they have enjoyed free range grazing during the dry season. As the native pasture in the highland is at its peak in quality soon after the annual wildfires endemic to the highlands (Falvey 1980), buffalo may be grazing succulent regrowth prior to the onset of the wet season and their peak work load. The benefit of this interaction cannot be easily reproduced elsewhere as it takes its benefit from the geographical relationship of the highlands and lowlands in this area.

TRACTION

Carts of various designs are pulled by buffalo in many countries of the world. With adequate resting and douching or wallowing, the buffalo can be utilized for this role to a similar extent to cattle, although speed still favours the cattle. In India a pair of buffalo is recognized as being able to pull a heavier load than a pair of cattle.

Observations in China suggests that castrated male buffalo moving at approximately three km per hour can draw a load of 900 to 1,360 kg or loads of 400 to 1600 kg over 25 km in one day depending on their breed (Epstein, 1971). In Indonesia, buffalo of liveweights between 500 and 600 kg convey produce in carts with gross loads of up to two tonnes by road during the cool temperatures of the night. On the Indian subcontinent buffalo, sometimes in conjunction with cattle, draw heavy loads; a pair of buffalo are said to be capable of hauling a two tonne load over 25 to 32 km in a day. However, the most efficient utilization of buffalo traction must surely be that of one buffalo pulling up to four loaded trucks along a narrow gauge railway line, as is practised in Taiwan.

Buffalo drawn carts, in common with many carts utilized with other animal species, have no brakes except the animals themselves. Well trained animals can slow down in a short distance but their physical conformation is actually quite poorly adapted to this purpose. Road transport on hard surfaces requires protection of the feet by use of shoes, which may be constructed from discarded automobile tyres as is practised in Indonesia, closely woven straw pads as is practised in Taiwan, or from metal similar to those used with horses. Carts with pneumatic rubber wheels are more efficient than wooden or steel rimmed wheeled carts; work in the Philippines has confirmed increases in the loads able to be hauled (Cockrill, 1974). Four wheel wagons are utilized in those areas of Europe where buffalo are still employed for road transport, namely Bulgaria and Yugoslavia and until about 30 years ago, Italy.

BUFFALO AS PACK ANIMALS

Buffalo are also utilized as pack animals for the transport of grain and other commodities. It has been conservatively estimated that a buffalo weighing over 600 kg can transport at least 250 kg at a speed of three kilometres per hour (Cockrill, 1974). Figures for buffalo in China indicate that loads of 100 to 150 kg can be carried for a distance of 25 km in one day (Epstein, 1971). Such a capacity suggests that the buffalo may be a superior pack animal to horses, mules, donkeys and elephants but may not be as efficient as the pack camel.

Pack buffalo have been utilized to a greater extent in the past. It is reasonable to assume that the decline in popularity of pack buffalo and pack animals in general is related to the rapid expansion of road construction. Once roads have been constructed, carts are obviously a more efficient form of transport. Thus pack animals are relegated to the remote areas isolated by lack of roads or in some cases roads with slopes of too great a gradient for the use of carts.

Buffalo may also provide the power for milling and oil extraction purposes. Commonly the design of such implements requires the animal to walk a circular route to power an eccentric mortar and pestle arrangement. Irrigation systems powered by a Buffalo Wheel utilize a similar principle. The traditional practice of blindfolding of the animals is still followed in many cases although no valid explanation of the necessity for this act has been presented. Buffalo are also utilized to puddle clay for brick manufacture in Sri Lanka and to draw snow ploughs in Bulgaria and Greece (Cockrill, 1974).

WORK CAPACITY

A common means of assessing the working capacity or output of buffalo and cattle, apart from those relating to traction and packing as previously discussed, is to estimate the area ploughed per animal unit per time unit. This means of comparison has proved useful in surveys such as that conducted through the Kasetsart University in Thailand, although they cannot allow for differences in soil types and environments, nor of the condition of the buffalo. Tables 8.2 and 8.3 illustrate the work output and the periods of the

Table 8.2.

Working hours of buffalo in Thailand.

Zone of Thailand	Number of Buffaloes	Area Cultivated per buffalo (ha)	Number of hours worked per day	Area Ploughed per day per buffalo (ha)
North	1.8	1.1	5.2	0.11
Korat	2.0	1.7	5.1	0.08
Tha Pra, Udorn, Ubol	1.8	2.2	4.8	0.08
Central plain and southeast	3.0	1.9	4.9	0.11
All Zones	2.1	1.7	5.0	0.10

Source: After Cockrill (1974)

year that buffalo are worked in Thailand. One conclusion that can be drawn from this data is that buffalo are not being utilized efficiently with regard to time. Even when the need for rest periods is considered, it would seem that a greater work output would be possible in a year. The agricultural calendar, as determined by rainfall, is often the limiting factor rather than buffalo themselves. Nevertheless, the prime economic advantage of machine over buffalo cultivation is related to this time factor. In regions where continuous cropping is desired or where unfavourable soils or seasons require rapid cultivation of large areas, machines can be utilized even on a 24 hour per day basis whereas buffalo require rest periods and may not be able to work during the hottest period of the day.

Table 8.3

Months worked by Thai buffalo.

	Months worked per year		Days worked per month												Total days per year
Zone of Thailand	*Range*	*Average*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*	
North	2-8	3.3	0	1.1	0.9	0.7	4.3	17.3	19.3	16.1	1.8	2.9	0.7	1.1	66.2
Korat	4-12	5.6	3.9	3.9	3.9	3.9	15.2	25.9	28.3	15.0	3.9	3.9	3.9	3.9	136.9
Tha Pra, Ukorn, Ubol	1-12	5.3	0.9	0.8	2.2	3.5	22.3	25.2	26.7	26.9	20.7	6.3	1.9	0.9	138.3
Central Plain and southeast	3-10	7.9	10.3	7.8	3.0	4.1	17.4	22.8	22.2	21.8	11.3	8.8	6.6	10.0	146.1
Average		5.5	3.8	3.4	2.5	3.0	14.8	22.6	23.7	23.3	12.2	5.5	3.3	4.0	122.1

Source: After Garner (1979).

In Thailand, buffalo are used for work 60 to 146 days per year with an average of 122 days. Other surveys have indicated figures of 50 to 60 days work per year for the central region and 20 to 78 days for the northern region. Buffalo were worked for an average of five hours per day and are capable of ploughing 0.02 to 0.06 hectare per hour. One buffalo working seven hours per day can plough and harrow 3.7

hectares in three months at an average rate of 24 days preparation per hectare. A separate study in the northeast of Thailand indicated that a buffalo must be worked for 72 hours to plough and harrow each hectare of land and that the requirements for unirrigated crops was similar to that for paddy rice. Ratios of 1.7 hectares of cultivated crops per buffalo and an average cultivation rate by buffalo of 0.1 hectare per day are common.

In China, areas of land that can be cultivated by different buffalo breeds in a working day of eight to ten hours vary from 0.25 to 2.3 hectares (Epstein, 1971), although these differences may not reflect the relative capacities of different breed types as much as they do different soil characteristics. The size of the animal, its condition as determined by nutrition and health, its training, the method of harnessing and the speed of travel are some of the factors that affect working capacity. Castration, often suggested to be a requirement for producing tractable draught buffalo, also affects working capacity. Intractability of uncastrated bulls is seldom a problem according to Cockrill, (1974).

The efficiency of work output of the buffalo can be increased by improvements in harnesses, implements and vehicles. Research concerning improvements in the harnessing of buffalo in Thailand indicates increases in drawbar-pull power of 24 percent and horsepower developed of 70 percent. Great interest among farmers during the development of new harnesses was attributed to obvious improvements in work output. Existing systems of yoking represent the intention of safe and simple animal control. Improvements in existing systems including improved nutrition may be of greater immediate and possibly long term benefit than replacement of working buffalo with machines.

A study conducted in Swangsi province, China, suggested that swamp buffalo were less efficient draught animals in terms of absolute draught power and speed of ploughing than crossbred Murrah River buffalo (cited in Chantalakhana, 1979). However, the differences between the breed types is not great in absolute terms and seems largely to be related to the sizes of the animals. Supportive justification for crossbreeding between the Murrah and the Swamp buffalo breeds include increases in milk production which again relate to nutrition and may not be of major importance in the immediate future in those countries where animals are not usually milked. Caution and planned research is warranted in these situations to avoid the situation of a decrease in draught capacity.

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CHAPTER 9

THE HORSE

The horse has been the working animal most closely associated with man across most of the world. Today the importance of the horse has necessarily declined as western cultures rely on oil driven machinery and developing countries follow their traditions of utilizing ruminants as working animals. In tropical regions, the poorer quality of forage favours the husbandry and utilization of ruminants over horses because of the superior ability of ruminants to digest such feed. Related to this point is the pressure on grain crops in developing countries for human consumption rather than for the feeding of horses.

ORIGINS

Fossil records suggest that the horse has evolved from a foxterrier sized animal (Eohippus) through animals larger than todays draught horses during the Pleistocene era (E. giganteus) (Howell, 1965).

The paleontology of the horse is viewed by Zeuner (1963) to be the evolution of a species and subsequent differentiation of sub-species through geographical separation. This is substantiated by the evidence that interbreeding between either the horse, the half-ass, the ass or the zebra will produce mules. Differentiation within these sub-species has continued and specific identifiable races are now recognized within sub-species.

In the case of the true horse (*Equus caballus* L.), two wild races are known to have survived into modern times. These are Przewalzke's horse, a herd of which is maintained near Munich, West Germany, and the tarpan, which became extinct during the nineteenth century from hunting, stimulated by the nuisance of the wild horse to agriculture.

DOMESTICATION

The horse was not domesticated during either the Palaeolithic or Mesolithic periods and is probably one of the later species to be domesticated. It is definitely known that the horse was domesticated by about 2000 BC because references to horse drawn chariots are plentiful from that time onwards. Domestication must have preceded the use of the horse for drawing chariots, because an advanced degree of training is required for such a task. However, domestication of the horse may not be as old as the chariot itself. Cattle were first utilized for drawing carts and refining of cart designs probably took place during that early phase with the horse being introduced to the task when equipment was able to be utilized with an animal of a more flighty nature.

The origin of the domestic horse has been suggested to be western and central Europe north of the Alps, eastern Europe and western Asia north of the mountains as far east as Russian Turkestan (Zeuner, 1963). The probable site of first domestication is thus suggested to be Turkestan where areas of fertile soils were separated by non productive areas thereby introducing the need for working animals; in the first instance these would have been cattle. However, as water sources became less available with the advance of primitive agriculture, domestication of the horse allowed these people to become semi-nomads practising a form of shifting cultivation.

Ancient civilizations in Mesopotamia possibly came into contact with the horse in the third millennium BC although the first reliable evidence only dates to about 1800 BC, and by about 1700 BC the horse was spread through all countries of that region. The horse is known, from the evidence of art work, to have been common in Egypt by about 1600 BC and, in common with the horse of Mesopotamia, was probably quite similar to the Arab breed of today.

In central Macedonia, the horse was also domesticated by about 2000 BC with the earliest picture of a domesticated horse in Europe dating back to about 1550 BC. Zeuner (1963) postulates that the history of the domesticated horse began in Macedonia around 2500 BC. By 2000 BC it had spread to the Caucasus area and was known in Asia Minor (Mitanni) and by 1800 BC it had reached Troy. During 1700 BC it spread over the whole of the civilized Near and Middle East, in association with the chariot.

The history of the domestic horse in other regions, such as the Indian subcontinent and China, is similar with complete absence of evidence older than about 2000 BC. Suggestions of earlier dates from osteological evidence are regarded to be unreliable. One interesting archaeological find in China was an early graveyard where hundreds of horses and chariots of the Bronze era were buried. A Cavalry was developed after the use of chariots which was facilitated by the occurrence of wild horses in some parts of China (Zeuner, 1963). The pasture legume, lucerne, was later (128 BC) introduced to China by a Chinese general, Chan K'ien, to feed the valuable horses that he had purchased from Iran (Hyams, 1972).

During more recent history, the many breeds of horses recognized today came into existence through the process of deliberate selection. The most important breeds to the study of working animals are the draught horses. These originated during the seventeenth century when the powerful horses that had been bred to carry knights wearing heavy armour into battle, became less popular and alternative uses for the horses were sought (Epstein, 1971). The most common use of horses in many sections of developed countries is as pleasure animals. Figures such as those from a study in Lane County, Oregon, USA, indicated that only four percent of horses are used as working animals (Cole and Ronning, 1974). While these horses may represent many of the some eighty different breeds recognized today, they are not of interest to the discussion of working animals save that they do represent a genetic pool that may be useful in the future if working horses with some different characteristics are required.

Today, the horse is bred in nearly every province of China except those in the south east where buffalo are the predominant draught species. Epstein (1969) has classified the horse species of China into seven major types and six local breeds. Mongolian ponies, the ponies of north-eastern China, the Sanho horse, the Kazakh pony, the Tibetan pony, the Tatung pony are all utilized as either pack or draught animals (Epstein, 1969). The vastness of China with its many environments has created the need for horses of various abilities to suit work in their environment. While the history of horses in China may be of slightly shorter duration than that of Europe, their role in the history of China has been similar to that of Europe.

In India, horses and ponies numbered a total of some 1.3 million head in 1961, which represents a reduction of more than ten percent from the population recorded in 1956. This decrease in numbers is related directly to the increase in motor transport and it appears that the horse is being replaced to a larger extent than any other animal utilized for road transport. Five breeds of horses occur naturally in India (Singh, 1966) and differences between these breeds are the products of both deliberate selection and geographical separation.

The horse is utilized today in the Philippines, primarily for transport in hilly areas and coconut plantations and is not usually involved in agriculture as a draught animal for cultivation. Horses are said to be superior to other animals because they exhibit a higher degree of stamina than do other domestic stock that can be utilized for the same purposes. Similarly, in the highlands of Thailand, horses are utilized together with asses and mules as pack animals (Falvey, 1977) because they are said to be better adapted to the tasks than cattle. Opium trains are usually composed of pack horses, asses and mules that travel along winding mountain trails across Burma, Thailand and China. Opium being an especially light weight crop per unit value does not require large numbers of animals, however the persons associated with the opium trade also transport jade and other items, which require many tens of animals per train.

THE HORSE AS A WORKING ANIMAL

PACK HORSES

Pack horses can carry a load equivalent to approximately one quarter of their body weight. The Mongolian pony which weighs between 250 and 300 kg is accepted as being capable of carrying 80 to 100 kg for pack work or drawing a load of 800 to 1,000 kg over distances of between 40 and 60 km per day. The Kasakh pony is said to be capable of carrying a load of 100 kg per day, but perhaps the most remarkable work output of a pack horse is that of the Tibetan pony which can carry a 90 kg load on its 275 to 320 kg body, all day over steep gradients in rugged mountain terrain without showing any great fatigue (Epstein, 1969).

Hauling of loads, sometimes using sleds is practised in many places such as the southern Philippines, where it is claimed that a horse is capable of hauling a load of 225 kg while buffalo would usually only haul about 130 to 185 kg. Similarly, horses are said to be able to haul such loads for longer periods than can buffalo, probably because of their faster natural walking pace (ADAB, 1978).

The importance of reserve power in working animals to enable them to cope with the short duration exertion associated with some tasks, such as starting a wagon moving as opposed to keeping it moving, is possibly another advantage of the horse over some other working animals. Well trained horses can accomplish ten times the normal rate of work, and can exert a temporary pull nearly as great as their liveweight. This is probably related to high reserves of glycogen in the tissues of horses and in inherently higher metabolic rates than other domestic animals.

Cattle can haul a load of a similar weight to that which horses can haul on a per beast basis, however, the speed at which cattle will haul that load is only about two-thirds as fast as the horse. The work output of a horse team weighing a total of 2,023 kg has been recorded pulling against a dynamometer reading 1,773 kg which is equivalent to starting a load of about 25 tonnes twenty times consecutively.

The absolute work output of a horse increases with body weight but the increment in output decreases with liveweight increments after a certain point. A mature horse can easily exert the 10 to 20 kg of draught required to maintain the movement of a one tonne wagon on a level surface although the 34 to 100 kg required for unsealed roads may sometimes require more than one animal. Speed of movement affects efficiency at speeds above four km per hour and it has been estimated that at a speed of 18 km per hour, work output is reduced to ten percent of that which could be expected from a slower rate.

The size of horse best utilized for different tasks is related to the required level of work output and the reserve energy of the horse to overcome obstacles. For example, the mean draught required to pull a plough through unbroken ground is perhaps an irrelevant term in calculating the size and number of horses to be utilized, because it does not indicate the magnitude of the short term draught that is required to overcome exceptionally hard sections. In most circumstances, the types of horses available for a particular task are limited so that the aspect of choosing the correct horse for each task is not applicable. An individual farmer or horse owner is usually forced to utilize his horse for a wide range of purposes.

Horses used for riding have been excluded from this discussion because they are usually used for pleasure rather than work. One obvious exception is the stock horse used on ranches where an agile, intelligent horse with the ability to start, turn and stop quickly is essential. Similarly some riding horses are utilized out of necessity rather than pleasure.

THE WORKING HORSE IN DEVELOPED COUNTRIES

The horse, with its centre of domestication close to Europe and its adaptation to a cool or temperate environment, figured substantially in the development of western agriculture. The acceptance of the horse as the standard unit of work is evidenced by the use of the term horse-power in engineering today; a fitting remembrance to the animal that was largely replaced by the industrial revolution to which that term belongs. Early physiological experiments indicated that a horse could work at a constant rate of 22,000 foot-pounds per minute; this figure was increased to 33,000 foot-pounds per minute for use as the unit of horsepower after James Watt had constructed his steam engine. The French developed their unit of work the cheval-vapeur on the energy that was required to lift a weight of 75 kg one metre in one second, and thus arrived at a unit of work that is 0.66 that of the British "horsepower" (Lewinsohn, 1954).

As the industrial revolution began, the limitations of the horse and the possibility of producing a better form of power and locomotion was realized. The increasing frequency of accidents with horse drawn vehicles on crowded roads added to interest in alternatives and the drain of horses for military purposes associated with the Napoleonic wars, provided the impetus for the development of railways. The three purposes for which horses had historically been used namely food, clothing and transport, were reduced to two main purposes with the construction of the first railway (Lewinsohn, 1954).

Today the utilization of draught horses in western agriculture is uncommon. Occasional use of horses may be made in areas where productivity is low but economic reliance on draught horses in the agriculture of developed countries is difficult to find. Even in Japan, horse ploughing of dried paddy fields declined rapidly in this century (Matsuo, 1976). Perhaps the major working role of the horse in the developed countries is as a stock horse in the remote regions where extensive sheep and cattle ranching are practiced.

PHYSICAL ATTRIBUTES OF THE HORSE

The popularity of the horse in history has been largely associated with its intelligence and ability to endure demanding work at speeds uncommon for other animals. Endurance is assisted by the makeup of the hooves of the horse which are adapted to the absorption of the concussion shocks that occur especially at higher speeds. Some of the important characteristics in this respect are; the angle of the hoof to the ground, the plantor cushion and the cartilaginous plates (Cole and Ronning, 1974).

The ability of the horse to sweat is important to its suitability to working. The horse is better adapted to cold, temperate and sub-tropical areas than it is to hot, tropical areas, as is suggested by its insulating hair coating. In hotter climates the coat remains short by constant shedding of longer hairs. The Arabian horses, which are better adapted to hotter climates than most other breeds are also lighter and have greater surface area to body volume ratio than do horses adapted to colder climates.

The horse is not adapted to working at altitudes in excess of 3,000 metres and enlargement of the heart in response to low atmospheric oxygen levels is a common problem in such conditions. These problems can be partially overcome by maintaining a number of working horses at different altitudes so that they do not have to adapt to any other conditions; a practice employed by the Peruvian army (Cole and Ronning, 1974).

The primary physical requirement in the development of the draught horse has been strength and stamina. Thus the draught breeds are heavy, well-muscled and have a forward-located centre of gravity through the supporting of much of the animal's weight on the forelegs. According to tradition, the draught horse has also been selected to have a large chest capacity supposedly to enable increased respiratory capacity. The draught breeds present in western countries today have been bred for size and physical appearance to cater for the increased interest in showing of these animals. An early description of the attributes of a good show draught horse is presented by Anderson (1943) and it is of interest to note that, while many of the selection criteria may once have been related to work output, they now have become formalized characteristics to which horses must conform in order to earn points, and these characteristics may nowadays be unrelated to work output. The draught breeds of other countries tend to be smaller and have been selected primarily for working ability under various conditions.

MANAGEMENT

Horses require regular attention from their tenders to prevent the onset of disease and the many ailments that are specific to horses. Traditions common to the tending of horses may sometimes be unnecessary in terms of animal health when pleasure horses are kept under hygienic conditions and exercised sensibly; nevertheless, the origins of these traditions such as regular grooming and washing probably lie in the essential management of working horses in older times when horses did not always enjoy comfortable and clean stalls.

Feeding requirements of horses are critical if regular work output is desired. The provision of a ration high in carbohydrate for working horses is a standard recommendation and is evidenced by the use of the feeding bag which allows the horse to eat during brief rests from work without the bother of unharnessing. An important distinction between horses and ruminants under working conditions is the aspect of feeding management. In remote conditions where grain feeds may not be available for the feeding of horses, tenders may cut nutritious forage to feed to their horses while such inputs for working cattle are less often observed. For example, in the mountainous north of Thailand, the nutritious grass species Thysolaena maxima (L.) is cut and carried, sometimes several kilometres to horse feeding stalls. In the same area, cattle utilized for pack purposes are seldom offered any feed apart from that which they can forage themselves in the forest (Falvey, 1981). Nevertheless, horses, together with asses and mules, are preferred to cattle for pack purposes because they are faster, more reliable and more intelligent.

The National Academy of Science, Washington (1973) has noted the different nutrient requirements of horses performing different work, particularly with respect to energy requirements. Some of the factors of importance are the type of work undertaken, the condition of the horse, the relevance and degree of its training for the task in hand, the ability of the operator, fatigue, environmental temperature and dietary composition. They adopt the assumption that the energy requirements of draught horses are three times those of the basal metabolic rate for light work of two to three hours per day and 3.5 times for medium work of four to five hours per day when loads of approximately ten percent of the body weight of the horse are pulled at a rate of 3.5 km per hour. Other systems have utilized different bases and the variations between those systems possibly lie in the interpretation of the terms light, medium and heavy work.

Calm disposition of a horse is held to be of great importance in maximizing work output as a quieter animal is better able to economise on wasteful movement and less likely to become excited by extraneous stimuli. Shoeing is of importance, and while not essential, is of proven value on hard surfaces and is probably of value even on soft surfaces under working conditions. Other aspects of horse management that are traditionally recommended include; regular exercise during periods when the horse is free from work, filing of teeth to prevent the occurrence of sharp points that may prevent efficient mastication, gradual rather than sudden changes of diet and protection of the horse from excesses of cold and heat.

Numerous references to the management of horses are available, perhaps because the horse more so than any other animal, has provided the source of power for western civilizations. Objective recommendations are however difficult to separate from subjective beliefs concerning the management of horses. An interesting combination of the two is presented by Clark (1956).

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CHAPTER 10

ASSES AND MULES

For most purposes the word donkey is interchangeable for that of ass, with the possible exception of those sources who insist that the Onager be referred to as an ass, and the true ass as a donkey. This exception seems unnecessarily confusing and is not adhered to in this text. Perhaps a useful delineation is to reserve the term donkey, for domestic asses as distinct from wild assess; a further distinction is also necessary to separate the true asses from the half-asses as is discussed in the following section.

THE ONAGER AND THE TRUE ASS

It is important to distinguish between the Onager or half-ass (Equus hemionus) and the true ass (Equus asinus). The term, half-ass, is misleading and has presumably been used because the Onager bears certain physical similarities to the true ass. It is however, a different subspecies of the Equus family that traces its origins to geographical separation and consequent inbreeding over a long period of time, as has been discussed in the previous chapter. Physically, the Onager differs from the horse and the true ass in terms of possessing ears that are longer than those of the horse yet shorter than those of the true ass. Front hoofs are narrow, forelegs are chestnut in colour and the tail appears tufted rather than being composed of long hairs as is the case in the horse. The true ass is similarly separated from the Onager by stripes along its back, shoulders and forelegs.

Geographically, the Onager occupied the dry lands from

Syria to Mongolia and once occurred as far to the north-west as Europe, where the true horse also occurred. The subspecies tolerates coldness very well and for this reason, Zeuner (1963) believes that it is possible that in the Upper Pleistocene period, it was able to migrate into central Europe.

The Onager was utilized as a working animal by the ancient Sumerians. Certain scholars regard the Onager as untameable, however, archeological evidence from the Royal Cemetery of Ur in Chaldea in the form of art work depicting Onagers pulling carts, has refuted this suggestion. Thus Onagers may have been used as working animals at a similar date (approximately 2500 BC) to horses although in a different region. When the horse was introduced to Mesopotamia (approximately 1100BC), it apparently replaced the Onager as the working equine. However, despite its demise as a working animal, the Onager may have continued to be utilized for breeding with horses to produce mules. This breeding programme probably continued into the Roman period because references by many authors to the crossing of wild asses and horses during this period could not have meant the true asses, which never occurred in the wild state in that area (Zeuner, 1963).

Today the Onager still exists in north-western India although it became extinct in the Mesopotamina region about one century ago. The Onagers of the Rann of Cutch in India are described as being swift of foot, able to survive on sparse, poor quality vegetation and showing a preference for open places when afraid (Zeuner, 1963a). The Onager is not utilized as a working animal today; its early role as a working animal was most probably a reflection of the unavailability of more docile and easily managed alternatives, which suggests the reason that it was so easily displaced by the horse.

THE TRUE ASS

The true ass (Equus asinus) originated in Africa and there were once three wild races that evolved through geographical separation within the continent of Africa. The original distribution of the wild ass was probably continuous from Somalia, through the Libyan Desert to Morocco although they also apparently occurred as Equus hydruntinus in Europe during the Upper Pleistocene period (Peuner 1963). These wild ass races are now either extinct or close to extinction in Africa, with those referred to today being escaped domestic asses that have adapted to the wild.

The ass was originally domesticated in the Nile Valley civilization although the particular site is unspecified. Libya possesses the earliest archeological reference to the domesticated ass which dates to approximately 2500 BC, and

1. *Limits of the distribution of the ass.*

2. *Presumed area of domestication of the ass.*

Adapted after Cole and Ronning (1974)

Figure 10.1 Premodern distribution of the ass.

its seems likely that the domestic ass was thence brought to Egypt. The three races of wild ass then present in Africa shared in the development of the domestic ass as the practice spread to other regions of the continent. Spread of the technology to areas outside Africa took some time and some of the earlier references to the use of the ass on the continent of Africa are contained in the Bible (see for instance Genesis 12:16 which suggests the importation of asses, from Egypt to Palestine). The meaning of the name of the town Damascus in cuneiform script is the town of the asses, although this may refer to wild asses which Zeuner (1963a) believes were probably Onagers rather than true asses. The period of more rapid spread of the ass across the Middle East coincides with that period when the camel became more popular over a wider area, which was possibly in response or at least associated with the increasing nomadism necessitated by soil deterioration and aridity. The distribution of the ass and the presumed area of domestication are represented in Figure 10.1 which is adapted from Cole and Ronning (1974).

Initially the ass was used by the Egyptians as a pack animal which remained its sole function for a long period, until riding became an accepted practice. Utilization of the ass for draught purposes came even later. Among early peoples, only the Jews and Nubians engaged in the riding of asses regularly, although the practice has become almost universal over the last 2,000 years.

The ass did not reach Europe until sometime before the Middle Ages, presumably because of the presence and utilization of the horse. Even during the period of great trade under the Romans the ass, although introduced, was not utilized extensively except along the coast of Mediterranean France. The potential value of the ass and its hybrid progeny, the mule, as beasts of burden was possibly the reason that it was introduced to other countries to which they were thought to be suitable. The ability of the ass to adapt readily to wild conditions has led to populations of feral asses emerging as pest species in some countries. The total population of the ass today is something around 40 million with the largest populations being present in the countries; Ethiopia, Brazil, Mexico, Turkey, Afghanistan and Morocco.

In India, the one million or so asses present are of two local breed types and at least five imported breeds (Singh, 1966). Information concerning the relative working ability of the different breeds is scarce and, to a certain extent, many of the new breeds mentioned in recent literature represent the popularity of asses as pets in the richer countries. The asses of China were, according to Epstein (1969), introduced in about 300 BC and since then have been bred in various sections of China, particularly Mongolia, Sinkang, Tibet and southern China. Epstein distinguishes the following types;

the Kwanchung ass, a large animal weighing around 350 kg that is suited to draught work, the Shensi which weighs about 230 kg and is utilized for pack work, and the medium and small Chinese asses are for either short distance pack work or powering of flour mills.

ATTRIBUTES OF THE ASS

The poor opinion held of asses in all areas where they are employed is possibly due to its unexcitable temperament and also to the long standing association between poverty and the ass. The less thrifty horse, in terms of feeding requirements, has been the animal of prestige while the ass has been the poor man's slave over much of the history of the domesticated ass. However, in ancient Egypt and indeed into quite recent times, large white asses have been prized and used as royal mounts by Sultans. Romans similarly paid excessive sums of money for special asses and in ancient Greece, the ass was the sacred beast of the goddess Hesta.

The feeding requirements of the ass are more modest than those of the horse (Hyams, 1972) which is possibly an important attribute that has redeemed it from total obscurity. The ass can survive and work when consuming a diet of poor quality whereas the horse requires supplementary feeding during work. The ass is the preferred animal in some areas such as Dusan due to its strength and stamina. The ass exhibits adaptation to both hot and cold climates by the degree of hair covering, although the ability to work with economy of movement probably assists to a greater extent in hot climates. The stubbornness of the ass appears to be an inherent part of its nature although differences between breeds do exist with respect to this trait. For example, the Kwangchung draught ass of China is noticeably more tractable than is the Siumi pack ass (Epstein, 1969).

One distressing aspect of importance in the management of the ass is its apparent disinterest in danger. Asses will make little attempt to avoid wolf attacks and at times death, whereas a horse stallion will attack wolves and drive them away.

THE ASS AS A WORKING ANIMAL

From use as a pack animal, the ass was utilized for the treading of corn and the pulling of carts, practises that can still be seen today. In some instances, an ass may be yoked with a camel if no more equal pairing can be arranged (Zeuner, 1963); the spirit of the Biblical injunction, that animals not equally matched should not be yoked together is of little consequence in those countries where the alternative is increased manual labour or hunger. The use of asses as pack animals began with the transport of crop harvests in ancient Egypt and progressed to the transport of materials during time of war. Packing by the ass is still its principal use today in countries as far distant from each other in many ways, as Ireland and Thailand.

During the Roman period, the ass was utilized extensively in the industries of grain milling and gardening. For grain milling, a blindfolded donkey turned the grinding stone by walking continuously in a circle while yoked to the mill stone. This innovation was also commonly utilized in water wheels and mechanical appliances using asses as the source of power.

As a pack animal, the ass can carry between 47 and 67 kg according to Sudanese Government regulations although, as Cole and Ronning (1974) note, nongovernment asses carry between 90 and 135 kg. The ass travels at a speed between three to five km per hour and can accomplish regular distances of 25 to 32 km per day although distances of 55 km have been recorded (Epstein, 1969).

Riding asses are recognized as a separate breed to pack asses because their load, the human, is more difficult to carry and makes additional demands. The riding ass is generally about 10 to 20 cm taller and walks at a faster rate than a pack ass. However, it is difficult to distinguish between the two breeds because the riding ass may be loaded up with goods before the rider climbs on top. One therefore suspects that the larger breed may have arisen simply to provide an animal with a greater carrying capacity, rather than specifically for riding purposes.

THE MULE

The limitations of the ass as a working animal are compensated for when its essential role in the production of mules is considered. Crosses between the horse and the ass and the Onager and the ass have been tried over several centuries with the most successful hybrid by universal acclaim being the progeny from a male ass and a female horse. The reciprocal cross, that of a male horse with a female ass produces the hinny, which is quite rare and probably is of inferior value as a working animal. Neither hybrid is usually fertile. It is also practically more difficult to produce hinnies, as horse stallions are not always willing to mate with jenny asses whereas the reverse is not true of the jackass. Horse stallions kept for crossing with jenny asses are usually prevented from mating with mares. If experience from China can be applied generally, fertility from the hinny-producing crosses is significantly lower than that from mule producing crosses or intraspecies crosses of asses and horses (Epstein, 1969). Occasionally mules from Onager stallions and Tibetan pony mares are bred in Tibet and the ability of the hybrid to thrive on feed and endure hard work is claimed to be superior to that of the common mule.

The origin of this highly respected working animal on the curious basis of crossbreeding of two subspecies has never been determined. Reports of fertile mules have occurred but the basis of mule production has always remained the intersubspecies cross. Their value, especially when compared to the ignominy of the common ass, was recognized early as attested to in accounts of golden or silver shoes being made for the mules of royalty. The mule is notoriously sure footed and is able to carry fragile merchandise along narrow, winding mountain tracks by virtue of its soft tread. This ability to tread softly has similarly made the mule the preferred riding beast for ladies and for drawing carriages and hearses in some cultures. The Romans utilized mules for the transporting of weapons and in their postal service.

Today there are about 15 million mules in the world, predominantly in Spain, Ethiopia and the eastern European countries although they are still utilized in many countries for a variety of tasks. They are bred in China in those regions where asses occur and their sizes vary according to the sizes of their parents with the preferred cross being a Mongolian mare and a large Kwanchung jackass (Epstein, 1969).

ATTRIBUTES OF THE MULE

Much of the discussion concerning the ass is applicable to the mule with a few tempering remarks to indicate the greater utility of the mule. Nevertheless, the mule is an oft-maligned hybrid that is believed to be stupid and stubborn. Neither criticism is valid and these characteristics have probably arisen from an inherent ability of the mule to work within its capabilities and to be far more aware of those capabilities than his driver (Cole and Ronning, 1974). In common with the camel, the popular belief concerning the character of the mule, may not be entirely true and may have entered folklore as a function of the colourful expressions used by those persons who work closely with these animals. Perhaps a kind way of describing the temperament of the mule is to say that it has derived its intelligence from the horse and its surefootedness from the ass.

The mule can be released at the end of each day's work to feed itself without the associated problems of overeating and overdrinking that are common in horses. Other aspects of management of the mule are similarly less demanding than that of the horse. It is adapted to hot climates especially, but is similarly able to withstand cold. These features, in common with those of the ass, render the mule a valuable working animal in desert regions where extremes of temperature are encountered. Shoeing of mules and asses is recommended for regular working conditions but is in fact less critical than it is for horses worked on similar surfaces.

Attention to feed is suggested to be important in India where the small mule population may be required to work under very harsh conditions. Similarly care with housing is recommended as is grooming and watering (Singh, 1966). Nevertheless, these inputs have not always been provided, and the mule has survived and worked well where the horse or the pony usually did not.

THE MULE AS A WORKING ANIMAL

Both the mule and the hinny are used as pack animals. While the mule would normally be the preferred pack animal the hinny also finds a role when the team or animal must be led by a man walking, because the gait of the hinny is more compatible with that of the average person. Mules walk at a speed of about 5 km per hour whereas hinnies walk at about 4 km per hour due to their shorter legs and consequently shorter steps.

Mules utilized for draught purposes are usually larger than those utilized for pack purposes. The former may weigh about 340 kg compared to an average of 270 kg for pack mules. Draught mules are the animal of choice over horses in situations where inexpert drivers are employed, because the mule shows a greater degree of self regulation than does the horse and is more easily controlled by inexperienced operators. The mule can begin work at three to four years of age and continue until the age of 18 or 20 years. Training is relatively easy and routine compared with that of the horse. The mules of China are considered to be too small for heavy draught work, although the larger mules, specifically those from Kwangchung, can draw carts loaded with up to two tonnes. Pack mules of China are known to be capable of transporting loads 10 to 20 kg heavier than can horses of an equivalent size (Epstein, 1969).

In general, the mule is the preferred equine for remote regions where its special characteristics become advantageous. The ass may compete with the mule in some places but it is usually considered to be inferior and kept by peasant farmers who, if they owned mules, would be unable to maintain ownership of livestock by natural reproduction due to the infertility of the mule.

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CHAPTER 11

CAMELS

ORIGINS

Camels probably originated in America from the Protylopus, an animal of about 50cm in height. Humpless animals related to the camel such as llamas, vicunas and guanacos continue to exist in Latin America today. During the Pleistocene era, the genus Camelus evolved in North America and it is postulated that these animals migrated to Asia when there was a land bridge joining the continents. After migration, camels spread widely across the dry regions and gave rise to the two sub-species known today as the Bactrian camel and the Dromedary.

The wild dromedary probably survived until relatively recent times when it was completely domesticated (Zeuner, 1963a). The Bible contains many early records of domesticated camels (Genesis 14, 24, 25 and 31). These references to camels coincide with the time of Abraham which is thought to be during 1800 to 1700 BC. Archeological evidence from Palestine supports the contention that domesticated camels were common by the seventeenth century BC. Raids upon Palestine by the camel-riding Midianites from the Arabian desert, and the utilisation of camels by the Queen of Sheba when she visited King Solomon of Jerusalem in 955 BC further suggest the Arabian origin of the dromedary (Zeuner, 1963).

HISTORICAL USE

Camels were favoured animals for war purposes in Iraq, Syria and Greece because they were superior to horses in some conditions and were apparently detested by horses to the extent that horses refused to enter battle against them. This development occurred during the fifth or sixth century BC and became a tradition of warfare in that region of the world to the extent that the Romans once maintained camels for war purposes in northern Africa. Other references to camels in the Middle East and northern Africa and as far east as India are limited. Camels may have been considered unclean by the Egyptians and hence not featured in their early art and literature (Zeuner, 1963). Evidence in India reaches back to little more than 200 BC in keeping with the common theme of a fairly late date of camel domestication and a slow rate of spread of technology based on the use of the camel.

All of the above references to domestication of the camel refer to the dromedary. This history of the Bactrian camel is less well documented; their presence in Russia in both the present day and ancient times has influenced interpretation of some osteological evidence from Russia and neighboring countries. However, as there is little difference between the skeletons of the dromedary and the Bactrian camel, such evidence may not be categorical.

The earliest evidence of the Bactrian camel comes from the period 3000 to 2500 BC. This and other evidence gives rise to the suggestion that near humpless camels may also have been present in ancient times.

In the eighth century BC, Bactrian camels are known to have been used as domestic animals in Persia (Iran). Their utilisation as domestic animals seems to have been less important than that of the dromedary although no definite statement can be made as to types of camel referred to in early documents. Today the domestic Bactrian camel is restricted primarily to central Asia.

In recent times increased desertification has extended the use of camels. A further factor in the spread of camels was the Islamic wars that took dromedaries to the extremities of the environment in which they could comfortably survive which is where they remain today. Camels today number about 14.0 million with 56 percent of that number being found in Somalia, Sudan, India and Mauritania. All together the camel is present in more than 35 countries of the world. Camel populations in the major camel-raising countries of the world are presented in Table 11.1 (Knoess, 1977).

The camels of China in the Provinces of Inner Mongolia, Sinkiang, Tsinghai, Chamdo, Kirin, Hopen, Shansi, Shensi and Kansu have been present as domestic camels only since dates later than the definite appearance of other domestic animals (Epstein, 1969). Evidence of their presence goes back only about two thousand years. They are known to have been used for pulling the carriages of royalty, for ploughing and as pack animals about one thousand years ago. Camels are not as important in China today as they were in those times which is possibly related to different beliefs which do not especially revere the camel above other domestic animals. Nevertheless, caravan trade links still rely on camels and the more arid regions of south western China provide some environments to which the camel is better adapted than other domestic animals.

Camels have also been employed in the development of new lands. In the last century and the early part of this century, camels provided the principal form of transport for the construction of rail links and other development in inland Australia (McKnight, 1969). Many thousands of camels were imported and many more were bred within Australia, the latter being better suited to local conditions. They were originally introduced as pack animals to carry heavy loads over long distances where feed and water were extremely limited. Caravans of camels were comprised of up to 40 animals the nose rope of each animal being attached to the tail or saddle of the preceding animal and the lead camel being supervised by the herder. On some occasions, several caravans would travel together when moving large quantities of material. The employment of camels as draught animals to pull carts was an innovation that enabled loads of up to 500 kg to be shifted by one beast compared to a usual maximum of 250 kg. Carts obviated the need for daily loading and unloading although they did require the following of tracks or smooth terrain.

Teams of six or eight camels, hitched in pairs were common and their rate of travel approximated that of the pack camel. Camels were also utilised for pulling earth scoops such as for dam construction and to a very limited extent for ploughing. The mining industry of Australia also provided steady employment for camels in the taking of machinery and supplies to mines and the bringing back of ore. In this role competition from cattle and donkey drawn carts increased although camels proved superior during each drought year. Cobb and Co., the historic mail coach company of early Australia, even utilised camels on some sections during drought periods. Graziers also utilised camels to transport their annual wool clip to market from remote inland stations. With the development of the inland railway which the camel assisted to construct, and the introduction of motor transport, the camel's role in Australia disappeared as a working animal and it is today recognised as a feral animal and a pest.

The camel, in almost all cases the dromedary, has also been introduced to the Canary Islands, North America, Italy and southern Spain (Knoess, 1977); in the Canary Islands it is still utilised to pull ploughs (Hyams, 1972).

Table 11.1

The Camel Population of Twenty Countries in 1975:

Country	*Thousand head*
Algeria	*180*
Chad	*303*
Egypt	*105*
Ethiopia	*1,010*
Kenya	*530*
Libya	*120*
Mali	*160*
Mauritania	*722*
Morocco	*190*
Saudi Arabia	*606*
USSR	*253*
Nigeria	*250*
Somalia	*3,089*
Sudan	*2,600*
Tunisia	*211*
Afghanistan	*300*
India	*1,153*
Iraq	*338*
Mongolia	*670*
Pakistan	*850*

Source: Knoess (1977)

THE DROMEDARY AND THE BACTRIAN CAMEL

The dromedary (Camelus dromedarius L.) is the single humped camel of north-western India, northern Africa and Arabia and the Bactrian camel (C. bactrianus L.) is the two humped camel of central Asia found as far east as China (Epstein, 1969). Some authorities list these two types as separate species although the principal differences lie in development of the hump. A vestigial anterior hump is known to occur in the dromedary although outward physical evidence is not obvious.

The two types interbreed and have been deliberately interbred in some countries where dromedaries are usually the preferred dam. Hybrids are single humped and exhibit marked heterosis.

ADVANTAGES AND DISADVANTAGES OF THE CAMEL

Camels are an oft maligned species that, as a function of the attention they attract, are either loved or hated by those who have had contact with them. Camels are slower breeders than other domestic animals with the obvious exception of the elephant. They may be six or more years old when they first calve and may only calve once every three years which probably represents an adaptation to the environment in which the species has evolved. That is, the camel can survive and be of service to man in an environment not suitable for other domestic working animals.

Management of camels requires more skill than for the more common domestic animals. Periods of natural foraging seem essential to the well being of the camel and their low level of intelligence (Hyams, 1972) requires that some retraining be carried out after each of these periods. Camel herders are infamously portrayed as men of special talents and antisocial nature. Whether contact with camels makes herders socially unacceptable or whether persons of an antisocial nature enter this trade is unclear. The bad temper of the camel is often apparently unfairly vented on its herder. Against these comments on the nature of the camel, Knoess (1977) suggests that the camel is easy to control.

The Roman garrisons located in northern Africa that relied on camels for their military manoeuvres kept the camels outside the garrison walls to minimise exposure to the offensive smell and temper tantrums of camels. Perhaps these two factors are the principal reasons why camels are seldom utilised in regions where cattle or horses are available. Nevertheless, camels may be observed today pulling carts and in some cases ploughing fields in north western India where cattle, buffalo and horses also are present. In Turkey, camel caravans may even be led by the herdsman riding on a donkey.

Camels can survive on the vegetation supported by saline soils and do not need to drink frequently. Their feet are adapted to walking on sandy soils without sinking or slipping unduly. The skin of the camel is thicker than that of other ruminants and is responsible for their low rates of evaporation. The hump provides an energy reserve in the form of fat and is therefore different in composition and function to the hump of zebu (Bos indicus) cattle. The belief of the hump acting as a water storage is clearly wrong because oxidation of hump fat would lead to a greater loss of water via the increased pulmonary evaporation required to supply the additional oxygen for metabolism of fat. The lips of the camel are adapted to the consumption of thorny desert plants and the camel is capable of extending its neck markedly in order to browse from trees. Other adaptations to the desert include long eye lashes and an ability to close the nostrils.

Camels can tolerate dehydration to the extent of losing up to 30% of their body weight as water. Most other mammals succumb to circulatory failure after a loss of about 12%.

Under conditions of dehydration, water loss in urine and faeces is minimised and low water levels in blood are tolerated. Diverticula in the rumen of the camel, each closed by a sphincter, also contribute to water retention (Cole and Ronning, 1974).

MANAGEMENT

The most critical period for the management of camels is the breeding season. The male comes into rut (musth) during the colder months of the year and may become aggressive particularly towards competing males. Typical outward signs of musth in the camel are: grinding of the teeth; swallowing of air, and belching; secretion of a dark red liquid with an unpleasant odour from the poll gland, and adopting a stance with legs apart and tail flapping. The rigors of musth lead to camels losing much liveweight over this period. Subordinate males do not usually exhibit musth to the same extent; however, should their fear of the dominant male not adequately suppress the signs of musth, fights usually ensue.

In a sparsely vegetated environment, nutrition is a major consideration for an animal the size of a camel which despite its ability to survive without water for some time, requires daily grazing. The high degree of adaptation of the camel ensures its survival in this environment. However, under working conditions, the herdsman must ensure that camels have at least six hours grazing per day unless they have previously been well nourished as evidenced by a well developed hump.

Supplementary forage may be cut and fed to camels if sufficient other feed is unavailable. Similarly, under conditions of strenuous work, a grain supplement may be fed. In India, a diet for a working camel not allowed access to grazing comprises one kg of crushed grain, one kg of crushed barley, nine to eighteen kg of green fodder, seven kg of "bhoosa" (forage) and some salt (Singh, 1966).

Individual feeding troughs are required to ensure even intakes and to reduce biting. A daily supplement of one half of one litre of sesame oil is provided for camels transporting heavy loads of 240 kg over 35 to 60 km per day in China (Epstein, 1969).

Watering of camels is critical to their work performance. Stories of camels existing for several weeks without water are possibly true, although they are easily exaggerated. Under normal conditions camels are watered every second day when they consume about fifty litres. In hot weather camels grazing dry fodder will show distress after four days of work without water (Howell, 1965) and in the Sahara Desert, eight days' work without water is considered to be an absolute maximum. However, as with sheep, consumption of succulent forage under cool conditions may obviate the need for watering entirely; such conditions are rare. An additional consideration in camel management is that camels must be accustomed to lack of water if they are expected to work under conditions of infrequent watering. When watered after a period of dehydration, camels may drink more than 100 litres.

Training of the young pack camel is effected by tethering it to a trained adult and eventually by teaching it to respond to a nose rope. Loading is introduced gradually to the trainee camel until it slowly is integrated into the team of working adults at an age of about seven years. The loads carried by pack camels are usually much less than the maximum in order to avoid decreasing their long term utilisation. Riding camels are taught to kneel to facilitate saddling and mounting and are taught to respond to reins by one person riding and using the reins while another person leads the camel. Specific training includes inducing to sit and rise on command by pulling the head downward while being tapped behind the knee with a stick. This process is repeated until the camel rises upon command.

Harnessing of camels requires some modifications of conventional harnesses due to the different conformation of camels. When conventional harnesses are employed, the efficiency of work production may be reduced by up to fifty percent compared to harnesses designed especially to suit the stature and muscular distribution of the camel.

Other inputs necessary to the wellbeing of camels include ectoparasite control by the application of oil to the skin followed by the application of mud and its subsequent removal after a few days. Management of camels is at least as critical as that of any other working animal. This is largely a reflection of the harsh environment in which the camel is required to work. The working life of a camel varies from six to twenty years depending almost entirely on the level of management practiced.

The importance of camel husbandry is possibly the reason that many of the management decisions relating to optimal usage of camels have been relegated to folklore or even to religious teaching. Over the period since domestication of the camel, life in the arid regions of the Middle East and surrounding countries has depended to a large extent on the camel. In other civilisations that had not developed with the camel such as early Australia, overloading or improper loading of camels required the constant surveillance of specially appointed persons to ensure that the camels were used to their optimal economic benefit (McKnight, 1969).

CAMELS AS WORKING ANIMALS

Camels were first domesticated for use as pack and riding animals and later for ploughing. Today in northern Africa, dromedaries are utilised by semi-nomads to carry their possessions including ploughs, and upon arrival at a suitable agricultural site, are utilised to draw the plough. The superior strength of the dromedary compared to the horse or the cattle beast on a per animal basis, combined with the dual working purpose of the dromedary necessitates its retention in this system.

In the India sub-continent, the camel numbers something above one million head with about 50% in Rajastan province where the population is increasing. It is utilised for riding, pack purposes, ploughing, threshing, drawing carts, powering water wheels and crushers for sugar cane and oil seeds. The camel is usually yoked singly although pairs can be managed and under conditions of necessity, a camel may be yoked with a buffalo, a donkey or a cattle beast to draw a plough. In Baluchistan province it is reported that a person and a camel have been yoked to the same plough on occasions (Singh, 1966).

Several breeds of dromedaries are recognised with respect to their relative suitability to different types of work. In India the breeds are called: Riverine, Desert and Hill. The Riverine and Hill are pack breeds while the Desert is suited to riding. The attributes of a pack camel are described by Singh (1966) as including a well developed hump, thick neck, a large head, broad chest, strong legs and sound foot-pads. A good riding camel, on the other hand, is a more active, lighter animal with slender legs.

Desert camels can travel about 48 km per day for many days with comfort at an average speed of about nine km per hour. Treks of up to 100 km in one day are not uncommon but cannot be maintained. Occasional sprints can even produce figures such as 184 km in twelve hours (Howell, 1965). Pack camels can carry 150 to 200 kg over twenty km at about four km per hour. Camels can draw carts with loads of about 480 kg (Singh, 1966) or up to one tonne if yoked as a pair (Epstein, 1969). It is usually recommended however that pack loads not exceed 100 kg.

Pack camels may be worked more efficiently at night or in the early morning to avoid additional stress from high temperatures. The working life of a camel varies markedly with an average of about fifteen years, although in early Australia, working lives of camels of twenty five to thirty years were not uncommon (McKnight, 1969).

The Bactrian camel of China is capable of carrying a 120 to 150 kg load over 35 to 40 km per day continuously or up to 85 km non continuously (Epstein, 1969). Camels can also carry loads of 275 kg over 1,160 km in thirty days. It is of interest that camels are the preferred mode of transport for speed over long distances if replacement horses are not available en route.

Maximum loads for camels were determined in Australia where camel operators compared the strengths of their animals; on one occasion a dromedary rose with a weight of 865 kg loaded on its back (McKnight, 1969). Bactrian camels have been noted to be able to transport loads of up to 680 kg (Howell, 1965). Such figures, while they do provide some indication of the strength of the camel, are of little practical value to a study concerned with continuity of work.

Traditions related to the working of the camel seem to be well founded in the logic that overworking will reduce the total work output of an animal. Camels are usually rested one day per week and maximum loading of camels varies according to the distance to be covered each day, the terrain to be crossed, the duration of the work period and the recent working history of the animal. Camels are not left standing with their loads unless this is unavoidable and rests are called after about a half day's work to allow time for urination which, in the case of the male camel, may take several minutes to complete.

Male dromedaries have been tested for draught capacity in the pulling of moldboard ploughs. On average, one animal can cultivate one hectare of medium resistance land to a depth of 16 cm in 20 hours when working a seven hour day.

It has been suggested that the camel may cease to be employed as a working animal and should therefore be viewed as a milk and meat producer for those regions to which it is adapted (Knoess, 1977). However, it is unlikely that the camel, particularly the dromedary will cease to be a working animal because the areas to which it is adapted may remain largely undeveloped, and the residents of these regions are relatively poor. As has been introduced earlier in this book, working animals are usually associated with poorer peoples and, in a realistic view of world development, many of these people will remain poor and thus dependent on their working animals.

The large caravans of old which comprised up to five thousand camels (Cole and Ronning, 1974) have probably disappeared forever. However, it would be premature to dismiss the working role of the camel at this time while promoting the milk and meat aspects of camel utilisation. The need for improved harnessing techniques to increase the efficiency of work output of camels has been noted (Knoess, 1977) and the camel has been mentioned by the Food and

Agriculture Organisation of the United Nations as an animal species suited to a special environment and therefore worthy of consideration in the programme for conservation of genetic resources (Phillips, 1967).

THE LLAMA AND THE ALPACA

The llama and the alpaca belong to the other genera that with Camelus (the Dromedary and the Bactrian Camel) make up the family Camiliadae. Within this genera are also the two wild breeds of Vicuna and Guanaco. The presence of these members of the Camilidae family in South America is accepted to be supportive evidence that the ancestors to both camels and llamas lived in the Americas, and that continental drift and subsequent changes in the environments produced species adapted to vastly different conditions.

The llama and the alpaca were probably first domesticated in the Inca civilisation of Peru about 1500 years BC for use as pack animals and for hair production (Cole and Ronning, 1974). The distinction between llamas and alpacas, as evidenced in their relative sizes and hair qualities, represents centuries of breeding and selection in controlled herds soon after the first date of domestication, probably before 1000 BC (Hyams, 1972). The llama is larger than the alpaca, with llama males weighing up to 120 kg compared to 70 kg for alpacas. The alpaca produces an annual fleece that weighs about two kg and is composed of both hair and wool whereas the llama produces only a coarse hair of little commercial value (Fitzhugh et al., 1978).

The estimated population and distribution of Camilidae in South America, as determined by McDowell (1972) is presented as Table 11.2 where it is evident that the population of llamas exceeds the combined total of that of alpacas and their wild relatives, vicuna and guanaco.

Llamas are utilised in long caravans, sometimes comprised of several hundred animals (Hyams, 1972) with each animal carrying a load of about 35 kg (occasionally up to 50 kg) and travelling about 20 km per day. Male alpacas are also employed as pack animals and their loading capacity is far inferior to that of the llama. Both breeds are well adapted to high altitudes and are usually encountered at altitudes between 4,200 and 5,000 metres. In common with the yak, llamas and alpacas are adapted to high altitude work by virtue of a high red blood cell count. Some insulation must also have developed during the evolutionary process to permit the animals to thrive in mountainous areas on the equator where diurnal temperature variations may be in excess of 25oC. (Cole and Ronning, 1974.).

In common with its near relative the camel, the llama exhibits remarkable endurance under adverse conditions. Similarly, something of the contrary nature of the camel is evident in the llama if it is loaded to exceed the limit which the llama thinks it should carry. The llama is also noted to express its irritation or annoyance by spitting out a mixture of saliva and regurgitated rumen contents.

A common feature of the llama, the alpaca, the camel and the yak is their specialisation for working in specific conditions to which no other animal species is suited and in which little competition from mechanical innovations is experienced. These remote regions, where such animals are worked, are likely to remain undeveloped and thereby ensure the continued reliance of man upon these animal species.

Table 11.2.

Estimated Population and Distribution of Camilidae in South America.

Species	Country			
	Peru	Bolivia	Chile	Argentina
Llama	915,000	2,500,000	70,000	500,000
Alpaca	289,000	300,000	20,000	Some
Vicuna	30,000	2,000	-	-
Guanaco	Some	Some	Some	100,000

Source: McDowell (1972)

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CHAPTER 12

ELEPHANTS

Elephants are excluded from some discussions relating to domestic animals on the basis that they are not domesticated but caught wild and tamed rather than raised by man (Cole and Ronning, 1974). However, this is not always true as can be observed in Thailand where elephants have been an integral part of the forestry industry. Management of elephants includes the production of offspring which are, after a few years trained in a special school. As the complete life cycle of elephants is spent in captivity under the management of man, the elephant is certainly a domestic animal.

Two species of elephant are recognised; the Indian elephant (Elephas maximus L.) and the African elephant (Loxodonta africana). Both are said to be derived from an animal that resembled a subaquatic moeritheres, the remains of which have been discovered in Egypt. These animals, while only about one quarter the size of elephants, possessed skeletal structures capable of supporting great weight, thereby allowing the subsequent evolution of a much larger animal (Howell, 1965). The mammoth (E. primegenus) is also postulated to have shared these forebears.

THE INDIAN ELEPHANT

The Indian elephant is utilised as a working animal to a far greater extent than is the African species. It is more docile than the African species which, while it may have been employed as a beast of war by north African rulers, is today known mainly as a wild animal.

The Indian elephant was probably indigenous to the Indian peninsula including Sri Lanka and today is found throughout most of South-East Asia. References to the presence of the Indian elephant in southern China sometime between the years, 500 and 1000 have been cited by Zeuner (1963). It also seems that an isolated colony of elephants was present in Syria until the eighth century B.C. and it has been postulated that the Indian elephant actually covered the region between India and Syria at an earlier date but became extinct before prehistoric times in all areas except those two countries. The Indian elephant of Syria, which is sometimes referred to as the Syrian elephant, probably became extinct through the high demand for ivory during the ninth and eighth centuries B.C. The Syrian race of the Indian elephant was most probably never utilised as a working animal, even in warfare although in Persia elephants were used as beasts of war after contact with India (Zeuner, 1963).

The long association between the elephant and man in India is testified to by the frequent references to elephants in Indian religions; the Hindu god, Ganesha for example, is depicted as possessing an elephant's head.

Today there is said to be about seven thousand wild elephants in India (Singh, 1966). Captured wild elephants are tamed and trained to work in the timber industry by hauling logs from the site of tree felling to the nearest stream.

THE AFRICAN ELEPHANT

The African elephant is larger, possesses larger ears and lacks the forehead bulges of the Indian elephant. These factors as well as variations in the back-bone shape and teeth structure have contributed to the classification of the African elephant to be a separate species from the Indian. The wild elephant of Africa is commonly portrayed as a danger of the African hinterland. The larger races of the African elephant such as that of East Africa and Kenya average a height of three metres at the shoulder and are never considered as working animals. Smaller races occur elsewhere, such as the Sudan and Zaire where, in the latter case at least, they have been trained to work in the forests (Zeuner, 1963).

Elephants have been utilised in Africa during different periods of its history, particularly that part of northern Africa that shared in the Roman and earlier contacts with western Europe. For example, it is known that the Carthaginians employed African elephants as transport beasts in their wars and that such use extended through the period of the Romans. As with the African elephants that have been tamed for use in the forests of Zaire, these elephants belonged to a race of African elephants that was smaller than the giants of East Africa. Estimates of the height of these elephants suggest these races to have been up to one metre shorter than the eastern elephants (Zeuner, 1963).

The African elephant is not restricted to forested areas to the same degree as the Indian elephant. Thus the African elephant has been more accessible to man and suffered accordingly. Damage to crops led to the disappearance of elephants from some areas of Africa and when domestication of the smaller races became feasible, they virtually disappeared as a wild race.

DOMESTICATION

The difficulties of domesticating an animal the size of the elephant were overcome to enable the use of the elephant in warfare and for pulling heavy loads. It was only after the value of elephants in warfare was realised that domestication became widespread in the civilised world.

Elephants are docile of nature and although they may not respect pens, they are easily restrained by foot chains and are easy to lead and control once trained. To a large extent, man has preferred to let elephants range wild and to capture some for taming as required. This reluctance to raise elephants in captivity was not, as is sometimes suggested, because it is not possible to do so, but rather it is a reflection of the costs of raising elephants in captivity. Females require special treatment during their long pregnancy and young elephants are often not trained until they reach ten years of age. Thus it may be more economical to harvest wild elephants. The major centres of complete domestication were therefore those regions where little or no resource of wild elephants existed.

Capture of elephants has been effected by many means, predominantly those exploiting the large size of the animal. Separation of young from a herd by men on foot or horse, noosing by strong rope and food drugged with opium are all useful techniques. Traps utilising nooses or stockades where decoy tame elephants are placed to attract wild elephants are effective and the latter system is utilised widely in India today. Pits may be dug such that once an animal has stumbled into the pit, it cannot climb out unassisted. Such pits need only be shallow because the weight of the elephant limits its ability to climb over obstacles or up large steps. Zeuner (1963) claims that such methods of capturing elephants would have been within the capabilities of primitive man, thereby showing that the size of the animal presented little obstacle to early domestication.

The earliest evidence of domesticated elephants is dated between 2,500 to 1,500 B.C. and from the fifth century B.C. onwards evidence of their domestication is plentiful. Domestication of elephants was restricted to India and it was over 2,500 years before the technology reached the West largely as a consequence of the improved systems introduced by the Persians. Upon their introduction to the Western world the elephant and the camel revolutionised warfare; the elephant was utilised in a role similar to that for which the modern tank was designed while the camel provided a fast independent cavalry. Hannibal marched elephants with his large army through Gaul from Spain during the Punic wars (218 to 202 B.C.) (Strayer et al., 1961). Elephants were recognised as a prerequisite to successful warfare to the extent that loss of a battle often culminated in the forfeiture of all elephants. However, the Roman army with its reliance on strategy and vast manpower resources was seldom overcome by an opposing army relying on elephants. Both Indian and African elephants were utilised in warfare.

The Romans disliked elephants as beasts of war because they did not adapt to the Roman system of warfare. Among those armies who utilised elephants, the disadvantages of elephants were recognised and eventually led to their disuse after several centuries. The feeding requirements of a herd of elephants presented problems during a period of war. The low stamina of the beast, exhibited in the form of requiring regular rest periods, the greater problem in guiding compared to horses, and occasional unwillingness to obey commands combined to make the elephant unreliable in battle.

Elephants became a symbol of power because they were associated with military triumph. Although the Roman army seldom utilised elephants, their soldiers were scared of enemies employing elephants. Caesar is known to have kept at least one elephant for ceremonial use and Polyaenus reported that Caesar rode an elephant across the Thames River, England in 54 B.C.

The African elephant was possibly utilised for peaceful purposes about the time of Christ until agriculture eventually claimed most of the arable land and desertification claimed the marginal areas. Another purpose to which the North African race was put was performing in the Roman circus executing all of the feats seen in today's circuses. When this race became extinct through over capturing, elephants ceased to be seen in Rome and those introduced to Europe several centuries later were of the Indian species.

Elephants with their many drawbacks were not utilised widely as beasts of burden or for extraction of timber from forests in older times possibly because slaves were abundant in most societies. They were restricted mainly to areas in which topographical or vegetational peculiarities, made use of manpower impractical. Today however, utilisation of slave labour is unacceptable and the elephant has so far been assured a specific role in timber extraction from Asian forests. It may be concluded that the principal advantages of the elephant are its trunk and tusks and its unit size. With regard to the latter, one elephant is obviously stronger than one animal of any other domesticated species and is therefore superior in situations where per animal strength is of primary importance.

CHARACTERISTICS OF ELEPHANTS

Elephants exhibit the mechanical features necessitated by extreme bodyweight. Their great weight prohibits bounding, allows only a stiff legged walk and precludes the stepping over of objects higher than a few decimeters. The shortness of the elephant's neck is compensated for by the long trunk with which it procures food without the necessity of head movement. The memory and the thickness of skin of the elephant have been eulogised. In fact, their memory is probably inferior to that of a dog and hide thickness is about two centimeters. Elephants possess reasonable vision but this is limited by their short neck which severely limits sideward head movement; this is partially compensated for by acute senses of hearing and smell. Elephant feet pads spread upon contact with the surface upon which they are walking and contract when their weight is removed. This enables elephants to walk comfortably in muddy environments because they can easily extract their feet. The Indian elephant is usually considered to have five nails on the forefeet and four on the hindfeet. The elephants only pace in its use as a working animal is a walk which varies from 3.4 km per hour in the morning to 3.7 km per hour in the afternoon (Tumwasorn, 1980) or up to 5 km per hour (Singh, 1966).

Elephants live longer in the wild than they do in a domesticated state with eighty years being a long life. Adult elephants weigh less than four tonnes and the type of animal commonly used in circuses weighs between two and one half and three tonnes. Mean liveweights for mature male and female elephants in Thailand of 3,218 and 2,898 kg respectively have been recorded (Tumwasorn, 1981). Liveweights correlated with various body traits and a multi-variable predictive equation incorporating liveweight, body length, height, girth and front foot circumference have been prepared. The extreme difficulty of determining the liveweights of elephants has prompted Tumwasorn (1981) to suggest the use of this relationship for future research concerning the elephant.

Elephants are valued according to their age and training. Well trained tuskers, elephants with well matched prominent tusks, are the most highly valued because good training of a tusker enables the animal to lift timber for stacking or to carry logs over obstacles. The value of the ivory in the tusks is an added consideration that is not realisable until late in life. In Thailand, it is considered a wasteful crime to shoot an elephant solely for ivory because of the limited number of wild elephants in the country and the utility of domestic elephants in the forestry industry. Mahouts of elephants often form lasting bonds with their elephant. Instances of mahouts preceded in death by their elephant, pining themselves to death or even the reverse case are commonly spoken of in popular stories. The prestige of owning an elephant is great in many cultures such as that of the Karen ethnic group found in Burma and Thailand. The high unit cost of elephants contributes to this prestige and the outcome is seen in some Karen households where all surplus resources have been diverted to the purchase of an elephant to the end that the household may live quite poorly. The relatively high income obtained by a working elephant may repay such sacrifice but only over many decades.

MANAGEMENT

In India, the belief that elephants raised in captivity rarely breed is confounded by the use of management systems not orientated towards breeding. Females reach sexual maturity between eight and fifteen years of age and may breed every two and one half years thereby providing up to fifteen calves in the lifetime of one cow. Gestation periods vary from 18 to 22 months.

The condition of musth in bull elephants, similar to that occurrence in camels, interferes with working patterns. Male elephants are dangerous during this period which lasts about three weeks. Generally male elephants are worked harder and restrained during rest sometimes with the feeding of certain feeds that are supposed to quieten the elephant. This obvious display associated with procreation contrasts with the low sexual activity of the cow in which it is often not possible to detect heat. Musth can be divided into four stages and Toke Gale (1950) has described the various changes that occur in the penis, testicles and musth glands during this period.

After having given birth, the cow is very protective of her calf which she suckles for up to three years although early weaning, at one and one half years of age, is practiced for elephants raised in captivity.

Feeding requires constant attention. In the wild, elephants seem to eat continuously. Perhaps this is related to the relatively short digestive tract length which is approximately the same length as that of the horse and through which ingesta passes rather quickly, taking between twelve and twenty-four hours. Digestibility is correspondingly poor, evidence to which is the straw-like appearance of faeces. The nutrition and growth of the African elephant has been reviewed by Laws et al. (1975) who note that the elephant, as a non ruminant that consumes whole plants, obtains a highly fibrous diet which is acted upon by microbial fermentation to a limited extent in the colon and caecum. Alternative feeding regimes for elephants have not been studied in detail and it is generally recommended that elephants should be allowed access to forest areas where they can select their own diet. Concentrate rations designed to supplement natural foraging are fed to captured elephants in India; rations are usually composed of rice grain, coarse wheat flour, tamarinds and onions. Medium-sized elephants utilised by the Indian army are provided with a daily ration of 6.8 kg of grain, 80 kg of dry fodder, 150 kg of green fodder, 56 kg of salt and 28 g of oil (Singh, 1966). Mature elephants require about 200 litres of fresh water per day. Water is sucked into the trunk and then poured into the throat in a fast and efficient series of movements.

It is important to guard against overworking of elephants. The size and weight of the elephant actually decreases the utility of the elephant as a working animal as is evidenced by the need for long resting periods. Work is generally restricted to three hours in the morning and three in the afternoon thereby avoiding the hottest part of the day to minimise the added danger of heat stress.

Bathing of elephants after the performing of work is important in order to minimise skin problems that interfere with the animal's working ability. Elephants swim well, and because they can breath via their trunk with all of their body submerged, temporary relief from their excessive weight can be obtained. Shelter in the form of trees or a roof is required to prevent undue exposure to sun, rain and wind. Proper harnessing is critical to the continuous working of the elephant as ill fitting harnesses can easily abrade the relatively sensitive skin of the elephant.

An additional management constraint is the restricting of the lifting of logs by tuskers during the hot season because tusks are more easily cracked at that time of the year (Corvanich, 1979). With regard to resting periods, a formalised system of three days work followed by two days rest has been adopted in Thailand with a period of complete rest between March and May, the hottest period the year.

In Burma, the points of the tusks of timber elephants are sometimes cut to reduce the damage that may occur in fights between elephants. The shape of tusks is regarded as an indicator of the temperament of an elephant and Toke Gale (1959) notes that cutting the tip off the tusks of a temperamental elephant is dangerous in itself. It is important during this operation to avoid cutting off any more of the tusk than is absolutely necessary due to the risk of exposing the central tusk nerve.

Elephants that have been captured are tamed initially by securing the legs and pulling them to a training site by use of a tame elephant. Taming takes between ten and thirty days for elephants of less than twenty years. Food and water are withheld from the captive for the first two to three days until it becomes more tractable. Thereafter the two men assigned to look after the welfare of the elephant tend it constantly, but ensure that it eats only sparingly and does not sleep. These tactics aim to weaken the captive to prevent undue opposition during training. The two trainers soon begin talking to and touching the captive elephant and occasionally standing on its back with the provision of rewards for successful learning such as ripe tamarinds and salt. After twenty days the captive should be sufficiently docile to be released near the camp with only cane fetters fitted to its legs. Learning of commands takes place over the next few months until the captive joins a team of six or eight trained baggage elephants. Over time it will learn to manipulate logs but will probably not be a very good worker until the age of twenty-five or thirty years.

The alternative of capture, taming and training is the training of young domestic elephants, such as is practiced in Thailand. Elephants were first utilised in the logging industry in Thailand during the nineteenth century by British logging companies and today have reached a population of about 12,000 head. The practice was introduced from India and Burma and the commands still used today reflect this origin (Corvanich, 1976). In the last century, catching and training of wild elephants was the rule but today it is very uncommon. Working elephant cows employed in the vicinity of the elephant training school of Thailand are cared for at the school during parturition and the calves raised there. In other cases the calves are delivered to the school for training after they have reached an age of four to five years.

The actual age at which training can begin depends largely upon the care that has been exercised during the early life of the calf and the effect this has on its health and growth rate. Initial training in this school involves teaching young elephants to be submissive by restraining them with ropes, placing them in crushes and thereafter teaching the young elephant to use chains and to lift one foot upon command. The initial period of inducing submission requires at least one month, after which the programme becomes more rigid. The course does however, include holidays because experience has shown that constant schooling or working can be deleterious to elephants to the extent that some may even die. Up to the age of ten years, a daily schedule beginning at 0600 hours is followed. The first activity each day is leading the elephants to their bathing site while teaching them to walk in single-file. During their years of schooling, elephants are taught to walk in double and single-file, and to stop walking upon command. The mahout then commands the elephant to lift a front leg so that he can climb onto it, after which the elephant is commanded to lift the mahout up and down. The elephant is then made to practice picking up objects that have fallen onto the ground and to move objects about with its trunk. Next, harnessing equipment is fitted and elephants are taught to pull logs both singly and in co-operation with another elephant. The elephants also have to become accustomed to the arranging of harnessing equipment and chains for walking from one work site to another via highways. Working in mountainous terrain is introduced gradually on a twice weekly basis. Traditionally local music is played especially toward the end of each day's training.

According to the system utilised at the school in Lampang, Thailand, elephants of ages one through three years stay with their mothers. From four through five years of age they enter the pre-school and from six through ten years of age, they are trained according to the pre-determined schedule. After graduation, elephants of ages 11 through 18 are worked in the forests although they do not reach their peak work output until ages 19 through 38 years. Between 39 and 48 years their strength wanes and after 49 years they age rapidly. Elephants older than 61 years are regarded as too old to work at all. These ages have been determined from many years of experience and while they cannot be regarded as absolute, they are utilised as guidelines in the employment of elephants in Thailand. The school, which was created in 1969 by the Royal Thai Ministry of Agriculture and Co-operatives, is also a centre for the treatment of elephant diseases, and graduates of the school may return occasionally for medical attention.

THE WORKING ELEPHANT

The initial reasons for the domestication of the elephant were possibly related to its apparent strength. Size implies strength but, in fact this is not true if animal species are compared on the basis of work output per unit body weight or feed input. Use as war beasts was perhaps the greatest contribution elephants made as working animals. Today the elephant is utilised mainly for dragging logs but it is still classified as a beast of burden in India (Singh, 1966) where an optimum load varies from 450 and 550 kg. The strength of the elephant is small if converted to a body weight base and compared with other animal species. One spectacular if uncontrolled demonstration of this fact was a tug of war staged at Surin, Thailand, in 1964 where a strong healthy elephant weighing 3.5 tonnes was beaten by a platoon of fifty soldiers whose whole total weight was 2.9 tonnes.

The haulage power of an elephant is generally considered to approximate half of its body weight. Hauling of loads of varying weight is accomplished by various conformations of co-operating animals. The harnessing of elephants for single, tandem or team hauling is a skilled operation that requires the mahout and assistant to judge each situation for its requirements and to assist the operation in various ways such as placing small poles under the log or shifting soil under a log. The lifting capacity of a tusked elephant averages 700 kg although this capacity is seldom fully realised.

It has been calculated that for an average hauling distance of one km, 450 to 600 cubic metres of timber can be moved by one elephant during a year if the terrain is smooth (Corvanich, 1979). This figure may reduce to as little as 150 cubic metres in rough terrain. Rests are usually called at 500 metre intervals to maintain the working ability of elephants; if this is considered in conjunction with their 160 day working year, their rather low total work output is easily understood. A study conducted by the Royal Thai Forest Industry Organisation about fifteen years ago indicated that elephants were 17% more expensive than machines however, Corvanich (1979) suggests that this disadvantage would have decreased with increases in oil prices. An additional advantage of the elephant over machinery is the income derived from sale of tusks which are currently priced at US$15.00 per kg. The value of tusks in logging operations through the ability to lift logs is partially compensated for in elephants that are tuskless or have poorly developed tusks by increased trunk strength.

Absolute measurements of the work output of elephants is of little comparative value since their inefficiency is accepted as a necessary drawback to their use. Alternative sources of power in situations to which elephants are suited are expensive and in many cases their use would be impractical. For example, access to mountainous forests for elephants is effected more easily than for mechanical equipment and the combined use of elephants for dragging logs to rivers or roads where they are further transported by floatation or trucking, may be the most economic alternative in many cases. The elephant is therefore destined to play a continuing role as a working animal in the forests of developing countries.

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CHAPTER 13

YAK

The origins of the Yak (Bos grunniens) are unknown. It is derived from the now rare wild yak which is the only species of the subgenus Poephagos. It is found in both the wild and domesticated states (Zeuner, 1963). The first record of the yak is that of Martial X111 who described an expensive fly-whisk, the Muscarium bubalum, made from the tail of "a type of ox". The tail of the yak is composed of very fine hairs which grow from the base and has been utilised for fly whisks in Asia since those times. Later, in the thirteenth century, Marco Polo described yaks from the country of Tamgut which is believed to be that area now known as Koko Nor, a lake. The main use made of yaks at that time was as pack and working animals and occasionally as riding animals. Little has changed since then in many of the areas where yaks are found. Marco Polo also made accurate references to the quality of the yak's hair although he apparently was subject to some exaggeration when he described their size as being comparable to that of elephants.

Various types of yak have been bred that vary mainly with relation to colour and horn growth. Yaks can interbreed with cattle of both the Bos taurus and B. indus breeds and hybrids, although sterile in the case of the male, are quite popular due to their quieter temperament. Today, yaks are found from Tibet and Ladak to Mongolia. In the northern areas, Zeuner (1963) believes that yaks have been introduced and, in the Sayan Mountains, the limits of yak distribution coincide with those of the reindeer and the camel. The yak is strictly limited to mountainous areas above 2,700 metres in altitude and has therefore not spread very far into China. It is found only in the border provinces of Yunnan, Szechuan and Kanso where it is utilised for commercial communications with Tibet. The yak is also encountered in northern Nepal and Kashmir, Bhutan, north eastern Afghanistan and southern provinces of the USSR.

Initial domestication is generally believed to have occurred in Tibet, probably by the introduction of wild yak calves whose dams had been killed by hunters (Epstein, 1969). The adaptation of the yak to the rugged environment, and the relative ease of domestication led to an increase in the number of domesticated yaks. Domestication possibly took place three to four thousand years ago (Hyams, 1972) and the total population of yak hybrids has been estimated to be about 1.0 to 1.7 million (Fitzhugh et al., 1978).

Domesticated yak kept in some zoological gardens are atypical because the yak is very poorly adapted to low altitudes and high temperatures (Epstein, 1976). The yak thrives on sparse vegetation which is often buried by snow, in rugged mountains where temperatures are well below freezing for long periods of each year. This is assisted by the evolutionary adaptation of a fine dexterous upper lip and a slender tongue.

Domesticated yak are significantly smaller than wild yak. Wild yaks may reach shoulder heights of 205 centimeters for bulls and 156 centimeters for cows whereas domesticated yaks average 117 to 130 centimeters and 106 to 198 centimeters respectively. Horn size also varies between wild and domesticated yak but they share the attributes of long, hard, durable feet and strong legs.

Mature bulls weigh 380 to 400 kg and mature cows weigh 260 to 270 kg at about six to seven years of age. They are capable of carrying loads of up to 150 kg on rugged mountain tracks. Even when consuming feed of poor quality, yaks can carry 50 to 75 kg for 13 to 16 km per day continuously for several months (Epstein, 1976). They are noted to be more sure-footed than mules and to be adept in negotiating both snow and swamps. When crossing swamps, yaks apparently continue their walking motion through the swamp without adopting any definite swimming action.

Chauri is the Sherpa word for the female hybrid of yak and cattle (Epstein, 1976); other transliterations are Tsauri and Chawrie (Schulthess, 1967). Unlike the male hybrid, which is called the Zhopkgo in the Sherpa language, Chauri are fertile when mated with either yak or cattle bulls. Male hybrids develop all secondary sexual characteristics but do not produce spermatozoa; the corollary of crosses between Bos indicus or B. taurus cattle and B. banteng (bali cattle). Male hybrids from backcrossing are similarly infertile and only bulls with more than 87.5 per cent yak or cattle blood are fertile (Epstein, 1976).

Hybrids are superior to both yak and cattle in terms of their strength, working ability and milk production. Their liveweights average around 20% higher than midparent values and may be as high as 50% under experimental conditions. Hybrids are of quieter temperament and are said to be easier to work than purebred yaks. Thus hybrids are preferred as pack and draught animals, which once led to a trade in these animals from Nepal to Tibet, although Cole and Ronning (1974) maintain that hybrids show a lower degree of stamina than do yaks. Hybrids are also preferred because they produce more milk than yak cows and reach maturity at an earlier age than yaks. Differences in hybrids in size, conformation, coat colour and temperament are the corollary of differences between mules and hinnies. The major difference between the two hybrid types is associated with a similarity of progeny and dams and is expressed primarily in terms of hardiness and resistance of either low or high temperatures. This is related to the higher haemoglobin count of hybrids sired by a cattle bull than in those hybrids resulting from the reciprocal cross.

Management of yaks and their hybrids require high inputs. This is traditionally conducted by the Sherpa ethnic group in Nepal who migrate seasonally with the yak, seeking pastures at different altitudes as temperatures vary. During the coldest months of the year, December and January, the yaks are fed on what little pasture is available supplemented with oak leaves and hay, but they are never moved below altitudes of 2,700 metres. Herds are moved up to higher altitudes as soon as possible until July and August, after which time they begin their move down to the lower altitudes again. Management of the yaks and their hybrids is regarded to be a prestigious occupation among the Sherpa and most of the animals are owned by richer Sherpa families.

The yak has been noted as one of the animals to be considered as part of the Food and Agriculture Organisations' programme to preserve animal genetic resources as a species adapted to special circumstances.

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CHAPTER 14

OTHER WORKING ANIMALS

The principal animal species utilised to perform work for man are cattle, buffalos, horses, asses, camels, yak and elephants, as discussed in the preceding chapters. However, there are many other animal species that are used to more limited extents, yet are equally essential to man in some regions. Such animals are the reindeer, the elk and the dog. While there are many other species that perform work such as the coconut harvesting monkey; goats trained to pull small carts and carrier pigeons, these are only of peripheral interest to this study of working animals.

THE REINDEER (Rangifer taradus spp.)
and
THE ELK (Alces alces)

During the Upper Palaeolithic period, the reindeer was one of the most important animal species from the viewpoint of food and clothing. It occupied large areas of the high latitudes of the northern hemisphere where today it still exists in a semi domesticated form. This level of domestication is based on the retention of the traditional nomadic state of both man and the reindeer. In some areas complete domestication for draught, riding and milk production has taken place. The date of first domestication may be as early as 12,000 B.C.

Reindeer roamed over large parts of Europe until comparatively recent times. Reports and osteological evidence suggest this presence of reindeer until at least the Roman period and possibly up until the Middle Ages (Zeuner, 1963). The latter date is less certain because the evidence of reindeer in England in this case, may represent their reintroduction by invading Norsemen. The absence of reindeer in this and similar regions today is possibly related to the dietary preferences of the reindeer as much as to climatic factors, despite the reindeer's adaptation to extremely cold environments. The dietary preferences of reindeer are the largest constraint to their being raised in captivity. Seasonal migrations of reindeer under natural conditions seem to be largely associated with quests for particular lichen species during the different seasons. While the reindeer, in common with other members of the deer family, does graze pasture and browse trees, it is very selective in the species of grass and tree bark that it will consume. Various kinds of seaweed and fungi are relished and meat is also consumed to a limited extent which renders the reindeer unique among ruminants. Reindeer consume fish and lemming, a rodent of cold climates, possibly in response to sodium and nitrogen deficiency which may also be related to their other peculiar traits of drinking urine and sea water, chewing leather, eating bird droppings and licking salty soils. In any case, their wide ranging diet yet strict preferences makes their complete domestication difficult while, at the same time, rendering them easy to capture.

The migratory habits of the reindeer may be governed by calving patterns, avoidance of external parasite attacks, avoidance of very short daylight hours as well as feeding preferences and climatic conditions. They are captured by the use of decoy domesticated reindeer, the use of urine or salt as a lure and the use of a lasso. Today as for centuries, these techniques are utilised under the semi-domesticated system of husbandry that allows the reindeer to migrate over a wide area and to breed under natural conditions.

The succession of reindeer from a crucial economic position in the northern cultures during the Upper Paloeolithic period/era to its use much later as a draught animal, probably came about through contact with settled agriculturalists to the south. Herding of reindeer may have begun during the second millennium B.C. and riding of reindeer seems to have originated during the first millennium B.C. Today reindeers are ridden by the tribes of the northern latitudes including the Tungus, Yukaghir, Soyot, Karagas, Samoyed, Ostyak and Vogul (Zeuner, 1963). The great similarity of the reindeer saddle to that of the horse, indicates a probable source of the technology. Pack saddles also are used by those tribes that utilise reindeers as pack animals. Sledges drawn by reindeer are generally regarded to be an adaptation of dog-sledge technology, because of the similarity of both sledge and harness designs.

Reindeer are said to be capable of carrying pack loads of 27 to 32 kg or pulling 40 to 135 kg on a sledge over a distance of 32 to 40 km in one day (Cole and Ronning, 1974). They are reputedly easy to tame and train to these tasks and among those people who have raised reindeer under captivity, training appears to be as easily accomplished as that of the domestic water buffalo.

The elk, particularly the moose, is a close relative of the reindeer and is of interest to a discussion of working animals. The elk possibly originated on the American continent in common with the reindeer. Elk share many characteristics with reindeer such as a predilection toward holding the head lower than the shoulders. Experiment stations have been established in the USSR in order to improve the draught, pack and riding capabilities of the elk (Cole and Ronning, 1974). As the largest member of the deer family, the elk is seen to share the attributes of the reindeer such as ease of training and tolerance of extremely cold temperatures, while possessing the potential to carry heavier loads and provide a larger output per beast. The elk has been utilised by the Red Indians of North America to haul sledges upon which their belongings were packed when moving from one camp site to another. Such utilisation has an indefinite history although it does suggest similarities with the previous discussion concerning the evolution of reindeer domestication.

The reindeer and the elk represent exceptions to the general rule that working animals are utilised primarily in undeveloped tropical countries or, when utilised in western countries, represent an anomaly to the trend of change from animal to mechanical power. However, there is a certain similarity in the utilisation of the reindeer and the elk in the inhospitable arctic regions and the continued use of manual labour in some environments. Both represent technologies suitable to the regions in which they are practised, and may not easily be replaced by more sophisticated techniques. This situation would rapidly disappear if an exploitive need to develop these regions arose, such as the discovery of valuable mineral deposits. However, for the immediate future, reindeers will continue to fulfil a specialised role and in some circumstances reindeer technology may bear extension to some parts where they are not currently utilised. The research being conducted with elk in the USSR further testifies to the likelihood of its continued use as a working animal.

THE DOG (Canis familiarus)

The dog was probably the first animal that man domesticated. The role of the dog today as man's best friend can be taken as an indication of the predilection this species possessed towards domestication. It has been suggested that pet keeping was the first step towards domestication of the dog which was effected by the hunter having pity on the cubs of a wolf bitch (Canis lupis) that he had killed and bringing them into his home. Over time, the tamer dogs stayed with man and wilder ones escaped to fend for themselves. Domestication of the dog occurred during the pre-Neolithic period but it cannot be determined whether it eventuated from pet keeping or from the dog's role as a scavenger following man to eat the unwanted fraction of the hunt. The latter alternative has been disputed on the basis that no records exist of wolves becoming domesticated by this means despite ample opportunity (Cole and Ronning, 1974); Zeuner (1963), on the other hand, is less sure and suggests that the alternative of social parasitism may be reasonable. Other suggestions have been made, such as the role of dogs as food or sacrificial animals. The pet keeping domestication of the dog is perhaps the most appealing if for no other reason than the dog's endearing nature. It seems therefore that dogs are an exception to the common theme of domestication arising from a need and soon leading to the utilisation of the animal for work.

Over the long history of the domesticated dog, many breeds have been developed by man for varied purposes such as herding, sledge drawing, hunting, guarding, or simply being pleasant house companions. The work purposes for which dogs are utilised today are similar to those of history. The Eskimos utilise them to draw sledges over distances of up to 800 km within a period of ten days. They are also utilised in these arctic regions as rescue animals for lost persons, an ability also exploited elsewhere for tracking. Dogs can also be invaluable for the herding of livestock.

In purely economic terms, the saving in labour allowed by the use of the dog in this role, substantiates the value of the dog, particularly in high-cost western cultures. Dogs are also utilised as guides for blind persons and for the detection of game for hunters and many other tasks.

It is easy to eulogise the dog as the domestic animal that lives in the closest association with man. We could categorise the dog into the roles of the pack animal such as a St. Bernard carrying brandy to a lost person or as a traction animal such as the Husky sledge pullers of the Eskimoes. However, the importance of the dog to the overall subject of working animals is quite limited when one calculates the essentiality of these roles to large proportions of the world. The principal role of the dog, as with the finely purebred horse to a certain extent, is in the production of pleasure.

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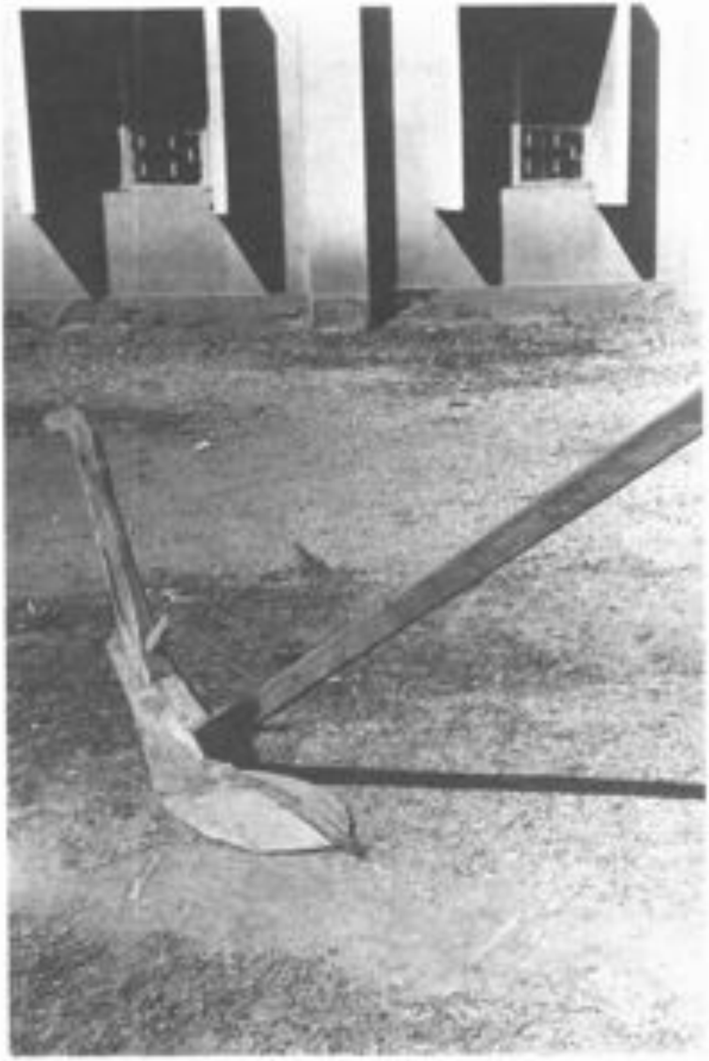
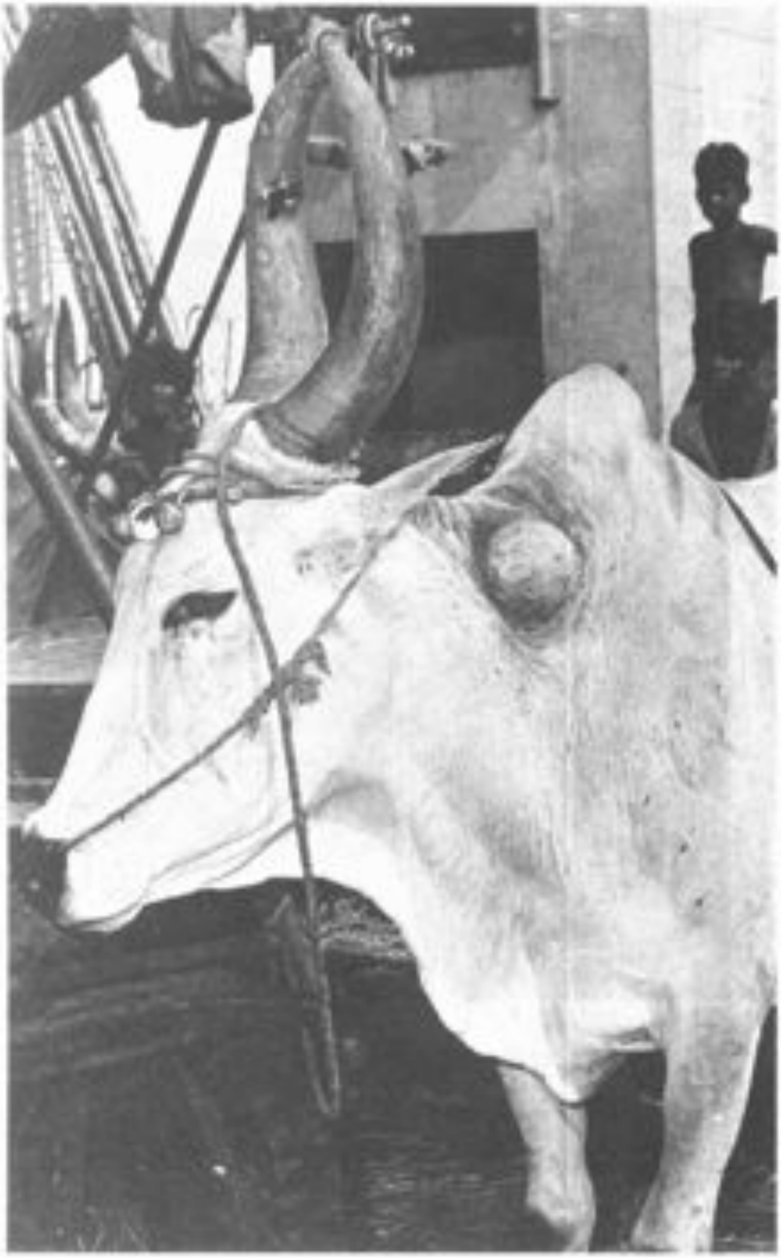


Traditional Wooden Plough.Orissa,India.



Neck Gall Due to Rough Yoke Rubbing on Neck, India.

Neck Gall Bullock Due to Rough Yoke, India.

Bull of the Khilhari Breed, India.

Head Yoke with Yoke Anchored to Horns, Mexico and Latin America.

Mules Pulling Harrows, Mexico.

Traditional Porseuyr Cart, Central India.

Donkey Cart with Moped Wheels Pulling 400 Kg, China.

Traditional Bullock Cart with Cane Basket and Traditional Yoke System, India.

Traditional Drum Carts, Northern Thailand.

Paddy Paddling Machine, Thailand.

Tandem Cart Harness, Northern Thailand.

Buffalo Bull Belonging to Nilli - Rare Breed, India.

Offset Disc Plow in Paddy Field, India.

The "Iron Buffalo" Engine or Road Vehicle, Thailand.

Two Wheeled "Iron Buffalo" Cultivating Paddy Field, Thailand.

Working Elephant Between Jobs, Thailand.

Camel Cart, Malpura, India.

PART C

THE FUTURE

CHAPTER 15

FUTURE OF WORKING ANIMALS

Animals will continue to be required as power sources in the future. In India, for example, where seventy percent of holdings are less than two hectares in area, power tillers are not economic (Ramaswamy, 1979). It seems likely that at current prices, mechanisation will not replace animals unless holdings increase in size. New technology may extend the range of farm sizes to which machines are suited but it is not conceivable that subsistence farmers can economically utilise machines under present conditions. However, it is true that subsistence farmers could, in some situations, become cash croppers if fertilizer and machinery were purchasable. Assistance with credit may raise the subsistence farmer to a cash cropping level, however experience with such projects indicates that success is limited because of fatalistic religious views, inconsistencies of weather or profit making by local businessmen. Poor farmers will be with us always and while they may not always be in the same countries throughout history, it is the poor farmer who will rely upon animal power in the future as in the recent past.

The current role of working animals is indicated by figures such as the 58 to 96 percent of market produce in India being moved by cattle cart (Ramaswamy, 1979). The number of carts and details of their loads are presented in Table 15.1. A total of 15,000 million tonne-km represents an industry of major importance to India and one not easily replaced.

The economic utilisation of trucks in developing countries is limited by road construction and trucks incur higher maintenance costs than do cattle carts when used on poor roads. In addition, the individual loads of farmers are commonly too small for trucks while being well suited to cattle carts, an indication of the interactive evolution of the agricultural system around the available technology.

Table 15.1
The Number of Carts, Their Loads, Distances and Days of Work for Cattle Carts in Rural and Urban India (after Ramaswamy, 1979).

Particulars	*Rural Areas*	*Urban Areas*
Number of carts (x 10^6)	*12.00*	*3.00*
Average load (tonnes)	*0.50*	*0.75*
Aver. distance of haulage (km day-1)	*10.00*	*20.00*
Aver. number of work days per year	*52.00*	*260.00*
Freight in rural areas (tonne-km 10^6)	*3120.00*	-
Freight in urban areas (tonne-km 10^6)	-	*11700.00*
Total for India (tonne-km 10^6)		*14,820.00*

Improvements in cart design such as the use of pneumatic tyres and bearings as well as improved harnessing have already improved the economics of utilising cattle carts and should continue to make an impact as this technology is adopted over a wider area (Ramaswamy, 1979). Thus improvements in the animal power system and restrictions on the opportunities for replacement of animal power with machines appear to be ensuring a continual reliance on animal power in countries such as India.

The past changes in the numbers of Indian work animals in general and buffalo in particular, are presented in Figures 15.1 and 15.2 respectively. The number of cattle carts used (Figure 15.3) shows a similar rate of increase. While India is only one of many countries in the world where animals are employed for work, it is one of the largest and most diverse of those countries. The generalities that emerge from Indian experience apply to most Asian situations and it is considered likely that similar developments will be observed in the neighboring countries with similar levels of economic

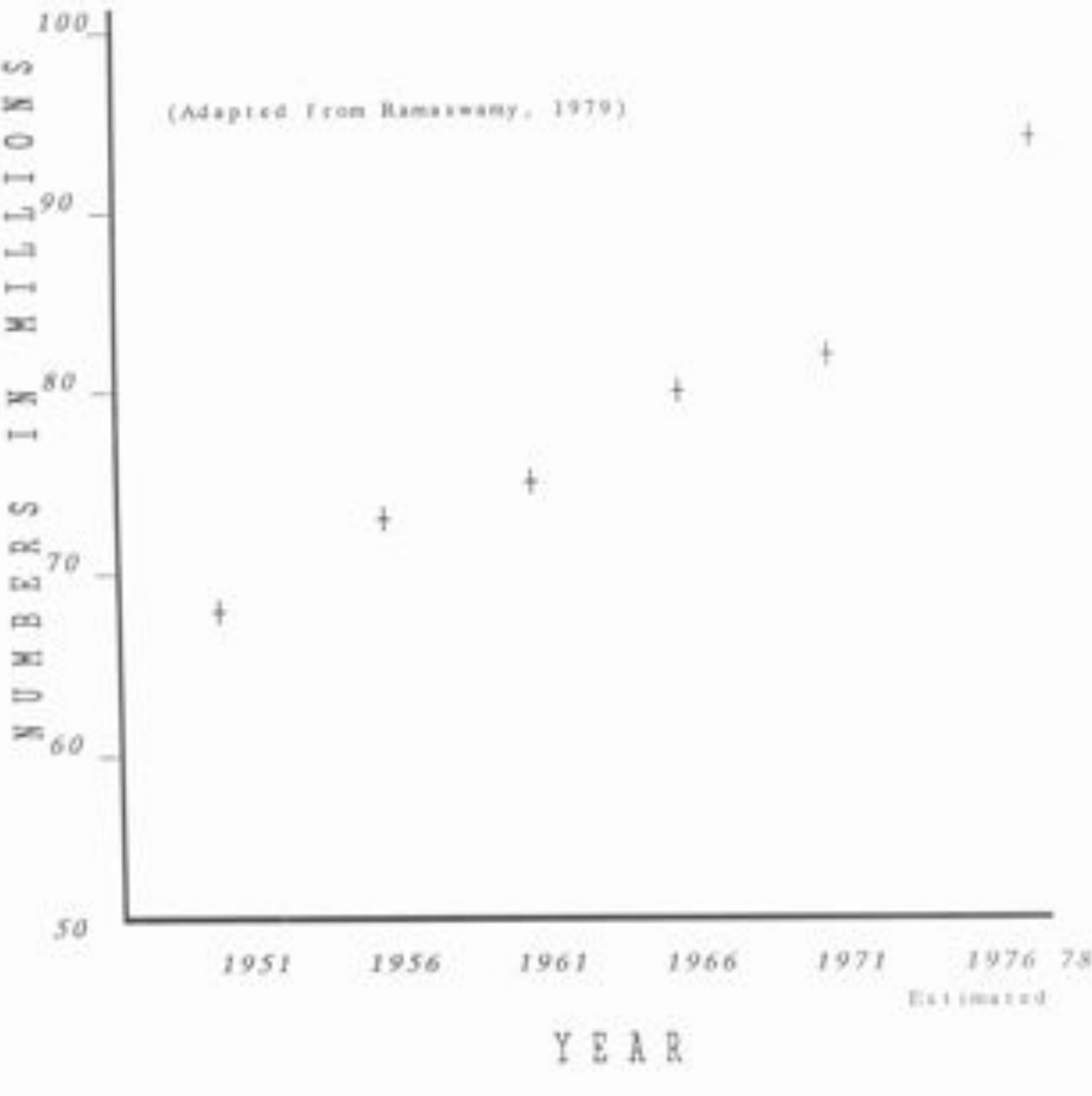


Figure 15.1 Growth of Work-Animal Population in India, 1951-78

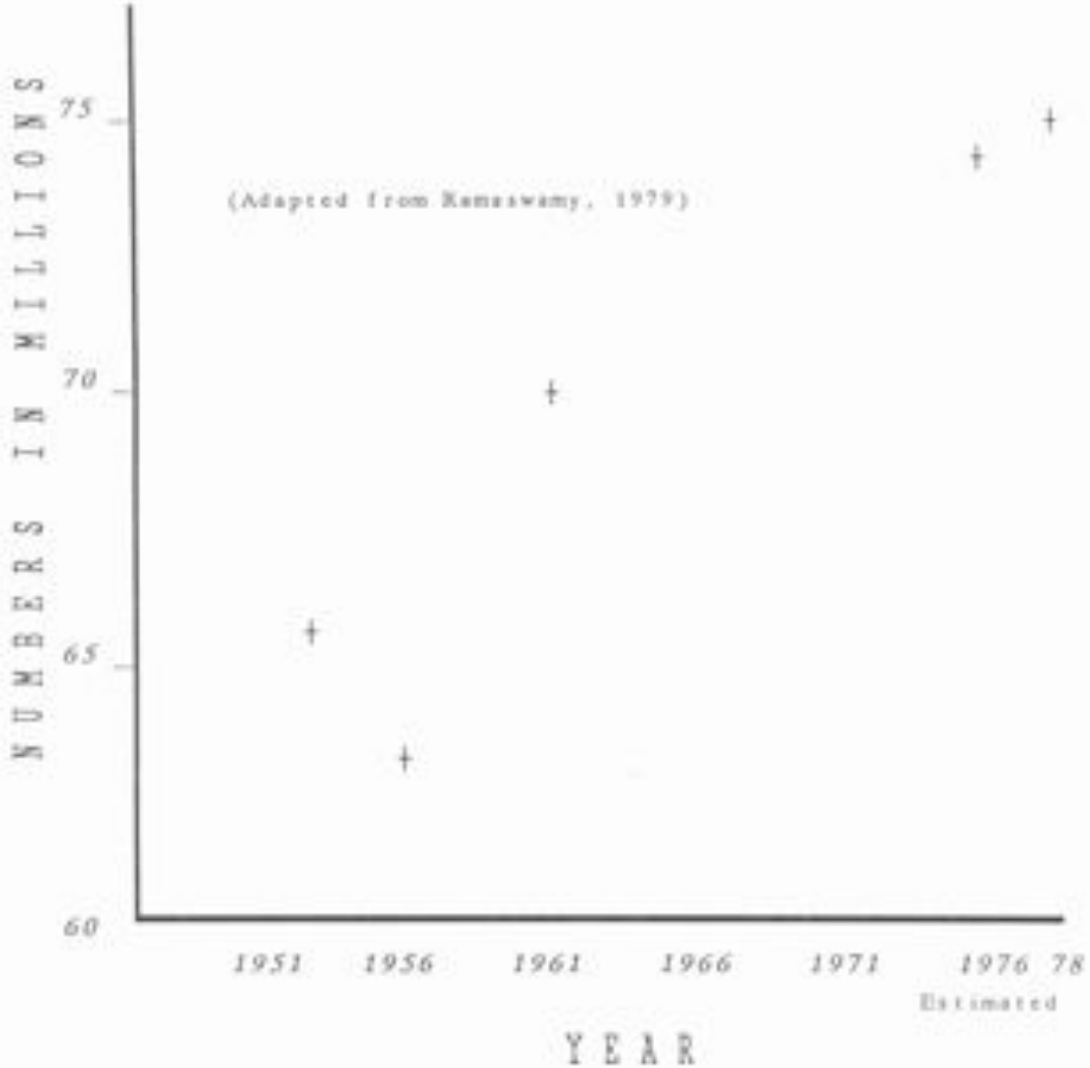


Figure 15.2.Use of Buffaloes as Work Animal in India.
1951-78

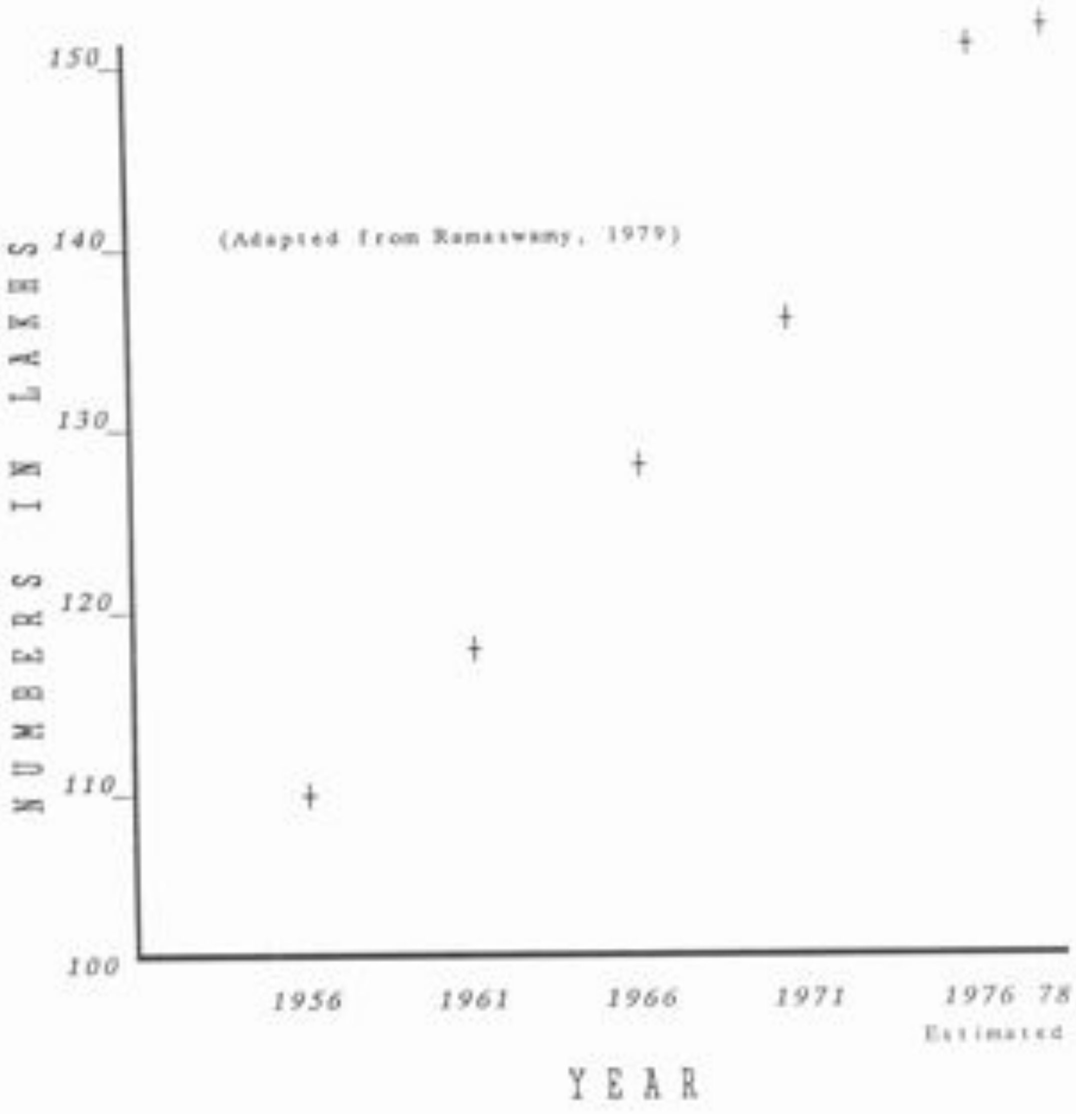


Figure 15.3. Growth in Cart Numbers in India. 1951-78

development. In the island countries of the Pacific and elsewhere, the short distances of travel favour animal power except where the terrain is steep. The countries most likely to experience a decreasing reliance on animal power in the next decade will be those which have benefited from past increases in oil prices and employed this benefit to initiate a rapid transfer from animal to machine power.

It is encouraging to note that increased attention is being paid to the role of working animals in national planning. While efforts toward developing these sectors are minimal, their inclusion in national development plans draws attention to their importance; previously national plans for livestock development may not even have acknowledged the contribution of working animals to the economy. An example of increased awareness of working animals in planning in a developing country is Sri Lanka. In the National Development Plan for Livestock over the period 1979 to 1983, the Ministry of Rural Industry and Development has mentioned the contribution of animals to draught and traction and includes plans for the improvement of this livestock sector. Specifically, it is estimated from 1973 figures that, of the 494,307 cattle and 178,038 buffalo in the country, 98,860 and 35,600 pairs of cattle and buffalo will be available for draught purposes. These animals can cultivate an estimated maximum area of 140,000 hectares which fails to meet that required each year by 60%. In addition to this apparent deficiency in numbers of working animals, all cultivation must be carried out within a period of 45 days to benefit from rainfall patterns. The traditional means employed to ease the deficiency of animal power has been the importation of stock from India when foreign exchange was sufficient. One breeding station in Sri Lanka concentrates on the production of draught animals and is completely unable to meet the demand for their supply. Means suggested for increasing the availability of working animals are:

(i) *A ban on the slaughter of all breeding and working cattle and buffalo under twelve years of age.*

(ii) *Reservation of grasslands for the grazing of cattle.*

(iii) *Use of a single buffalo plough as in the Philippines.*

(iv) *Cross breeding of local buffalo using Murrah/Surti.*

(v) *Cross breeding of local cattle with Indian cattle.*

While plans to assist the production of draught animals may be less formalised than this example and may be easily criticised as simplistic and limited, all represent an advance compared to the previous lack of attention paid to the sector. However, in almost every case, draught and traction are viewed as secondary products to meat and milk when the reverse is usually true.

NUMBERS OF WORKING ANIMALS

In acknowledging that working animals are a necessary part of the future development of many regions of the world, one must also acknowledge that such development will be hampered by the numbers of animals available. The simple solution of increasing numbers of animals is not applicable to many countries where competition for land space is already critical. Arguments concerning the limited forage resources in Africa in areas to which animal power has been hailed as the energy source of the future are relevant here (McCown et al., 1979). Similarly the data of Shah (1976) for Bangladesh indicate a need for an alternative solution; Shah estimated demand for draught animals in Bangladesh at 11 million cattle when the current population was 7.6 million. One means of increasing the work output efficiency of animals is to utilise females for work as well as males recognizing that work output is usually lower and pregnancy restricts the number of days per year for which a cow can work. This solution introduces an interesting problem that will require both observation and research in the future; working females may have a lower work output than males but the additional stress of working may reduce their productive efficiency. Thus the cost of a reduced calf drop will be the increased numbers of females that will be required to provide the number of calves originally anticipated. A decrease in calving rate from 60% to 50% will require 20% increase in the numbers of females carried. Such a requirement may not necessarily prejudice the economics of the practice of employing females for work when the alternative is carrying increased numbers of male cattle. From the above hypothetical figures the work output of females would have to be very much lower than that of males before increasing the numbers of male cattle became the more viable alternative. In some cases the effect on reproduction may be more severe particularly under conditions of extremely poor feed quality.

Employment of animals with lower work outputs may also restrict agriculture in those regions where weather conditions require rapid preparation of soil; a situation analogous to that of machines economically replacing animals through greater work outputs.

One alternative is the utilisation of other animal species. In Bangladesh, a marked preference for cattle as draught animals is probably related to a preference for cattle milk rather than buffalo milk. Nevertheless, buffalo may be more efficient working animals in many parts of Bangladesh while also providing milk (Shah, 1976). The social cost of losing a traditional product would require recognition of the need for change.

ANIMAL POWER IN WEST AFRICA

A predominance of African literature on the subject of working animals comes from West Africa. This is probably due to a longer history of experimental introduction of the technology. It has been estimated that there were 170,000 planters drawn by horses or donkeys in use in Senegal in 1972 (Uzureau, 1974); a similar number of weeders were also estimated to be in use. The employment of cattle in place of horses and donkeys is increasing particularly where additional power is needed. A peanut lifter is utilised exclusively with a pair of cattle because the power output is high and the feeding requirement of cattle is low. In Mali, tractors were utilised to plough 30,000 hectares while animals were utilised to plough 30,000 hectares in 1972-73. Adaption of animal power rather than mechanical power by Mali farmers was attributed to its technical and financial appeal.

This seems to be at variance with the sentiments of other researchers who have arrived at different estimates of the popularity of animals for work purposes in different regions of West Africa (Orev, 1972 c.f., Uzureau, 1974). Only about one percent of farmers are estimated to be served by animal power if it is assumed that animals are worked in pairs (Orev, 1972). Resistance to more rapid adoption was seen by Orev to be unrelated to economic factors despite the named advantages of:

(i) *Speed of operation. A larger area can be cultivated more quickly (than by hand), thus increasing production.*

(ii) *Better cultivation. The West African farmer often sows more than he can weed and loses much of the sown area to weeds; animal draught could eliminate this.*

(iii) *Farmyard manure. Draught animals are stabled. The manure can be collected and spread where needed; at present it is scattered in the brush.*

(iv) *Farmers will get accustomed to keeping livestock thus learning to associate farming and livestock, further increasing quantities of manure produced.*

(v) *Farmers can get some extra income from carting, until every unit possesses its own draught animals.*

Lack of adoption of draught animal technology cannot be related to ignorance due to the very early history of the area in using working animals. The only suggestion offered is that the technology was not appropriate and adequate forage was not available for livestock (Orev, 1972). The transplanting of Andropogon gayanus from elsewhere in the region to serve as fodder, possibly in a rotational ley farming system has been advocated. However, Orev feels that mechanisation would be more socially acceptable and draws a parallel between pilgrim Moslems who now travel to Mecca by aeroplane rather than by camel caravan and the inappropriateness of working animals as an intermediate step to mechanisation.

Constraints to animal draught power can possibly be overcome subject to meeting future needs as introduced by Uzureau (1974) viz:

> *(i) In some areas there are difficulties in persuading the farmer to keep the animals all year round other than in the crop production season. This problem can easily be overcome where there is a market for the animals for meat production because, in that case, the farmer looks upon the oxen as a direct source of revenue.*
>
> *(ii) The need to provide feed for the animals during the dry season. Both in Mali and to a lesser extent in Senegal this is a problem which can be overcome, sometimes through the growing of fodder crops in the fallow land, and even without special fodder.*
>
> *(iii) The difficulty of persuading the farmers to use fertilizer as part of a crop rotation system which would permit them to maintain or even increase soil fertility.*

The last point provides an introduction to a means by which animal power can be introduced to farmers. Just as mechanised power sources are introduced with cash crops as a total system, so a system based on animal power will require introduction to the farmer rather than simply promoting the use of animal power per se. The development of any area requires an overall appreciation of the farming system and alternatives both within and to that system.

IMPLEMENTS

Advances in implement design which contribute to increased efficiency have been recorded for specific regions although it is widely held that further great advances are technically possible. One study showed that animal drawn equipment in Botswana was poorly adapted to the conditions of that country and resulted in slow working of soil and an associated excessive loss of moisture (Gibbon et al., 1974). A project was thus initiated to design and construct an animal drawn two-wheeled implement carrier. In many ways the concept was one of adapting tractors and implement technology to a new power source. Implements for ploughing, weeding, planting, inter-row cultivation and fertilizer application can be easily placed into position to perform the appropriate tasks. Refinements to the design each have their origins in the solution of a practical problem; for example, the implement carrier can be raised to provide greater ground clearance during travel to and from the site of work. Presumably such a carrier can also be utilised to transport other materials simultaneously. However, recent experience in Botswana suggests that this particular tool bar may not be universally appropriate.

Such a concept is not new at the individual level as indicated by another description of rice production by machinery powered by animals (Pradhan, 1966). An economic comparison suggested that alternative implement design and a range of equipment may be profitable in India by allowing faster operation with technical gains in plant establishment. One interestingly basic example is the use of a disc harrow instead of a conventional cattle drawn plough for shallow burying of seed. Dribbling of seed behind a traditional plough is technically satisfactory while not involving large labour costs (Pradhan, 1966). In economic terms, the drudgery component of any task will tend to be minimised if alternatives are available. Perhaps the most critical of Pradhan's measurements used to compare alternative implements for rice production is that of the power required for the task because the first limiting factor is commonly the availability of working animals at specific times of the year.

Implement design has not received significant support from the governments of developing countries in the past. This reticence could possibly be interpreted as an unwillingness to commit their countries to continued reliance on animals as power resources. The inputs of agricultural engineers have largely been restricted to the use of tractors and there can be little doubt that the most far reaching innovation has been that of the two-wheeled tractor that replaces animals on a one-to-one basis. The development of implements suitable for use in conjunction with such two-wheeled tractors has received markedly more attention than has the development of better implements for use with animals. While such implements have evolved into efficient tools over their centuries of use, major constraints in the design of the implements have been ease of transport of the implement by one man and limited access to new technology; these have restricted both the sophistication and number of implements used. Similarities in the design of the plough across the world may reflect adaption to such criteria rather than reflecting the evolution of the most efficient implement in engineering terms.

The challenge for agricultural engineers involved in this field in the future will be the improvement of animal drawn implements including means of harnessing; perhaps not a glamorous profession but one that promises significant rewards to primary producers in the poorer regions of the world.

RESEARCH

The relative performance of crossbred cattle for use as working animals in countries such as India and Bangladesh is a high priority for research. Dairy breeds introduced to crossbreed with native cattle in attempts to increase milk yields may not be in the best interests of work performance. Katpatal (1977) notes that crossbreeds can perform ploughing and carting tasks well but quantitative information is not universally available. This research topic should not be restricted to technical considerations because social and economic factors may also be of importance. A possible outcome of such research is that crossbred animals may perform as well as native cattle while temperatures are low and the duration of work is short. If the farmer must then change his routine to accommodate the limitations of crossbred animals, the economic cost in terms of speed of land preparation and the social cost in terms of reduced sharing of animals and other factors should be considered. This aspect of research in developing countries requires close attention and a great appreciation of local requirements among researchers. Logically, the primary function of cattle in a given circumstance should be determined before a political decision to improve the production of one part of the farming system is acted upon. In many parts of the world, it is evident that the primary reason for raising cattle is to provide a source of power with secondary benefits from meat, milk and other products. In that case, a decision to increase milk production should be costed against any decreased efficiency of working ability.

Other more basic research is also required to quantify the relationship between nutrition, health and working ability (Reh, 1982). Such studies would logically include low nutritional levels to make results relevant to practical situations. Existing studies have not concentrated on this aspect, perhaps on the assumption that feed quality can be improved or perhaps because many early studies were conducted in the temperate zone for application in western agriculture of earlier times. Today, most of the world's working animals are employed in Asia where the opportunities to increase feed quality for working animals exist yet are limited either by environmental or economic constraints. Hence there is a need to evaluate work performance and nutritional level within breed types. Such studies would necessarily require quantification of the contribution that various physical attributes of different breeds play in work output. It may also be suggested here that a wider range of measurements may be required to compare the working ability of different animals or breeds; the role of intelligence and stamina may be as important as static and dynamic power output.

The number of detailed studies being undertaken at present is low. Studies of significance include those of the International Livestock Centre for Africa in which crossbred (native x dairy) cattle are compared in terms of work output and milk production under two different management systems (ILCA, 1979). Cows will be utilised for milk production or for both milk and work while male animals will be employed for work output at different nutritional levels. From such studies it will be possible to improve knowledge concerning:

- the relationship between milk yield and work output;
- the energy requirements of working cows;
- the energy output of working cows;
- the effect of work on the health of working cows in terms of fertility, abortion and incidence of sickness;
- the economics of utilising cows instead of male cattle for work purposes, and
- the practicability of recommending the utilisation of cows for work in farming situations.

Technical aspects of research should also involve implement design (Rijk, 1977). Technical increases in efficiency resulting from the implementation of results from such research may render previous economic analyses inaccurate. Hence the need for accurate, detailed economic studies to determine the conditions under which mechanisation is more profitable than animal power and also the conditions under which manual power could profitably be replaced by animal power. Indivisibly bound to such studies would be a sociological evaluation of the implications of any changes that may occur as a result of economic pressure or resistance to change despite apparent advantages in economic terms.

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