UNITED NATIONS

GENERAL ASSEMBLY

Distr.
GENERAL

A/CONF.100/PC/39
4 March 1981

ORIGINAL: ENGLISH

PREPARATORY COMMITTEE FOR THE UNITED NATIONS CONFERENCE ON NEW AND RENEWABLE SOURCES OF ENERGY
Third session
30 March-17 April 1981
Item 2 of the provisional agenda*

SUBSTANTIVE PREPARATIONS FOR THE CONFERENCE

Report of the Ad Hoc Working Group on Draught Animal Power

UN LIBRARY
MAR 23 1981
UN/SA COLLECTION

* A/35/43 (Part II) and Corr.1, para. 67.

CONTENTS

		Paragraphs	Page
INTRODUCTION		1	3
I.	DRAUGHT ANIMALS AND DEVELOPMENT	2 - 29	3
II.	MAGNITUDE OF DRAUGHT ANIMAL POWER	30 - 45	9
III.	ECONOMIC CONSIDERATIONS OF DRAUGHT ANIMAL POWER	46 - 62	14
IV.	FARMING OPERATIONS	63 - 76	18
V.	TRANSPORTATION	77 - 102	22
VI.	HARNESSING DEVICES	103 - 128	28
VII.	INFRASTRUCTURE FOR DRAUGHT ANIMAL POWER	129 - 149	33
VIII.	CONCLUSIONS AND RECOMMENDATIONS	150 - 162	38

Annexes

I. ILLUSTRATIONS OF IMPROVED METHODS

II. LIST OF PARTICIPANTS

***

BIBLIOGRAPHY

Note

At the meeting of the Ad Hoc Working Group on Draught Animal Power, organized at Bangalore from 2 to 6 February 1981 by the secretariat of the United Nations Conference on New and Renewable Sources of Energy, it was decided to use the following terms in the present report:

Draught animal power (to refer to animal energy);

Mechanization (to refer to tractorization).

/...

INTRODUCTION

1. The United Nations Conference on New and Renewable Sources of Energy to be held in August 1981 at Nairobi will include draught animal power in its work programme. The secretariat of the Conference requested the Food and Agriculture Organization of the United Nations (FAO) to make a survey of the state of the art of draught animal power. FAO entrusted the task to Professor N. S. Ramaswamy, Director of the Indian Institute of Management, Bangalore, who started this consultancy on 1 April 1980. Professor Ramaswamy collected data from several sources - from published material surveys, field visits to various countries and consultations with FAO specialists. The present document is a summary of a detailed report produced by the consultant.

I. DRAUGHT ANIMALS AND DEVELOPMENT

Food and energy

2. The third world has entered the third development decade with more anxieties than ever before in human history. In spite of spectacular achievements in nuclear, electronic, space and numerous other scientific and technological fields, the problem of achieving economic and social progress, on an equitable basis, continues to be formidable and has challenged man's ingenuity. Among the several issues confronting the developing countries, food and energy will be the major ones for the next two decades. Development is usually associated with industrialization and the use of sophisticated technology. While this is largely true, the experience of the last two development decades shows that even a high growth rate and prosperity in industrial countries will have less over-all impact, unless improved technology can be made available to a significant part of the millions engaged in agriculture. Even under the best of conditions, where industry grows at a rate of 8 to 10 per cent, organized industry cannot absorb the millions that will be added to the work force during the next two decades. A way has to be found to retain as many as possible in the rural areas by utilizing local resources and employing labour-intensive techniques. Draught animal power fits nicely with its labour-intensive and low-skill character, least capital-consuming technology - well in tune with rural life because of its multifaced uses. Therefore, while efforts towards rapid industrialization and high technology (where it is a "must") should continue, development of the decentralized rural sector through the effective delivery of modernization and organization to it will offer new life and hope to the millions.

3. Draught animal power is an outstanding example of mass-level application of appropriate technology to the millions of small farmers who have missed the fruits of development in the third world. For both food and energy, the renewable draught animal - integrated with the popular milk and meat systems produced by its own species - has no equal. It converts the sun's infinite energy, through plant life, into energy and numerous products and services for man's well-being.

4. Eighty-five to 90 per cent of Asia and Africa depend on manual and draught power, and the benefits of mechanization go to barely 10 per cent. Thus, man and

beast still share the energy burden between them, mutually dependent on a symbiotic relationship. As the main instrument of production of the small farmer, it is more fairly and evenly distributed than any other. Four hundred million draught animals in the developing countries, valued at $100 billion, make available 150 million hp, the replacement of which may need $250 billion. The modernization of draught animal power would amount to strengthening the instruments that would enable the small man to make a decent living, which he has been unable to do so far, as he has not been able to join the development stream fully in the last two decades.

5. Already, a billion people are suffering under severe conditions of hunger and poverty. Two thirds of the population of Asia and Africa are engaged in agriculture. The third world countries are now importing approximately 90 million tons of good grains, whereas in the past some of them were net exporters. It is feared that this figure may go up to a staggering 150 million tons by the end of this century, by which time two more billions will have been added to the world population, the bulk of them, again, in the developing countries. Although the developed countries can perhaps produce this additional food requirement, most of the low-income countries cannot afford to pay for the same. Moreover, the non-oil-producing countries need their precious foreign exchange to pay for the ever-increasing cost of petroleum imports. For many of these countries, the foreign exchange burden will be beyond their means.

Draught animal power: renewable energy

6. In many world forums, the opinion has been expressed that the developing countries should increase their food output in the aggregate at the rate of 3.4 per cent, that is, about 1 per cent above the population growth rate. Power availability is one of the main constraints to achieving the increase in land and labour productivity essential for meeting world food production targets and for raising rural incomes. Energy is the key input, around which the impact of other inputs such as fertilizers water, pesticides, etc. would show better results. Energy is required for increasing the area and the intensity of cultivation. It is in this context that leaders and professionals should look at draught animal power as a source of renewable energy and give more attention to it than hitherto, as an input to agriculture and small-scale transportation. The search for new energy sources such as the sun, wind, tide, etc. will and should continue with vigour. However, it will take many years for these new forms of energy to become available for mass application at a price within the means of millions of farmers. Meanwhile, draught animal power technology is known, and is available (or can be made available) within the financial and organizational means of most farmers. All that is required is modernization and development, wherever draught animal power is the only way and/or appropriate to given situations.

7. During their working life, draught animals provide not only motive power to millions of ploughs and other agricultural implements but also fuel for rural homes and fertilizer for the soil. When dead, they yield meat, skin, bone and numerous other valuable products useful to man. The important role of work animals, which has been critical for man's sustenance for thousands of years,

strangely enough continues to be so even today for many developing countries, which will have to depend on draught animal power for many more years to come. Unfortunately, over the centuries man's symbiotic relationship with animals has progressively changed. Animals today are a mere inert commodity for utilitarian exploitation. It is not even now too late to restore harmony and balance in the land-draught-animal-man continuum, for the benefit of all.

8. Oxen were perhaps the first and most widely-used work animals. Even today they continue to be the mainstay in most parts of the developing countries for agriculture and transport operations. Buffaloes are popular for ploughing in Asia, and they haul vehicles in India and to a lesser extent elsewhere.

9. The horse - an efficient work animal well developed in the developed countries - displaced oxen in the first half of the century. Although they continue to play a part in agriculture in Poland, China and some Latin American countries, elsewhere in Asia horses are mostly used for light transportation in urban areas only. Donkeys are mainly used as pack animals, although they haul carts in a few countries in Africa and Latin America, and in China in a big way. Mules are used for both ploughing and carting, wherever horses and donkeys are in use.

10. Camels are mainly used as pack animals, for transportation of goods and people, and in a few cases they are also used for ploughing. In a few countries, such as India, they also haul carts. Llamas work only as pack animals in Tibet and the adjoining mountainous provinces of China. They are also used for ploughing and carting. Elephants are used for logging in Sri Lanka, India, Burma and Thailand. For logging, developed countries use horses and Latin American countries cattle.

11. Besides work, draught animals yield during their lifetime a variety of products such as milk, wool, fibres, etc. Dung and urine are useful as fertilizers. Dung is used as direct fuel, and for producing methane gas. It is used in construction as plaster, and as feed (recycled). India annually uses 60 to 80 million tons of dried cattle and buffalo dung for fuel, replacement of which by coal and oil would cost $3 billion. Camels, llamas and yaks yield fibre. Containers made of dung and mud are reputed for the conservation of grains. As regards conservation, animals contribute to ecological maintenance and restoration, which is not well recognized. Grazing animals help in distribution of seeds of grasses and legumes through their faeces. Plant coverage prevents soil erosion. Animals provide the incentive to grow grass and plant cover.

12. While their utility during their working life is impressive their value after death is equally so. Most parts of the animals are useful. Meat of all the species is eaten, as 90 per cent of the world population is non-vegetarian. The skin of all animals is extensively utilized. Buffalo hair is used for brushes. Blood, bone, hoof and horn extracts and numerous other by-products are used by industry, particularly the pharmaceutical sector. Draught animals help in maintaining and restoring the ecological balance.

Draught animal power and petroleum-based mechanization

13. Development of draught animal power does not mean discouragement and/or

discontinuance of mechanization by petroleum-based power. In fact, petroleum-based power can be encouraged wherever technically feasible and economically viable. Similarly, draught animal power need be developed only where it is recognized as being inevitable or appropriate where circumstances conducive to it exist. Draught animal power could be considered as complementary to manual labour on one side and petroleum-based power on the other. In most situations, there is no real competition or conflict between draught animal power and petroleum-based power, as has been demonstrated in China and some parts of India. Wisdom lies in using all sources, manual labour, draught animal power and petroleum-based power in the right mix, and not to consider one in place of the other. When more suitable and economic sources of energy are developed in the future, draught animal power could possibly be phased out. Meanwhile, it is in the developing countries interest to upgrade their draught animal power systems.

Consequences of neglect

14. In spite of its significant contribution and further potential, draught animal power continues to be a neglected factor in the rural economy of most developing countries with the result that there is an enormous wastage of its potential. Neglect of draught animal power is perhaps one of the reasons for food deficits in some countries. A modernized and well-managed draught animal power system will certainly benefit man and society.

Draught animal power to be subsidized

15. It is well known that there is a direct correlation between energy and rate of development. Conscious of this, many countries have subsidized energy in varying degrees, particularly to rural enterprises. Diesel oil is subsidized; so also is rural electrification for energizing pumpsets. Water is supplied almost free in some places; elsewhere, only nominal charges are collected. However, it is noteworthy that animal energy, which is a major input to agriculture, has not been subsidized as it ought to be.

Changed cost of mechanization

16. In the developed countries the farmers knew the importance of energy, and draught horses were developed at enormous effort and expense. Even today the best draught horses are still working in parts of the western world, at a cost cheaper than current rates of energy. In fact, in Poland, it was observed that draught animal power was cheaper. The third world countries, seething with unemployment and under-employment, should have no difficulty in getting labour for agricultural production with draught animal power. However, there are also many regions in the developing countries where attitude itself may still be a limitation for developing draught animal power.

17. Most mechanization took place in the West when the cost of energy was based on $2 per barrel of crude oil and labour costs were high. The current price of oil is between $30 and $40 per barrel, and may go up to $60 in the near future, changing the proportion of energy cost drastically. The economics of

mechanization, justified in terms of savings in labour and increased yields, are no longer universally valid. A review is called for by altering the parameters of the calculations in order to identify situations where draught animal power is economical and to be preferred. Even where it is not exactly economical by cost considerations, there are innumerable situations where draught animal power will be the only feasible solution, owing to factors such as lack of infrastructure, maintenance, spare parts, and foreign exchange for the import of oil, as well as the high cost of equipment and oil.

Difficulties in developing draught animal power

18. With the change in energy cost and other factors compelling the continuance of the draught animal power system, the Governments' attitude should undergo change by way of new policies and priorities, whereby draught animal power gets at least as much attention as the other agricultural inputs. Draught animal power constitutes live animals; their development and care take time and effort. They are in the decentralized sector, the modernization of which is not easy for countries with millions of fragmented holdings owned by marginal farmers. There is unfortunately a tendency among governmental bodies to overlook draught animal power.

19. Various diseases such as foot and mouth disease, rinderpest, etc. are afflicting many developing countries. The programmes for the eradication of these diseases in Asia have not yet been fully successful in most countries of that continent. Countries which have successfully tackled this problem are afraid to bring in animals from those which have not controlled these diseases. Trypanosomiasis is a special problem in some African countries, although it is not likely to be a hindrance to draught animal power with control measures and spread of agriculture.

20. The need for speed of operations, that is, timely ploughing, is an important factor where animals are generally, but not always, at a disadvantage, particularly so when working with bad implements. But China has shown that it is possible to raise two crops with animals alone, if they are properly trained and used.

21. In many African countries where there is no tradition of using animals for draught, it has been difficult to introduce work animals; but once people become familiar with using draught animal power, there are examples showing that it becomes popular.

Trucks and draught animal power

22. There are terrains which are not paved or where pathways are too narrow. In such conditions, motorized transport is not feasible. Even in India, 50 per cent of the villages are not connected with motorable roads. For relatively long distances, and with loads of 5 tons or more, trucks are economical. However, for small-scale transportation, say less than 1 ton, over short distances, animal-drawn vehicles may be advantageous. So also in operations where the loading time and unloading time is high - compared to travel time - trucks are not economic because of low utilization. Trucks have also become very costly for small farmers and operators.

23. For transportation of goods between villages on unpaved roads, animal-drawn vehicles seem more feasible. When animals are kept for ploughing, the recurring cost for rural transportation is only the incremental maintenance cost on the animals. Thus, animal-drawn vehicles become complementary to draught animal power ploughing and, with a little extra cost, make it more viable.

24. Even in towns, animal-drawn vehicles are appropriate for a number of needs and situations. For small-scale transportation over short distances in cities, these animal-drawn vehicles are economic. For jobs such as garbage collection and disposal and movement of kerosene, water, oil, vegetables, household effects, stationery, etc., animal-drawn vehicles are convenient.

Draught animal power and pasture for feed

25. One argument against draught animal power is that animals compete with humans for the use of cultivable land. This view has been contested by many experts on the grounds that most of the feeds given to animals are not edible by human beings and that, for the most part, they constitute agricultural waste. The feed which draught animals consume is largely forage which includes fodder grasses, straws, hay and wayside legumes. Moreover, pasture lands are often cultivated on soils not suitable for other crops. According to FAO, grazing and harvested forage account for 75 per cent of the feed available to draught animals. Only in a few countries does the feed include food grains, oil cakes, meals, vegetable residues and other industrial by-products.

26. It is argued that the use of draught animal power is an excellent form of converting reject and waste into energy on the one hand and of utilizing land which cannot be used otherwise. Production systems have to be integrated whereby both crop and fodder can be raised without affecting crop output.

Draught animal power and milk-meat system

27. There is a suspicion in some circles that draught animals will compete for land with animals of the milk-meat system. Although some animals are raised exclusively for meat in developed countries (and some developing countries as well), in Asia it may be possible to raise dual-purpose animals, whereby females give milk and males work; both will be available as meat in the end. Such a suboptimal solution is inevitable in countries where draught animal power is a critical need.

Cruelty to animals

28. A growing number of people are legitimately concerned about the bad treatment given to draught animals in some parts of the developing countries and fear that this new interest in draught animals may cause further suffering to animals. But it must be noted that the major part of the suffering the animals undergo now is due to the poor efficiency and neglect of the draught animal power system. With its upgrading, the agony of the animals can be considerably reduced. With modernized draught animal power implements and through better breeding, improved nutrition and health care, animals will be in a better condition to carry on the work, their burden will be reduced and their efficiency greatly increased.

Conclusion

29. For upgrading the draught animal power system, policy makers and professionals must have an appreciation of their critical role and the wastages and lost opportunities caused by long years of neglect. Some of the obvious ways of accomplishing this are: (a) like fertilizer, water, diesel oil, electric power, artificial insemination for milch cattle and numerous agricultural needs, draught animal power must also be supported and subsidized; (b) countries should collect and maintain statistics of draught animal power; (c) bank credit and insurance should be made easily available for draught animal power, as in the case of tractors, milch cattle, etc.; (d) agricultural implements for draught animal power should be improved; (e) animal-drawn vehicles should be redesigned for increased efficiency under local working conditions; (f) adequate feed and health care should be given to draught animals; (g) forage and forage crop growing should be intensified where economically possible; (h) draught animal power should receive the same attention as the milk and meat production systems.

II. MAGNITUDE OF DRAUGHT ANIMAL POWER

Large animals: regionwise distribution

30. Most countries maintain statistics of livestock numbers and report the same to FAO. But they do not collect or give figures of draught animals separately. As per the latest FAO handbook, the total number of large animals (cattle, buffalo, equines, camels) in the world may be about 1,477 million distributed as follows (in millions of head):

Developed market economies: 293.0 or 20 per cent		
	All developed: 451.2 or 31 per cent	
Eastern Europe and USSR: 158.2 or 11 per cent		
		World 1,447.0 or 100 per cent
Developing market economies: 899.8 or 61 per cent		
	All developing: 1,025.8 or 69 per cent	
Asian centrally planned economies 126.0 or 8 per cent		

31. It may be noted that the total constitutes all purposes, i.e. (a) milk and then meat; (b) meat only; (c) draught and then meat; (d) other purposes. In order to arrive at the order of magnitude of draught animal population, a combination of methods and sources was used. A few developing countries provided precise data, while some others gave rough figures. As regards the rest, the guesses made were both informed and ill-informed. The ultimate result of all these efforts has helped to make a rough estimate of the possible number of draught animals, by species, in the developing countries, which is given in the following table:

(All figures are given in millions)

Species	Milk + Meat + Draught a/ Total world	Developed (all)	Developing (all)	Possible draught animal power in developing countries	
Cattle and yaks b/	1,212.0	425.0	787.0	246	61%
Buffaloes	130.6	0.9	129.7	60	15%
Horses	61.8	22.4	39.4	27	7%
Mules	11.6	0.7	10.9	10	3%
Donkeys	42.8	2.0	40.8	40	10%
Camels	16.8	0.2	16.6	16	4%
Llamas	1.4	-	1.4	1	-
Elephants c/	-	-	-	-	-
Total	1,477.0	451.2	1,025.8	400	100

a/ Packing and logging included.

b/ Yaks of China have been included under cattle.

c/ There may be about 20,000 elephants engaged in logging work.

32. It may be seen from the above that there may be 400 million draught animals, including young stock below three years of age which are not put to work. The number of animals at present working may be between 280 and 300 million. FAO has estimated that the number of animals working currently exclusively for agriculture and adjunct transportation may be about 165 million (excluding China). China's 50 million animals at work takes this figure to 215 million. To this figure, animals engaged in the following kinds of work are to be added to get to a figure for draught animals working: (a) urban transportation by all the animal species; (b) non-farm operations in rural areas; (c) pack animals (camels, donkeys, mules, llamas); (d) logging, herding, etc. Thus, a figure between 280 and 300 million for draught animals at work appears to be a reasonable estimate. It may be noted that these estimated figures are given here only to indicate the order of magnitude.

Market value of draught animals

33. The market price of draught animals varies considerably. Taking a figure of $200 for the most widely used typical animals, the market value of draught animals and associated equipment may be about $100 billion. In the Indian subcontinent, the market value of large animals and associated equipment may be close to the investment in organized industry ($25 billion).

Power available

34. The draught power of an animal depends on the species, breed, size, body weight, etc. Further, it will of course vary depending on food and nutrition, state of health, environment, terrain condition, training and management. It may be misleading to give typical and average figures, since there could be a variation of as much as 100 per cent within each of the parameters. The majority of draught animals produce 0.4 to 0.8 hp on a sustained basis. Taking a lower conservative figure of 0.5 hp per draught animal, the power made available by 300 million draught animals may be of the order of 150 million hp.

35. These animals are spread out amongst millions of small farms and small-scale transport operators. The number of small holdings below 5 hectares may be over 100 million.

36. Replacing the majority of them by tractors is not very feasible in many low-income countries, at least in the foreseeable future, although it will have to be done when the necessary conditions emerge progressively. As an academic exercise it is possible to work out the approximate capital cost of replacement. In India it costs about $1,000 to make available one kW of electric power at the point of application. A simplistic way of equating oxen power to tractors is to consider that five pairs of oxen represents 5 hp. Draught animal power provides 150 million horsepower; the value of the tractors needed to replace this power would amount to $250 billion (considering $8,000 for a 25 hp tractor). The implications of such a situation in terms of capital flow, foreign exchange, petroleum consumption, displacement of labour etc., are obvious. Also, the figure quoted represents only part of the total cost; the investment required to produce this equipment and the oil would be more than three times that figure.

Employment, rate of return

37. The above figures indicate the order of magnitude of draught animal power in terms of numbers, investment, replacement costs, etc. Further, draught animals are more equitably distributed among millions of people than the other instruments of production of society. Draught animal power is labour intensive. Development in developing countries should focus on creating jobs and incomes. For instance, the number of people employed - directly and indirectly, part-time and full-time - in the animal-drawn vehicle system in India may be 15 million, close to that of organized industrial employment. Although India may be a special case, its experience may be valuable to a few other countries which are discouraging urban transport by draught animal power. At least 3 million carts ply in the urban areas, providing employment and a reasonable return to the owners and carters - in fact, to the more than 6 million people involved in the system. The investment per person employed will be less than $500 and when the system is made more efficient, the return will be much more. This may be true of some other countries as well. Studies show that in urban areas, a hired cart with two animals costing about $700 would bring in a revenue of $7.50 per day, shared equally by owner, carter and the animal and affording employment to more than one person. In India, draught animal power is nearly equal to the installed capacity of electric power (30,000 megawatts). The investment in the animal-drawn vehicle system

($4 billion) is two thirds that of the railways and equal to that of the roadways. While it is true that animal-drawn vehicles cannot do what the railway and roadway systems can do (in terms of ton-kms moved), it is equally noteworthy that these two modes cannot accomplish what draught animal power does under a given set of conditions. Therefore, each has its place in the economy.

Area cultivated, tractors

38. Countries inhabited by about 2 billion people depend on draught animal power for agricultural operations to a varying extent (20 to 90 per cent). FAO has estimated the share of manual, animal and machine for soil preparation as shown in the table below.

Area cultivated 1975
(millions of hectares)

					Power sources			
	Total		Hand labour		Draught animal power		Tractors	
	Area	%	Area	%	Area	%	Area	%
Developing countries	470	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

The above excludes China. China cultivates 100 million hectares, 50 per cent of that by tractors. Contribution of hand labour and percentage shares are not known.

39. Although the following figures do not affect the power available, the number of tractors in developing countries in 1978, which, according to FAO, was about 2.7 million, gives an idea of the respective importance of tractorization in different regions:

Africa	: 202,887	Far East	: 436,156
Latin America	: 898,905	Others	: 4,303
Near East	: 538,541	Asian centrally planned economies	: 619,847

As against this, the advanced countries had 17 million tractors.

40. The Winrock Livestock Research Centre prepared a report indicating that draught animal power constitutes a major share in farm input. The report comments as follows: (a) a minimum of 600 kilocalories per hour per hectare is required to achieve sustained agricultural growth in developing countries (only half of that figure is available in South Asia and South-East Asia); (b) if some of these countries were to mechanize, all their foreign exchange earnings would have to be allotted for oil and equipment; (c) investment for mechanization in a typical African country would be $10,000 as against $600 for animal-based technology; (d) 20 per cent of the world's population depends largely or wholly on draught animal power for movement of goods by animal cartage or packing.

41. Winrock estimates of average farm size, agricultural workers per hectare and power available from various sources for cultivation in several rice-producing countries of Asia are given below:

Country	Arable land per farm (hectares)	Agri-cultural workers (Number per hectare)	Type of power (kcals per ha per hour)			
			Human	Animal	Mechanical	Total
Sri Lanka	1.59	1.20	77	95	71	243
Taiwan Province	1.11	1.95	125	105	105	335
India	2.62	.90	577	131	5	713
Iran	6.17	.37	237	31	99	367
Nepal	1.22	2.49	160	308	3	471
Pakistan	2.37	1.09	70	185	8	263
Philippines	3.66	.71	46	67	15	128
Thailand	3.64	1.10	71	118	35	224
Viet Nam	1.57	2.10	135	157	15	307

Tillage effort for different sources

42. To prepare one hectare of land for planting, FAO estimates the requirements as follows: (a) 500 man-hours if done by hand with a spade or hoe; (b) 60 man/animal hours if done by a pair of bullocks; (c) 25 man/tractor hours if done with a 6 hp, two-wheel tractor and tiller; (d) 4 man/tractor hours, if done with a 50 hp, four-wheel tractor and plough.

43. Each country, and even each farm, is a special situation. One source or a combination of sources of energy would be feasible or appropriate at a given time. The total demand as well as the local needs being far above present levels, there is no real conflict amongst these three sources. The figures for draught animal power would perhaps be significantly less if improved implements (multipurpose, wheeled tool bars) were used.

FAO projections for the year 2000

44. Taking past and current trends, FAO has made certain calculations for arriving at inputs for agriculture towards the year 2000. For an over-all growth rate of 3.4 per cent for output of crops, an increase of 2.3 per cent of total power input is required (the increase for Latin America and Africa is 2.8 per cent, Near East 2.3 per cent and Far East 2.1 per cent) both for extension of the harvested area and an increase in the yield. Growth rates as well as the use of tractors will be higher for Latin America and the Near East, where 80 per cent of the total tractor power in the developing countries is now located. The FAO figures indicate that the growth of draught animal power will be slow, thus apprehending that the gap may have to be met by hand labour, which may result in shortages during peak demand periods. The impact of shortages can be minimized if draught animal power is augmented through conscious efforts and mechanized power brought in wherever possible. There is obvious scope for choice in the mix of power input, provided planning is done properly. The share of mechanical power will rise; but the bulk of power needs still has to come from human labour and draught animal power.

Conclusion

45. Draught animal power can play its potential role only if conscious attempts are made to upgrade it. If a laissez-faire attitude is taken, there will be over-all loss to agricultural production, the farmers and society at large. Upgrading the draught animal power system does not mean that more animals have to be brought into position, although this is also required for a number of countries, particularly in Africa. The emphasis should be to get more output from the same system by: (a) increasing the number of days' utilization of draught animals; (b) better feed and health care; (c) better implements and carts, which means better utilization of power generated; (d) better recovery and use of by-products during working life and after death of the draught animals.

III. ECONOMIC CONSIDERATIONS OF DRAUGHT ANIMAL POWER

46. Economic evaluations of draught animals have been made from time to time from various points of view, analysing a particular component or situation. The draught animal power system as a whole has never been assessed. Only recently, when the energy crisis reached critical levels, were serious reviews of the system's efficiency attempted in a comprehensive manner. The problem was, no doubt, complex because of the inherent difficulties in measurement and establishing concepts and norms for comparisons.

Forces towards mechanization

47. With low-cost energy, farm mechanization progressed in Europe, North America, Japan and other industrialized countries at a rapid pace. This was partly due to the high labour costs and unwillingness of the younger generation of farmers to work with animals. Many developing countries in Latin America and a few in the Near East and Far East followed the lead of advanced countries and opted for farm mechanization as quickly as possible. Some developing countries believed that mechanization was a good thing per se without bothering about economic analysis. Others made a comparative analysis of draught animal power versus tractors. Most studies were at the micro level and did not cover all relevant factors. It was generally believed that crop yields would increase owing to intensity of ploughing, which in itself was considered sufficient argument for going in for mechanization. In some countries the milk-meat system got high priority in government planning, which resulted in some bias against, and neglect of, work animals even as regards professional studies and research.

Factors in economic evaluation

48. The comparative studies done in the 1940s and 1950s were based on an unequal comparison of the primitive non-modernized state of draught animal power with the sophisticated tractor technology. The new knowledge emerging from recent studies provides a new basis on which energy concepts and policies are being developed. According to this, the picture can be complete only if all segments of the animal energy system are utilized properly and if the system is duly upgraded.

49. The economics of draught animal power will also change the way it is utilized. When animal-drawn vehicles are used for transportation as an adjunct to farm operations, the utilization of draught animals increases, making draught animal power economically more viable. It is not so much the volume of goods transported that should count for assessing the importance of animal-drawn vehicles to the economy, or comparison with the railways and roadways. Even in a country like India, which has the largest number of animal-drawn vehicles in the world, their share may be only 5 per cent in terms of ton-kms moved. But this low figure does not tell the whole story, since this 15 billion ton-kms in 500,000 villages and hundreds of towns could not have been handled by any other means. Similarly, in China, most rural transportation near the farms is being carried by animal-drawn vehicles, while in Thailand and the Philippines mechanized transport is used. It is not correct to compare draught animal power transport volume with mechanized systems for purposes of policy and resource allocation. Criticality, optimization and the opportunity cost of resources should also be taken into account in economic evaluation. The social cost of importing petroleum fuel and equipment, and the investment involved in the manufacture of mechanized equipment, must be included in the evaluation. The foreign exchange involved and the financial resources for the creation of the infrastructure required for mechanizing the system may be beyond the financial and organizational capability of many developing countries.

Employment aspect

50. In the developing countries, employment generation is one of the main goals of development planning. It has been widely recognized that animal husbandry is a technology easy to transfer and involves skills which have relevance to the rural areas of developing countries. A large proportion of farm households keep livestock such as cows, buffaloes and donkeys, which can be handled by women and younger members of the family. Rearing and utilization of livestock enables the better utilization of farm family labour and also provides employment to landless labourers. Transportation of goods using draught animals provides employment and earnings during the off-season.

Draught-milk-meat systems

51. The conversion of plant food to draught effort, particularly in the absence of any alternative possibility for substitution of meat by high protein vegetable foods, is feasible. This factor has to be taken into account while considering draught animal power and its possible integration into the meat-milk system.

Importance of draught animals

52. In some developing countries, in the absence of animals, the cultivable area cannot be taken up for crop production, as has happened actually in some developing countries. Similarly, poor yields can be increased if draught animal power is introduced. What can be gained by the proper and combined utilization of various sources of energy is demonstrated by the conditions in China where the food crop yields are more than twice those of India as a result of a rural social organization which has been able to make more intensive use of human, animal and machine power in the right mix.

53. Most farming in many countries of Africa is still carried out by hand (as much as 90 per cent). Part of this can definitely be transferred to animals, which will increase the productivity of land and also release men, and more particularly women, from the bondage of drudgery and labour. The women could possibly involve themselves in other and less health-hazardous activities.

Models for economic evaluation

54. FAO and other international agencies, such as the International Crop Research Institute for Semi-Arid Tropics (ICRISAT) at Hyderabad and the Indian Rice Research Institute (IRRI) in the Philippines, have evaluated the economics of draught animal power for farm operations. FAO has presented a simple method for calculating the cost-benefit analysis of using draught animals in tropical countries. This method is in a way incomplete because, apart from work in farm operations, animals make other contributions which are not considered, such as animal waste during their working life and meat and by-products after death. However, this methodology is useful for certain purposes, which can be used for similar studies in the developing countries. Other models have been presented by Bingswanger, Makhijani and Alan Poole.

Losses in the draught animal power system

55. A few examples will illustrate the losses in the existing system, which serve to depress its economic contribution. Pilot studies have shown that, owing to the vertical load and injury to the neck, the working life of an animal is reduced by as much as two to three years. If half of the 100 million draught animals in the Indian subcontinent lost two years out of their estimated 10 years of working life, 100 million animal years are lost. India is one of the biggest exporters of leather. It is estimated that by modernizing slaughter, export potential will go up from $500 million to $2,000 million. Similarly, by recovering the wastes in slaughter houses, another $500 million can be saved.

56. Although India had an early start in gobar-gas technology, only 80,000 units are in operation, while China has over 7 million units. In India the dung is used directly as fuel for household use and some part is used as manure. Passing dung through a gobar-gas plant will improve its quality as manure. At present, farmers are felling trees for firewood, resulting in deforestation and upsetting the ecological balance. It is possible to work out figures to show the impact of gobar-gas units on soil enrichment, utility value of gas for lighting and heat, saving out of less deforestation, the imputed values for ecological balance, sanitation and environmental hygiene, etc. There is enormous potential for processing human, animal and vegetable wastes into energy. Thus, while working out the economic contribution of draught animal power, gobar-gas ought to find a place.

Other benefits

57. Draught animals are mostly owned by the small and marginal farmers. Most of them do not have adequate insurance or bank accounts and credit facilities. Animals constitute one of their assets, and draught animal power functions not only as cash tradable but also as an insurance in case of emergency, accidents, death, marriage, etc. People in some parts keep animals precisely for that risk. In Africa, some communities keep animals as a source of wealth.

Policy implications

58. The United Nations system does not have the basic statistics of draught animals in various countries with data such as distribution of species, breeds, draught capabilities, effect of energy on yields, etc. This shows the gap in current information awareness. There are no special groups working in the United Nations system on the comprehensive aspects of draught animal power, although FAO has done a good deal of work on agriculture implements, harnessing devices, introduction of animals in Africa and so on, as part of projects undertaken on agricultural production or rural development.

59. Agricultural economists and emerging energy specialists have been compelled to work on models based on limited data. Since there has been no international conference or working group meeting of experts on draught animal power, these studies stand isolated without the benefits of interaction amongst scholars and experts, which would have helped in finding out the applicability of such models

for the varying situations among countries. The contribution of yield in relation to energy input has been studied on the effect of tractorization energy input to yield/outputs. Since a combination of other inputs come into play, resulting in the aggregate output, there are no conclusive studies of the delineated causative impact of draught animal power or tractor.

60. Studies have shown that an increase in yield from tractorization has not always corresponded to the set targets. The impact of energy on agricultural production has to be studied over a much longer period. Studies under controlled conditions are to be taken up in the developing countries on such aspects.

61. Energy, transport and communication have been subsidized to varying degrees in some developing countries in order to provide the necessary infrastructure for economic development. Similar subsidies have also been given for social services, education, research and development, public health and so on. Specifically, in the agricultural sector itself, subsidies have been extended to fertilizer, pesticides, seeds and extension work in order to foster and facilitate higher agricultural yields. Draught animal power is one energy element which has not yet been given attention for such a subsidy programme, whereas it ought to receive the same attention as any other energy infrastructure.

Conclusion

62. Although economic evaluation of draught animal power at present can only be tentative and general, rather than conclusive and precise, there is a need to establish more precise evaluation models. This is required at policy-making levels.

IV. FARMING OPERATIONS

Shortage of farm power

63. There is a shortage of farm power for the current level of world requirements in additional area to be cultivated and also in increased yield. India has estimated that provision of energy has to be doubled to get optimal farm output. The energy scene is worse in many of the low-income countries. Subsistence agriculture is still the situation in large areas of Asia and Africa and a few Latin American subregions. FAO has estimated that a growth rate of 2 to 3 per cent in power input is required for the next two decades.

64. Mechanization can continue to increase at a pace technically feasible and economically viable. The FAO estimates show that 80 per cent of the tractor power in the developing countries is concentrated in Latin America and the Near East: their share of mechanical power is expected to go up from 27 per cent and 18 per cent to 54 per cent and 36 per cent, respectively, by the year 2000. But in Africa and the Far East, mechanized power is expected to be only 8 per cent and 9 per cent of total power inputs by 2000. While the over-all share of mechanical power may go up from 8 per cent in 1975 to 19 per cent in 2000, the bulk

of power needs would still have to come from humans and animals. In Africa, human energy would still be as high as 82 per cent in most areas, and in the Far East 66 per cent. To the extent possible, part of this labour should be passed on to draught animal power. Projections of mechanization are based on present perceptions of oil prices. In any event, whatever the increase or decrease in the pace of mechanization, the case for increasing and upgrading would not materially change.

65. There is evidence that rapid mechanization has been hindered by technical, infrastructural and maintenance problems, which of course have to be remedied quickly. Meanwhile, there are so many conflicting views among energy experts and economists about the basic efficiency of draught animal power. But whatever the validity of their divergent views, there is no difference of opinion regarding the need for increased power for manual labour and animals, as the total demand for power is more (in Asia and Africa) than can be met by mechanized sources. In fact, there is no conflict or competition - each source can complement and supplement the other. China uses both machines and draught animal power for cultivation; but for other operations, it largely uses the abundant manual labour.

Increased productivity of draught animal power

66. Even if more animals cannot be raised or commissioned for various locational reasons in each country, there is no doubt that there is immense scope for getting more output from the existing draught animals by (a) increasing the number of days of draught animal utilization; (b) improving the food and health care in order to enable animals to give more output; (c) improving the efficiency of implements, carts and harnesses; (d) increasing recovery and use of by-products of draught animals; and (e) improving the infrastructure and organizational support and establishing breeding programmes for more powerful breeds in relation to environment and work required.

Upgrading levels of technology

67. The over-all situation in the third world is briefly outlined to give an overview of the scene. The developing countries can be grouped into certain categories based on similarities of socio-economic and cultural factors which influence the levels of technology in farm operations. Upgrading of the levels of technology is dependent not only on technical, economic, social and political conditions, but also on eco-zones, farming systems, organizational factors, infrastructural facilities and local administration. There are basically three levels of technology available for farm operations: hand-tool, draught animal and mechanical power technology. Within each level itself, efficiency can be increased by upgrading the system through technical and organizational improvements. Successive transition from a lower to a higher level, or a combination, will depend upon the constraints and vantage points inherent in every situation.

Agricultural engineering: research, extension and marketing

68. There has been considerable agricultural engineering research conducted by international organizations such as FAO, IRRI, and ICRISAT, which aims at improving

the design of animal-drawn agricultural tools and implements. FAO has produced a publication entitled Farm Implements for Arid and Tropical Regions (1969) which serves as a compendium of the existing tools and implements used for various stages of agricultural operations in the arid and tropical regions. The publication sets out the major factors which should be borne in mind while attempting to improve tools and implements for draught animal power. They must be (a) adapted to allow efficient and speedy work with the minimum of fatigue; (b) not injurious to man or animal; (c) of simple design, so that they can be made locally; (d) light in weight for easy transportation; (e) ready for immediate use without loss of time for preparatory adjustments; and (f) made of easily available materials.

69. The following suggestions for agricultural implements are useful for many countries in Asia and Africa:

(a) Informative literature regarding the various parts, their proper working and handling, repairs and maintenance should be circulated in the form of pamphlets and illustrated posters among the farmers as well as the field staff; such literature should be in the regional languages; programmes in rural communication regarding the efficiency of the improved tools and implements should also be carried out for selected villages;

(b) Demonstration of the improved implements should be organized regularly on farmers' land to show their proper use and handling;

(c) Village craftsmen should be given training in the fabrication and repair of improved agricultural implements under the technical supervision of a competent government agency;

(d) Adequate workshop facilities and tools should be made available to these craftsmen to carry out the repairs efficiently and cheaply;

(e) Arrangements should be made to stock spare parts in sufficient numbers for the implements;

(f) Arrangements should be made to make these implements available to the cultivators on hire purchase or outright purchase through co-operative societies;

(g) Medium-term or short-term loans with a low rate of interest should be liberally granted for the purchase of such implements;

(h) State governments should set up workshops in each district where repair work, particularly of an advanced nature, could also be undertaken; such workshops are to be utilized as training centres for village craftsmen.

70. Non-availability of raw materials and spares has been a hindrance for the continuous usage of improved implements. Even though the farmer is convinced of the utility of the improved implements, the non-availability of spare parts makes him discard the new one and return to the old one. In using the country wooden plough, he does not require either additional resources or skills to repair or replace parts. A review of product development and extension clearly indicates

the following points: (a) in view of the importance of improving the design, and thus the effectiveness, of small agricultural tools and implements, target-oriented programmes should be seriously attempted; (b) adequate attention must be paid to the production of small agricultural tools and implements, extension and other supporting services; (c) institutions, established in the area of agricultural research, extension and training in rural areas, should be linked as an integrated infrastructure; (d) the transfer of technology has been only in the areas of farm machinery where imitation of foreign technology was easier; only a small rural segment can benefit by this and extension should focus to include the small-farm sector adequately; (e) the area of the adoption of small agricultural tools and implements is mostly untouched; the traditional designs still hold sway and they are to be replaced.

Pamphlets and publications

71. The FAO publication entitled The Employment of Draught Animals in Agriculture is a manual which admirably presents the application of animal-drawn equipment in the tropical regions of Africa. The report deals with draught animals, implements using direct traction or involving an intermediary machine, rural skills which must play their part so that the animals and implements may be properly used, and some economic considerations having a major influence on the rational use of animal traction. FAO has also brought out, under its Better Farming series, a manual entitled "Farming with Animal Power", which deals with choosing and preparing feeds, types of working animals, tools for use with animal power, income from animal power, mechanized farming, etc. It also gives certain examples of animal power farming, which deals with the cost-benefit analysis in a simple way to make the farmers understand the gains from using animal power. This is a good extension exercise which should be used extensively in all the developing countries which are in need of increased draught animal power as a source of energy for farming operations. On behalf of FAO, ICRISAT and other international agencies, a number of experts have fabricated improved tools and implements.

Design centres, extension

72. Developing countries have set up a number of agricultural engineering centres for the design, development and standardization of agricultural tools and implements. In addition to this, invariably almost all the agricultural universities in these countries have departments of agricultural engineering. One of the criticisms levelled against these is that agricultural engineering is mostly oriented towards mechanization rather than manual or animal power. Even where research has been done for improving the design of animal-drawn implements, owing to lack of extension work the research has not reached the farms. Most of the output stays at the applied research levels and is not commercialized or widely applied in field operations.

73. Most of the implements are not designed as an integrated unit to suit the animals. Mis-matching of the implements with the animals creates problems. The farmers are often not told about the draught strength required by the animal for using the improved implements. What is required is an integrated look at the complete system and evolving specifications for the usage of improved implements.

This not only calls for providing the improved implements but also assisting the farmer in improving the strength of the draught animals by better feeding and maintenance. Unless these two aspects, the draught animal power and the improved implements, are co-ordinated, the effort in the extension work of improved implements is likely to have insufficient impact. Most of the agricultural programmes overlook this aspect, and a new orientation is called for.

74. Many Governments have set up organizations and other agencies for extension work in order to make farmers aware of the improved design of agricultural implements, but their work has not made much impact, perhaps due to inadequate follow-up. Moreover, most of the extension workers are either urban-based or technicians who do not appreciate the difficulties of the farmers regarding draught animal power. There is a need to review the entire framework of manufacturing, marketing and extension work in the area of improved animal-drawn tools and implements as it functions today in the developing countries. Surveys should be conducted at the field level in different countries in order to assess the specific reasons for the failure of extension and marketing as well as the escalating manufacturing costs.

Other adjunct operations

75. Draught animals are used for other adjunct operations such as threshing, water lifting, grinding, crushing, cotton ginning, etc. In terms of volume, the use of draught animal power for such work is declining. Not much effort has gone into redesign, methods improvement, etc. Surely there is scope for increasing productivity. It is proposed that studies should be conducted to improve the technology currently in use and also to locate new uses for draught animals in rural areas.

Conclusion

76. Improved agricultural equipment and implements for draught animals will contribute to increased crop yield at reduced cost and effort. More work is necessary not only in designing improved implements but also in making them available to farmers on a wide scale.

V. TRANSPORTATION

Scope for animal-drawn vehicles

77. Some countries have shown some interest in animal-drawn vehicles, whereas most other countries have shown very little concern. There is enormous economic loss and wastage in the system, and excellent opportunities for better transport capability, employment, increased earnings, etc. are not exploited. There is tremendous scope for augmenting the contribution and increasing the productivity of the animal-drawn vehicle system in many developing countries by (a) improving the design of existing animal-drawn vehicles; (b) increasing the utilization of these vehicles; (c) increasing their numbers and varieties, and diversifying their uses; (d) introducing suitable animal-drawn vehicles where

appropriate; (e) improving breeds and draught animal numbers suitable for animal-drawn vehicles; and (f) creating and improving existing infrastructure for the development of animal-drawn vehicles.

Where animal-drawn vehicles are inevitable

78. There are many types of situation where animal-drawn vehicles are the only way of transportation for people and goods. In India, 50 per cent of the 500,000 villages are not yet connected by motorable roads. Similar conditions exist in other parts of Asia and Africa. Even where some sort of roads exist, they are often too narrow or rugged for motorized transport. In some places there is no infrastructure for mechanized transport. Loads are carried on heads, mainly by women in some countries. In all these situations, animal-drawn vehicles may be a feasible solution, provided other conditions are conducive.

79. There are situations where animal-drawn vehicles can do just as good a job as motorized transport. For instance, trucks, small vans and tractors are manufactured only in a few countries; they have to be imported as well as oil, involving foreign exchange. There are more important activities of the economy needing foreign exchange, where substitution is not feasible.

80. Animal-drawn vehicles may present traffic problems and appropriate safety measures and regulations must be considered by the authorities. Registration of animal-drawn vehicles is also necessary. A minimum of bureaucracy at government level will be required.

Rural transportation

81. Most rural transportation in the developing countries is on a small scale, for short distances. Animal-drawn vehicles are economical for loads of one half to two tons for relatively short distances. Trucks need heavier loads and longer distance runs in order to be economical. Trucks and vans have to be utilized for 250 to 300 days a year to pay their way. But animal-drawn vehicles, because of their low capital cost, are economic even with a 50-day utilization in rural areas. In operations involving high loading and unloading time compared to the travel time (transport of sugar-cane, cotton and tobacco to the processing factories), or involving numerous distribution points, animal-drawn vehicles have many advantages.

82. In certain regions, much of the animal-drawn vehicle transport is farm-based in rural and semi-urban areas. When a farmer uses draught animal power for tillage, he can go for a cart as well and become self-sufficient. Those who do not own carts may hire them. The use of animal-drawn vehicles as an adjunct equipment on farms improves the utility and economics of draught animal power. During the off-season, farmers can ply the animal-drawn vehicles for others and earn extra income. This approach has been used only by a very few countries, but it is worth while noting that China uses rural-based draught animals for 300 days a year while India obtains only 50 to 100 days of use for the rural carts.

83. Professional carting in rural areas can be augmented if better organized. There is good demand for transporting cash crops such as sugar-cane, tobacco, cotton, etc. where there is continuous work. In India, half of the carts engaged in short distance sugar-cane transport have been improved by the provision of pneumatic tyres and smooth bearings, which have doubled the cart capacity for the same effort: with improved animal-drawn vehicles, carters earn better incomes ($3 a day) and the employment is higher. In the Dominican Republic also, ox-carts are used to bring sugar-cane to factories from nearby fields; the factories themselves have helped in modernizing the carts through loans, repair facilities, etc.

Urban transportation

84. In contrast to the rural areas, urban animal-drawn vehicle transport is done by professional carters. A number of people own carts for hiring out. Animal-drawn vehicles compete with small vans, have work for most days, and earn a fair amount. Studies in India have shown that earnings are split equally between owner and carter. Animal-drawn vehicles are used for transporting innumerable kinds of articles, such as water, oil, garbage, household effects, cutlery, furniture, paper, construction materials, beverages, vegetables, fruit and so on; some can be transported at night, or during off-peak hours. Intra-city transportation involves short distances, small loads, a number of collection (garbage, furniture) and distribution (oil, water, vegetables, crockery) points, high loading and unloading time, narrow roads and lanes, etc.

85. Of India's 15 million carts, about 3 million are in urban areas. When villages expand, more carts come into being; when small towns grow into larger ones, more carts become necessary. Only when the town becomes a metropolitan city does the number of carts come down drastically.

Volume moved

86. Volume in terms of ton-kms or passenger-kms is not the proper indicator of the contribution of animal-drawn vehicles. The significant point is that, for certain types of movement, animal-drawn vehicles are the only feasible or economic means of transport. In India, two thirds of rural transportation is by animal-drawn vehicles, and total freight handled by animal-drawn vehicles may be in the region of 15 billion ton-kms. A casual glance indicates that the figure for China will be impressive as well. The most significant point to note here is that these loads are scattered among millions of points of collection and distribution and loads are not available on a continuous basis. Replacement by a motorized system is not technically or economically feasible for some years. In fact, there is scope for expansion in certain areas. Many developing countries could benefit highly from well-organized animal-drawn vehicle systems.

Modernization of animal-drawn vehicles system

87. The first step in modernizing and upgrading the animal-drawn vehicle system is to improve the design of vehicles, whereby (a) the capacity of the cart is increased, for a given draught effort by the animal; (b) the burden and injury

to the animal is reduced; (c) damage to roads is reduced; (d) versatile and more efficient designs are evolved to suit terrain, produce to be carried, animal characteristics; and (e) cost of road building and maintenance can be reduced. These improvements would, in turn, lead to enlarged and multipurpose capability, reduced costs of operation per unit volume moved, improved earnings to the carters, enhanced and diversified employment opportunities, comfort and longer working lifespan for the animals, better efficiency of the animal as a result of better feed, less overwork, correct handling without cruelty, etc.

Horse-drawn carts

88. Horse-drawn carts used in the developing countries are greatly superior to the ox-drawn carts as regards design. In developing countries, horse-drawn carts are mostly used for light loads (people and goods) in urban areas (except in China and Mexico). Horses and mules are better draught animals, and can haul heavier goods at a faster pace, essential and desirable requirements for urban operation. Bullock-carts are slow, and reduce traffic capacity. It is therefore proposed that horse and mule-drawn carts be encouraged for urban transport. Horse and mule-drawn carts will be also feasible for situations in rural areas where there is continuous professional carting, that is, independent of tilling work for the animals. The basic design for the improved cart should include pneumatic tyres, smooth bearings and improved harnesses. Implementation of these proposals would require extensive breeding and raising programmes for horses and mules.

Pneumatic tyres and smooth bearings

89. In urban light transport carts, only cab (solid rubber) tyres are used. Pneumatic tyres of 3 or 4 ply to support 3 to 4 tons of load are required for heavy-duty transport. Special animal-drawn vehicle tyres are made in India. These tyres are to be of a special design so as to accommodate slow movement and rugged terrain (stones, thorns, etc.), and should be not easily punctured, and cheap and easy to maintain. Now carters are frequently using worn-out truck wheels and tyres which are heavy. Because of the low volume of tyres required, tyre companies have no incentive to manufacture specifically designed tyres for animal-drawn vehicles. In order to encourage animal-drawn vehicle tyres, it is proposed that rebates on taxes and other incentives could be extended to tyre companies in certain countries. The same points hold good for ball or taper-roller bearings. Now animal-drawn vehicles are using truck bearings which are costly as they are meant for high speed, high precision, heavy loads, etc. Animal-drawn vehicles need slow speed and cheap bearings. Here again, bearing companies have to be encouraged with incentives to make suitable bearings for animal-drawn vehicles, for slow speed, cheap but smooth, and finally easy to maintain and lubricate.

Bullock-carts

90. The first attempt to improve the cart was the provision of pneumatic tyres, smooth ball or taper-roller bearings and shock absorbers. Most of the carts in

China and the Latin American countries and about 15 per cent of India's 15 million carts have been improved in these two aspects. Owing to continuous wobbling, the iron rims or steel wheels damage the roads by breaking the surface or cutting ruts all the way. The annual cost of road repairs is estimated to be $100-200 million for India alone. The large diameter wheel with an iron rim (plain or rubber-coated) may have to be retained for special rugged terrain conditions in rural areas, but the bearings have to be made smooth for such carts also. The main benefit of rubber tyres and smooth bearings will be reduction in the friction of the axle bearing and rolling on the road, leading to a higher hauling capacity for the same draught effort. By these two improvements alone, the capacity has been increased from 1 to 3 tons on level roads. Wherever higher capacity is not required, a single animal can pull one or even one and a half tons easily, thereby reducing both capital and recurring cost.

91. There is scope for improving the platform features to suit the materials to be carried. Tyre weight also can be reduced by 50 per cent, thereby increasing the carrying capacity. The provision of a braking device is essential. At present, the animal itself is used (with its neck) to reduce speed and to stop the vehicle. Improvements to harnessing devices, described elsewhere, have a provision for braking (using the animal's body weight) with the help of a belt taken around the animal's rump, as in the case of the present single-horse cart.

92. In the existing traditional design, a good part of the draught effort is unnecessarily wasted in overcoming the friction of the rough and loose crude bearings and rolling, and in hauling the heavy platforms. With improved design, one animal can pull where two were needed with the traditional design.

Consequences of the traditional design

93. In order to appreciate the importance of modernization, it is necessary to understand the consequences of the present state of affairs. The defective aspects of design, namely, rough and loose bearings, iron-rimmed tyres on wooden wheels, heavy platforms, crude harnessing devices, etc., have many unfortunate consequences: low carrying capacity and low earnings, reduced life for the animals, injury to the animals and their consequently reduced efficiency, and damage to the road. As a consequence of the uneconomic working of the above and some other factors, such as lack of credit and availability of better designs at a reasonable cost, animal-drawn vehicles have declined in most countries. Simultaneously, draught animal power in tillage also suffers as animals are under-utilized.

94. With an improved vehicle, the carters can transport in a single-animal cart as much as they do now in a double-animal cart. The recurring cost will come down, assuming that the cost saved by having one less animal is offset by the increased cost of the improved cart. Professional carters in the towns can do the same. Thus, if single-animal ploughing for marginal farms (less than 1 ha) and improved single-animal carts are introduced, the number of animals required for a country can perhaps be reduced which, in turn, will have its advantages. The present tradition in the Indian subcontinent (and elsewhere) of invariably using two animals for carting (and ploughing) can be changed for certain situations and load levels.

95. Millions of rural people have no land. Carts will provide employment on a professional basis. They can cater to rural needs during demand periods and ply in towns during slack periods. Marginal farmers have no animals to till the land as they cannot afford to keep animals. The practice of ploughing with a single animal and using it for carting will enable the marginal farmers to keep animals, increasing their earnings and raising the productivity of land as well.

96. The economy and society benefit tremendously when designs are improved. A modernized animal-drawn vehicles system will have a pronounced impact in all the developing countries if they take a sustained interest in this programme. Most countries have not only neglected animal-drawn vehicles, but are adopting policies to eliminate them. A review is called for in the context of the increased cost of fuel and motorized equipment, which have made transport costs in towns prohibitive. Employment opportunities are also increasing significantly. Transport will open up new areas in Africa for industry and trade.

Modernization steps

97. All over, worn-out truck axles, wheels and tyres are improvised for use in carts. When volume picks up, special animal-drawn vehicle wheels and tyres can be made at a cheap rate. The introduction of steel sections has made the carts lighter. A simple wooden pole, acting against the rim, can function as a brake. If socio-economic surveys confirm the view of the present report that animal-drawn vehicles have a significant role to play, then research and extension must be taken up in a big way. Some parts have to be made centrally, for standardization and precision, while everything else can be left to the village artisans. Governments will have to legislate on rules and regulations, standards etc. Watering facilities on busy roadways and sheds (totally lacking today) should be provided. All carts should be registered so that their design and use can be regulated. For city-based draught animals, commercial feed has to be manufactured. Carts with iron-rimmed wheels should be banned.

Increasing animal-drawn vehicle utilization

98. Farmers using draught animal power for tillage, landless rural people, the unemployed urban population, etc. should be encouraged to possess or obtain on hire animal-drawn vehicles. Suitable incentives and organizational means should be introduced. Programmes similar to the promotion of village industries and handicrafts should be extended to animal-drawn vehicles. When the cart is improved, it will stand on its own merits, attracting private initiative.

Pack animals

99. Camels, donkeys, mules, yaks and llamas are used as pack animals. There is scope for increasing this mode in Africa and Asia, where not even roads for animal-drawn vehicles are available. Frames and carriages used should also be improved considerably. In fact, except for general information, very little has been done to study and explore their potential. Wherever possible, packing

should be converted to hauling as the latter is far more efficient where there are roads. In come countries, even now, materials are transported in sledges (even in the Philippines). It is proposed that a special study on pack animals should be made to tap its potential.

Logging

100. Logging is done by well-bred work horses in advanced countries. The technology equipment, harnessing devices, etc. are to be documented for use in the developing countries where the practices are still inefficient. Oxen, with head harness, do logging in Latin America and Malawi. Head harnessing presents many inconveniences and the method should be revised. Elephants do logging in India, Sri Lanka, Burma and Thailand; they have been successfully used in Zaire in the forests. FAO has dealt with logging by elephants in its booklet on logging operations for a training course, and has suggested a number of steps to improve the system. Random observations indicate that adjunct equipment, used in the advanced countries, will be of great help in improving the efficiency and reducing the cost of elephant logging operations.

101. Logging by horses in Sweden employs a variety of equipment for handling, skidding, rolling, pushing, dragging and carrying, including simple tools and two-wheeled carriages. Four-wheeled carriages are also used, which make the movement of logs easy for the horses. For heavy logs to be moved over rough or slushy terrain, crawler-type vehicles are used (like the drag lines of earth-moving equipment). Sweden holds annual shows to demonstrate the best varieties of work horses, harnesses, equipment, etc. Pedigree certificates for horses, as well as medals and prizes, are awarded in order to provide the necessary incentive. It is not known whether anything of this nature to upgrade the technology and techniques is being done in the case of logging by cattle and elephants. Methods improvement projects and cost economic studies are to be conducted to improve the system efficiency.

Conclusion

102. Modernization of animal-drawn vehicles can substantially increase the total freight moved by animal energy in rural areas and also in some urban areas. Animal systems for logging can be improved for increased efficiency. Research and testing of improved-design vehicles and implements must be undertaken on a systematic basis.

VI. HARNESSING DEVICES

103. The efficiency of the application of draught animal power is dependent on the harnessing device, which is the link between the animal and the implements or cart. However strong the animal and well designed the implement or the cart, the animal's efforts are wasted if the harnessing system is defective. The object of the harnessing device is thus to ensure that the draught power generated by the animal shall be utilized to the maximum extent. Besides, it should not injure the animal, be comfortable for the animal, easy to put on and take off, be amenable, to the extent possible, to manufacture with local materials, and be cheap enough for purchase by farmers and carters.

Design difficulties

104. In contrast to the case of mechanical equipment, where standards are universal and variables are few and controllable, in the case of the animals there are innumerable diversities and numerous factors to be taken into account in designing harness, such as: species of animals, variation in their body structure, size, shape, strength, temperament, etc. Further, the harness has to be fabricated in numerous dispersed locations, making use of local materials and talent in order to retain the employment potential. The cost has to be within the reach of the small farmers as well as carters. These multiple objectives and constraints have rendered present designs of harness generally very unsatisfactory in most parts of the world (except in the case of equines in advanced countries, and to a lesser degree, in some developing countries).

Horse harness

105. In advanced countries necessary research and development resources have been deployed in the past to improve the efficiency of the system, of which implements, carts and harnesses formed important parts. The efficiency of draught power transmission increased many times. The third world has not taken full advantage of the opportunities. The same concepts and design features were applied to donkeys and mules, which have a somewhat similar body structure.

Cattle harness

106. Most of the developing countries use cattle for ploughing and carting. The situation regarding harness for cattle and buffalo is indeed bad in most countries. Advanced countries had developed some good designs in Europe in the past but they have not been adopted by the third world, where a tremendous amount of work remains to be done in improving the efficiency of harnessing, which is primitive in some areas and inefficient in others, resulting in colossal waste of draught power.

Improvement of the harnesses

107. A number of educational institutions and a few design and development agencies have tried to introduce better harnesses. These attempts largely failed because the efforts had no back-up from scientific laboratories for design experiments, testing, measurement, etc. FAO introduced conventional devices for oxen (head and neck yokes) in Africa as part of the "oxenization" programmes.

108. Improvements to the harnesses can be taken up in the short term and the long term. Immediately, better technologies already available in some parts of the world should be transferred to those countries which could take advantage of them. Within the countries, these designs have to be adapted to local conditions by research institutions and, later, disseminated through extension work. Projects of this kind can be started forthwith, as there seems to be enough better harnessing technology in use in some parts of the world. Collection of detailed information, documentation and dissemination are the first steps in this programme. Typical examples would be harnesses evolved by the developed

countries for equines and the double yoke harness and independent hitching devices used in China for agricultural implements and vehicles. The logging methods employed in Europe and Canada are worth adopting in similar situations in developing countries.

109. In the long run, improved harnesses are to be designed in research and development centres and then tested in the field under varying conditions. Priority is to be given to cattle and buffaloes, which are the most extensively used animals in Asia and Africa. In this matter, it is necessary to start almost afresh.

Equines for tillage

110. Harnesses for horses and mules for ploughing are already well developed after a great deal of research in advanced countries. What is required for disseminating this knowledge to the developing countries is assembling this literature in a central place, extracting useful information, preparation of manufacturing manuals indicating performance data, and preparation of pamphlets in a simple form. Donkeys are not normally used for ploughing, except in isolated areas in Africa and in some parts of Latin America and China. The harness concept for donkeys is somewhat similar to that for horses and mules.

Cattle and tillage

111. In developing countries the popular method of using oxen is to use two animals hitched together, with a wooden pole placed on the neck or head. Animals are also used singly in some regions. A rigid pull beam connects the yoke to the implement. As this method has survived for centuries, changes proposed later should be introduced only after sufficient evaluation.

112. The collar similar to that of the horse is not suitable for cattle, but a collar design was used in Europe consisting of a soft collar with hames, to which traces are attached. This design should be studied in research centres and adapted to conditions in developing countries.

113. The wooden pole yoke, placed on the neck of two animals, is the most typical harness for cattle in the Indian subcontinent, in South-East Asia, and some countries in Africa and the Near East. The typical practice is to have a pull beam or a chain at the centre, to which the plough or equipment is attached. It is felt that there is scope for improvement. The collar yoke is definitely one possibility. The animals could also be hitched independently to an even bar with the traces. In some locations in China, in addition to a V-shaped yoke pulling the implement, one end of the implement is attached to a belt slung on the animal's back on the rear side, which is supposed to take the vertical component of the pull. In the case of two animals hitching, the traces are connected to the even bar. The relative efficiency of the neck yoke and the Chinese method described above has to be assessed. In the Indian system, only two animals can be used while in the Chinese method more than two of different sizes and strength can be yoked.

Head yokes: Latin America

114. Latin American countries are using the head yoke. The Zebu cattle of Asia have long necks and a hump, the Latin American cattle have short necks. It is claimed that the head harness is suitable for short-necked cattle without humps; on the other hand, it is argued that the head harness is not the right way of harnessing. The ill effects of the head yoke are to be investigated. In this yoke, a suitably shaped wooden pole is fitted behind the horns, to which it is anchored with rope and leather belting. The horn may break. Since two animals are rigidly hitched together, their freedom of movement is restricted. When the animal can use its whole body weight, draught power is increased. It is doubtful whether this effort can be transmitted through the head. The Chinese method of independent hitching with a V-shaped yoke on the neck (or the collar) should replace the head yoke.

Buffaloes for tillage

115. In India the typical practice is to harness two buffaloes with a neck yoke. In China and other countries, single animals with a V-shaped wooden neck yoke connected to traces are used. The neck yoke probably does not permit maximum draught efficiency and hurts the animal's neck tissues. In some parts of China the agricultural implement for buffaloes is so designed that one end of it, attached to a strap, rests on the animal's back. A separate V-shaped yoke on the neck pulls the implement. Pressure on the neck is believed to be reduced but this has to be verified. Research is needed to assess the efficiency of these and other ideas compared to the traditional methods.

Other animals for ploughing

116. Yaks are used in China for ploughing to a limited extent. Little is known about the use and potential of yaks and these have to be looked into. Camels are used for ploughing in the Near East and India. Harnesses are not well designed and special studies are needed.

Harnesses for vehicles

117. Harness designs are very important. Wrong designs not only reduce power transmission, but also cause damage to animals, resulting in important economic loss.

Horse-carts

118. As in the case of tillage, horse-carts were highly developed in the advanced countries. In Asia, this possibility has remained unknown and therefore bullocks and buffaloes are being used. It is proposed that horses should be tried, as they are faster and can pull heavier loads and are therefore better for city conditions. Since city transportation is viable on a commercial scale, the system can bear the extra cost of harness and maintenance of horses.

Cattle-carts

119. Four-wheeled carts, drawn by two bullocks, carry 3 to 5 tons. There is no vertical load on the animal's neck. It is proposed that collar harness and hames, connected to the cart through traces, should be improved. Collar harness will certainly improve the area of contact and increase the efficiency of application.

120. At present, single-animal and two-animal carts are drawn by the pole yoke on the neck, connected to the cart by a pair of rigid pull beams. The majority of bullock-carts are two-wheeled (both single-animal and two-animal drawn) in which the third point of the load (20 to 50 kgs) rests on a small area of the animal's neck. The animal has not only to pull the load by the neck but also carry weight on it. In movement, the neck tissues become inflamed, and develop sores, rending rapidly unproductive a majority of the animals. There is tremendous loss due to sickness and lost animal years.

121. There is a need to devise braking systems as most of these carts do not have any such mechanism. Also the double yoke can be introduced here with great advantage. This system avoids rubbing and injury to the neck and hence results in high efficiency. Studies are also needed to assess the extent of advantage that the double yoke has over the neck yoke, and the damage being caused by the neck yoke.

122. The head yoke is used for drawing carts in Africa and Latin America. It is believed that this is not a good method. The animal's neck has to carry the vertical load as a cantilever, besides hauling the load. The maximum power of the animal cannot be obtained in this way. It is proposed that the double yoke method should be adopted instead. While the double yoke concept can be copied straightaway, the collar yoke has to be tried in place of the V-shaped yoke.

123. In the Chinese system, more than two animals - and that too in combinations of horses, mules, donkeys and cattle of different sizes and ages - can be hitched. Independent hitching also allows using more than two animals of differing species, size and strength to haul heavy loads.

Carts drawn by other animals

124. The situation regarding buffalo-carts is the same as for bullock-carts. The double yoke method can be copied straightaway. As regards mule-carts, the harness concept of the horse-cart is applicable. With some modification, the same is applicable to donkeys also. Camel-carts are already modernized to some extent in India but the harness must be further improved. There are innumerable variations in camel-cart designs and harnesses, the efficiency of which is to be assessed.

Pack animals

125. Camels, donkeys, mules, llamas and yaks are the most popular pack animals. The frames and other materials used for pack animals need much improvement,

especially for donkeys. Pack animals are important in hilly regions and in areas with no roads. A study should be made for improving carriages and frames for the use of pack animals.

Logging

126. The excellent harnesses and equipment used for logging by horses in Europe and in North America should be made known to other countries which are now using crude devices. The logging harnesses are similar to draught horse harness with minor variations to take care of the heavy loads to be pulled with maximum effort over short distances. The head harness used in Chile, Colombia and the Dominican Republic does not seem to be suitable for logging. Harness concepts described earlier for tillage and carting can be usefully employed for logging as well. For buffaloes, used for logging in some parts of Asia, the collar-cum-belt harness should be tried, instead of the neck harness. No effort has been made to design harness for elephants, which needs priority attention.

Other equipment

127. Equipment in use for adjunct operations, such as threshing, water lifting, crushing, grinding, etc. vary a great deal from country to country. Most of them are of crude design. Various methods have been in use for water lifting by draught animal power: (a) the Persian wheel, in its numerous variations; (b) bucket of water being lifted by animals walking on a ramp, up and down; (c) animals moving in a circle, activating a rope system whereby two buckets of water go up and down alternately; (d) animals walking in a circle and the motion being converted to reciprocating movement to lift water; (e) circular movement of animals to move a set of blades in a pipe lifting water. In all these cases, improving the harnessing devices, taking the concepts from ploughing and carting, would result in a significant increase in efficiency.

Conclusion

128. There is tremendous scope for transfer of technology from the developed to the developing countries and among the latter themselves. Immediate documentation and extension of existing technology for transfer to others can start. Concurrently, research and development has to be launched to improve the existing designs for cattle, buffaloes and other animals (excluding equines). Logging and packing are the other two aspects where specific studies are called for. A multidisciplinary team, consisting of engineering designers, ergonomists, animal husbandry specialists and nutritionists, should work together on harness design. FAO and various institutions in the United States of America, France, the United Kingdom of Great Britain and Northern Ireland, India, Sweden, have useful expertise in this area.

VII. INFRASTRUCTURE FOR DRAUGHT ANIMAL POWER

129. To facilitate rapid development of draught animal power it is essential that a number of programmes be initiated for providing the necessary physical and

soft-ware infrastructure. Requirements would naturally vary from country to country, depending on the state of draught animal power and environments. Some examples are given below to illustrate the kinds of measures required.

Breeding, feeding and health control of draught animals

130. Scientific breeding for developing farm animals which would meet draught needs and be economically viable made tremendous strides in the past in Europe and North America. Research done then produced excellent work horses, breeds of which are even now working in various countries. China has ongoing programmes for raising work animals, particularly donkeys, mules and horses. In India, top quality bullocks were being bred for centuries but for a variety of reasons enthusiasm has now waned. Nowadays in general there are no specific programmes for breeding draught animals. FAO, however, has already initiated some such programmes in Africa and Asia. Comprehensive breeding programmes must be established in all countries where draught animal power will continue to be of economic significance. The draught animal characteristics must suit the economic, agricultural or feed resource conditions of the area. Mountain areas, with different eco-conditions, would call for special breeds. Animals for the transport of heavy loads at slow speed, and of light loads moving fast, have to be developed. In order to promote successful programmes in developing countries, Governments and United Nations agencies should help in a decisive way. A number of concrete steps are essential to facilitate successful breeding and raising of draught cattle. Promotion programmes by way of price incentives, long-term and short-term credits, strengthening of small farmers' and marginal farmers' development programmes, farmers' organizations, etc. need to be launched to make the breeding of draught animals attractive and effective.

131. Apart from cattle and buffaloes, equines have to be bred and raised in Asia for the urban transportation of light and heavy goods. Donkeys and mules are totally neglected. China's experience of raising these hardy animals is worth emulating.

132. Many countries in Asia and Africa still have the problem of typical livestock diseases, such as foot and mouth disease, rinderpest, etc. All of them have programmes to eradicate the same. It has been noticed that in some countries funds, facilities and medicines are not adequate. Some African countries are unable to promote draught animal power because of tsetse fly and trypanosomiasis. FAO has active programmes to control the disease.

133. Veterinary services in some countries tend to be hospital or urban-based. Since the farmers are widely dispersed, mobile veterinary services should be strengthened, particularly in locations where there is a concentration of animals and the dearth of services is keenly felt.

134. Draught animals in many developing countries are fed with materials derived from crop residues and left-over stubble from agricultural land. Often there is no organized cultivation or arrangement for their grazing. The farmer gives concentrates to provide energy for the hard work. A common practice in many countries is to feed straw of paddy or wheat or any other cereal or millet.

Unbalanced rations are commonly the reason for poor conditions of animals in countries where paddy cultivation is dominant. Inadequate feeding practices are extremely frequent for draught animals and this reduces their efficiency.

135. The animal's nutritional requirements for energy should be adequately met through the proper deployment of feed resources. If special fodders cannot be grown, straw can be supplemented with molasses and urea which add to the nutrient requirements. The use of agricultural wastes and industrial by-products should be promoted. Practical methods for producing feeds and distributing them to farmers at reasonable prices should be generalized wherever required and feasible.

136. Utilization of the land on an optimal basis would necessitate a combination of crops which would least deplete the essential nutrients from the soil and replenish the critical nutrient to it. This can be achieved by the rotation of crops, including forage crops and legumes, intercropping with legumes and/or earmarking a small portion of the land for legume cultivation. There are various native plants in many countries which could be grown and used for animal feeding. In certain places, hay and silage can be developed. Pasture improvement on marginal lands still offers much prospects. All these ideas are known but they have not been introduced extensively due to lack of extension and proper training.

Financing, credit for draught animal power

137. To help the small farmers, a number of Governments have attempted numerous organizational methods. Extension of credit and the formation of co-operatives have been part of these measures to bring institutional credit and organized forms of delivery of modernization to the rural areas. Except in isolated affluent sectors and regions such as sugar-cane growing areas, milk co-operatives, meat-marketing agencies, etc., the system has not been adequate to meet rural needs. Special attention is to be given to establishing farmers' organizations with responsible farmers in their management.

138. Since the commercial banking system was not attuned and equipped to give credit to draught animal power and adjunct activities, some Governments have tried rural banks to supplement the commercial banks. A larger flow of credit has been achieved by combining the efforts of rural banks, co-operative credit societies, rural branches of commercial banks, etc. However, much greater efforts are still required to meet the needs of the farmers.

139. Insurance facilities should be extended to all sectors of draught animal power. The death of an animal indeed may completely disrupt a small farming operation.

140. Pilot studies in various parts of the world have indicated that the productivity of tillage could be increased by the use of better implements. ICRISAT at Hyderabad has demonstrated how the animals' working time and cost of tillage can be reduced considerably (with much less burden on the animals and men) by the use of suitable improved implements. The specific reasons why

improved implements and carts are not yet widely used should be investigated. Country-based research and development institutions should immediately develop expertise in draught animal power implements and carts. The tendency has all along been to work on farm mechanization and associated knowledge of mechanized equipment. While this can continue, expertise in draught animal power design and testing should be developed simultaneously, particularly in the areas where such power is significant.

Value-adding infrastructure

141. In order to enable marginal farmers to take advantage of improved animal-drawn vehicles and implements, hiring systems should be introduced along the lines of tractor service systems. Already in Indian cities, carts and animals can be hired, and the system is self-supporting. Banking and insurance companies could help in organizing co-operatives where private initiative is lacking. Another possibility is to encourage manufacturers to start hiring activities also. This is easily feasible in towns, where hiring agents are making good money, particularly in improved carts.

142. A global programme of biogas development should be considered along the lines of the International Dairy Development Programme and International Meat Development Programme of FAO. The adverse consequences of not putting up biogas plans and the spectacular benefits that will result from introducing biogas in areas such as forest economy, ecology, sanitation, etc. are to be evaluated. The input-output calculation will have to take into account this vital and rich output, on an individual farm basis and community basis, of the draught animal power-meat-milk systems.

143. In the advanced countries animals are raised for slaughter and the total system is organized on a commercial basis. Therefore, all component parts of the slaughter system, starting from the collection of animals, transportation to slaughter, stunning methods, slaughter itself, recovery of by-products and their processing, etc., are all modernized. In most developing countries draught animals are disposed of immediately after their utility for agricultural work is over, because of old age or injury. In neither case, is any attempt made to fatten them before slaughter, although the animals at the time of slaughter are in very poor condition, affecting the quality and quantity of meat availability. Fattening them for a period of three to six months would considerably enhance the quality and quantity of meat. Where economically feasible, the desirability of a fattening programme of draught animals through a suitable marketing agency should be explored.

Laws on utilization of draught animals

144. In the advanced countries the laws concerning rearing and utilization of animals and their products are fairly comprehensive. Not even rudimentary laws exist in many developing countries, or where they have been enacted they are not enforced at all. It is recommended that a compilation of the existing laws should be made so as to formulate suitable laws for developing countries. Governments should enact legislation and set up suitable decentralized rural-based

enforcement machinery for the registration and licensing of draught animals and for ensuring humane treatment of the animals. Cruelty to animals should be made a punishable offence under this legislation. Laws for the control of draught animals on roads and ways should be incorporated as far as possible into existing traffic rules and regulations.

Information

145. It will be useful to compile a directory of experts and prepare handbooks in the various fields of draught animal power (breeding, feeding, implements, carts, harnesses, energy relationships, socio-economic factors, etc.). It will be helpful to have a handbook on draught animal power suited to respective areas, along the lines of the FAO Handbook for Africa.

146. One of the reasons cited for the present state of affairs in the field is that extension work deals with various aspects such as meat and milk production but does not cover draught animal power adequately. Extension workers should be trained in draught animal power and equipped with literature and other materials by means of which they could create awareness amongst farmers and carters of the benefits of modernization. Extension must be at farm level. FAO has produced some audio-visual materials for draught animal power extension; this activity should be intensified. Pamphlets showing the economics of draught animal power tillage-cum-animal-drawn vehicles should be produced for dissemination among countries where such tillage is significant. Details of manufacture and extension could also be given.

Policies and institutional aspects

147. A number of centres in the agricultural universities and specialized institutions in many developing and developed countries have become interested in draught animal power, and some are already involved in the study of energy problems. Most of these institutions have not included draught animals as one of the subjects for study. FAO may arouse their interest by sending them material on draught animal power, emphasizing its contribution to and importance for the energy situation. The United Nations system may even consider funding the development of expertise on draught animal power in these institutions.

148. Where the magnitude of draught animal power activity warrants, Governments should consider the establishment of autonomous Animal Energy Development Boards with adequate financial resources. Such an organization would be responsible for organizing and overseeing the development and management of the draught animal power system. It would, namely (a) carry out or co-ordinate the required investigations; (b) train personnel; (c) organize institutions for research work and programmes on breed and ranch development; (d) modernize slaughterhouses; (e) organize the marketing of draught animals, etc. The Board could be an advisory body to the Government in all matters relating to draught animal power.

Conclusion

149. Only a well-equipped infrastructure can upgrade draught animal power. Such an infrastructure is missing in most developing countries. It should and can be strengthened rapidly with relatively little inputs.

VIII. CONCLUSIONS AND RECOMMENDATIONS

150. Conclusions and recommendations were indicated alongside the description of the problems and situations. A few of the more important findings and recommendations have been taken out for enumeration in this final section, under the following categories:

(a) Immediate operative action by way of international assistance, and initiation of programmes and projects in order to create awareness, to develop expertise and infrastructure, to effect movements, to transfer technology, etc.;

(b) Socio-economic studies to identify problems and to formulate policies and action;

(c) Research and development plans for design improvements, testing, adaptation, comparative evaluation, field experiments, etc.

151. Energy is one of the main inputs for the development of agriculture. Unfortunately, for compelling reasons, many developing countries have to depend upon draught animal power for a long time to come, though maybe not for ever. Draught animal power need be considered possibly only as an interim phase; but it must complement other forms of energy and be encouraged only wherever it is inevitable or appropriate. Mechanization will continue to be even encouraged. Draught animal power does not compete with it.

152. Draught animal power is an excellent example of appropriate technology with great scope for mass level application and employment opportunities. But draught animal power will not take off unless there is deliberate intervention and assistance from the United Nations system and from the professionals in developed and developing countries. Finally, the Governments themselves will decide on the importance of draught animal power.

153. There is an urgent need to bring draught animal power, where it is suitable and appropriate, to the attention of the international development agencies as well as the national Governments of the developing countries themselves. In order to enable developing countries to equip themselves with the necessary knowledge and technical competence to develop and optimally utilize the full potential of draught animal power, it is recommended that those concerned with draught animal power, directly and indirectly, all over the world, should:

(a) Take immediate action on aspects where enough is known about problems and remedies;

(b) Take long-term measures by way of studies, and thereafter appropriate decisions and actions.

154. Some of the steps that Governments and international agencies could possibly take under appropriate situations are indicated below:

(a) To make the draught animal power system an integral part of agriculture, including forestry, and rural development structures and processes and include draught animal power in forums on energy and agricultural development;

(b) To consider draught animal power on a par with other agricultural inputs, such as fertilizer, water, diesel, etc. and to qualify it for subsidy as well as adequate resource allocation and institutional and infrastructural support;

(c) To interlink draught animal power with the milk-and-meat system by ensuring co-ordinated policy measures mutually reinforcing one another and benefiting all three systems with regard to resource allocation, breeding, feeding, health care, research and development, etc;

(d) To introduce draught animal power in appropriate development programmes for international technical and funding assistance.

United Nations co-ordinating arrangements

155. It is proposed that the United Nations should make arrangements for the initiation and co-ordination of projects related to draught animal power, and the collection of information on draught animal power through United Nations agencies (FAO, UNIDO, etc.).

Regional centres

156. It is recommended to set up five regional centres for draught animal power, two each in Asia and Africa and one in Latin America, to serve the respective regions in areas such as:

(a) Conducting socio-economic studies, research and development work, testing;

(b) Education, training, extension;

(c) Facilitating transfer of technology;

(d) Collection, evaluation and dissemination of appropriate or relevant information regarding draught animal power.

Workshops and conferences

157. In order to upgrade the draught animal power system to levels where it can be effective, it is proposed that national and regional seminars and workshops should be organized on specific problems (redesign of draught animal power equipment, information systems, research, infrastructure) of draught animal power development in the country or in the region.

Immediate action for modernization

158. On the basis of prevailing knowledge of economic evaluation of the different aspects and the current perceptions of the workers in the various fields, it is

recommended that suitable steps should be taken by national Governments to modernize the draught animal power system with international assistance where necessary. Some of the illustrative kinds of techniques and policies which can be transferred with advantage (after adaptation to local conditions) are:

(a) Compilation and categorization for use in the developing countries, particularly of implements, carts and harnesses, of knowledge available in developed countries on draught cattle and horses; transfer of this technology and adaptation to local conditions;

(b) Breeding and rearing of suitable draught animals wherever there is a shortage of draught animal power;

(c) Increasing the number and improving the quality of donkeys, mules and horses for transportation and farm work;

(d) Increasing the utilization of all draught animals and improving transport capability in agriculture during off-season and as specialized means of transport in rural and urban areas;

(e) Introducing pneumatic tyres, smooth bearings, brakes and lighter platform, etc., in order to improve capacity of carts;

(f) Replacing the neck yoke and head yoke systems by the double yoke system (back for vertical load and neck for hauling) for ploughing and carting; introducing collar-cum-hames yokes in place of neck and head yokes.

Infrastructure for draught animal power

159. It is recommended that the following kinds of action should be taken by countries, with appropriate international assistance where necessary, with a view to providing the requisite infrastructure for the development and management of draught animal power. Specifically it is recommended:

(a) Developing countries, which have a large population of draught animals, should establish Animal Energy Boards as apex organizations with functions such as (i) recommending guidelines, standards, norms, for traffic safety; (ii) co-ordinating draught animal power programmes undertaken by other agencies or Governments; (iii) sponsoring draught animal power research projects and socio-economic studies; (iv) mobilizing financial support for draught animal power improvement; (v) formulating and monitoring draught animal power schemes and projects; and (vi) advising Governments on national draught animal power policies, etc.;

(b) Developing countries should collect statistics on draught animal power on a regular basis;

(c) Credit and insurance systems for draught animals should be organized and strengthened as has been done for milch cattle;

(d) Appropriate farmers' organizations should be established;

(e) Incentives should be given to individuals for breeding draught animals;

(f) Laws defining working norms for draught animals should be introduced;

(g) Measures should be taken for increasing feed availability for draught animals;

(h) Appropriate veterinary services, including field-based and mobile facilities, should be established or strengthened;

(i) Training and extension activities in draught animal power, including increased provision of training material, should be intensified.

DAP expertise

160. In order to develop expertise in draught animal power at all levels, the following are recommended:

(a) Compilation of a bibliography of published and unpublished material classified according to the various components of the draught animal power system;

(b) Preparation of a directory of institutions and individuals having expertise in (and interest in developing) draught animal power;

(c) Assessment of future implications for draught animal power as a result of government policies and development targets, general economic and environmental trends within the country and outside, particularly relating to present and future energy costs;

(d) Evaluation of the economic and social impact and implications of introducing (i) draught animal power in place of manual labour; (ii) petroleum-based power in place of draught animal power in the context of savings in petroleum and foreign exchange; (iii) appropriate combinations of manual, draught animal power and petroleum-based sources; (iv) the impact of draught animal power on the yield of crops and pressure on land.

Research and development studies

161. With a view to facilitating transfer of improved technology and practices as well as to developing new designs, it is recommended that countries with a significant interest in draught animal power should establish research and development centres, with help if required from the United Nations and other international agencies, to carry out design, development, testing and evaluation work on agricultural implements for draught animal power, animal-drawn vehicles, harnesses and hitching devices, logging techniques and devices, breeding programmes, and draught animal management, and to encourage research on fodder, range and pasture improvement.

Organization of co-ordinating bodies

162. Considering that immediate draught animal power development acitivities should be initiated, considering the need for international co-operation and co-ordination of such activities and the difficulty of establishing at this juncture a co-ordinating unit for this purpose, it is recommended that in the first place United Nations agencies, including FAO, should encourage and assist existing decentralized regional and/or national institutions to collect and diffuse appropriate information on draught animal power techniques and ongoing programmes and to initiate or promote studies and research as required; it is further recommended that meanwhile a co-ordinating mechanism should be envisaged and organized in an appropriate United Nations agency.

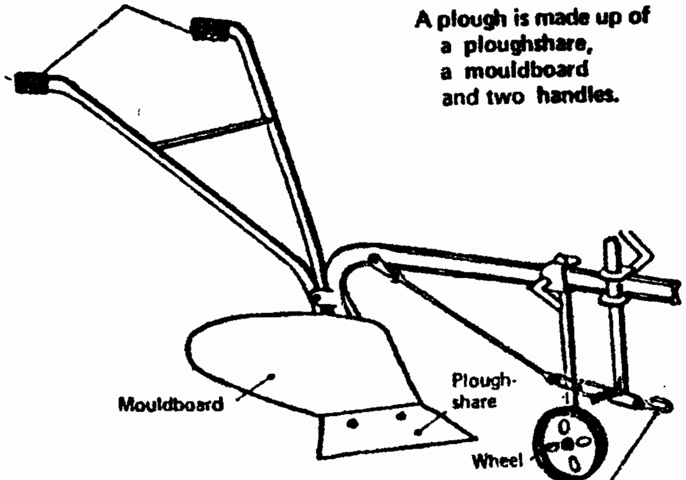
Annex I

ILLUSTRATIONS OF IMPROVED METHODS

The plough

Usually
simple ploughs
are used.

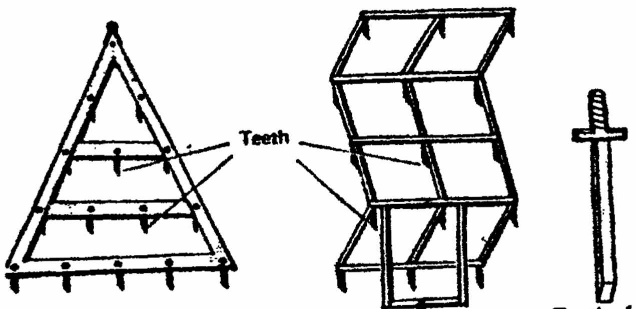
A plough is made up of
a ploughshare,
a mouldboard
and two handles.



Plough

The harrow

The harrow is used for breaking clods.

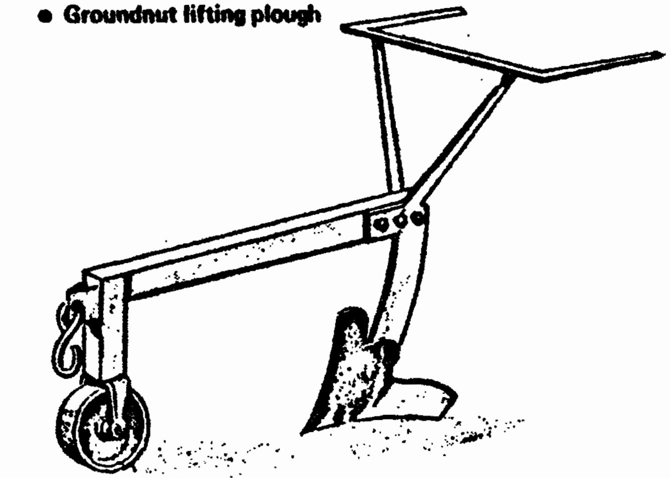


Wooden harrow

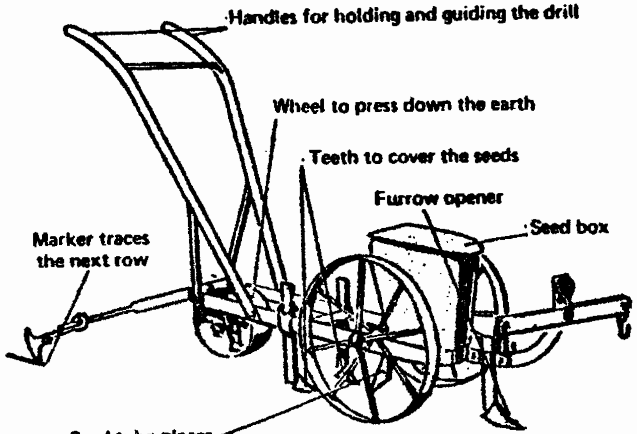
Iron harrow

Tooth of
harrow

- **Groundnut lifting plough**



Lifting plough



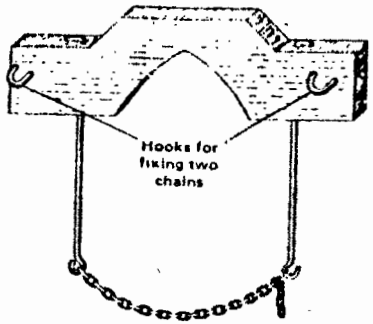
Seed drill

SOURCE - FARMING WITH ANIMAL POWER - FAO

/...

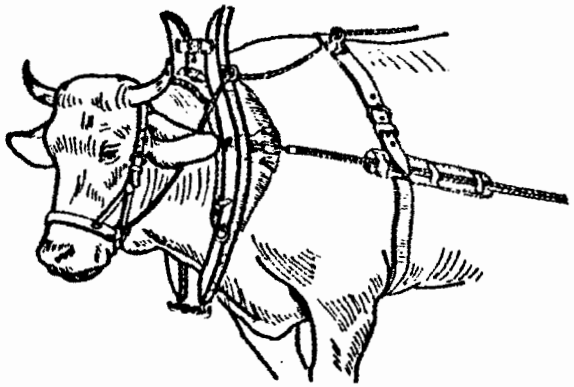
- **The single yoke**

The single yoke
is used to harness one animal.
A chain is fixed
to either side of the single yoke.



Single neck yoke

It can also be used as a collar,
in the same way as for donkeys



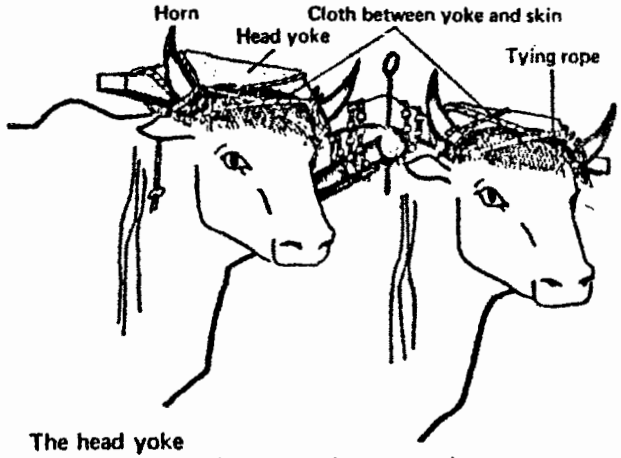
Ox with collar

- **The head yoke**

The head yoke is placed behind the horns
and is tied to them
with rope or thongs of leather.
In order not to injure the animal,
put a pad of straw or kapok wrapped in cloth
between the yoke and the head.

Hook for fixing chain

Head yoke

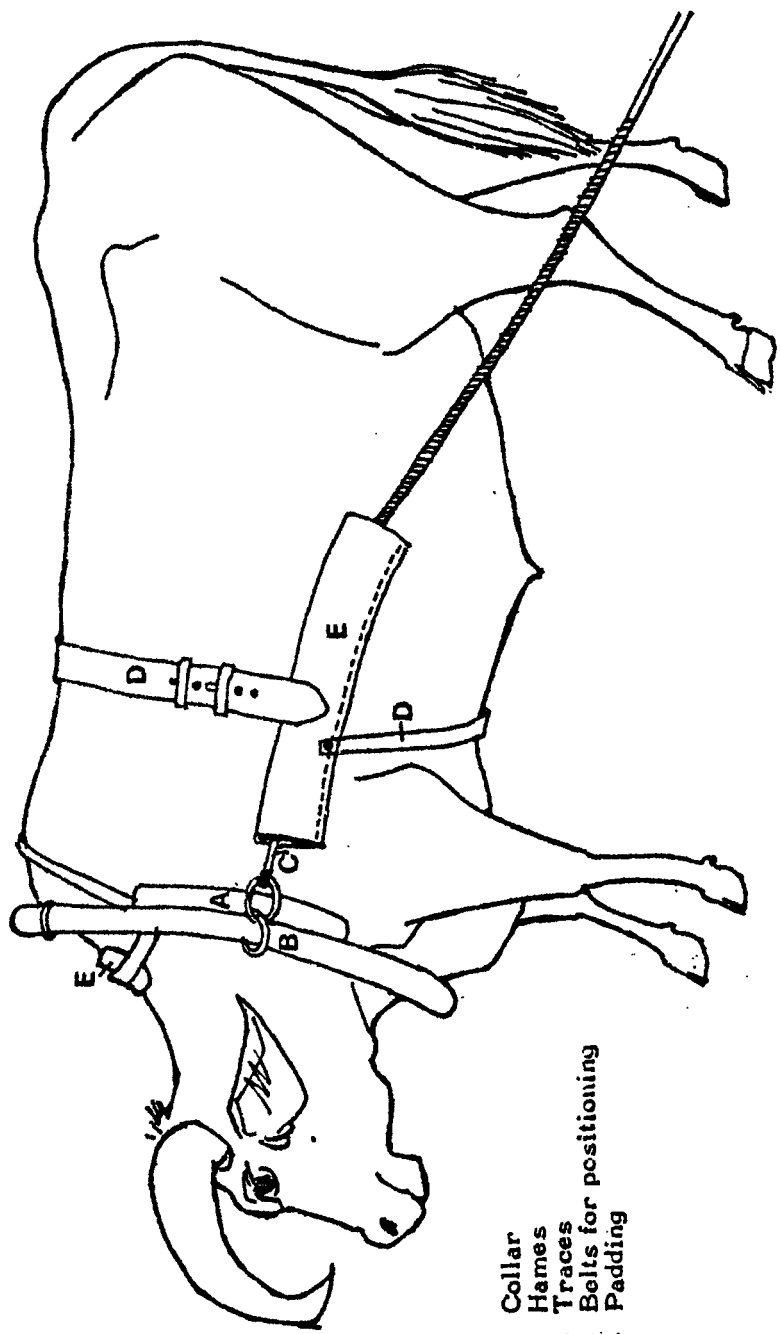


The head yoke
is mostly used for oxen other than zebus.
This yoke gradually develops the neck muscles.
So do not start with work
that is too tiring.

/...

SOURCE - FARMING WITH ANIMAL POWER - FAO

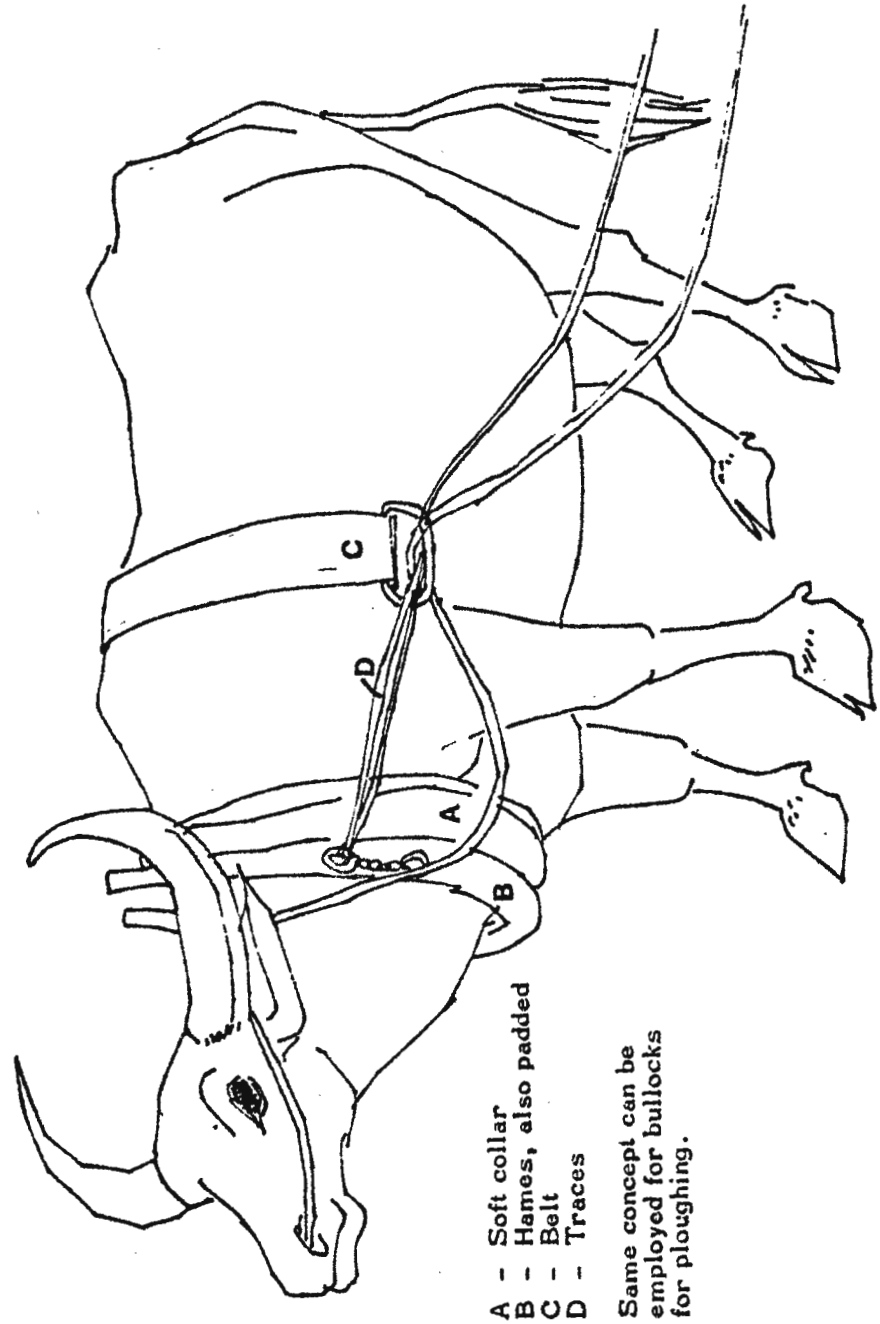
Bullock Harness for Ploughing



A - Collar
B - Hames
C - Traces
D - Belts for positioning
E - Padding

/...

Buffalo Harness for Ploughing



A - Soft collar
B - Hames, also padded
C - Belt
D - Traces

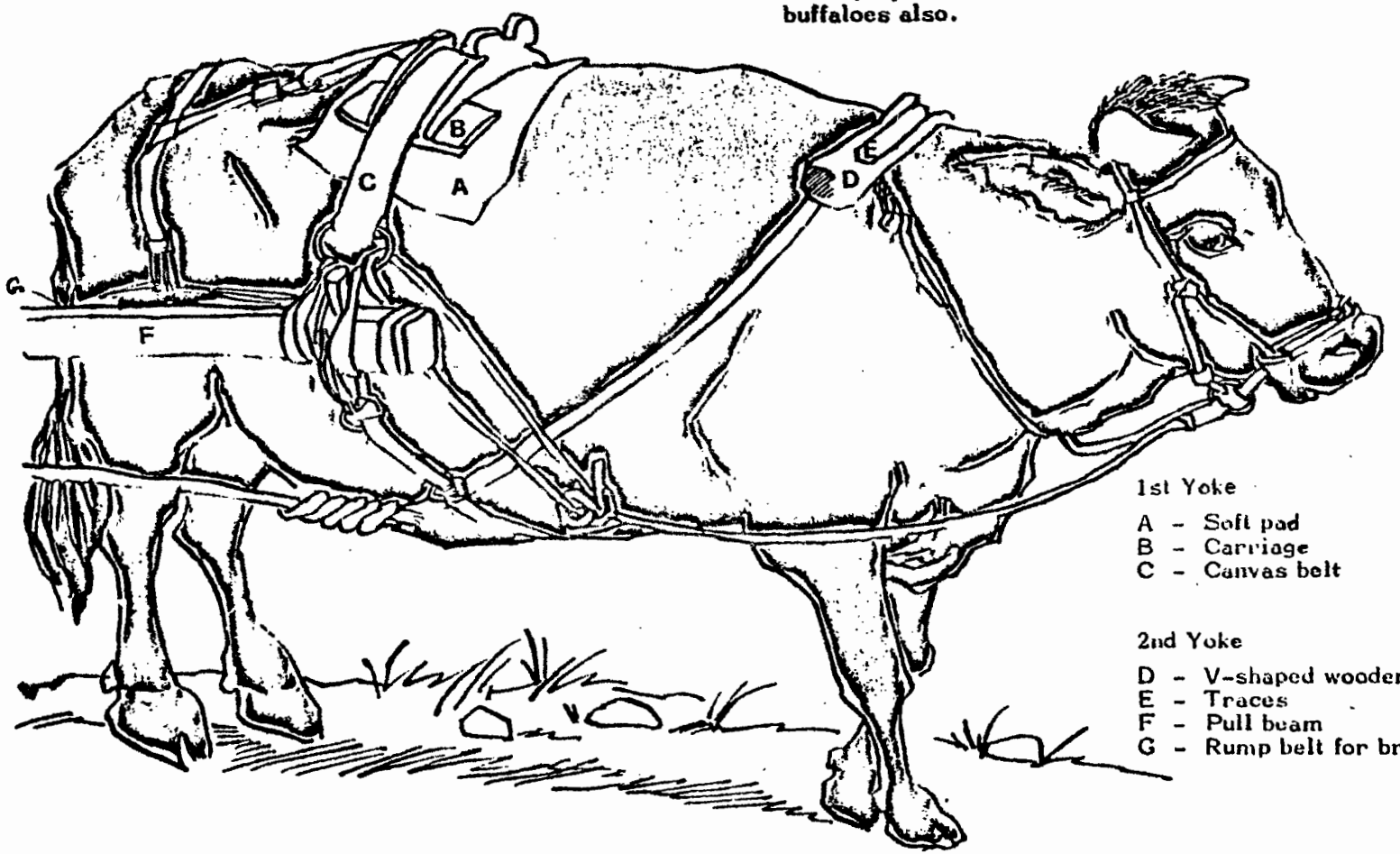
Same concept can be employed for bullocks for ploughing.

Bullock Cart

Double-Yoke Harness

First yoke carries vertical load.
Second yoke pulls vehicle. Traces attached to pull beams and frame of cart.

Same design can be employed for buffaloes also.



1st Yoke

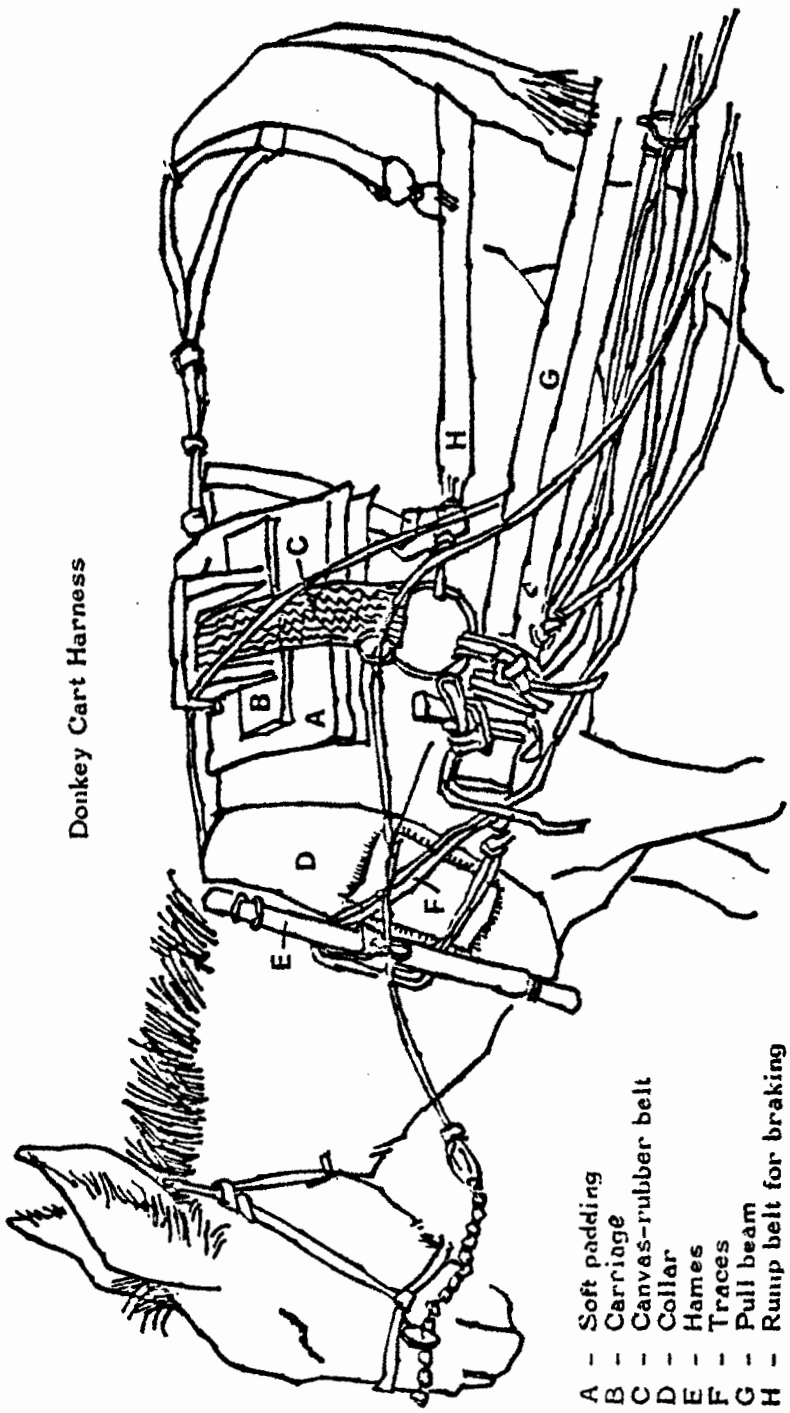
A - Soft pad
B - Carriage
C - Canvas belt

2nd Yoke

D - V-shaped wooden piece
E - Traces
F - Pull beam
G - Rump belt for braking

/...

Donkey Cart Harness

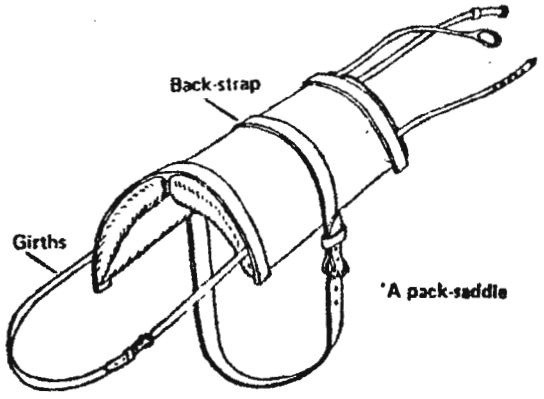


A - Soft padding
B - Carriage
C - Canvas-rubber belt
D - Collar
E - Hames
F - Traces
G - Pull beam
H - Rump belt for braking

Donkeys at work

- **Carrying loads**

Put a **pack-saddle** on the donkey's back.
A pack-saddle is made of
- two pads placed on the donkey's back;
- a piece of leather or plaited rope
  called a **back-strap**
  which is fixed to the pads;
- thongs of leather or rope
  called **girths**
  which hold the pack saddle on the animal's back.

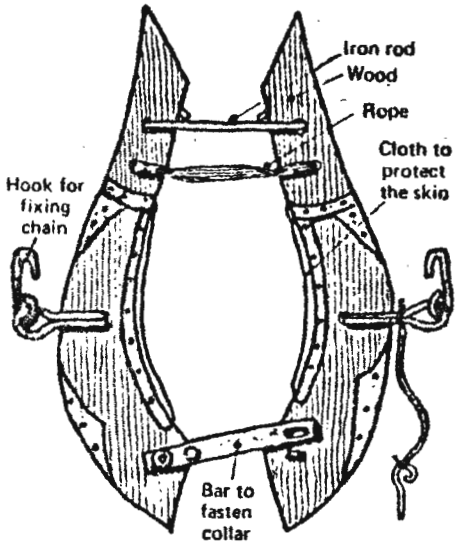


*A pack-saddle

- Baskets are fixed on the pack-saddle.

You can easily make a pack-saddle yourself.
The pads are made with
old sacks stuffed with grass and sewn up.
The back-strap and the girths
can be made of leather or plaited rope.

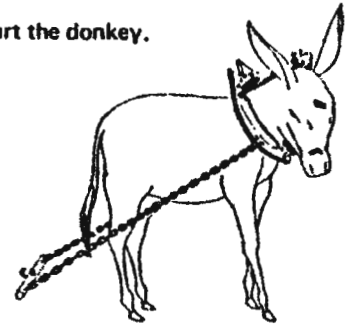
The donkey must get used to carrying the pack-saddle.
At first put it on without a load,
then gradually increase the load.



Donkey collar

It is difficult to make a good collar.

It must not hurt the donkey.



Donkey with collar

SOURCE - FARMING WITH ANIMAL POWER - FAO

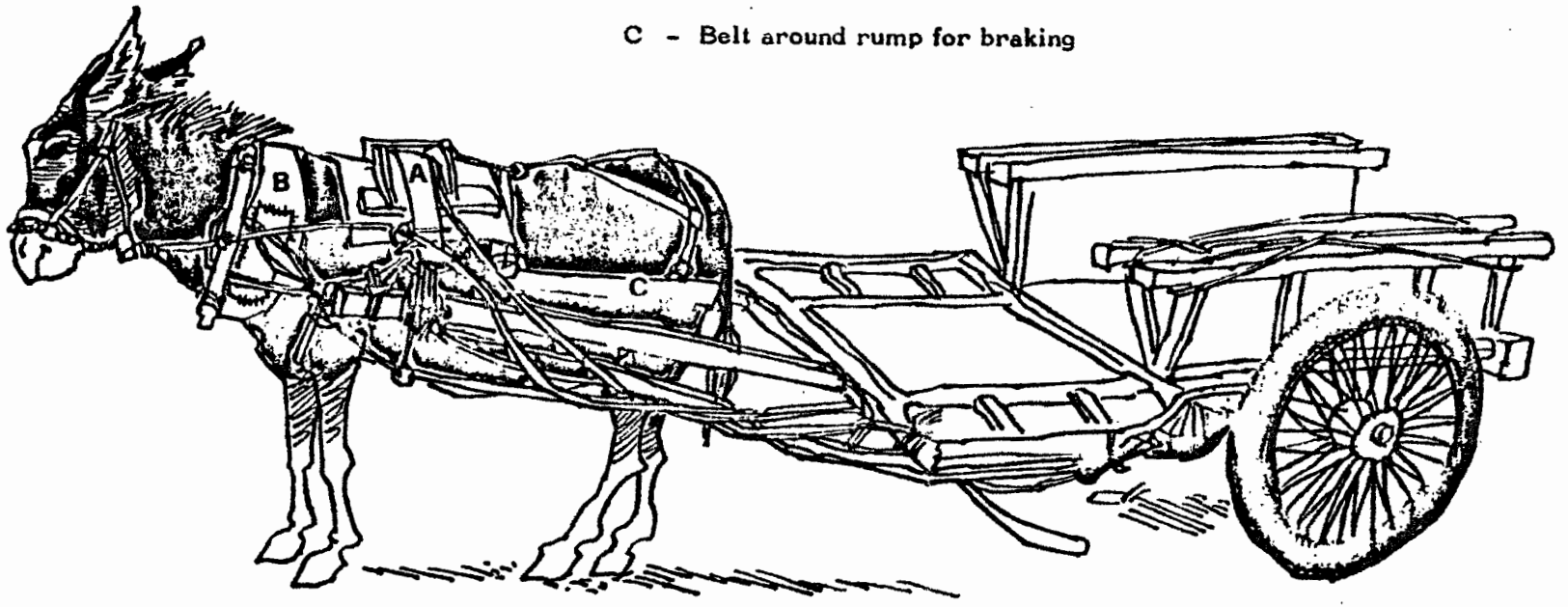
Donkey Cart (600 kg Capacity)

Double-yoke harness
Pneumatic tyres
Smooth bearings

A - First yoke for vertical load - padding, carriage, belt - attached to pull beam

B - Second yoke for hauling - collar, hames and traces - attached to pull beam and cart frame

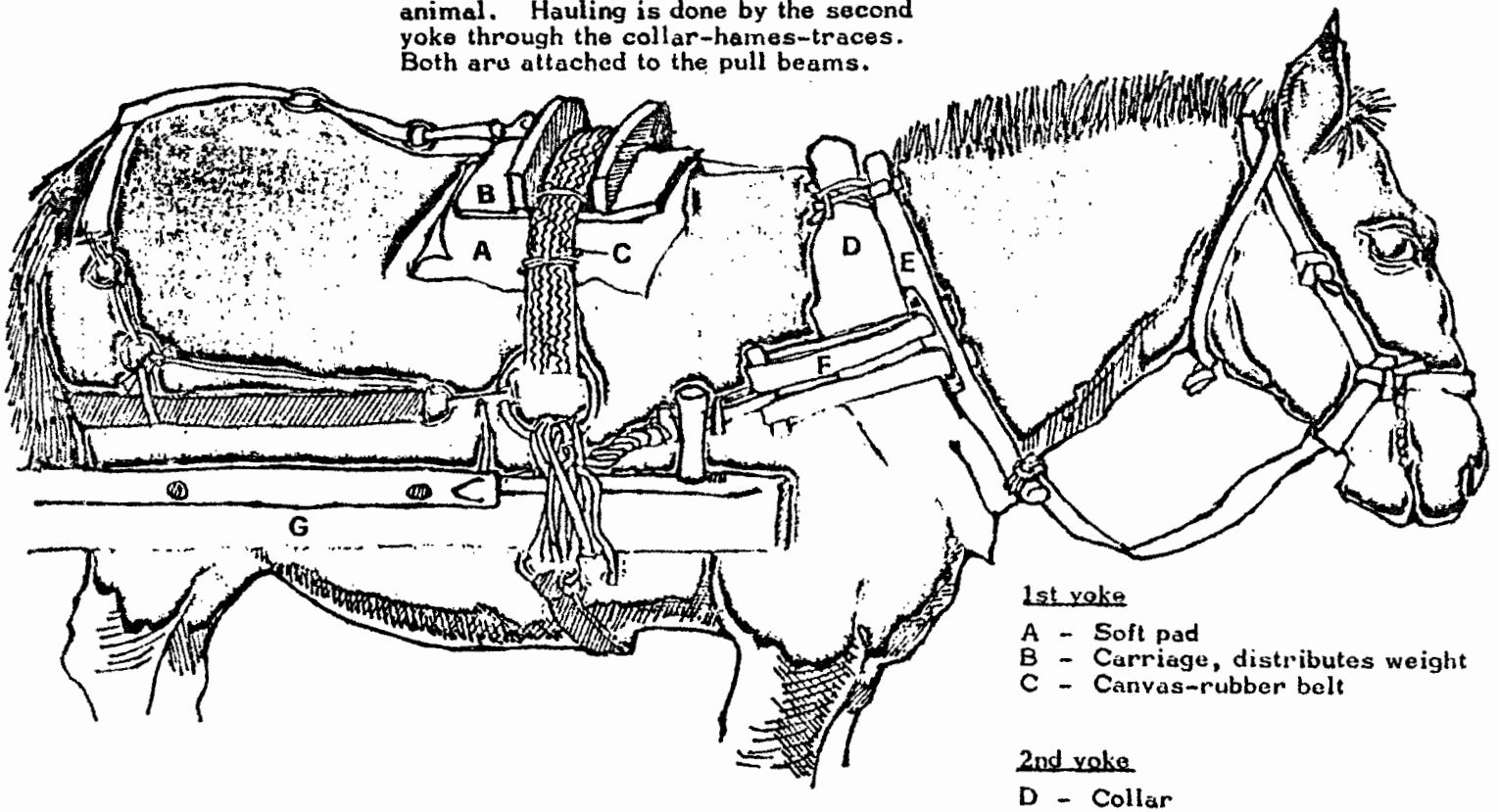
C - Belt around rump for braking



Horse Cart

Double-yoke Harness

Vertical load component is taken care of by the first yoke on the back of the animal. Hauling is done by the second yoke through the collar-hames-traces. Both are attached to the pull beams.



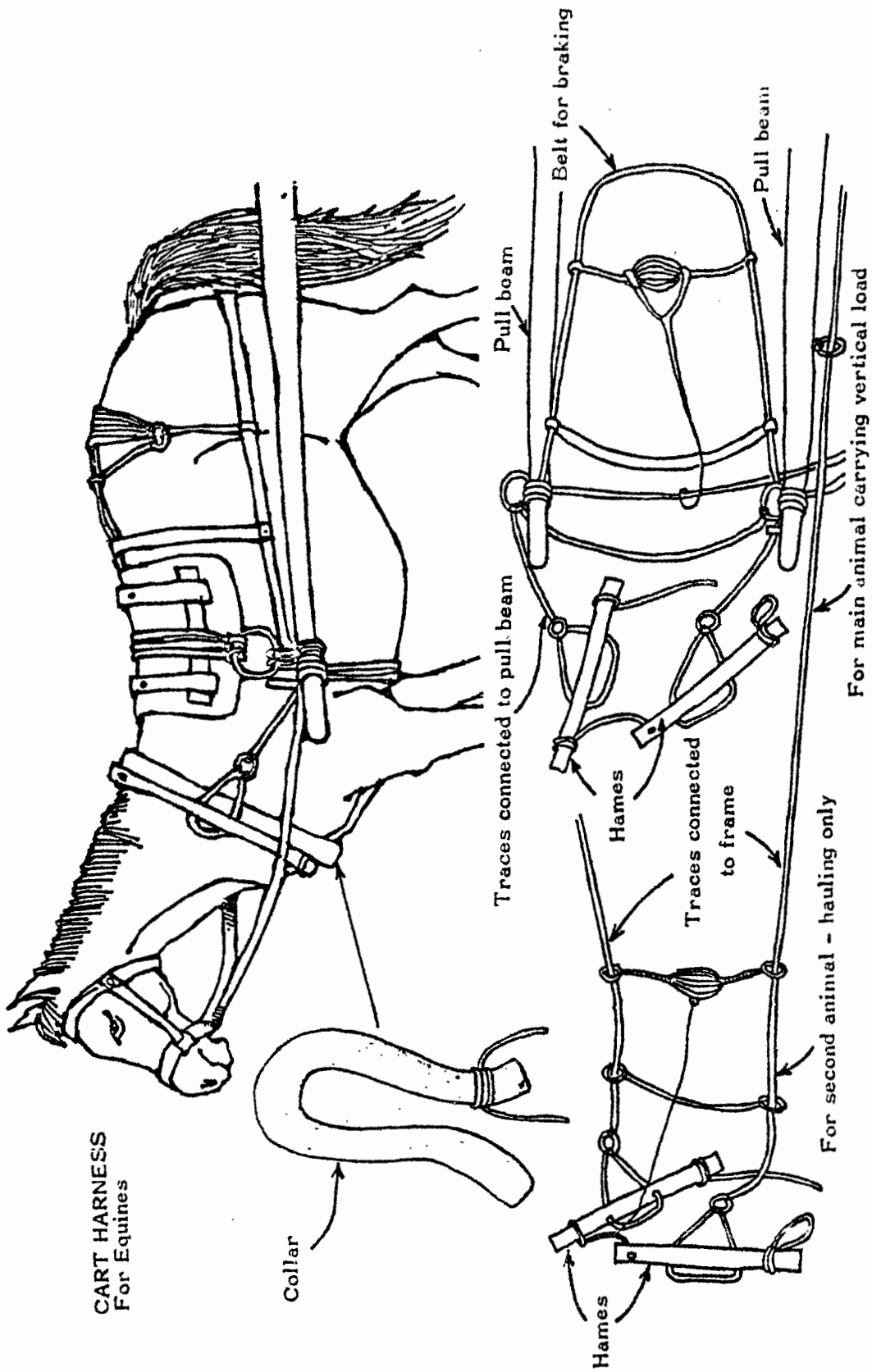
1st yoke

A - Soft pad
B - Carriage, distributes weight
C - Canvas-rubber belt

2nd yoke

D - Collar
E - Hames
F - Traces
G - Pull beam

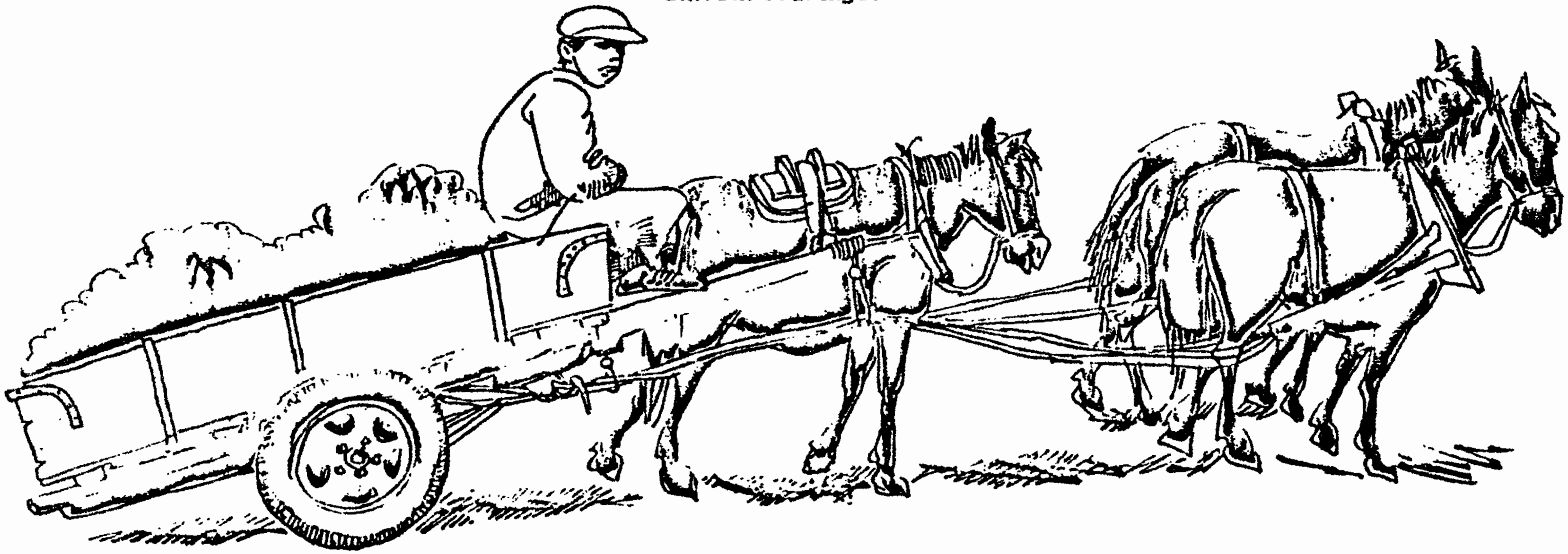
/...

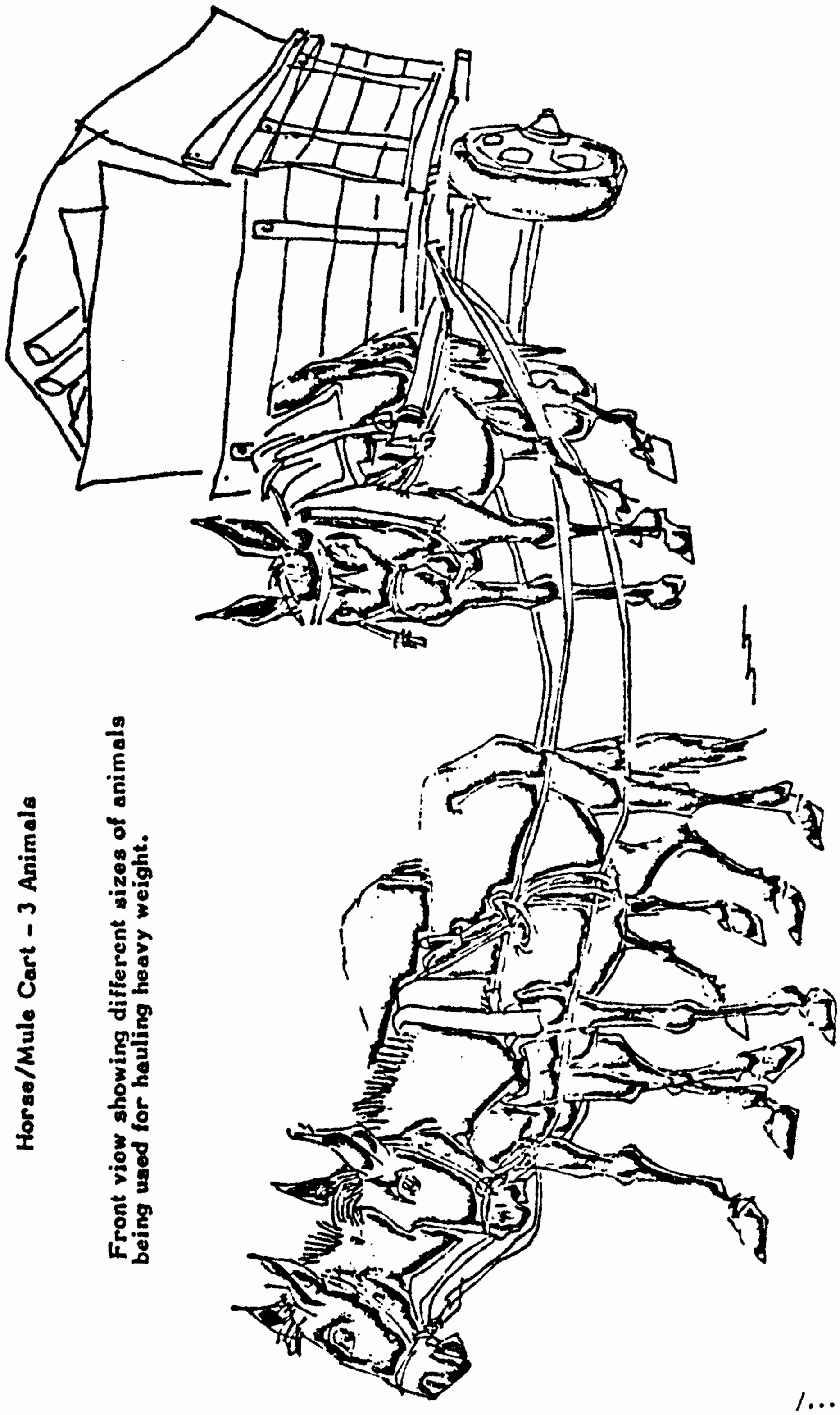

CART HARNESS
For Equines
Collar
Pull beam
Traces connected to pull beam
Belt for braking
Pull beam
Hames
Traces connected to frame
For main animal carrying vertical load
For second animal - hauling only
Hames

Horse Cart - 3 Animals

Two-wheeler cart, hauled by three animals -
The first horse carries the vertical load and also pulls -
The other two animals (they can be mules, cattle or donkeys)
merely pull - traces connected to the frame.

3 tons can be hauled in this cart with pneumatic tyres and smooth bearings.





Horse/Mule Cart - 3 Animals

Front view showing different sizes of animals being used for hauling heavy weight.

Annex II

LIST OF PARTICIPANTS

Members of the Working Group

Sanogo ADAMA	Director, Studies Assistance Funds Ouagadougou, Upper Volta
B. R. CHOUDHARY	Director, Live Stock Services Dacca, Bangladesh
Priyath GUNAWARDENA	Chief Engineer Industrial Development Board Moratuwa, Sri Lanka
Noel HOLDER	Managing Director Livestock Development Co. Ltd. Georgetown, Guyana
Mahmoud A. KHEIRELDIN	First Under Secretary of State for Animal Production Ministry of Agriculture Dokki Giza, Egypt
Cesar NOVOA	Institute Veterinario de Investigaciones Lima, Peru
SOEGONDO	Secretary of Directorate General of Livestock Services Jakarta, Indonesia
Getachew WORKU	Expert in Animal Breeding and Improvement Ministry of Agriculture Addis Ababa, Ethiopia
Conrado ZAMORA G.	Director of Agriculture Extension Mexico 8 D.F., Mexico

Observers

T. R. JAYARAMAN	Retd. Vice-Chancellor Bangalore, India
M. V. PYLEE	Vice-Chancellor University of Cochin Cochin, India
P. SHIVALINGAM	Vice-Chancellor Perarignar Anna University of Technology Guindy, Madras, India

Harkripal SINGH	Area Sales Manager M/s. Dunlop India Limited Bangalore, India
H. S. KUMARSWAMY	Senior Design Engineer R and D Department M/s. Dunlop India Limited West Bengal, India
M. D. KHANDKE	Manager - Agriculture M/s. Dunlop India Limited Calcutta, India
D. M. BURDE	Organizer, Akhil Bharat Krishi Wardha (Maharashtra), India
B. C. CHOADHRY	Secretary, Vishvandeedam Farm Bangalore, India
G. L. DALMIA	Institute for Social and Economic Change Bangalore, India
S. GIRIYAPPA	Institute for Social and Economic Change Bangalore, India
S. GANESH	Manager (Tech) Small and Village Industries Wing Industrial Development Bank of India Bombay, India
S. GOPAL	District Manager MRF Limited Bangalore, India
S. K. GADAG	Secretary, Animal Drawn Improved Agricultural Implements Research and Development Centre Vishwakarma Improved Agricultural Implements Manufacturing Association Bijapur, India
C. V. KRISHNA	Development Engineer Government of Orissa Agricultural and Co. Op. Department Government Implement Factory, Satyanager Bhubaneswar, India
B. KEMPEGOWDA	Agricultural Engineer University of Agricultural Sciences Hebbal, Bangalore, India
B. S. KESHAVA MURTHY	Director, Institute of Animal Health and Veterinary Biologicals Hebbal, Bangalore, India

C. R. KESHAVAMURTHY	Superintending Engineer Ministry of Shipping Transport (Road Wing) Regional Office Bangalore, India
M. N. MENON	Animal Husbandry Commissioner Government of India Kerala, India
Nalin MEHTA	Akhil Bharat Krishico Seva Sangh Bharatiya Vidya Bhavan Bombay, India
P. G. NAIR	Senior Scientist National Dairy Research Institute Bangalore, India
I. J. PATEL	Gujarat Agricultural University Ahmedabad (Gujarat), India
S. L. RAPTE	Head and Professor of Agricultural Engineering Marathawada Agricultural University Parbhani (Maharashtra), India
Radhakrishna BAJAJ	General Secretary Akhil Bharat Krishi Goseva Sangh, Gopuri Wardha (Maharashtra), India
M. R. A. RAO	Manager - Tropical R and D Vicon Ltd. Bangalore, India
A. V. RAI	Professor and Head of the Department of Animal Genetics and Breeding University of Agricultural Sciences Bangalore, India
R. V. RAO	Senior Scientist National Dairy Research Institute Bangalore, India
N. S. R. SASTRY	Associate Professor Haryana Agriculture University Hissar, India
Cpt. V. SUNDARAM	Founder, Blue Cross of India Besant Gardens Madras, India
C. P. SINGH	Professor and Head of the Department of Farm Power and Machinery Panjah Agricultural University Ludhiano (Punjab), India

K. R. SWAMINATHAN	Head, Farm Machinery Tamil Nadu Agricultural University Coimbatore, India
K. R. SURESH KUMAR	Sales Engineer Indian Oil Corporation Bangalore, India
M. M. SINHA	Senior Scientists National Dairy Research Institute Bangalore, India
Tulsidas VISHRAM	Executive Chairman Akhil Bharat Krishi Gosevasangh Bombay, India
G. C. YADAV	Scientist (Farm Operations) Coordinating Cell, ICAR Dryland Research Project Hyderabad Andhra Pradesh, India
Zafar FOTEHALLY	National Committee on Environmental Planning Bangalore, India

United Nations bodies

Secretariat of the United Nations Conference on New and Renewable Sources of Energy	Louis A. Wiltshire S. Arungu-Olende
Economic and Social Commission for Asia and the Pacific	Charn Charussilapa Srinivasa Murthy

Specialized agencies

Food and Agriculture Organization of the United Nations	Mr. Alwan R. Van Vaerenbergh G. E. Thierstein

Government of India representatives

Manju SHARMA	Department of Science and Technology New Delhi
T. NARAYANAN	Director, Animal Health Planning Commission New Delhi
Kartar S. YADAV	Joint Commissioner Department of Agriculture New Delhi

Representatives of the Indian Institute of Management, Bangalore

K. R. RAMACHANDRAN	Offg. Director Bangalore
K. L. K. RAO	Dean Programmes (co-ordinator of arrangements) Bangalore

Consultant

N. S. RAMASWAMY	Director, Indian Institute of Management Bangalore, India

BIBLIOGRAPHY

Books

Benor, Daniel and Harrison, James Q. (1977). Agricultural Extension: The Training and Visit System. World Bank.

Binswanger, H. P. (1978). The Economics of Tractors in South Asia.

Binswanger, H. P., Ruttan, V. W. et al. (1978). Induced Innovation, Technology, Institutions and Development. The Johns Hopkins University Press, Baltimore and London.

Cockrill, W. Ross (1974). The Husbandry and Health of the Domestic Buffalo.

Cole, H. H. and Garrett, W. N. (1980). Animal Agriculture: The Biology, Husbandry and Use of Domestic Animals. W. H. Freeman and Company, San Francisco.

Food and Agriculture Organization of the United Nations (1977). Farming with Animal Power. FAO, Rome.

Food and Agriculture Organization of the United Nations (1969). Farm Implements for Arid and Tropical Regions. FAO, Rome.

Hapjen, H. J. and Biesalski, E. (1978). Small Farm Implements. FAO, Rome.

Harris, Marvin (1977). Cannibals and Kings. Fontana/Collins.

Indian Council of Agricultural Research (1979). Characteristics of Cattle and Buffalo Breeds in India. ICAR, New Delhi.

Makhijani, A. and Poole, A. (1975). Energy and Agriculture in the Third World. Ballinger Publishing Company, Cambridge, Mass.

Piemental, O. (1974). Energy Use in World Food Production. Cornell University Press, Ithaca.

Stout, B. A. (1979). Energy for World Agriculture. FAO, Rome.

Winrock International Livestock Research and Training Center (1977). Ruminant Products: More than Meat and Milk. Arkansas.

Winrock International Livestock Research and Training Center (1978). The Role of Ruminants in Support of Man. Arkansas.

Zutshi, D. N. (1979). Improved Implements and Tools of Farming for Hilly Regions in India.

Reports and articles

General

Chambers, Robert (1978). Livestock, Landlessness and Livelihoods: Optimising What, For Whom, and How?

Chancellor, William J. (1969). Social and Institutional Factors in Mechanisation of Agriculture in Thailand and Malaysia by Tractor Hire Services. American Society of Agricultural Engineers.

Desai, Ashok V. (1978). India's Energy Consumption: Composition and Trends. Centre for Development Studies, Trivandrum.

Food and Agriculture Organization of the United Nations (1974). Socially Oriented Technologies for Agro-Economic Development.

Food and Agriculture Organization of the United Nations (1979). Symposium on the Interrelationships between Resources, Environment, Population and Development.

Food and Agriculture Organization of the United Nations (1977). The State of Natural Resources and the Human Environment for Food and Agriculture.

Food and Agriculture Organization of the United Nations (1979). Draft Report on a Mission to the Islamic Republic of Pakistan.

Food and Agriculture Organization of the United Nations. 1978 and 1979 Production Yearbook, vols. 32 and 33. FAO, Rome.

Food and Agriculture Organization of the United Nations (1972). Near East Regional Study. FAO, Rome.

Food and Agriculture Organization of the United Nations (1979). Logging Operations: A Report of the FAO/Norway Training Course. FAO, Rome.

Giles, G. W. (1968). Towards a More Powerful Agriculture. Report to the Government of Pakistan.

Harris, Marvin. The Cultural Ecology of India's Sacred Cattle. Current Anthropology, 7.

Inns, F. M. (1980). Animal Power in Agricultural Production Systems. World Animal Review, No. 34.

Koegel, Richard G. The Young Farmer's Training Centre of Maradi, Niger Republic. American Society for Agricultural Engineers.

North Swedish Horse Association, The. Procedure in Draught Testing.

Odend'hal, S. (1972). Human Ecology, 1, 3.

Odend'hal, S. Energetics of Indian Cattle in their Environment. Human Ecology, 1.

Revelle, R. (1976). Science, 192.969.

Revelle, Roger (1980). Energy Dilemmas in Asia: The Needs for Research and Development.

Revelle, Roger. Energy Use in Rural India.

Report of the West Africa Rural Technology Meeting (1979). Commonwealth Secretariat, London.

Stanford University and West Africa Rice Development Association (1979). Political Economy of Rice in West Africa: A Summary of Principal Results. Food Research Institute.

Singh, Inderjit and Day, Richard H. (1975). A Microeconometric Chronicle of the Green Revolution.

Smith, A. J. Feeding the 5,000 Million. Centre for Tropical Veterinary Medicine.

Thingalaya, N. K. (1976). Marginal Farmers and Agricultural Labourers in South Kanara District. Syndicate Bank, Manipal, India.

Turk, K. L. (1975). Other Roles of Animals. Prepared for the Rockefeller Foundation Review on "The Role of Animals in the Future World Food Supply". New York.

United Nations Conference on New and Renewable Sources of Energy (1979). Report of the Secretary-General.

Ward, Gerald M., Sutherland, Thomas M. and Sutherland, Jean M. (1980). Animals as an Energy Source in Third World Agriculture. Science, vol. 208.

Livestock

Choke, B. N. Non-Political Background of the Cow.

Corvanich, Amnuay. Elephant Logging in Thailand.

Council of Scientific and Industrial Research (1970). The Wealth of India, vol. VI. New Delhi, India.

Dandekar, V. M. India's Sacred Cattle and Cultural Ecology.

Dandekar, V. M. Sacred Cattle and More Sacred Production Functions.

Food and Agriculture Organization of the United Nations (1979). Assistance in the Capturing of Wild Buffaloes for Animal Draught Purposes.

Food and Agriculture Organization of the United Nations (1974). The Husbandry and Health of the Domestic Buffalo. FAO, Rome.

Food and Agriculture Organization of the United Nations (1972). Near East Regional Study.

Food and Agriculture Organization/World Bank (1979). Report of Small Holders Cattle and Buffalo Development Project.

Food and Agriculture Organization/World Bank (1978). Report of the Livestock Sector Survey.

Faulkner, D. E. (1978). The Future of the Camel.

Howard, C. R. The Draught Ox: Management and Uses. Reprint: Zimbabwe Rhodesia Agric. J., vol. 77 (1).

Indian Council of Agricultural Research (1979). Characteristics of Cattle and Buffalo Breeds in India.

Inns, Frank M. (1979). Animal Power in Agricultural Production Systems. University of Dar es Salaam.

Katpatal, B. G. (1977). Performance of Zebu Cattle and Their Crosses with Tanrus Cattle.

Knoess, Dr. K. Taming, Training and Testing of Bullocks and Camels as Draught Animals.

Mettrick, H. (1977). Oxenisation in the Gambia: An Evaluation. University of Reading.

National Commission of Agriculture (1976).

Plucknett, D. C. and Nicholls, D. F. Integration of Grazing and Forestry.

Raj, K. N. India's Sacred Cattle: Theories and Empirical Findings.

Report of the Consultancy of Stewart Odend'hal to the Ford Foundation. Past, Present, and Future Research on Livestock in Bangladesh with Particular Emphasis on Draught Power and Mechanisation.

Report of the FAO/World Bank Cooperative Programme. Indonesia. Livestock Sector Study, vol. I. FAO, Rome.

The Rockefeller Foundation (1980). Integrated Crop and Animal Production: Making the Most of Resources Available to Small Farms in Developing Countries.

Role of Draught Animals in Agriculture. Reprint: Asian Livestock, vol. V, No. 6, June 1980.

Roy et al. Cross-bred Bullocks vs. Indigenous Bullocks for Draught Purpose under West Bengal Conditions.

Singh, I. J. and Rao, A. R. (1978). Cattle and the Energy Needs of Indian Agriculture.

Smith, A. J. Is There a Future for Animal Production in the Developing Countries? Centre for Tropical Veterinary Medicine.

Smith, A. J. Role of Draught Animals in Agricultural System in Developing Countries. University of Edinburgh, Centre for Tropical Veterinary Medicine.

Starkey, P. H. (1979). Work Oxen in Sierra Leone.

Subrahmanyam, K. V. and Ryan, James G. (1975). Livestock as a Source of Power in Indian Agriculture: A Brief Review. Occasional Paper No. 12. International Crop Research Institute for the Semi-Arid Tropics, Hyderabad, India.

Technical Report No. 16: Mechanisation and Draught Power. Land and Water Resources Sector Study.

Technical Report No. 12: Livestock. International Bank for Reconstruction and Development. International Development Association.

Turk, K. L. (1975). Other Roles of Animals: Significance of Animals in Farming Systems and in the Provision of Farm Power and Pleasure. Cornell University.

Use of Draught Oxen in Forestry in Malawi.

Vaidyanathan, A. (1978). Aspects of India's Bovine Economy: Some Preliminary Results. Centre for Development Studies, Trivandrum, India.

Ward, Gerald M. et al. Animals as an Energy Source in Third World Agriculture.

Winrock International Livestock Research and Training Center Report (1977). Ruminant Products: More than Meat and Milk.

Winrock International Livestock Research and Training Center (1978). The Role of Ruminants in Support of Man.

Winrock International Livestock Research and Training Center (1979). Animal Traction Power in Developing Countries. A State of the Arts Study.

Mechanization

Bansal, R. K., Lal, Harbans and Nayande, V. M. (1980). Mechanising Farming in the Semi-arid Tropics of India, ICRISAT, Hyderabad, India.

Binswanger, H. P., Ghodake, R. D. and Thierstein, G. E. (1979). Observations on the Economics of Tractors, Bullocks and Wheeled Tool Carriers in the Semi-arid Tropics of India. ICRISAT, Hyderabad, India.

Binswanger, Hand P. (1978). The Economics of Tractors in South Asia. Agricultural Development Council, New York and ICRISAT, Hyderabad, India.

Chancellor, William J. (1978). The Role of Fuel and Electrical Energy in Increasing Production from Traditionally Based Agriculture. Transactions of the ASAE. Vol. 21, No. 6, pp. 1060-1067. American Society of Agricultural Engineers.

Clarke, Norman A. (1979). The Contribution of Draught Animals to the Livestock Sector in Sind. FAO/UNDP project PAK/74/018.

Dagg, Heuston. Agricultural Mechanisation Policy in the United Republic of Tanzania. Paper presented in March 1980 at the Annual Conference of the Tanzanian Society of Agricultural Engineers.

Food and Agriculture Organization of the United Nations (1972). The Employment of Draught Animals in Agriculture. FAO, Rome.

Food and Agriculture Organization of the United Nations (1979). Agricultural Mechanisation in Relation to Production, Employment and Income Distribution in Developing Countries. FAO, Rome.

Food and Agriculture Organization of the United Nations. Animal Power and Harness.

Farrington and Abeysekera, W. A. T. (1979). Issues in Farm Power and Water Use in Sri Lanka. Agrarian Research and Training Institute, Colombo.

Garner, Jean K. (1957). Increasing the Work Efficiency of the Water Buffalo in Drawing the Plough and Other Drawn Implements through the use of Improved Harness. USOM/Thailand.

Gibbon, David, Heslop, Colin and Harvey, James. (May 1978). The Hashasha and Atulba Toalbar. Development Studies Discussion Paper. University of East Anglia.

Gibbon, David et al. A Minimum Tillage System for Botswana. University of East Anglia.

Giles, G. W. (1975). The Reorientation of Agricultural Mechanisation for the Developing Countries, Part I: Policies and Attitudes for Action Programmes. FAO, Rome.

Government of India: Ministry of Shipping and Transport (1980). Socio-Economic Study of Animal-Drawn Transport in the Rural Areas of the Country: Summary of Findings.

Hopfen, H. J. (1976). Farm Implements for Arid and Tropical Regions. FAO, Rome.

Hopfen, H. J. and Biesalski, E. (1978). Small Farm Implements. FAO, Rome.

Howard, C. R. The Draught Ox: Management and Uses. Zimbabwe. Rhodesia Agric. J., vol. 77 (1).

Hussian, A. A. Mainmul et al. Design and Development of Neck Harness for Cattle in Bangladesh.

Johnston, Bruce F. (1979). The Choice of Technology in Strategies for Agricultural Development: Mechanical Innovations in East Africa. Working Paper, International Institute for Applied Systems Analysis, Austria.

Johnston, Robert K. The Policies of Mechanisation in Sudanese Agriculture. University of Toronto.

Kinsey, B. H. (1980). Interpreting Technological Options for the Benefit of Policy-Makers: Evaluating the Policy Dimensions of Selected Agricultural Technology. University of East Anglia, Norwich.

McDowell, R. E. and Hildebrand, P. E. (1980). Integrated Crop and Animal Production: Making the Most of Resources Available to Small Farms in Developing Countries. Working Paper. The Rockefeller Foundation.

Mathews, M. D. P. and Pullen, D. W. M. Cultivation Trials with Ox-Drawn Equipment in the Gambia.

Mettrick, H., Roy, S. and Thornton, D. S. (1976). Agricultural Mechanisation in Southern Asia. University of Reading.

Nolle, Jean. Thoughts of a Designer of Animal-Drawn Equipment.

Parker et al. Comparative Economic Analysis of Farm Data on the use of Carabo and Tractors in Lowland Rice Farming.

Raj, K. N. (1973). Mechanisation of Agriculture in India and Sri Lanka. ILO.

Ramaswamy, N. S. (1979). Management of Animal Energy Resources and the Management of the Bullock Cart System. IIM-B, India.

Ramaswamy, N. S. (1979). Management of Animal Energy Resources: A National Need. Science and Society, vol. II.

Singh, Gajendra and Chancellor, William J. (1975). Energy Inputs and Agricultural Production under Various Regimes of Mechanisation in Northern India. Transactions of the ASAE, vol. 18, No. 2, pp. 252-259. American Society of Agricultural Engineers.

Singh, Gajendra and Chancellor, William J. (1976). Changes in Energy Use Patterns from 1971 to 1974 on the Selected Farms in a Farming District in Northern India. Agricultural Mechanisation in Asia.

Singh, Gajendra and Chancellor, William J. (1973). Studies on Relations Between Farm Mechanisation and Crop Yield. ASAE.

Smith, A. J. The Role of Draught Animals in Agricultural Systems in Developing Countries. University of Edinburgh, Centre for Tropical Veterinary Medicine.

Starkey, P. H. (1979). Work Oxen in Sierra Leone. Njala University Collete, Sierra Leone.

Thierstein, G. E. Possibilities for Mechanising Rainfed Agriculture in the Semi-Arid Tropics.

TNAU - Catalogue of Improved Agricultural Implements and Farm Machinery. Coimbatore.

Vietmeyer, Noel D. (1977). Why Not a Tractor that Provides Meat, Cheese - and Love? Science.

Ward, Gerald M., Sutherland, Thomas M. and Sutherland, Jean M. (1980). Animals as an Energy Source in Third World Agriculture. Science, vol. 208, pp. 570-574.

Winrock International Livestock Research and Training Centre (1979). Animal Traction Power in Developing Countries: A State of the Arts Study. Arkansas.
