Chapter 16

Draught Animal Power in Mountain Highland Agriculture: Issues and Options

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Introduction

Draught animal power (DAP) is an important input in mountain highland agriculture, and in some places it has no viable alternative. The attributes of draught animals – energy for agricultural operations, physical products, income/employment gains, and sociocultural and ecological services – are vital for the sustainable development of mountain highland agriculture. The various agricultural transformation processes taking place in the Hindu Kush-Himalayan (HKH) region demand more use of DAP. This demand is likely to increase many times relative to the current supply. Thus the supply of DAP should be managed in parallel with the development of cash cropping in hill and mountain areas. Institutional policies and programmes dealing with animal husbandry, particularly animal breeding, are not conducive to the DAP system. They need to be reviewed and reformed from a regional perspective taking into account the present status and future prospects of mountain agriculture. This paper discusses several important issues currently faced by DAP and highlights some options crucial for its improvement.

DAP and Mountain Farming Systems

Draught animal power (DAP) is an outstanding example of the application of appropriate technology by marginal and small farmers, particularly in the developing world. In the diverse ecosystems of the mountains of the HKH region, DAP is the only feasible source of energy for agricultural work. Large-scale substitution by fossil fuel-operated energy systems is not only difficult but also inappropriate. There is unlikely to be any acceptable alternative to DAP within the foreseeable future.

In subsistence farming regions, productivity and yields will only be improved if mixed farming involving DAP is developed (Bodet 1987). However, despite its potential contribution to agriculture, DAP has not been addressed adequately in the context of mountain farming systems. Several studies have been made that describe the close link between DAP and productivity and sustainability (Singh 1985, 1998; Singh and Naik 1987; Singh et al. 1995; Singh and Partap 1999; Partap and Singh 1999). The average yield and intensity of cropping have been found to be influenced more by availability of power per unit area than by irrigation, fertiliser consumption, or the use of high-yielding varieties (Srivastva and Yadav 1987).

Mountain agriculture is in a transitional phase and is currently witnessing transformation in selected pockets. However, most agriculture in the HKH region is still traditional. Whether traditional or transformed, the predominant feature of mountain agriculture is that the cropped area uses draught animal power and human muscle power (i.e., animate energy) for virtually all agricultural operations. This renewable energy is, as it should be, part of the strategy for sustainable agriculture. Machines using fossil fuel power cannot be used to any appreciable extent, thus animals and humans remain the most suitable source of agricultural power. The debate on the sustainability of mountain agriculture generally overlooks this vital factor. In the predominantly agrarian society of the HKH region, animals are omnipresent. In fact, they are an integral, inseparable, and indispensable part of mountain and highland farming systems.

The current livestock development policies of the Hindu Kush and Himalayan countries focus on conventional animal husbandry involving cross breeding, health care, and fodder cultivation for specialised milch cattle, coupled with market-oriented production. The cattle population in many highland areas is stagnating or declining (Singh 1999, Tulachan 1998) and this, together with continued institutional neglect of the DAP system, could result in a decline in the supply of DAP.

Improving the sustainable use of DAP is vital for the development of regenerative agriculture in the mountains. Potential options, technological advances, and the institutional support necessary for augmenting and promoting the DAP system need to be given their due priority in the sustainable development of mountain agriculture. DAP should receive the support it deserves.

No Alternative to DAP

In order to meet the increased demand resulting from population growth and rising standards of living and overcome the present state of under-nutrition, malnutrition, and poverty, agricultural production in the mountains needs to increase substantially, and the increase should be sustainable. Among other things, this will require adequate and sustainable power resources. Draught animals are the most economical and readily available source of energy in rural mountain areas. Thus DAP, complemented with manual work, should be part of an ecologically sound, environmentally friendly, and mountain-specific approach to increasing agricultural productivity in the region.

There is a direct relationship between the level of energy use, human, animal, or fossil, and the level of production per unit of land. In fossil energy driven systems, the relatively high use of energy explains the relatively high productivity. But the source of energy is not important for the level of production. There are organic integrated systems in which virtually no fossil energy is used that are at least as productive as modern systems in terms of overall production, but have less negative impact on the environment and are possibly socially more acceptable (Durno et al. 1992). Studies in the Philippines showed that the same yield of rice could be obtained on mechanical, transitional, and traditional farms (Kuether and Duff 1981). Thus using comparative energy balances as a basis for formulating policies can be misleading unless the data are combined with information on such factors as production, availability, and cost, and the impact on the environment, gender, and the community as a whole (Reijntjes 1992).

Transformation of agriculture and cropping practices often goes hand in hand with mechanisation. But mountains are the exception. Almost complete transformation has been seen in some favourable pockets of the mountains, without any appreciable degree of mechanisation. A very limited use of fossil fuel energy is visible in some transitional areas like the wide valley areas of the foothill ranges in the Indian central Himalayas, where a handful of farmers occasionally use hired tractors for land preparation because the land is flat, easily accessible, and well-linked to the plains, but this is atypical of the mountains proper.

DAP and farm mechanisation

There are many reasons why DAP is preferable to fossil fuel power in mountain agriculture (Gill 1981, Bhalla and Chadha 1982, Nair 1982, Ramaswamy 1983, Bodet 1987, Singh and Naik 1987, Reijntjes 1992, Singh and Partap 1999).

- The source of energy already exists in the region. DAP does not have to be manufactured or bought at a high cost.

- The use of animals considerably increases a farmer's 'work force'. It enables the farmer to diversify agriculture, to increase the cultivated area, and to carry out agricultural work in time.
- Machine-based energy systems cause the production activity to concentrate on a limited number of crops, thus reducing the diversity of the production system.
- Animal-drawn implements are cheaper than mechanised equipment. Animal-drawn implements can be made locally and are more suitable for the small, often fragmented and scattered farms found in the highland areas.
- Draught power does not need expensive and non-renewable fuels. Draught animals can be fed residues and by-products available on a farm, producing in return not only energy but also food (milk from female cattle), methane (biogas), and manure, as well as many other products obtainable after death.
- The use of draught animals enables farmers to integrate livestock and crop production and permits the exploitation of the potential of cattle on settled, subsistence farms.
- Mechanisation causes direct labour displacement in land preparation. If it does not also contribute directly to increasing cropping intensities and yields, or to facilitating a switch to more labour-intensive crops, there will be a net loss of employment opportunity in areas where alternative sources of income are scarce.
- The fossil energy used in machines is a finite resource and its use has a considerable negative impact on the environment.
- Most farmers in the HKH region cannot afford technologies based on fossil fuels.

These points all highlight the advantages of DAP over mechanisation in mountain areas, where the characteristics of the resource base are altogether different from those in the plains.

The Primary and Secondary Roles of Draught Animals

In addition to providing draught power for agriculture as their primary role, draught animals play many other roles in mountain farming systems that may be referred to as their secondary roles. Primary roles include ploughing or tillage, levelling, puddling, earthing-up, weeding, and threshing. The secondary functions range from direct, visible contributions, such as supplying dung and milk, to less visible gains such as contributions to employment, income generation, farmers' security and companionship, sustaining livelihoods, and sustainability of the farming systems. The secondary roles of draught animals are inseparable from those of most other classes of livestock (Table 16.1).

Draught power is one of the basic requirements for cropping in an agricultural system. Notwithstanding the availability of good seed, fertile soils, irrigation facilities,

Table 16.1: Contributions of draught animals and other livestock species to mountain agriculture						
Contributions	Draught Cattle		Buffaloes	Goats	Sheep	Pack Animals
	Male	Female				
Agricultural Operations						
Ploughing	X					
Levelling	X					
Puddling	X					
Weeding, earthing-up	X					
Threshing	X	X				
Loading, pack-carrying	X[a]					X
Physical Products						
Dung, manure	X	X	X	X	X	X
Milk		X	X			
Meat				X	X	
Wool					X	
Income/Employment Gains						
Direct productivity improvement	X					
Smaller gains through sales	X			X	X	
Larger gains through sales	X	X	X			X
Off-farm activities	X					X
Income through hiring out	X					
Social, Cultural, Ecological Gains						
Cropping diversification	X					
In situ manuring of fields	X	X		X	X	
Renewable energy supply	X					
Religious, ethical values	X	X				
Festivities, fairs, rituals	X	X				
Social status, prestige	X	X				
Encouragement of social cohesion	X	X				
Enhancement of sustainability of the farming system	X					

[a] Used only by transhumant societies

and a favourable climate, crops cannot be sown and harvested without draught power. Untimely or inadequate supplies of draught energy lead to a decrease in crop production.

In the mountains, as in many parts of the world, the productivity of the farming systems depends largely on animals' ability to convert fodder into manure. In mountain areas, especially at high altitudes, crop residues decompose very slowly. The ruminant digestive system helps speed up nutrient recycling in cropland. Ruminants also help transfer the soil nutrients from forest vegetation to croplands, improving the fertility of the agro-ecosystems.

The dung produced in stalls must be transferred to cultivated land, which requires considerable time and effort and also results in a loss in quality. Manuring in situ, by tethering the animals directly in the fields, is an important strategy developed by mountain farmers over the ages in which draught animals play a crucial role.

Draught animals provide employment for a great number of people, for whom they are a crucial source of family income. In the fast changing scenario of the present day, the DAP system is emerging as a big income-generating enterprise for a large number of marginal and small landholders, landless families, and some middlemen.

In times of emergency, draught animals can be sold for cash. They are often sold to meet substantial expenses such as weddings, building houses, and higher education of children. They are an asset and give farmers status, companionship, prestige, and security. They also occupy a prominent position in the sociocultural setting in many highland areas and thus cement the social cohesion of mountain people (Table 16.1).

DAP and the Agricultural Transformation Process

Traditional subsistence agriculture is still the most common practice across vast areas of the HKH region. The majority of the mountain population overwhelmingly subsists on and engages in traditional agriculture. This is the result of the high degree of inaccessibility and isolation: the greater the inaccessibility the greater the chances of traditional management. In isolated areas, farmers tend to be self-sufficient, but wherever the possibility exists, farmers try to extract benefits by adopting cash cropping. Natural diversity has been and is being utilised by traditional farmers both for sustenance and for developing diverse food production and livelihood systems.

Commercialisation of mountain agriculture

Commercialisation of mountain agriculture represents the efforts of mountain farmers to use their scarce land resources more efficiently to generate income. In terms of growing crops this means growing cash crops; diversifying; using inputs from science and technology; and building sound upland-lowland linkages (Partap 1995).

Mountain environments provide niche areas that are especially suitable for particular activities and products. Such niche areas can provide a comparative advantage for the mountains over the plains for activities related to such things as horticulture[1], floriculture, spice cultivation, and growing or collection of medicinal and aromatic

[1]In South Asia used broadly to mean cash crop farming, such as fruit farming, vegetable farming, floriculture, and mushroom production.

plants. In general it is horticulture, in particular fruit farming, that receives the most focus during the process of transformation. In the lower fertile valleys, with irrigation facilities and linked with markets, transformation is based on growing vegetables. In some high altitude areas, particularly between 1,800 and 2,500m, orchards are at the core of the process. In certain areas, especially in the central and western parts of the Indian Himalayas, apple farming has brought about a significant change in mountain agriculture. These areas are moist and thus provide a niche for off-season vegetable farming as well. Generally, apple cultivation and off-season vegetable cultivation are found together. In some lower areas transformation is based on the introduction of high-yielding varieties of cereals.

Impact on DAP

One thing is common to the transformed systems mentioned above: they are all energy intensive. In addition to requiring small to large amounts of external inputs, the systems require a large amount of animate energy (see below). As mentioned above, machines powered by fossil fuel are both rare and inappropriate in most mountain areas, in contrast to the plains. DAP and human energy are thus the only sources of energy available for managing the process of transformation.

Families with marginal landholdings in the central Himalayas often don't own draught animals; they generally depend on hired (or shared) bullocks for land preparation as do families with insufficient labour – as a consequence of male migration or otherwise. Small landholders generally keep bullocks throughout the year, or sometimes only during the ploughing season. Medium and large landholders usually keep a pair of bullocks throughout the year if they have sufficient labour, or hire them if labour is insufficient. Purchase, sale, and exchange of draught animals is very liberal among all the groups. Exchange of labour and sharing of bullocks and/ or ploughs within a community is more common in transformed areas than the traditional or high hill areas.

In recent years, DAP has emerged as a good source of profit and employment for some families in transformed areas, especially those with small and marginal landholdings. In addition to preparing their own land, these families hire out their bullocks with or without a ploughman at prescribed rates. This practice, further strengthened by the transformation process, has emerged as an income-generating enterprise for a number of households.

Transformation and livestock fodder

Transformation in mountain agriculture is likely to severely affect the supply of livestock fodder from cultivated land. At present, in the central Himalayas an estimated 35% of livestock fodder comes from cultivated land. With the continuous pressure on common property resources (CPRs), the dependence on cultivated land for fodder is likely to increase. But the changing trends in cropping patterns and the move towards high-value commercial crops means that supplies of fodder are likely to decrease. The major type of transformed agriculture is horticulture, and in areas where horticulture dominates the land has almost ceased to provide fodder for livestock. Similarly, the trend in cereal cropping is away from millet towards wheat and rice, and from all of these to crops like white seeded soybeans. But millet crops provide more dry fodder than wheat and rice because they have a higher straw to grain ratio, while soybeans provide no fodder at all.

Adoption of high-yielding varieties (HYVs) and use of external agro-inputs have helped to increase the productivity of major crops. However, dwarf HYVs have low straw to grain ratios and thus produce less fodder, and animals also don't like the fodder from HYVs as much as that from the long-stalked native varieties. Mountain farmers therefore value the high fodder yielding native varieties of crops. The poor straw yield inherently associated with the dwarf high-yielding varieties is one of the factors that has worked against large-scale adoption of new varieties of food crops.

Use of DAP in Different Farming Systems

There are many variables in mountain agriculture that determine the use of DAP. An intensive study was made of the use of DAP in different farming systems found in the central Himalayas in India (Singh 1998). The farming systems were divided into four categories, that found in the low hills (the Siwaliks), that in the mid hills in areas farmed according to traditional practices, that found in areas of the mid hills where transformation had taken place, and that in the high hills or mountains. The distribution and density of draught animals found in different areas and on different sizes of farm are shown in Table 16.2. The number of cattle per household was greatest in the mid hills zone in areas still using the traditional system of agriculture, and lowest in the high hills. The distribution and density of draught animals suggest that most of the draught animal population is concentrated in the villages using a traditional system of agriculture.

Only traditional villages had two or more draught animals per household; less than two bullocks per household indicates some degree of hiring and/or sharing. The average number of draught animals per household and per ha cropland is determined to some extent by the degree of inaccessibility or isolation, in terms of both distance from the main road in the region and from the plains and traditional influence. Where there is out-migration or working away of adult males, farms have fewer bullocks and there are fewer per ha cropland.

Table 16.2: **Distribution and density of draught animals in the villages sampled in different farming systems**

Type of Farm	Marginal	Small	Medium	Large	Overall
Low hills					
Population, no. per village	77	84	23	16	200
(%)	(39)	(42)	(12)	(8)	(100)
No. per household	0.7	0.8	1.6	0.5	0.7
Density, no. per ha cropland	2.0	1.4	1.1	0.2	0.9
Mid Hills: Traditional					
Population, no. per village	39	108	92	13	252
(%)	(16)	(43)	(37)	(5)	(100)
No. per household	1.5	2.2	3.0	2.2	2.2
Density, no. per ha cropland	4.0	2.6	1.8	0.8	2.1
Mid Hills: Transformed					
Population, no. per village	11	25	25	16	77
(%)	(14)	(33)	(33)	(21)	(100)
No. per household	0.4	1.1	1.4	1.8	1.0
Density, no. per ha cropland	1.8	1.5	1.0	0.9	1.1
High Hills					
Population, no. per village	5	7	39	7	58
(%)	(9)	(12)	(67)	(12)	(100)
No. per household	0.1	1.4	1.9	2.3	0.5
Density, no. per ha cropland	0.5	2.8	1.7	1.0	1.3

Source: adapted from Singh (1998)

Note: marginal <0.5 ha; small 0.5-1.0 ha; medium 1.0-2.5 ha; large >2.5ha

The extent to which animals were shared or hired is shown in Table 16.3. Some hiring in and out took place in all zones except the high hill zone. Except in the traditional mid hill villages, large landholders did not hire out bullocks. When not all households can afford to own a pair of bullocks, sharing is clearly a positive indicator for DAP use since it tends to keep the population of draught animals in balance, promotes efficient and economic use of the existing population, and also stimulates social cohesion. Hiring in of DAP saves expenditure on bullock rearing throughout the year, whereas hiring out creates opportunities for employment and income generation for small and marginalised farmers.

Tractive performance and use of power

Most draught power is used for ploughing operations. The tractive effort of bullocks ranges from 9% of body weight during weeding and earthing up operations, through 16% during ploughing at 2.4 km per hour, to 19% during puddling operations at 1.6 km per hour (Table 16.4). These high values indicate the special ability of the lightweight and hardy native draught animals to generate a high percentage of body weight as tractive effort. On average a pair of bullocks tills and levels 1,100 sq.m of land per day during seven hours of continuous work. The average draught power output per animal (average weight 250 kg) during ploughing is 0.26 kWh (0.35 hp).

Table 16.3: Percentage of different landholding groups in the villages sampled in different farming systems participating in sharing and hiring of DAP					
Type of Farm	Marginal	Small	Medium	Large	Overall
Low hills					
Sharing	32	27	7	6	25
Hiring in	34	36	14	70	38
Hiring out, all households	12	12	7	0	10
(households owning bullocks)	(37)	(31)	(9)	(0)	(28)
Mid hills: Traditional					
Sharing	23	0	7	0	7
Hiring in	0	2	23	17	8
Hiring out, all households	35	24	19	17	25
(households owning bullocks)	(47)	(24)	(19)	(17)	(25)
Mid hills: Transformed					
Sharing	24	9	0	0	11
Hiring in	52	39	39	11	40
Hiring out, all households	20	26	11	0	17
(households owning bullocks)	(100)	(50)	(17)	(0)	(34)
High hills					
Sharing	11	20	10	0	9
Hiring in	51	0	0	0	30
Hiring out, all households	0	0	0	0	0
(households owning bullocks)					

Source: adapted from Singh 1998

Note: marginal <0.5 ha; small 0.5-1.0 ha; medium 1.0-2.5 ha; large >2.5ha

Table 16.4: Power output of draught animals during different agricultural operations (total effort of pair of bullocks)			
	Average speed km per hour	Tractive effort kg[1]	Power kW[2]
Ploughing	2.4	78	0.52
Levelling	2.7	48	0.36
Puddling[3]	1.6	95	0.42
Weeding and earthing up[3]	2.6	47	0.34

Source: Singh 1998

Figures are based on eight hours' operation (seven hours ploughing and one hour levelling) by a pair of bullocks. Each bullock weighed 250 kg

[1] actually kilogram force or kgf, equivalent to 9.806 Newtons

[2] 1kW = 1.34 hp

[3] Estimates based on Singh and Naik 1987

In practice one pair of bullocks is sufficient to complete all the operations over an area of 1.5 ha. At the rates described above, ploughing and levelling of this area would take a pair of bullocks working every day for eight hours approximately two weeks. The area of cropland in the villages studied and the number of pairs of bullocks available to work it are shown in Table 16.5. In the high mountains and the traditionally farmed area in the mid hills the number of bullock pairs available was sufficient or considerably more than sufficient to work the area of cropland. In the transformed area of the mid hills the number of bullock pairs was somewhat less than needed to easily work the area, and in the low hills there were far less

Table 16.5: Cropland area and DAP available in the sampled villages in four zones of the central Indian Himalayas	Low hills	Mid hills – traditional	Mid hills – transformed	High hills
Total cropland area, ha	228	118	68	43
No. of available bullock pairs,	100	126	38	29
Average area operated per bullock pair, ha	28	0.9	1.7	1.5
Balance in area operated per bullock pair, ha[1]	(+) 0.8	(-) 0.6	(+) 0.2	0

Source: Singh 1998

[1]Based on 1.5 ha as a standard area to be operated by a pair of bullocks

pairs than needed if all the work was to be performed by DAP instead of with tractors.

All agricultural operations carried out by draught animals, i.e., ploughing, levelling, puddling, weeding, and threshing, also require a certain amount of human energy. There are many other operations that require human energy alone – hand-weeding, irrigation, transport and application of manure, breaking of clods, sowing and transplantation, application of fertiliser and pesticides, harvesting, and hand-threshing. The average working hours and energy invested by people and animals per hectare for the cultivation of crops in the four different zones is shown in Figures 16.1 and 16.2. Agricultural transformation is an energy-intensive process. The working hours per hectare and the energy per hectare from humans, bullocks, and overall were highest in the mid hill areas where agricultural diversification had taken place, followed closely by the low hills. More energy per hectare was required for

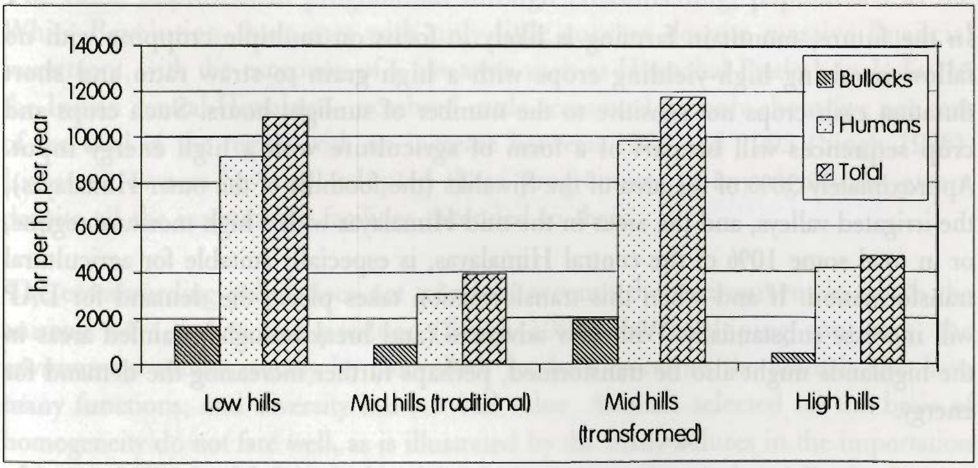

Figure 16.1: Average working hours invested per ha per year in different farming systems by humans and bullocks

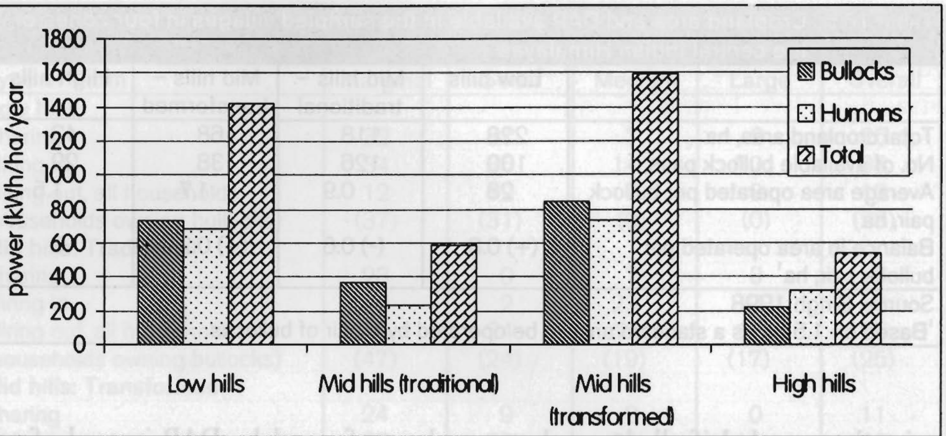

Figure 17.2: **Average energy invested per ha per year in different farming systems by humans and bullocks**

traditional mid hills agriculture than in the high hills, but the actual working hours for people were less as a greater proportion of the energy was supplied by DAP. The average number of days worked by bullocks varied enormously, from only 59 days a year in the high hills to as many as 236 days a year in the transformed mid hill area. In high hill agriculture only 41% of the total animate energy used in crop cultivation was supplied by DAP, in the low hills about 52%, in transformed mid hill agriculture about 54%, and in traditional mid hill agriculture as much as 62%. The transformed agricultural system made the most efficient use of the available DAP and human resources, and this was reflected in a higher degree of crop diversification and higher crop yields in the area.

Cash Cropping and the Prospects for DAP

In the future, mountain farming is likely to focus on multiple cropping with no fallow involving high-yielding crops with a high grain to straw ratio and short duration cash crops not sensitive to the number of sunlight hours. Such crops and crop sequences will be part of a form of agriculture with a high energy input. Approximately 30% of the area of the Siwaliks (the foothills of the outer Himalayas), the irrigated valleys, and the areas in the mid Himalayas with a high moisture regime, or in total some 10% of the central Himalayas, is especially suitable for agricultural transformation. If and when this transformation takes place, the demand for DAP will increase substantially. With new advances (and breakthroughs), rainfed areas in the highlands might also be transformed, perhaps further increasing the demand for energy.

Commercialisation of agriculture in the mountains basically relies on cropping systems based on horticulture. Singh (1998) found that vegetable cultivation required the maximum input per hectare of both DAP and human energy. Although fruit farming itself requires no DAP input (e.g., apple orchards), the area under fruit trees is extensively used for vegetable cultivation. As a result the orchard-vegetable cropping system actually demands more DAP than a cereal-based system.

Horticulture is emerging as a dominant activity with fairly extensive development potential in mountain areas (Banskota and Jodha 1992; Partap 1995) so that the prospects for DAP appear to be bright. However, in transformed areas buffaloes are preferred to cattle (Singh 1998) so that the DAP supply in such areas is likely to depend increasingly on a hiring system. Inter-village hiring might dominate, with animals coming from villages adhering to more traditional farming practices, because the transformed village communities would have less time for cattle rearing. In the more distant future, villages engaged in cash crop farming might also come to depend on hired human labour.

Commercialisation based on increased cultivation of nuts, timber species, or medicinal and aromatic plants would lead to a reduced demand for DAP.

Conventional Animal Husbandry and DAP

Crossbreeding of indigenous cattle with European bulls has, for decades, been the standard institutional approach for improving the production and productivity of cattle in the Indian Himalayas, as in the rest of the HKH region and all developing countries.

The cattle improvement programmes through crossbreeding, popularised as the White Revolution, have met with only little success despite massive financial investment, with the exception of a few areas such as Himachal Pradesh in India. In the Indian central Himalayas, crossbred cattle accounted for only about five per cent of the total in the region with no increase between 1988 and 1993 (Singh 1998). Livestock owners have not adopted these programmes to any significant extent despite all the institutional facilities extended to them.

The crossbreeding policy does not take into account the environment in which the animals have to live and produce (Singh 1994). In developing countries, the environment cannot usually be controlled. In these countries the animals also have many functions, and diversity has survival value. Animals selected on the basis of homogeneity do not fare well, as is illustrated by the many failures in the importation of 'upgraded animals' from industrialised countries to less industrialised countries (Orskov 1995).

Female crosses of European (*Bos taurus*) and zebu (*Bos indicus*) breeds of cattle have been accepted by farmers in warm climates, however, thanks to the increased lactation length, higher milk production, and earlier age of calving of the crossbred animals. Crossbred females have also been fairly well received in the Himalayan Terai owing to their production traits. But the White Revolution technology has only been really successful in areas where a large amount of fertile land could be devoted to the production of animal feed, where good veterinary services could be provided, and where there was a mechanical alternative to DAP. Where these conditions are generally lacking, it is still possible that such animals could be accepted by individual families. But in mountain areas with a community-based setting, programmes are only likely to be successful if they are acceptable at the community level, not only by individual families.

The animals bred by mountain farmers are multipurpose. They provide both manure and power for agriculture and milk for the household. Improving one trait, like milk production, at the expense of another, like draught power, would upset the balance needed for integrated production.

There has been little acceptance of crossbred males for draught purposes in the plains because of the general opinion that their working performance is inferior to that of the indigenous cattle, since they do not have a large distinctive hump and are unable to tolerate high temperatures (Goe 1983; Singh and Naik 1987). Farmers all over India consider crossbred bullocks to be inferior to local bullocks in stamina, strength, and vigour (Mali et al. 1983). Research scientists have also concluded that, whereas crossbred females can be good milk producers if fed adequately, the field performance of their male counterparts is very low and the animals are not suitable as work animals (Annaji Rao 1983). At the same time a crossbred bullock requires at least 50% more feed than a bullock of indigenous breed; so even if it had the same unit of work output its economic efficiency would be only two-thirds that of a local animal (Rajpurohit 1975).

Main Constraints to the Use of DAP

In order to improve the prospects for DAP it is first necessary to identify the major constraints, the reasons for the reduction in the draught power of animals, and inefficient and uneconomic patterns of use. Research and development to overcome these problems will help the development of DAP as one of the options for enhancing the productivity and sustainability of mountain farming systems. The major constraints identified so far are summarised in Table 16.6 and discussed further below.

Table 16.6: The major constraints to DAP in mountain agriculture	
Major constraints	Major effects and consequences
RESOURCE RELATED	
Topographic Variation Difficult, undulating terrain, reduced accessibility, altitudinal variation, weather extremes	Difficult to make full use of DAP, loss of time and energy of humans and animals, difficult to transport inputs and outputs, increased vulnerability.
Fragmented and Scattered Holdings Small terraced fields, long distances between parcels of land	Difficult to use DAP efficiently, enormous loss of human and animal energy and time, less than potential yields, difficult to transport inputs and outputs.
Problem Soils Low water holding capacity, high proportion of gravel, nutrient deficient, low pH, shallow depth, vulnerability to erosion	DAP supported cultivation abandoned in some places, reducing the use of DAP
Climatic Extremes Rain, snow, hail storms, strong winds, seasonal hazards	Breakdowns in the continuous use of, and loss of benefits from, DAP, decreased potential of draught animals, risks to animal health
Imbalanced Land Use Low ratio of CPR to cultivated land, changing cropping patterns, increased intensity of resource use	Reductions in grazing area and fodder supply leading to poor nutrition of draught animals, decreased draught capacity of animals, and higher cost of bullock maintenance.
Changing Floristic Composition Endangered climax species, emphasis on monocultures of non-fodder trees and annual crops	Decreased amount of fodder for draught animals, decreased draught capacity of animals, reduced use of animals
Changing Livestock Composition Lower proportion of draught animals in herd	Shortage of draught power for agriculture, overuse of existing animals leading to reduced draught capacity, excessive burden on human beings for agricultural operations
MANAGEMENT RELATED	
Lack of Improved Harnesses and Implements Often inefficient and primitive implements	Draught capability not fully harnessed, increased cases of injuries, loss of animal days, slow rate of work
Improper/Inadequate Health Care Neglect of ethno-veterinary services, inadequate health care infrastructure	Decrease in draught capacity of animals, slow growth rate, high infertility incidence in females, reduced lifespan and working life, high mortality rate, loss of animal days
Mishandling of Animals Yoking to defective implements, overwork, inhuman/merciless treatment	Continuous overstress on animals, reduced draught output, reduced working life
Conventional Animal Husbandry Policies and Programmes Changing husbandry priorities, crossbreeding, neglect of DAP	Reduced proportion of draught animals, increased number of often unusable crossbred bullocks, reduced supply of draught power to agriculture, increased burden on human resources to fill the power deficit
Source: Singh 1998	

Resource-related constraints

Topographic variation creates some difficulties in the full use of DAP. Undulating terrain, variation in altitude, and steepness of slopes reduce the accessibility to many areas and severely affect resource management, including management of DAP.

The fragmented and scattered landholdings are the result of the overall terrain conditions, the need for farmers to maximise the diversity of their holdings to ensure food security, and the law of inheritance which encourages the division of already small plots among all heirs and has led to fragmentation of property over many generations. The distance between and small size of plots leads to enormous losses in terms of human labour and DAP and much waste of time in going from one tiny field to another.

In the mountains, common property resource (CPR) areas are being converted to cropland. This reduction in grazing area and depletion of forage mean a loss of good nutrition for draught animals and thus a reduction in their draught capabilities. These also lead to manifold problems for agriculture (e.g., insufficient nutrient flow from forests and pastures to cropland) and in the social system (including paucity of fuel, fodder, forest-based foods, wood for agricultural tools and implements, and timber for house construction). It is difficult to maintain unproductive animals without the support of CPRs. Moreover, the high cost of increased stall feeding favours keeping buffaloes rather than cows, since milk prices are based on the amount of fat in the milk (Jodha 1992). Overall the proportion of draught animals kept in cattle herds is gradually being reduced in many parts of the Himalayas, and this imposes another constraint on the DAP system.

Management-related constraints

The agricultural implements being used for draught are still inefficient and often primitive as is the harness system. Some institutes and research organisations have produced improved designs, but they are generally not suitable for increasing the capabilities of draught animals – they cost too much and the extension facilities are inadequate. The harnesses and implements used today are almost the same as those seen in ancient works of art. "India has put satellites in space and harnessed the atom," says Ramaswamy, a leading DAP expert, "but our carts are 5,000 years old, because professors are scared they may not get promotion if they work on designing better carts." An estimated million or more animal hours of work are lost annually in India as a result of the traditional defective yoke that inflicts injuries on the necks of animals.

Health services for draught animals are far from adequate. There is little emphasis on a humane approach, draught animals tend to receive less care and are ill treated and overworked. This further reduces their efficiency.

Finally, as discussed above, conventional livestock husbandry policies and programmes have had several long-term negative effects on the DAP system, mainly as the result of creating an environment for developing specialised milch breeds at the cost of the multipurpose (strictly speaking, dual purpose) draught breeds that are suitable for mountain agro-ecosystems.

Improving the DAP System

In order to use DAP to enhance agricultural production and sustainability, it has to be combined with other agricultural techniques, policies, and programmes. Some of the potential technological and institutional options are discussed below. Enhancement of DAP is an essential component in ensuring the sustainability of agricultural development in mountain areas.

Potential options

Some of the options available for improving the use of the existing potential of DAP resources, and thus contributing to increased agricultural productivity, are as follow.

- Increasing the number of days of bullock use per year and number of work hours per day through diversification in crop production, e.g., multiple cropping, mixed cropping, cash cropping, annual-perennial links
- Using more animal species as DAP resources; for example yaks, dry cows (as used extensively in Bangladesh), donkeys, mules, and horses. Yaks, for example, found in high Himalayan areas, are regular breeders, may live up to 40 years of age, and may give birth to 20 or even more offspring (Negi 1990).
- Involving work animals in more activities – for example, some transhumant societies also use bullocks as pack animals
- Increasing power output per animal – this can be achieved through improved (and matching) designs of yokes, harnesses, and animal-drawn implements; providing balanced nutrition and better health care to mothers, calves, and work animals; and proper training of animals
- Consolidation of scattered holdings – if possible this would contribute to more efficient DAP management and the avoidance of loss of time and energy
- Improving the condition of CPRs like common forests and grazing lands, through the type of techniques and strategies described in Jodha (1992, 1995) and Miller (1995). This would ensure regular supplies of fodder and other biomass to the farming system and would be a key element in improving the sustainability of the system overall.

Technological advances

Research and technology must look at DAP as an integral part of the whole farming system. In order to be upgraded, the DAP system needs practical technological innovations that can be used by farmers. Farmers' traditional technologies can be instrumental in guiding such innovations. Technological advances should not remain confined to laboratories, they must reach the farms and be within the financial means of farming communities. Furthermore, to be effective, technological advances in the DAP system must be combined with long-term strategies for sustainable mountain agriculture.

The best research and development efforts should be applied to the DAP system and related technologies in the search for ways in which farmers may make better use of a resource already at their command. Such techniques could lead to an enhancement of the status of DAP, so that its value as an effective contributor to food production and rural prosperity is more readily recognised and accepted (Kemp 1987).

Animal nutrition and optimum rates of work are two areas in need of further investigation. The criteria vary according to the geographical area in question. Research into animal nutrition must be based on a knowledge of the feed resources available in a particular mountain area. Rates of work depend largely on the interactions between the task, the implement, the harness, the animals, and the operator (Kemp 1987).

Nutrition of draught animals

The feeding practices commonly followed by farmers in the mountains are simple. They depend on naturally available feed resources and crop by-products and vary with the seasons. The performance of livestock in terms of growth, reproduction, and working capacity, is influenced by the availability of feed and the feeding schedule.

Ideally, animals should be fed a balanced diet that provides all the nutrients required. The actual quantity needed of the different ingredients depends on the body weight and working capacity of the animal. The energy and nutrients needed to maintain health and other physiological activities when the animal is in a resting state are called maintenance rations. The additional rations that provide the energy and nutrients necessary for work are called work production rations. Draught animals need to be fed sufficient to provide work energy, not just enough for survival.

Normally good quality green fodder (legume) is sufficient for maintenance. If the fodder quality is poor (non-legume), then it should be supplemented with adequate quantities of concentrate mixture. If the fodder is of very poor quality (such as dried grass and crop residues), it can be treated with urea to improve digestibility. For many years roughage has been treated with chemicals such as sodium hydroxide, calcium hydroxide, and others to improve the nutritive value. But urea (essentially ammonia) treatment has a stronger appeal than calcium or sodium hydroxide treatment since it increases the nitrogen content of straw as well as the palatability, digestibility, and energy values. Urea treated straw, fed to livestock, results in increased intake and better growth rates than untreated straw. The straw is treated by adding 40 to 50g of urea per kg of straw at a moisture level of around 60% and covering tightly for about four weeks before using as feed. The urea is hydrolysed by the enzyme urease, releasing ammonia. This method is safer, cheaper, and more convenient than other methods for storage and handling. It can be used conveniently on small farms. However, roughly two-thirds of the urea-ammonia is wasted (Kumar 1986).

Certain physical treatments can also be used to increase fodder value. Chopping of roughage increases voluntary intake, grinding increases intake and digestibility and reduces wastage. Pelleting reduces dustiness and volume, and thus also leads to increased feed intake. Soaking is one of the oldest and cheapest methods used. One to two hours' soaking removes dust from straw and stovers and makes them moist, which improves their palatability and increases feed consumption. Soaking also removes the oxalates present in rice straw, these bind calcium and if left reduce the calcium availability for the animals (A. Kumar, unpublished report).

Under normal conditions, a working bullock derives energy first from the carbohydrates in the feed, and then from stored fat. Only if there is an excess demand for energy, will it be met from protein containing tissues such as muscles. If the diet contains sufficient carbohydrates, then mature draught animals need no extra protein over and above that in the maintenance diet.

Feed should be given to work bullocks according to their nutrient requirements, and these depend upon their work potential and body weight. The heavier the work, the greater the requirements. Some green fodder should be given to meet the calcium and Vitamin A requirements. Cereals such as maize, wheat, and barley should be given to working animals as they are responsible for the production of propionic acid in the rumen, which is a good source of glucose and energy. Crop residues should be provided to draught animals as per availability. The quality of crop residues can be improved through proper chemical and physical treatment. Jaggery, molasses, and mustard oil, all of which are rich in energy, can also be fed to the animals.

Designing new harnesses and implements

It should be possible to develop improved designs for yokes, harnesses, and other implements by considering the engineering principles involved in transferring power from an animal to an implement. If draught animals could be equipped with more efficient and more comfortable harnesses, their pulling capacity could be tripled and their working lives increased by a factor of two or three (BRT 1990). Apart from providing increased pull, the newly designed yokes and harnesses should be helped to eliminate suffering.

As a result of various inherent local factors and environmental considerations, it is possible that the population of draught animals will go down. It would be useful to design a new harness system for a single animal, rather than a pair. A pair of animals is thought to be 14-20% less efficient than a single animal in terms of power conversion efficiency (Kumar 1991). Such a harness would help maintain the actual amount of draught power available despite a decrease in the animal population.

The draught of a plough (and any other agricultural implement) is dependent on weight, shape, and scouring properties; the size and number of furrows; presence of different attachments; soil characteristics; slope of the land; speed of travel; and skill of the operator (Goe 1983). Therefore efficient agricultural implements need to be developed for specific site characteristics.

Widespread use of any newly designed yokes, harnesses, and implements will largely rely upon the vocational training of local craftsmen. Care must be taken to ensure that the local craftsmen are suitably trained in the maintenance and repair of harnesses, yokes, and implements. The hand tools used in mountain agriculture should also be given new shapes and designs suitable to local site-specific conditions, and acceptable to local farmers.

Such technological improvements in tools, implements, yokes, and harnesses would increase the efficiency of the DAP system and help farmers increase their productivity by integrating DAP technology into their present system.

Institutional intervention

The conventional type of institutional intervention can have a negative impact and actually contribute to lack of sustainability in the animal husbandry sector through the effect on DAP (Singh 1998). An appropriate, long-term cattle breeding policy could be instrumental in increasing the use of DAP in mountain areas. The conventional policy needs to be reviewed thoroughly so that a more appropriate new breeding policy can be developed.

The lack of adequate policy measures for strengthening DAP as a part of the development of sustainable mountain agriculture is a basic problem that needs to be addressed. DAP should be treated as an important component in the integrated energy system and as an input qualifying for institutional and infrastructural support.

Adequate infrastructural facilities are needed, these include R&D and extension services for the design and introduction of more efficient, matching harnesses and animal-drawn implements and for the improvement of the DAP system. Such facilities would greatly encourage efforts towards the sustainable development of mountain agriculture. Statistics should be published from time to time on draught animals, their usage patterns, and other points of interest, to help researchers and scholars in this field.

In the mountains and highlands, there is a good chance of developing a policy framework with a long-term perspective for promoting and upgrading the DAP system and ultimately developing sustainable agriculture.

Conclusions

The contribution of DAP is vital for the sustainable development of mountain agriculture. The nature and intensity of the problems related to DAP are different for different mountain areas, and for different ecological zones or farming systems in the same area. In the HKH region, agriculture is in a phase of transition towards market-oriented cash crop farming. Commercialisation of agriculture is advocated by institutional policies and fuelled by the policies of economic liberalisation adopted by governments in the HKH countries. The aim is to increase farm employment and income and to take full advantage of ecological niches in the Himalayan mountains. Three principal types of transformation dominate, based either on fruit trees, vegetables, or high-yielding varieties (HYVs) of cereals.

Agricultural transformation processes are energy-intensive. In the transformed areas, the scenarios for DAP management are beginning to change as the cattle population, and the number of draught animals, is reduced, and plough (and DAP) sharing arrangements are dropped in favour of hiring. Although the transformed areas need more DAP, they produce less animal fodder than areas under traditional agricultural management. Commercialisation of agriculture actually supports intervention towards DAP development, but does not itself contribute to it. The way in which the transformation processes and the DAP system can complement each other should be investigated so that problems with DAP do not emerge as a binding constraint to crop production. Possible actions include providing credit to small and marginalised farmers so that they can raise draught animals in adjoining non-transformed areas and rent out DAP to farmers in transformed villages; and development of support areas like forests and pasture and proper management of agroforestry systems in areas with commercialised farming.

The optimum amount of DAP required for realising defined or maximum levels of production from individual crops, cropping systems, and farming systems needs to be established. This is necessary so that a quantitative analysis can be made of the linkages between DAP and agricultural productivity and sustainability in mountain areas. It is also needed to plan for sustainable use of DAP in agriculture. Planning nutrition will be pivotal in increasing the working capacity of animals. It will be necessary to develop animal feeding systems that involve management of CPRs and formulation of balanced rations for work animals and pregnant mothers and calves. In order to improve the efficiency of the mechanism for transforming DAP into useful work it will be necessary to design new, efficient, and site-specific equipment such as agricultural implements and harnesses. This is one of the keys to realising the full potential of the available draught animal resources.

An appropriate long-term cattle-breeding policy aimed at conserving the uniquely adapted draught qualities of the native breeds may well be valuable for the welfare of the animal sector in the long term. As yet no policies exist on the DAP system as such. A sound, ecozone specific DAP policy to support, promote, augment, and develop DAP systems should be an essential part of our approach to the sustainable development of agriculture in mountain regions.

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