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Draught Animal Power in Mountain Agriculture

A Study of Perspectives and Issues in the
Central Himalayas, India

Vir Singh

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Draught Animal Power in Mountain Agriculture

A Study of Perspectives and Issues in the Central Himalayas, India

Vir Singh

MFS Series No. 98/1

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Preface

This discussion paper in the Mountain Farming Systems' series of ICIMOD looks at an often ignored aspect of mountain farming systems — draught animal power.

The author has taken pains to examine and assess draught animal power in the light of the transitions taking place in mountain agriculture in three agro-ecological zones. He has also assessed the perspectives and attitudes towards this neglected factor.

The Paper was written as a the result of an ICIMOD Research Fellowship; a programme implemented by ICIMOD through which the Centre invites proposals for research from scholars throughout the region. On behalf of ICIMOD, Dr. Tej Partap carried out the technical editing of this document.

I am indebted to Dr. N.S. Jodha who has been a great source of inspiration for me in my work in the mountains. When I was working on this project, he provided me with volumes of very useful literature. Shri Sunderlal Bahuguna has always encouraged my efforts to work for the Himalayas.

My special thanks are due to my co-workers in the field investigations: Navin Nathani, Vijay Arora, Dr. G.C.S. Negi, Bala Singh Bhandari, Sachin Negi, and Anil and Mahesh Chandra Raturi. Dr. Jagdish Kumar, Senior Economist at Ranchi, helped me to select the study villages. Cattle breed characterisation was the joint effort of Dr. R.L. Sharma and Dr. C.B. Singh. Dr. M.L. Sharma, Dr. C. Das, and A.K. Singh provided me with information from secondary sources. Dr. Anil Kumar, Assistant Professor at the Animal Science Department, Ranchi, provided me with information on the draft animal power in the region.

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I feel pride in the help, trust, and cooperation I have received from the farmers of the region, especially those from the study villages who are a wonderfully rich repository of traditional knowledge.

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Vir Singh

Abstract

This discussion paper discusses several important issues relating to the role of draught animal power (DAP) in sustainable agricultural development in the Central Himalayas of India and gives recommendations for policy changes and technology development.

The nature and intensity of problems related to DAP are different for different ecological areas – Shivalik Hills, Middle Himalayas (traditional), Middle Himalayas (transformed), and Greater Himalayas, and the policy measures to overcome these specific problems also have to be different. Even within the transformed Middle Himalayas, three principal types of transformation have been included in the study: vegetable-based, modern cereal crop-based, and fruit tree-based. These areas vary greatly in terms of demand for and supply of DAP, accessibility, adoption of new technologies, and so on. These all have important implications for the potential for mechanization, animal breeding strategy, and feed and fodder supply.

Also discussed in the paper is the commercialisation of agriculture as an important strategy in the hills and mountains of the Hindu Kush-Himalayan Region promoted in recent years to achieve the multiple objectives of increasing farm employment and incomes and protecting the environment. Commercialisation of agriculture has increased the demand for DAP relative to its supply. The author asserts that this may lead to the adoption of mechanical technology in the hills and mountains with negative environmental impacts. These issues are discussed and analysed in the paper.

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One

Issues Related to Draught Animal Power (DAP) in Mountain Agriculture

Draught animal power (DAP) is the most appropriate and the most economical source of power in rural areas, particularly in Third World countries (Ramaswamy 1983, Singh and Naik 1985, Bodet 1987, and Kemp 1987). Renewable DAP is an outstanding example of application of appropriate technology by marginal and small farmers, and it has no equal. In the mountains where there are several different ecosystems, 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. Within the foreseeable future there is unlikely to be a feasible alternative to DAP, and therefore it becomes an important consideration in sustainable mountain agriculture.

In subsistence mountain farming regions, productivity can only be improved through mixed farming involving DAP (Bodet 1987). Despite its potential contribution to agriculture, DAP, at least in the context of mountain farming systems in the Indian Central Himalayas, is one of the least explored fields. Nevertheless, studies by Singh (1985), Singh and Naik (1987a), and Singh et al. (1995) provide us with interesting information on this very important aspect of mountain agriculture; examining as they do the close links between DAP and productivity/sustainability. Average yields and intensity of cropping are found to be influenced more by availability of power per unit area than by irrigation, fertilizer consumption, and use of high-yielding varieties (Srivastva and Yadav 1987). Further applied research and development need to be undertaken to make DAP systems more efficient in terms of both productivity and sustainability.

1.1 Mountain Agriculture

Mountain agriculture is distinguishable from the agriculture of the plains in that only a few, and sometimes none, of the characteristics of the former are shared by the latter. From all perspectives it appears to merit more research attention and careful development interventions than it has received. To date, mountain agriculture has been marginalised, giving the impression that its contribution to the overall economy is insignificant. In fact, positive attributes of diversity or heterogeneity, 'niche' or comparative advantages, and human adaptation mechanisms (Jodha 1990 and Jodha et al. 1992) are inextricably linked with mountain agriculture, and it has great potential for contribution to national and international economies. Mountain agriculture can provide products that mainstream agriculture cannot. Genetic variability among plants and domestic animals

and the whole spectrum of biodiversity, ranging from alpine pastures to sub-tropical forests to marginal foodgrain crops to domestic animals, is of great value for the future of farming worldwide. Partap (1996) predicts that marginal lands could be the focus of agriculture in the 21st century.

Whereas mainstream agriculture revolves around cultivated land, mountain agriculture is holistic and involves all land-related activities such as cropping, animal husbandry, forestry, and their interlinkages (Partap 1995). Whereas mainstream agriculture is dependent on external inputs, mountain agriculture is self-dependent, being nourished by the inputs grown and prepared within the systems, rendering it self-contained and self-reliant. This multi-component farming system of forests, cropland, livestock, and human beings represents an overwhelming feature of solar-powered agriculture. The system also uses natural subsidies in the form of forest biomass and recycled nutrients. Mountain agriculture may thus be referred to as naturally subsidised, solar-powered agriculture.

Mountain agriculture is currently in a transitional phase in selected pocket areas. By and large, however, traditional agriculture provides sustenance to the majority of mountain dwellers. Whether traditional or transformed, the predominant feature of mountain agriculture is that cropped areas use draught animal power and human muscle power (i.e., the animate energy) for virtually all the agricultural operations. This renewable energy is, as it should be, part of the strategy for sustainable agriculture. Fossil energy is a finite resource and has considerable negative impacts on the environment; added to which most farmers in the mountains cannot afford fossil energy-technologies.

Debate on the sustainability of mountain agriculture misses out the animate energy system. As mechanisation based on fossil fuels is not applicable because of area specificities, animals and/or manual tools remain the most suitable sources of agricultural power. In a predominantly agrarian society, animals are omnipresent. In fact, animals are an integral, inseparable, and indispensable part of mountain farming systems.

Among these animals, draught animals are a boon for mountain agriculture. In many areas draught animals are the preferred species of domestic animal, whether they are kept in the household or not.

Bullocks are draught animals with no equals. During the last decade, draught animal management in particular and cattle management in general have been the pivotal force behind the transformation processes in mountain agriculture. Transformation processes have been encouraged in selected areas, but the current economic liberalisation process taking place in HKH countries further calls for commercialised and export-oriented farming.

The transformation processes in mountain agriculture have been studied in detail, but how they have affected the DAP system and how new livestock management practices

have emerged remain to be studied. The transformed system is yet to be competitive and sustainable. Even traditional mountain agriculture has witnessed substantial transformation with respect to the livestock sector, in general, and the draught animal system in particular. This altered management system is yet to be properly analysed.

1.2 Livestock in Mountain Farming Systems

Livestock acquire special importance in mountain farming systems on both ecological and socioeconomic grounds. They are an integral part of the farming system and a 'bridge' connecting two types of land, viz., uncultivated forest land and cultivated land. This linkage is crucial for the ecological and economic sustainability of the system. Forests, especially natural ones, are rich repositories of nutrients which enrich cultivated land. These nutrients are transferred to the cultivated land by livestock. Nutrient transfer takes place in two ways. Forest biomass—tree leaves and ground flora—are fed to the livestock. The biomass is also used as bedding materials in the livestock shed. Both dung and bedding material are converted into manure, which is transferred to the cultivated land. The livestock also recycle the nutrients from cultivated land. Crop residues are fed to the animals and thus the nutrients in them are recycled into the cropland. The biomass transfer and cyclic flow pattern of nutrients, mediated by livestock, infuse vitality into the production system and livestock themselves fulfill their requirements for maintenance and production (milk, draught power, etc). This dynamic relationship among forest ecosystems/CPRs, livestock, and agro-ecosystems is vital for the sustainability of mountain agriculture.

As indicated above, livestock are interposed in this flow-pattern to capture energy and transform it into work and milk. Animals are not essential to the system, for vegetation from CPRs and crop residues can be composted directly – as they are to an extent in Chinese agriculture. Composting, however, wastes energy. Livestock recover some of the energy otherwise entirely lost in the composting process (Jackson 1985).

The two common livestock-raising systems are the sedentary and transhumant. Animals in the sedentary system are kept in and around the village throughout the year. All animals, except buffaloes, are kept grazing in the daytime. At night, crop residues and leaves are fed to the animals. Buffaloes and crossbred cows are mostly stall-fed. Buffaloes and cattle are the species preferred. Some families keep small or large herds of goats.

In the transhumance system, animals move to different locations, mainly depending on the crop seasons. Sheep and goats are the species preferred. All animals are kept grazing during summer when they stay at high altitudes. During the winter months animals move to lower altitudes. Nomadic herders generally do not have permanent houses nor do they cultivate crops, while some tribes practice transhumance, have their own cultivated land, and also practice cropping under traditional livestock-based farming systems.

Buffaloes are the milch animals preferred in the mountains. Cows are mainly kept to produce bullocks. Buffaloes are also given preference for feeding with high quality feed particularly in the sedentary system. Bullocks are provided with feed during the ploughing season and also on special occasions when *goudhan* (cattle wealth) is celebrated. Livestock size and composition are dictated by ecological and socioeconomic realities of the region. Cattle size is determined mainly by draught requirements. People's reverence for cattle is not a factor in livestock population composition, as is sometimes believed. This is clear from the fact that buffaloes and goats are increasing in numbers while cattle numbers are constant or decreasing.

As providers of manure, exploiters of waste, sources of power, forms of investment, risk cushions, transporters, and sources of raw materials (milk, meat, wool, etc), livestock benefit mountain farmers directly. Furthermore, livestock play an important role in the cultural identity of mountain people (Jodha and Shrestha 1990).

1.3 DAP - Related Issues and Concerns

DAP, combined with other factors, has a great potential for increasing agricultural productivity, sustainability, and income and employment in mountain areas. But there are some constraints because of the linkages with the entire livestock sector and overall production system.

There is considerable lack of knowledge with regard to the DAP system in mountain agriculture. Most research activities have been carried out on non-draught animal species. The significant contributions of mountain agriculture have been ignored. Close examination of the vital role of draught animals is imperative.

What are the animate energy systems in the mountains and what role do animals play in integrated energy systems? Animal substitution by fossil fuel-powered machines is extremely difficult. But are draught animals superior to farm mechanisation? It is often argued that draught animals are a burden on households when they have no work to perform, i.e., during the idle period. The role of draught animals, however, is not limited to power supply only. Many more benefits accrue to farming communities from them. The secondary roles of these draught animals need to be examined.

While the predominant picture of mountain agriculture is one of traditional, subsistence agriculture in the middle mountains, seminal changes with respect to agricultural practices have taken place in some places. How have these transformation processes influenced the distribution/use of DAP?

It is worthwhile to examine the factors and processes contributing to unsustainability first. Studies undertaken by ICIMOD (Jodha 1990, 1993, Jodha et al. 1992, Shrestha 1992, and Singh 1992) have shown that, in many mountain areas, the resource base for mountain agriculture has deteriorated visibly. In this respect we shall base our

discussion on the livestock sector so that it closely examines DAP. Some of the changes arising from transformation of hill agriculture are: new cropping patterns, reduced fodder supply, increased focus on milk (i.e., white revolution). Each of these changes has made an impact on the DAP management strategies of the farmers.

It is argued that the bovine population size, including draught animals, is high in dryland agriculture (largely indistinguishable with traditional agriculture) because of the uncertainties involved in it (Patel 1993). Thus, with the development of irrigated agriculture (mostly transformed), the bovine density is expected to decline. It is also often argued that the decline in size of landholdings results in an increase in the demand for draught animals because of their indivisibility, which may not always be true (Subrahmanyam and Rao 1995). It is shown that the distribution of milch animals is more skewed than that of land, and 60 per cent of rural households own milch animals. Further, the landless, marginal and small farmers account for 72 per cent of the ownership of bovines (Khanna 1989). The state-wise, cross-section data reveal a positive correlation between the density of draught animal power and rainfall as well as the proportion of farmers on small and marginal farms (Rao 1994). The relationship between the size of landholding and maintenance of DAP is expected to be negative, since a decline in the size of holding will not allow for proportionate decline in DAP because of the indivisibility involved. On the other hand, the proportion of households not maintaining DAP increases with a decline in the size of holding (Vaidyanathan 1988). Some of these conditions determine the DAP management pattern. One crucial issue, therefore, is related to the DAP management pattern. How are the distribution and density of draught animals, hiring/sharing, and other use-patterns of DAP influenced by major variables in the farming system? What is the DAP contribution to the cultivation of different crops? What are the energetics of DAP usage? What are the maintenance costs of bullocks?

In examining these different management patterns quantitatively, it is also imperative to look into the prevailing draught animal husbandry practices, purchase and disposal systems, nutrition of draught animals, ethnicity aspects, and principal constraints in DAP systems. The cattle population is slowly but surely moving towards a composition oriented to increasing milk production. Conventional animal husbandry; involving cross-breeding, health care, and fodder cultivation for specialised milch cattle, coupled with market-oriented production, emphasis on farm mechanisation, and neglect of the DAP system are highlights of the current livestock policies of the mountain provinces of India (Mishra 1995). With the observed stagnation in the cattle population, a trend in declining DAP supply in mountain agriculture is expected in future. An important research issue then is : what are the various institutional policies and programmes that affect the overall DAP system?

The prospects for developing the DAP system will, to a great extent, depend on careful planning and strategies of farmers that could be pivotal in improving the effectiveness of DAP in the various agricultural operations. To examine this issue will involve the study

of farmers' choices; decisive roles in structuring livestock holding size in accordance with resource base quality and changing needs; maintenance of breeds suitable to the environment; and their harness system, implements, and tools.

What will be the future of DAP in mountain agriculture? The current changes and transformations in mountain agriculture, which are largely determined by factors such as constantly decreasing holding size resulting from increasing family fragmentation, institutional policies and programmes, commercialisation of agriculture, increasing use of external inputs, altered cropping patterns, and environmental degradation, will decide the future scope for DAP systems in mountain farming. DAP has no viable alternatives in mountain agriculture. Improving its sustainable use is the best way of supporting regenerative mountain agriculture. What are the options, technological aspects, institutional options, and human aspects to promoting and improving DAP.

The current study attempts to examine the above issues based on a field survey carried out in the Central Himalayas of India and the secondary information available.

To closely examine the vital role and contributions of DAP to sustainable mountain agriculture, the following were undertaken.

- Analysis of drought animals' inter-relationship with mountain farming/energy system components and their role in mountain agriculture.
- An inventory of the DAP management situation through livestock population and composition, distribution and density, sharing and hiring, and DAP-related husbandry practices with respect to operating system variables.
- Quantification of DAP's contribution to mountain agriculture in terms of the tractive performance of animals, DAP potential and balance, DAP contribution to crop cultivation, and DAP share in overall crop production energetics.
- An analysis of institutional policies leading to changes in DAP and its use and future scope.
- Opportunities for improving the DAP system and its efficiency.

1.4 The Study Area

The northern part of the Indian State of Uttar Pradesh lies in the Himalayan mountains. The Himalayan area of the state is divided into Garhwal and Kumaon, together known as the Indian Central Himalayas – popularly known as Uttarakhand. The Garhwal division has five districts – Uttarkashi, Chamoli, Pauri, Tehri, and Dehradun – stretching over an area of 29, 968 sq. km. The Kumaon division has four districts – Pithoragarh, Almora, Nainital, and Udham Singh Nagar – spread over an area of 20, 984 sq. km.

The total area of Garhwal and Kumaon (Indian Central Himalayas) is 50,952 sq. km., according to Landsat imagery. This region falls between 28-30° N latitude and 77-81° E longitude. In the north, the region borders Tibet, while, towards the east, the River Kali marks its border with Nepal. On its western side lies Himachal Pradesh, the other Himalayan state of India.

The region consists of mountains and high hills ranging in altitude from 250 to over 3,500 masl. On the basis of altitudinal variations, the Central Himalayas can be categorised as sub-tropical (250-1200m), sub-temperate (1200-1700 m), temperate (1700-3500 m), and alpine (3,500 m and above).

The population, according to the official 1991 census, is 59,27,000, registering an increase of 22.56 per cent over the 1981 population. The average density of population is 116/km². The main occupation is agriculture, and this is characterised by the abundance of marginal and uneconomic holdings. Nearly 65 per cent of the working population are engaged in agriculture and nearly 78 per cent of the population live in villages, the total number of which is 15,166.

The Shivaliks, the first and the southernmost hills (10 to 50km wide), are from 500 to 1,200 masl. They are separated from the Lesser or Middle Himalayas to the north by a major fault, the Main Boundary Thrust (MBT). The Lesser Himalayas, where the northwest-southwest ranges rise sharply from 1,200-2,500m and above, are characterised by the presence of numerous transverse valleys. Beyond the Middle Himalayas lie the Greater Himalayan ranges, which are separated from the former on the south by the Main Central Thrust (MCT). In the ranges of the Greater Himalayas lie another series of valleys, then finally their headwaters in the glaciers and permanent snow above 5,000m (Ram et al. 1993).

Within the mountainous landscapes of the Shivaliks, slopes are generally too steep and soils too shallow to support any type of agriculture. Therefore, agriculture is concentrated in valley areas called Dun Valleys.

The Middle or Lesser Himalayan mountains occupy the largest land area within the Central Himalayas and the majority of the mountain population live there. Nearly 60 per cent of the total cultivated land lies in this zone, out of which nearly 30 per cent of the agricultural land is in the valleys, 60 per cent at mid-altitudes, and 10 per cent at high altitudes. Terraces at mid-altitudes are built on gentle slopes and present a highly sophisticated traditional farming system. Selected pockets in this region, particularly those with irrigation and marketing facilities and where the public system has taken a special interest, have undergone significant transformation. This transformation in agriculture of the upper reaches of the middle mountains has produced negative changes in the farming system at high altitudes in the middle mountains. Particularly in pockets where extensive transformation in terms of horticultural crop introduction has taken place, farming operations have been carried out on steep slopes unfit for cultivation.

The forests in the Middle Himalayas are the most critical part of the farming system and meet most of the villagers' household needs. Biotic pressure on these forests is excessive and beyond their regenerative capacity. A macro picture of the Middle Himalayas gives a gloomy ecological perspective and is of concern to local inhabitants as well as policy-makers and development agencies. This zone is a hot spot of local socio-ecological movements and external development interventions.

The Greater Himalayas are generally referred to as areas under perpetual snow (2,500m) and high altitude grasslands or meadows and adjoining areas which remain under snow during most of the winter season. According to the figures presented on the basis of landsat imagery (Ram et al. 1993), 21.59 per cent (11,002 sq. km.) and 4.95 per cent (2,522 sq km) of the area of the Greater Himalayas in the Central Himalayas are under permanent snow and high altitude grasslands, respectively.

These grasslands, or alpine pastures, commonly called *Bugyal*, lying between the mountain range under perennial snow towards the north and the timber line towards the south are of crucial ecological and economic significance. For about six months in a year they provide pastures for the herds of most of the transhumant pastoralists, tribal people, and traditional nomads.

There are no permanent human settlements in this zone. Throughout the summer and the rainy seasons, the transhumant pastoralists and tribals live in villages close to the alpine meadows. They raise crops and own large numbers of livestock. Before the onset of the winter season, these people vacate their summer houses and return to their winter camps (the villages) in the Middle Himalayas. The nomads move to the alpine meadows after snowmelt in the summer with large numbers of animals, rear them on the highly nutritive fodder, and before winter return to their houses in the foothills. Apart from livestock grazing, they collect medicinal and aromatic plants and carry out a limited amount of farming on the alpine pastures.

The lower valleys in the Shivaliks and Middle Himalayas are hot in summer and cold in winter. The average temperature in the valleys varies from 3°C-30°C, while the very high mountains in the Greater Himalayas are covered with snow even in summer. At 1,500-2,000m, the mean monthly temperature ranges from 5.5°C-8.0°C in January and from 19°C-27°C in June. In the foothills, temperatures range from 13 to 21°C in the cold months and from 30 to 40°C in the hot months. At higher elevations, between 3,000-4,000m, during the snow-free period the mean maximum daily temperature ranges from 8.6 to 21.2°C and the mean minimum daily from 4.6 and 10.5°C, in June and October, respectively.

In general, the monsoon (mid-June to mid-September) accounts for about three-quarters of the annual precipitation. The average annual rainfall of the four land forms of the Central Himalayas, namely, foothills (600m), Shivaliks and the adjoining Lesser Himalayas (1,700m), Lesser Himalayas (2,200m), and Greater Himalayas (3,600m), as reported by Ram et al. (1993) is 2,056, 2,986, 1,360 and 1,585mm, respectively.

1.5 The Methodology

The study was based on intensive interviews with households in 12 villages in four different farming systems, three villages in each, in the Central Himalayas. The study sites were selected on the basis of stratified random sampling. Basing our study in four sub-regions, each treated as a separate stratum having a marked distinction with respect to farming system, was a logical way of addressing DAP-related issues. The four strata (farming systems) are as follow.

- The Shivalik Hills/Foothills of the Outer Himalayas
- The Middle Himalayas or Lesser Himalayas : Traditional Areas
- The Middle Himalayas or Lesser Himalayas : Transformed Areas
- The Greater Himalayas

In the Shivalik range and the foothills of the Himalayas, farming takes place on comparatively fertile and flat land. Almost all the villages in this sub-region are located at lower altitudes, below 1,000m. In the middle hills, altitude is one of the factors governing the use of animal energy, type of cropping system, cropping pattern, and so on. Three locations of up to 1,200m, 1,200-1,700m, and 1,700-2,500m were the basis for villages selected in the traditional and transformed farming systems.

One village was selected randomly from each altitude range under each type of agricultural management. Cultivated land in most of the villages in the Middle Himalayas is located in all three altitudinal ranges, but the largest parcel of land is within a specific range. Almost all the villages in the Greater Himalayan zone are above 2,500m and,

Box 1

Basis of Categories of Farmers in the Central Himalayas

In compliance with the perspective and issue based study all the farm families in the selected villages were categorised into four groups on the basis of landholding size, following the methods standardised for economic studies in Uttarakhand mountain areas (Jagdish Kumar—Personal Communication, June 1996) :

- households having no land were classified as 'landless';
- households having equal to or less than 25 *nali*(s) (0.5 ha) land were classified as 'marginal';
- households having more than 25 *nali*(s) but equal to or less than 50 *nali*(s) (1.0 ha) were classified as 'small';
- households having more than 50 *nali*(s) but equal to or less than 100 *nali*(s) (2.0 ha) were categorised as 'medium'; and
- households having more than 100 *nali*(s) were termed as 'large'.

(A *nali* is the unit of land measurement in the mountains of the Central Himalayas; 50 *nali*(s) are equal to 1.0 ha)

Four hundred and four families were selected out of a total of 1,739 in the sample villages. Out of the selected families, 12 were landless, 152 marginal, 126 small, 62 medium, and 52 from the large holding category

moreover, they are not a permanent feature of the zone. The villages are inhabited for nearly six months a year and then the villagers move to winter camps at lower altitudes.

The terms 'traditional' and 'transformed' are only applicable to the Middle Himalayas. In the Shivalik range, a mix of traditional and transformed patterns and a high degree of uniformity are evident almost everywhere. The farming system can be classified broadly as transitional. Greater Himalayan farming systems are also remarkably uniform. These are very traditional and almost primitive, more or less impervious to development interventions, unlike the systems at lower altitudes. On the contrary, villages in the Middle Himalayas are clearly distinguished; they are either traditional or transformed with respect to their farming systems. Transformation, nevertheless, is seldom complete. Some patches of land, especially those under rainfed conditions, are managed traditionally, even in transformed villages.

Since transformation of agriculture leads to changes in the use of energy, this criterion, was obviously of great help for the study of DAP issues. Three principal types of transformation in the farming systems of the Middle Himalayas are identified for study purposes: (i) transformation from foodgrain to vegetable-based cropping systems, (ii) transformation in terms of a genetic change in foodgrain crops followed by an alteration in cropping patterns, and (iii) transformation in terms of the development of an orchard-based farming system. From each transformed category, one village was selected. All three transformed villages selected represent different altitudinal ranges. The vegetable-based cropping systems in some valleys have abundant irrigation facilities. Genetic transformation in foodgrain crops has taken place in irrigated valleys as well as at mid-altitudes. The fruit tree-based (orchard) farming system, on the contrary, is found in selected pockets at high altitudes. Hence, we were able to select villages from all three altitudinal ranges.

From each category of landholding, 30 per cent of the households, or at least five, were randomly selected. If the total number of households in any category did not exceed five, all of them were covered in the investigation.

All the families selected were interviewed and an inventory made using a well-structured schedule specifically designed for the study. Much of the information, both quantitative and qualitative, was gathered using the diary method rather than a structured questionnaire; thus a mixed approach was used as suggested by Jodha (1995b). This was necessary in order to record cross-sectional information linked with DAP issues: local oral history, farmers' perspectives, strategies, their perceptions of public policies and programmes, and future vision. Information was generated often through group discussions involving farmers of all age groups and both sexes.

The opinions of key persons, NGOs, social workers, sociologists, economists, animal scientists, agriculturalists, ecologists, public departments, and even of Hindu priests were also incorporated. To execute the field survey exercise, seven potential cooperators

belonging to various occupational groups, who had a deep understanding of mountain farming systems, were employed.

Measurement of DAP Output

DAP output during ploughing and levelling operations was measured by following a slightly modified version of the method used earlier by Matthews (1987). This method differs slightly from that of Singh and Naik (1987a) and has the advantage of calculating power directly into the metric system (kW) rather than into the outdated foot-pound system (horsepower). This method is elaborated upon in Annex 1.

Experiments on DAP output during ploughing and levelling operations were carried out at two sites, one in each of the two villages of Jagdhar and Dikholgaon in Tehri district. These took place in October and November when the fields were being prepared for wheat cultivation after the millet and paddy harvests. Power output at the time of puddling (for rice transplantation) and weeding and earthing-up (*danala*) operations for the millet crops was derived from our estimates based on earlier experiments by Singh and Naik (1987a).

Measuring the Energy Content of Human Labour

Measuring the energy content of human labour, which is one of the main sources of motive power in rural energy systems, is infinitely more complex, both conceptually and empirically. In particular, in relationships vis a vis human labour, complexities arise because of varying perspectives concerning whether human labour is a factor of production that can be substituted by energy, or whether it is a form of energy that can be substituted by other forms of energy (Ramani et al. 1995). However to expedite analysis of the functioning of a production system and/or ecosystem, depicting the energy flow pattern and assessing human labour in terms of energy are crucial, particularly when a concrete strategy is needed. Considerable variation in the criteria for converting human labour into energy is found in the literature. The energy figures used by Revelle (1976), Gopalan et al. (1979), and Bhatia and Sharma (1990) seem to be on the high side. In our analysis, we have used the human energy input value recommended by ICAR (1978), i.e., 0.1 hp or 0.075 kW per adult per hour; and it appears to be appropriate when we compare human weight with that of a local bullock.

Characterisation of Cattle Breeds

In any discussion on DAP use, particularly in relation to long-term sustainability, knowledge of the cattle breeds providing the draught power is imperative. Fifty working bullocks in five villages of the Tehri District were studied with the help of two animal breeders. Farmers' views on the breeds they chose and likely substitutes were also recorded.

In addition to primary sources, data, particularly those on livestock, were collected from secondary sources to generate the information needed. The data collected from both sources were analysed and interpreted. While presenting the quantitative information, the relative simplicity and transparency associated with the issues facing DAP were kept in mind.

1.6 The Study Sites

Location and forest and farming system types in the study areas are shown in Table 1.1. Whereas all the villages in the Shivalik/foothill range are situated at lower altitudes (600-800 m), those in the Greater Himalayas are situated at high altitudes (above 2,500m). The villages in the Middle Himalayas represent three altitudinal ranges, namely, lower (below 1,200m), mid – (from 1,200 to 1,700m), and higher altitudes (from 1,700 to 2,500m). The high altitudes in the Middle Himalayas should be distinguishable from those in the Greater Himalayas. Analysing the Middle Himalayas according to altitudinal ranges offers some benefits as the vegetation communities and farming systems acquire distinct characteristics with change in altitude. Although the villages are located at the altitude shown, croplands owned by these villages may be situated within a very wide range of altitudes. In most cases, croplands in Middle Himalayan villages will be found at all three altitudinal ranges.

The Shivalik and foothill villages are situated mostly in the valleys, on even land, and slope direction does not play a significant role. Two of our hill villages are situated on gently undulating land, and most of the houses on particular slope directions, but slope direction here cannot be said to affect botanical composition and/or the microclimate of the area, as would be the case in the Middle and Greater Himalayas. Slope direction, as given in the Table, reflects the general situation only. In the majority of cases, a single village covers more than one direction.

Accessibility/inaccessibility of the villages has been assessed by distance from the main or link road. Five of our sample villages are very close to a road and are easily accessible. The other five are situated at a distance of 0.5km from the road. Two villages – Banali and Gangi – are very inaccessible or isolated.

Sal (*Shorea robusta*) forest in the Shivalik and foothill range, Banj oak (*Quercus leucotrichophora*) at middle elevations, and Kharsu oak (*Q. semecarpifolia*) at higher elevations on the outskirts of the Greater Himalayas represent the central climax communities (Singh and Singh 1987). Alpine meadows in the Greater Himalayas, between the timber line and permanent glaciers, are also regarded as the climax community. In the hills, *Shorea robusta* is the dominant forest species, but the community land has been badly invaded by two exotic species, viz., *Lantana camara* and *Parthenium* sp. These species are non-palatable and poisonous, obstructing natural regeneration of grazing lands.

Table 1.1: Location and Environmental Background of Study Sites

Villages	District	Altitude in masl	Slope Direction	Accessibility (Distance from Road, km)	Catchment Area (River)	Forest Type, State of Grazing Lands	Farming System
<u>Sivaliks/Foothills</u> Ganga Bhogpur Krandgaon Naigoth	Pauri Dehradun Udhamsingh Nagar	600 800 700	Valley Valley, East Valley, North	0.5 0 0.5	Ganga Ganga Kali	<i>Shorea robusta</i> , Grazing lands invaded by <i>Lantana</i> and <i>Parthenium</i> weeds	<ul style="list-style-type: none"> • Cereal crop-dominated farming system; • Cattle-dominated herd; • Transitional phase of development; • Low to high risks.
<u>Middle Himalayas: Traditional</u> Taily Sunoli Goom Banali	Almora Pauri Tehri	1,200 1,600 1,800	South-East South South-East	0.5 0 12.0	Gagas-Ramganga Saneh-Ganga Bidaina-Tons	<i>Pinus roxburghii</i> in Taily Sunoli and Goom, <i>Quercus leucotrichophora</i> in Banali, Grazing lands mostly degraded	<ul style="list-style-type: none"> • Cereal (millet) crop-dominated farming system, • Cattle-dominated herd; • Traditional system of food production; • Minimum risks.
<u>Middle Himalayas: Transformed</u> Suri Kandhla Badethi Chaupariyalgaon	Nainital Uttarkashi Tehri	900 1,250 2,000	North-East North-East North-West	0 0 0	Kosi Bhagirathi Henwal-Ganga	<i>Pinus roxburghii</i> in Suri and Kandhla Badethi, <i>Quercus leucotrichophora</i> in Chaupariyalgaon, Grazing lands mostly degraded	<ul style="list-style-type: none"> • Horticulture-dominated (& genetically transformed) cereal crop-dominated farming system; • Buffalo-dominated herd; • Modern phase of development; • Very high risks.
<u>Greater Himalayas</u> Bagauri Juma Gangi	Uttarkashi Chamoli Tehri	2,550 2,600 2,650	South-West East East	0.5 0.5 21.0	Bhagirathi Alaknanda Bhilangana	<i>Quercus semecarpifolia</i> in Gangi and Juma, <i>Cedrus deodara</i> in Baguari, Alpine meadows (the high altitude grazing lands) in good condition	<ul style="list-style-type: none"> • Livestock-dominated farming system; • Ovine (sheep and goat)-dominated herd; • Almost primitive system of food production • Minimum risks

All the principal farming system types are represented by the study sites. In fact, each stratum represents a principal farming system type. The hills have a cereal-based farming system and the high mountains a livestock-based one. The middle mountain areas, under traditional agricultural practices, are a classical example of a millet-based farming system. Agricultural transformation in this zone has led to two basic changes: one, development of a horticultural crop-dominated farming system and, two, a high-yield cereal crop-dominated farming system. The farms can be divided into vegetable-based and fruit tree-based farming systems. The cereal-based farming system in this area incorporates new 'improved' varieties of cereals, requiring a change in agricultural practices. Extensive and liberal use of external farm inputs and strong linkages with the market are essential to maintain and manage this system. The herd composition also varies from one sub-region to the other. Hill villages and the traditional middle mountains have cattle-dominated herds, but the cash crop oriented middle mountain region has herds that are mainly buffaloes. Ovine species (especially sheep) are in the majority in the high Himalayan villages. Since the high mountains have plentiful grazing facilities, ovines, which thrive on grazing, appear to be the most suitable animals for this region.

Information on socioeconomic characteristics of the sample villages has been presented in Annexes 2 to 11. The average family size ranges from 5.33 persons in the Greater Himalayan villages to 7.09 in the Shivalik/foothill villages and is close to 10.50 in the Middle Himalayan villages (Annex 2). The average size of operated landholdings is the smallest (0.36 ha) in the Greater Himalayan villages and largest (1.05 ha) in the traditional villages in the Middle Himalayas (Annex 3). There are no landless families, apart from in Bagauri villages (25%). Marginal and small landholdings constitute the majority of farming households. In Khandgaon village, all the households operate in 'large' holding groups. This village came into being only a few years ago. All the families were allotted an equal area of land when they were displaced from the mountains. On the contrary, all households in Bagauri village have medium-sized farms. This village is a classical example of a livestock-dominated farming system (Annexes 4 to 6). All the land holdings are extremely fragmented. In the Shivaliks, some four to six parcels (in Khandgaon village only 1) of land per household were noted; and the figure was as high as from eight to 11 in the Middle Himalayas and five to seven in the Greater Himalayan Zone. Livestock holdings are discussed in Chapter 4. Most cultivated areas in the Shivalik/foothill area are devoted to lowland (irrigated) rice and lowland wheat, showing that it is a cereal crop-dominated farming system. Cropping intensity is the highest (200%) in Khandgaon village (Annex 7). Millets (finger and barnyard millets) together account for about 50 per cent of the total cultivated area in the traditional areas of the Middle Himalayas. The average cropping intensity in this group of villages is 158 per cent (Annex 8). Among the villages with a transformed agricultural system in the Middle Himalayas, Suri and Chaupariyalgaon villages devoted 50 and 71 per cent respectively of their total cultivated area to vegetables, while Kandhla Badethi gives more importance to 'rice-wheat' rotation, devoting 39 per cent of the cultivated area to lowland rice and lowland wheat. Almost all varieties of these two crops in this village are 'improved' ones. Vegetables also cover about 20 per cent of the area. The farming

system in Chaupariyalgaon village is orchard-based, but actually the floors of the apple orchards are used for cultivation of off-season vegetables. The cropping intensity is as high as 200 per cent in Kandhla Badethi, and they no longer keep fields fallow. The cropping intensity in Suri village is 192 per cent and in Chaupariyal village it is a little low at 179 per cent; the latter could be higher but, during winter season, because of heavy snowfall at higher altitudes, the entire area under orchards is not used (Annex 9). In the Greater Himalayan zone, a very high priority is given to pseudo-cereals (amaranth and buckwheat). Kidney beans are given top priority in Bagauri village. Potato cultivation has occupied an important place in the livestock-based farming system during recent years only. Cropping intensity in this zone is low (92%) (Annex 10). The average productivity rates for different crops from different sites are given in Annex 11.

Two

Role of Draught Animals

Agricultural production in the mountains needs to increase substantially, and it should be sustainable. Increased demands as a result of population growth and the rising standards of living are only one end of the scale; at the other is the need to overcome malnutrition and poverty. This will require adequate energy and its sustainable use; and this does not exclude manual farming, nor does it mean that farm mechanisation is the only way out to meet energy demands. Manual operations will continue to be an essential input for development of sustainable agriculture, and mechanisation is not a sound basis for agricultural progress in the mountains.

A primitive energy system involving draught animals still exists in the mountains, and this system, complemented with manual operations, can become part of an ecologically-sound, environmentally friendly, and mountain-specific approach to sustainable and increased production in the region. Draught animals are the most economical and readily available source of energy in rural mountain areas.

To understand the vital role of draught animals, it is imperative to examine various energy sources, advantages of draught animal-based energy systems (and the disadvantages of farm mechanisation), and multiple uses of draught animals. This is examined in the following sections in the specific mountain context. The vital role of draught animals has been quantified in a separate chapter.

2.1 Energy Systems in Mountain Agriculture

Three basic energy systems are used globally: (i) manual farming tools, (ii) draught animal power, and (iii) mechanised systems. In fact, these energy systems, barring in some marginal areas, are usually found side by side, although they vary in distribution and relative importance (Bodet 1987). In some regions, mainly characterised by marginality, fragility, inaccessibility and diversity, for example the Himalayas, there is virtually no scope for the development of fossil fuel-powered, machine-based energy systems. Almost all agricultural production in such regions relies solely on manual farming tools and draught animal power systems, or animate energy systems.

Experience shows that there is a direct relation between the level of energy used, whether human, animal, or fossil, and the level of production per unit of land. In fossil energy-

driven systems, the relatively high energy use explains the relatively high productivity. However, there are organic, integrated systems in which virtually no fossil energy is used, that, in terms of overall production, are at least as productive as modern systems but which have a less negative impact on the environment and may be socially more acceptable (Durno et al. 1992).

That the source of energy is not important for the level of production is also demonstrated by comparative research in the Philippines (Kuether and Duff 1981) where it was found that the same yield of rice could be obtained from mechanical, transitional, and traditional farms. Basing policies on comparative energy balances only, therefore, can lead to wrong decisions if these data are not combined with information on, e.g., production, availability, cost, impact on environment, gender, and the community as a whole (Reijntjes 1992).

Agricultural/cropping transformation and mechanisation often go hand in hand. But, in this respect too, mountains are the exception. Almost complete transformation in some favourable pockets of the mountains, it has been experienced, has not invited mechanisation to any degree. In transitional areas, e.g., the Shivalik and foothill range where a handful of farmers occasionally hire tractors for ploughing, limited use of fossil fuel energy is visible, and this is because there is even land which is easily accessible and well-linked to the plains.

Energy systems used for agricultural work in the mountains exist as an integrated system. A system using farming tools can exist independently; and, to a great extent, so can a mechanised system. But the draught animal power system can never exist independently. When, through the use of an implement, an agricultural operation absorbs an animal's energy, it will simultaneously absorb human energy. So both systems (animal power being dominant) are inseparably integrated. Use of a mixture of energy technologies in crop production is referred to as an integrated energy system. For agricultural work we can call it an 'animate energy system' since the energy is produced by a living system. Fossil-fuel energy, on the contrary, can be referred to as a non-animate source of energy. The former is renewable, the latter non-renewable. In this text, unless specified, the word 'energy' refers to the energy used for agricultural work, e.g., tillage, weeding, puddling, threshing and so on.

2.2 Animal vs. Farm Mechanisation

Draught animal power is obviously the most suited to mountain agriculture. A number of sound reasons why it is preferable to fossil-fuel power can be found in the literature (Gill 1981, Bhalla and Chadha 1982, Nair 1982, Ramaswamy 1983, Bodet 1987, Singh and Naik 1987a and Reijntjes 1992).

- 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 increases a farmer's 'work force'. It enables the farmer to plant diverse crop species to increase the area cultivated and to carry out agricultural work in time.
- Machine-based energy results in the concentration of production on a limited number of crops, thus reducing the diversity of the 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, mountain farms.
- Draught power does not need expensive and non-renewable fuels. Draught animals can also be fed residues and by-products available on the farm, producing, in return, not only energy but food (milk from the female cattle), methane (biogas), manure as well as other products obtainable after their death.
- The use of draught animals enables farmers to integrate livestock and crop production and permits the exploitation of the potential of cattle kept 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.
- Fossil energy used in machines is a finite resource and its use has a considerable negative impact on the environment. Most farmers in the mountains cannot afford fossil energy-based technology.
- Where animals are used as draught power, it is possible for farmers to either cultivate more land or use the time for other activities.

The above-listed arguments clearly reveal DAP's supremacy over mechanisation. In the mountain areas, owing to specific resource base characteristics altogether different from those of the plains, improvement in the efficiency and sustainable use of the system are essential.

2.3 The Primary and Secondary Roles of Draught Animals

In addition to providing draught power for agriculture, draught animals play many other roles in the mountain farming system; these can be referred to as their secondary roles. Primary roles include ploughing or tillage, levelling, puddling, earthing-up, and weeding and threshing.

In the Central Himalayan mountains, unlike in the plains, draught animals are not used for tillage or for operating water-wheels. Table 2.1 gives a broad picture of their contributions to the mountain economy in comparison with other livestock species.

Draught animals perform several secondary functions also. These range from direct, visible contributions, in terms of supplying physical items such as dung and milk, to less

Table 2.1: Contribution of Draught Animals and Other Livestock Species to Mountain Farming

Contributions	Draught Cattle		Buffaloes	Goats	Sheep	Pack Animals
	Male	Female				
Agricultural Operations						
Ploughing	✓					
Levelling	✓					
Puddling	✓					
Weeding, Earthing-up	✓					
Threshing	✓	✓				
Loading, Pack-carrying	×					✓
Physical Products						
Dung, Manure	✓	✓	✓	✓	✓	✓
Milk		✓	✓			
Meat				✓	✓	
Wool					✓	
Income/Employment Gains						
Direct Productivity Improvement	✓					
Smaller Gains through Sale	✓			✓	✓	
Larger Gains through Sale	✓	✓	✓			✓
Off-farm Activities	✓					✓
Income through Hiring-out	✓					
Social, Cultural, Ecological Gains						
Cropping Diversification	✓					
<i>In situ</i> Manuring of Fields	✓	✓		✓	✓	
Renewable Energy Supply	✓					
Religious, Ethical Values	✓	✓				
Festivity, Fairs, Rituals	✓	✓				
Social Status, Prestige	✓	✓				
Encouragement of Social Cohesion	✓	✓				
Improving the Sustainability of the Farming System	✓					

× Used only by transhumant societies.

visible gains in terms of employment, income generation, farmers' security and companionship, sustaining livelihoods, and sustainability of the farming system. The secondary roles of draught animals are inseparable from those of almost all other classes of livestock.

Draught power is one of the basic requirements for crop farming in an agricultural system. Notwithstanding the availability of good seeds, fertile soils, irrigation facilities, and a favourable climate, crops cannot be sown and harvested without draught power. Untimely and inadequate supplies of draught energy lead to a decrease in crop production. Several studies (Larson 1962, Allmaras et al. 1967, McColly 1971, Lindstrom et al. 1981, and Benoit and Lindstrom 1987) have demonstrated the direct relationship between tillage and productivity. Draught animal power, in a mountain context, must be regarded as an essential input for improved productivity and sustainability.

The weeding season is characterised by long, heavy working days. These are burdensome, particularly on women. The use of oxen-drawn weeders reduces labour constraints and the drudgery of women (Reoleveld et al. 1995).

In the mountains, the productivity of farming systems depends on the conversion of fodder into manure. In mountain areas, especially at high altitudes, crop residues decompose very slowly. The ruminant digestive system helps speed up nutrient recycling. Ruminants also help transfer the soil nutrients from forest vegetation to croplands, improving the fertility of the agro-ecosystem. The dung produced in the stall is transferred to cultivated land, and this requires a long time, apart from human labour; and due to nutrient loss its quality decreases. *In situ* manuring, i.e., by tethering the animals directly in the fields, is an important strategy developed by mountain farmers over the ages and in which draught animals play a crucial role. During the dry season, cattle (and small ruminants) graze harvested fields left fallow and provide manure directly. The draught animals also provide manure directly to the fields while performing agricultural operations. Results of an experiment (Powell and Ikpe 1992) showed that millet yields in corralled areas (which receive both manure plus urine) were over twice as high as yields where only manure from stall-kept animals had been spread. The residual benefits of urine were also observed. Yields in plots where cattle and sheep had been corralled the previous year were about 1.5 times greater than yields from areas on which manure had been spread by hand.

The only food item derivable from draught species (cattle) in the Central Himalayas is milk, which is obtained from cows in the process of reproduction. Cattle meat is strictly forbidden in the Hindu-dominated Central Himalayas, as also in many other Indian states and in Nepal.

Draught animals provide employment for a great number of people, for whom they are a crucial source of family income. In a fast changing scenario, the DAP system is emerging as an income-generating enterprise for many marginal and small-holders, landless families, and some middlemen. This will be discussed later.

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 for children. Economically poultry are regarded as 'coins' and sheep and goats are 'small bills' (Bayer and Waters-Bayer 1992), but for many villages in the Central Himalayas, particularly those situated in remote areas, draught animals function as 'bullock banks'. In Banali, one of our sample villages, for example, draught animals are the best cash animals. They are an asset and give farmers status, companionship, prestige, and security.

2.4 The Sociocultural Role of Bullocks

Draught animals have high cultural value. *Gaudhan* (cattle wealth) dominates the Hindu psyche. Regarding the cow as sacred is not just a sentimental expression, the cow is sacred because it produces bullocks, the source of power and basis of agricultural production. The value of bullocks is reflected in many local festivals. Thanksgiving days are observed to highlight the services they give to society.

In *Chaitra* (April), bullocks are fed *Khichri*, a special mixture of pulses and rice. The *Khichri* is cooked together with leaves of *Ayar* and *Somya* collected from the forest by children. It is brought home and offered to the bullocks. This festival is known as *Ayarkutu* and is celebrated to bring good health to bullocks.

Special 'bullock holidays' are also observed in the region. On *amavasya*, the feast of the new moon, bullocks are not used for agricultural work. On the occasion of all important festivals, bullocks, in addition to special care, are given rest at home. *Chaturbhuj*, a very rare type of bullock, is never yoked to the plough. Persons seeking God's blessings visit Shiva temples with their bullocks and offer to give him a male calf (so that it grows into a sacred bull) if their wishes are fulfilled. Sacred bulls are never used for field work. There is a saying "The head of the family and its bullock must be strong". It means that the health of the head of the family and that of its bullock are the bases for the well-being of the entire family.

This infers that draught animals occupy a prominent position in the farm economy. These are the collective gains that accrue to the whole community rather than to individual households.

Draught animals thus cement the social cohesion of mountain people. All these factors and draught animals' crucial role in productivity, income generation, employment creation, and nutrient cyclic flow management are all pivotal to the sustainability of the farming system.

Three

DAP and Transformation Processes

Agricultural transformation has led to an alteration in the energy system in rural areas. Mechanisation was central to Green Revolution technology. It accords no value to draught animals. Although producers in some highly patronised pockets have widely adopted the new HYVs, irrespective of farm size and tenure, factors such as soil quality, access to irrigation water, and other biophysical-agroclimatic conditions (Conway and Barbier 1988) have been formidable barriers to adoption. The impressive economic contributions of the Green Revolution to large farms in the *Terai* area are to a considerable extent attributable to the massive amounts of fossil fuel energy farm machines use. Farmers in almost all categories in the mountains, who have to be content with HYVs, mono-cropping, and use of very small amounts of chemicals, have to operate all farming activities with human and animal energy.

The following paragraphs will discuss mountain agricultural transformation processes in the special context of DAP. Discussion on current transformed scenarios will be preceded by a description of traditional scenarios and unsustainability indicators and contributing factors. It will be followed by a discussion on limitations households face, changing cropping patterns affecting livestock fodder and the White Revolution technology; all of these have wide-scale implications on DAP.

3.1 The Predominant Situation

In vast areas of the Central Himalayas, a predominant traditional subsistence agriculture is in evidence. The majority of the mountain population is engaged in traditional subsistence agriculture. Inaccessibility or isolation creates favourable conditions for traditional agricultural management. The greater the inaccessibility the greater the chances of traditional management. In isolated areas, farmers tend to be self-sufficient. Natural diversity has been and is used by traditional farmers for sustenance and for developing diverse food production and livelihood systems.

Production activities in traditional areas are less diversified. There are two types of farming system: (i) cereal crop-dominated, and (ii) livestock-dominated. The cereal crop-dominated system is found in the Shivalik and foothill zones as well as in the middle mountains. In general, wheat/paddy-based cropping patterns predominate on

irrigated land, maize-based on rainfed land in the hills, millet-based on upland mid-altitude lands, and pseudo-cereal-based on high altitude summer camp lands in the middle mountains.

Agriculture in the hills is mostly irrigated agriculture. In the Middle Himalayas it is rainfed for the most part and, in the Greater Himalayas, it is totally rainfed (see Table 2.3). Whereas in the hill zone, both traditional and high-yielding varieties of crops are cultivated simultaneously, in traditional farming areas in the middle mountains crops are usually of traditional varieties. Herds are cattle dominated. DAP, the principal component of the animate energy system, is managed as either independent, shared, hired-in, or hired-out animal labour. Linkages with the market system are poor.

The livestock-dominated farming system of transhumant pastoralists who reside half a year in the Greater Himalayan zone includes herds dominated by ovine species, especially sheep. The average holding is very large and a high frequency of bullock sharing in the energy use system is observed. Alpine meadows are an important component of the farming system, and they are the main source of livestock feed for about six months of the year. Linkages of this system with the external market are also poor. The livestock-based farming system, in fact, is in a primitive stage of development.

3.2 Unsustainability Indicators

Unsustainability indicators relating to the livestock sector in the mountain farming system are listed in Table 3.1. Decreased livestock holdings (number of livestock per family) and a reduction in the proportion of cattle and bullocks in the overall herd composition and draught animals per household; a decrease in area under forests/pastures which serve as sources of livestock fodder and consequent reduction in grazing land due to construction and other activities (especially in the alpine zone); colonisation of exotic plants (*Lantana* sp and *Parthenium* sp) at lower altitudes in the Shivalik and foothill zone; and conversion into cultivated land almost everywhere are among the indicators of unsustainability.

In the context of resource management, increased use of slowly degrading pine needles in animal sheds is observed. These replace leaves of oak and rhododendron which decompose rapidly to enrich manure quality. Promotion of White Revolution technology involving the intensive crossbreeding of local cows with exotic bulls, mainly through artificial insemination which is not conducive to mountain area conditions, should also be regarded as a negative change. In recent years, emphasis by the public sector has been on monocultures of foodgrain crops (such as white-seeded soyabeans) and trees (such as *Eucalyptus*, Poplar, Silver Oak) that do not provide fodder and instead replace fodder-providing crops. Increased use of common property resources (CPRs) for non-pastoral activities and replacement of social sanctions against their use by legal measures are the negative indicators that decrease the options for development of CPRs and, consequently, of livestock resources. A few years ago, a portion of arable land (PPR

Table 3.1: Unsustainability Indicators Related to the Livestock Sector in the Mountain Farming System

Indicators	Range of Change	Indicators	Range of Change
I. LIVESTOCK RESOURCE BASE		III. PRODUCTION FLOWS	
Decreased size of livestock holding		Reduced dung production	(-) 63-80 %
Reduced proportion of cattle in herd		Reduced application of manure to cropland	(-) 60-75 %
Reduced number of draught animals per household		Reduced per ha production of crop by-products (straw)	(-) 33-70 %
Increased proportion of crossbred cattle		Decreased level of concentrate feeds	(-) 73-84 %
Reduced proportion of draught animals in the herd		Reduced milk productivity (per head per day)	
Decreased area under forests/pastures		Cows	(-) 33-50 %
Reduced availability of grazing area due to		Buffaloes	(-) 50-67 %
(a) construction works in the high Himalayas		Higher intensity of plough hining (no. of families)	(+) 0-40 %
(b) invasion of exotic plants in the lower hills		Reduced intensity of plough sharing (no. of families)	(-) 30-7 %
(c) conversion into cultivated land		Decreased availability of suitable wood for tools and implements	Low-High
II. RESOURCE MANAGEMENT		Increased time spent in fodder collection from CPRs	(+) 200-400 %
Increased use of pine needles as bedding material		Increased dependence on human labour for agricultural work	(+) 100-200 %
Use of weeds as bedding material		Fodder supplies from	
Emphasis on White Revolution technology for animal husbandry		Common Land	(-) 50-75 %
Emphasis on non-fodder annuals and trees		Private Land	(+) 100-150 %
Emphasis on HYVs with narrow straw-grain ratios		Increased bullock-work hours per day without rest	(+) 67-167 %
Increased use of CPRs for non-pastoral activities			
Replacement of social sanctions of CPR use by legal measures			
Reduced fallow periods for use of PPR as CPR			

Source : Adapted from Singh(1992). Some of the statistics are based on the present study.

(Time Frame : Approx. 40 Years)

Private Property Resource) was left fallow for about six months a year. During the fallow period that private land used to function as a CPR on which livestock were grazed. Now, due to reduced fallow periods, especially in highly transformed areas, livestock owners have no opportunity to use Private Property Resources (PPRs) as CPRs. Emphasis on high-yielding varieties (HYVs), generally characterised by a narrow straw-grain ratio, in place of native plant varieties with reverse characteristics (i.e., a wider straw-grain ratio) leads to reduction in fodder supplies from cultivated land.

Today, in livestock production flow-patterns, one finds a considerable reduction in dung production, manure application, straw production, concentrate feeds, and milk productivity. A decrease in supplies of wood suitable for agricultural tools and implements is another noticeable negative change. Ecological degradation and reduction in the area of the commons lead to reduction in fodder supplies, while a steep increase in fodder supply from private lands is evident; and these are, obviously, negative indicators. Draught bullocks are overworked throughout the day and receive less care; this is a negative indicator (increase in working days and total work hours with adequate feeding and care would be a positive indicator). A decrease in draught animals also leads to increased dependence on human labour, often resulting in an increase of the burden women farmers bear. Ploughs are hired rather than shared, and this is symptomatic of a breakdown in social cohesion. Negative indicators portraying the dynamism of unsustainability are, of course, not independent. Changes at one level are bound to induce changes at other levels.

3.3 Factors Contributing to a Decline in DAP

Rising population pressure is one of the principal factors causing environmental degradation, in general, and agricultural deterioration in particular. The gravity of the situation can be realised from the statistics on population density in the Central Himalayan region. In 1971, there were 5.22 persons per ha of cultivated land. In 1981 and 1991, this figure was 5.66 and 7.1 persons per ha of cultivated land, respectively. In the present study areas, human density on cultivated land ranges from 8.44 in the hill zone to 14.75 in the high mountains. In the middle mountains, these figures for traditional and transformed areas are 9.87 and 11.62 persons per ha of cultivated land, respectively. In other words, population pressure in our study areas is considerably higher than in the Central Himalayas as a whole.

The average size of per capita cultivated land, an important indicator of the pressure on land, in the Central Himalayas in 1991 was 0.14 ha. Per capita cultivated land figures for our study areas are : 0.22 ha in the hills, 0.13 ha in the middle mountains (traditional), 0.09 ha in the middle mountains (transformed), and 0.10 ha in the high Himalayas. In most of the areas in the Himalayan mountains, according to Partap and Watson (1994), per capita cultivated land declined by 30 to 45 per cent from 1960 to 1980, and this occurred despite the extension of agriculture on to sub-marginal lands/steep slopes.

There is a myth regarding population pressure in mountain areas. It is often stated in official reports that the density of population in mountain areas is much lower than that of the plains. This calculation is made on the basis of the number of persons per square kilometre of geographical area. The fact that population pressure on cultivated land in the mountains is comparatively higher than that in the plains often remains concealed. From the point of view of mountain specificities, this pressure is bound to become intolerably high. Thus, the compulsions for expansion by clearing forests on commons and reserves, and even on steep slopes, have been and are great.

Human population growth generally favours a corresponding growth in livestock population. However, due to a corresponding increase in the number of households, the livestock holding size (number of livestock per household) decreases. This vast population of livestock, in addition to being an important source of family income, nutrition, and agricultural power, also contributes to a general deterioration in the environment, particularly when CPRs have been lost, legal sanctions on the use of CPRs prevail, no community system for CPR management exists, and animals are deprived of cropland produce (mainly the foodgrains as concentrate feed). Common land available per head of livestock in our study areas ranges from 0.02 ha in the Greater Himalayas to 0.34 ha in the Middle Himalayas under traditional farming systems. This stocking rate is too high to allow for the ecological regeneration of the commons. Some pressure on the commons is eased when animals can be provided with fodder from agroforestry systems, reserve forests, and alpine meadows.

An environment has been created for improvements in milk productivity through conventional White Revolution technology. Yet this technology (discussed in detail in a different section of this chapter) has achieved only limited success. The changes in herd composition this has promoted are leading slowly to a decline in multipurpose cattle of native breeds and a steep rise in the population of single-purpose and voraciously-grazing ovines, and this situation will aggravate ecological decline and draught power deficit (Singh 1992).

3.4 The Current Scenario

Commercialisation of mountain agriculture represents the efforts of mountain farmers to use scarce land resources more efficiently for gainful employment and increased incomes. The cropping approach is based on cash crop farming and intersystemic linkages; new forms of diversification (activities); using inputs from science and technology; and building sound upland-lowland linkages (Partap 1995).

Mountain environments provide suitable niches for special activities and products, and harnessing these niches with appropriate location-specific farming activities has comparative advantages in the mountains in relation to the plains. The diverse agro-ecological conditions or farming situations prevailing in the mountains form suitable niches for fruit crop farming, floriculture, spice cultivation, and medicinal and aromatic

plants. In the process of transformation, it is fruit crop farming that receives most focus. In the lower fertile valleys equipped with irrigation facilities and well-linked with markets, vegetable-based transformation has taken place. In some areas at high altitudes, particularly between 1,800 and 2,500m, orchards are the core of the process. In selected pockets at high altitudes establishment of apple orchards has brought about a significant change in mountain agriculture. With its high moisture regime, this area also provides an appropriate niche for off-season vegetable farming. Generally, apple cultivation and off-season vegetable cultivation are found together. In lower valleys, changes in the genetic compositions of cereal crops are common.

Generally, transformation in any area is not uniform or total. Several cropping systems, representing both traditional as well as transformed farming, occur concentrated in the same agro-ecological zone, and thus transformation is actually the result of diversified farming activities. This mix of cropping practices tilted towards a commercial farming system, in addition to providing on-farm and off-farm employment opportunities and raising economic standards of the households improves the security of the overall system. One thing is common to the development of the transformed systems mentioned above. They are all energy intensive. In addition to the use of from low to high external inputs, the systems require large amounts of animate energy, as discussed in Chapter 2. In mountain areas, owing to specific circumstances, fossil fuel-powered machines have not become a part of the transformation process as one expects in the plains, for example. Draught animal power and human energy form the only sources of energy initiating and maintaining the transformed system.

3.5 Household Limitations

Different production systems within different agro-ecological zones in the mountains tend to adopt a particular transformation process. The local soil conditions, regional climate, cropping preferences, local productivity, profitability considerations, security aspects, and sustainability are the main factors driving a particular transformation process. The general process, however, is constrained by household limitations. Only those farmers who have profitable amounts of land can afford to meet external input and energy requirements and only these who have sociopolitical awareness can get access to appropriate technology and marketing facilities; these are the farmers who become involved in the transformation process.

Families with marginal landholdings generally do not maintain draught animals. They rather depend on hired bullocks for land preparation. Small landholders generally keep bullocks either throughout the year or only during the land preparation period (ploughing season). Hiring-in and hiring-out draught animals are common practices. Sharing bullocks or ploughs is common, particularly in untransformed areas.

Transformation has reduced the incidence of sharing and has encouraged the incidence of hiring. Families with insufficient labour, as a consequence of male migration or otherwise, generally do not rear bullocks and depend exclusively on hired ploughs.

The incidence of plough hiring persists, particularly among medium-sized groups, if there is a labour shortage. Purchase, sale, and exchange of draught animals among all groups are very frequent.

In recent years, DAP has provided handsome profits and employment for some families, especially in the small and marginal landholding groups. In addition to preparing their own land, these families hire out their bullocks, with or without ploughmen, at prescribed rates. This practice, further strengthened by the transformation process, has emerged as an income-generating enterprise for a number of households.

Unlike in traditional areas, labour exchange and DAP-sharing within a community is rare in transformed areas. And this should be taken as a negative implication on the transformation process.

3.6 Changing Cropping Patterns and Livestock Fodder

Transformation in mountain agriculture is set to have a severe affect on livestock fodder supplies from cultivated land. Presently, an estimated 35 per cent of the livestock fodder supply comes from cultivated land. With continuous pressure on CPRs, dependence on cultivated land for fodder supplies is likely to increase. Yet, the changing trend in cropping patterns involving high-value commercial crops precludes opportunities for increasing dependence on cultivated land for livestock fodder. In the horticulture-dominated farming system, the foremost type of transformed agriculture, land is no longer used to provide fodder for livestock.

The trend of changing cereal cropping pattern is also not conducive to livestock health. The total area under agricultural crops has declined over the past decade, i.e., from 1980-81 to 1990-91. A look at the total production and productivity of foodgrain crops (Govt. of UP 1993) reveals that the decline is particularly evident in the case of cereals. Among the cereals, according to mid-1980s estimates (Singh and Naik 1987b), nearly 56 per cent of the total dry fodder derivable from cropland in the Kumaon Himalayas was contributed by two millet crops, finger millet and barnyard millet. Yet both these crops have registered a maximum decrease in area cultivated over the last decade. Pulses, the second source of good fodder from cultivable crops, have also declined in terms of area sown. Soyabeans are the only pulse/oilseed crop to maintain an increasing trend in area under cultivation as well as in production. But giving this 'introduced' crop, so much emphasis does not provide fodder, and it usually replaces the millets, which are also the principal fodder crops. Barley, the only cereal that provides dry fodder as well as concentrate has also registered a considerable decline both in area under cultivation and production.

Increase in the productivity of important crops has been possible thanks to the adoption of HYVs and external agro-inputs. Since dwarf HYVs are characterised by narrow straw-grain ratios, their adoption in favourable areas has not led to an increase in fodder

supplies. Moreover, the fodder provided by HYVs is less preferred than that provided by the long-stalked native crop varieties. Mountain farmers give great importance to the high fodder-yielding native varieties of crops. Poor straw yields inherently associated with the dwarf, high grain- yielding varieties have been among the factors that have had an adverse impact on the agricultural transformation process, particularly in the large-scale adoption of new varieties of food crops.

3.7 White Revolution Technology - Implications on 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 Himalayan mountains, as also in the whole country and, in fact, all over the Third World. In the Central Himalayan region, crossbreeding programmes initially began in 1956 at Vikas Nagar, Dehradun district in Garhwal where Jersey bulls imported from Europe were introduced. This activity was extended to Ranikhet in Almora district in Kumaon region in 1963. In 1969, the crossbreeding programme was taken up on a massive scale by the Indo-German Project (IGADA) in Almora (Agricultural Finance Corp. Ltd. 1987).

Cattle improvement through crossbreeding, popularised as the White Revolution, despite massive financial investments, has met with little success. In 1982 there were 94,240 crossbred cattle accounting for about five per cent out of a total of 1,909,929 cattle. In 1988, the crossbred cattle (81198) accounted for about four per cent of the total cattle (1,941,962) in the region. Out of the total bullock population crossbred bullocks accounted for about five per cent in 1982 and about four per cent in 1988 (Table 3.2).

Table 3.2: Native and Crossbred Cattle in the Central Himalayas, India

Cattle	1982	1988
Total Cattle	1,909,929	1,941,962
Native Cattle	1,815,689 (95.07)	1,860,764 (95.82)
Crossbred Cattle	94,240 (4.93)	81,198 (4.18)
Total Bullocks	71,0787	756,593
Native Bullocks	672,868 (35.23/94.67)	729,244 (37.55/96.39)
Crossbred Bullocks	37,919 (1.99/5.33)	27,349 (1.41/3.61)

Source : Based on the data given in the statistical books for all districts.
Figures in parentheses denote percentage of total cattle/percentage of total bullocks.

There have been no official figures on crossbred cattle since then. In the present study, no exotic breed phenotype nor its productive capacity was in evidence anywhere.

While the crossbreeding programme has been considerably successful in the Himalayan Terai, in the hills and mountains it has been largely discarded. In the context of mountain areas, the White Revolution technology can be questioned on the following grounds.

- The production of crossbreds cannot be sustained without adequate supplies of feed such as cultivated leguminous fodder and concentrates – the cakes and foodgrains. If limited cultivated land is spared for livestock production (for raising leguminous fodder) and if a large proportion of the foodgrain goes to the animals (to meet their need for concentrates), then animals would be in direct competition with human beings.
- Leguminous fodder crops grow well on irrigated land. In the mountains of the Central Himalayas only about 10 per cent of the arable land is irrigated. If a sizable area of this land is put under fodder cultivation, it might further aggravate the problem of family food supplies in an area that is already food-deficit and imports large quantities of foodgrains from the plains. In a subsistence farming situation, setting aside fertile land for purposes other than food production is very risky.
- Native cattle can eat considerably more poor quality roughages than exotic cattle breeds because the gut contents of local cattle account for 33 per cent of the body weight, far more than in the case of exotic cattle in which the gut contents account for only 20 per cent of the body weight (Orskov 1984). Indigenous breeds convert the roughages, supplemented with green fodder (grasses and leaves), more efficiently than their crossbred counterparts (Nair 1982 and Jackson 1985). Native cattle can sustain and produce to some extent, by feeding on poor quality roughages of crop residues on which exotic cattle cannot even survive.
- Crossbreds are more prone to diseases, external parasite attacks, and weather extremes, and mountain farmers prefer to keep breeds that are hardy and adapted to local environment and feed resources. Exotic breeds cannot cover long distances; negotiate with rugged, narrow, and stony paths; or graze on steep mountain slopes, but local cattle can.
- Crossbreeding as such is very expensive technology for livestock development. This not only compells livestock owners to depend on the market system for essential feed items—cakes, brans, mineral mixture, vitamins, additives, etc — but also requires a whole veterinary network to take care of the health aspects and manage breeding programmes. Indigenous livestock, on the other hand, consume the feeds produced within the system.
- Local cattle consume biomass from forests and grazing lands and transfer its nutrients to cultivated land, eat crop residues, and recycle the nutrients to the same land on

which they grow. The linkages of local cattle with other farming system components are stronger than those of exotic or crossbreds whose linkages, especially with common property resources, are either non-existent or very weak.

- The crossbreeding policy does not take into account the environment in which the animals have to live and produce (Singh 1994). In developing or less industrialised countries, the environment cannot usually be controlled. As animals have many functions, diversity has survival value. Moreover, animals selected on the basis of homogeneity do not fare well, as is illustrated by the many failures following importation of 'upgraded animals' from industrialised countries to less industrialised countries (Orskov 1995).
- The energy efficiency of crossbred dairy cows under specific mountain conditions is very low (Singh and Sharma 1993).

Female crosses of European (*Bos taurus*) and zebu (*Bos indicus*) breeds of cattle, however, have been well accepted by farmers in warm climates thanks to their increased lactation length, higher milk production and earlier age of calving. Crossbred females have also been fairly well received even in the Himalayan *Tera*i owing to their production traits. White Revolution technology was successful, significantly, only in areas where large chunks of fertile land could be devoted to animal feeding, where good veterinary services could be provided, and where there was mechanisation. Nevertheless, it was successful at family level, not at community level. In the community-based setting of the mountains, only programmes that are acceptable at the community level are likely to be successful, not those accepted by individual families.

Crossbreeding, in essence, aims to create highly specialised animals. Dairy farmers in industrialised countries keep cows that provide a lot of milk, beef farmers keep specialised beef animals. The market-oriented approach in these countries has led to homogeneity of both crops and animals in a new, controlled environment (Orskov 1995). This may not be the case in poor regions. Neither the farmers themselves nor their crops or animals in such regions are specialised. Diversity in the whole system and diversity in every component of the system provide the key to a sustainable standard of living. This is especially true of farmers in marginalised mountain areas.

Draught breeds kept by mountain farmers are multipurpose ones. They provide manure and power for agriculture and milk for the household. Pouring exotic genes into local cattle, if it is successful, will lead to the extinction of draught power.

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 indigenous cattle, since they do not have the large distinctive hump and are unable to tolerate high temperatures (Goe 1983; Singh and Naik 1987a). Farmers all over India have been reported to consider crossbred bullocks inferior in stamina, strength,

and vigour to local bullocks (Mali et al. 1983). Scientists who have worked on the draught efficacy drive for crossbred bullocks have concluded that crossbred females are good milkers if fed adequately, but when examining the field performance of their male counterparts, it is found to be extremely low, and these animals are not suitable as work animals (Annaji Rao 1983).

Roy et al. (1972) and Anand and Sundaresan (1974) have argued in favour of crossbred bullocks on the basis of these animals' heavier body weights and better field performances between 06.00 and 08.00 hours; but they have admitted that working crossbreds after 10.00 hours is difficult.

Rajpurohit (1979), after examining the performance of crossbred bullocks as draught animals critically, stated that the physical efficiency of bullocks should not be confused with economic efficiency. According to him, a crossbred bullock requires at least 50 per cent more feed than an indigenous breed of bullock; its economic efficiency, therefore, for the same unit of work, turns out to be only two-thirds that of the latter.

It should be emphasised, however, that energy output depends on many other factors; timely operations, timely availability of inputs, weather conditions, and so on; and not merely on the type of breed. Despite the fact that local animal breeds have very useful attributes compatible with mountain specificities and, therefore, need to be preserved, the crossbreeding programme might be useful in the Terai and foothill areas where fodder is plentiful and crossbreds are often used for cart haulage.

Four

DAP Management

Many variables influencing mountain agriculture determine the use of DAP. In order to examine the different DAP management systems, a quantitative assessment of the contributions of draught animals has been made. Various draught animal husbandry practices and the main constraints in the DAP system have also been closely examined. An understanding of DAP management during the current process of agricultural transformation would also help us assess the future prospects of DAP and its links with agricultural development.

4.1 Livestock Population and Composition

The data presented in Table 4.1 are on livestock population and herd structure at village and household levels. Livestock are classified into broad categories according to their functions. In the study of draught animals, this classification seems logical because comparison in terms of broad functional groups is more credible.

While in the Shivalik hills and middle mountains bovine-dominated herds are found, in the high Himalayas the overall livestock population is represented by ovine species (on an average 96%). The Greater Himalayan zone is ideally a livestock-based farming system, whereas, in the lower zones, cropping is the predominant land-based activity. Ovines (sheep and goats) are almost entirely fed on grazing and browsing grasses, bushes, and other vegetation found on common property resources (CPRs). On the other hand, cattle (bullocks and cows) partly depend on grazing and forage supplies from the commons and partly on crop residues and tree fodder from cropland (the agro-forestry system), but buffaloes are mostly stall-fed. Abundance of grazing areas are found in the alpine meadows of the Greater Himalayas, therefore a dense population of goats and sheep and a livestock-dominated farming system has developed. A considerable proportion of ovines (25%) is also found in the herds in hill villages, and this is attributable to comparatively larger areas of common land and the presence of grazing grounds in the subtropical forests in the adjoining Terai area. Ovines are not found to any considerable extent in the livestock populations of middle mountain villages. In the lower and middle areas of the Himalayas, goats are the main, or sometimes the only, ovines in the high Himalayan region. The high altitudes are very suitable for sheep raising. Sheep can withstand cold, and the alpine pastures, apart from being a source

Table 4.1: Livestock Population and Composition (Per Village and Per Household Averages) at Different Study Area

k Species	Shivaliks		Middle Him: Traditional		Middle Him: Transformed		Greater Himalayas	
	Per Village	Per Household	Per Village	Per Household	Per Village	Per Household	Per Village	Per Household
A. Bovines	859 [75.22]	3.16	791 [92.73]	7.00	204 [84.65]	2.73	527 [3.31]	4.39
<i>a. Cattle</i>	<i>674</i> [59.02]	<i>2.48</i>	<i>668</i> [78.31]	<i>5.91</i>	<i>95</i> [39.42]	<i>1.27</i>	<i>457</i> [2.87]	<i>3.81</i>
i. Bullocks	200 [17.51]	0.74	252 [29.54]	2.23	77 [31.95]	1.03	58 [0.36]	0.48
ii. Cows	297 [26.01]	1.09	257 [30.13]	2.27	9 [3.73]	0.12	223 [1.40]	1.86
iii. Male Calves	107 [9.37]	0.39	77 [9.03]	0.68	4 [1.66]	0.05	102 [0.64]	0.85
vi. Female Calves	70 [6.13]	0.26	82 [9.61]	0.73	5 [2.07]	0.07	74 [0.46]	0.62
<i>b. Buffaloes</i>	<i>185</i> [16.20]	<i>0.68</i>	<i>123</i> [14.42]	<i>1.09</i>	<i>109</i> [45.23]	<i>1.46</i>	<i>70</i> [0.44]	<i>0.58</i>
i. She-buffaloes	133 [11.65]	0.49	86 [10.08]	0.76	62 [25.73]	0.83	60 [0.38]	0.50
ii. Female Calves	52 [4.55]	0.19	37 [4.34]	0.33	47 [19.50]	0.63	10 [0.06]	0.08
B. Ovines	283 [24.78]	1.04	51 [5.98]	0.45	30 [12.45]	0.40	15290 [96.02]	127.42
<i>a. Goats</i>	<i>250</i> [21.89]	<i>0.92</i>	<i>51</i> [5.98]	<i>0.45</i>	<i>30</i> [12.45]	<i>0.40</i>	<i>4497</i> [28.24]	<i>37.48</i>
<i>b. Sheep</i>	<i>33</i> [2.89]	<i>0.12</i>	-	-	-	-	<i>10793</i> [67.78]	<i>89.94</i>
C. Pack Animals	-	-	11 [1.29]	0.10	7 [2.90]	0.09	106 [0.67]	0.88
<i>a. Mules</i>	-	-	<i>11</i> [1.29]	<i>0.10</i>	<i>7</i> [2.90]	<i>0.09</i>	<i>10</i> [0.06]	<i>0.08</i>
<i>b. Horses</i>	-	-	-	-	-	-	<i>96</i> [0.60]	<i>0.80</i>
Total Population (A+B+C)	1142 [100.00]	4.20	853 [100.00]	7.55	241 [100.00]	3.22	15923 [100.00]	132.69
Total Cattle Units*	921	3.39	817	7.23	247	3.29	3642	30.35

Figures in parentheses are percentages of the total livestock population.

* Conversion factor : Cow=1.0, Bullock=1.2, Cow Calf=0.5, Buffalo=1.5, Buffalo Calf=0.75, Goat=0.2, Sheep=0.2 Mule/Horses=1.0.

of fodder, also help facilitate the growth of fine quality wool. Sheep are reared by virtually all families, especially for their wool. Wool trading is one of the oldest occupations in this area.

Pack animals account for only a meagre proportion of the livestock population, with the percentage being greatest in the transformed villages (3%), whereas there are none in the hills. Pack animals in mountain regions usually include donkeys, horses, mules, and ponies. In our samples, there were only mules and horses. In the Greater Himalayas, however, ovines (mostly the males) are also used as pack animals. In our sample village, Gangi, bucks and rams were found transporting more luggage and farm produce than traditional pack horses. Each buck or ram carries 10kg at a time on an average; the range is from six to 12kg.

Among the bovines, while the hills and middle mountains (traditional) constitute the majority of cattle (59 and 78%, respectively), the middle mountains (transformed) have more buffaloes (45%). Among the cattle, bullocks account for 32 per cent in the transformed villages, 30 per cent in traditional villages, and only 18 per cent in the hill villages. In our samples there were no male buffaloes, either adult or young. Buffalo bulls are kept for breeding purposes only. A village usually keeps only one buffalo bull, sometimes two to three villages share a single bull. Male buffalo calves are also not maintained. A few days after birth, they are deprived of milk and starved to death.

The average livestock holding size is, naturally, highest (133 livestock head per household) in villages that have livestock-dominated farming systems, i.e., the Greater Himalayan villages practising transhumance. In the Middle Himalayan villages practising the transformed agricultural system, the average livestock holding size (a little over 3 head) is the smallest. The livestock holding size is moderate (a little over 4 head) in the hill villages and fairly large (nearly 8 head per household) in traditional middle mountain villages. The livestock holding size pattern suggests that, as we proceed from the primitive type of farming system (the livestock-based transhumant system in the Greater Himalayas) to the present traditional system in the Middle Himalayas, to the transitional system in the hills, and finally reaching the modern farming system, the importance of animals decreases. The relationship between animal size and development is virtually negative.

Buffaloes are obviously preferred in the transformed management system. Most, but not all, households, on an average, maintain one or more buffaloes. The larger grazing areas in the foothills and Greater Himalayas emphasise the priority for grazing animals rather than stall-fed ones. When feed supplies, especially green fodder, are limited, buffaloes are given preference. In the middle mountains feed supplies have become scarce as a result of large-scale deforestation. In the transformed areas, fodder scarcity has intensified due to the introduction of commercial crops that do not provide fodder. Thus, livestock holdings here are small and to convert the scarce feed resources into more remunerative, directly consumable or marketable products, buffaloes are preferred.

Maintaining unproductive periods without grazing support is difficult. An optimum livestock size is also necessary for soil fertility management under the traditional system. A greater density of external inputs for cropping in the transformed system also reduces the demand for animals producing dung.

Cattle populations are most dense in Middle Himalayan villages practising the traditional agricultural system (nearly 6 head per household, on an average), followed by the Greater Himalayan villages and hill villages, the smallest being in the transformed villages in the Middle Himalayan zone. The bullock holdings, except for in traditional villages, however, do not correspond to cattle holdings. While each household in the traditional villages owns, on an average, more than the required number, i.e., two bullocks, in all the other categories the number is below the required figure: in the transformed villages only one bullock per household is kept, and this is more than in the hills and the Greater Himalayan region. This is because of the greater proportion of females in the cattle population in the hills and the Greater Himalayas. Despite the lower percentage of cattle in the herd in the transformed system, bullock holdings are fairly large, and this is augmented by the almost negligible proportion of females in the cattle population. The traditional system is exceptionally rich in cattle with nearly equal proportions of males and females. Cattle sizes and sex ratios are the main determinants of adjustments in DAP in the mountain farming system. A holding of less than two bullocks per household suggests a certain amount of hiring or sharing. The hill villages also hire mechanical (tractor) equipment, and this might be the reason for smaller bullock holdings in these villages.

When we look at livestock holdings in terms of cattle units, they are nearly equal in the hills and middle mountains (transformed). In comparison to the overall livestock holdings, the value of cattle units decreases drastically in the Greater Himalayan villages because of the very large proportion of ovines (Table 4.1).

4.2 Distribution and Density of Draught Animals

The spread of draught animals throughout each zone depends on a number of factors. The most important factor is the land holding size. An overwhelming majority of farmers in each zone in the Central Himalayas have marginal and small landholdings. On an average, 95 per cent in the Shivalik zone are marginal and small holdings. As we ascend towards the Greater Himalayas, the percentage of these landholding groups decreases from 67 in the Middle Himalayas (traditional) to 64 in the same zone where transformed agriculture is practised and 63 in the Greater Himalayas. Most of the population of bullocks, the only draught animals in the region, however, are with the small and medium landholding groups, except in the Shivalik or foothill zone where more than three-quarters of the bullock population is concentrated in the marginal and small holding groups. In the Greater Himalayas, two-thirds of the total bullock population is owned by the medium-sized holding group (Table 4.2). Among all the sample villages, Bagauri, a village in the Greater Himalayan zone, has no bullocks. The distribution of

animals according to landholding categories among villages within each zone is very uneven (see also Annex 12).

In order to be functional, each household should keep two bullocks. But the overall average suggests that, apart from the traditional Middle Himalayan zone, holdings are less than functional, being the smallest (0.48) in the Greater Himalayas. In the Shivalik hills the average is only 0.74 bullocks per family and in the transformed Middle Himalayas, only 1.13 bullocks are kept. Comparatively, the overall bullock holding in the traditional Middle Himalayan area is 2.23.

The fact that holdings do not meet requirements indicates that sharing and hiring take place. In the Shivalik hills and Middle Himalayas (traditional) holdings increase with an increase in landholdings up to medium farmlands but are the least on large farms in the former zone and decrease slightly in the latter. In the other two zones, nevertheless, holdings increase with the size of landholding (see also Annex 13).

Bullock density (number of bullocks per ha of cultivated area) decreases constantly with an increase holding size in the first three zones; they decrease most sharply in traditional areas in the Middle Himalayas. In the Greater Himalayas, however, bullock density increases sharply on small farms and then decrease with the increasing holding size. The overall average is the lowest on the Shivalik hills, followed by transformed areas in the Middle Himalayas and the Greater Himalayas; and it is highest in traditional area of the Middle Himalayas. Among all the zones, traditional areas in the Middle Himalayas are the richest in terms of both bullock holdings and density. Bullock density figures, with respect to various landholding groups, corroborate those of Singh (1995) and Subrahmanyam and Rao (1995) in their studies of southern and western regions of India. It is interesting to note that the average density across zones of draught animals in our case (1.37) is appreciably higher than that at all-India level (0.48) (see also Annex 14).

The degree of remoteness is a powerful factor affecting bullock population. A greater degree of remoteness has been found to encourage more a greater population of bullocks in the villages. Banali, one of the remotest villages, for example, has the largest number. Gangi, another village, the remotest of all the sample villages, ranked third in bullock population. Gangi, being very far from the plains, does not have a greater demand for bullocks from the surrounding villages. In the villages of the inner Himalayas, the bullock trading system is negligible. Taily Sunoli, another village in the traditional area of the Middle Himalayas, which ranks second in bullock population, is also very far from the plains; though very close to the main road. The villages which are very far from the plains practising traditional agriculture also favour the DAP system and discourage bullock trading. The situation of adult male migration leads to a decrease in bullock holding size and density and affects DAP management overall, as also the limited substitution of DAP by tractors in the Shivalik villages. The total effect depends on the relative strengths of all these factors.

Table 4.2 Distribution and Density of Draught Animals

Landholding Category	Shivaliks			Middle Himalayas: Traditional			Middle Himalayas: Transformed			Greater Himalayas		
	Bullock Population No. per Village (%)	Bullock Holding Size, No. per Household	Bullock Density No. per ha Cropland	Bullock Population No. per Village (%)	Bullock Holding Size, No. per Household	Bullock Density No. per ha Cropland	Bullock Population No. per Village (%)	Bullock Holding Size, No. per Household	Bullock Density No. per ha Cropland	Bullock Population No. per Village (%)	Bullock Holding Size, No. per Household	Bullock Density No. per ha Cropland
Marginal	77 [38.50]	0.67	1.96	39 [15.48]	1.50	4.02	11 [14.29]	0.44	1.82	5 [8.62]	0.07	0.46
Small	84 [42.00]	0.77	1.36	108 [42.84]	2.16	2.64	25 [32.47]	1.09	1.45	7 [12.07]	1.40	2.79
Medium	23 [11.50]	1.64	1.05	92 [36.51]	2.96	1.78	25 [32.47]	1.39	0.95	39 [67.24]	1.86	1.70
Large	16 [8.00]	0.48	0.15	13 [5.16]	2.17	0.82	16 [20.78]	1.78	0.87	7 [12.07]	2.33	1.00
Overall	200 [100.00]	0.74	0.88	252 [100.00]	2.23	2.13	77 [100.00]	1.03	1.13	58 [100.00]	0.48	1.34

4.3 Sharing and Hiring of DAP

DAP sharing and hiring is a way of coping with the prevailing state of unequal distribution, population size, and density of draught animals. While sharing bullocks or ploughing has been an old practice in community-based agricultural activities, hiring arrangements are a recent phenomenon that has been strengthened by external development interventions in recent years. Mountain farmers have witnessed three styles of change stages in DAP usage patterns over the last 30-40 years. These are as follow.

Stage 1 : An independent DAP use system with arbitrary sharing of ploughs : Every farm family tended to keep at least one pair of bullocks and a pair of male calves to replace them after retirement.

Stage 2 : High intensity of DAP sharing : Many families started to keep only one bullock. At the time of ploughing and other agricultural operations it was used together with bullocks belonging to brothers and or close relatives.

Stage 3 : High intensity of DAP hiring : In this stage, many families ceased to keep draught animals and became dependent on hiring.

While all three patterns exist side by side in mountain agriculture, they vary in distribution and relative importance.

In the traditional areas of the Middle Himalayan zone, as many as 85 per cent of households are independent in DAP use. In the Greater Himalayas, nearly 60 per cent and, in transformed areas of the Middle Himalayas, nearly half of the total landholdings are independent in terms of draught power. In the Shivaliks or foothills, only a minority of farm households (37%) depend on independent DAP use. Nearly one-quarter of the total holdings in the Shivaliks depend on the sharing of DAP, and this is the highest figure amongst all the zones. Low-scale sharing is observable in all other zones, it being the lowest in the traditional middle mountain areas. Hiring intensity is the highest in the transformed area of the Middle Himalayas, with as many as 40 per cent of households depending on hiring for DAP. A little behind are the Shivalik hills. In the Greater Himalayan zone, 30 per cent of the holdings participate in hiring DAP. This figure seems high because one of our sample villages in this zone, Bagauri, has no draught animals. One-quarter of the total households in this village are landless, the rest come into the marginal landholding group. Out of these, 40 per cent of families use hand tools only, while others hire ploughs. In two other villages in the same zone, namely Gangi and Juma, the hiring system is absent.

Sharing-hiring ratios for the Shivalik, Middle Himalayan (traditional), Middle Himalayan (transformed), and Greater Himalayan zones work out at 0.67, 0.89, 0.26, and 0.31,

respectively. In two of the traditional middle mountain villages, Taily Sunoli and Banali, hiring is not practised at all, but the third traditional village, Goom, owing to its location, depends heavily on hiring.

Nevertheless, the sharing-hiring ratio is the highest in traditional areas. The same reason could be ascribed to the Greater Himalayan region where this ratio has narrowed because of one village's complete dependence on hiring DAP. In the transformed area this ratio is the lowest of all. Hiring out is virtually unheard of in the Greater Himalayas, but it is frequently found in the traditional mountain villages. Whereas the hiring out of all holdings and bullock holdings is equal in the traditional villages, it is in a one to three ratio in the transformed villages in the Middle Himalayas as well as in the Shivaliks (Table 4.3).

It can be inferred from the above that traditionalism together with remoteness promotes an independent DAP system, encourages sharing, raises the sharing-hiring ratio, and strengthens hiring-out management in the greater economic interests of all holdings and bullock owners. The transformation in agriculture, on the other hand, does just the reverse, apart from encouraging the hiring-out system in favour of bullock owners.

Apart from in the Shivalik zone, generally, dependence on sharing and hiring decreases with an increase in the size of land holdings, with the exception of medium-sized holdings in the Middle Himalayan zone. In the first zone, sharing and hiring persists throughout all landholding groups, but sharing is highest in the marginal group and hiring in the large group. Big farmers in two villages, namely Ganga Bhogpur and Khandgaon in this zone, depend to some extent on mechanical power so their DAP requirements have decreased. While the overall sharing and hiring percentages in traditional villages are the lowest, marginal and medium farmers in these villages actively participate in sharing and hiring activities, respectively. In the transformed villages, the sharing persists with marginal and small farmers, hiring prevails throughout all groups. More than half of the marginal farm families actively participate in hiring, small and medium farmers participate to the same degree (39%) and then there is a sharp decrease in the large farm category. In the Greater Himalayan villages farmers with large holdings are independent in the DAP system, the incidence of sharing is highest among small farmers and hiring highest among marginal ones. As already stated, two out of the three sample villages in this zone have no DAP hiring system. While hiring out is non-existent in the Greater Himalayan zone, it prevails in all other zones. Apart from the traditional middle mountain villages, large landholders do not hire out bullocks. The remarkable pattern in the traditional villages is that hiring-out at all holding and bullock-owning holding levels, apart from for marginal farm families, is equal, and at all holding levels it decreases with the size of landholding. All marginal landholders who own bullocks and half of the small holders in transformed villages take advantage of the DAP hiring-out system.

Landholding Category	Shivalks			Middle Himalayas: Traditional			Middle Himalayas: Transformed			Greater Himalayas		
	Sharing	Hiring-in	Hiring-out All-Holdings/ Bullock Owning Holdings	Sharing	Hiring-in	Hiring-out All-Holdings/ Bullock Owning Holdings	Sharing	Hiring-in	Hiring-out All-Holdings/ Bullock Owning Holdings	Sharing	Hiring-in	Hiring-out All-Holdings/ Bullock Owning Holdings
Marginal	32.17	33.91	12.17/36.84	23.08	0.00	34.62/47.37	24.00	52.00	20.00/100.00	11.27	50.70	0.00
Small	26.61	35.78	11.93/30.95	0.00	2.00	24.00/24.00	8.70	39.13	26.09/50.00	20.00	0.00	0.00
Medium	7.14	14.29	7.14/9.09	6.45	22.58	19.35/19.35	0.00	38.89	11.11/16.67	9.52	0.00	0.00
Large	6.06	69.70	0.00	0.00	16.67	16.67/16.67	0.00	11.11	0.00	0.00	0.00	0.00
Overall	25.37	37.87	10.29/28.00	7.08	7.96	24.78/24.78	10.67	40.00	17.33/34.21	9.17	30.00	0.00

In the event that households cannot afford to own a pair of bullocks, sharing DAP is clearly a positive indicator, for it keeps the population of draught animals in balance, increases the efficient and economic use of the existing population, and induces social cohesion. Sharing occurs in three ways : (i) two families maintain one bullock each and share each other's bullock for agricultural work, (ii) one family ploughs the fields of another one season and the latter reciprocates in the next season, and (iii) sharing among close relatives living in different villages. The first practice was the most prevalent a decade ago, but now maintaining a single bullock is rare. Today, the last two practices are more prevalent. The sharing arrangement is most common among marginal and small holders, since in the larger landholding groups draught animals remain busy for longer durations, and it would be difficult for them to spare their animals.

With the emerging trend of commercialisation, it seems that the tendency to hire in and out will increase.

The hiring system operates in two ways; one hires only the draught animals, or one can hire both animals and ploughman. The current average rates in the former case are Rs 80 per day, and, in the latter, Rs 130 per day. The family hiring-in the DAP has to provide fodder for the animals and two meals for the ploughman, if hired with the animals. Over the decade, an almost 50 per cent increase in hiring rates has been observed. While the hiring-in of DAP saves the expenditure on rearing a bullock of one's own, hiring-out has created avenues of employment and income generation for others. The hiring arrangement also helps keep the bullock population under control. Both hiring and sharing practices, in this respect, are conducive to environmental conservation.

The three stages of development of the DAP system were talked about at the beginning of this section and are indicative of gradual deterioration of the DAP system; the alternative management emerging appears to be an appropriate response.

4.4 DAP and Aspects of Ethnicity

Social stratification and caste systems in the rural societies of the Central Himalayas are often considered unique. Caste is one of the fundamental and distinct social institutions in Hindu social life. It provides a system of hierarchical status ascription to different social groups, primarily based on birth, endogamy, and ritual purity. Studies of caste stratification synthesised by Rawat (1993) suggest that the hierarchy of various regional caste groups (*jatis*) in the system was primarily influenced by the 'varna' model, wherein ritual considerations of purity and pollution form the basis of differentiation. Members of a particular caste, which is the real social division at least at local or regional levels, observe certain ritual acts. The behaviour of a particular caste also influences the DAP system to a certain extent, particularly in the Kumaon Himalayas.

High-ranking Brahmins in Kumaon regard ploughing as beneath their dignity. Some high-ranking Brahmins, e.g., Joshi, Pandey, Tiwari, Pant, and Dalakoti, keep bullocks but do not till their lands, they rather employ a *halia* (ploughman) from other castes or

lower status brahmins, e.g., Bhatt, Sati, and Kawdal. The bullocks and agricultural implements would be their own. The *halia* is paid in foodgrains or cash (Rs 50 per day or less). If a Brahmin tills the land himself, ignoring the social customs, he is ostracized from his caste. He is then not permitted to share 'Hukka-pani' with people belonging to the same caste. This system does not apply to Garhwal. In Garhwal, only certain individuals from the Brahmin caste who work as priests are not supposed to plough themselves.

There was no household in our sample survey for whom ploughing was forbidden. This custom, in fact, is now disappearing and the current generation is rising above such customs. In the years to come this will no longer be a DAP-related issue.

4.5 Bullock Nutrition

Draught animals in the hills and mountains are stall-fed and grazed. The mountain areas are devoid of cultivated fodder. However, cultivated fodder crops cover a sizable area of cropland in the hills. Sorghum and clover are the two main fodder crops cultivated. Green grasses during the flush season and tree leaves throughout the year are the main green fodder in the mountains. Herbaceous weeds extracted from the fields during weeding are also used for animal feed. Crop residues of wheat, rice, millets, and pulses (apart from soybeans and pigeon peas) and grass hay are the main dry roughages fed to the animals. The concentrate feeds generally include ground barley and wheat and this feed is often provided to the bullocks during ploughing season only. In some households, prior to the ploughing season, bullocks are fed ghee (refined butter), approximately half a kilo per bullock. Bullocks are also given special 'recipes' during certain festivals.

The amount of green and dry roughages stall-fed to a pair of bullocks is greater in the transformed middle mountains and the hills than in the traditional middle mountains and high Himalayas (Table 4.4). The amounts of fodder given in the table (values are on a fresh weight basis) does not include the biomass consumed during grazing.

Bullocks in the high Himalayas rely on grazing rather than on stall-feeding. In this zone they are grazed for about 2,100 hours a year. During the summer, they graze on alpine pastures and during winter on sub-alpine pastures. In traditional mountain areas too, the grazing period is quite long (about 1,700 hours per year). In the hills and transformed mountain areas grazing length is relatively shorter, about 900 and 700 hours, respectively.

Table 4.4: Annual Feed Consumption and Grazing Period by Pairs of Bullocks at the Study Sites

Item	Shivalik Hills	Middle Himalayas Traditional	Middle Himalayas Transformed	Greater Himalayas
Stall-fed Green Roughages, kg	2,497	1,111	2,625	694
Stall-fed Dry Roughages, kg	1,513	794	1,875	421
Stall-fed Concentrates, kg	106	111	118	29
Grazing Hours	860	1,168	665	2,084

On working days, bullocks are generally not grazed. They are only stall-fed. Grazing is also avoided when the weather is bad. Some roughages are also given to the animals at night when they return home after grazing. Concentrate feeds are known to farmers, but their use is particularly restricted on working days and this too depends on availability.

4.6 Castration and Training of Bullocks

Temperament, physical development, and training largely determine the amount of work a bullock is capable of doing (Goe 1983). Almost all male calves not to be used for breeding are castrated. These transhumant pastoralist societies seldom keep a bull in the herd, as is normally the case in other areas. Although most of the bullocks in the herd are castrated, those left uncastrated are used for breeding purposes.

Depending upon the breed, the type, and the growth of the animal, the best castration results are obtained when the animal is about 12 months old (Singh and Moore 1978). However, according to Goe (1983), early castration (before one year), while causing less stress, will suppress muscular development of the fore and hindquarters, especially the shoulder, neck, and thigh areas. While it is recommended that male cattle be castrated between 1.5 to 2.0 years of age (FAO 1972), in the mountain areas, in most

cases, castration is carried out between 2.5-4.0 years (Table 4.5). Judging from the quality of mountain cattle (slow growth rate, light weight, and small body compared to breeds in the plains), this seems to be appropriate.

Table 4.5: Usual Age and Weight at which Bullocks are Trained for Work in Central Himalayan Villages, India

Age Castrated, yr.	2.5-4.0
Age Trained for Work, yr.	2.5-3.5
Duration of Training, days	15-20
Age Nose-ringing, yr.	2.5-3.0
Working Life, yr.	8.0-10.0
Mature Weight, kg	140-340

There are two methods of castration used in the mountains. The traditional method, locally known as *lodi*, is applied in many remote areas, mainly in tribal villages in the Greater Himalayas. The *lodi* method is very brutal. The animal is laid down on the ground with its limbs tied. The testicles are held between two canes and crushed by a stone. This heinous shock treatment given to the animal severely affects its health and reduces its capabilities for work in the long run. In the majority of villages, castration now is performed with an instrument known as Burdizzo's castrator, or castrating pincers, designed to crush and destroy the spermatic cord and the blood vessels that supply the blood to the testicles, leaving the testicles to dry up and be absorbed. The operation, if performed by an experienced operator, is bloodless and no open wound is left open to infestation by worms or insects. The farmers do not perform this by themselves. A trained operator from a nearby veterinary dispensary occasionally visits the villages and performs this operation. To avoid or minimise insect infestation and infection, farmers

have the operation carried out in winter (and only sometimes in summer). They generally try to avoid the rainy season.

Nose-ringing is a common practice in all mountain areas, barring parts of Kumaon. In many villages in Almora district, this practice applies only to purchased bullocks or calves and not to *gharia* ones (those produced at home), for these bullocks are "gentle, disciplined, and easily manageable". In Garhwal, nose-ringing has increased in recent years, ever since the movement of bullocks from one area to the other began to take place, because of declining numbers of *gharia* bullocks. Nose-ringing becomes essential under such conditions, as the animal can be controlled in this way. The animal is ringed before training starts. It is done with an iron needle called a *syuda*. The needle is inserted in the nostril, piercing the nasal septum. A string is threaded through the hole. Normally, no antiseptic is applied on the wound; only mustard oil is applied occasionally.

Training the animal is very important. The optimum time for training depends on body weight and the physical development of the animal. In areas where not much feed is available, training should be delayed. In mountain areas, training usually commences from 2.5 to 3.5 years. Training an animal for heavy work before it attains maturity might have adverse effects. The time required to train an animal properly depends on the type of breed, the skill of the trainer, methods used, age and temperament of the animal, and type of work, e.g. ploughing, levelling, threshing. Mountain bullocks are generally trained in 15 to 20 days. There are many local methods of training. A pair of young bullocks is yoked (no other implement is attached) and made to walk and run in the field. The first operation they perform is levelling. Another method is by yoking the animals to a plough. The iron ploughshare is removed to avoid injury to the animals. One person handles the plough, while another walks in front of the bullocks holding out *gur* (jaggery) and salt to tempt the animals. Sometimes the animal is tied to a pole and is frightened, causing it to run in a circle.

4.7 Bullock Purchase and Sale

Until recently, 'farmer-to-farmer' bullock marketing was the dominant system in the mountains. Of late, 'farmer-to-middleman-to-farmer' bullock exchange has become popular, because of the feeling that bullocks are becoming a burden on the household during idle times. A local middleman, known as a *galledar* in Garhwal, will purchase bullocks from a farmer and exchange them against poor quality bullocks with another. In this process, the middle man will receive a commission. The middleman has a poor reputation. He is often regarded as a 'merciless', a 'cruel' or a 'wicked' man because he treats the bullocks he exchanges on commission in an inhuman manner.

In recent years, when the cattle population began to decrease and reproduction of bullocks on the farms, particularly in the transforming villages, became a rare occurrence, a 'farmer-trader-farmer' system of sale and purchase came into operation. This is an inter-regional arrangement. Traders are people from the plains adjoining the hills. In

accessible areas of Garhwal, this system is predominant. Come ploughing season and traders with large numbers of small-sized bullocks arrive. When the season is over, the bullocks will be taken to the plains.

The families hiring-out bullocks generally keep a pair throughout the year. However, about 10 per cent of the medium and large farms in accessible areas of Garhwal, according to the farmers' own estimates, actively participate in this system of purchase and sale. They purchase a pair of bullocks just before the onset of ploughing season and sell them after sowing season is over. In this process, the traders are the main beneficiaries. The farmers have to pay more while purchasing and incur losses while selling the same pair of bullocks. Perhaps they do compensate the loss by saving on the maintenance costs.

Traders do not have bullocks who calve. They simply maintain them for sale. The hill breeds are bred in the mountains. Some of the remote villages are 'bullock banks'. These villages provide buffer stock for the other villages which do not keep bullocks for calving. Banali, one of our sample villages in the traditional area of the middle mountains, is a unique example of a place where intensive bullock breeding takes place.

The cost of a pair of bullocks ranges from Rs 2,500 to Rs 3,000 in the villages where bullocks are kept for breeding purposes and from Rs 3,500 to Rs 5,000 in other villages. Breeding is a good enterprise for villages such as Banali. During the previous year, the sale of bullocks and male calves fetched about Rs 900,000 for this village.

Bullock fairs taking place in the hills and mountains emphasise the importance of DAP in the mountain farming systems. These fairs are held twice a year before the onset of sowing. Both users and traders take advantage of such fairs.

Old, retired bullocks, in most cases, are kept at home in lieu of the services they have rendered to the family. But, in some areas, they are sold at nominal prices to outsiders who perhaps take them to abattoirs. In recent years, many incidents of protest have taken place against this practice in some parts of the Kumaon Himalayas.

4.8 Main Constraints

Identification of the main constraints is the first step to overcoming them and rendering the system sustainable. A summary can be found in Table 4.6.

Resource-related Constraints

Topographic variation creates some difficulties in using DAP. Undulated terrain, altitude variation, and steepness of slopes create some barriers by reducing accessibility to many areas and thus severely affecting the management of resources.

Table 4.6: Summary of Main Constraints and Their Effects on the Use of DAP in Mountain Agriculture

Main Constraints	Main Effects/Consequences
Resource – Related	
<u>Topographic Variation</u> (difficult and undulated terrain, reduced accessibility, altitudinal variation, weather extremes)	Difficulties in full use of DAP, loss of time and energy of humans and animals, difficulties in transportation of inputs and outputs, increased vulnerability
<u>Fragmented and Scattered Holdings</u> (small terraced fields, long distance between parcels of land)	Difficulties in efficient use of DAP, enormous loss of human and animal energy and time, less than potential yields, difficulties in transportation of inputs and outputs
<u>Problem Soils</u> (low water holding capacity, high proportion of gravels, nutrient deficiency, low pH, shallow depth, vulnerability to erosion)	Abandonment of DAP/cultivation practices on some terraces, DAP's positive impact not fully realised
<u>Climatic Extremities</u> (rains, snowfall, hail storms, strong winds, seasonal periodical hazards)	Breakdowns in the continuous use/benefits of DAP, decreased potential of draught animals, risks to animal health
<u>Imbalanced Land Use</u> (low CPRs – cultivated land ratio, changing cropping patterns, increased resource intensities)	Reduced grazing area and fodder supply leading to poor nutrition of draught animals, decrease in draught capability of animals, higher bullock maintenance costs
<u>Changing Floristic Composition</u> (endangered climax species, emphasis on monoculture of non-fodder trees and annual crops)	Decreased amounts of fodder for draught animals, reduced draught capabilities, decrease in use of draught animals
<u>Changing Livestock Composition</u> (less proportion of draught animals in herd)	Shortage of draught power for agriculture, overuse of existing animals leading to reduced draught capabilities, excessive burden on human beings for agricultural operations
Management – Related	
<u>Lack of Improved Harnesses and Implements</u> (often inefficient and primitive implements)	Draught capability not fully harnessed, increased cases of injuries, loss of animal days, slow rate of work
<u>Improper/Inadequate Health Care</u> (neglect of ethno-veterinary services, inadequate health care infrastructure)	Decrease in draught capability of animals, slow growth rate, high infertility incidence in females, reduced lifespan and working life, high mortality rate, loss of animal days
<u>Mishandling of Animals</u> (yoking to defective implements, overwork, inhuman/merciless treatment)	Continuous overstress on animals, reduced draught output, reduced working life
<u>Conventional Animal Husbandry Policies and Programmes</u> (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 cope with power-deficit

Fragmented and scattered landholdings are a result of overall terrain conditions. This situation is rendered more difficult by the law of inheritance which makes all heirs in a family co-parceners of private land. Fragmentation of property has taken place over many generations, leading to enormous losses in terms of human labour and DAP and also in terms of the time taken going from one tiny field to another.

Low CPR-cropland ratio in the mountains and the greater proportion of ecologically less important and non-fodder tree monocultures result in the lack of good nutrition for draught animals and a consequent reduction in their capabilities. It also creates a lot of problems for agriculture (insufficient nutrient flow from forests/pastures to cropland) and in the social system (paucity of fuel, fodder, forest-based foods, foodgrains, minor timber for agricultural tools and implements, and timber for house construction).

The change in herd composition with a lower proportion of draught cattle has imposed another constraint on the DAP system. This is clearly reflected in the current livestock population trend and the emerging DAP systems which have to manage with less animals.

Reduction in grazing space and depletion of forage potential have made it difficult to maintain the productivity of large numbers of animals. Maintaining unproductive animals without CPR support is difficult. Moreover, the high cost of increased stall feeding favours keeping buffaloes rather than cows, in the context of milk prices based on the amount of fat in milk (Jodha 1992a).

Management-related Constraints

Harnesses and agricultural implements need improvement. Health care is inadequate, animals are mishandled, and conventional policies and programmes are constraints to progress.

Agricultural implements and harnesses are often primitive and inefficient. Some institutes and research organizations have produced improved designs but they are not suitable for increasing capabilities of draught animals or else. They cost too much. Extension facilities are inadequate. 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 be promoted if they work on designing better ones." Because of the traditional defective yoke that inflicts injuries on the necks of animals, it is estimated that more than a million animal hours of work are lost annually in India. Earlier work (Sarkar 1981) confirmed that wooden ploughs in numerous shapes and sizes have many disadvantages. Twenty-four to 30 days are required to prepare one hectare of land with a pair of bullocks with these ploughs, and even after five to six passes one finds undisturbed soil 11 cm below the surface, resulting in poor yields from many crops. The line of draught does not pass through the centre of resistance of the plough and, therefore, the plough does not move steadily at a uniform depth.

Health services for draught animals are far from adequate. Conventional livestock husbandry policies and programmes also have several long - term negative repercussions on the DAP system, mainly by creating an environment for developing specialised milch breeds at the cost of multipurpose (strictly speaking, dual purpose) draught breeds suitable for mountain agro-ecosystems.

It is difficult to quantify the 'average' performance of animals. Average or daily performance depends on species and their breeds, animals' weight, age and type of work, and geographical location. Climatic factors, such as excess heat, cold, and moisture, place additional stress on the animals. Physiological state, quality of feed, harness design, yokes or implements, and human behaviour can also affect working performance. Physical condition, training and health of the animal, skill of the draughtman, texture of ground surface, and length and frequency of work periods are factors that can affect the tractive efforts of the animals to a considerable degree. An increase in speed causes a reduction in tractive effort exerted or in the length of the work period (Sarker 1981 and Goe 1953).

5.1 Quantification of DAP Output

Table 5.1 shows that most draught power is expended when bullocks are used for ploughing. Though maximum tractive effort estimated is for puddling, the power expended is less than for ploughing due to a considerable decrease in the rate of work. The

Five

Tractive Performance of Animals

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5.1 Quantification of DAP Output

Table 5.1 shows that most draught power is expended when bullocks are used for ploughing. Though maximum tractive effort estimated is for puddling, the power expended was less than for ploughing due to a considerable decrease in the rate of work. The average speed of bullocks was maximum when they were yoked for levelling operations, but decreased tractive effort reduces the power output in comparison to ploughing. The power developed in this operation is close to that in weeding and earthing-up. The data

Table 5.1: Bullock Draught Power Output during Different Agricultural Operations

Operations	Average Speed (km/h)	Tractive Effort (kgf) ¹	Power (kW) ²
Ploughing	2.4	78	0.52
Levelling	2.7	48	0.36
Puddling*	1.6	95	0.42
Weeding & Earthing up*	2.6	47	0.34

Figures are based on eight hours' operation (seven hours' ploughing and one hour's levelling) by a pair of bullocks.

Each bullock weighed 250 kg.

¹ 1kgf = 9.806 newton

² 1kW = 1.34 hp

* Estimates based on Singh and Naik (1987a)

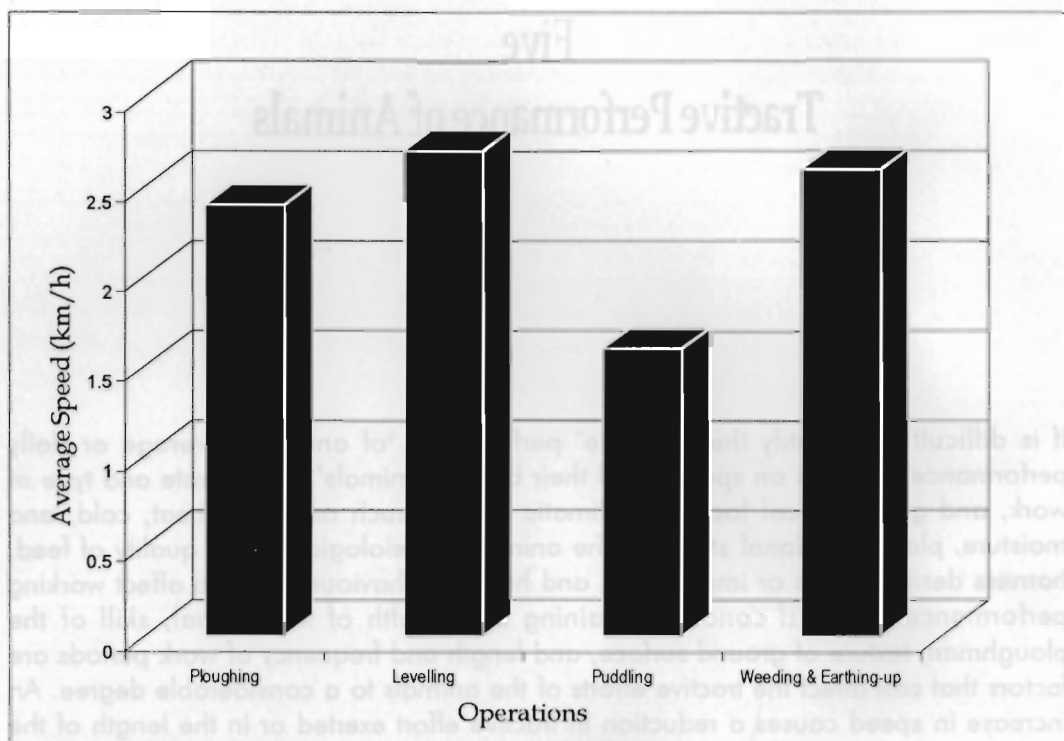


Figure 5.1: Bullock Work Rate during Different Agricultural Operations

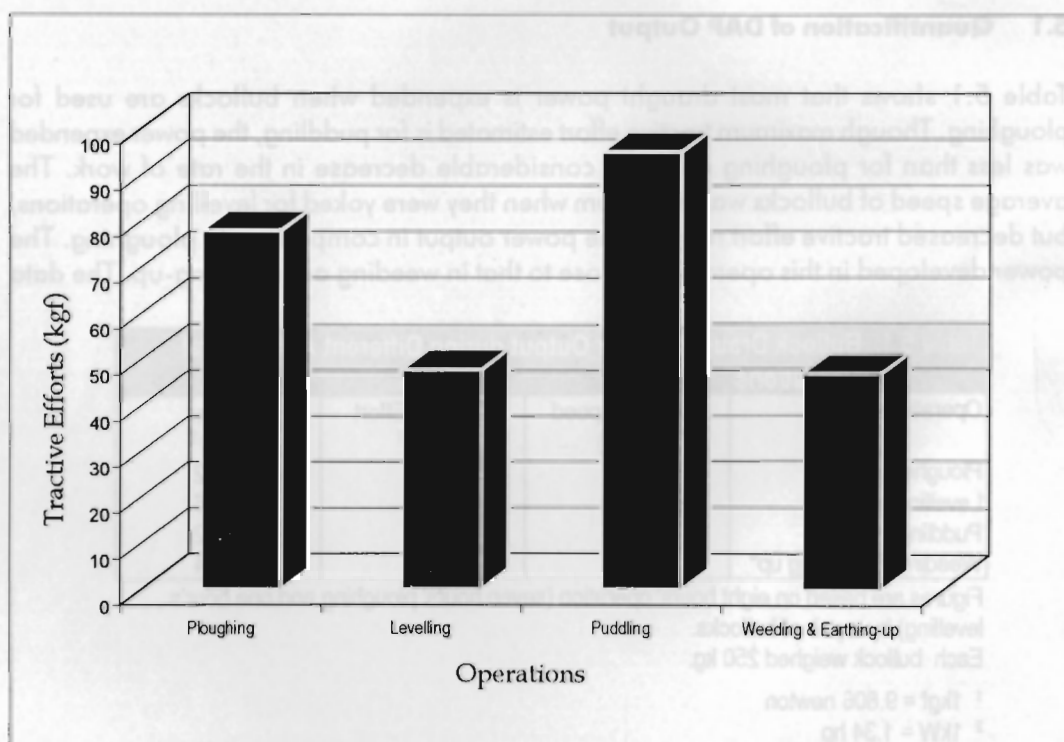


Figure 5.2: Bullock Tractive Efforts during Different Agricultural Operations

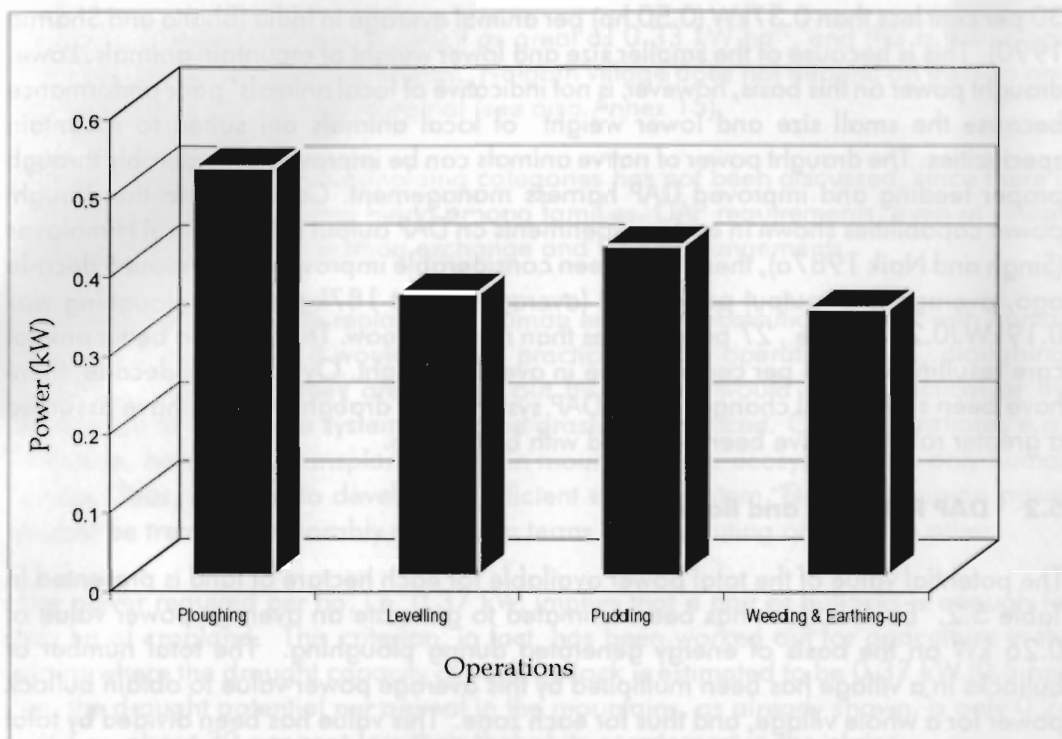


Figure 5.3: Bullock Draught Power Output during Different Agricultural Operations

recorded are based on the performance of two bullocks, together weighting 500kg, each bullock weighing 250kg. Thus, at a given speed, the tractive efforts range from nine per cent during weeding-earthing up operations to 19 per cent during puddling operations. For levelling and ploughing operations, these values are 10 and 16 per cent. In general, tractive efforts, except for those of mules, asses, and elephants, range from 10 to 14 per cent of the body weight at speeds of 2.5 to four km per hour (Goe 1983), but, in our case, at about the same speed tractive efforts during ploughing were nearly 16 per cent of the body weight, and this might be indicative of a special ability of light, native draught animals to generate a greater percentage of body weight as tractive effort than heavy animals in other regions of the world.

A pair of hired bullocks on an average ploughs and levels 1,100 square metres per day during eight hours' work, and this includes roughly one hour's rest. However, when the bullocks are one's own, they normally work for about five hours a day and, in this duration, they, on an average, plough and level just 700 square metres. Average depths and widths of furrow were recorded to be 13.5 and 14.0 cm, respectively. At a government farm in Chinyalisaur in Uttarkashi, Haryana bullocks ploughed a flat land area of 1,800 square metres in just three hours' time.

Taking draught power developed during ploughing as a standard, per animal (average weight 250kg) draught power output in our case comes to 0.26kW (0.35 hp), which is

30 per cent less than 0.37kW (0.50 hp) per animal average in India (Bhatia and Sharma 1990). This is because of the smaller size and lower weight of mountain animals. Lower draught power on this basis, however, is not indicative of local animals' poor performance because the small size and lower weight of local animals are suited to mountain specificities. The draught power of native animals can be improved considerably through proper feeding and improved DAP harness management. Compared to the draught power capabilities shown in earlier experiments on DAP output in the Central Himalayas (Singh and Naik 1987a), there have been considerable improvements. About a decade ago, average DAP output per animal (average weight 187kg) during ploughing was 0.19kW (0.25 hp), i.e., 27 per cent less than recorded now. This is due to better animal care resulting in a 34 per cent increase in average weight. Over the last decade, there have been substantial changes in the DAP system, and draught animals have assumed a greater role and have been provided with better care.

5.2 DAP Potential and Balance

The potential value of the total power available for each hectare of land is presented in Table 5.2. Each bullock has been estimated to generate an average power value of 0.26 kW on the basis of energy generated during ploughing. The total number of bullocks in a village has been multiplied by this average power value to obtain bullock power for a whole village, and thus for each zone. This value has been divided by total cropland area in the village to calculate the bullock power available for one hectare of cropland.

On the basis of considerable evidence, it has been accepted that 0.37 kW per ha of cropland should be available if any increase in productivity is to be expected (Mc Colly 1971). This shows that, if all the power is to be provided by bovines, all the zones, barring the traditional area in the Middle Himalayas, face a shortage, at least theoretically, of bovine power for agricultural work. While there is DAP surplus in traditional agriculture, Shivalik hill agriculture shows a substantial deficit. Transformed and high altitude agriculture indicate only a marginal DAP deficit. The high DAP deficit in the Shivaliks is, to some extent, substituted by tractors hired for land preparation. Among the villages in

Table 5.2: DAP Potential and Balance for Mountain Agriculture

Particulars	Shivaliks	Middle Himalayas: Traditional	Middle Himalayas: Transformed	Greater Himalayas
Cropland Area, ha	228.33	118.33	68.00	43.33
Bullocks, No.	200	252	77	58
Available DAP, kW*	52.00	65.52	20.02	15.08
DAP, kW per ha of Cropland	0.23	0.55	0.29	0.35
Surplus (+), or Deficit (-) of DAP**	(-) 0.14	(+) 0.18	(-) 0.08	(-) 0.02

* DAP value of each bullock = 0.26 kW

** Based on 0.37 kW per ha requirement of total power. If the available human power is added, the total available power will be more than required.

this zone, Khandgaon faces a deficit as great as 0.33 kW ha^{-1} , and this is the village that frequently uses fossil fuel energy. Naigoth village does not depend on tractors and here DAP deficiency is only marginal (see also Annex 15).

DAP potential in various landholding categories has not been discussed, since there is considerable exchange and hiring among families. DAP requirements, even at village level, are fulfilled by the existing exchange and hiring arrangements.

Can this power deficit be replaced by human energy? Substitution of DAP with human energy is possible, but it would be less practical. Some operations, e.g., ploughing, levelling, puddling, if they are carried out by humans would be impractical or the production of the whole system would be drastically reduced. Other operations, e.g., irrigation, harvesting, transplanting, etc in mountain agro-ecosystems use only human energy. Thus, in order to develop an efficient energy system, DAP and human power should be treated inseparably and not in terms of substituting one for the other.

The power required per ha, i.e. 0.37 kW , implies that a pair of bullocks is enough for two ha of cropland. This criterion, in fact, has been worked out for agriculture in the plains where the draught capacity of each bullock is estimated to be 0.37 kW (0.5 hp). Yet, the draught potential per animal in the mountains, as already shown, is only 0.26 kW , i.e., about 30 per cent less than that of its counterpart in the plains.

This suggests that the cropland area operational for a pair of bullocks in the mountains should be equal to 1.4 ha, this figure can be stretched to 1.5 ha. The corresponding power requirements for mountain agriculture would, therefore, be 0.35 kW per ha of cropland. The overall power balance would thus be slightly lower than shown in the Table.

How much land can a pair of bullocks work without compromising the intended productivity? When farmers were asked this question, most of them said that a pair of bullocks could work 1.5 ha (75 *nali*(s)). In our case, the average cropland area per pair of bullocks was as large as 2.28 ha in the Shivaliks and 1.74 ha in the transformed area in the Middle Himalayas, similar in the Greater Himalayas (1.5 ha), and far less than appropriate in the traditional area in the Middle Himalayas (Table 5.3).

Table 5.3: Cropland Area Operated Annually by Available Bullock Pairs

Particulars	Shivaliks	Middle Himalayas		Greater Himalayas
		Traditional	Transformed	
Cropland Area, ha	228.33	118.33	68.00	43.33
Available Bullock Pairs, No	100	126	39	29
Area Operated Per Bullock Pair, ha	2.28	0.94	1.74	1.49
Balance in Area Operated Per Bullock Pair, ha*	(+) 0.78	(-) 0.56	(+) 0.24	(-) 0.01

* Based on 1.5 ha as a standard area to be operated by a pair of bullocks.

5.3 Bullock Work Hours

Recording animal working hours is necessary to evaluate the power actually used in the farms. Use of human energy is inevitably linked to all agricultural operations carried out by draught animals, i.e., ploughing, levelling, puddling, weeding, and threshing. Other operations—hand-weeding, irrigation, transport of manure and application, breaking of clods, sowing and transplantation, fertilizer and pesticide application, harvesting and hand-threshing – use human energy only.

From Table 5.4 (all values expressed in terms of one ha of cropland over a period of one year), it is clear that in the Shivalik villages ploughing and harvesting operations for all crops need more bullock and human hours, respectively. Time needed for ploughing differs from crop to crop, the minimum being for pulses, oilseeds, and fodder (40 hours each) and the maximum for vegetables and lowland wheat. Variations in the usage of bullocks for ploughing depend on how much preparation the fields need before sowing a particular crop. Farmers have general estimates based on their own experiences. The same is true for other operations. Among all crops, lowland wheat and vegetables need more animal and human power, respectively.

Winter crops use more bullock hours, while summer crops use more human hours. On the whole, some 1,700 bullock hours and 9,000 human hours are needed to cultivate all crops in a period of one year in the Shivaliks. Human work hours are more than five times those of bullocks.

In the Middle Himalayan villages under the traditional system, bullock and human hours spent on the various operations needed to raise summer crops needed more work than for winter crops. Human hours in this area are three times those of bullock hours. Upland wheat requires more bullock hours and upland rice more human hours (Table 5.5).

In the Middle Himalayan village under transformed agricultural management, summer cropping consumes more bullock and human hours than winter cropping. Human hours devoted to annual cropping are five times the bullock hours. Lowland wheat requires the highest number of bullock hours and summer vegetables the highest number of human hours (Table 5.6).

In the Greater Himalayan villages human hours devoted to crop cultivation are about nine times the bullock hours. Amaranth crops need more human and bullock hours (Table 5.7) than other crops.

Among the four areas studied, the transformed Middle Himalayan villages require maximum bullock and human hours, followed by the Shivalik villages. Whereas the total bullock hours required by traditional Middle Himalayan villages is nearly twice the requirement of the Greater Himalayan villages, the overall human hours required for the latter are more than in the former. The total work hours invested in summer season

Table 5.4: Working Hours of Bullocks in Various Operations for Cultivation of Different Crops per Hectare of Cropland in Shivalik Villages

Operations	Summer Crops							Winter Crops							Annual Total		
	Up-land Rice	Low land Rice	Maize	Oil-seeds	Pulses	Vege- tables	Fodder	Total Summer Crops	Up-land Wheat	Low land Wheat	Barley	Pulses	Oil-seeds	Vege- tables		Fodder	Total Winter Crops
1. Ploughing*	B: 80 H: 80	80	80	40	40	120	40	480	80	120	80	40	40	120	40	520	1000
2. Levelling	B: 18 H: 18	18	18	9	9	27	9	108	18	27	18	9	9	27	9	117	225
3. Puddling	B: 18 H: 60	18	18	9	9	27	9	108	18	27	18	9	9	27	9	117	225
4. Weeding	B: - H: 180	-	-	-	-	-	-	60	-	-	-	-	-	-	-	60	180
5. Irrigation	B: - H: 36	-	80	-	-	-	-	80	-	-	-	-	-	-	-	80	80
6. Manure Trans- port & Application	B: 18 H: 120	27	45	-	18	200	-	308	-	18	-	-	-	250	-	268	576
7. Clod Breaking	B: - H: -	-	-	-	-	-	-	54	-	18	-	-	-	54	6	78	132
8. Sowing	B: - H: 16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1510
9. Transplantation	B: - H: -	-	120	60	60	200	60	740	120	150	120	60	60	200	60	770	1510
10. Fertilizer & Pes- ticide Application	B: - H: -	-	-	-	-	60	-	60	-	60	-	-	-	60	-	120	180
11. Harvesting	B: - H: 180	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	180
12. Threshing	B: 120 H: 98	200	180	8	8	200	4	452	16	40	16	8	8	200	4	292	744
Total	B: 552 H: 552	1061	579	437	510	1325	293	175	-	50	-	-	-	100	-	150	325
								1540	180	200	180	200	200	400	180	1540	3080
								50	70	80	80	50	-	-	-	280	330
								660	70	80	80	150	120	-	-	500	1160
								778	168	227	178	99	49	147	49	917	1695
								4757	484	763	494	467	437	1411	299	4355	9112

* One Tractor-hour = 10 Bullock Hours
B = Bullock, H = Human

Table 5.5:
Working Hours of Bullocks in Various Operations for Cultivation of Different Crops per Hectare
of Cropland in Middle Himalayan Traditional Villages

Operations		Summer Crops						Winter Crops			Annual Total
		Upland Rice	Finger Millet + Pulses	Barnyard Millet	Amaranth + Kidney bean	Total Summer Crops	Upland Wheat	Barley	Total Winter Crops		
1. Ploughing	B:	108	54	54	54	270	108	108	216	486	
	H:	126	63	63	54	306	126	126	252	558	
2. Levelling	B:	9	-	-	-	9	9	-	9	18	
	H:	9	-	-	-	9	9	-	9	18	
3. Puddling	B:	-	-	-	-	-	-	-	-	-	
	H:	-	-	-	-	-	-	-	-	-	
4. Weeding	B:	27	54	27	-	108	-	-	-	108	
	H:	100	100	100	-	300	-	-	-	300	
5. Irrigation	B:	-	-	-	-	-	-	-	-	-	
	H:	-	-	-	-	-	-	-	-	-	
6. Manure Transport & Application	B:	-	-	-	-	-	-	-	-	-	
	H:	125	50	50	-	225	125	125	250	475	
7. Clod Breaking	B:	-	-	-	-	-	-	-	100	100	
	H:	-	-	-	-	-	100	-	-	-	
8. Sowing/ Transplantation	B:	-	-	-	-	-	-	-	-	-	
	H:	9	9	4	9	31	9	9	18	49	
9. Fertilizer & Pesticide Application	B:	-	-	-	-	-	-	-	-	-	
	H:	-	-	-	-	-	-	-	-	-	
10. Harvesting	B:	-	-	-	-	-	-	-	-	-	
	H:	150	180	150	180	660	150	150	300	960	
11. Threshing	B:	-	50	50	25	125	75	75	150	275	
	H:	120	100	100	100	420	75	75	150	570	
Total	B:	144	158	131	79	512	192	183	375	887	
	H:	639	502	467	343	1951	594	485	1079	3030	

B = Bullock, H = Human

Table 5.6: Working Hours of Bullocks in Various Operations for Cultivation of Different Crops per Hectare of Cropland in Middle Himalayan Transformed Villages

Operations	Summer Crops						Winter Crops						Annual Total		
	Upland Rice	Low Land Rice	Fin. Millet + Pulses	Barnyard Millet	Soya-bean	Oil-seeds	Vege-tables	Total	Upland Wheat	Low Land Wheat	Pulses	Oil-seeds		Vege-tables	Total
1. Ploughing	108	108	54	54	108	54	162	648	108	162	108	108	162	648	1296
2. Levelling	126	108	63	63	126	54	189	729	126	189	126	126	189	756	1485
3. Puddling	9	9	4	4	9	4	13	52	9	13	4	4	13	43	95
4. Weeding	9	9	4	4	9	4	13	52	9	13	4	4	13	43	95
5. Irrigation	-	63	-	-	-	-	-	63	-	-	-	-	-	-	63
6. Manure Transport & Application	-	189	-	-	-	-	-	189	-	-	-	-	-	-	189
7. Clod Breaking	-	-	54	27	-	-	-	81	-	-	-	-	-	-	81
8. Sowing/Transplantation	-	54	154	127	154	-	600	1089	-	54	-	-	400	454	1543
9. Fertilizer & Pesticide Application	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10. Harvesting	-	48	-	-	-	-	48	96	-	36	-	-	48	84	180
11. Threshing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	150	150	50	50	150	50	200	800	125	150	100	100	200	675	1475
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	189	189	-	100	-	-	189	289	478
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9	200	9	4	9	4	250	485	9	54	4	4	250	321	806
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	50	-	-	100	-	100	250	-	50	-	-	100	150	400
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	150	200	180	150	150	150	150	1130	150	200	150	150	300	950	2080
	-	-	50	50	50	-	-	150	75	80	50	-	-	205	355
	120	150	100	100	100	150	-	720	75	80	100	100	-	355	1075
	117	180	162	135	167	58	175	994	192	255	162	112	175	896	1890
	564	1158	560	498	798	412	1739	5729	494	926	484	484	1889	4077	9806

B = Bullock H = Human

Table 5.6: Working Hours of Bullocks in Various Operations for Cultivation of Different Crops per Hectare of Cropland in Middle Himalayan Transformed Villages

Operations	Summer Crops							Winter Crops					Annual Total		
	Upland Rice	Low Land Rice	Fin. Millet + Pulses	Barnyard Millet	Soya-bean	Oil-seeds	Vege- tables	Total	Upland Wheat	Lowland Wheat	Pulses	Oil- seeds		Vege- tables	Total
1. Ploughing	B: 108	108	54	54	108	54	162	648	108	162	108	108	162	648	1296
	H: 126	108	63	63	126	54	189	729	126	189	126	126	189	756	1485
2. Levelling	B: 9	9	4	4	9	4	13	52	9	13	4	4	13	43	95
	H: 9	9	4	4	9	4	13	52	9	13	4	4	13	43	95
3. Puddling	B: -	63	-	-	-	-	-	63	-	-	-	-	-	-	63
	H: -	189	-	-	-	-	-	189	-	-	-	-	-	-	189
4. Weeding	B: -	-	54	27	-	-	-	81	-	-	-	-	-	-	81
	H: -	54	154	127	154	-	600	1089	-	54	-	-	400	454	1543
5. Irrigation	B: -	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	H: -	48	-	-	-	-	48	96	-	36	-	-	48	84	180
6. Manure Transport & Application	B: -	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	H: 150	150	50	50	150	50	200	800	125	150	100	100	200	675	1475
7. Clod Breaking	B: -	-	-	-	-	-	-	189	-	-	-	-	189	289	478
	H: -	-	-	-	-	-	189	189	-	100	-	-	-	-	-
8. Sowing/ Transplantation	B: -	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	H: 9	200	9	4	9	4	250	485	9	54	4	4	250	321	806
9. Fertilizer & Pesticide Application	B: -	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	H: -	50	-	-	100	-	100	250	-	50	-	-	100	150	400
10. Harvesting	B: -	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	H: 150	200	180	150	150	150	150	1130	150	200	150	150	300	950	2080
11. Threshing	B: -	-	50	50	50	-	-	150	75	80	50	-	-	205	355
	H: 120	150	100	100	100	150	-	720	75	80	100	100	-	355	1075
Total	B: 117	180	162	135	167	58	175	994	192	255	162	112	175	896	1890
	H: 564	1158	560	498	798	412	1739	5729	494	926	484	484	1689	4077	9806

B = Bullock H = Human

Table 5.7: Working Hours of Bullocks in Various Operations for Cultivation of Different Crops per Hectare of Cropland in Greater Himalayan Villages

Operations		Summer Crops				Winter Crops			Annual Total
		Amaranth	Amaranth	Kidney bean	Potab	Total	Wheat	Naked Barley	Total
1. Ploughing	B:	108	54	27	54	243	54	54	108
	H:	108	54	54	54	270	54	54	108
2. Levelling	B:	9	9	-	9	27	18	-	18
	H:	18	18	-	27	63	18	-	18
3. Puddling	B:	-	-	-	-	-	-	-	-
	H:	-	-	-	-	-	-	-	-
4. Weeding	B:	-	-	-	-	-	-	-	-
	H:	200	-	100	300	600	-	-	600
5. Irrigation	B:	-	-	-	-	-	-	-	-
	H:	-	-	-	-	-	-	-	-
6. Manure Transport & Application	B:	-	-	-	-	-	-	-	-
	H:	150	75	75	200	500	150	50	700
7. Clod Breaking	B:	-	-	-	-	-	-	-	-
	H:	-	-	200	100	300	-	-	300
8. Sowing/ Transplantation	B:	-	-	-	-	-	-	-	-
	H:	5	5	45	200	255	15	10	280
9. Fertilizer & Pesticide Application	B:	-	-	-	-	-	-	-	-
	H:	-	-	-	-	-	-	-	-
10. Harvesting	B:	-	-	-	-	-	-	-	-
	H:	200	200	200	250	850	150	100	1100
11. Threshing	B:	25	25	-	-	50	25	-	75
	H:	150	150	200	-	500	125	150	775
Total	B:	142	88	27	63	320	97	54	471
	H:	831	502	874	1131	3338	512	364	4214

B = Bullock H = Human

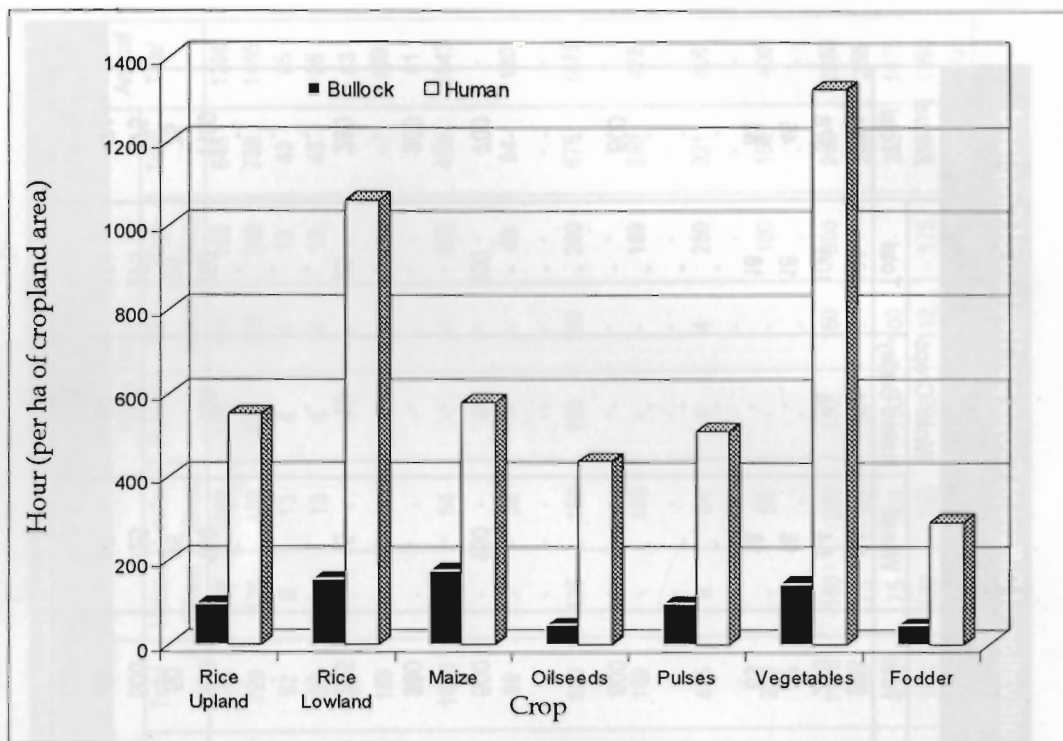


Figure 5.4: Working Hours of Bullocks for Cultivation of Summer Crops in the Shivaliks

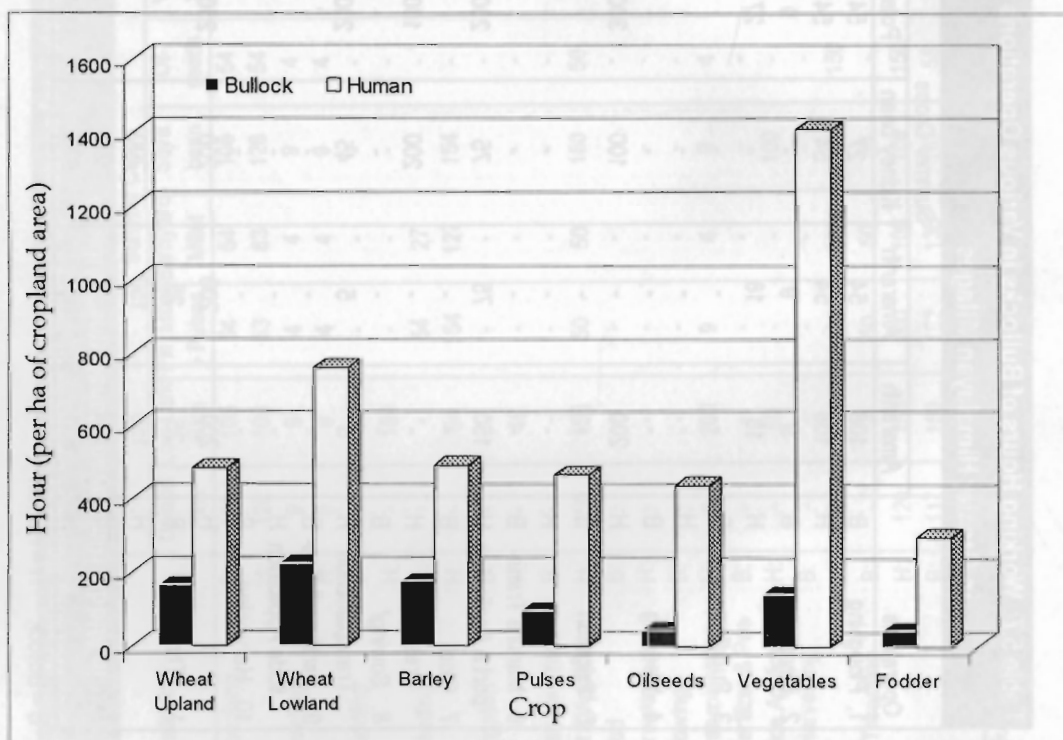


Figure 5.5: Working Hours of Bullocks for Cultivation of Winter Crops in the Shivaliks

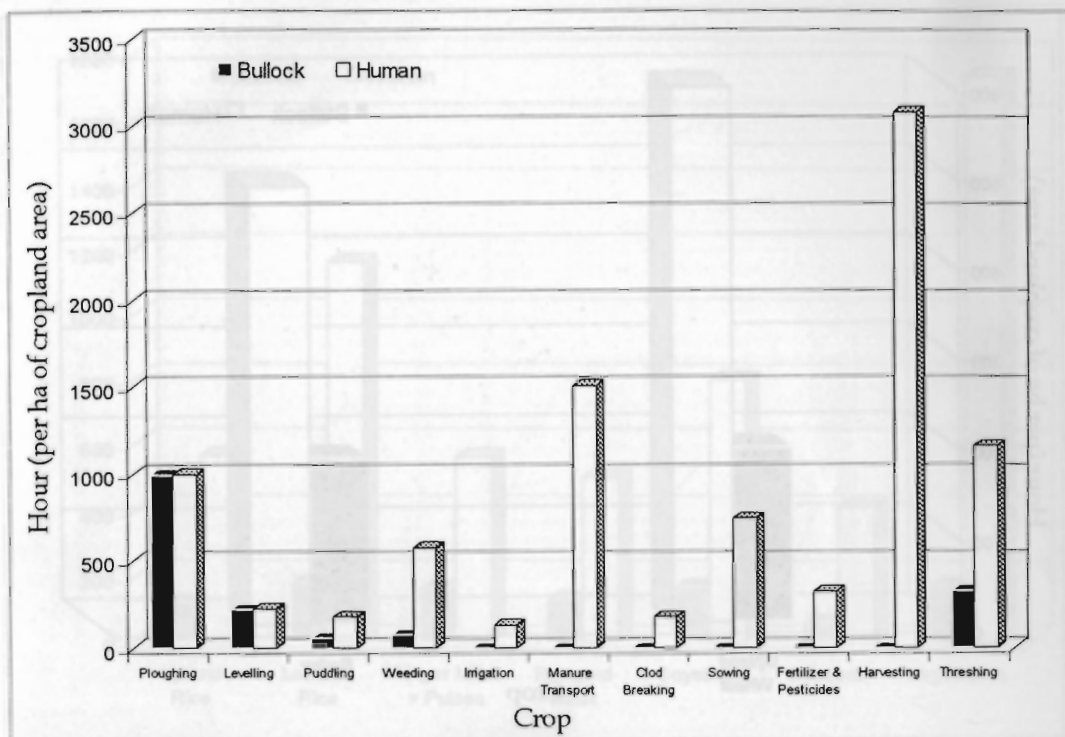


Figure 5.6: Working Hours of Bullocks during Different Agricultural Operations in the Shivaliks

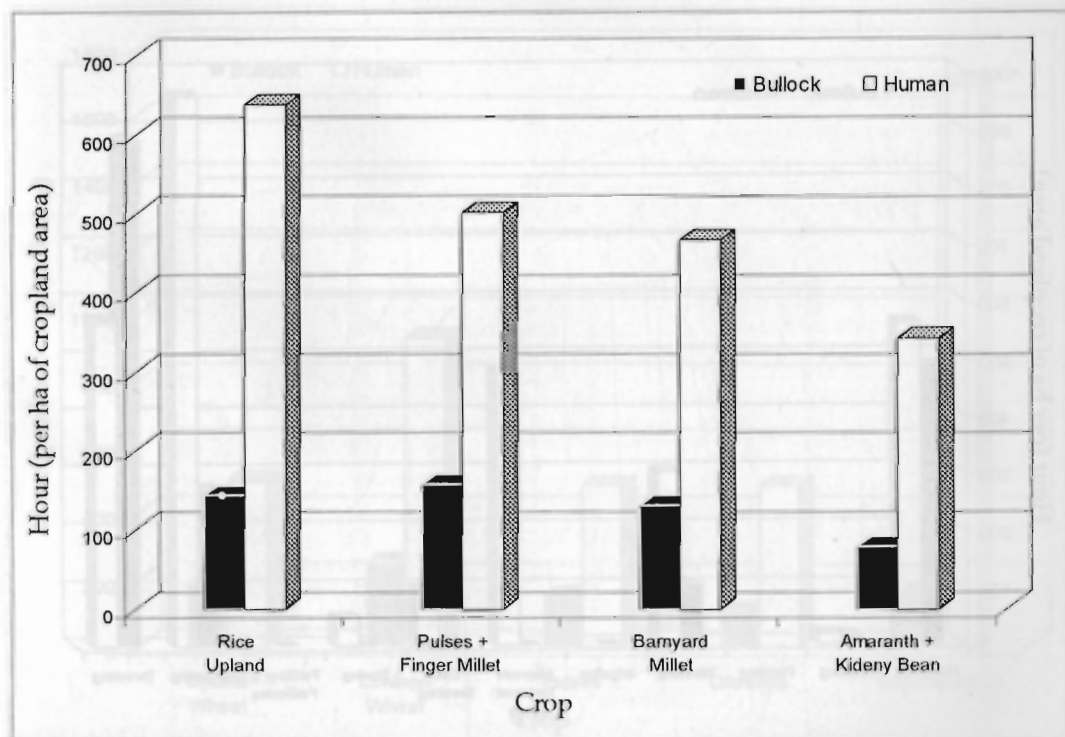


Figure 5.7: Working Hours of Bullocks for Cultivation of Summer Crops in the Middle Himalayas (Traditional)

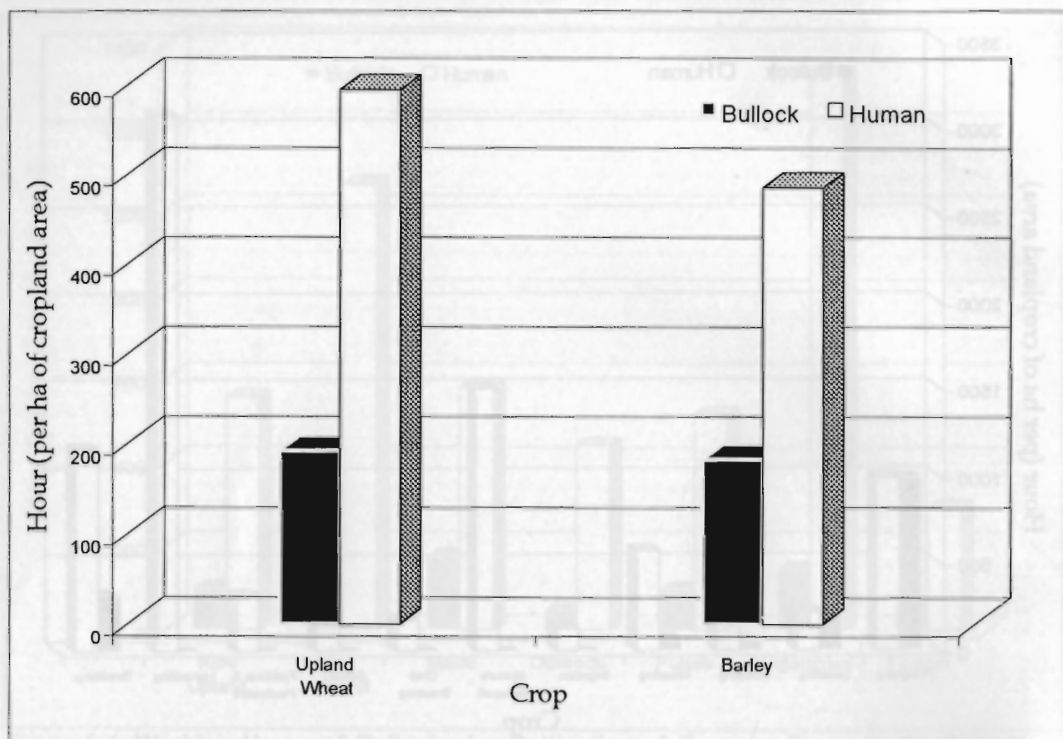


Figure 5.8: Working Hours of Bullocks for Cultivation of Winter Crops in the Middle Himalayas (Traditional)

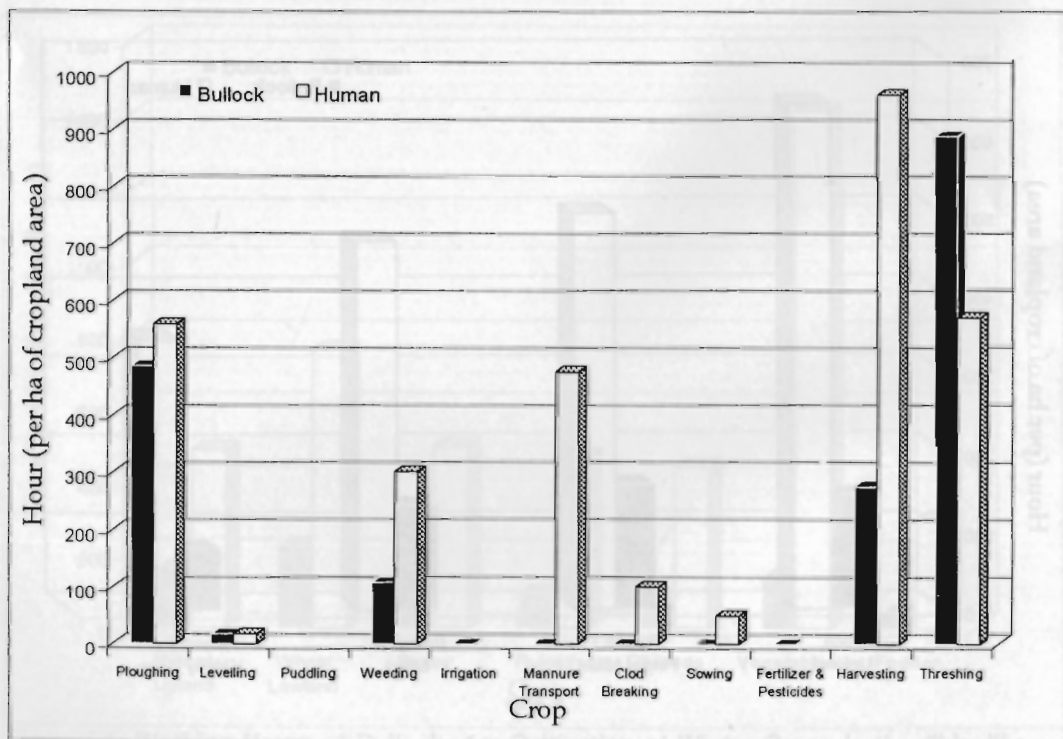


Figure 5.9: Working Hours of Bullocks during Different Agricultural Operations in the Middle Himalayas (Traditional)

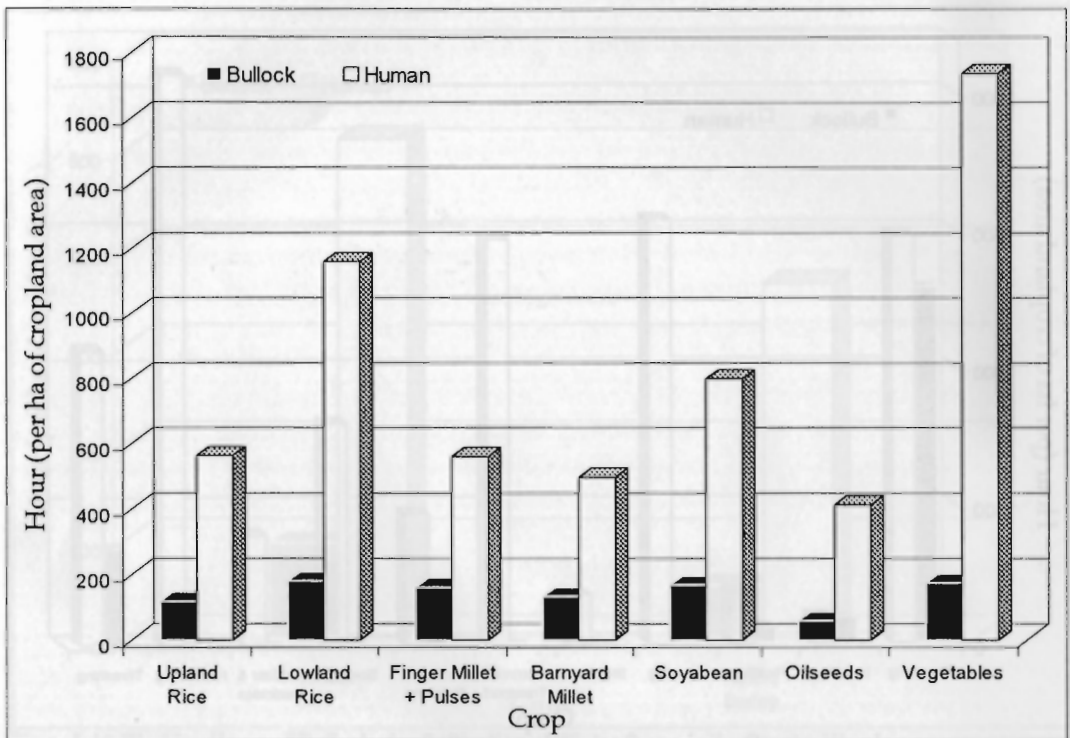


Figure 5.10: Working Hours of Bullocks for Cultivation of Summer Crops in the Middle Himalayas (transformed)

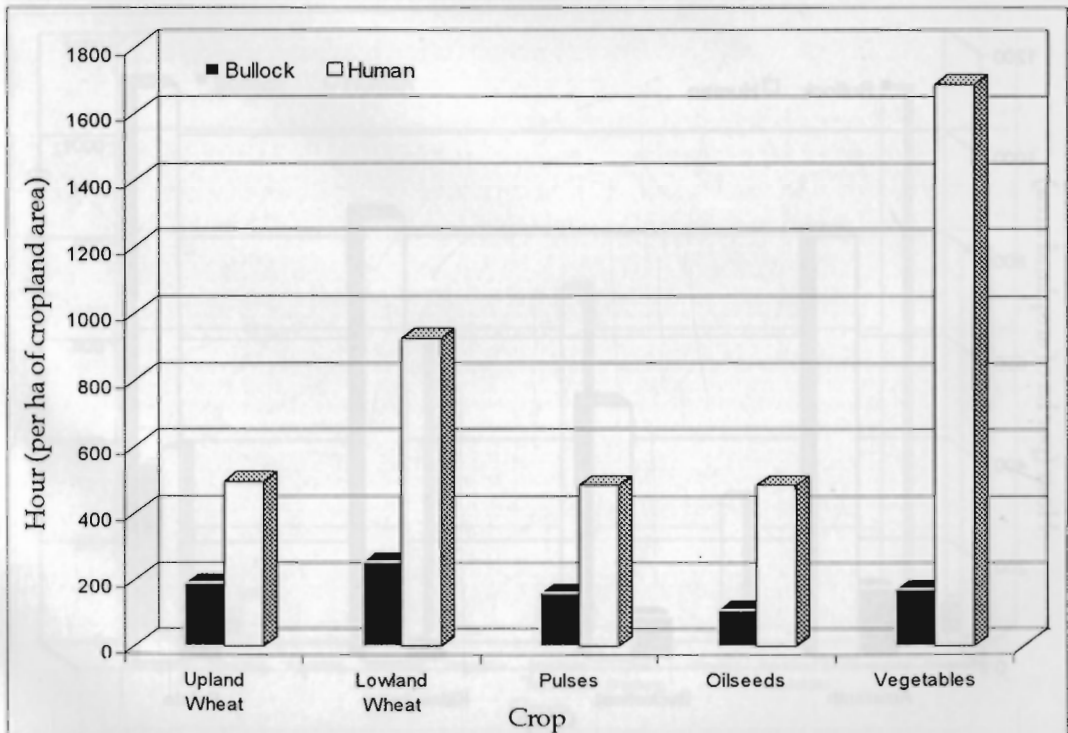


Figure 5.11: Working Hours of Bullocks for Cultivation of Winter Crops in the Middle Himalayas (transformed)

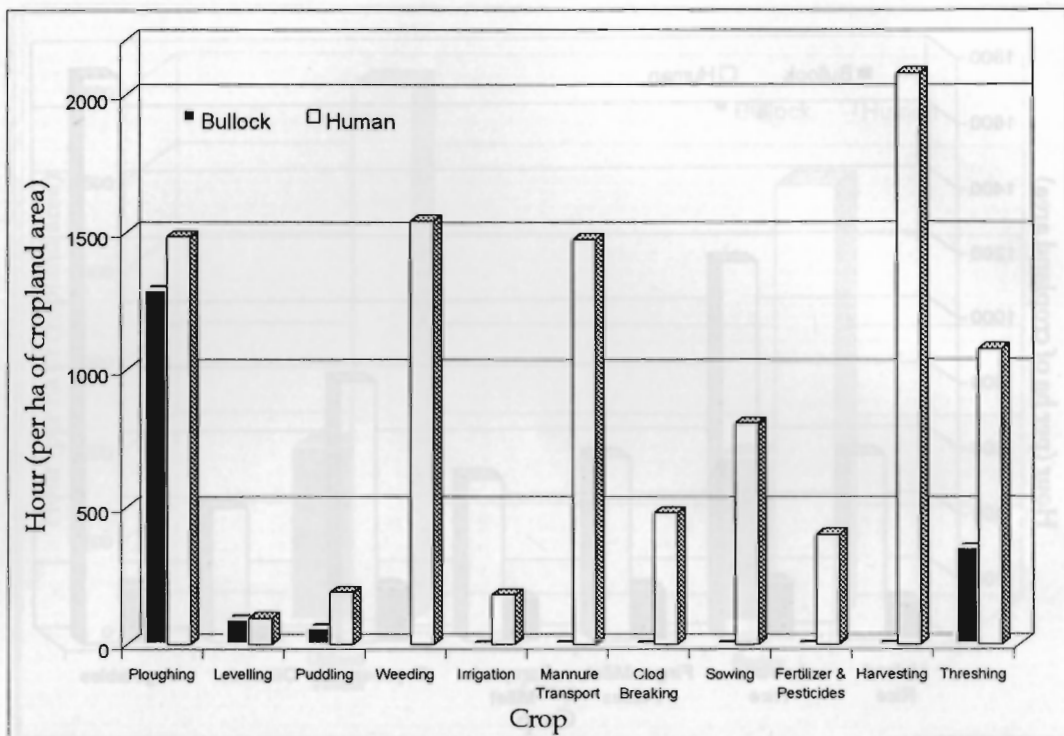


Figure 5.12: Working Hours of Bullocks during Different Agricultural Operation in the Middle Himalayas (transformed)

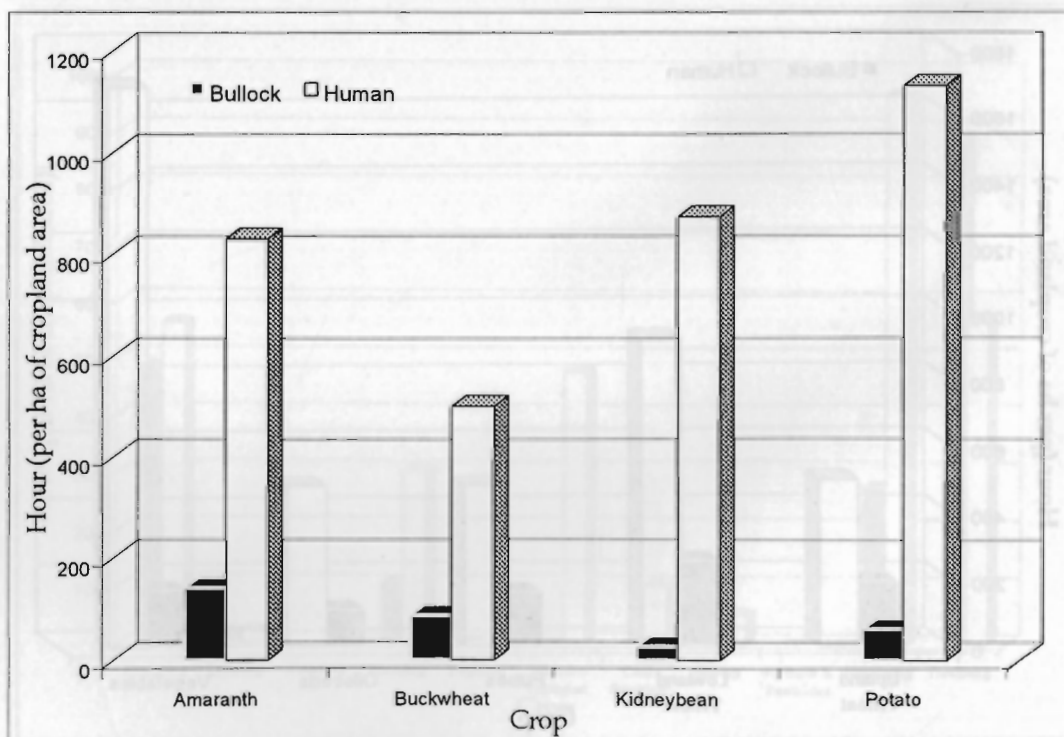


Figure 5.13: Working Hours of Bullocks for Cultivation of Summer Crops in the Greater Himalayas

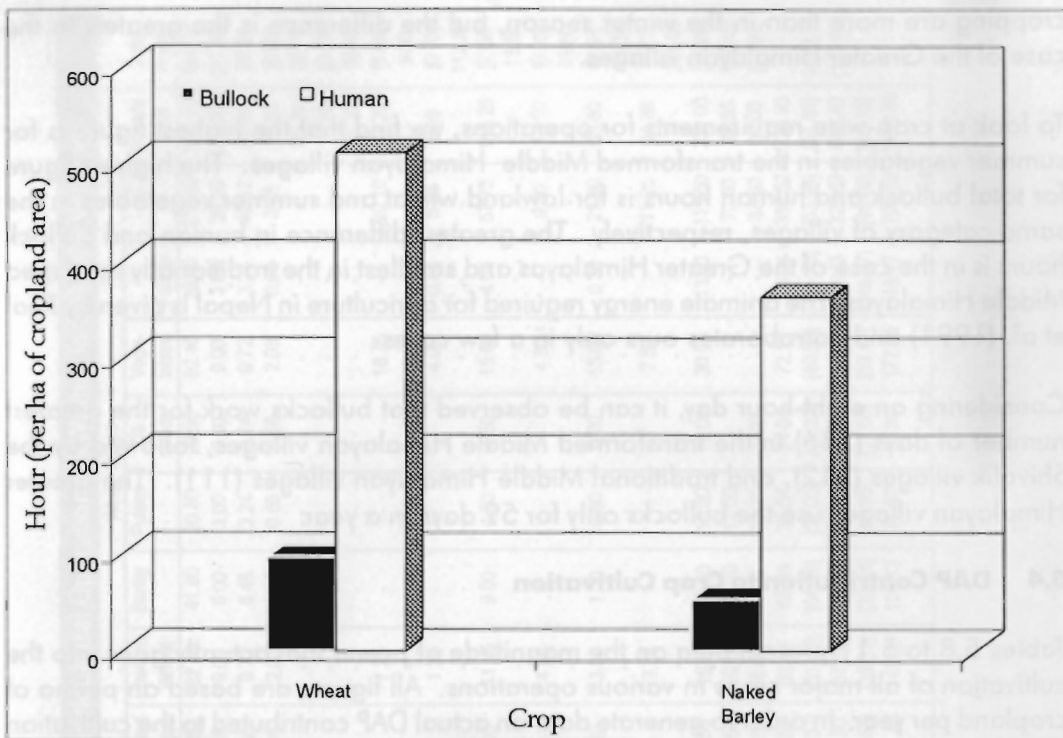


Figure 5.14: Working Hours of Bullocks for Cultivation of Winter Crops in the Greater Himalayas

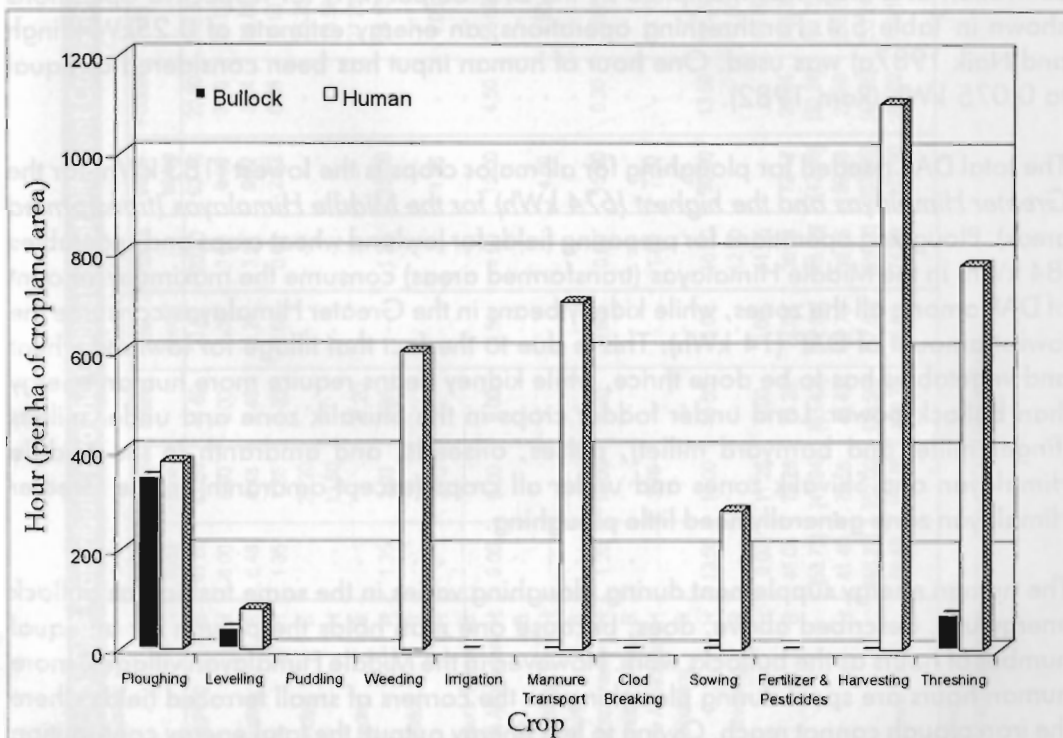


Figure 5.15: Working Hours of Bullocks during Different Agricultural Operation in the Greater Himalayas

cropping are more than in the winter season, but the difference is the greatest in the case of the Greater Himalayan villages.

To look at crop-wise requirements for operations, we find that the highest figure is for summer vegetables in the transformed Middle Himalayan villages. The highest figure for total bullock and human hours is for lowland wheat and summer vegetables in the same category of villages, respectively. The greatest difference in human and bullock hours is in the case of the Greater Himalayas and smallest in the traditionally managed Middle Himalayas. The animate energy required for agriculture in Nepal is given by Rijal et al. (1991) and corroborates ours only in a few cases.

Considering an eight-hour day, it can be observed that bullocks work for the greatest number of days (236) in the transformed Middle Himalayan villages, followed by the Shivalik villages (212), and traditional Middle Himalayan villages (111). The greater Himalayan villages use the bullocks only for 59 days in a year.

5.4 DAP Contribution to Crop Cultivation

Tables 5.8 to 5.11 present data on the magnitude of power that actually goes into the cultivation of all major crops in various operations. All figures are based on per ha of cropland per year. In order to generate data on actual DAP contributed to the cultivation of individual crops per ha per year, the total hours devoted to an operation for the cultivation of a crop was multiplied by the DAP output (kW) for respective operations shown in Table 5.4. For threshing operations, an energy estimate of 0.25kW (Singh and Naik 1987a) was used. One hour of human input has been considered as equal to 0.075 kWh (Ram 1982).

The total DAP needed for ploughing for all major crops is the lowest (183 kWh) for the Greater Himalayas and the highest (674 kWh) for the Middle Himalayas (transformed areas). Ploughing operations for preparing fields for lowland wheat crops and vegetables (84 kWh) in the Middle Himalayas (transformed areas) consume the maximum amount of DAP among all the zones, while kidney beans in the Greater Himalayas consume the lowest amount of DAP (14 kWh). This is due to the fact that tillage for lowland wheat and vegetables has to be done thrice, while kidney beans require more human energy than bullock power. Land under fodder crops in the Shivalik zone and under millets (finger millet and barnyard millet), pulses, oilseeds, and amaranth in the Middle Himalayan and Shivalik zones and under all crops (except amaranth) in the Greater Himalayan zone generally need little ploughing.

The human energy supplement during ploughing varies in the same fashion as bullock energy use, described above, does, because one man holds the plough for an equal number of hours as the bullocks work. However, in the Middle Himalayan villages, more human hours are spent during ploughing for the corners of small terraced fields where the iron plough cannot reach. Owing to less energy output, the total energy contribution of man will be less than that of bullocks.

Table 5.8: DAP Contribution to the Cultivation of Different Crops for All Agricultural Operations (kWh/ha) in Shiwalik Villages

Operations	Summer Crops						Winter Crops						Annual Total	Total Power				
	Upland Rice	Lowland Rice	Maize	Oil-seeds	Pulses	Vege- tables	Fodder	Total	Upland Wheat	Lowland Wheat	Barley	Pulses			Oil-seeds	Vege- tables	Fodder	Total
1. Ploughing	B: 41.60 H: 6.00	41.60 6.00	41.60 6.00	20.80 3.00	20.80 3.00	62.40 9.00	20.80 3.00	249.60 36.00	41.60 6.00	62.40 9.00	41.60 6.00	20.80 3.00	20.80 3.00	62.40 9.00	20.80 3.00	270.40 39.00	520.00 75.00	595.00 [41.92]
2. Levelling	B: 6.48 H: 1.35	6.48 1.35	6.48 1.35	3.24 0.68	3.24 0.68	9.72 2.03	3.24 0.68	38.88 8.10	6.48 1.35	9.72 2.03	6.48 1.35	3.24 0.68	3.24 0.68	9.72 2.03	3.24 0.68	42.12 8.78	81.00 16.88	97.88 [6.90]
3. Puddling	B: - H: -	25.20 13.50	- 27.20	- -	- -	- -	- -	25.20 13.50	- -	- -	- -	- -	- -	- -	- -	- -	25.20 13.50	38.70 [2.73]
4. Weeding	B: - H: 1.35	- 2.03	- 3.38	- -	1.35 -	15.00 -	- -	27.20 23.10	- -	- 1.35	- -	- -	- -	- 18.75	- 20.10	27.20 43.20	70.40 [4.96]	70.40 [4.96]
5. Irrigation	B: - H: -	- 2.70	- -	- -	- -	1.35 -	- -	4.05 -	- -	1.35 -	- -	- -	- -	4.05 -	0.45 -	5.85 9.90	9.90 [0.70]	9.90 [0.70]
6. Manure Trans- port & Application	B: - H: 9.00	- 9.00	- 9.00	- 4.50	- 4.50	15.00 -	4.50 -	55.50 -	9.00 -	11.25 -	9.00 -	4.50 -	4.50 -	15.00 -	4.50 -	57.75 113.25	113.25 [7.98]	113.25 [7.98]
7. Clod Breaking	B: - H: -	- -	- -	- -	- -	4.50 -	- -	4.50 -	- -	4.50 -	- -	- -	- -	4.50 -	- -	9.00 13.50	13.50 [0.95]	13.50 [0.95]
8. Sowing/ Transplantation	B: - H: 1.20	- 15.00	- 1.20	- 0.60	- 0.60	- 15.00	- 0.30	- 33.90	- 1.20	- 3.00	- 1.20	- 0.60	- 0.60	- 15.00	- 0.30	- 21.90	- 55.80	55.80 [3.93]
9. Fertilizer & Pes- ticide Application	B: - H: -	- 3.75	- -	- -	- 1.88	- 7.50	- -	- 13.13	- -	- 3.75	- -	- -	- -	- 7.50	- -	- 11.25	- 24.38	24.38 [1.72]
10. Harvesting	B: - H: 13.50	- 15.00	- 13.50	- 15.00	- 15.00	- 30.00	- 13.50	- 115.50	- 13.50	- 15.00	- 13.50	- 15.00	- 15.00	- 30.00	- 13.50	- 115.50	- 231.00	231.00 [16.28]
11. Threshing	B: - H: 9.00	- 11.25	- 9.00	- 9.00	- 11.25	- 72.12	- 24.04	- 353.38	- 65.58	- 92.12	- 68.08	- 36.54	- 24.04	- 72.12	- 24.04	- 382.52	- 735.90	735.90 [51.85]
Total	B: 48.08 H: [53.73]	73.28 [47.94]	75.28 [63.42]	24.04 [42.31]	36.54 [48.86]	72.12 [42.05]	24.04 [52.24]	353.38 [49.76]	65.58 [64.37]	92.12 [61.68]	68.08 [64.76]	36.54 [51.05]	24.04 [42.32]	72.12 [40.53]	24.04 [51.73]	382.52 [53.94]	735.90 [51.85]	1419.30 [100.00]
Total Power (B+H)	89.48 [46.27]	152.86 [52.06]	118.71 [36.58]	56.82 [57.69]	74.79 [51.14]	171.50 [57.95]	46.02 [47.76]	710.16 [50.24]	101.88 [35.63]	149.35 [38.32]	105.13 [35.24]	71.57 [48.95]	56.80 [57.68]	177.95 [59.47]	46.47 [48.27]	709.15 [46.06]	1419.30 [48.15]	1419.30 [100.00]

B = Bullock, H = Human

Figures in parentheses denote per cent of total power (B+H).

Table 5.9: DAP Contribution to the Cultivation of Different Crops for All Agricultural Operations (kWh/ha) in the Middle Himalayas: Traditional Villages

Operations	Summer Crops					Winter Crops			Annual Total	Total Power
	Upland Rice	Finger Millets + Pulses	Barley	Amaranth + Kidney bean	Total	Upland Wheat	Barley	Total		
1. Ploughing	B: 56.16 H: 9.45	28.08 4.73	28.08 4.73	28.08 4.05	140.40 22.95	56.16 9.45	56.16 9.45	112.32 18.90	252.72 41.85	249.57 [49.77]
2. Levelling	B: 3.24 H: 0.68	- -	- -	- -	3.24 0.68	3.24 0.68	- -	3.24 0.68	6.48 1.35	7.83 [1.32]
3. Puddling	B: - H: -	- -	- -	- -	- -	- -	- -	- -	- -	- -
4. Weeding	B: 9.18 H: 7.50	18.36 7.50	9.18 7.50	- -	36.72 22.50	- -	- -	- -	36.72 22.50	59.22 [10.00]
5. Irrigation	B: - H: -	- -	- -	- -	- -	- -	- -	- -	- -	- -
6. Manure Transport & Application	B: - H: 9.38	- 3.75	- 3.75	- -	- 16.88	- 9.38	- 9.38	- 18.75	- 35.63	35.63 [6.02]
7. Clod Breaking	B: - H: -	- -	- -	- -	- -	- 7.50	- -	- 7.50	- 7.50	7.50 [1.27]
8. Sowing/Transplantation	B: - H: 0.68	- 0.68	- 0.30	- 0.68	- 2.33	- 0.68	- 0.68	- 1.35	- 3.68	3.68 [0.62]
9. Fertilizer & Pesticide Application	B: - H: -	- -	- -	- -	- -	- -	- -	- -	- -	- -
10. Harvesting	B: - H: 11.25	- 13.50	- 11.25	- 13.50	- 49.50	- 11.25	- 11.25	- 22.50	- 72.00	72.00 [12.16]
11. Threshing	B: - H: 9.00	12.50 7.50	12.50 7.50	6.25 7.50	31.25 31.50	18.75 5.63	18.75 5.63	37.50 11.25	68.75 42.75	111.50 [18.84]
Total	B: 68.58 [58.36] H: 47.93 [41.14]	58.94 [61.02] 37.65 [38.98]	49.76 [58.69] 35.03 [41.31]	34.33 [57.16] 25.73 [42.84]	211.61 [59.12] 146.33 [40.88]	78.15 [63.69] 44.55 [36.31]	74.91 [67.31] 36.38 [32.69]	153.06 [65.41] 80.93 [34.59]	364.67 [61.61] 227.25 [38.39]	591.92 [100.00]
Total Power (B+H)	116.51	96.59	84.79	60.06	357.94	122.70	11.29	233.99	591.92	

B = Bullock, H = Human

Figures in parentheses denote per cent of total power (B+H).

Table 5.10: DAP Contribution to the Cultivation of Different Crops for All Agricultural Operations (kWh/ha) in the Middle Himalayan Transformed Villages

Operations	Summer Crops						Winter Crops						Annual Total	Total Power		
	Upland Rice	Lowland Rice	Finger Millet +Pulses	Barnyard Millet	Soya -bean	Oil-seeds	Vege- tables	Total	Upland Wheat	Lowland Wheat	Pulses	Oil-seeds			Vege- tables	Total
1. Ploughing	B: 56.16 H: 9.45	56.16 8.10	28.08 4.73	28.08 4.73	56.16 9.45	28.08 4.05	84.24 14.18	336.96 54.68	56.16 9.45	84.24 14.18	56.16 9.45	56.16 9.45	84.24 14.18	336.96 56.70	673.92 111.38	785.30 [49.50]
2. Levelling	B: 3.24 H: 0.68	3.24 0.68	1.44 0.30	1.44 0.30	3.24 0.68	1.44 0.30	4.68 0.98	18.72 3.90	3.24 0.68	4.68 0.98	1.44 0.30	1.44 0.30	4.68 0.98	15.48 3.23	34.20 7.13	41.33 [2.61]
3. Puddling	B: - H: -	26.46 14.18	- -	- -	- -	- -	- -	26.46 14.18	- -	- -	- -	- -	- -	- -	26.46 14.18	40.64 [2.56]
4. Weeding	B: - H: -	- 4.05	18.36 11.55	9.18 9.53	- 11.55	- -	- 45.00	27.54 81.68	- -	- 4.05	- -	- -	- 30.00	- 34.05	27.54 115.73	143.27 [9.03]
5. Irrigation	B: - H: -	- 3.60	- -	- -	- -	- -	- 3.60	- 7.20	- -	- 2.70	- -	- -	- 3.60	- 6.30	- 13.50	13.50 [0.85]
6. Manure Transport & Application	B: - H: 11.25	- 11.25	- 3.75	- 3.75	- 11.25	- 3.75	- 15.00	60.00	- 9.38	- 11.25	- 7.50	- 7.50	- 15.00	- 50.63	- 110.63	110.63 [6.97]
7. Clod Breaking	B: - H: -	- -	- -	- -	- -	- -	- 14.18	- 14.18	- -	- 7.50	- -	- -	- 14.18	- 21.68	- 35.85	35.85 [2.26]
8. Sowing/ Transplantation	B: - H: 0.68	- 15.00	- 0.68	- 0.30	- 0.68	- 0.30	- 18.75	36.38	- 0.68	- 4.05	- 0.30	- 0.30	- 18.75	- 24.08	- 60.45	60.45 [3.81]
9. Fertilizer & Pesticide Application	B: - H: -	- 3.75	- -	- -	- 7.50	- -	- 7.50	18.75	- -	- 3.75	- -	- -	- 7.50	- 11.25	- 30.00	30.00 [1.89]
10. Harvesting	B: - H: 11.25	- 15.00	- 13.50	- 11.25	- 11.25	- 11.25	- 11.25	84.75	- 11.25	- 15.00	- 11.25	- 11.25	- 22.50	- 71.25	- 156.00	156.00 [9.83]
11. Threshing	B: - H: 9.00	- 11.25	- 12.50	- 12.50	- 12.50	- 11.25	- -	37.50	- 18.75	- 20.00	- 12.50	- -	- -	- 51.25	- 88.75	169.38 [10.68]
Total	B: 59.04 H: [58.41]	85.86 [49.71]	60.38 [58.98]	51.20 [57.82]	71.90 [54.57]	29.52 [48.86]	88.92 [40.54]	447.18 [51.00]	78.15 [67.83]	108.92 [61.06]	70.10 [65.88]	57.60 [61.34]	88.92 [41.24]	403.69 [56.90]	850.87 [53.63]	1586.35 [100.00]
Total Power (B+H)	101.70	172.71	102.38	88.55	131.75	60.42	219.35	876.86	115.22	178.37	106.40	93.90	215.60	709.47	1586.33	

B = Bullock, H = Human

Figures in parentheses denote per cent of total power (B+H).

Table 5.11: DAP Contribution to the Cultivation of Different Crops for All Agricultural Operations in the Greater Himalayan Villages (kWh/ha)

Operations	Summer Crops					Winter Crops			Annual Total	Total Power
	Amaranth	Buckwheat	Kidney Bean	Potato	Total	Wheat	Naked Barley	Total		
1. Ploughing	B: 56.16 H: 8.10	28.08 4.05	14.04 4.05	28.08 4.05	126.36 20.25	28.08 4.05	28.08 4.05	56.16 8.10	182.52 28.35	210.87 [39.52]
2. Levelling	B: 3.24 H: 1.35	3.24 1.35	-	3.24 2.03	9.72 4.73	6.48 1.35	-	6.48 1.35	16.20 6.08	22.28 [4.18]
3. Puddling	B: - H: -	-	-	-	-	-	-	-	-	-
4. Weeding	B: - H: 15.00	-	-	-	-	-	-	-	-	45.00 [8.43]
5. Irrigation	B: - H: -	-	7.50	22.50	45.00	-	-	-	45.00	-
6. Manure Transport & Application	B: - H: 11.25	-	-	-	-	-	-	-	-	52.50 [9.84]
7. Clod Breaking	B: - H: -	5.63 -	5.63 15.00	15.00 7.50	37.50 22.50	11.25 -	3.75 -	15.00 -	52.50 22.50	- [4.22]
8. Sowing/Transplantation	B: - H: 0.38	- 0.38	- 3.38	- 15.00	- 19.13	- 1.13	- 0.75	- 1.88	- 21.00	- [3.94]
9. Fertilizer & Pesticide Application	B: - H: -	-	-	-	-	-	-	-	-	-
10. Harvesting	B: - H: 15.00	- 15.00	-	-	-	-	-	-	-	82.50 [15.46]
11. Threshing	B: 6.25 H: 11.25	6.25 11.25	-	-	12.50 15.00	6.25 9.38	-	18.75 20.63	82.50 58.13	76.88 [14.41]
Total	B: 65.65 H: [50.90]	37.57 [49.95]	14.04 [17.64]	31.32 [26.97]	148.58 [37.24]	40.81 [51.52]	28.08 [50.70]	68.89 [51.19]	217.47 [40.76]	533.52 [100.00]
Total Power (B+H)	63.33 [49.10]	37.65 [50.05]	65.55 [82.36]	84.83 [73.03]	250.35 [62.76]	38.40 [48.48]	27.30 [49.30]	65.70 [48.81]	316.05 [59.24]	533.52
	128.98	75.22	79.59	116.15	398.93	79.21	55.38	134.59	533.52	

B = Bullock, H = Human

Figures in parentheses denote per cent of total power (B+H).

Figures in parentheses denote per cent of total power (B+H).

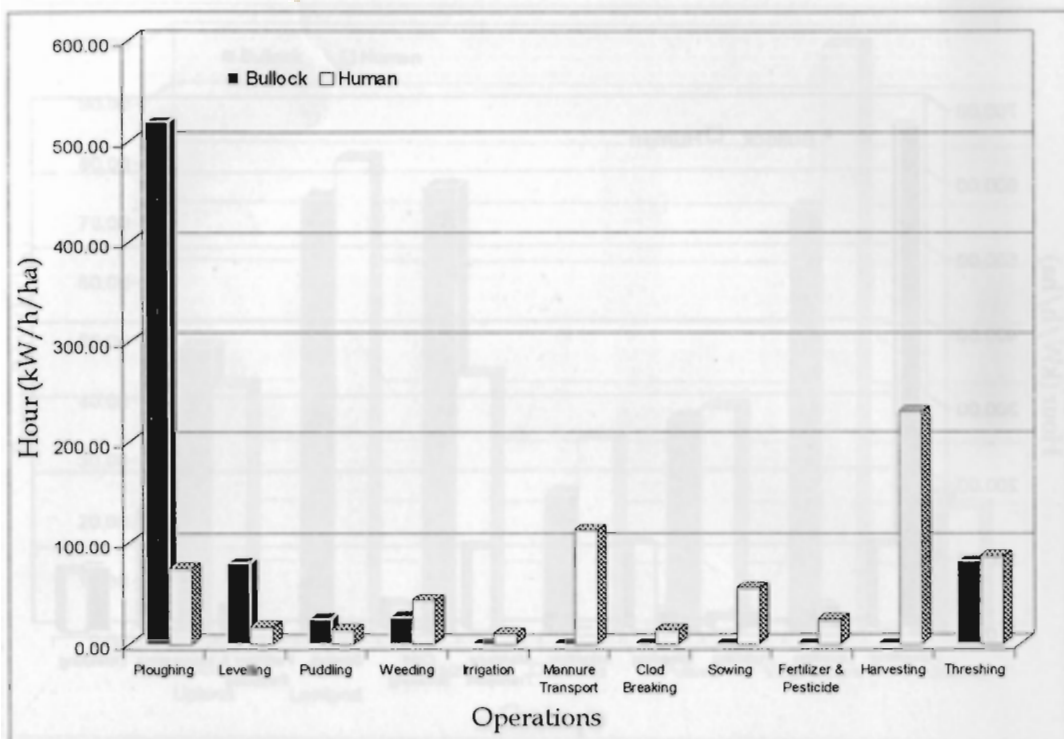


Figure 5.16: DAP Contribution during Different Agricultural Operations in the Shivaliks

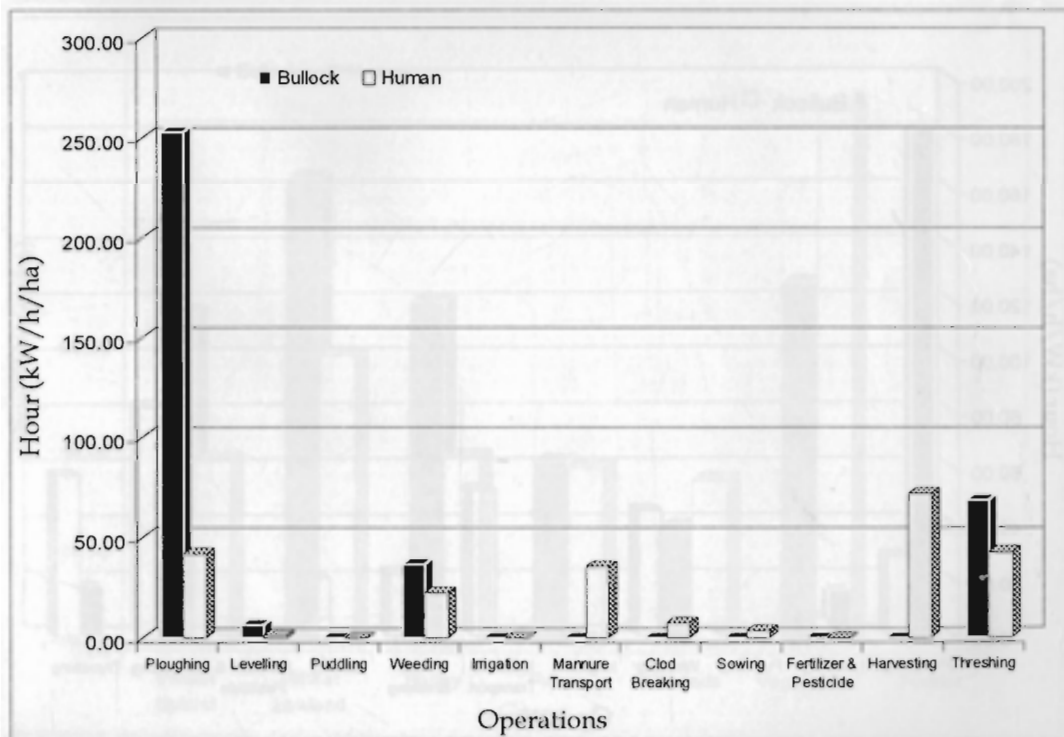


Figure 5.17: DAP Contribution during Different Agricultural Operations in the Middle Himalayas (traditional)

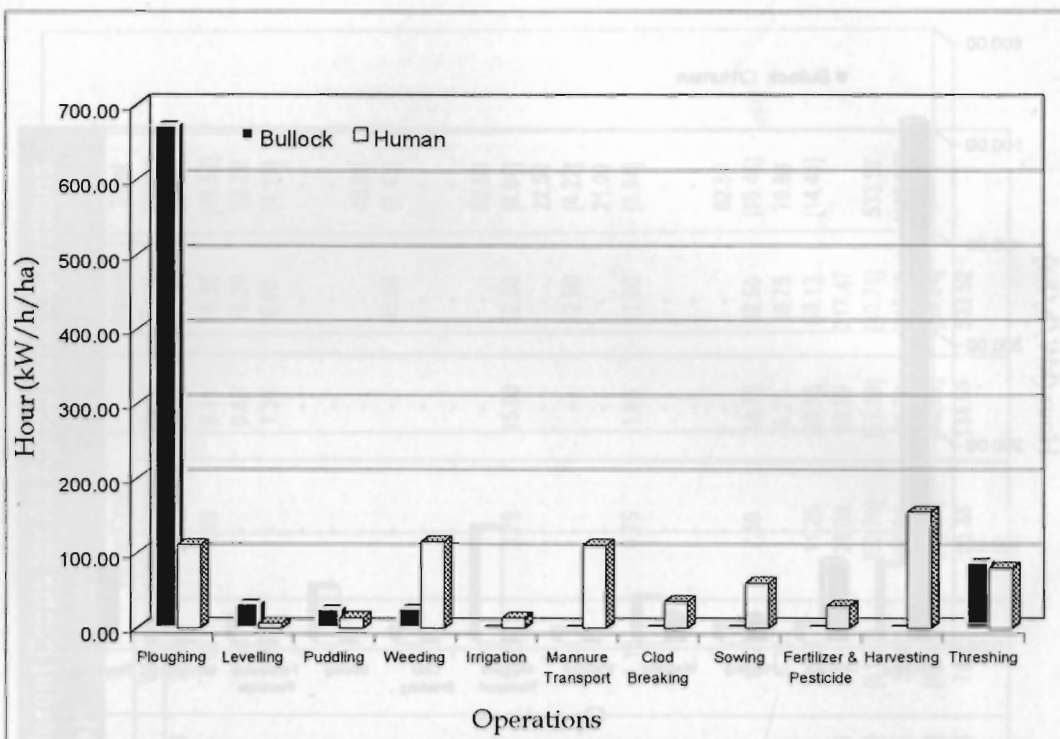


Figure 5.18: DAP Contribution during Different Agricultural Operations in the Middle Himalayas (transformed)

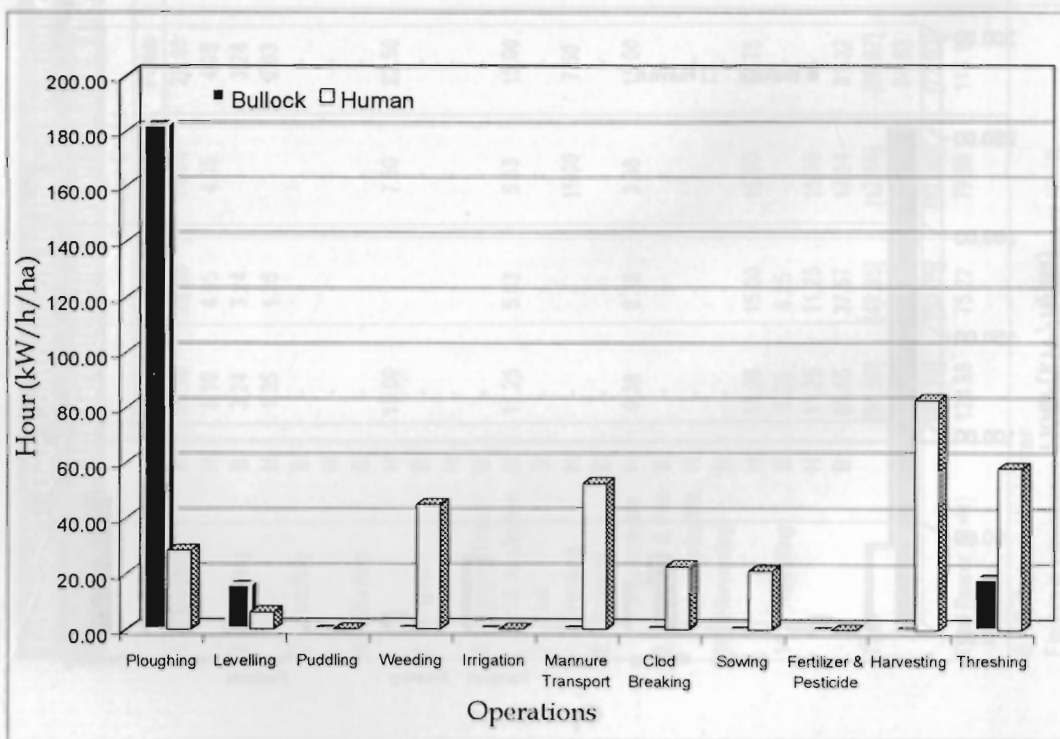


Figure 5.19: DAP Contribution during Different Agricultural Operations in the Greater Himalayas

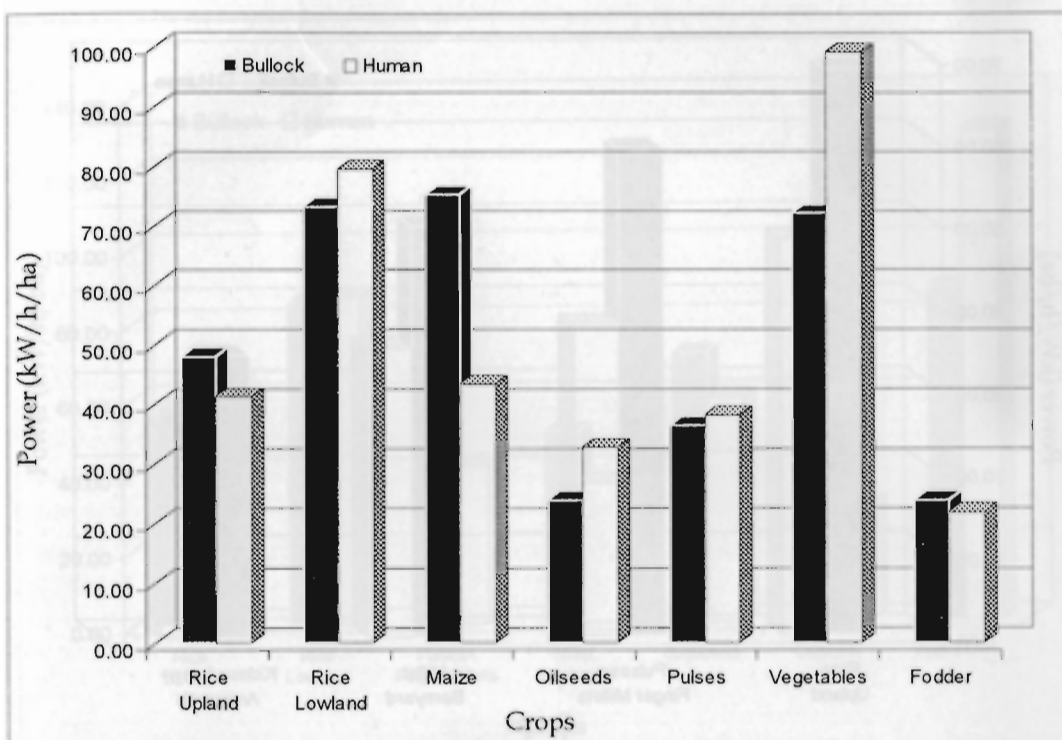


Figure 5.20: DAP Contribution to Cultivation of Summer Crops in the Shivaliks

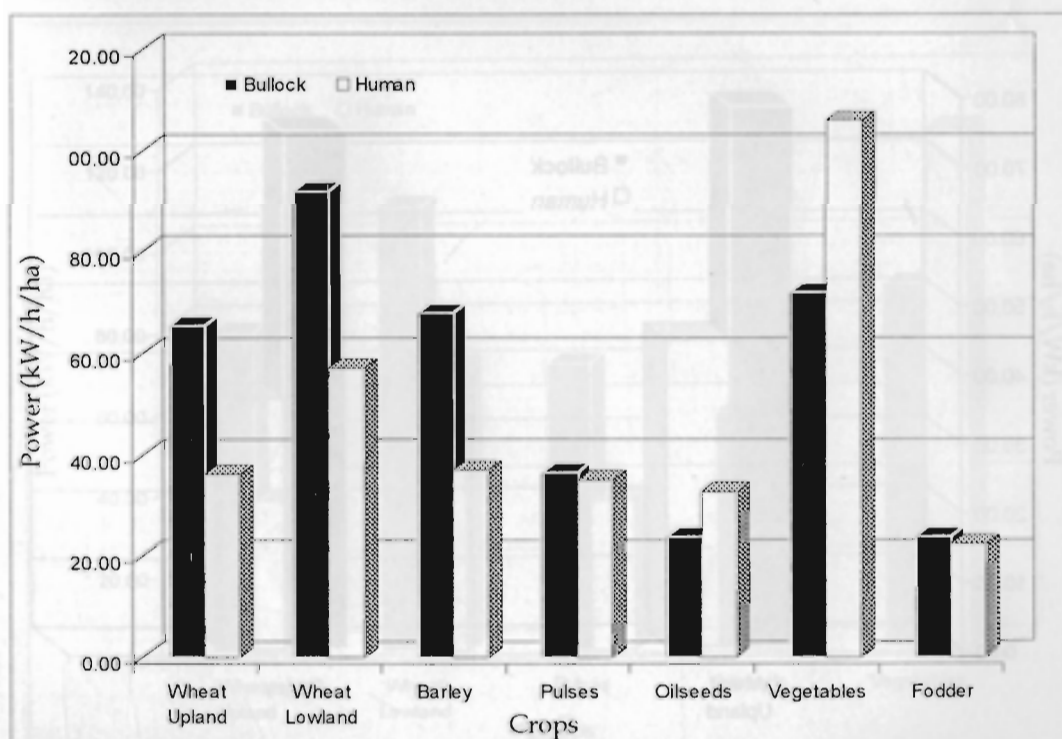


Figure 5.21: DAP Contribution to Cultivation of Winter Crops in the Shivaliks

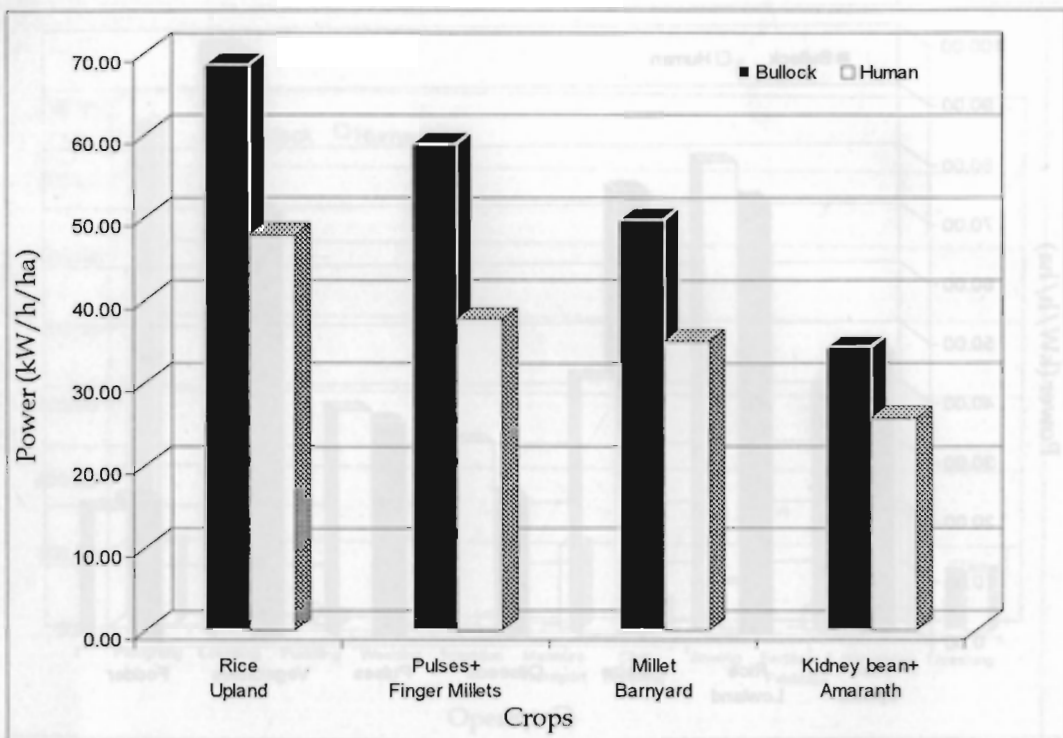


Figure 5.22: DAP Contribution to Cultivation of Summer Crops in the Middle Himalayas (traditional)

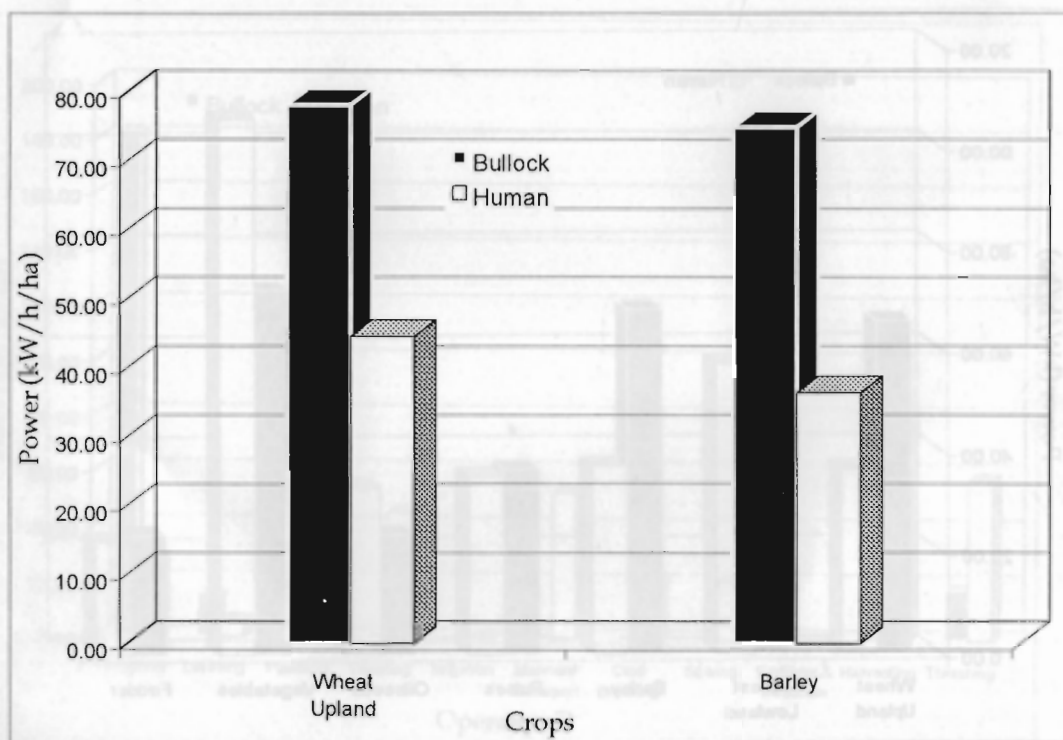


Figure 5.23: DAP Contribution to Cultivation of Winter Crops in the Middle Himalayas (traditional)

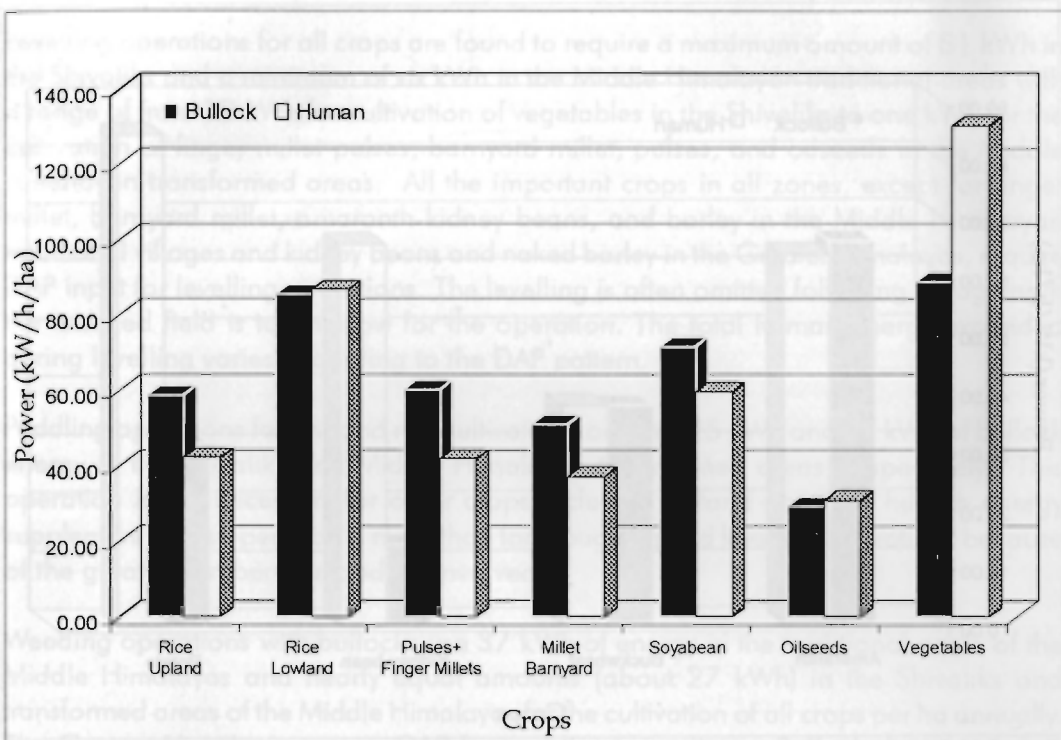


Figure 5.24: DAP Contribution to Cultivation of Summer Crops in the Middle Himalayas (transformed)

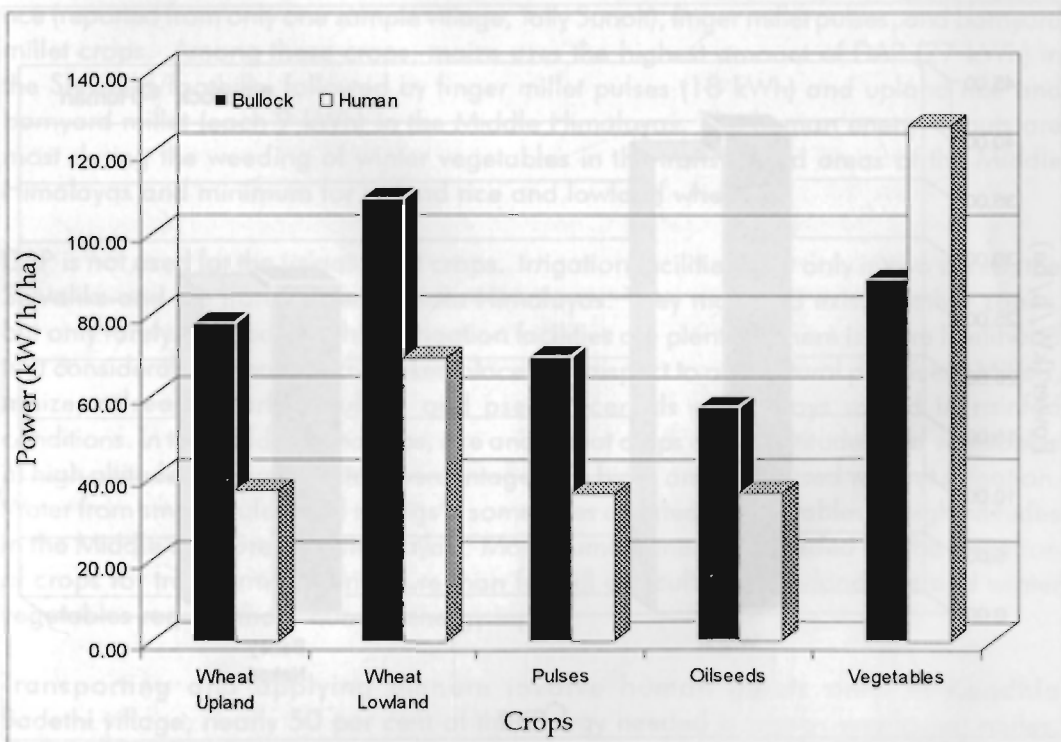


Figure 5.25: DAP Contribution to Cultivation of Winter Crops in the Middle Himalayas (transformed)

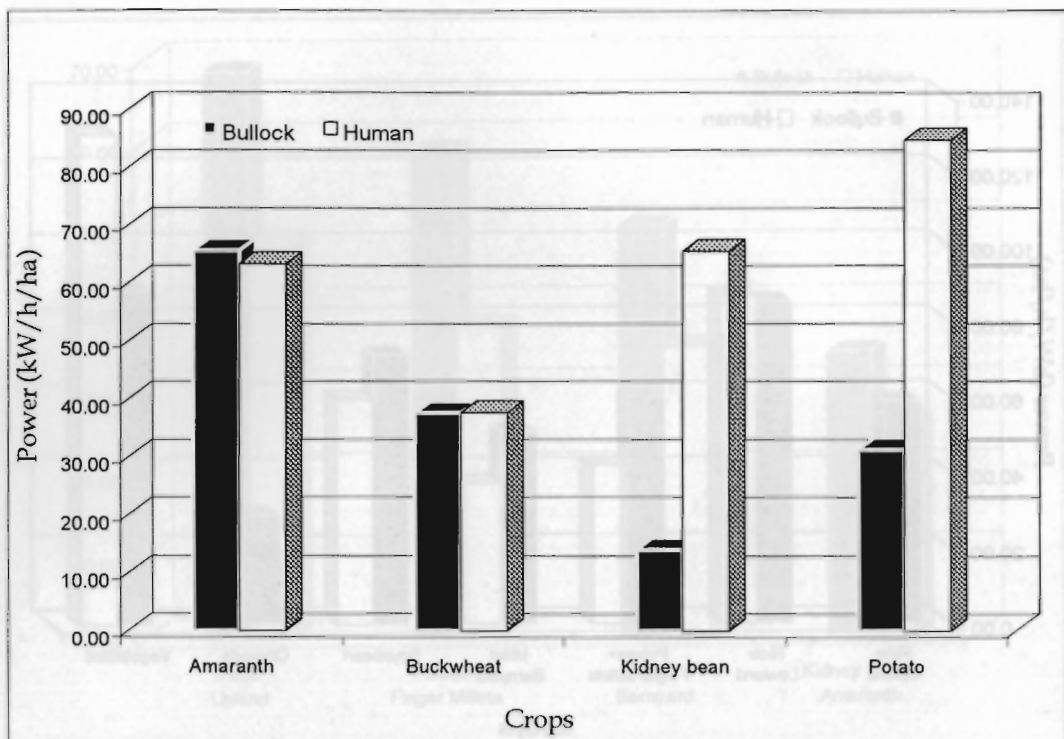


Figure 5.26: DAP Contribution to Cultivation of Summer Crops in the Greater Himalayas

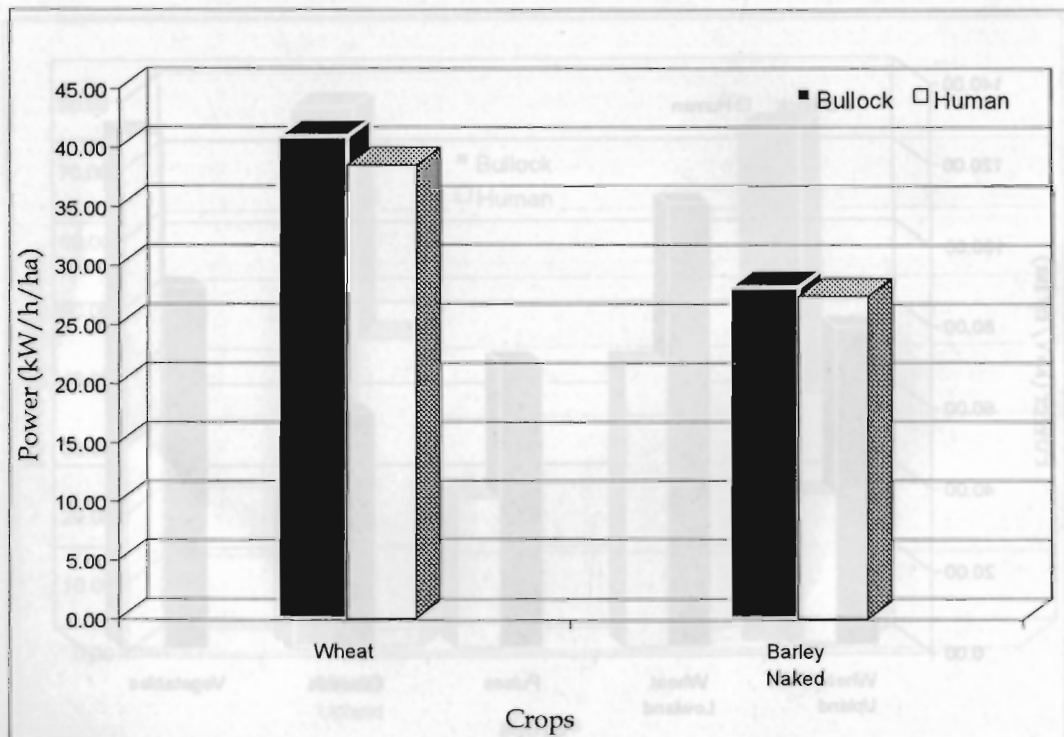


Figure 5.27: DAP Contribution to Cultivation of Winter Crops in the Greater Himalayas

Levelling operations for all crops are found to require a maximum amount of 81 kWh in the Shivaliks and a minimum of six kWh in the Middle Himalayan traditional areas with a range of from 10 kWh for cultivation of vegetables in the Shivaliks to one kWh for the cultivation of finger millet-pulses, barnyard millet, pulses, and oilseeds in the Middle Himalayan transformed areas. All the important crops in all zones, except for finger millet, barnyard millet, amaranth-kidney beans, and barley in the Middle Himalayan traditional villages and kidney beans and naked barley in the Greater Himalayas, require DAP input for levelling operations. The levelling is often omitted following ploughing if the terraced field is too narrow for the operation. The total human energy expended during levelling varies according to the DAP pattern.

Puddling operations for lowland rice cultivation consume 25 kWh and 27 kWh of bullock energy in the Shivaliks and Middle Himalayan transformed areas, respectively. This operation is not necessary for other crops including upland rice. The human energy supplement in this operation is more than for ploughing and levelling operations because of the greater number of mandays involved.

Weeding operations with bullocks use 37 kWh of energy in the traditional areas of the Middle Himalayas and nearly equal amounts (about 27 kWh) in the Shivaliks and transformed areas of the Middle Himalayas for the cultivation of all crops per ha annually. The Greater Himalayas use no DAP for weeding operations. Bullock-drawn weeders are used only for maize (reported from only one sample village, Ganga Bhogpur), upland rice (reported from only one sample village, Taily Sunoli), finger millet pulses, and barnyard millet crops. Among these crops, maize uses the highest amount of DAP (27 kWh) in the Shivaliks/foothills, followed by finger millet pulses (18 kWh) and upland rice and barnyard millet (each 9 kWh) in the Middle Himalayas. The human energy inputs are most during the weeding of winter vegetables in the transformed areas of the Middle Himalayas and minimum for upland rice and lowland wheat.

DAP is not used for the irrigation of crops. Irrigation facilities exist only in two zones, the Shivaliks and the transformed Middle Himalayas. They may also exist in other zones, but only rarely. In areas in which irrigation facilities are plentiful, there is more likelihood that considerable changes have taken place with respect to agricultural practices. Millets, maize, oilseeds, barley, pulses, and pseudo-cereals are always raised in rainfed conditions. In the Middle Himalayas, rice and wheat crops at mid-altitudes and vegetables at high altitudes, where moisture percentages are high, are also raised without irrigation. Water from small rivulets and springs is sometimes diverted to vegetables at high altitudes in the Middle and Greater Himalayas. More human energy is needed for the irrigation of crops for transformed agriculture than for hill agriculture. Lowland rice and winter vegetables require more human energy inputs.

Transporting and applying manure involve human inputs only. In Kandhla Badethi village, nearly 50 per cent of the energy needed is met by employing mules. One mule hour service is equal to eight hours of labour. The total human energy spent

during compost transport and application is the maximum per ha area (113 kWh) in the Shivaliks with almost the same value (110 kWh) in the transformed Middle Himalayas and minimum in the traditional Middle Himalayas. Vegetables in the hills and mountains, including potatoes in the Greater Himalayas, require high energy inputs to accomplish this task. In the fields in which finger millet, barnyard millet, pulses, oilseeds, and pseudo-cereals are grown, energy requirements for manure transport and application are the lowest. The energy expended in this operation, apart from individual crop requirements, varies according to the amount of manure available, distance from the households to the fields, cropping patterns/rotations, and cropping intensities.

Clod-breaking requires only human inputs. Clod breaking (or beating) is required especially to prepare the fields for lowland wheat after rice harvesting. The huge amounts of water used for cultivation makes the soil compact and form such fields the first tillage results in unworkable clods or lumps, and these need to be beaten to finer or workable sizes. Lowland wheat in the Shivalik hill areas requires about eight kWh per ha of cultivated land. Even upland wheat areas in 'rice-wheat' rotations need quite high amounts of human energy (8 kWh) for clod breaking. The maximum amount of energy (15 kWh), however, is invested in the preparation of the fields for kidney bean cultivation in the Greater Himalayas. Field preparation for vegetable cultivation in the Middle Himalayan transformed areas is also an energy-intensive exercise (about 14 kWh) when clods need to be broken.

While sowing operations for cultivation of foodgrain crops need low human energy inputs, transplantation of lowland rice and vegetables requires huge amounts of energy, because many mandays are employed in this process.

Human energy used for fertilizer and pesticide applications on all crops on every hectare of cropland annually is higher in transformed areas (30 kWh) than in the Shivaliks (24 kWh). Use of chemical fertilizers and pesticides in the two other study areas is rare. Vegetables need a lot of work and the energy needed is higher than lowland rice and wheat. No upland crops, or crops raised under rainfed conditions, apart from soybeans, use human energy for chemical and pesticide applications. The energy needed for soybeans for this operation is equal to the energy needed for vegetables.

The total human energy input for harvesting crops on each ha of cropland annually is highest (231 kWh) in the Shivaliks, followed by the transformed agricultural areas (156 kWh), and the Greater Himalayas (83 kWh) and lowest (72 kWh) in the traditional agricultural areas. The energy needed for harvesting for vegetable crops is greater than for good grain crops

Human energy for threshing all crops on each ha of land annually ranges from a high of 87 kWh to a low of about 43 kWh in the Shivalik hills and traditional agricultural areas, respectively. These figures for transformed areas and the Greater Himalayas are 81 kWh and 58 kWh, respectively. Threshing wheat, barley, pulses, pseudo-cereals, and millets is carried out with animal energy inputs.

Animal energy for threshing is maximum (about 89 kWh) in the transformed agricultural areas and minimum (about 19 kWh) in the Greater Himalayas. These values for the Shivalik hills and traditional agricultural areas are 83 and 69 kWh, respectively.

Among all the agricultural operations, the total (bullock and human) power contribution is highest during ploughing. It ranges from about 40 to 42 per cent for Greater Himalayan and Shivalik hill agriculture to about 50 per cent for Middle Himalayan agriculture. Harvesting and threshing operations use quite high percentages of total power, second only to ploughing. Weeding (except in the Shivalik hill zone) and transporting and applying manure, in terms of uses of power, are third. All other operations use only low amounts of total power. DAP predominates in ploughing, levelling, puddling, and weeding operations and, in the Middle Himalayas, in threshing also.

Looking at crop-wise contributions from bullock and human power, we find that it is summer vegetables in the transforming mountain areas that need maximum energy input per ha (about 219 kWh), followed by winter vegetables (about 216 kWh) and lowland wheat (about 178 kWh), in the same area, and winter vegetables (178 kWh) in the hills. In the traditional mountains and Greater Himalayan mountains, upland wheat (about 123 kWh) and amaranth (about 129 kWh) use the highest amounts of power. Fodder in the hills and naked barley in the Greater Himalayas use the lowest amounts of power, about 46 and 55 kWh per ha, respectively. Barley in the hills and traditional mountain areas and upland wheat in the transformed mountain areas and Greater Himalayan zone use the greatest amounts of DAP out of the total power input, i.e., about 65, 67, 68, and 52 per cent respectively, while vegetables, amaranth-kidney beans, vegetables, and kidney beans, in these respective areas, use the greatest share of human energy, i.e., nearly 57, 43, 59, and 82 per cent, respectively. This pattern demonstrates that irrigated crops use more human energy (kidney beans in the Greater Himalayas being an exception) and unirrigated crops generally use more DAP.

The overall bullock and human energy that goes into per ha crop cultivation for all operations annually amounts to about 1,419, 592, 1,586, and 534 kWh in the hills, traditional mountains, transformed mountains, and high Himalayas, respectively. This means that agricultural transformation is an energy-intensive process. Transitional hill agriculture, in terms of power use, is in second place, traditional mountain agriculture in third place, and 'primitive' high mountain agriculture last. Looking at the DAP contribution to overall power, we find that high mountain agriculture uses only about 41 per cent of DAP, hill agriculture about 52 per cent, transformed agriculture about 54 per cent, and traditional agriculture as much as 62 per cent of DAP for crop cultivation. This pattern suggests that cropping intensity increases pressure on human beings in terms of energy needed. The reason that high mountain agriculture is the exception is that there is less diversification in the cropping, and no household in a typical livestock-based farming setting (Bagauri, for example) owns any bullocks and many households carry out all operations manually. Furthermore, kidney beans, raised mainly around the homesteads, and potato cultivation require human energy for the most part. The

contribution of human energy to the cultivation of other crops in this area, nevertheless, is only about 50 per cent. The transformed agricultural system makes most efficient use of available DAP and human resources, and this is reflected in the greater degree of cropping diversification and higher crop yields in the area.

5.5 DAP and Crop Production Energetics

Ecosystems are solar-powered machines in which the kinetic energy of sunlight is stored as organic molecules by green plants which, in turn, can be used either for the vegetative growth of plant structures or for their maintenance (Mitchell 1979). In addition to solar energy, agro-ecosystems also use other forms of energy. The main forms of energy used in mountain agriculture can be broadly classified into direct energy (animate and biomass) and indirect energy (fertilizers and pesticides). In this section, we shall analyse the overall energy budget of crop production in mountain agro-ecosystems and discuss DAP contribution to crop production in the overall energy scenario and its relation to other energy forms.

The energy values for different agricultural operations for cultivation of different crops have been taken from Tables 5.11 to 5.14, and they have been converted into kilojoules (1 kWh = 860 kcal/h; 1 kcal = 4.186 kJ). The input and output values have been converted to energy by multiplying the quantities with the standard values reported by Mitchell (1979), which have also been used by several other workers, e.g., Pandey and Singh (1984), Singh et al. (1984), Negi et al. (1989), Ralhan et al. (1991), Singh (1991b), and Maikhuri (1996). These values, summarised in Table 5.12, are expressed on a fresh weight basis.

Table 5.12: Energy Values for Different Items

Item	kJ/kg.
Human foods	
Grains	16233.00
Pulses	17094.00
Leaf Vegetables (Fresh)	2839.20
Roots, Tubers	3956.40
Vegetables (Fresh)	2410.80
Livestock Feed	
Green Fodder (Cultivated)	3956.40
Tree and Shrub Leaves	4204.20
Legume Hay	14985.60
Straw	13986.00
Hay	14557.20
Manure	7320.60
Fertilizer	30340.80
Pesticides (Insecticides)	148000.00

Source: Based on Mitchell (1979); the value for pesticides (insecticides) is based on Ralhan et al. (1991)

Tables 5.13 and 5.14 include input and output values for all the principal crops per ha per year. Total input values in the Greater Himalayas and the traditional Middle Himalayas are low compared to the Shivalik hills and transformed Middle Himalayas. This is because there is a larger number of crops in the latter zones than in the former. Agriculture in the Shivalik hills and the transformed Middle Mountains uses fertilizers and pesticides, and thus they import energy from the market.

Table 5.13: Energy Input and Output for Crop Cultivation at the Study Sites (The Values are 105 k J/hal/yr)

	Input						Output			
	DAP	Humans	Seed ^a	Manure	Fertilizer	Pesticides	Total	Grains ^b	Crop Residue	Total
SHIVALIKS										
Upland Rice	1.73	1.49	16.23	7.32	0.00	0.00	26.77	357.13	363.64	720.77
Lowland Rice	2.64	2.86	16.23	7.32	37.93	7.40	74.38	519.46	573.43	1092.89
Maize	2.71	1.56	6.49	7.32	0.00	0.00	18.08	324.66	839.16	1163.82
Summer Oilseeds	0.87	1.18	4.86	3.66	0.00	0.00	10.57	48.70	-	48.70
Summer Pulses	1.32	1.38	10.26	3.66	15.17	2.96	34.75	170.94	149.86	320.80
Summer Vegetables	2.60	3.58	59.35	18.30	75.85	5.92	165.60	262.23	-	262.23
Summer Fodder	0.87	0.79	6.49	3.66	0.00	0.00	11.81	-	1186.92	1186.92
Upland Wheat	2.36	1.31	16.23	7.32	0.00	0.00	27.22	324.66	391.61	716.27
Lowland Wheat	3.32	2.06	16.23	10.98	37.93	2.96	73.48	568.16	671.33	1239.49
Barley	2.45	1.33	9.74	7.32	0.00	0.00	20.84	292.19	377.62	669.81
Winter Pulses	1.32	1.26	8.55	3.66	0.00	0.00	14.79	153.85	134.87	288.72
Winter Oilseeds	0.87	1.18	2.43	3.66	0.00	0.00	8.14	97.40	-	97.40
Winter Vegetables	2.60	3.81	50.36	18.30	75.85	8.88	159.80	311.39	-	311.39
Winter Fodder	0.87	0.81	2.56	3.66	0.00	0.00	7.90	-	989.10	989.10
Total	26.53	24.60	226.01	106.14	242.73	28.12	654.13	3430.77	5677.54	9108.31
MIDDLE HIMALAYAS (TRADITIONAL)										
Upland Rice	2.47	1.73	16.23	7.32	0.00	0.00	27.75	405.83	447.55	853.38
Finger Millet + Pulses	2.12	1.36	2.60	3.66	0.00	0.00	9.74	329.82	481.52	811.34
Barnyard Millet	1.79	1.26	2.60	3.66	0.00	0.00	9.31	211.03	503.50	714.53
Amaranth + Kidney beans	1.24	0.93	1.62	0.00	0.00	0.00	3.79	297.36	134.87	432.23
Upland Wheat	2.81	1.60	16.23	7.32	0.00	0.00	27.96	340.89	391.61	732.50
Barley	2.70	1.31	9.74	7.32	0.00	0.00	21.07	259.73	335.66	595.39
Total	13.13	8.19	49.02	29.28	0.00	0.00	99.62	1844.66	2294.71	4139.37

Note: The main vegetables are potatoes, peas, cabbage, and French beans.

^a Seeds for potatoes refer to tubers and for cabbage seedlings

^b Grains for potatoes and other vegetables refer to the edible parts

Table 5.14: Energy Inputs and Outputs for Crop Cultivation at the Study Sites (The Values are 105 k J/ha/yr)

	Input					Output				
	DAP	Humans	Seed ^a	Manure	Fertilizer	Pesticides	Total	Grains ^b	Crop Residue	Total
MIDDLE HIMALAYAS (TRANSFORMED)										
Upland Rice	2.14	1.52	16.23	7.32	0.00	0.00	27.21	373.36	405.59	778.95
Lowland Rice	3.09	3.13	16.23	7.32	45.51	7.40	82.68	535.69	615.38	1151.07
Finger Millet + Pulses	2.17	1.51	2.60	3.66	0.00	0.00	9.94	329.82	481.52	811.34
Barnyard Millet	1.84	1.34	2.60	3.66	0.00	0.00	9.44	211.03	503.50	714.53
Soya Bean	2.59	2.15	10.26	7.32	45.51	8.88	76.71	307.69	-	307.69
Summer Oilseeds	1.06	1.11	4.86	3.66	0.00	0.00	10.69	32.47	-	32.47
Summer Vegetables	3.20	4.70	50.26	18.30	75.85	5.92	158.23	410.46	-	410.46
Upland Wheat	2.81	1.33	16.23	7.32	0.00	0.00	27.69	340.89	391.61	732.50
Lowland Wheat	3.92	2.50	16.23	10.98	45.51	2.96	82.10	568.16	671.33	1239.49
Winter Pulses	2.52	1.31	8.55	5.49	0.00	0.00	17.87	170.94	149.86	320.80
Winter Oilseeds	2.07	1.31	2.43	5.49	0.00	0.00	11.30	81.17	-	81.17
Winter Vegetables	3.20	4.56	57.33	18.30	45.51	2.96	131.86	456.61	-	456.61
Total	30.61	26.47	203.81	98.82	257.89	28.12	645.72	3818.29	3218.79	7037.08
GREATER HIMALAYAS										
Amaranth	2.36	2.28	1.62	7.32	0.00	0.00	13.58	259.73	-	259.73
Buckwheat	1.35	1.36	3.25	3.66	0.00	0.00	9.62	178.56	-	178.56
Kidney Bean	0.51	2.36	10.26	3.66	0.00	0.00	16.79	307.69	404.61	712.30
Potato	1.13	3.05	39.56	18.30	0.00	0.00	62.04	233.43	-	233.43
Wheat	1.47	1.38	16.23	7.32	0.00	0.00	26.40	227.26	293.71	520.97
Naked Barley	1.01	0.98	9.74	1.83	0.00	0.00	13.56	194.80	251.75	446.55
Total	7.83	11.41	80.66	42.09	0.00	0.00	141.99	1401.47	950.07	2351.54

Note : The main vegetables are potatoes, peas, cabbage, and French beans. In the Greater Himalayas, only potato cultivation is in practice.

^a Seeds for potatoes refer to tubers and for cabbage, seedlings

^b Grains for potatoes and other vegetables refer to the edible parts

Transformed agriculture imports more energy than transitional hill agriculture. Traditionally, mountain agriculture uses only negligible energy through imported inputs. If energy used in the cultivation of fodder crops is not taken into account, total energy input is highest for transformed agriculture; it being 6.5 times higher than for traditional agriculture and 4.5 times higher than high Himalayan agriculture. The crops requiring improved cultivation practices in the hills and transformed middle mountains use higher energy inputs. The crops raised under traditional practices, even in these areas, do not require greater energy inputs. Millet crops, for example, are provided with almost equal inputs of energy in the traditional and transformed areas. The share of imported energy in the hills and transformed middle mountains is 41 and 44 per cent of the total energy input, respectively.

Winter fodder crops in the hills, amaranth-kidney bean crop combination in the traditional mountains, barnyard millet in the transformed mountains, and buckwheat in the high Himalayas are the crops requiring the lowest inputs of energy. Among all these crops, the amaranth-kidney bean cultivation requires the minimum energy input. Amaranth, intercropped with kidney beans, is generally raised in the summer crop cropping system and manure is rarely used. Summer vegetables in the hills and transformed mountains, upland rice and upland wheat in the traditional mountains, and potatoes in the high Himalayas are the most energy-intensive crops in these zones. Among these crops, summer vegetables in the hills need maximum energy inputs. Winter vegetables in the hills and summer vegetables in the transformed mountains receive the greatest amounts of imported energy, i.e., 53 and 52 per cent of the total energy inputs for these crops, respectively.

The total energy output in the hills and transformed mountains is considerably higher than in the traditional mountains and high Himalayas. If fodder output energy in the hills is omitted, the maximum energy output is in the transformed mountains. The total biomass energy output in the transformed mountains is not all that higher than in the hills, but it is nearly three-fold the output in the high Himalayas and nearly two-fold the output in the traditional mountains. If only agronomic yields (main product) are taken into account, the total energy output in the transformed mountains is 1.1, 2.1, and 2.72 times higher than in the hills, traditional mountains, and high mountains, respectively.

The gross energy output - input ratio, which is indicative of the energy efficiency of an agro-ecosystem, is considerably higher in the traditional area than in all the other three areas. This is due to a very low energy input compared to energy output in traditional agriculture. Output - input ratios for hill, transformed, and high Himalayan agriculture are 2.98, 3.81, and 2.51 times lower, respectively, than for traditional mountain agriculture. If only the main product (agronomic yields) is considered then these ratios, in the respective areas, are 3.53, 3.13, and 1.88 times lower than for traditional agricultural areas. The high energy input compared to the energy output in hills and transformed mountains and overall low energy output in the high Himalayas are attributable to the relatively lower energy efficiency of agriculture in these areas.

The energy efficiency of crops in which large amounts of imported energy are to be employed is lower than for all other crops. For example, the output - input ratios for vegetable crops in the hills and transformed mountain area are lower than for other crops. There is a lack of useful by-products from these crops. Since fodder crops in the hills do not yield grains (the main product), their output (grain) - input ratios are zero. Nevertheless, their output (biomass) - input ratios are the highest among all the crops in all other areas. A single foodgrain crop that has the highest output - input ratio is the amaranth intercropped with kidney beans in the traditional middle mountains. These ratios of crops, such as upland rice, maize, upland wheat, finger millet, barnyard millet, kidney beans, and naked barley, which do not use imported energy, are also quite high (Tables 5.15 and 5.16).

The output (biomass) - input ratios for maize in Mexico, Guatemala, Nigeria, the Philippines, and India are 80.8, 11.2, 29.8, 14.3, and 13.3, respectively (Reijntjes 1992). In our case, the ratio (64.4) lies within this range. The output - input ratios for selected crops in Nepal, reported by Rijal et al. (1991), are comparable to ours in many

Table 5.15: Energy Efficiency of Crop Cultivation at the Study Sites (10⁵ k J/ha/yr)

	Output (Biomass) - Input Ratio	Output (Grain) - Input Ratio	% of Animate Energy/ DAP to Total Input Energy	Animate Energy/DAP (k J) per kg Biomass Output
SHIVALIKS				
Upland Rice	26.92	9.61	12.03/6.46	67.08/36.04
Lowland Rice	10.69	6.98	7.39/3.55	75.34/36.16
Maize	64.37	17.96	23.62/14.99	53.38/33.88
Summer Oilseeds	4.60	4.60	19.39/8.23	683.33/290.00
Summer Pulses	9.23	4.92	7.77/3.80	135.00/66.00
Summer Vegetables	1.58	1.58	3.73/1.57	79.23/33.33
Summer Fodder	100.50	0.00	14.06/7.37	5.53/2.90
Upland Wheat	26.31	11.93	13.48/8.67	76.46/49.17
Lowland Wheat	16.87	7.73	7.32/4.52	64.82/40.00
Barley	32.14	14.03	18.14/11.76	84.00/54.44
Winter Pulses	19.52	10.40	17.44/8.92	143.33/73.33
Winter Oilseeds	11.97	11.97	25.18/10.69	341.67/145.00
Winter Vegetables	1.95	1.95	4.01/1.63	71.22/28.89
Winter Fodder	125.20	0.00	21.27/11.01	6.72/3.48
<i>Total</i>	13.92	5.24	7.82/4.06	44.77/23.23
MIDDLE HIMALAYAS (TRADITIONAL)				
Upland Rice	30.75	14.62	15.14/8.90	73.68/43.33
Finger Millet + Pulses	83.30	33.86	35.73/21.77	64.44/39.26
Barnyard Millet	76.75	22.67	32.76/19.23	62.24/36.53
Amaranth + Kidney bean	114.04	78.46	57.26/32.72	80.37/45.93
Upland Wheat	26.20	12.19	15.77/10.05	90.00/57.35
Barley	28.26	12.33	19.03/12.81	100.25/67.50
<i>Total</i>	41.55	18.52	21.40/13.18	77.25/47.57

Note : The main vegetables are potatoes, peas, cabbage, and French beans.

Seeds for potatoes refer to tubers and for cabbage, seedlings.

Grains for potatoes and other vegetables refer to the edible parts.

Table 5.16: Energy Efficiency of Crop Cultivation at the Study Sites (10^5 k J/ha/yr)

	Output (Biomass) - Input Ratio	Output (Grain) - Input Ratio	% of Animate Energy/ DAP to Total Input Energy	Animate Energy/DAP (k J) per kg Biomass Output
MIDDLE HIMALAYAS (TRANSFORMED)				
Upland Rice	28.63	13.72	13.45/7.86	70.38/41.15
Lowland Rice	13.92	6.48	7.52/3.74	80.78/40.13
Finger Millet + Pulses	81.62	33.18	37.02/21.83	68.15/57.22
Barnyard Millet	75.69	22.35	33.69/19.49	64.90/37.55
Soyabean	4.01	4.01	6.18/3.38	263.33/143.89
Summer Oilseeds	3.03	3.03	20.30/9.92	1085.00/530.00
Summer Vegetables	2.59	2.59	4.99/2.02	58.52/23.70
Upland Wheat	26.45	12.31	14.95/10.15	84.49/57.35
Lowland Wheat	15.10	6.93	7.82/4.77	77.35/47.23
Winter Pulses	17.95	9.57	21.43/14.10	191.50/126.00
Winter Oilseeds	7.18	7.18	29.91/18.32	676.00/414.00
Winter Vegetables	3.46	3.46	5.89/2.43	56.23/23.19
<i>Total</i>	<i>10.90</i>	<i>5.91</i>	<i>8.84/4.74</i>	<i>90.89/48.74</i>
GREATER HIMALAYAS				
Amaranth	19.13	19.13	34.17/17.38	290.00/147.50
Buckwheat	18.56	18.56	28.17/14.03	246.36/122.73
Kidney Bean	42.42	18.33	17.09/3.04	63.78/11.33
Potatoes	3.76	3.76	6.74/1.82	70.85/19.15
Wheat	19.73	8.61	10.80/5.57	81.43/42.00
Naked Barley	32.93	14.37	14.68/7.45	66.33/33.67
<i>Total</i>	<i>16.56</i>	<i>9.87</i>	<i>13.55/5.51</i>	<i>98.16/39.95</i>

Note : The main vegetables are potatoes, peas, cabbage, and French bean. In the Greater Himalayas, only potato cultivation is in practice.

Seeds for potatoes refer to tubers and for cabbage, seedlings.

Grains for potato and other vegetables refer to the edible parts.

cases. Yet our figures are higher (except for soybean) than those of Pandey and Singh (1984), Singh et al. (1984), Srivastava and Shah (1984), Negi et al. (1989), and Ralhan et al. (1991) from parts of the same region. These researchers, in fact, have used higher bullock and human labour input estimates than ours. In our case, we believe that on the spot measurement of bullock power has increased the credibility of the exercise.

Since, owing to the inherent topographical conditions and other site specifics, mechanical energy is not feasible for mountain agriculture, animate energy in general and DAP, in particular, constitute the most important components of the energy system. Therefore, to maintain productivity of mountain agriculture, measures to improve DAP efficiency should be encouraged. The share of animate energy and DAP in traditional mountain agriculture (21 and 14%) is higher than in high Himalayan agriculture (14 and 6%), transformed mountain agriculture (9 and 5%), and is the lowest (8 and 4%) in hill agriculture.

Although, as noted also in the previous section, improved agro-techniques, as practised in the cultivation of commercial crops, require more animate energy inputs (including DAP), the percentage of these forms of energy is decreased as a result of higher input levels of other types of energy, particularly those to be imported from the market.

The animate energy expended to produce each kg of useful biomass is the minimum in the hills followed by the traditional mountains, and transformed mountains and maximum in the high Himalayas. The DAP input per kg of useful biomass produced is minimum in the hills, followed by the high Himalayas, and is almost equal in the middle mountains. This means that hill agriculture is the most responsive to animate energy and DAP. If fodder crop cultivation, the exception for the hills, is not taken into account, the animate energy and DAP input per kg of biomass produced in this area would be 86.37 and 44.81 kJ, respectively. Thus, with regards to animate energy, hill agriculture would be less responsive than traditional mountain agriculture, but more responsive than agriculture in other areas, while, with regard to DAP, it would be more efficient than in traditional and transformed mountain agriculture, but less than in the high Himalayas.

Barring fodder crops, maize and winter vegetables in the hills make the most efficient use of animate energy and DAP. Barnyard millet, in the traditional mountains, uses these two energy forms the most efficiently. Winter vegetables and barnyard millet in transformed agriculture are the most responsive to animate energy and DAP, in that order, while kidney beans are the long crop with the maximum use of these energy forms in the high Himalayan area. Among all the crops in all these areas (apart from fodder crops), maize makes the most efficient use of animate energy and kidney beans of DAP, while summer oilseeds, in the transformed middle Himalayas, demonstrate least efficient use. How biomass production increases with every unit increase in DAP (or animate energy) remains an important research issue.

5.6 Cost of Maintaining Bullocks

Gross maintenance costs per pair of bullocks per year at household level is the highest in the agriculturally transformed areas of the Middle Himalayas (Rs 7,147) and the lowest in the Greater Himalayas (Rs 2,254). A similar trend is noticed in the net maintenance cost (Table 5.17). The costs are based on current local market prices for different items.

The maximum cost is incurred for feeding. It ranges from as high as 71 per cent in the Shivalik hills to as low as 48 per cent of all maintenance in the costs agriculturally traditional areas of the Middle Himalayas. The highest cost for feed in the hills is because of a nearly 50 per cent share of cultivated fodder in the greens fed to bullocks. The cultivated greens cost Rs 0.80 per kg while other greens (extractable from the forests) cost Rs 0.50 per kg. In the Shivaliks, as much as 26 per cent of the total investment is on green fodder alone, while in the traditional areas it is only about 12 per cent. The cost incurred on dry fodder in all areas, nevertheless, is higher (ranging from 25% in

Table 5.17: Maintenance Cost (Rupees) of a Pair of Bullocks per Household per Year at Different Study Sites

Particulars	Shivalik Hills	Middle Himalayas: Traditional	Middle Himalayas: Transformed	Greater Himalayas
Feed Cost	4423 [70.79]	2302 [47.62]	4716 [65.99]	1124 [49.87]
Green Fodder	1623 [25.98]	556 [11.50]	1313 [18.37]	347 [15.39]
Dry Fodder	2270 [36.33]	1191 [24.64]	2813 [39.36]	632 [28.04]
Concentrate	530 [8.48]	555 [11.48]	590 [8.26]	145 [6.43]
Labour Cost	1562 [25.00]	2333 [48.26]	2121 [29.68]	1066 [47.29]
Grazing	566 [9.06]	1831 [37.88]	1284 [17.97]	24 [1.06]
Upkeep	996 [15.94]	502 [10.38]	837 [11.71]	1042 [46.23]
Miscellaneous Cost	60 [0.96]	150 [3.10]	125 [1.75]	45 [2.00]
Overhead Cost	203 [3.25]	49 [1.01]	185 [2.59]	19 [0.84]
Total Cost	6248 [100.00]	4834 [100.00]	7147 [100.00]	2254 [100.00]
Economic Gains	512	1203	1075	133
Dung, Farmyard Manure	244	658	347	133
Hiring Out	268	545	728	-
Net Maintenance Cost	5736	3631	6072	2121
Maintenance Cost Per Day	15.72	9.95	16.64	5.81

Figures in parentheses indicate the percentage of total maintenance cost.

the traditional to 39% in the transformed areas). Expenditure on concentrates is meagre, from six per cent in the Greater Himalayan villages to 11 per cent in the traditional, Middle Himalayan villages. A high percentage of proteins in the high quality green fodder gathered alpine pastures during grazing would perhaps take care of the low amount of concentrates fed to bullocks in the Greater Himalayan region.

The cost of human labour for grazing and upkeep (at home) of a pair of bullocks ranges from 28 per cent in the Shivalik hills to 48 per cent in the traditional middle mountains. The cost of grazing is the lowest (1%) in the high Himalayas and the highest (38%) in the traditional middle mountains. Keeping bullocks at home is more costly than grazing them in the hills and high Himalayan areas.

The highest economic returns in terms of dung/farmyard manure (assuming they are saleable) per pair of bullocks per family per year are observed in the traditional mountains (Rs 1,203), followed by the transformed mountains (Rs 1,075), and the hills (Rs 512), and they are lowest (Rs 133) in the high Himalayas. In the latter, there is no practice of hiring out bullocks, but, through this practice, each family earns, on an average, Rs 545 in the traditional mountain villages, Rs 728 in the transformed mountain villages, and Rs 268 in the hill villages (Table 5.17).

Livestock Development Interventions and DAP

Animal husbandry is a priority area in terms of increasing incomes and creating employment opportunities in the Central Himalayas. In a region as poor as the mountains, a new economy should be developed based on resource-base management. Livestock form an important resource base in the region and, fortunately, they attract the attention of policy-makers. But, unfortunately, the policies and programmes do not cater to the farmers' needs for agricultural power and they are broadly mismatched with the DAP system. The present chapter critically reviews the various elements of institutional interventions with respect to animal husbandry development, with special reference to the DAP system.

6.1 Conventional Animal Husbandry

Institutional intervention in the animal sector focusses on three aspects: crossbreeding, health care, and fodder production. The cattle improvement programme, or the so-called White Revolution, or Operation Flood, is being carried out extensively in Himalayan areas, with the sole purpose of increasing milk production. The other two, i.e., the health care and fodder production programmes are complementary to it. More than half of all funds allotted to the animal husbandry sector in the Central Himalayan districts are normally spent on crossbreeding cattle.

The National Commission on Agriculture, while endorsing the policy of large-scale crossbreeding, was aware of the fact that *"such a step would hamper the supply of draught animals adapted to farm conditions in the country"* (Nair 1982). But, unfortunately, this was not taken seriously and deliberate crossbreeding today is considered to be the greatest loss to domesticated animal diversity in India (Kothari 1996). As a result, on a country level, it is estimated that 20 per cent of the cattle breeds, 50 per cent of goat breeds, 30 per cent of the sheep breeds, and 100 per cent of the poultry breeds are threatened. According to D.S. Balain, former Chief of the National Bureau of Animal Genetic Resources, India, the Ongole breed of cattle has already been lost in India (Tantia et al. 1993).

In order to combat the great degree of vulnerability inherently associated with crossbreds, which is often expressed in terms of various diseases and physical and physiological

Table 6.1: Local vs Crossbred Cattle : Normal Husbandry Practices

Particulars	Local	Crossbred
Mating	Local bull, mostly while grazing	Artificial insemination, or exotic bull
Feed/Feeding	Non-farm (CPR) fodders, crop residues, food wastes; grazing and stall-feeding	Cultivated fodders, concentrate (foodgrains and cakes), mineral mixture etc.; stall-feeding
Milking	Female family members	Paid skilled labour if a large number of animals is maintained
Daily Care	Women and children	Paid labour on a dairy farm
Use of Milk	Domestic consumption	Sale in the market
Use of Male Calves	Ploughing and other agricultural work	No use in the mountains, carting in the Terai area
Treatment of Sick Animals	Family care and herbal medicines	Vet care and modern drugs

abnormalities, provision of adequate health coverage is an obvious part of the cattle development programme. In the Indian Central Himalayas, a network of veterinary hospitals, animal husbandry centres, dispensaries, A.I. centres, and semen centres has been built up to take care of animal health. Animal health cover is taken care of by 157 veterinary hospitals, 492 animal husbandry centres, and 10 'D' class dispensaries. Money is even drained out of the country by importing exotic bull semen from Western countries. Management of imported semen, often associated with the health package, is given special emphasis. In mountain areas of the Central Himalayas, imported semen is stored in the Deep Frozen Centres located at Srinagar (Garhwal) and Lal Kuan (Kumaon) and caters to the needs of 52 A.I. Centres and 161 A.I. Sub-centres located throughout Garhwal and Kumaon. During 1984-85, as many as 2,468 crossbred animals per A.I. Centre and 1,512 crossbred animals per A.I. sub-centre were produced (Table 6.2).

Health coverage in easily accessible areas, nevertheless, provides castration facilities for draught animals. This facility is not free of cost and, in some places, farmers have to pay for this service. Farmers in one village of Banali reported that they pay as much as

Table 6.2: Animal Health Cover Network in the Central Himalayas, India

Particulars	Kumaon	Garhwal	Total
Veterinary Hospitals	75	82	157
Animal Husbandry Centres	261	231	492
'D' Class Dispensary	7	3	10
A.I. Centres	44	8	52
A.I. Sub-centres	123	38	161
Crossbreds Produced			
Per A.I. Centre	404	2064	2468
Per A.I. Sub-centre	1077	435	1512

Source: Uttarakhand Vikas Vibhag, 1994 -1995. *Progress Report*. Lucknow : Uttarakhand Vikas Vibhag.

Rs 50 per castration. Draught animals in many remote villages and those kept by transhumant societies are usually deprived of this facility, and they have to resort to painful traditional measures.

One of the basic problems facing the native females is that of small size, and this is a big constraint to the crossbreeding programme. Inconvenient 'marriage' between large-sized exotics and small-sized locals leads to a high incidence of dystocia. Health coverage supporting crossbreeding is not able to solve this problem.

The health care infrastructure, on the whole, is inefficient and cannot cover the entire livestock population spread over a wide range of inhabited areas. The infrastructure seems strong enough, but is constrained by a high degree of inaccessibility and expensive treatment and/or costly medicines. The staff members available generally dislike taking care of animals in remote areas, and it is also difficult to carry the animals to veterinary centres located, almost always, in areas linked to central facilities. Treatment of some common diseases (milk fever and mastitis, the most common problems among the high-yielder crossbreds, for example) is sometimes more expensive than the cost of the animal itself. Even if the veterinary expert's consultancy is free of cost, specific medicines for the treatment of some diseases are too costly for an average farmer. The entire health coverage does not give due importance to the diagnosis of diseases prevalent in the area, which otherwise could help to introduce preventive measures against these prevalent diseases and, therefore, increase the productivity of animals.

Each veterinary hospital, on an average, covers an area of 325 sq. km., while each animal husbandry/animal service centre has to cover an area of 104 sq. km. Supplies of liquid nitrogen to maintain frozen semen are often disrupted, and this results in a very low conception rate. Health programmes have so far overlooked the problem of endoparasites; a recurrent problem in both native and crossbred cattle. More than 50 per cent of the cattle population at all altitudes is affected by endoparasites, i.e., parasites living within the body of the host. Animals in the valleys suffer mostly from liver fluke, while those at mid- and high altitudes are infested mainly by *Ascaris* parasite. These parasites nourish themselves at the expense of the host and cause severe diseases with fatal results. Periodic deworming of animals on a wide scale could improve or sustain their production potential, but this seems to be the least priority of the conventional health improvement programme.

Deficiency diseases caused by inadequate supplies of certain nutrients leading to infertility or declined productivity are a great hazard to animals. The existing health service network does not address this problem effectively.

Fodder production, the third item in conventional animal husbandry, is mainly focussed on, (i) the cultivation of exotic grasses both on cultivated land and in pastures, (ii) pasture improvement through urea and micro-nutrient applications, and (iii) cultivation of common fodder crops, mainly legumes, on cropland.

The State Animal Husbandry Department is growing exotic grasses and legumes on its farms at Pashulok (Dehradun) and Bhararisain (Chamoli). Fodder seeds are distributed to farmers. Training programmes given by fodder experts are also conducted extensively to boost the programme.

The fodder production programme, however, ignores the mountain resource base completely. CPRs are the most important regional, natural heritage with an enormous potential to provide massive fodder supplies to local livestock. Ironically, the official fodder cultivation programme does not take CPRs into account. Plantation of indigenous fodder-yielding trees and shrubs, which provide more fodder of the desired nutritive value per unit area and also have a crucial ecological role (Singh et al. 1988), are given no priority. In the foreseeable future, there is little possibility of allocating cropland for raising conventional fodder crops, as the conventional institutional programme advocates. Foodgrain crops (rice, wheat, millets, pulses, etc) will remain the staple food for humans. So the nutrition of livestock can be raised by improving the nutritive values of crop by-products. Crop residues, in fact, constitute the principal component of feed for ruminants in almost all small-scale crop-livestock systems (Orskov 1984, 1995). In the Central Himalayas, nearly 35 per cent of the total feed requirements of ruminants come from crop residues alone (Singh and Naik 1987 b). Thus, mountain crops offer a good potential for sustainable animal husbandry. Choosing the right crop varieties with large straw-grain ratios and more nutritive value, coupled with further improvements in the nutritive value through chemical treatment, would provide a promising package for the sustainable productivity of livestock. But, unfortunately, this is not part of the current institutional strategy.

Introducing exotic plants which can provide greater quantities of fodder is a potential risk for Himalayan ecosystems (Singh 1991a, 1991b). There are certain local grass species that provide more fodder per ha than exotic ones. These, planted on the bunds and common lands, could provide greater amounts of fodder. Repeated applications of chemical fertilizers, aimed at improving the productivity of pasture land, is also an ecological hazard to the delicate mountain eco-balance, in addition to posing risks to grazing stock.

6.2 Production for Market

Crop, livestock, and, of course, farming households have linkages, in varying degrees, to the market (Yadav 1990). Growing commercialisation is indicative of the efforts of mountain farmers to use scarce land resources more efficiently for gainful employment and increased incomes (Partap 1995). Production for market, in fact, is the central theme of current development interventions. Despite its subsistence characteristics, mountain agriculture apparently is strengthening its linkages with the market. Transformation, in a sense, represents a situation of feeble intersystemic linkages and a high degree of linkages with the market.

The change in livestock parameters, being promoted particularly through crossbreeding of indigenous cattle with exotic meat/milk type breeds, is not only aimed at creating less diversified herd compositions, incorporating single-purpose and less suitable animals, but also at consolidating the market system in mountain areas. Every element of the so-called cattle improvement programme; or the white revolution (semen, medicines, feed, instrument, technical know-how etc), depends heavily on the market. The only aim is to supply an increased amount of milk to the market. Rising prosperity in the cities and newly-established mountain towns has created a greater demand for animal products. Breed improvement, health care, and fodder cultivation programmes were to meet the demand for milk and other animal products in the cities and towns equipped with modern amenities. To increase this supply, an organized milk collection programme was also launched. The latter, however, could work only in the foothill and *Tera*i areas, not in the mountains. In the mountains, livestock owners have evolved their own system of collection and distribution. The great degree of inaccessibility in the region did not allow the institutional system of collection and distribution to operate successfully in the region.

Since the breed improvement programme did not succeed to a great extent, cows (crossbred ones) did not provide any marked increase in the cattle population. The traditional milch animal, the buffaloes, did a laudable job. Their proportion in the herds increased significantly and that of cattle decreased or remained stagnant (Singh and Sharma 1990). A study in eight villages of two different catchment areas in the Tehri district of Garhwal revealed that, in the total milk pool of the mountain villages, buffalo milk production was as great as 98 per cent (Singh 1992). An estimated two-thirds of the total amount of buffalo milk in the Chamba block of Tehri district were supplied to the local market. Cow's milk is almost always consumed at home. Selling cow's milk is still widely believed to be an inauspicious act. The indigenous cow is, thus, directly linked to the health of a family.

An overwhelming majority of mountain people operates almost entirely in a subsistence economy in which money plays a minor role in daily life. Life's necessities are provided through land-based activities and very little is brought from or sold to the market. The farmers' world (the mountain farming system) is largely self-sufficient (Jackson 1985, Singh and Sharma 1990). But, the present-day mountain village, with so many people living and working away and sending money home, cannot be considered to be self-sufficient or self-contained. Nevertheless, this is a latterday development caused by overpopulation and ecological degradation, leading to a state of unsustainability in the system (Jodha et al. 1992, Shrestha 1992, and Singh 1992). This, to some extent, alters the subsistence character of mountain villages and, as a result, the two economies operate side by side and inter-penetrate to a certain degree (Jackson 1985).

White Revolution technology is based on the cash economy, because it requires production inputs (bull semen, feed, medicines, instruments, and technical know-how)

from the market and the sale of produce to the market. This technology is tied to the international economy. Underlying current development interventions is the implicit assumption that it is an indicator of progress if all rural people are dragged into the cash economy. And yet, experience shows that, if subsistence farmers are dragged into the cash economy without a perspective-based approach, chances of their exploitation by the open market system will increase, for, in a pure cash economy, life is dictated by a continual series of transactions mediated by money through the market place.

The monetary economy, strengthened through commercialisation of farming, based on a mountain perspective (Partap 1995) that does not compromise with the ecological sustainability of the system, could be a promising step in mountain development, but the current, market-oriented development in the livestock sector carries potential risks to ecological sustainability (through maintaining genetic uniformity among animals, agricultural productivity (by posing a threat to DAP supply), and human health (by draining animal products, mainly the milk, the most complete source of nutrient, to the market). The long-term sustainability of the agricultural system should be our goal.

6.3 Emphasis on Farm Mechanisation

The conventional agricultural development strategy often stresses the need to introduce small tractors or power tillers into the mountain region. Government-sponsored institutes and agricultural departments, in pursuance of the strategy, have already introduced tractors and power tillers on their respective farms in mountain areas. In the Terai region, adjoining the Himalayan foothills, farm mechanization, thanks to institutional efforts, has revolutionised the regional agro-economy, but, despite institutional efforts, the poor mountain farmers opted out of this phenomenon. The Royal Commission on Agriculture of 1927 first set forth the objectives of livestock development in India: increased production per animal and a reduction in animal numbers. This strategy still forms the basis of the current White Revolution technology. It has been assumed that livestock numbers will decrease with the mechanisation of agriculture and that farmers will soon recognise the advantages of keeping one good animal from a quality breed rather than three to four poor ones from indigenous breeds.

As already discussed, farm mechanisation is neither relevant under mountain circumstances nor does it guarantee a decrease in livestock population in mountain areas. The problem of excessive numbers of animals in the region is primarily due to the availability of and free excess to CPRs. An increase in the cattle population is also necessitated by an increase in cultivated area. But the current management trend avoids overpopulation of cattle. Livestock population growth must also be analysed through the existing disease control programme, economics of livestock production from a farmer's and a landless stock owner's point of view, the general ecological state of the uncultivated land, production performance of croplands, and the livestock management system.

Rather than furthering the debate on mechanisation of mountain agriculture, which is not in tune with sustainability in the specific mountain context, institutional efforts should focus on efficient and sustainable use of draught animals in mountain agriculture.

In the *Terai* region, which has been flooded by tractors and other farm machinery, it has been experienced that production is concentrated on a limited number of crops which are most profitable and productive. But, in the hills and mountains, large-scale mechanisation, if it comes into force, would hamper both the diversity of crops as well as of farmers' strategies. The diversity in farmers' strategies is assisted by draught animal use. As Defoer et al. (1995) put it, visualising the diversity of their strategies allows farmers to evaluate their practices and allows researchers and extensionists to guide farmers in improving these practices. Monitoring crucial parameters based on farmers' criteria may help to fine tune extension programmes and policies.

6.4 Neglect of the DAP System

The DAP system, which is an outstanding example of mass application of appropriate technology and which has no alternative in mountain circumstances, is, ironically, not included in the development package for the mountains. This aspect is also missing from the debate on sustainability. The fact is that an approach towards sustainability that does not incorporate DAP considerations would itself be unsustainable. Animal husbandry departments in universities and research institutes hardly consider draught animals as a target of research projects. Official records are devoid of any data on the contribution of draught animals to the mountain agro-economy. Agricultural engineers do not regard agricultural implements, hand-tools, and the harness system as being worthy of improvement. In the Five-year Plans no fraction of the budget earmarked for the livestock sector is allocated to the improvement of draught animals. On the contrary, conventional animal improvement schemes are detrimental to draught animals, both conceptually as well as practically.

It goes without saying that the institutional neglect of the DAP system has been and still is a critical constraint to the improvement of agronomic productivity and amelioration of constraints to sustainability.

The main focus of researchers and agricultural technologists is on improvements in the efficiency of fossil fuel-powered machines. Some amount of work has also been carried out on animal-drawn vehicles and implements, but this is mostly geared towards agriculture in the plains. In the mountain farming system, where the role of DAPs is more pivotal, this field is still unresearched. In essence, any strategy that overlooks the value of DAP in mountain agriculture cannot achieve the goal of sustainable development.

Seven

DAP and Farmers' Strategies

Despite their greater suitability and relevance, traditional farming practices are losing their efficacy and feasibility in the face of the changing demography, institutions, and technologies (Jodha and Partap 1993). However, what has not changed, or what has not even been researched, is the DAP system. This is because of the strong, rather inseparable, convergence between attributes of DAP and specific characteristics of mountain agriculture. Despite the great degree of institutional intervention that, in the context of the livestock sector, mainly focusses on the development of specialised breeds to be maintained to yield marketable, edible products, farmers did not allow the DAP system to degenerate.

The tilled terraces provide a diversity of agricultural niches. Thus, wherever farmers take advantage of this diversity, increasing their security, DAP becomes a meaningful tool in the process. In their indigenous land and soil management technologies, the farmers skillfully ration the use of DAP according to the type of land, soil, crop, season, etc.

Low ploughing frequency is practised on fallow lands. DAP input in low amounts in the high Himalayan areas is complementary to the more delicate ecological balance. To take care of the soil moisture content, the ploughing frequency in upland (rainfed) areas is lower than in lowland (irrigated) areas. In upland areas, manure, in most cases, generally in the winter crop season, is applied after sowing because, in addition to increasing soil fertility, it also acts as a mulch to conserve the moisture of the soil.

The emergence of the current DAP management situation has already been discussed in detail and is a vital part of farmers' strategies.

7.1 Livestock Farming

The livestock holding size is according to the requirements of a family and the area specificities. In a cereal and fruit crop farming system, an individual household normally likes to have a buffalo for milk production, a female buffalo calf, a pair of bullocks, and sometimes a cow for the reproduction of bullocks. Male buffaloes are

not kept as they do not fit into the farming system. Male buffalo calves are starved to death a few days after birth. A pair of bullocks is generally kept on 1.5 ha of cropland. Usually marginal and smallholders do not maintain full pairs of bullocks. In this way, they save maintenance costs and use hired bullocks or share. If they keep bullocks, then they hire them out to earn cash income. Some small and marginal landholders raise their income by raising large numbers of goats and sheep. Livestock holding size, in fact, is a functional unit of the livestock population. In a livestock-based farming system, the composition of the livestock herd is different from those in the other systems. The herd consists of a very large number of sheep and goats. Bovine species are given less importance than bovines. Ovines are easier to maintain. Large numbers of livestock can be supported easily on the vast rangeland areas where high quality fodder species grow.

Transhumance in mountain areas is a response to local resource conditions and seasonal scarcity, allowing for the extensive use of natural regenerative processes, the management of risk through movement options, and the exploitation of vertical and horizontal spatial linkages created by the mountain area's diverse landscapes (Jodha and Partap 1993).

The cattle breeds in the mountains are suitable for farming systems with limited resources and are well adapted to a wide range of ecological conditions. The specific traits of the hill and mountain breeds of cattle and their suitability to mountain agriculture will be discussed shortly. Farmers' management of breeds especially suited to diverse local conditions and to specific purposes (e.g., draught power) is the strong potential of traditional strategies. However, no breed is a single-purpose breed. They perform more than one role. For example, goats and sheep, which are conventionally regarded as meat and wool animals, respectively, are also used extensively as pack animals, especially by nomadic mountain communities. In some areas, sheep and goats transport more produce even than conventional pack animals. Pack animals, in addition to performing their usual function, are also used for riding by tourists and thus become an additional source of income. Even bullocks are used as pack animals during transhumance and migration. Occasionally, buffaloes too offer the same service. Among all classes of livestock, except among the transhumant pastoralists, cattle are considered to be the most important, particularly because of their power attribute for mountain agriculture.

7.2 Draught Animal Breeds - Characterisation and Suitability to Terrain

The current conventional development intervention in the livestock sector, which in the mountains is centered around the crossbreeding of local cows with exotic bulls, has been launched to achieve the single target of increased milk production. But this kind of intervention totally ignores the cattle breeds found in the region and their unique role in agro-ecosystems. This programme also ignores the consequences it would have on the DAP system in mountain agriculture. The process of substituting

many local breeds with exotic ones leads to the loss of natural resistance and competitive ability of the animals. It will severely affect the long-term sustainability of the livestock sector.

While some deterioration might have already occurred, local cattle breeds are still thriving and contributing to the system. There is hardly any mention of local mountain breeds in the literature. Of course there are volumes portraying them as 'useless', 'unwanted', 'burden on the hills', 'uneconomic', 'ecological disaster', 'dung-cows' etc. All this is because of ignorance, because no systematic efforts have ever been made to examine the unique traits and characteristics of the poor men's cattle closely.

There cannot be one best breed of cattle or any other livestock species. But there might be a best breed for the farmer, for a farming community, and for a geographical region. Farmer's individual choice, type, and quality of breeding stock available in the community, type of farming system, physiological and regional adaptability of breeds, and a community's sociocultural set-up are some factors determining the population of any breed in a particular farming system or region. Local breeds, thus, are a result of natural selection and the deliberate selection of farmers in a particular area or community. By selecting an ideal breed or breeds in a particular farming system, farmers increase their ability to convert inputs into useful products.

In the central Himalayan areas, including the adjoining plains, there are three important types of cattle breed dominating the area. What is known as the hill or *pahari* breed is the most popular among mountain farmers. It is this breed that contributes the maximum to the farming system in the context of draught power supply and other ecosystem services. But this local breed has not so far been classified scientifically. In the following paragraphs, we have described in brief the basic qualities of the prominent breeds. An effort to characterise the so far non-descript breed has also been made.

i. Ponwar Breed

This is a well-defined breed of Indian cattle. It is considered to be a draught breed. Bullocks of this breed are found in the Sitarganj, Nanakmatta, Khatima, and Tanakpur areas of the *Terai* region in the Kumaon Himalayas. The bullocks of this breed are very active and very useful for draught purposes. The cows are poor milkers. These animals have coarse heads; narrow faces; concave foreheads; long, pointed horns; tight sheaths; and long, tapering tails. Black and white are the prevailing colours among these animals. Animals of this breed prefer free grazing on *Terai* grasses. They are well adapted to the hot and humid climate of the *Terai* area and quite resistant to the insects and worms of this region. This breed is generally accepted as the most suitable cattle breed for the *Terai*.

ii. Jwalapuri Breed

This breed has not yet been documented as a cattle breed of India, but it is found in large numbers in the areas of outer Garhwal, namely, Jwalapur, Hardwar, Rishikesh, Bhaguwala, etc.

The body size is small to medium and the colour is white, black, and red and sometimes a mixture of white with black or red colours. The animals are sluggish, with loose skin and short, strong and straight legs. The body is low set and the animals are well adapted to *Terai* conditions and docile in nature. The muzzle, knee, pastern, and switch of the tail are black. The tail is very long, sometimes touching the ground.

Cows of this breed are poor yielders but the bullocks are good draught animals. They are used to performing all agricultural operations but are especially liked for puddling rice fields.

iii. Other Breeds of Cattle

In the *Terai* area of the Indian Central Himalayas, particularly in Kashipur, Rudrapur, Pantnagar, and Kichha, crossbred cattle constitute a major proportion of the livestock population. Crossbred females are reared primarily for their milk. The majority of these animals are crosses of Jersey and Holstein/Friesian with local cattle.

Crossbred females are of very large in size and heavy in weight and are good milk producers, but the males are not ideally suited to field operations. In the *Terai* area they are used for carting heavy loads. Due to their sluggish nature, bulky bodies, and humplessness, they are not used for ploughing and other agricultural operations.

In the hills and mountains, however, non-descript cattle make up the core of the livestock sector. The body size and weight of cattle decrease gradually as we proceed from the Shivalik hills to the Middle Himalayan mountains. The prevalent breeds of cattle are of the draught varieties; they produce good working bullocks highly suitable to mountain conditions, while their progeny give small quantities of milk.

On the basis of body colour, female cattle generally fall into three groups : the white cows called *Dhauri*, the blacks called *Kali* and the reds called *Gauri*. Their male counterparts are locally called *Dhaur*, *Kala*, and *Gaur*, respectively. The body is small, short, and set low with small, strong and straight legs. The hooves are small but compact and most suitable for walking and grazing on steep slopes. The tail is long with a black switch. Small body size, light weight, hardiness, activeness and tolerance of severe cold are the other traits inherent in the local cattle, enabling them to adapt to and perform well in specific geographical conditions. The animals can climb a few stairs and walk easily for grazing, even on steep mountain slopes. The bullocks are well

trained to cross narrow footpaths and rivulets with gravelled bases and to work in small, terraced fields at various altitudes.

Since the mountain cattle breed is non-descript, and hence the animal's body measurements are not available in the literature, we have attempted to describe the breed by way of recording measurements of important body parts indicative of the breed's characteristics. This exercise has been carried out only in relation to male cattle, i.e., bullocks, on which our whole discussion is based. A reconnaissance survey was carried out in which five villages in Tehri district in the Garhwal Himalayas, namely, Sawali, Jagdhar, Dharkote, Dikholgaon, and Pali, were selected. In each village, five pairs of bullocks, in total 50 working bullocks of different ages, were selected for examination. The different measurements are given in Table 7.1.

The average circumference of the mouth just above the muzzle is 39cm with a maximum of 40cm and a minimum of 36cm in different sample bullocks. The average distance between eye and muzzle is 20cm, ranging from 18 to 21 cm. The average values for from ear base to muzzle, poll to muzzle, eye to eye, and horn to horn recorded are 32, 40, 15, and 14 cm, respectively. These figures are indicative of the short face of the bullock breed.

Average length of the horn, ear, and width of the ear are found to be 17, 22, and 11cm, respectively. The average length of the neck is 40 and that of the back 73cm. Average distance between hook and hook, hook and pin, hook and hip bones is the same in each, i.e., 29cm, while the distance between hip to pin is 20cm. These values appear to indicate sloping rumps. The average length between shoulder and pin bone is 113 cm (ranging from 96 to 132 cm) and the average heart girth registered is 151 cm (ranging from 122 to 165 cm). These two values are very important for estimating the live weight of an animal. The heights at hump, shoulder, elbow, and knee are 113, 72, 56 and 36cm, respectively, indicative of the short legs and low set body of the animals. The dewlap of the majority of the bullocks, as observed, is thick, wrinkled, fleshy, and heavy with an average width of 75cm. The average body weight based on the measurements from shoulder to pin bone distance and heart girth (circumference just behind the fore legs) registers 250kg and ranges between 140 and 340kg (Table 7.1).

Farmers in many parts of the mountains identify cattle breeds that appear to be different from the aforementioned ones. For example, farmers in Banali village identify two distinctive breeds of bullocks — Malkoti and Rathi. Malkoti has been named because, they say, their ancestors had brought these bullocks from the Malkot area. The Rathi seems to be a mixture of a local breed and one from Rath.

The latter is a non-descript breed classed among dual-purpose breeds. This is a medium-sized breed found in Rajasthan. The bullocks are compact and active, and the cows are fairly good milkers. However, in general, farmers, almost everywhere,

Table 7.1: Important Body Measurements of Work Bullocks

Particulars	Average(cm)	Minimum - Maximum(cm)
Mouth Circumference	39	36-44
Eye to Muzzle	20	18-21
Ear to Muzzle	32	30-36
Poll to Muzzle	40	36-48
Eye to Eye	15	12-20
Horn to Horn	14	12-16
Horn Length	17	10-29
Ear Length	22	15-30
Ear Width	11	10-14
Neck Length	40	30-55
Back Length	73	66-80
Height at Hump	113	96-129
Height at Shoulder	72	65-81
Height at Elbow	56	33-73
Height at Knee	36	-
Hook Bone to Hook Bone	29	22-38
Hook Bone to Pin Bone	29	21-37
Hook Bone to Hip Bone	29	23-38
Hip Bone to Pin Bone	20	10-35
Shoulder to Pin Bone (L)	113	96-132
Heart Girth (G)	151	122-165
Belly Circumference	167	150-190
Hoof Length	6	5-9
Hoof Circumference	27	24-32
Dewlap Width	75	-
Tail Length	82	70-90
Body Weight *, kg	250	140-340

* The weights of animals were calculated from body measurements by using the following formula (G.B.Pant University 1982, Singh 1985) :

$$\text{Weight, kg} = L \times G^2 / 10317$$

where, L = Length from point of shoulder to pin bone in cm and

G = Heart girth, i.e., circumference of ani.immediately behind the front legs, in c

identify their bullocks by skin colour. While interviewed, most of the farmers referred to only two types of bullocks : *Pahari buld* (the hill bullock) or *Ghariya Bail* (the ox produced at home) and *Desi Bail* or *Malya buld* (the ox from the plains). The third category is that of the *Jersey Bail*, which is how people refer to any crossbred bullock. Since the latter breed is only rarely used for field preparations, it hardly comes into group discussion.

A bullock that does not perform well and sits down in the field while ploughing is locally called *Galya Buld* (the useless ox) and such an animal is sold to traders from outside. Animals that are diseased and weak are also sold. Those with a proven high degree of

draught power are retained for longer periods. Transhumant pastoralists keep the animals that are amenable to herding and capable of walking long distances.

Whereas the characteristics of the majority of cattle breeds found in the plains of India have been described properly, no systematic work has ever been carried out on breeds contributing appreciably to the economy of marginal areas. The breeding management system, based on generations of natural selection and deliberate selection by farmers, that has resulted in the existing local breeds with unique traits for surviving and working efficiently in the mountain environment, deserves appreciation and extensive investigation. This would help to conserve local breeds and ameliorate the whole DAP system.

7.3 Harnesses, Implements and Tools

Harnesses, implements, and tools have not only a marked influence on the amount of DAP generated, but the use of DAP would be impossible without the help of these implements.

The use of poorly-designed harnesses and yokes causes inefficient transfer of power from the animal to the implement. Improper hitching requires the animal to exert greater tractive efforts than actually needed to overcome the implement draught (Goe 1983). Farmers generally use light wood (such as that of the ash tree in the upper region of Garhwal, for example) to make yokes. Such yokes are adjustable and comfortable, allowing for increased tractive effort on the part of the animals. The leveller farmers use is also light, and sometimes when it does not work, especially when preparing fields after rice harvest, the levelling process is assisted by manual operations (breaking of clods). In many parts of the Himalayas, where wood from the desired species is not available, the yokes are somewhat heavier (for example, those made of pine wood).

Ploughshares are constructed almost always from oak wood. This is the most important part of a plough. Every family keeps two ploughshares in the case of emergency. Two ploughshares a year are needed. The iron part of the plough is usually pointed like a javelin, rather than being flat as found in the plains, because it has to take care of the gravels and stones found in mountain soils. Puddlers and weeders are made of wood only. No iron is used in them. The weeder (locally known as a *danala*) is consumed very rapidly. In many cases, one *danala* is hardly usable by the next cropping season.

Materials used in harness construction are sometime treated with a preservative, e.g., mustard oil, to increase its lifespan.

All families have hand tools. Even families that hire in bullocks for land preparation will have agricultural implements at home. In our survey, Bagauri village is the exception. The entire village depends on hiring bullocks and ploughs for land preparation.

The agricultural implements and tools, as well as the harnesses, are all made from locally available materials (except for iron ploughshares and the iron parts of hand hoes) and by local persons specialised in the field. These tools and implements are designed by the farmers in such a way that they not only fulfill their needs but also fit into local conditions. The harnesses, tools, and implements, indeed, reflect local traditional art, science, and technology.

A list of district-wise agricultural tools and implements, based on the latest figures available at the district statistical offices, is presented in Table 7.2. Traditional wooden ploughs are maximum in number, reflecting their suitability for mountain agriculture. The 'improved' tools and implements, being popularised by the public system and distributed under various development schemes free of cost, as well as being sold at subsidised rates, cannot replace the traditional ones. Threshing machines, sprayers, sowing machines, and tractors could be introduced, mostly in the plains of the Nainital and Dehradun districts. Certain 'improved' designs fail to show a marked advantage over traditional types in mountainous areas. They are usually heavier than the traditional types, costs (if not available at subsidised rates) are higher, materials for construction are not always readily available, and they may require special tools and components for repair. If the agricultural implements were suitable to the area-specific conditions and are more effective than the traditional types, the farmers would readily accept them.

Table 7.2: Agricultural Implements in the Districts of the Central Himalayas, India

Districts	Wooden Plough	Iron Plough	Improved Harrow & Cultivator	Threshing Machine	Sprayer	Improved Sowing Machine	Tractor
Pithoragarh	92194	3419	667	-	344	212	1
Almora	128488	3543	14427	707	23	1032	3
Nainital	39039	48333	13231	6642	3320	3662	7292
Uttarkashi	37416	657	336	22	98	3	-
Chamoli	63243	39	6	1	1	683	-
Pauri	67166	2595	353	42	42	5	16
Tehri	81321	85	202	1	1	2	2
Dehradun	28313	15620	1079	566	566	425	673
Total	537180	74291	30301	7981	4395	6024	7987

Compiled from the statistical books published by the respective district statistics' offices.

The figures are according to the 1988 Animal Census.

Eight

The Future of DAP in Mountain Agriculture

The evidence and discussions presented in the previous chapters suggest mixed prospects for DAP in mountain agriculture. However, despite all the constraining factors and agricultural transformation, DAP will continue to be the main source of animate energy in future.

As we have seen earlier, intra-regional and inter-regional inaccessibility favour the conservation of DAP. Traditionalism also encourages it. Social factors, such as migration, working away in the plains, or paucity of male labour in the households, discourage DAP. The public intervention system in the field of animal husbandry also works against DAP. In future, inaccessibility problems will largely be addressed thanks to the road network covering more and more areas of the mountains. Traditional agriculture will gradually give way to transformed or commercial agriculture. Migration is also likely to intensify in future, creating a greater shortage of male labour at home. The conventional institutional programmes will perhaps also intensify in the region. These arguments suggest that the future of DAP will be gloomy. But, indeed, the future of DAP will depend on a number of complex situations.

8.1 Size of Holdings

The overall population of draught animals appears to be directly proportional to the number of holdings. But it is not. The size of holdings, indeed, is an important factor governing the population of draught animals. Medium and large-sized holdings tend to maintain a pair of bullocks. Marginal and small holders do not always depend on independent DAP use. In future, with the increase in human population, the total number of holdings will increase. It will be followed by holding fragmentation, i.e., the size of holdings will decrease. Medium and large holdings will turn into marginal and small holdings. It should mean that the population of draught animals will decrease. But this might be compensated for by joining together small and marginal holdings and hiring out DAP for economic gain.

The size of holdings, therefore, is likely to keep DAP in balance, nevertheless, making it more remunerative for a large number of small and marginal landholders. In other

words, instead of influencing DAP resources, the landholding size will only influence DAP management.

8.2 Institutional Policies and Programmes

Institutional policies and programmes relating to the animal husbandry sector elaborated upon elsewhere are, in fact, not DAP friendly. If they become successful and lead to a change in draught animals' genetic composition by incorporating exotic genes, the future of DAP will perhaps be grim. But chances of this programme and other complementary ones becoming successful seem slight, because farmers have already rejected the programme 'choosing' buffaloes as a more promising alternative to the high milk-yielding crossbred cows.

8.3 Commercialisation of Agriculture

Commercialisation of agriculture in the mountains basically relies on the cash crop-based cropping systems. As we have seen earlier, vegetable cultivation requires a maximum input of DAP as well as human energy. One assumes that fruit farming (apple orchards, for instance) requires no DAP input. But the fact is that the area under fruit trees is used extensively for vegetable cultivation. As a result, it has been noted that the orchard - vegetable cropping system demands more DAP than a cereal - based system.

Since orchard-vegetable cropping is emerging as a dominant farming system in mountain areas (Banskota and Jodha 1992, Partap 1995), the prospects of DAP appear to be bright. However, as we have noted earlier, the transformed areas prefer buffaloes to cattle; the DAP supply in these areas in future will depend heavily on the hiring-in system. The inter-village hiring system will be dominant perhaps, for transformed village communities will have less time for cattle rearing. The non-transformed villages will hire out DAP to such villages. In the distant future, the villages engaged in cash crop farming may also depend on hired human labour, for, unlike in the traditional villages, community-based cultural activities are losing ground in transformed villages.

Commercialisation in terms of the increased cultivation of non-perishable nuts, timber species, and medicinal and aromatic plants will, of course, lead to a reduced demand for DAP.

8.4 Increased Use of External Inputs

Use of internal inputs (forest leaf litter, farmyard manure), to a certain extent, is complementary to DAP. In a natural farming system (the Fukuoka-type One Straw Revolution farming involving no tillage), the use of DAP might be completely eliminated. This kind of farming requires rice straw as a basic input. No other input, except seeds and occasional human labour, is needed. There was a lot of discussion over this in the

late 1980s, but then it faded away gradually. This farming system has not captured farmers' attention, even in Japan, where it had evolved, because of the complexity it involves. No-tillage farming in the mountains does not seem to be a reality in the foreseeable future. DAP will remain a basic input. Moreover, research findings have shown that no-tillage without residue cover results in more soil erosion than conventional tillage (Benoit and Lindstrom 1987).

The external inputs—improved seeds, chemical fertilizers, etc — have good responses only when other inputs, including DAP, are supplied in adequate measures. High-yielding seed varieties to be sown on irrigated land, for example, require a higher frequency of ploughing, that is, more input of DAP in order to realise potential yields. Reduced tillage, in fact, holds much promise for the development of sustainable dryland (rainfed) agriculture (Singh et al. 1994) but, for certain crops, for example, recently introduced crops, such as soybeans and vegetables, and high-yielding crops, such as lowland rice and wheat, it will be difficult to sustain yield potential without a high amount of DAP and other inputs. We have already elaborated upon these facts.

8.5 Altered Cropping Patterns

Multiple cropping with no fallowing practices, involving high-yielding, high grain-straw ratio crops and photo-period-insensitive, short duration cash crops is likely to be the future scenario of mountain farming. Such crops and crop sequences will be a part of high energy input agriculture. DAP demand will increase substantially. The input use of other energy, particularly external ones, viz., chemical fertilizers and pesticides, will also increase. Notwithstanding, increasing environmental awareness, of which the Central Himalayan region of India is a strong example, will lead to reduced or 'rational' use of external chemical inputs.

The majority of marginal and small farmers will also join the mainstream of mountain farming in future to increase their incomes. Yet they will not be in a position to depend heavily on high pay-off chemical inputs. DAP, in any case, will have a greater share in the overall energy scenario. In the foothills and Shivalik zone, where the transitional farming system is found, such changes in the farming system will perhaps be in favour of the use of fossil fuel-powered machines (e.g., tractors). The farmers in these areas will not possess tractors independently. They will depend largely on hiring them. Nevertheless, even then, DAP will have a substantial share in the power system.

8.6 Environmental Degradation

In mountain agriculture, cattle are vital components of land-use systems. Yet, when they are discussed in relation to the development of sustainable mountain agriculture, they are often accused of environmental degradation in the mountains. Ashish (1982) argues that the primary reason why hill farmers keep cattle is to provide manure for the fields. Many other researchers also look at cattle as having an essentially negative

impact on the environment and call for stall-feeding (GBP University 1982 and 1989, Pandey et al. 1982, Ashish 1982, Jackson 1985, and Banskota and Jodha 1992). But, in fact, neither are the cattle (bullocks and cows) kept to merely provide manure for the fields, nor are they the sole reason for environmental deterioration or a big threat to it.

Are draught animals contributing to overpopulation? If we look at Table 8.1, we find that the total ruminant population in the Central Himalayas shows a marginal increase (6.5%) from 1961 to 1988, i.e., over 27 years. Interestingly, the cattle population has decreased by about six per cent and that of sheep by about nine per cent over this period, while buffaloes and goats have registered an increase of 41 and 20 per cent during the same period, respectively. This trend shows that draught animals are not contributing to overpopulation of livestock, rather buffaloes and goats are doing so. A similar trend in cattle population stagnation has been observed in Himachal Pradesh, the other Himalayan state of India, where the share of male cattle in the bovine population was around 41 per cent during 1982 declining to 37.5 per cent by 1992 (Chand 1995). The declining trend in numbers of draught animals throughout the regions of India and during the inter-census periods is also evident (Pandey 1995).

The grazing of draught animals, therefore, is not to blame for environmental deterioration, nor will draught animals be responsible for environmental deterioration in future. Assuming that there is no increase in the area of land cultivated in the mountains in the future — and it should be a matter of institutional policy to see that there will be no increase at the expense of forest areas, since it would be self-defeating for the mountain people — the number of draught animals per village will decrease (Jackson 1985).

Some environmentalists fear that, in a free-range grazing system, livestock destroy the vegetation, prevent the regeneration of trees, and affect the environment, particularly CPRs, and thus reduce the productive potential of an area (World Bank 1991). These allegations are true to a certain extent. Yet, draught animals (cattle are most often

Table 8.1: Changing Trend in Numbers of Ruminant Livestock Population (x1000) in the Central Himalayas, India

Ruminant	1961	1966	1972	1978	1982	1988	Percent
Cattle	2057	2064	2180	2072	1910	1942	- 5.59
Buffaloes	585	633	677	699	768	827	+ 41.37
Sheep	384	413	353	405	408	348	- 9.38
Goats	751	884	737	948	865	904	+ 20.37
Total Population	3777	3994	3947	4124	3951	4021	+ 6.46

Source: Compiled from district statistical books

Note : Oral history from the study sites also reveals the same trend in livestock population and composition over a period of three decades.

These dynamics suggest important changes in the DAP system in mountain agriculture in the future.

accused) contribute little to this deterioration. Their frequent movement between mountains and plains also eases pressure on CPRs. Bullocks are stall-fed for as many days as they work in the fields, and these are the species that can be kept exclusively stall-fed. But sheep and goats are notoriously difficult to stall-feed.

The preponderance of goats and sheep greatly intensifies the deterioration of grazing lands, making it more difficult to sustain cattle in future (Mann 1997 and Bhagat 1982).

The advantages of moderate grazing are worth noting. Moderate grazing maintains the physical soil characteristics and soil fertility and also helps in the regeneration of CPRs through the seeds passed through the animal's alimentary canal. *In situ* manuring and grazing go side by side. Moreover, through grazing, animal feeding is more balanced as, by using its natural instincts, it will choose the vegetation that is most desirable for its taste and health. Continuous exercise of the limbs through grazing also helps the animal keep fit. Thus, moderate grazing, in addition to being environmentally regenerative, also helps increase an animal's productivity in terms of work and in terms of milk in the case of cattle.

Considering the vital role and attributes of draught animals in mountain agriculture and the possible future livestock population scenarios in the Central Himalayas, draught animals will be regarded as a great asset rather than a burden by environmentalists in future, as do farmers today. Whatever little damage they cause, out of mismanagement of resources, is more than compensated for in terms of their unique services to the agro-ecosystems.

Nine

Augmenting DAP in Mountain Agriculture

DAP is a powerful means of increasing agricultural productivity and the sustainability of the system - and not a solution to all problems. To use it as an essential ingredient for agricultural sustainability, the DAP has to be combined with other agricultural techniques, policies, and programmes.

The following sections highlight some potential technological and institutional options that can contribute to augmenting the DAP, thus stimulating the process of agricultural sustainability.

9.1 Potential Options

Improvement in the use of the existing potential of DAP resources would inevitably lead to increased agricultural productivity in the region. It can be secured through the following.

- Increasing the number of days of bullock use per year and the number of work hours per day. This will be possible through diversification in crop production, e.g., multiple cropping, mixed cropping, cash cropping, annual-perennial links, etc.
- Using more animal species as DAP resources; for example, yaks, which are 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), dry cows - as used extensively in Bangladesh, donkeys, mules, and horses
- Involving work animals in more activities, for example, some transhumant societies use bullocks as pack animals also
- Increasing power output per animal - this can be achieved through improved matching designs of yokes, harnesses, and animal-drawn implements; providing balanced nutrition and better health care to the mothers, calves, and work animals; and proper training of animals

- Consolidation of scattered holdings, if possible – this will contribute to efficient DAP management by avoiding loss of time and energy in mobility
- Improving the condition of CPRs, e.g., common forests, grazing lands, etc through the several techniques and strategies explained in detail by Jodha (1992b, 1995a) and Miller (1995) which would ensure regular fodder and other biomass supplies to the farming system and would be a key element to improving the sustainability of the system.

9.2 Technological Options

Research and technology must look at the DAP system as an integral part of the whole system. The DAP system, to be upgraded, needs technological innovations not only for use by scientists but also by farmers. Farmers' traditional technologies may be instrumental in guiding such innovations. Technological advances should not remain confined to laboratories, but they should reach the farms and they must be within the financial means of farming communities.

It will be necessary to re-emphasise that, to be effective, technological advances in the DAP system must be combined with the perspective-based strategies for sustainable mountain agriculture (Jodha et al. 1992).

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

Animal nutrition and optimum rates of work are two areas in need of further investigation. These two criteria vary according to the geographical area in question. Animal nutrition requires consideration of the feed resources available in the mountain region, while the rate of work would largely depend on the interactions between the task, the implement, the harness, the animals, and the operator (Kemp 1987).

i. Nutrition of Draught Animals

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

Animals should be fed a balanced diet which provides all the nutrients required by any animal in a 24-hour cycle. In a balanced diet, the quantity of various ingredients

increases or decreases according to the body weight and working capacity of the animal. Draught animals should be fed for maintenance and work production. Energy and other nutrients needed to maintain the health and other physiological activities when the animal is in a resting state are called maintenance rations. Rations apart from maintenance which provide the energy to work are called work production ratios.

Normally animals are maintained if green fodder of good quality (legume) is available. If the fodder is not of good quality, then other green fodders (non-legume) should be supplemented with adequate quantities of concentrate mixture. If the fodder available is of very poor quality (such as dried grass and crop residues), urea treatment can be applied to improve their digestibility.

For a long time now, roughages have been treated with various chemicals, such as sodium hydroxide, calcium hydroxide, and other chemicals, to improve their nutritive value. But ammonia treatment, rather than urea treatment, has a greater appeal than calcium or sodium hydroxide treatment. This treatment 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 rate than untreated straw.

For treating straw, 40 to 50g of urea are used per kg of straw, keeping the moisture level around 60 per cent. The stack, after urea treatment, is kept tight and covered for about four weeks before opening it for feeding. Here, urea is hydrolysed by the enzyme urease, releasing ammonia. It is safer, cheaper, and more convenient than other methods for storage and handling. It can be used conveniently on small farms. However, there is a wastage of two-thirds of the urea-ammonia (Kumar 1986).

Some physical treatments also help increase fodder value. Chopping roughages increases voluntary intake, grinding increases intake and digestibility of feed, and feed wastage is also reduced. Pelleting reduces dustiness and volume, resulting in increased feed intake. Soaking is one of the oldest and cheapest methods used in the villages. It removes dust from straws and stovers and makes them moist and improves their palatability. One to two hours' soaking increases feed consumption. Oxalates present in rice straw are removed by soaking, otherwise they bind calcium and reduce the availability of calcium for the animals (Kumar 1997).

a) Feeding Cows during Pregnancy

In the mountains, good care of animals is taken when they are producing milk or performing work. But, to have a healthy animal in future, the growth of the foetus should receive proper attention. So, it becomes very important to feed pregnant animals a balanced diet. During the last trimester of pregnancy, extra amounts of concentrate mixture are given to the animal. These extra amounts known as pregnancy allowances support the animal for the normal development of the foetus.

b) Feeding Growing Male Calves

Growing male calves should be fed more nutrients than the maintenance ration. After birth to 10 weeks of age, there is no difference in the growth of male and females. But afterwards the male grows faster. Just after birth, it is very important to give the calf the milk produced by the cow (colostrum) for three days. Colostrum is different from normal milk. It is rich in protein, vitamins, and antibodies, i.e., gamma globulins. Gamma globulins are absorbed into the system by the calf, developing resistance to all the diseases. Colostrum is also high in nutrients. It is slightly laxative and prevents constipation. Colostrum, being more easily digestible, provides more protein and minerals than normal milk. Normally 2.5 to 3.0 kg colostrum should be given daily. More colostrum than this at one time may cause diarrhoea. Calves are generally fed milk according to their body weights. Up to three weeks of age, the amount of milk given should be one-tenth of the body weight.

After two weeks of age, a 100g calf starter, which contains an appropriate amount of protein and energy ingredients, should be given. The quantity is increased gradually. Besides this, green soft roughage should be offered to the calf for the normal development of the rumen. The feeding schedule for calves up to three months of age is given in Table 9.1. After this age, good quality roughage should be fed to the calf and concentrate mixture should be gradually increased from 1.5 to 3.0 kg till the calf attains one year of age.

Table 9.1: Feeding Schedule for Calves up to Three Months of Age

Age of Calf	Whole Milk (kg)	Skimmed Milk (kg)	Calf Starter* (kg)	Good Quality Roughage (kg)
1st 3 days	2.50 (Colostrum)	-	-	-
4th to 7th day	2.50	-	-	-
2nd week	3.00	-	0.10	0.30
3rd week	3.25	-	0.30	0.50
4th week	3.00	-	0.40	0.60
5th week	1.50	1.00	0.50	0.70
6th week	-	2.50	0.65	0.75
7th week	-	2.00	0.80	0.85
8th week	-	1.75	1.00	1.00
9th week	-	1.25	1.20	1.10
10th week	-	-	1.30	1.20
11th week	-	-	1.40	1.30
12th week	-	-	1.50	1.50
13th week	-	-	2.00	2.00

Source : Kumar (1997)

- * Average composition of calf starter: crushed barley, maize, wheat, oats etc. 50 parts groundnut cake, linseed cake, soyabean cake, cotton seed cake, etc. 30 parts; wheat bran, rice bran, rice polish, etc. 8 parts; fish meal, meat meal, dried skimmed milk, etc 10 parts, mineral mixture, 2 parts. To 100 kg of the above mixture, the following may be added : molasses 5-10% according to availability, antibiotic supplement 20 gm, Vit A supplement 10 gm, salt 500g

c) Feeding Work Bullocks

Cattle use large amounts of roughage in their diet. These animals can synthesize many amino acids and vitamin-B in the rumen. The nutrient requirements of an adult bullock are for maintenance and for mechanical work. The feed that would provide energy and nutrients for the essential physiological processes of life, even when the animal is not working, is known as the maintenance requirement. Nutrients required for the maintenance of adult cattle are given in Table 9.2.

The animal requires nutrients and energy for work, and they have to be included in the ration over and above maintenance requirements. The energy for work is supplied by the oxidation of the large number of nutrients in the system. The energy for muscular work is provided by the break down of phosphocreatine and ATP in the muscles. However, the amount of high-energy phosphate compounds in the muscles is limited. So, for the continuation of work, these compounds are re-synthesized by the reverse process. The energy needed for this renewal is provided by the oxidation of muscle glycogen and also the glucose brought to the muscles through the blood. Lactic acid is an intermediate stage in this oxidation and may accumulate when the muscles become fatigued.

In normal conditions, a working bullock first uses carbohydrates for energy from the feed, then the fats are used up. Finally, if the demand for energy is in excess, protein tissues, such as muscles, are used. Thus, in the diet of draught animals, if carbohydrates are in sufficient supply, then a mature animal at work needs no extra proteins than those provided 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. The feeding standards for draught animals are given in Table 9.3. 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

Table 9.2: Nutrients Required for Maintenance of Adult Cattle Per Head Per Day

Live Weight (kg)	DCP* (kg)	ME** (Mcal)	Carotene (mg)	Calcium (g)	Phosphorus (g)
150	0.102	4.57	10	4	4
200	0.148	5.98	12	5	5
250	0.168	7.27	15	6	6
300	0.197	8.50	17	7	7
350	0.227	9.72	20	8	8
400	0.254	10.91	22	9	9

Source : Kumar (1997)

* Digestible crude protein (DCP).

** 3.615 Mcal of metabolizable energy (ME) = 1 kg of total digestible nutrients (TDN) = 4.409 Mcal of Digestible energy (DE) (Goe 1983).

Table 9.3: Nutrients Required for Working Bullocks Per Head Per Day*

Live Weight (kg)	Normal Work**		Hard Work**	
	DCP (kg)	ME (Mcal)	DCP (kg)	ME (Mcal)
200	0.24	7.20	0.25	9.70
300	0.33	11.20	0.42	14.40
400	0.45	14.40	0.57	17.30
500	0.56	17.60	0.71	23.00

Source : Adapted from Ray (1978), New Delhi : ICAR by Kumar (1997)

* These standards include maintenance needs.

** Normal work : 2-4 hours of ploughing per day; Hard work : 6 hours' ploughing per day

are responsible for production of propionic acid in the rumen, which is a good source of glucose and energy. Crop residues, as per availability, should be provided to draught animals. The quality of the crop residues can be improved through proper chemical treatment. Jaggery, molasses, and mustard oil which are rich in energy, can also be fed to the animals.

d) Computation of Rations

In the computation of rations, we should consider the following points.

- The capacity for consumption should be known by the total amount of dry matter (DM) in the ration which the animal can consume. Cattle generally consume 2.25 to 2.50 kg of DM per 100 kg of live weight.
- The main portion of the total DM to be consumed should come from roughages and the rest from concentrates. In adult bullocks, two-thirds to three-fourths of the total DM should come from roughages.
- After the amount of DM consumption of the animal is known, the quantities of available feeds and fodder are worked out in such a way that the required amounts of protein and energy are supplied in the rations.

The following are examples of balanced rations for draught bullocks.

Example I

A bullock of 250 kg body weight (which is the average body weight in the mountains) and working hard should be fed the following rations.

- | | |
|------------------------|--------|
| 1. Normal green fodder | 6.0 kg |
| 2. Straws | 3.5 kg |
| 3. Concentrate mixture | 3.0 kg |

The concentrate mixture should be as follows.

a. Guar meal or any oilseed cake	12 parts
b. Barley, wheat, oat, maize, etc	30 parts
c. Gram	27 parts
d. Wheat bran, rice bran, etc.	28 parts
e. Mineral mixture	2 parts
f. Salt	1 part

In place of normal green fodder, a farmer can use locally available grass, green sorghum, etc.

Example II

If protein-rich green fodder is available, the balanced rations for the average weight bullock working hard should be as follows.

1. Protein-rich green fodder	10 kg
2. Straws	2.5 kg
3. Concentrate mixture	2.5 kg

The concentrate mixture should be as follows.

a. Guar meal, any oil cake, etc	42 parts
b. Wheat bran, rice bran, etc	55 parts
c. Mineral mixture	2 parts
d. Salt	1 part

For protein-rich green fodder, the farmers can use any leguminous fodder cultivated in the lowland areas of the hills and Shivaliks and the leaves of *Grewia optiva*, *Celtis australis*, etc in the upper mountainous areas.

Example III

For a normal working bullock of average weight the balanced feed should be computed as follows.

1. Non-legume (grass, tree leaves etc) green	6.0 kg
2. Straws	2.5 kg
3. Concentrate mixture (as in Example II)	1.25 kg

If protein-rich green fodder is available, the following ration should be given.

1. Legume fodder	7.5 kg
2. Straws	2.5 kg
3. Concentrate mixture (as in Example II)	1.0 kg

If the draught animal is fed according to the norms given above, they will be able to use the feed resources available more efficiently. The animal will remain healthy and its working strength will increase substantially, and it will contribute to the DAP system more efficiently and more economically.

ii. Designing New Harnesses and Implements

Consideration of engineering principles involved in transferring power from an animal to an implement will result in improved yoke, harness, and implement design.

If draught animals could be equipped with more efficient and more comfortable harnesses, their pulling capacity could easily 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 would be helpful in eliminating suffering. The scientific finding is that the power developed by draught animals may be increased by 15 to 23 per cent by using improved designs of yokes and harnesses (Sharma 1994).

Due to inherent local factors and environmental considerations, there may be a considerable decrease in the draught animal population in future. There is the possibility of designing a new harness system that could use only one animal, rather than a pair. It has been found that a pair of animals is 14 to 20 per cent less efficient than a single one in terms of power conversion efficiency (Kumar 1991). If it is usable and acceptable to farmers, the draught animal population might be reduced to half its present size.

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 land; speed of travel; and skill of the operator (Goe 1983). Efficient agricultural implements, therefore, need to be developed according to specific site characteristics.

The increased use of newly-designed yokes, harnesses, and implements will largely rely upon the vocational training of local craftsmen. It has to be ensured that local craftsmen are 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 these must be acceptable to local farmers.

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

9.3 Institutional Options

The conventional institutional intervention, as we have observed, has a potentially negative impact, contributing to the process of unsustainability in the animal husbandry sector as far as DAP is concerned. An appropriate, perspective-based cattle breeding policy

would be instrumental in augmenting DAP in the mountains. To evolve a new breeding policy, the conventional policy should be reviewed thoroughly. There are specialised breeds for milk, meat, wool etc, but no specialised breeds of draught animals for mountain regions have ever been recognised. The traditional breeding and management skills of local farmers might be pivotal in developing a new breeding policy framework for mountain areas.

Lack of adequate policy measures for augmenting DAP for the development of sustainable mountain agriculture is a basic problem that needs to be addressed. DAP should be treated as an important ingredient of the integrated energy system and as an input qualifying for institutional and infrastructural support.

Adequate infrastructural facilities in terms of R & D and extension services for designing more efficient and matching harnesses and animal-drawn implements and for the improvement of the DAP system would greatly encourage efforts in the sustainable development of mountain agriculture. Statistics on draught animals, their usage patterns, and so on should be published from time to time to help the researchers and scholars in this field.

In the Central Himalayas, the chances of a perspective-based policy framework for promoting and improving the DAP system and ultimately developing sustainable agriculture are very bright. There are several NGOs and voluntary organizations in the region as well as grassroots' workers who are environmentally sensitive. In essence, there are a great many opportunities to infuse sensitivity into public institutions.

9.4 Humane Aspects

The traditional love for animals in India is amongst its greatest strengths. Good human behaviour towards animals is vital for harnessing their potential. A frightened animal, due to secretions of hormones, can work with greater vigour, but only for short durations. Animal's remaining under continuous strain, due to ill-treatment from the owner or driver, is detrimental to its health and work efficiency. Cruelty to animals can make them furious and violent, which might be risky for the driver. Inhuman treatment of animals reduces their working life and hence the economic gains they can provide.

In addition to their economic uses, draught animals are elements in complex cultural patterns. The sacred cow, for example, rules the psyche of the Indian masses. As a source of identity, security, and prestige for families, and a means of social cohesion through gifts and exchange with others, the draught animal gives humanity more than can be accounted for statistically. Humane treatment, love and care of animals, therefore, scores high on grounds of morality and justice.

Barbaric traditional methods of castration, underfeeding, imbalanced nutrition, work without food for long durations, and goading and beating with sharp sticks while performing work are examples of the maltreatment draught animals suffer.

Examples of the maltreatment of work animals one often confronts in the mountains are : barbaric methods of castration, underfeeding, imbalanced nutrition, work without rest and goading and beating with sharp sticks while performing work. These inhuman practices must be avoided. Draught animals are, after all, nurturers of a family and the only source of livelihood for many families. The animals understand the language of love and voice commands, and they return human affection in terms of vital contributions to livelihood.

Affectionate relationships and proper care, they say, doubles the working efficiency of animals. A properly yoked, properly harnessed and well-treated animal is more productive and cost-effective than those that are ill treated (Lord 1991). Humane aspects of dealing with the animals right from cow to calf care and while at work are crucial for maximum DAP output and sustained DAP input for agricultural production.

Ten

Summary and Conclusions

Draught animal power (DAP) is an outstanding example of mass-level application of perspective-based technology by mountain farmers, and it promises to play an important role in sustainable development of mountain agriculture.

Focussing on the three main agro-ecological zones, namely, the Shivaliks/foothills, the middle Himalayas (both traditional and transformed areas) and the Greater Himalayas (high mountains) in the Central Himalayan region of India, the study presents the current state of DAP in mountain farming systems, arguing for the vital role draught animals and the DAP system play in the context of sustainable development of mountain agriculture.

In addition to their vital services in terms of agricultural operations, the draught animals' role in providing income and employment to households is unique. Their social, cultural, and ecological contributions help promote the sustainability of the farming system. Draught animals, in fact, are the most important animal species in mountain agriculture.

The emerging commercialisation of agriculture through cash crop farming, in some favourable areas, demands more intensive use of energy, including DAP. Though this kind of development is to affect the DAP to a certain extent by way of reduced fodder supplies from the farms, its net effect in the Middle Himalayas, where most of the fodder requirements are met from CPRs, would be DAP - promoting. In the Shivalik hills commercialisation would be in favour of mechanisation.

The number of cattle per household is the largest in the Middle Himalayan zone under the traditional agricultural system and the smallest in the villages under transformed agriculture in the same zone. The cattle size and sex-ratios are the major determinants of DAP managerial adjustments in the mountain farming system. A size of less than two bullocks per household points to some degree of hiring and/or sharing. Degree of inaccessibility or isolation, both in terms of distance from the main road in the region and from the plains, and traditionalism influence the size and density of draught animals. Outmigration or working away of adult males discourages large bullock holding sizes and density and also affects overall DAP management as also does the limited substitution

of DAP by tractors in the Shivalik hills. The total effect, of course, depends on the relative strengths of all factors.

While the DAP hiring-out practice is completely absent in the Greater Himalayan zone, it prevails in all other agro-ecological zones. Large landholders, except in the traditional middle mountain villages, do not hire-out bullocks. In the event that all households cannot afford to own a pair of bullocks, sharing DAP is clearly a positive indicator, for 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. While hiring in DAP saves expenditure on bullock rearing throughout the year, hiring out, which has been strengthened through the commercialisation of agriculture, has created avenues of employment and income generation for some small and marginal families.

The most draught power is needed for ploughing. Tractive effort by bullocks, in terms of body weight, ranges from nine per cent during weeding-earthing-up operations to 19 per cent during puddling operations at speeds of 2.6 to 1.6 km per hour. Tractive effort during ploughing is about 16 per cent of bullocks at a speed of 2.4 km per hour. These high values are indicative of the special ability of the light weight and hardy, native draught animals to generate a greater percentage of body weight as tractive effort. A pair of bullocks, on an average, tills and levels 1,100 sq. km. per day after seven hours of continuous work. Per animal (average weight 250 kg) draught power output during ploughing is 0.26 kWh (0.35 hph).

Apart from in the Middle Himalayan area under traditional agriculture, all the agro-ecological areas face a shortage of DAP in terms of the available annual DAP potential. While agriculture in the transformed and high altitude areas faces only a marginal DAP deficit, in the hill areas the available DAP is much less than required. But nowhere in the hills and mountains have farmers faced a power crisis during peak periods. This is due to the DAP management system in the mountains. In the hills, some power requirements are met by tractors. A pair of bullocks can cover an area of 1.5 ha effectively. While in the Greater Himalayas the cropland area per bullock pair is more or less the same, in the traditional middle mountains, the cropland area is much less than a pair of bullocks can cover. Farmers in transformed mountain and hill agricultural areas own much larger cropland areas than a pair of bullocks can cover. The current DAP management practices cope well with this situation.

Use of human energy is inevitably linked with all agricultural operations carried out by draught animals, i.e., ploughing, levelling, puddling, weeding, and threshing. Other operations — hand-weeding, irrigation, manure transport and application, breaking of clods, sowing and transplantation, fertilizer and pesticide application, harvesting, and hand - threshing use only human energy. Transformed middle mountain agriculture requires maximum bullock and human hours and energy (11,696 hours and 1,586 kWh) per ha per year, followed by hill agriculture (10,807 hours and 1,419 kWh). While traditional middle mountain agriculture uses more energy (592 kWh) than high

mountain agriculture (533 kWh), the former requires less work hours (3,917) than the latter (4,685). Bullocks work for only 59 days a year in the high mountains, but in the transformed middle mountains they are used for as many as 236 days a year. Agricultural transformation is an energy-intensive process. Of the total animate energy, high mountain agriculture uses only 41 per cent DAP, hill agriculture about 52 per cent, transformed agriculture about 54 per cent, and traditional agriculture as much as 62 per cent DAP for crop cultivation. Cropping intensity increases pressure on human beings for energy use. High mountain agriculture is the exception, for many households in a typical livestock-based farming setting use only hand tools, and kidney bean and potato cultivation need a lot of human energy. The transformed agricultural system makes the most efficient use of available DAP and human resources, and this is reflected in the higher degree of cropping diversification and higher crop yields in the area.

The energy efficiency of the traditional agro-ecosystem is considerably higher than that of other agro-ecosystems. This is due to a very low energy input compared to energy output. Energy output - input ratios of crop production in the hills, transformed, and high Himalayan agro-ecosystems are 2.98, 3.81, and 2.51 times lower, respectively, than in the traditional agro-ecosystem. High energy input compared to energy output in the hills and transformed mountains and overall low energy output in the high Himalayas are attributable to the relatively lower energy efficiency of agriculture in these agro-ecosystems. The amaranth-kidneybean cropping pattern in the traditional middle mountains has the highest energy efficiency. Crops that do not employ imported energy (chemical fertilizers and pesticides), such as upland rice, maize, upland wheat, finger millet, barnyard millet, kidney beans, and naked barely, also demonstrate quite high energy efficiency.

Institutional policies and programmes relating to the animal husbandry sector and having a focus on crossbreeding of indigenous cattle with exotic bulls have serious negative repercussions on the DAP system in the mountains. Crossbred bullocks have poor compatibility with the local environment, feed resources, and harness system. Farmers' strategies in the DAP usage system that involve native cattle breeds adapted to and suitable for local conditions must be appreciated.

What will be the future of DAP? Despite a decrease in operational holding sizes, the commercialisation of agriculture involving short-duration cash crops will increase. Commercial crops need more energy inputs. There will be increased use of external energy inputs, but there will be no alternative to DAP as a source of motive power. The draught animal population might decrease but a new DAP management system will emerge. Perhaps the cow population will be concentrated in a few pockets, for example, in the foothills or adjoining plains, for the purpose of bullock reproduction. Trade in bullocks between the mountains and the plains will increase. Farmers of medium and large holdings become accustomed to maintaining bullocks only during ploughing season and a majority of them will resort to hiring. Many farms will experience shortages of DAP during 'turn around time' (the number of days between harvesting the first crop

and starting to prepare land for the next crop). The sharing practice will vanish perhaps. While some farmers of marginal and small holdings will switch to manual operations using no DAP, a majority of them will benefit from the hiring out of DAP to large farms and the trade in bullocks.

Since the nature and intensity of problems related to DAP are different for different farming systems/ ecological areas, the policy measures to overcome these specific problems will also have to be different. Even the transformed areas within the Middle Himalayas vary greatly in terms of demand and supply of DAP, accessibility, adoption of new technology, etc, and this has important implications for mechanisation, animal breeding strategies, feed and fodder supplies, and so on.

In some areas of the Shivalik hills, selective mechanisation (e.g., use of tractors for land preparation, threshing, etc) may be a desirable strategy because of higher cropping intensity, short turn-around time, accessibility, favourable terrain, and a high DAP-deficit.

DAP deficit may become a critical constraint to increased production in those areas of the transformed Middle Himalayas that specialise in the production of vegetables and improved varieties of cereal crops. The number of bullocks is declining over time in these areas, due to factors such as decreased fodder production on the farm and human labour shortages (because of the energy-intensive nature of the crops grown in these areas). Action needs to be taken so that DAP deficit does not become a binding constraint to increased production. Possible options include credit support to small and marginal farmers to raise bullocks in adjoining non-transformed villages, so that they can provide bullock rental services to farmers in transformed villages; development of technology to increase the use efficiency of available feed and fodder resources; selective mechanisation to reduce drudgery and cover peaks of human labour use, and so on.

An appropriate, perspective-based cattle breeding policy, especially aimed at conserving the uniquely adapted draught qualities of the native breeds, may well be valuable for sustained production in the long term. Policy recommendations should not be generalised to all agro-ecological regions. In some areas, where fodder availability can support the animals and where DAP deficit is not a problem due to less intensive crop production possibilities, crossbreeding might be desirable.

The promotion of crossbreeding is not a desirable strategy for areas in which crop production is the main enterprise but where DAP deficit is constraining crop production, e.g., the traditional areas of the Middle Himalayas.

The supply of DAP depends on the number of draught animals, their quality (size, health, breed, adaptability, etc), and the efficiency of the mechanism for transforming this power into useful work. An improvement in the DAP system would be instrumental in augmenting the sustainability of mountain agriculture. Better feeding and better

designing of ploughs, yokes, and harnesses are the key elements to realising the full potential of the draught animals available. Adequate infrastructural facilities in terms of R&D to promote and augment the DAP system are vital for sustainable development of mountain agriculture.

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Annexes

The power absorbed by a cultivation implement, or any machine, is a combination of the force required and the speed at which it is propelled.

The unit of force is the Newton (N), approximately equal to 0.10 kilogram force (kgf). Because 1 Newton is so small, forces on cultivation equipment are usually expressed in kilonewtons (kN). The unit of power is Watt (W), and values are usually expressed in kilowatts (kW). Speed is measured in metres per second (m/s) and the relationship of these three components is as follows:

Power = force x speed

i.e., $W = N \text{ m/s}$

or $kW = kN \text{ m/s}$

Although the power output of animals was traditionally often quoted in horsepower (hp) (one of the most usual power units), force in pounds and distance in feet, the metric system is preferred for scientific work (1 kW = 1.34 hp).

Annex 1

Calculation and Measurement of Power Output

The power absorbed by a cultivation implement, or any machine, is a combination of the force required and the speed at which it is propelled.

The unit of force is the Newton (N), approximately equal to 0.10 kilogram force (kgf). Because 1 Newton is so small, forces on cultivation equipment are usually expressed in kilonewtons (kN). The unit of power is Watt (W), and values are usually expressed in kilowatts (kW). Speed is measured in metres per second (m/s) and the relationship of these three components is as follows:

$$\text{Power} = \text{force} \times \text{speed}$$

$$\text{i.e., } W = N \text{ m/s}$$

$$\text{or } kW = kN \text{ m/s.}$$

Although the power output of animals was traditionally often quoted in horsepower (hp) (one of the most usual power units), force in pounds and distance in feet, the metric system is preferred for scientific work ($1 \text{ kW} = 1.34 \text{ hp}$)

For animal draught equipment, the force recorded in the draught line depends on the angle of the draught line to the working plane. The power applied is related to the force in the direction of travel and that is in a line parallel to the ground.

Using Figure 1 the actual force can be calculated from the recorded force and harness dimensions and inserted into the power equation when:

H = the height of the attachment to the yoke (m),

h = the working height of the implement hitch (m),

L = the length between the hitch and yoke (m),

Rf = the recorded draught force (kN), and

AF = the actual draught force (kN).

The pictorial layout of the implement and harness in Figure 1 is interpreted in Figure 1 as the forces acting on the hitch point when the implement is travelling in a steady state.

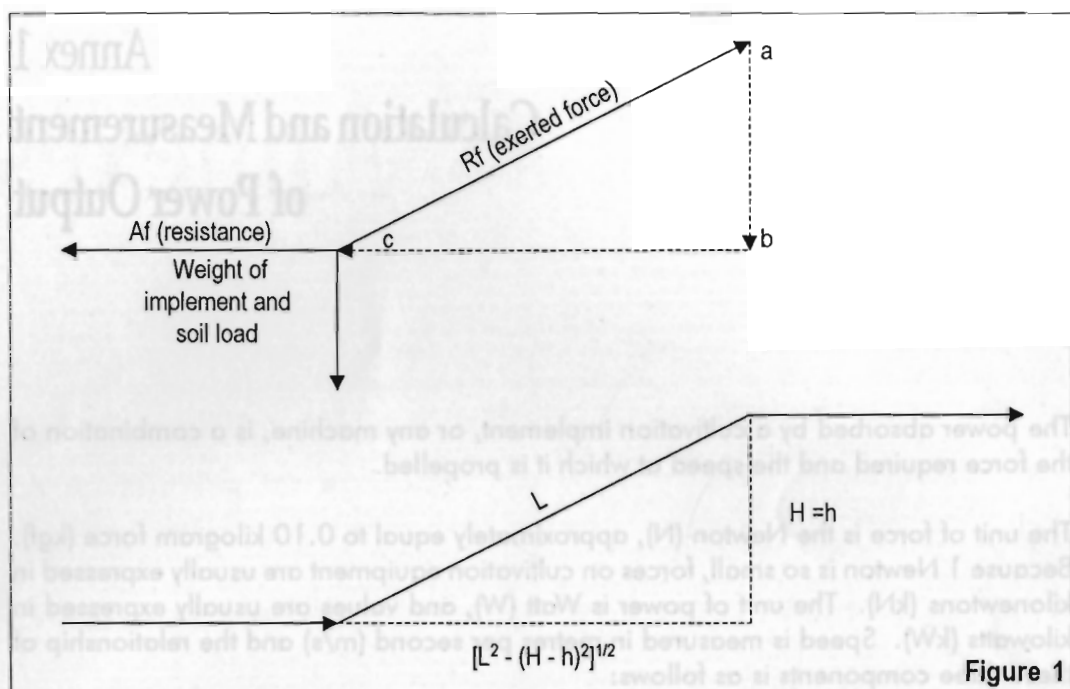


Figure 1

Distance ab is equivalent to the weight and soil load on the implement and distance bc is equivalent to the resistance of the implement, which is equal to the net draught force (actual force).

The geometric layout of the harness as shown in the Figure and because the two diagrams in the Figure represent "similar triangles",

$$R_f / A_f = L / [L^2 - (H - h)^2]^{1/2}$$

and, therefore,

$$A_f = R_f [L^2 - (H - h)^2]^{1/2} / L$$

when d is the distance travelled (m) and t is the time taken (seconds), the power equation becomes

$$kW = R_f [L^2 - (H - h)^2]^{1/2} / L \cdot d / t.$$

The sum inside the brackets becomes a constant for any single animal/implement combination.

The power output for each work period will be calculated as power x lapsed time and expressed in kilowatt hours (kWh).

[Source : Matthews 1987]

Annex 2: Some Demographic Features of Sample Villages

Particulars	Shivaliks			Middle Himalayas: Traditional				Middle Himalayas: Transformed				Greater Himalayas				
	Ganga Bhogpur	Khand Gaon	Naigoth	Per Village	Taily Sunoli	Goom	Banali	Per Village	Suri	Kandhla Badethi	Chaupaniya Gaon	Per Village	Bagauni	Juma	Gangi	Per Village
No. of Families	225	90	500	272	75	45	220	113	22	62	140	75	240	30	90	120
Total Population	2173	552	3050	1928	608	400	2495	1168	233	737	1400	790	1250	233	433	639
Adults	524	168	930	541	163	104	770	346	39	217	420	225	485	75	120	227
Males	[24.11]	[30.43]	[30.39]	[28.06]	[26.81]	[26]	[30.85]	[29.62]	[16.74]	[29.44]	[30]	[28.48]	[38.80]	[32.19]	[27.71]	[35.52]
Adults	675	162	900	579	182	96	770	349	72	229	280	194	464	98	120	227
Females	[31.06]	[29.35]	[29.41]	[30.03]	[29.93]	[24]	[30.85]	[29.88]	[30.90]	[31.07]	[20]	[24.56]	[37.12]	[42.06]	[27.71]	[35.52]
Male	450	119	660	410	113	110	478	234	50	167	350	189	163	30	140	111
Children	[20.71]	[21.56]	[21.57]	[21.27]	[18.59]	[27.50]	[19.15]	[20.03]	[21.46]	[22.66]	[25]	[23.92]	[13.04]	[12.88]	[32.33]	[17.37]
Female	524	103	570	399	150	90	478	239	72	124	350	182	138	30	53	74
Children	[24.11]	[18.66]	[18.63]	[20.70]	[24.67]	[22.50]	[19.15]	[20.46]	[30.90]	[16.82]	[25]	[23.04]	[11.04]	[12.88]	[12.24]	[11.58]
Family Size	9.66	6.13	6.12	7.09	8.11	8.89	11.35	10.34	10.59	11.89	10	10.53	5.21	7.77	5.33	5.33

Figures in parentheses denote percentage of total population in each village

Annex 3: Community Land and Cropland Area in the Sample Villages, ha (nali (s))

Particulars	Shivaliks			Middle Himalayas : Traditional				Middle Himalayas : Transformed				Greater Himalayas				
	Ganga Bhogpur	Khand Gaon	Naigoth	Per Village	Taily Sunoli	Goom	Banali	Per Village	Suri	Kandhla Badethi	Chaupaniya Gaon	Per Village	Bagauni	Juma	Gangi	Per Village
Community Land	87.00	21.00	105.00	71.00	35.00	16.00	103.00	51.33	40.00	25.00	50.00	38.33	60.00	20.00	30.00	30.67
	[4350]	[1050]	[5250]	[3550]	[1750]	[800]	[5150]	[2567]	[2000]	[1250]	[2500]	[1917]	[3000]	[1000]	[1500]	[1834]
Cropland	127.00	288.00	270.00	288.33	52.00	87.00	216.00	118.33	21.00	78.00	105.00*	68.00	25.00**	13.00	92.00	43.33
	[6350]	[14400]	[13500]	[11417]	[2600]	[4350]	[10800]	[5917]	[1050]	[3900]	[5250]	[3400]	[1250]	[650]	[4600]	[2167]
Irrigated	127.00	288.00	82.00	165.67	0.00	0.00	0.00	0.00	15.00	46.00	0.00	20.33	0.00	0.00	0.00	0.00
	[6350]	[14400]	[4100]	[8284]					[750]	[2300]		[1017]				
Unirrigated	0.00	0.00	188.00	62.67	52.00	87.00	216.00	118.33	6.00	32.00	105.00	47.67	25.00	13.00	92.00	43.33
			[9400]	[3134]	[2600]	[4350]	[10800]	[5917]	[300]	[1600]	[5250]	[2384]	[1250]	[650]	[4600]	[2167]
Percentage of Irrigated Land	100.00	100.00	30.37	72.56	0.00	0.00	0.00	0.00	71.43	58.97	0.00	43.47	0.00	0.00	0.00	0.00
Cropland Per Family	0.56	3.20	0.54	0.84	0.69	1.93	0.98	1.05	0.95	1.26	0.75	0.91	0.10	0.43	1.02	0.36
	[28]	[160]	[27]	[42]	[35]	[97]	[49]	[53]	[48]	[63]	[38]	[46]	[5]	[22]	[51]	[18]

Figures in parentheses are nali (s), the conversion unit of hectare (1 ha = 50 nali (s)).

Nali is the local unit of land measurement

*

Includes 65.00 ha (3250 nali (s)) under apple orchards.

**

Includes 15.00 ha (750 nali (s)) under apple orchards.

Annex 4: Number of Holdings under Different Farm Categories

Farm Category	Shivaliks			Middle Himalayas: Traditional			Middle Himalayas: Transformed			Greater Himalayas		
	Ganga Bhogpur	Khand Gaon	Naigath	Per Village	Taily Sunoli	Goom	Banali	Per Village	Sun	Kandha Badathi	haupaiva Gaon	Per Village
Landless	-	-	-	-	-	-	-	-	-	-	60 [25.00]	20 [16.67]
Marginal <= 0.5 ha	90 [40.00]	-	255 [51.00]	115 [42.28]	48 [64.00]	-	30 [13.64]	26 [23.01]	4 [18.18]	10 [16.13]	60 [42.86]	25 [33.33]
Small <= 1.0 ha	106 [47.11]	-	222 [44.40]	109 [40.07]	20 [26.67]	2 [4.44]	130 [59.09]	50 [44.25]	14 [63.64]	16 [25.81]	40 [28.57]	23 [30.67]
Medium <= 2.0 ha	23 [10.22]	-	20 [4.00]	14 [5.15]	7 [9.33]	30 [66.67]	55 [25.00]	31 [27.43]	3 [13.64]	31 [50.00]	20 [14.29]	18 [24.00]
Large > 2.0 ha	6 [2.67]	90 [100.00]	3 [0.60]	33 [12.13]	-	13 [28.89]	5 [2.27]	6 [5.31]	1 [4.55]	5 [8.06]	20 [14.29]	9 [12.00]
Total Holdings	225 [100.00]	90 [100.00]	500 [100.00]	272 [100.00]	75 [100.00]	45 [100.00]	220 [100.00]	113 [100.00]	22 [100.00]	62 [100.00]	140 [100.00]	75 [100.00]
											240 [100.00]	90 [100.00]
												120 [100.00]

Figures in parentheses are percentages of total holdings.

Annex 5: Cropland Area (ha) under Different Landholding Categories

Landholding Category	Shivaliks			Middle Himalayas: Traditional			Middle Himalayas: Transformed			Greater Himalayas		
	Ganga Bhogpur	Khand Gaon	Naigath	Per Village	Taily Sunoli	Goom	Banali	Per Village	Sun	Kandha Badathi	haupaiva Gaon	Per Village
Landless	-	-	-	-	-	-	-	-	-	-	0.00	-
Marginal	20.64 [16.25]	-	97.06 [35.95]	39.23 [17.18]	21.12 [40.62]	-	8.00 [3.70]	9.71 [8.21]	1.88 [8.95]	4.20 [5.38]	12.00 [11.43]	6.03 [8.87]
Small	63.38 [49.91]	-	122.54 [45.19]	61.97 [27.14]	17.00 [32.69]	1.68 [1.93]	104.00 [48.15]	40.89 [34.56]	11.22 [53.43]	14.40 [18.46]	26.20 [24.95]	17.27 [25.40]
Medium	29.90 [23.54]	-	36.00 [13.33]	21.97 [9.62]	13.88 [26.69]	48.00 [55.17]	93.50 [43.29]	51.79 [43.77]	5.40 [26.71]	48.80 [62.56]	26.00 [23.81]	26.40 [38.82]
Large	13.08 [10.30]	288.00 [100.00]	14.40 [5.33]	105.16 [46.06]	-	37.32 [42.90]	10.50 [4.86]	15.94 [13.47]	2.50 [11.90]	10.60 [13.59]	41.80 [39.81]	18.30 [26.91]
Overall	127.00 [100.00]	288.00 [100.00]	270.00 [100.00]	228.33 [100.00]	52.00 [100.00]	87.00 [100.00]	216.00 [100.00]	118.33 [100.00]	21.00 [100.00]	78.00 [100.00]	105.00 [100.00]	68.00 [100.00]
											25.00 [100.00]	90 [100.00]
												43.33 [100.00]

Figures in parentheses are percentages of the total area.

Annex 6: Landholding Size (ha) under Different Landholding Categories

Landholding Category	Shivaliks			Middle Himalayas: Traditional					Middle Himalayas: Transformed				Greater Himalayas			
	Ganga Bhogpur	Khand Gaon	Naigoth	Per Village	Tally Sundli	Goom	Banali	Per Village	Sun	Kandhla Badethi	Chaupariyal Gaon	Per Village	Bagauri	Juma	Gangi	Per Village
Marginal	0.23	-	0.38	0.34	0.44	-	0.27	0.37	0.47	0.42	0.20	0.24	0.14	0.20	0.32	0.15
Small	0.60	-	0.55	0.57	0.85	0.84	0.80	0.82	0.80	0.90	0.65	0.75	-	0.56	0.52	0.51
Medium	1.30	-	1.80	1.57	1.98	1.60	1.70	1.67	1.80	1.57	1.25	1.47	-	1.40	1.05	1.09
Large	2.18	3.20	4.80	3.19	-	2.87	2.10	2.66	2.50	2.12	2.09	2.03	-	-	2.10	2.33
Overall	0.56	3.20	0.54	0.84	0.69	1.93	0.98	1.05	0.95	1.25	0.75	0.91	0.10 ^a	0.43	1.02	0.36 ^b

^a Average includes 60 landless families.

^b Average includes 20 landless families.

Annex 7: Crop Area (ha) of all Households and its Distribution as a Percentage of Cultivated Area in the Shivalik Villages

Crops	Ganga Bhagpur		Khandgaon		Naigoth		Per Village	
	Crop Area	Percentage of Cultivated Area	Crop Area	Percentage of Cultivated Area	Crop Area	Percentage of Cultivated Area	Crop Area	Percentage of Cultivated Area
Summer Crops								
Upland Rice	0.00	0.00	0.00	0.00	32.80	6.38	10.93	2.45
Lowland Rice	64.93	26.22	273.60	47.50	77.50	15.07	138.68	31.10
Maize	44.62	18.02	0.00	0.00	51.36	9.99	31.99	7.17
Oilseeds	3.18	1.28	0.00	0.00	35.64	6.93	12.94	2.90
Pulses	3.18	1.28	7.20	1.25	60.20	11.70	23.53	5.28
Vegetables	4.91	1.98	4.32	0.75	12.50	2.43	7.24	1.62
Fodder	6.18	2.50	2.88	0.50	0.00	0.00	3.02	0.68
Winter Crops								
Upland Wheat	0.00	0.00	0.00	0.00	125.00	24.30	41.67	9.34
Lowland Wheat	97.95	39.55	259.20	45.00	70.00	13.61	142.38	31.93
Barley	2.54	1.03	0.00	0.00	8.00	1.56	3.51	0.79
Pulses	12.54	5.06	0.00	0.00	10.00	1.94	7.51	1.68
Oilseeds	3.18	1.28	17.28	3.00	19.32	3.76	13.28	2.97
Vegetables	3.18	1.28	8.64	1.50	12.00	2.33	7.94	1.78
Fodder	1.27	0.51	2.88	0.50	0.00	0.00	1.38	0.31
Total Cultivated Area	247.66	100.00	576.00	100.00	514.32	100.00	445.98	100.00
Total Cropland	127.00	-	288.00	-	270.00	-	228.33	-
Cropping Intensity	195.01	-	200.00	-	19.49	-	195.32	-

Annex 8: Crop Area (ha) of all Households and its Distribution as a Percentage of Cultivated Areas in the Middle Himalayan (traditional)

Crops	Taily Sundi		Goom		Banat		Per Village	
	Crop Area	Percentage of Cultivated Area	Crop Area	Percentage of Cultivated Area	Crop Area	Percentage of Cultivated Area	Crop Area	Percentage of Cultivated Area
Summer Crops								
Upland Rice	10.40	12.50	21.75	16.67	38.88	11.25	23.68	12.70
Finger Millet + Pulses*	20.80	25.00	43.50	33.33	86.40	25.00	50.23	26.95
Bamard Millet	20.80	25.00	21.75	16.67	82.02	23.74	41.52	22.27
Amaranth**	0.00	0.00	0.00	0.00	8.64	2.50	2.88	1.54
Winter Crops								
Upland Wheat***	28.60	34.38	40.00	30.65	118.00	34.15	62.20	33.37
Barley	2.60	3.13	3.50	2.66	11.60	3.36	5.90	3.17
Total Cultivated Area	83.20	100.00	130.50	100.00	345.54	100.00	186.41	100.00
Total Cropland	52.00	-	87.00	-	216.00	-	118.33	-
Cropping Intensity	160.00	-	150.00	-	159.97	-	157.53	-

* Finger millet is usually raised with pulses and pseudocereals. Various pulses are: Horsegram, Blackgram, Greengram, Black soyabean, Groundnut (only in Taily Sundi villages), Frenchbean, Ricebean etc. Pseudocereals Amaranth and Buckwheat are also raised with Finger Millet.

** Amaranth is usually intercropped with Kidney bean.

*** Nearly 50 per cent wheat is intercropped with Lentil and Rapeseed/Mustard.

Annex 9: Crop Area (ha) of all Households and Its Distribution as a Percentage of Cultivated Area in the Middle Himalayan Transformed Villages						
Crops	Sun		Kandla Basahni		Chaurparya goons	
	Crop Area	Percentage of Cultivated Area	Crop Area	Percentage of Cultivated Area	Crop Area	Percentage of Cultivated Area
Summer Crops						
Upland Rice	0.68	1.58	4.50	2.88	1.60	0.95
Lowland Rice	5.00	12.38	30.00	19.23	0.00	0.00
Finger Millets + Pulses	1.60	3.95	8.50	5.45	8.67	5.14
Barley and Millet	0.00	0.00	11.00	7.05	12.00	7.11
Soyabean	3.72*	9.21	6.00	3.85	2.40	1.42
Oilseeds	0.00	0.00	2.00	1.28	0.00	0.00
Vegetables	10.00	24.75	16.00	10.26	80.33**	47.58
Winter Crops						
Upland Wheat	3.96	9.80	22.50	14.42	16.33	9.67
Lowland Wheat	5.00	12.38	30.50	19.56	0.00	0.00
Pulses	0.00	0.00	3.50	2.24	3.75	2.22
Oilseeds	0.44	1.09	6.00	3.85	3.75	2.22
Vegetables	10.00	24.75	15.50	9.94	40.00***	23.69
Total Cultivated Area	40.40	100.00	156.00	100	168.83	100
Total Cropland	21.00	-	78.00	-	105.00	-
Cropping Intensity	192.38	-	200.00	-	160.79	-

*** 32.5 ha area under vegetables lie in Apple Orchards.

** 65 ha area under Apple Orchards is included.

* About one-third are inter-cropped with sesame.

Annex 10: Crop Area (ha) of all Households and Its Distribution as a Percentage of Cultivated Area in the Greater Himalayan Villages						
Crops	Bagauni		Juma		Gangri	
	Crop Area	Per cent of Cultivated Area	Crop Area	Per cent of Cultivated Area	Crop Area	Per cent of Cultivated Area
Summer Crops						
Amaranth	5.00	22.20	1.30	10.00	25.00	29.67
Buckwheat	2.50	11.11	2.60	20.00	7.50	8.90
Kidney Bean	10.00	44.44	2.60	20.00	2.50	2.97
Poleab	5.00	22.22	2.60	20.00	22.00	26.11
Winter Crops						
Wheat	0.00	0.00	0.00	0.00	27.25	32.34
Naked Barley	0.00	0.00	3.90	30.00	0.00	0.00
Total Cultivated Area	22.50	100.00	13.00	100.00	84.25	100.00
Total Cropland	25.00	-	13.00	-	92.00	-
Cropping Intensity	90.00	-	100.00	-	91.58	-

* Some minor crops such as millet and fox tail millet have not been included. They are often intercropped with major crops shown above.

Annex 11: Average Productivity (q/ha) of Different Crops at Study Sites

Crops	Shivaliks		Middle Himalaya : Traditional		Middle Himalaya : Transformed		Greater Himalaya	
	MP	BP	MP	BP	MP	BP	MP	BP
Upland Rice	22	26	25	32	23	29	-	-
Lowland Rice	32	41	-	-	33	44	-	-
Maize	20	60	-	-	-	-	-	-
Summer Oilseeds	3	-	-	-	2	-	-	-
Summer Pulses	10	10	-	-	-	-	-	-
Finger Millet + Pulses	-	-	14+6	28+6	14+6	28+6	-	-
Barley	-	-	13	36	13	36	-	-
Amaranth + Kidney bean	-	-	12+6	+9	-	-	-	-
Soyabean	-	-	-	-	18	-	-	-
Summer Vegetables	48+30	-	-	-	55+80	-	-	-
Summer Fodder	-	300	-	-	-	-	-	-
Amaranth	-	-	-	-	-	-	16	-
Buckwheat	-	-	-	-	-	-	11	-
Kidneybean	-	-	-	-	-	-	18	27
Potato	-	-	-	-	-	-	59	-
Upland Wheat	20	28	21	28	21	28	14	21
Lowland Wheat	35	48	-	-	35	48	-	-
Barley	18	27	16	24	-	-	-	-
Naked Barley	-	-	-	-	-	-	12	18
Winter Pulses	9	9	-	-	10	10	-	-
Winter Oilseeds	6	-	-	-	5	-	-	-
Winter Vegetables	50+40	-	-	-	58+80	-	-	-
Winter Fodder	-	250	-	-	-	-	-	-

Note : MP = Main Product, BP = By-Product

The main vegetables include potatoes and other vegetables, eg. peas, french beans, cabbage, etc.

In the Greater Himalayas, only potato cultivation is practised.

Annex 12: Distribution of Bullock Population among Different Landholding Categories

Landholding Category	Shivaliks			Middle Himalayas: Traditional			Middle Himalayas: Transformed			Greater Himalayas		
	Ganga Bhogpur	Khand Gaon	Naigoth	Taily Sunoli	Goom	Banali	Suri	Kandhla Badethi	Chaupariyal Gaon	Bagauri	Juma	Gangi
Landless	-	-	-	-	-	-	-	-	-	0 [0.00]	-	-
Marginal	33 [20.63]	-	198 [49.50]	68 [50.75]	-	50 [8.33]	2 [6.25]	2 [5.00]	30 [18.75]	0 [0.00]	8 [33.33]	8 [5.33]
Small	95 [59.38]	-	156 [39.00]	48 [35.82]	0 [0.00]	275 [45.83]	20 [62.50]	10 [25.00]	44 [27.50]	-	8 [33.33]	12 [8.00]
Medium	30 [18.75]	-	40 [10.00]	18 [13.43]	4 [18.18]	255 [42.50]	8 [25.00]	22 [55.00]	46 [28.75]	-	8 [33.33]	110 [73.33]
Large	2 [1.25]	40 [100.00]	6 [1.50]	-	18 [81.82]	20 [3.33]	2 [6.25]	6 [15.00]	40 [25.00]	-	-	20 [13.33]
Overall	160 [100.00]	40 [100.00]	400 [100.00]	134 [100.00]	22 [100.00]	600 [100.00]	32 [100.00]	40 [100.00]	160 [100.00]	0 [0.00]	24 [100.00]	150 [100.00]

Figures in parentheses are percentages of the overall bullock population in a village.

A negative (-) sign denotes non-existence of the category.

Annex 13: Bullock Holding Sizes among Different Categories

Landholding Category	Shivaliks			Middle Himalayas: Traditional			Middle Himalayas: Transformed			Greater Himalayas		
	Ganga Bhogpur	Khand Gaon	Naigoth	Taily Sunoli	Goom	Banali	Suri	Kandhla Badethi	Chaupariyal Gaon	Baguri	Juma	Gangi
Landless	-	-	-	-	-	-	-	-	-	0.00	-	-
Marginal	0.37	-	0.78	1.42	-	1.67	0.50	0.20	0.50	0.00	0.40	0.67
Small	0.90	-	0.70	2.40	0.00	2.12	1.43	0.63	1.10	-	1.33	1.50
Medium	1.30	-	2.00	2.57	0.13	4.64	2.67	0.71	2.30	-	2.00	1.83
Large	0.33	0.44	2.00	-	1.38	4.00	2.00	1.20	2.00	-	-	2.00
Average	0.71	0.44	0.80	1.79	0.49	2.73	1.45	0.65	1.14	0.00	0.80	1.67

Annex 14: Bullock Density on Cropland Area (No. Per ha) among Different Landholding Categories

Landholding Category	Shivaliks			Middle Himalayas: Traditional			Middle Himalayas: Transformed			Greater Himalayas		
	Ganga Bhogpur	Khand Gaon	Naigoth	Taily Sunoli	Goom	Banali	Suri	Kandhla Badethi	Chaupariyal Gaon	Bagauri	Juma	Gangi
Marginal	1.6 -		2.04	3.22 -		6.25	1.06	1.19	2.5 -		1.98	2.08
Small	1.5 -		1.27	2.82	0	2.64	1.78	0.69	1.68 -		2.38	2.88
Medium	1 -		1.11	1.3	0.08	2.73	1.48	0.45	1.84 -		1.43	1.75
Large	0.15	0.14	0.42 -		0.48	1.9	0.8	0.57	0.96 -		-	0.95
Overall	1.26	0.14	1.48	2.58	0.25	2.78	1.52	0.51	1.52 -		1.85	1.63

Annex 15: DAP Potential for Mountain Agriculture

Particulars	Shivaliks			Middle Himalayas: Traditional			Middle Himalayas: Transformed			Greater Himalayas		
	Ganga Bhogpur	Khand Gaon	Naigoth	Taily Sunoli	Goom	Banali	Suri	Kandhla Badethi	Chaupariyal Gaon	Bagauri	Juma	Gangi
Cropland, ha	127	288	270	52	87	216	21	78	105	25	13	92
Bullocks, No.	160	40	400	134	22	600	32	40	160	0	24	150
Available DAP, kW*	41.6	10.4	104	34.84	5.72	156	8.32	10.4	41.6	0	6.24	39
DAP, kW per ha	0.33	0.04	0.39	0.67	0.07	0.72	0.4	0.13	0.4	0	0.48	0.42
Surplus (+), or Deficit (-)	0.04	(-) 0.33	(+) 0.02	(+) 0.3	(-) 0.3	(+) 0.35	(-) 0.03	(-) 0.24	(+) 0.03	(-) 0.37	(+) 0.11	(+) 0.05

* DAP value of each bullock = 0.26 kW

** Based on 0.37 kW per ha requirement of total power. If available human power is added to it, the total available power will be more than required.

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ICIMOD is the first international centre in the field of mountain development. Founded out of widespread recognition of environmental degradation of mountain habitats and the increasing poverty of mountain communities, ICIMOD is concerned with the search for more effective development responses to promote the sustained well being of mountain people.

The Centre was established in 1983 and commenced professional activities in 1984. Though international in its concerns, ICIMOD focusses on the specific, complex, and practical problems of the Hindu Kush-Himalayan Region which covers all or part of eight Sovereign States.

ICIMOD serves as a multidisciplinary documentation centre on integrated mountain development; a focal point for the mobilisation, conduct, and coordination of applied and problem-solving research activities; a focal point for training on integrated mountain development, with special emphasis on the assessment of training needs and the development of relevant training materials based directly on field case studies; and a consultative centre providing expert services on mountain development and resource management.

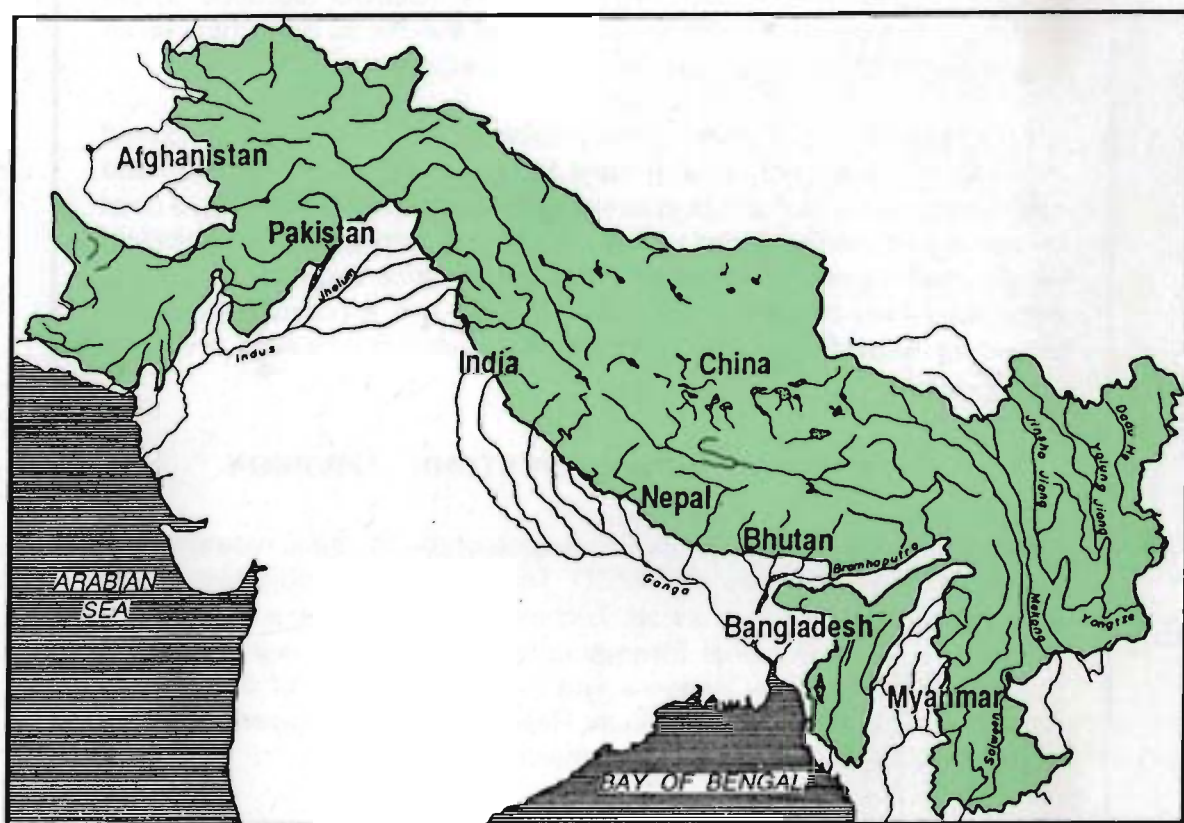
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