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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, fertiizer consumption, and use of high-yielding varieities (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 Udhamsingh 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/km^2. 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 Shiwaliks, 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. Particuarly 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 househlds 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 *nal(is)* 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 distinuished; 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 apppears 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
Sivaliks/Foothills						*Shorea robusta*, Grazing lands invaded by *Lantana* and *Parthenium* weeds	· Cereal crop-dominated farming system; · Cattle-dominated herd; · Transitional phase of development; · Low to high risks.
Ganga Bhogpur	Pauri	600	Valley	0.5	Ganga		
Knandgaon	Dehradun	800	Valley, East	0	Ganga		
Naigoth	Udhamsingh Nagar	700	Valley, North	0.5	Kali		
Middle Himalayas: Traditional						*Pinus roxburghii* in Taily Sunoli and Goom, *Quercus leucotrichophora* in Banali, Grazing lands mostly degraded	· Cereal (millet) crop-dominated farming system, · Cattle-dominated herd; · Traditional system of food production; · Minimum risks.
Taily Sunoli	Almora	1,200	South-East	0.5	Gagas-Ramganga		
Goom	Pauri	1,600	South	0	Saneh-Ganga		
Banali	Tehri	1,800	South-East	12.0	Bidalna-Tons		
Middle Himalayas: Transformed						*Pinus roxburghii* in Suri and Kandhla Badethi, *Quercus leucotrichophora* in Chaupariyalgaon, Grazing lands mostly degraded	· Horticulture-dominated (& genetically transformed cereal crop-dominated) farming system; · Buffalo-dominated herd; · Modern phase of development; · Very high risks.
Suri	Nainital	900	North-East	0	Kosi		
Kandhla Badethi	Uttarkashi	1,250	North-East	0	Bhagirathi		
Chaupariyalgaon	Tehri	2,000	North-West	0	Henwal-Ganga		
Greater Himalayas						*Quercus semecarpifolia* in Gangi and Juma, *Cedrus deodara* in Baguari, Alpine meadows (the high altitude grazing lands) in good condition	· Livestock-dominated farming system; · Ovine (sheep and goat)-dominated herd; · Almost primitive system of food production · Minimum risks
Bagauri	Uttarkashi	2,550	South-West	0.5	Bhagirathi		
Juma	Chamoli	2,600	East	0.5	Alaknanda		
Gangi	Tehri	2,650	East	21.0	Bhilangana		

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 corps from different sites are given in Annex 11.