Five
Tractive Performance of Animals

If is difficult to quantify the 'average' performance of animals. Average or daily performance depends on species and their breeds, animals' weight, rate 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 ploughman, 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 (Sarkar 1981 and Goe 1983).

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)

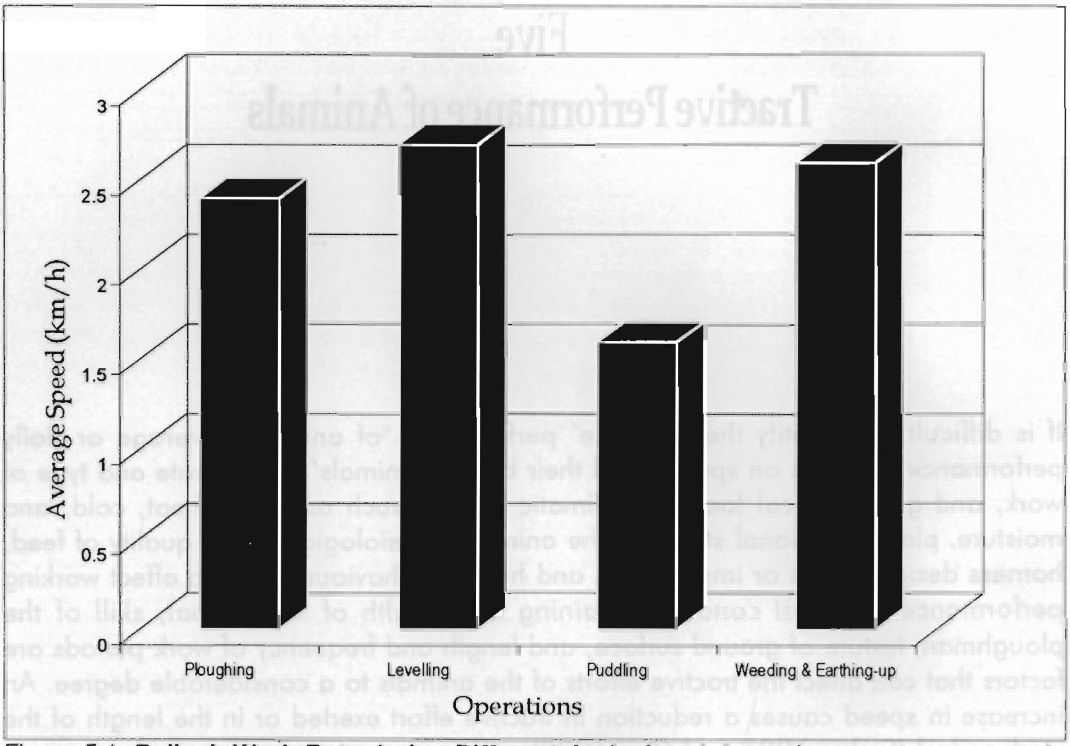

Figure 5.1: **Bullock Work Rate during Different Agricultural Operations**

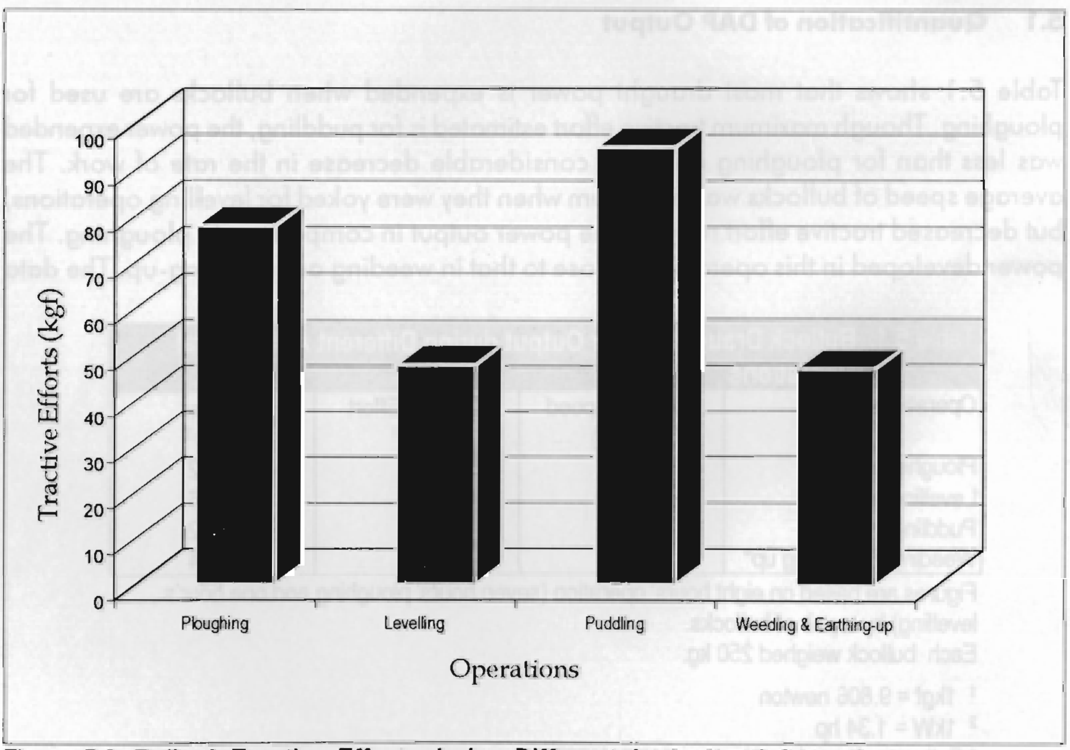

Figure 5.2: **Bullock Tractive Efforts during Different Agricultural Operations**

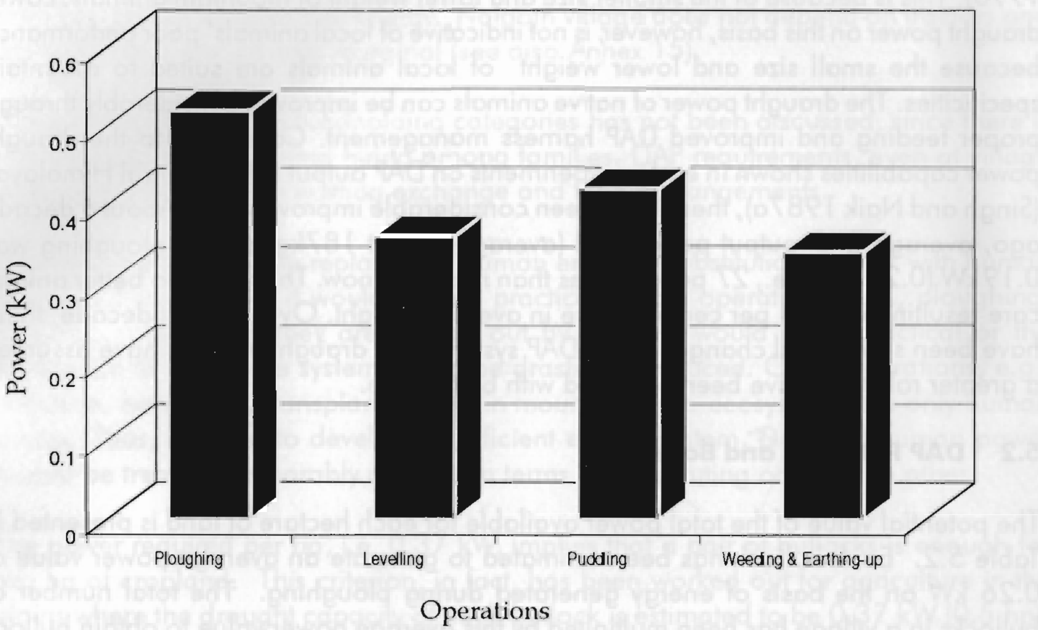

Figure 5.3: **Bullock Draught Power Output during Different Agricultural Operations**

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	80	80	40	40	120	40	480	80	120	80	40	40	120	40	520	1000
	H:	80	80	80	40	40	120	40	480	80	120	80	40	40	120	40	520	1000
2. Levelling	B:	18	18	18	9	9	27	9	108	18	27	18	9	9	27	9	117	225
	H:	18	18	18	9	9	27	9	108	18	27	18	9	9	27	9	117	225
3. Puddling	B:	-	60	-	-	-	-	-	60	-	-	-	-	-	-	-	-	60
	H:	-	180	-	-	-	-	-	180	-	-	-	-	-	-	-	-	180
4. Weeding	B:	-	-	80	-	-	-	-	80	-	-	-	-	-	-	-	-	80
	H:	18	27	45	-	18	200	-	308	-	18	-	-	-	250	-	268	576
5. Irrigation	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	H:	-	36	-	-	-	18	-	54	-	18	-	-	-	54	6	78	132
6. Manure Trans-	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
port & Application	H:	120	120	120	60	60	200	60	740	120	150	120	60	60	200	60	770	1510
7. Clod Breaking	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	H:	-	-	-	-	-	60	-	60	-	60	-	-	-	60	-	120	180
8. Sowing	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Transplantation	H:	16	200	16	8	8	200	4	452	16	40	16	8	8	200	4	292	744
9. Fertilizer & Pes-	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ticide Application	H:	-	50	-	-	25	100	-	175	-	50	-	-	-	100	-	150	325
10. Harvesting	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	H:	180	200	180	200	200	400	180	1540	180	200	180	200	200	400	180	1540	3080
11. Threshing	B:	-	-	-	-	50	-	-	50	70	80	80	50	-	-	-	280	330
	H:	120	150	120	120	150	-	-	660	70	80	80	150	120	-	-	500	1160
Total	B:	98	158	178	49	99	147	49	778	168	227	178	99	49	147	49	917	1695
	H:	552	1061	579	437	510	1325	293	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
		Upland Rice	Finger Millet + Pulses	Barnyard Millet	Amaranth + Kidney bean	Total Summer Crops	Upland Wheat	Barley	Total Winter Crops	Total
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:	-	-	-	-	-	-	-	-	-
	H:	-	-	-	-	-	100	-	100	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						
		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	Annual 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 Trans-port & Application	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	H:	150	150	50	50	150	50	200	800	125	150	100	100	200	675	1475
7. Clod Breaking	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	H:	-	-	-	-	-	-	189	189	-	100	-	-	189	289	478
8. Sowing/ Transplantation	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	H:	9	200	9	4	9	4	250	485	9	54	4	4	250	321	806
9. Ferfilizer & Pes-tiside 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 5.6: **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
		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	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:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	H:	-	-	-	-	-	-	189	189	-	100	-	-	189	289	478
8. Sowing/ Transplantation	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	H:	9	200	9	4	9	4	250	485	9	54	4	4	250	321	806
9. Fertilizer & Pestiside 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
		Amaranth	Amaranth	Kidney bean	Potato	Total	Wheat	Naked Barley	Total	Total
1. Ploughing	B:	108	54	27	54	243	54	54	108	351
	H:	108	54	54	54	270	54	54	108	378
2. Levelling	B:	9	9	-	9	27	18	-	18	45
	H:	18	18	-	27	63	18	-	18	81
3. Puddling	B:	-	-	-	-	-	-	-	-	-
	H:	-	-	-	-	-	-	-	-	-
4. Weeding	B:	-	-	-	-	-	-	-	-	-
	H:	200	-	100	300	600	-	-	-	600
5. Irrigation	B:	-	-	-	-	-	-	-	-	-
	H:	-	-	-	-	-	-	-	-	-
6. Manure Trans-	B:	-	-	-	-	-	-	-	-	-
port & Application	H:	150	75	75	200	500	150	50	200	700
7. Clod	B:	-	-	-	-	-	-	-	-	-
Breaking	H:	-	-	200	100	300	-	-	-	300
8. Sowing/	B:	-	-	-	-	-	-	-	-	-
Transplantation	H:	5	5	45	200	255	15	10	25	280
9. Fertilizer & Pes-	B:	-	-	-	-	-	-	-	-	-
ticide Application	H:	-	-	-	-	-	-	-	-	-
10. Harvesting	B:	-	-	-	-	-	-	-	-	-
	H:	200	200	200	250	850	150	100	250	1100
11. Threshing	B:	25	25	-	-	50	25		25	75
	H:	150	150	200	-	500	125	150	275	775
Total	B:	142	88	27	63	320	97	54	151	471
	H:	831	502	874	1131	3338	512	364	876	4214

B = Bullock H = Human

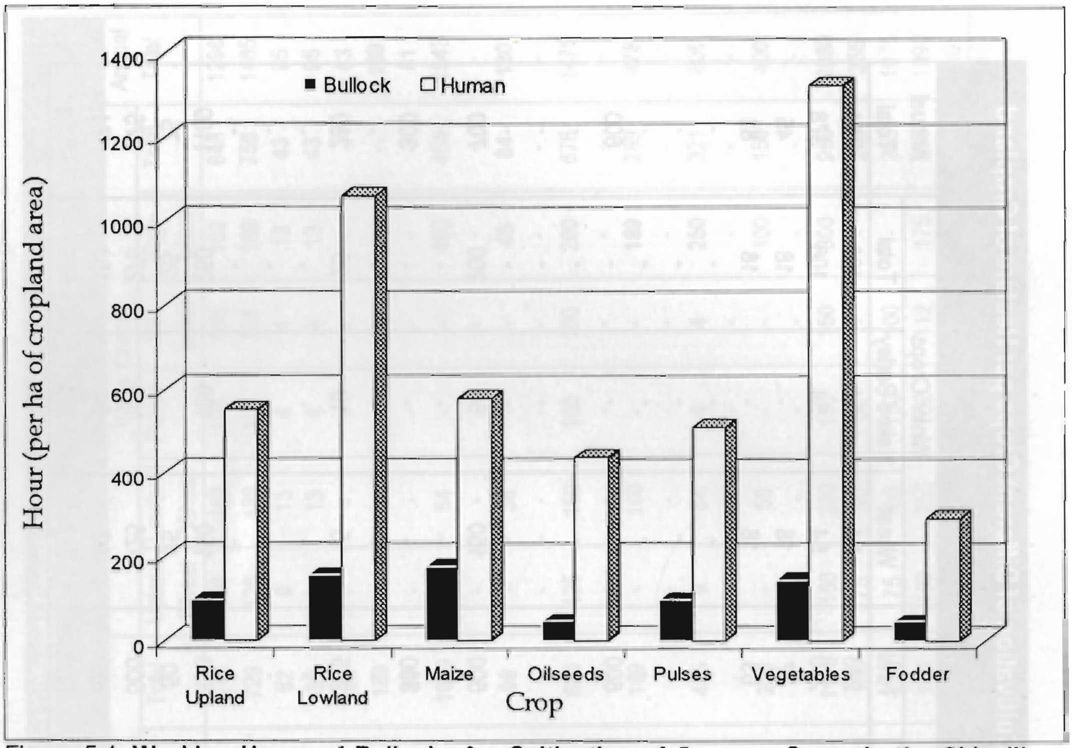

Figure 5.4: **Working Hours of Bullocks for Cultivation of Summer Crops in the Shivaliks**

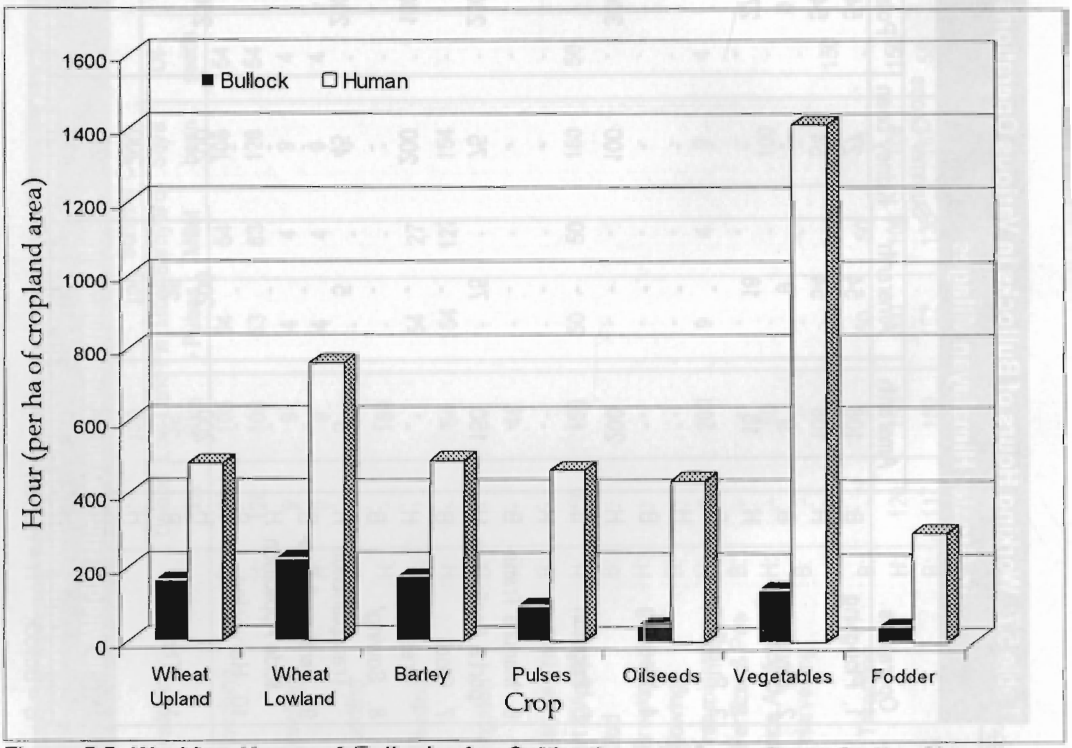

Figure 5.5: **Working Hours of Bullocks for Cultivation of Winter Crops in the Shivaliks**

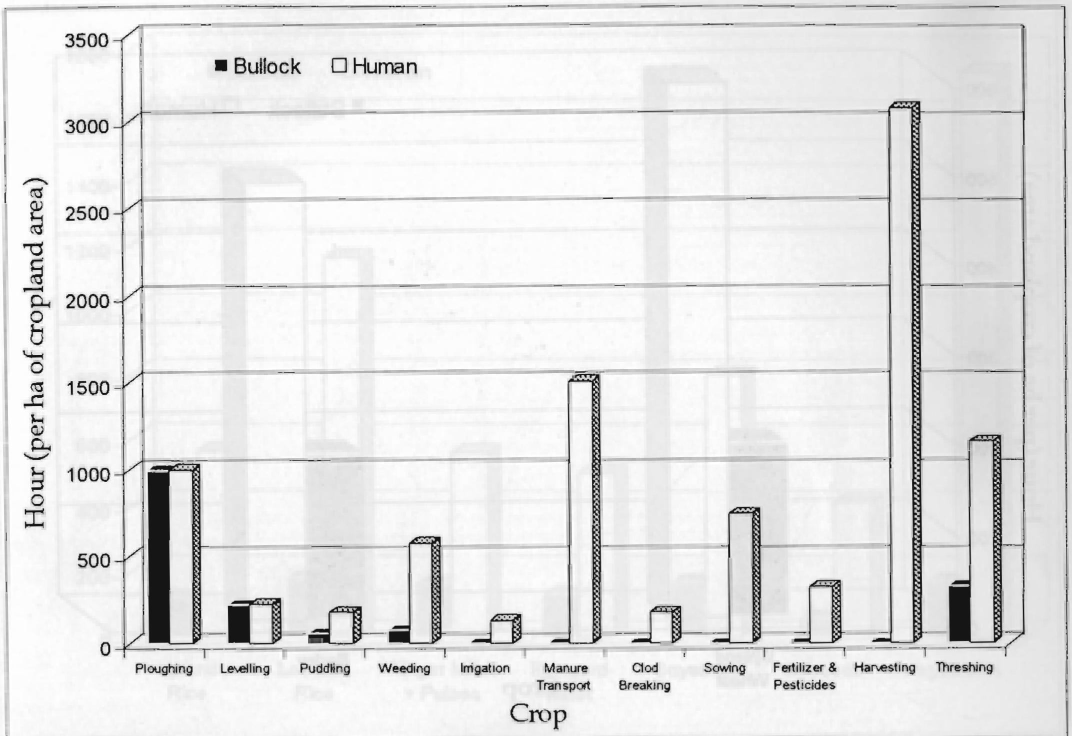

Figure 5.6: **Working Hours of Bullocks during Different Agricultural Operations in the Shivaliks**

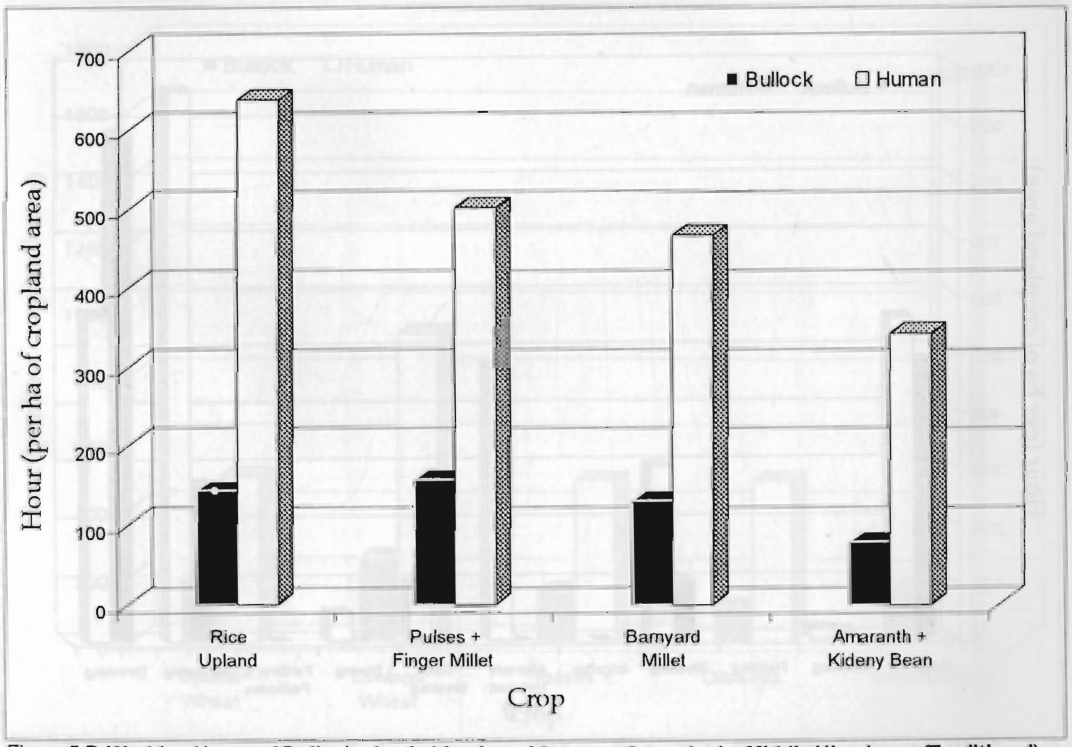

Figure 5.7: **Working Hours of Bullocks for Cultivation of Summer Crops in the Middle Himalayas (Traditional)**

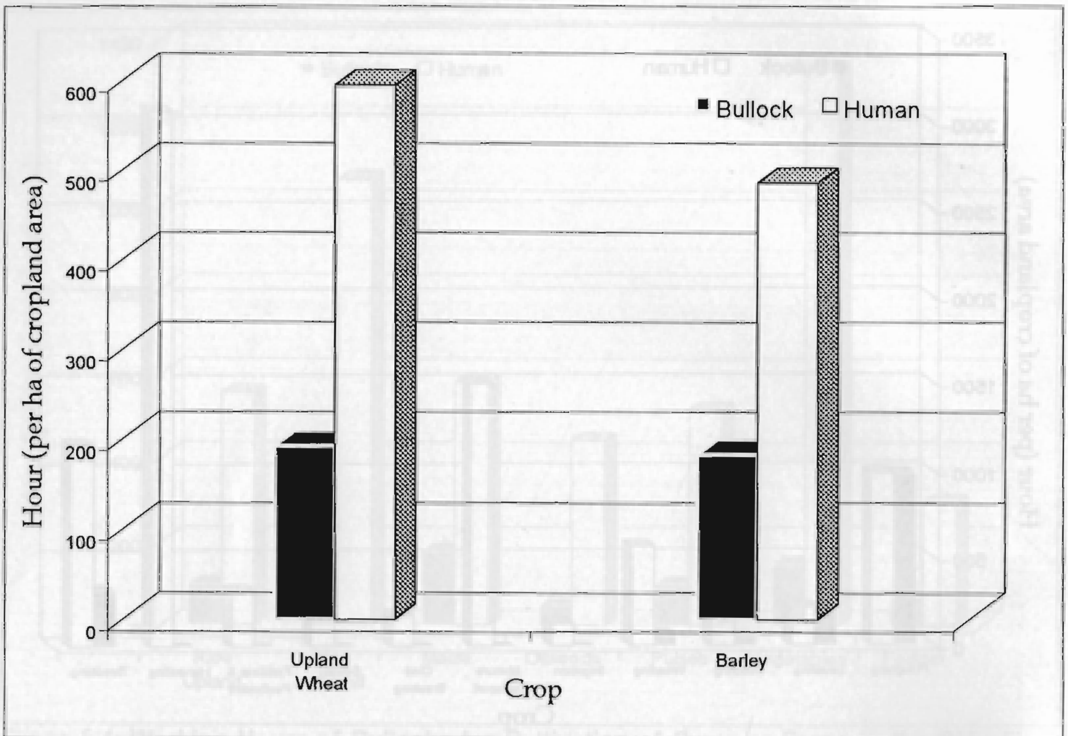

Figure 5.8: **Working Hours of Bullocks for Cultivation of Winter Crops in the Middle Himalayas (Traditional)**

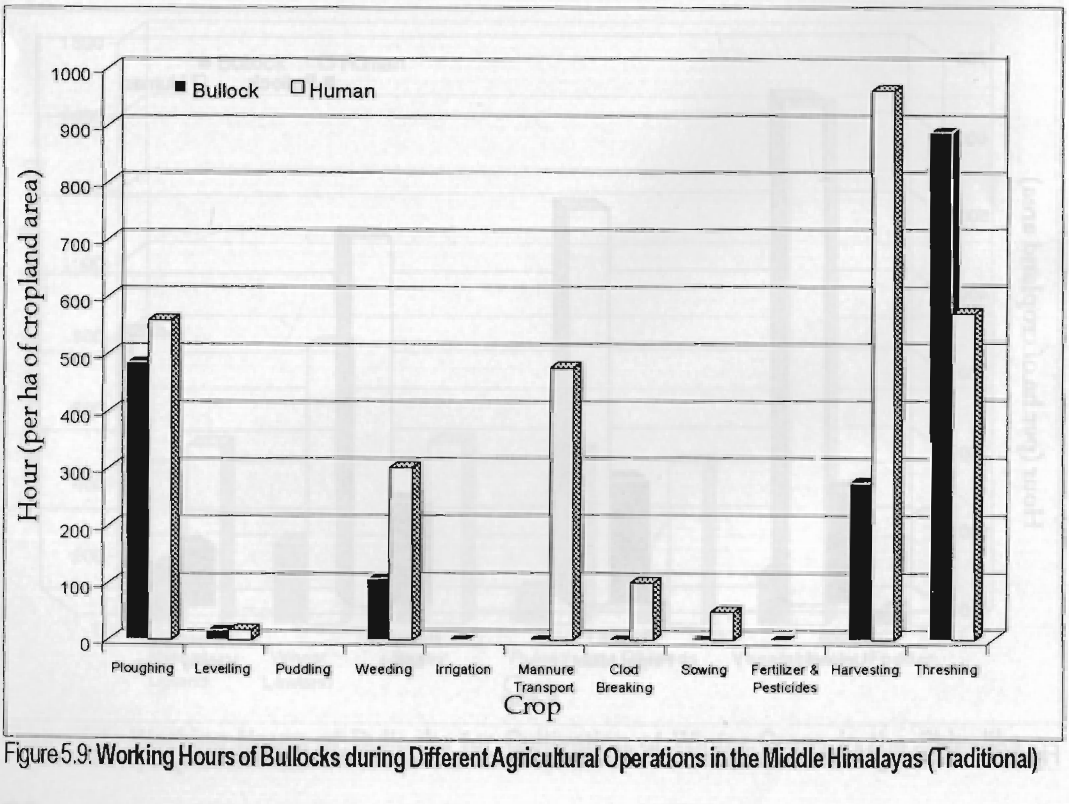

Figure 5.9: **Working Hours of Bullocks during Different Agricultural Operations in the Middle Himalayas (Traditional)**

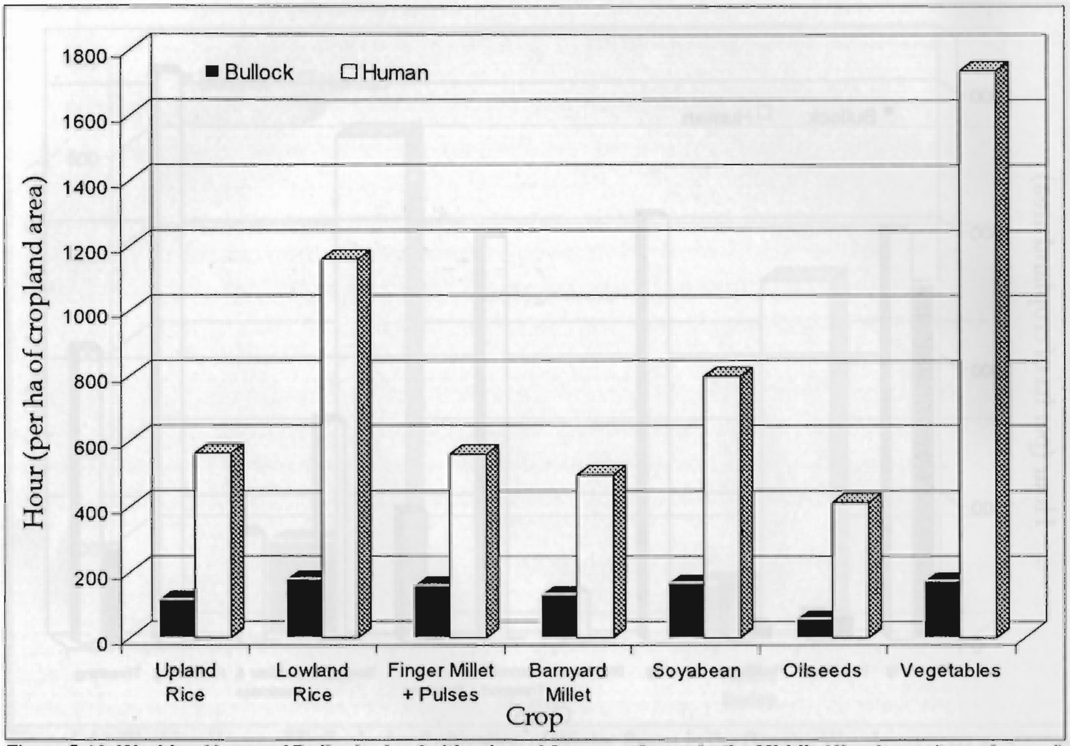

Figure 5.10: **Working Hours of Bullocks for Cultivation of Summer Crops in the Middle Himalayas (transformed)**

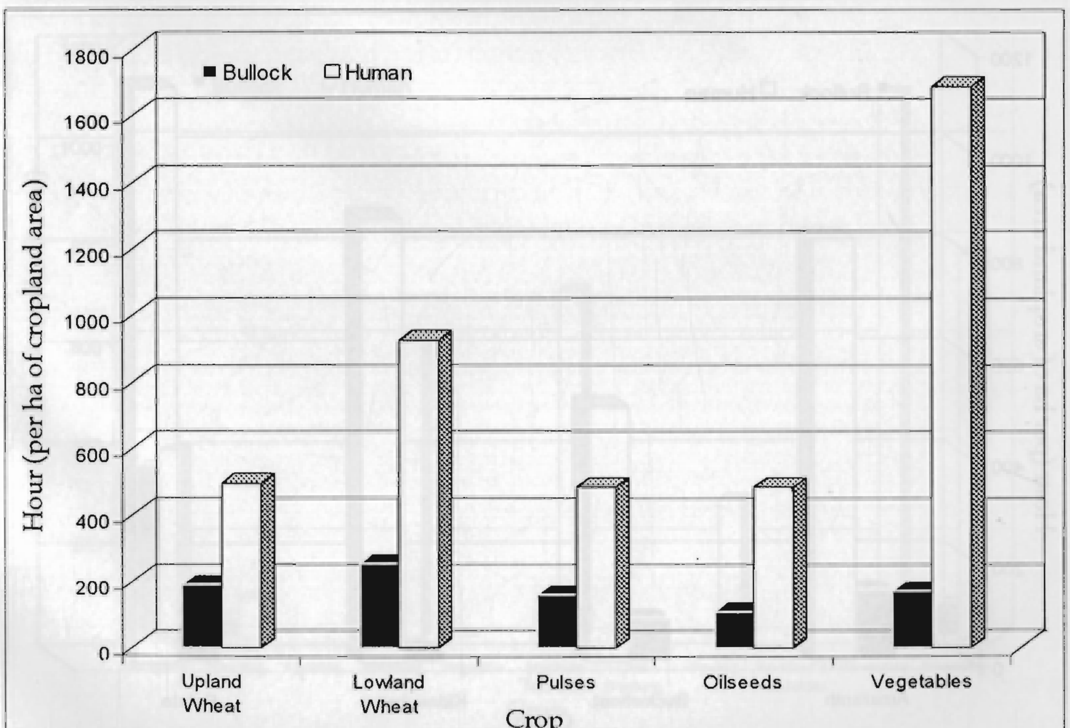

Figure 5.11: **Working Hours of Bullocks for Cultivation of Winter Crops in the Middle Himalayas (transformed)**

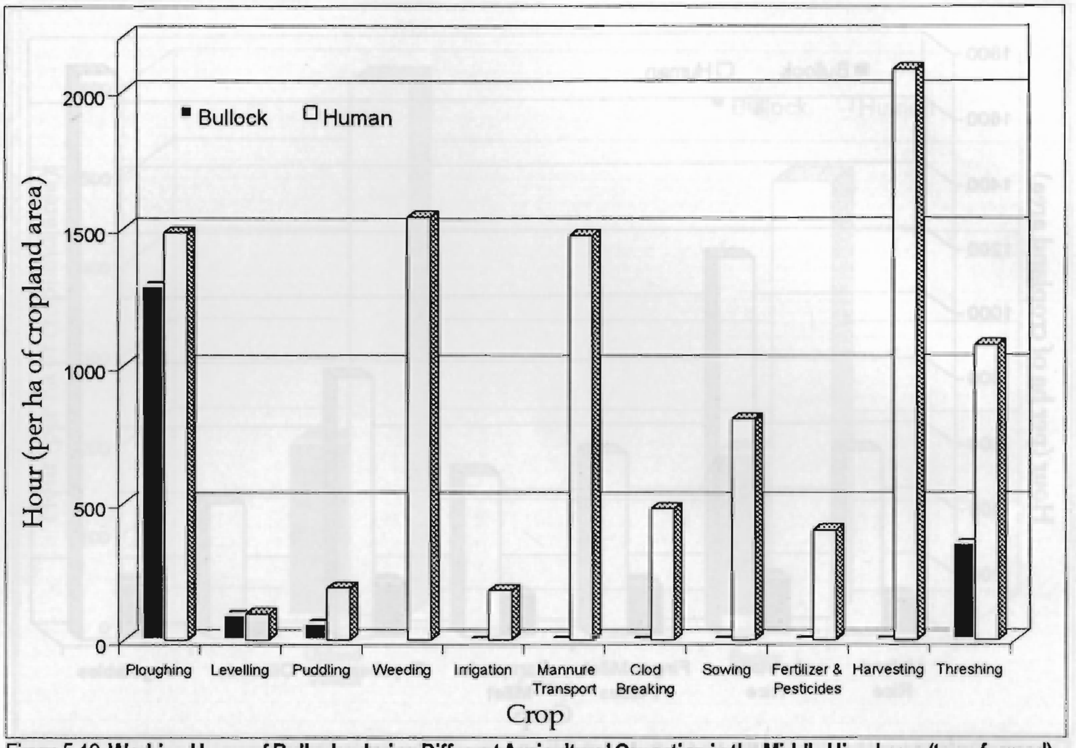

Figure 5.12: **Working Hours of Bullocks during Different Agricultural Operation in the Middle Himalayas (transformed)**

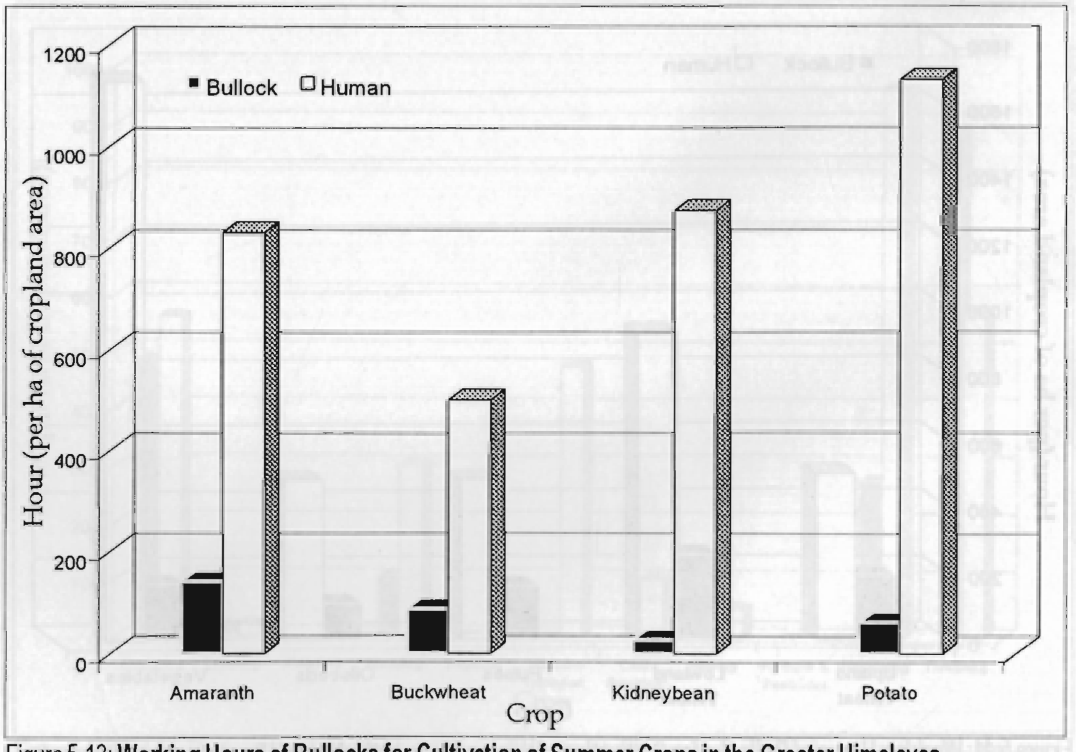

Figure 5.13: **Working Hours of Bullocks for Cultivation of Summer Crops in the Greater Himalayas**

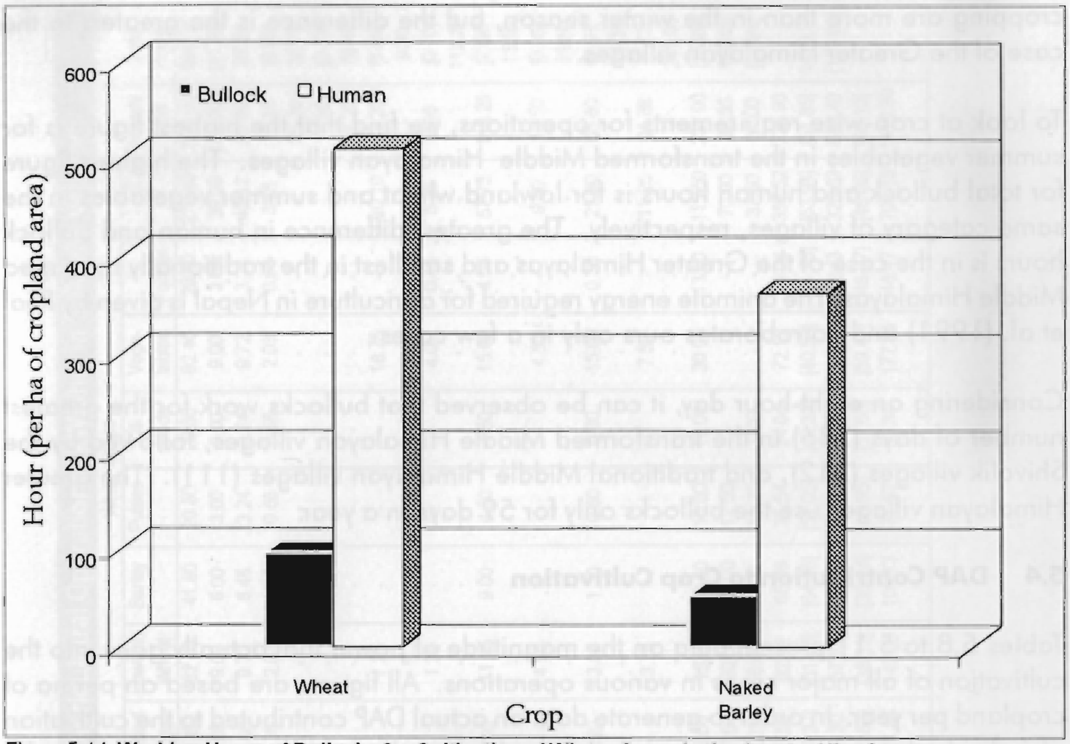

Figure 5.14: Working Hours of Bullocks for Cultivation of Winter Crops in the Greater Himalayas

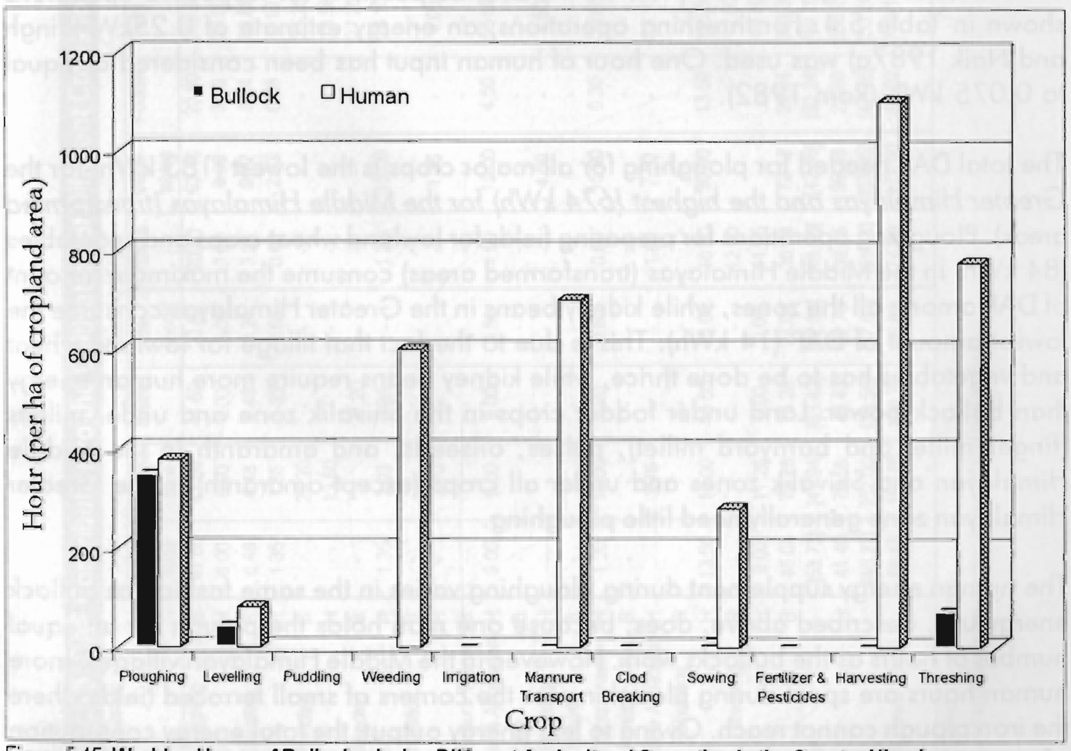

Figure 5.15: Working Hours of Bullocks during Different Agricultural Operation in the Greater Himalayas

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									
		Upland Rice	Lowland Rice	Maize	Oil-seeds	Pulses	Vege-tables	Fodder	Total	Upland Wheat	Lowland Wheat	Barley	Pulses	Oil-seeds	Vege-tables	Fodder	Total	Annual Total	Total Power
1. Ploughing	B:	41.60	41.60	41.60	20.80	20.80	62.40	20.80	249.60	41.60	62.40	41.60	20.80	20.80	62.40	20.80	270.40	520.00	595.00
	H:	6.00	6.00	6.00	3.00	3.00	9.00	3.00	36.00	6.00	9.00	6.00	3.00	3.00	9.00	3.00	39.00	75.00	[41.92]
2. Levelling	B:	6.48	6.48	6.48	3.24	3.24	9.72	3.24	38.88	6.48	9.72	6.48	3.24	3.24	9.72	3.24	42.12	81.00	97.88
	H:	1.35	1.35	1.35	0.68	0.68	2.03	0.68	8.10	1.35	2.03	1.35	0.68	0.68	2.03	0.68	8.78	16.88	[6.90]
3. Puddling	B:	-	25.20	-	-	-	-	-	25.20	-	-	-	-	-	-	-	-	25.20	38.70
	H:	-	13.50	-	-	-	-	-	13.50	-	-	-	-	-	-	-	-	13.50	[2.73]
4. Weeding	B:	-	-	27.20	-	-	-	-	27.20	-	-	-	-	-	-	-	-	27.20	70.40
	H:	1.35	2.03	3.38	-	1.35	15.00	-	23.10	-	1.35	-	-	-	18.75	-	20.10	43.20	[4.96]
5. Irrigation	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.90
	H:	-	2.70	-	-	-	1.35	-	4.05	-	1.35	-	-	-	4.05	0.45	5.85	9.90	[0.70]
6. Manure Trans-	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	113.25
port & Application	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	[7.98]
7. Clod	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.50
Breaking	H:	-	-	-	-	-	4.50	-	4.50	-	4.50	-	-	-	4.50	-	9.00	13.50	[0.95]
8. Sowing/	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	55.80
Transplantation	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	[3.93]
9. Fertilizer & Pes-	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24.38
ticide Application	H:	-	3.75	-	-	1.88	7.50	-	13.13	-	3.75	-	-	-	7.50	-	11.25	24.38	[1.72]
10. Harvesting	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	231.00
	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	[16.28]
11. Threshing	B:	-	-	-	-	12.50	-	-	12.50	17.50	20.00	20.00	12.50	-	-	-	70.00	82.50	169.50
	H:	9.00	11.25	9.00	9.00	11.25	-	-	49.50	5.25	6.00	6.00	11.25	9.00	-	-	37.50	87.00	[11.94]
	B:	48.08	73.28	75.28	24.04	36.54	72.12	24.04	353.38	65.58	92.12	68.08	36.54	24.04	72.12	24.04	382.52	735.90	
Total		[53.73]	[47.94]	[63.42]	[42.31]	[48.86]	[42.05]	[52.24]	[49.76]	[64.37]	[61.68]	[64.76]	[51.05]	[42.32]	[40.53]	[51.73]	[53.94]	[51.85]	1419.30
	H:	41.40	79.58	43.43	32.78	38.25	99.38	21.98	356.78	36.30	57.23	37.05	35.03	32.76	105.83	22.43	326.63	683.40	[100.00]
		[46.27]	[52.06]	[36.58]	[57.69]	[51.14]	[57.95]	[47.76]	[50.24]	[35.63]	[38.32]	[35.24]	[48.95]	[57.68]	[59.47]	[48.27]	[46.06]	[48.15]	
Total Power (B+H)		89.48	152.86	118.71	56.82	74.79	171.50	46.02	710.16	101.88	149.35	105.13	71.57	56.80	177.95	46.47	709.15	1419.30	

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: Upland Rice	Summer Crops: Finger Millets +Pulses	Summer Crops: Barnyard Millet	Summer Crops: Amaranth + Kidney bean	Summer Crops: Total	Winter Crops: Upland Wheat	Winter Crops: Barley	Winter Crops: Total	Annual Total	Total Power
1. Ploughing	B:	56.16	28.08	28.08	28.08	140.40	56.16	56.16	112.32	252.72	249.57
	H:	9.45	4.73	4.73	4.05	22.95	9.45	9.45	18.90	41.85	[49.77]
2. Levelling	B:	3.24	-	-	-	3.24	3.24	-	3.24	6.48	7.83
	H:	0.68	-	-	-	0.68	0.68	-	0.68	1.35	[1.32]
3. Puddling	B:	-	-	-	-	-	-	-	-	-	-
	H:	-	-	-	-	-	-	-	-	-	-
4. Weeding	B:	9.18	18.36	9.18	-	36.72	-	-	-	36.72	59.22
	H:	7.50	7.50	7.50	-	22.50	-	-	-	22.50	[10.00]
5. Irrigation	B:	-	-	-	-	-	-	-	-	-	-
	H:	-	-	-	-	-	-	-	-	-	-
6. Manure Transport & Application	B:	-	-	-	-	-	-	-	-	-	35.63
	H:	9.38	3.75	3.75	-	16.88	9.38	9.38	18.75	35.63	[6.02]
7. Clod Breaking	B:	-	-	-	-	-	-	-	-	-	7.50
	H:	-	-	-	-	-	7.50	-	7.50	7.50	[1.27]
8. Sowing/ Transplantation	B:	-	-	-	-	-	-	-	-	-	3.68
	H:	0.68	0.68	0.30	0.68	2.33	0.68	0.68	1.35	3.68	[0.62]
9. Fertilizer & Pesticide Application	B:	-	-	-	-	-	-	-	-	-	-
	H:	-	-	-	-	-	-	-	-	-	-
10. Harvesting	B:	-	-	-	-	-	-	-	-	-	72.00
	H:	11.25	13.50	11.25	13.50	49.50	11.25	11.25	22.50	72.00	[12.16]
11. Threshing	B:	-	12.50	12.50	6.25	31.25	18.75	18.75	37.50	68.75	111.50
	H:	9.00	7.50	7.50	7.50	31.50	5.63	5.63	11.25	42.75	[18.84]
Total	B:	68.58	58.94	49.76	34.33	211.61	78.15	74.91	153.06	364.67	
		[58.36]	[61.02]	[58.69]	[57.16]	[59.12]	[63.69]	[67.31]	[65.41]	[61.61]	591.92
	H:	47.93	37.65	35.03	25.73	146.33	44.55	36.38	80.93	227.25	[100.00]
		[41.14]	[38.98]	[41.31]	[42.84]	[40.88]	[36.31]	[32.69]	[34.59]	[38.39]	
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: Upland Rice	Lowland Rice	Finger Millet +Pulses	Barnyard Millet	Soya -bean	Oil-seeds	Vege-tables	Total	Winter Crops: Upland Wheat	Lowland Wheat	Pulses	Oil-seeds	Vege-tables	Total	Annual Total	Total Power
1. Ploughing	B:	56.16	56.16	28.08	28.08	56.16	28.08	84.24	336.96	56.16	84.24	56.16	56.16	84.24	336.96	673.92	785.30
	H:	9.45	8.10	4.73	4.73	9.45	4.05	14.18	54.68	9.45	14.18	9.45	9.45	14.18	56.70	111.38	[49.50]
2. Levelling	B:	3.24	3.24	1.44	1.44	3.24	1.44	4.68	18.72	3.24	4.68	1.44	1.44	4.68	15.48	34.20	41.33
	H:	0.68	0.68	0.30	0.30	0.68	0.30	0.98	3.90	0.68	0.98	0.30	0.30	0.98	3.23	7.13	[2.61]
3. Puddling	B:	-	26.46	-	-	-	-	-	26.46	-	-	-	-	-	-	26.46	40.64
	H:	-	14.18	-	-	-	-	-	14.18	-	-	-	-	-	-	14.18	[2.56]
4. Weeding	B:		-	18.36	9.18	-	-	-	27.54	-	-	-	-	-	-	27.54	143.27
	H:	-	4.05	11.55	9.53	11.55	-	45.00	81.68	-	4.05	-	-	30.00	34.05	115.73	[9.03]
5. Irrigation	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.50
	H:	-	3.60	-	-	-	-	3.60	7.20	-	2.70	-	-	3.60	6.30	13.50	[0.85]
6. Manure Trans-	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	110.63
port & Application	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	[6.97]
7. Clod	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35.85
Breaking	H:	-	-	-	-	-	-	14.18	14.18	-	7.50	-	-	14.18	21.68	35.85	[2.26]
8. Sowing/	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60.45
Transplantation	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	[3.81]
9. Fertilizer & Pes-	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30.00
ticide Application	H:	-	3.75	-	-	7.50	-	7.50	18.75	-	3.75	-	-	7.50	11.25	30.00	[1.89]
10. Harvesting	B:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	156.00
	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	[9.83]
11. Threshing	B:	-	-	12.50	12.50	12.50	-	-	37.50	18.75	20.00	12.50	-	-	51.25	88.75	169.38
	H:	9.00	11.25	7.50	7.50	7.50	11.25	-	54.00	5.63	6.00	7.50	7.50	-	26.63	80.63	[10.68]
	B:	59.04	85.86	60.38	51.20	71.90	29.52	88.92	447.18	78.15	108.92	70.10	57.60	88.92	403.69	850.87	
Total		[58.41]	[49.71]	[58.98]	[57.82]	[54.57]	[48.86]	[40.54]	[51.00]	[67.83]	[61.06]	[65.88]	[61.34]	[41.24]	[56.90]	[53.63]	1586.35
	H:	42.30	86.85	42.00	37.35	59.85	30.90	130.43	429.68	37.07	69.45	36.30	36.30	126.68	305.78	735.46	[100.00]
		[41.59]	[50.29]	[41.02]	[42.18]	[45.43]	[51.14]	[59.46]	[49.00]	[32.17]	[38.94]	[34.12]	[38.66]	[58.76]	[43.10]	[46.36]	
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
		Amaranth	Buckwheat	Kidney Bean	Potato	Total	Wheat	Naked Barley	Total	Total	Power
1. Ploughing	B:	56.16	28.08	14.04	28.08	126.36	28.08	28.08	56.16	182.52	210.87
	H:	8.10	4.05	4.05	4.05	20.25	4.05	4.05	8.10	28.35	[39.52]
2. Levelling	B:	3.24	3.24	-	3.24	9.72	6.48	-	6.48	16.20	22.28
	H:	1.35	1.35	-	2.03	4.73	1.35	-	1.35	6.08	[4.18]
3. Puddling	B:	-	-	-	-	-	-	-	-	-	-
	H:	-	-	-	-	-	-	-	-	-	-
4. Weeding	B:	-	-	-	-	-	-	-	-	-	45.00
	H:	15.00	-	7.50	22.50	45.00	-	-	-	45.00	[8.43]
5. Irrigation	B:	-	-	-	-	-	-	-	-	-	-
	H:	-	-	-	-	-	-	-	-	-	-
6. Manure Transport & Application	B:	-	-	-	-	-	-	-	-	-	52.50
	H:	11.25	5.63	5.63	15.00	37.50	11.25	3.75	15.00	52.50	[9.84]
7. Clod Breaking	B:	-	-	-	-	-	-	-	-	-	22.50
	H:	-	-	15.00	7.50	22.50	-	-	-	22.50	[4.22]
8. Sowing/ Transplantation	B:	-	-	-	-	-	-	-	-	-	21.00
	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:	-	-	-	-	-	-	-	-	-	82.50
	H:	15.00	15.00	15.00	18.75	63.75	11.25	7.50	18.75	82.50	[15.46]
11. Threshing	B:	6.25	6.25	-	-	12.50	6.25	-	6.25	18.75	76.88
	H:	11.25	11.25	15.00	-	15.00	9.38	11.25	20.63	58.13	[14.41]
	B:	65.65	37.57	14.04	31.32	148.58	40.81	28.08	68.89	217.47	
Total		[50.90]	[49.95]	[17.64]	[26.97]	[37.24]	[51.52]	[50.70]	[51.19]	[40.76]	533.52
	H:	63.33	37.65	65.55	84.83	250.35	38.40	27.30	65.70	316.05	[100.00]
		[49.10]	[50.05]	[82.36]	[73.03]	[62.76]	[48.48]	[49.30]	[48.81]	[59.24]	
Total Power (B+H)		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).

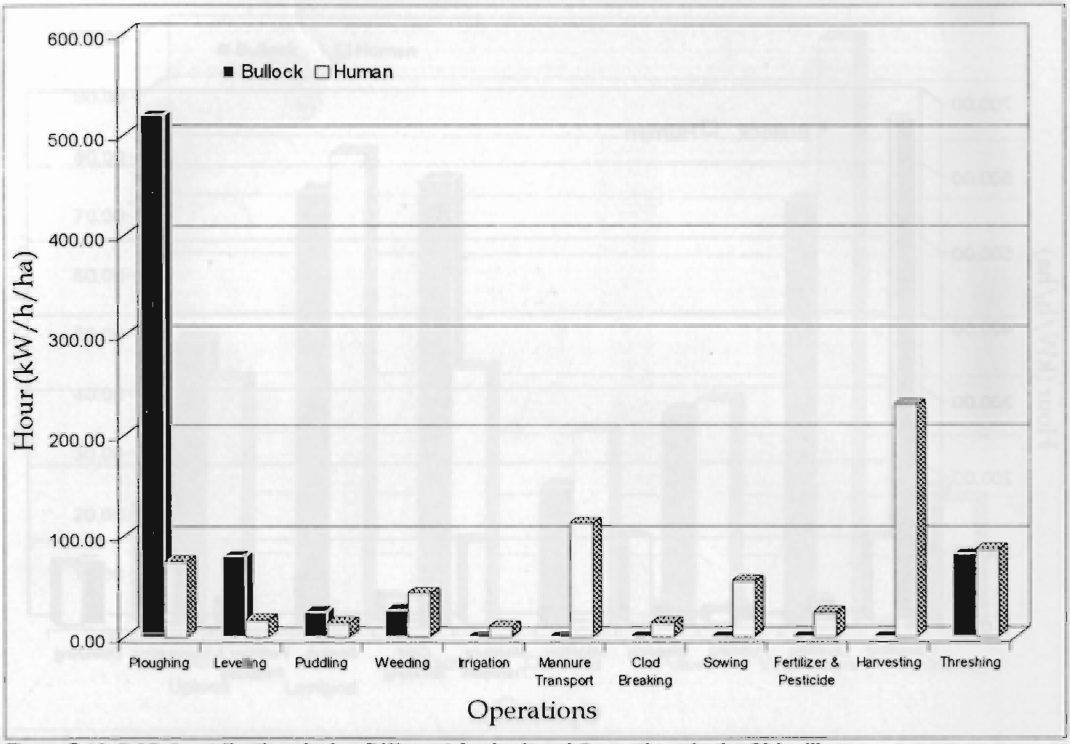

Figure 5.16: DAP Contribution during Different Agricultural Operations in the Shivaliks

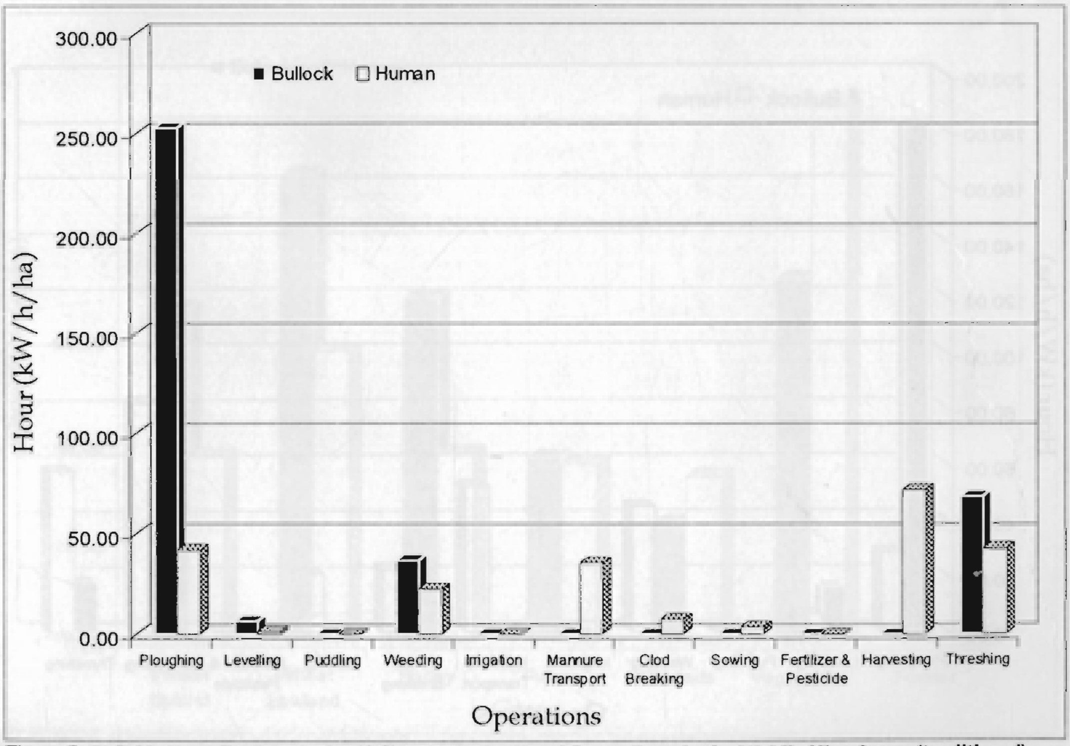

Figure 5.17: DAP Contribution during Different Agricultural Operations in the Middle Himalayas (traditional)

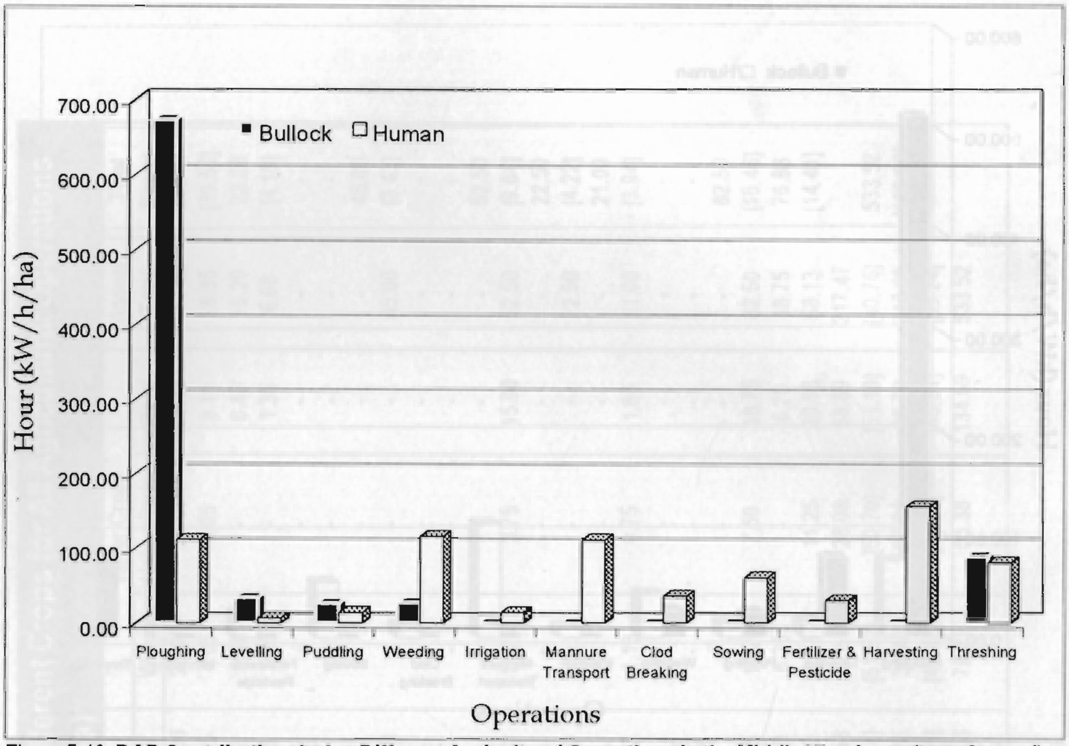

Figure 5.18: **DAP Contribution during Different Agricultural Operations in the Middle Himalayas (transformed)**

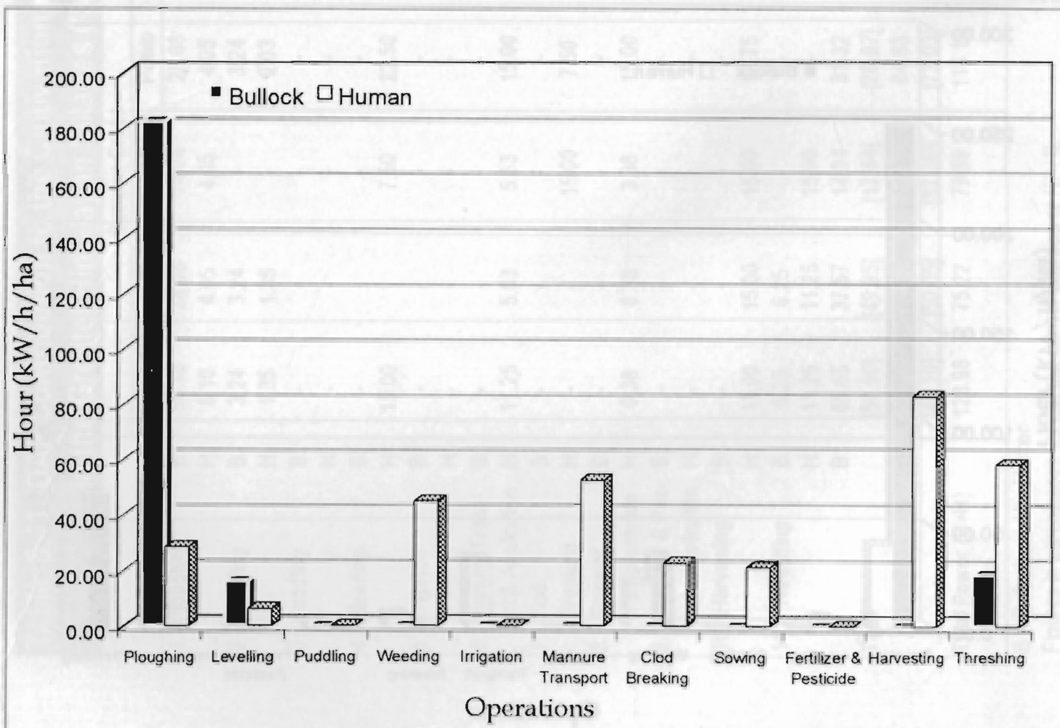

Figure 5.19: **DAP Contribution during Different Agricultural Operations in the Greater Himalayas**

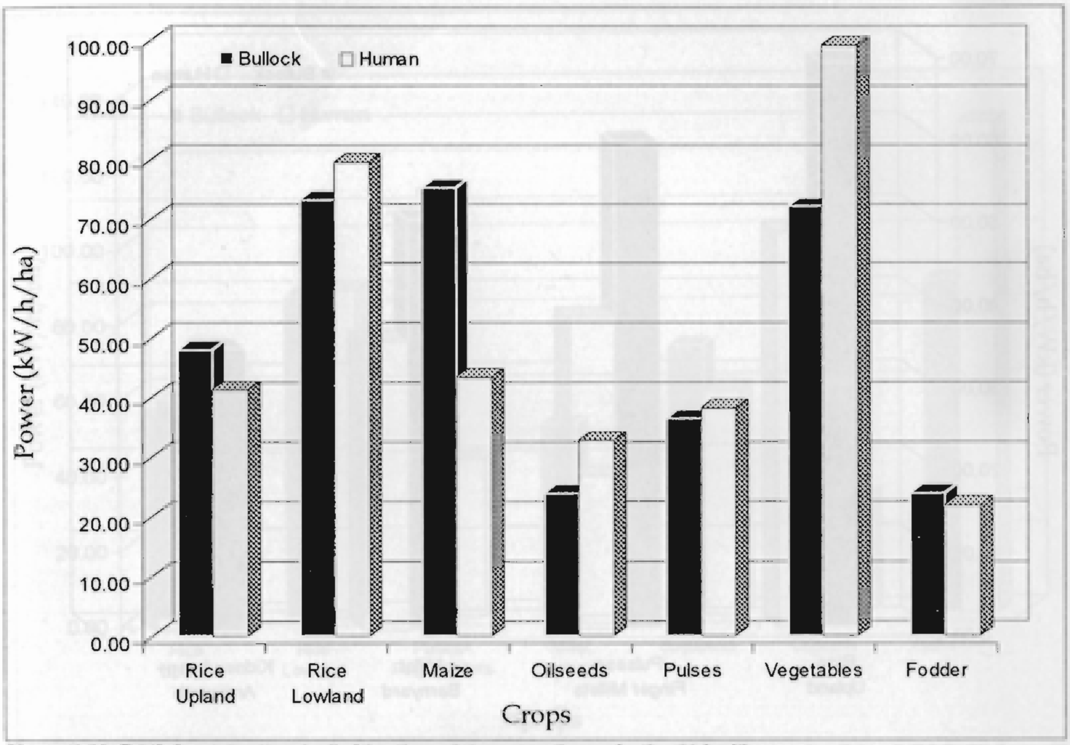

Figure 5.20: **DAP Contribution to Cultivation of Summer Crops in the Shivaliks**

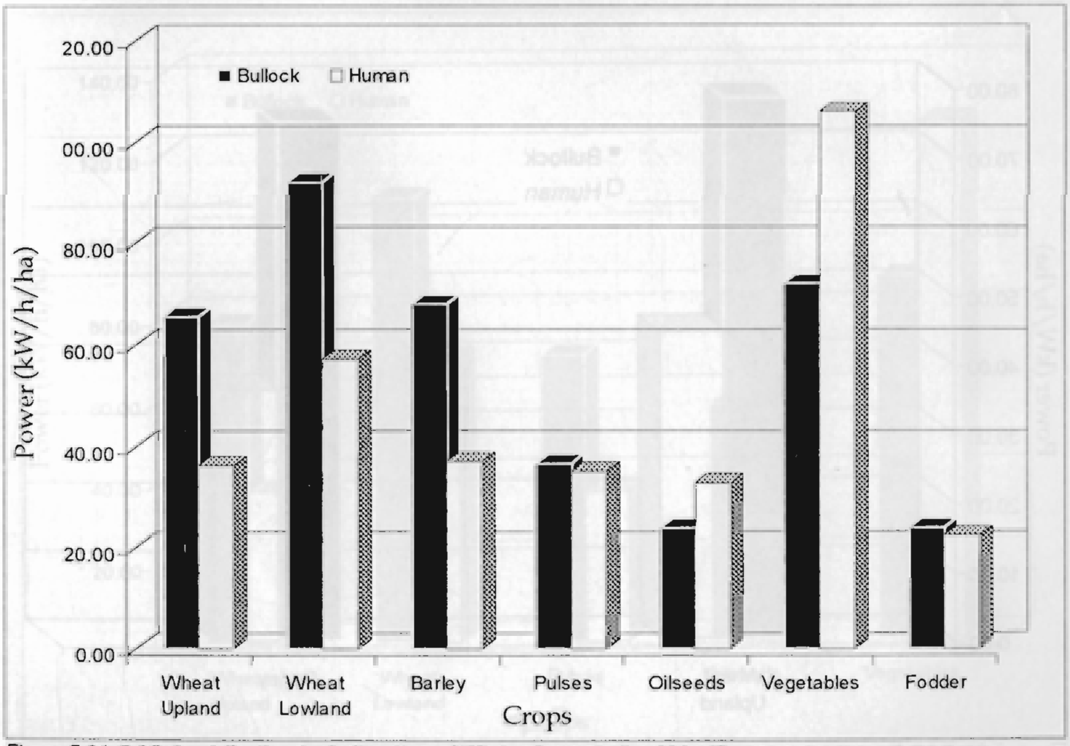

Figure 5.21: **DAP Contribution to Cultivation of Winter Crops in the Shivaliks**

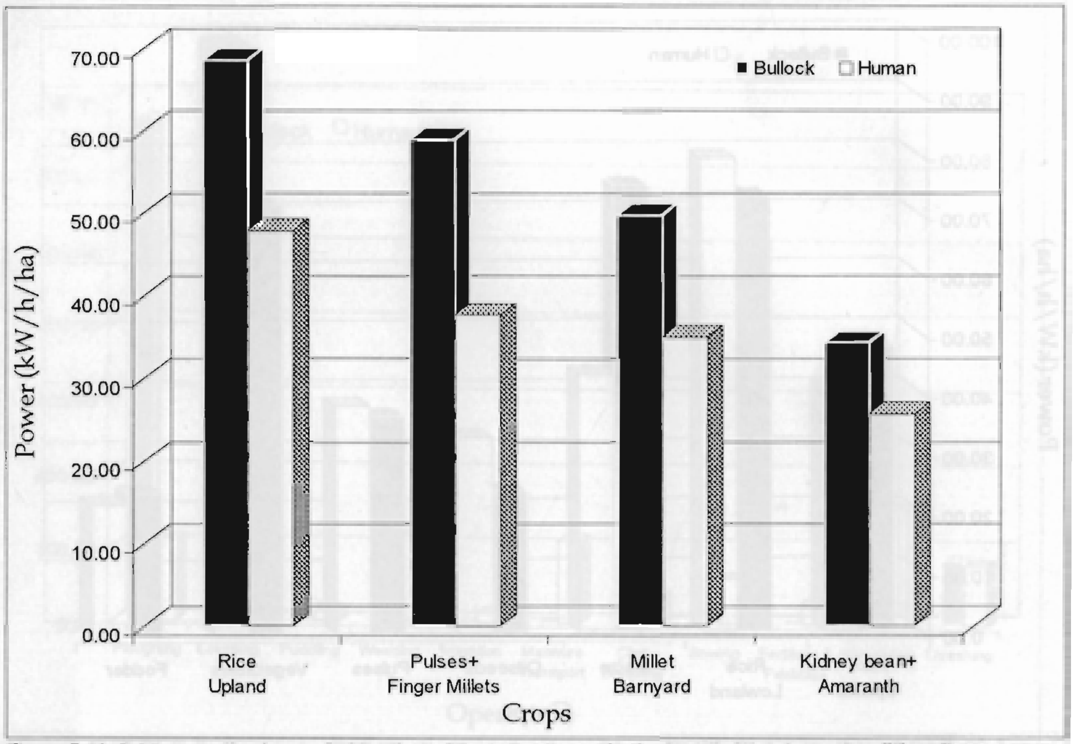

Figure 5.22: **DAP Contribution to Cultivation of Summer Crops in the Middle Himalayas (traditional)**

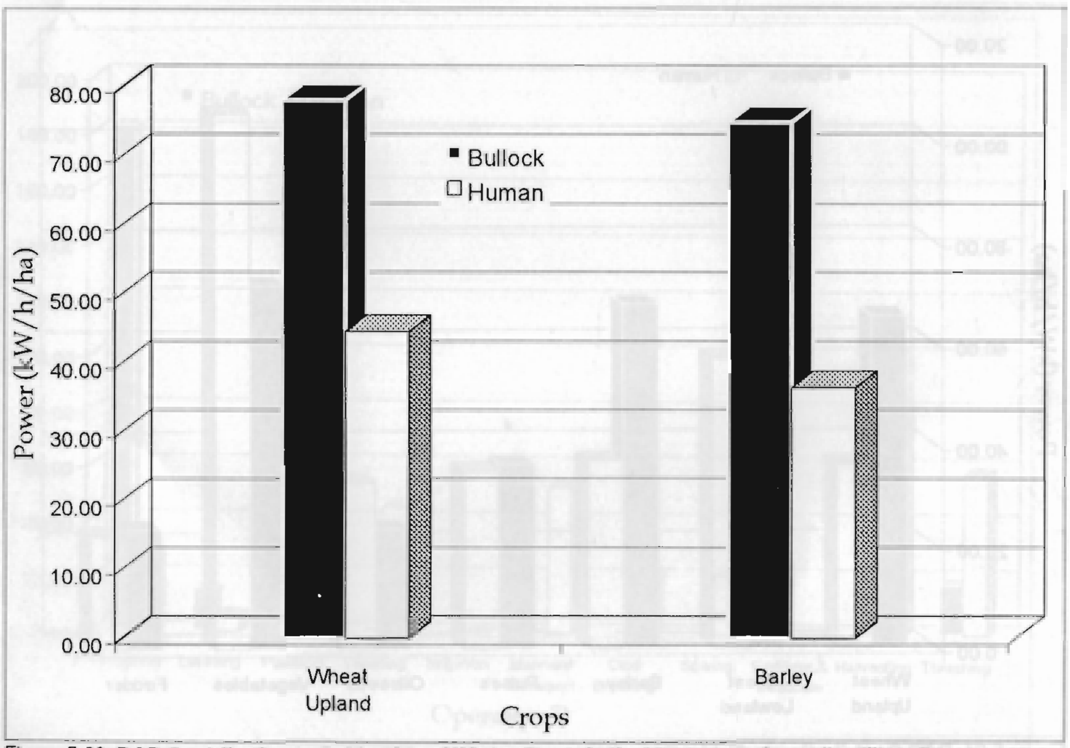

Figure 5.23: **DAP Contribution to Cultivation of Winter Crops in the Middle Himalayas (traditional)**

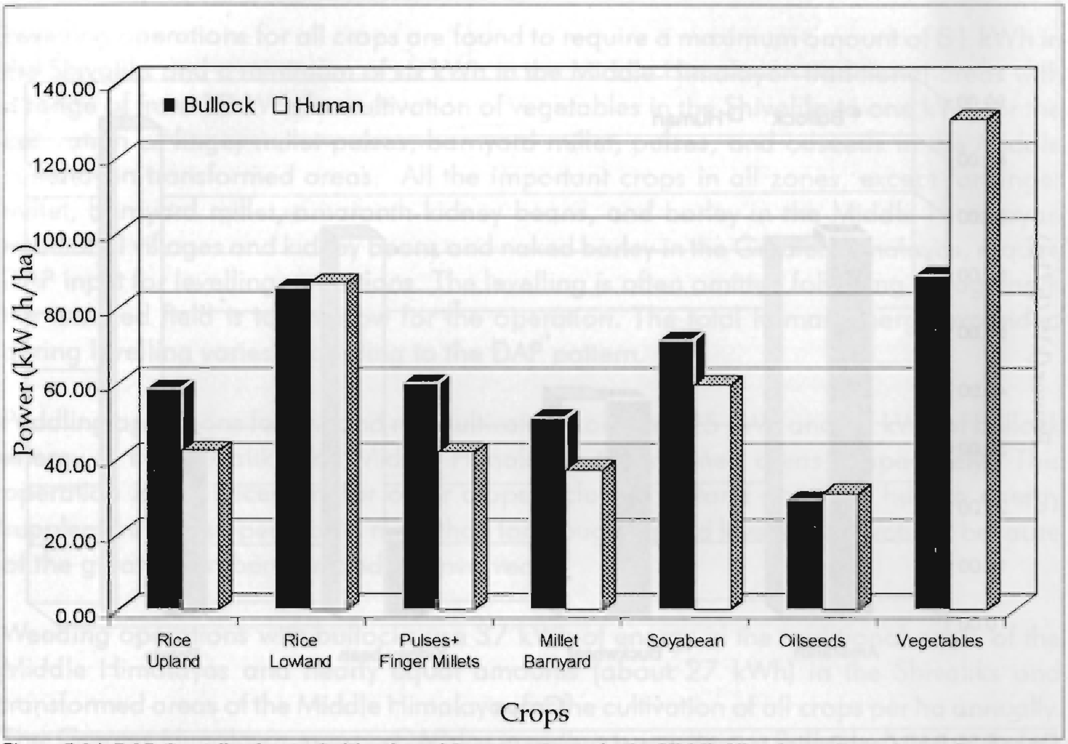

Figure 5.24: **DAP Contribution to Cultivation of Summer Crops in the Middle Himalayas (transformed)**

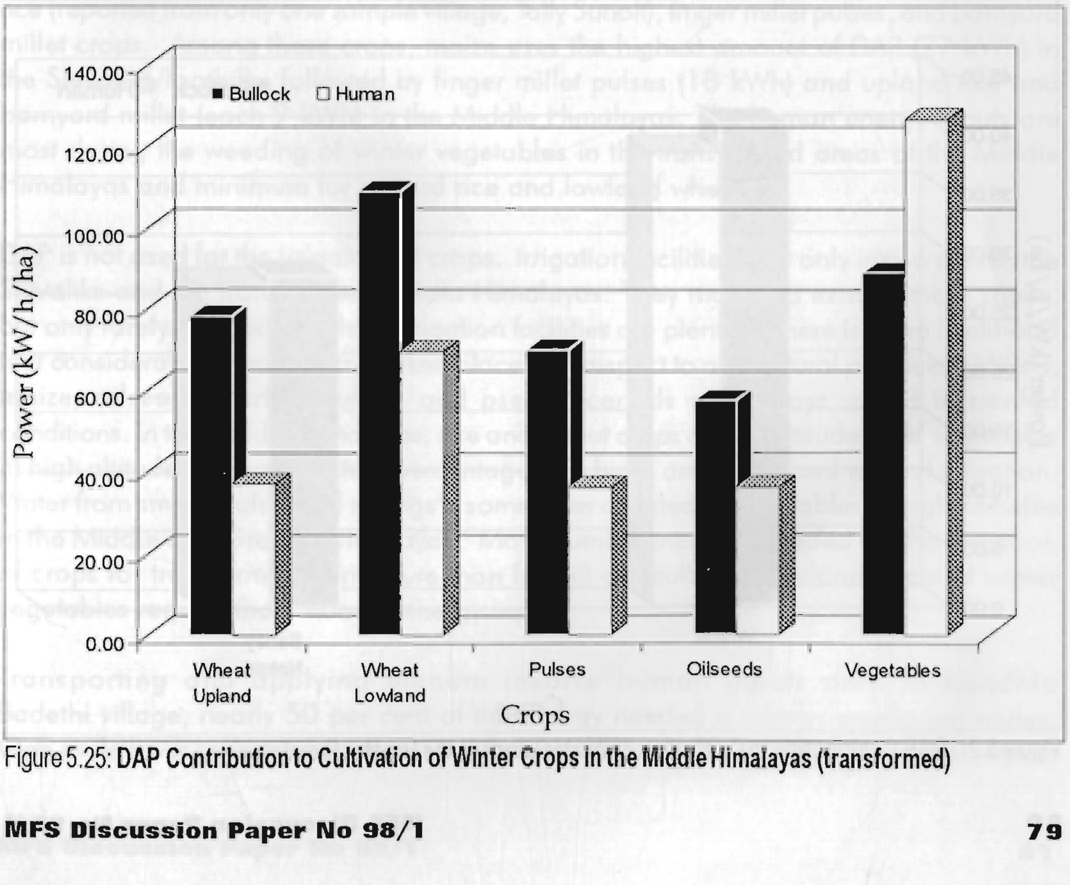

Figure 5.25: **DAP Contribution to Cultivation of Winter Crops in the Middle Himalayas (transformed)**

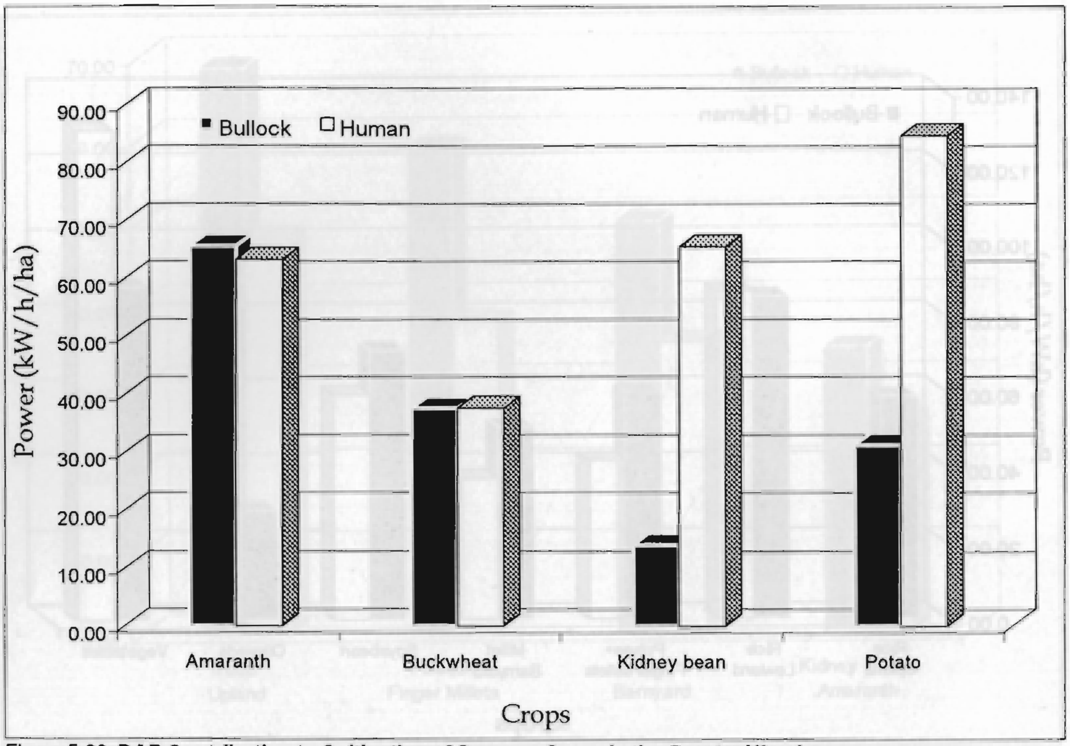

Figure 5.26: **DAP Contribution to Cultivation of Summer Crops in the Greater Himalayas**

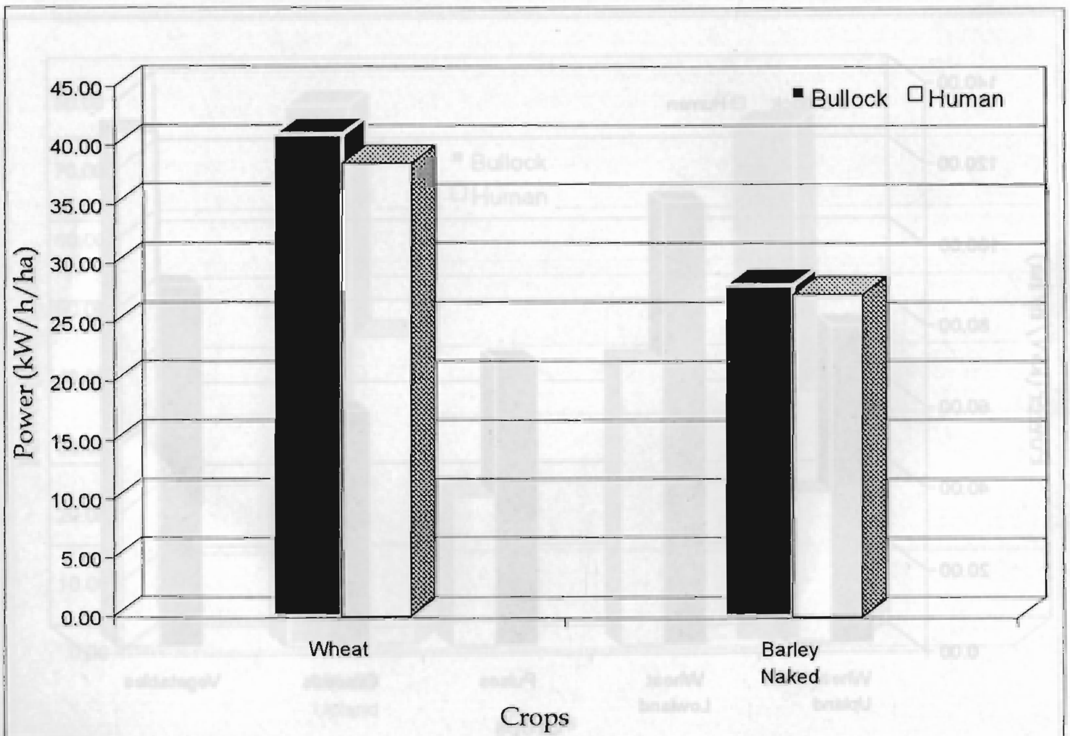

Figure 5.27: **DAP Contribution to Cultivation of Winter Crops in the Greater Himalayas**

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 kilo joules (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/ha/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 camp 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 (10^5k 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
Total	*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
Total	*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
Total	*10.90*	*5.91*	*8.84/4.74*	*90.89/48.74*
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
Total	*16.56*	*9.87*	*13.55/5.51*	*98.16/39.95*

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).

Hiring out bullocks, for some families, fetches in quite a good amount of money. Some marginal and small landholders, as noted during the study, earn as much as Rs 12,000 per year, and sometimes even more. If all other sociocultural, ecological, and economic (power contribution) roles of a pair of bullocks are taken into account, the benefits accruing to a family would, indeed, be much higher than the net maintenance cost.