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Energy Flow through Summer Cropping In a Mountain Agro-Ecosystem in Kumaun Himalaya

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ABSTRACT

Energy flow through a mountain agro-ecosystem was analysed in a cluster of five mid-altitude villages in the Pithoragarh district of the Kumaun Himalaya during summer (Kharif) cropping in 2007. Information was derived from 50 families (10 families in each village), resource persons and secondary sources. There were, on an average, 87 households per village. The average family size of the villages was 6.22. Average population per village was 476. An average land holding size was one ha. Upland rice and finger millet-pulses covered the largest area. On an average, there were 64 bullocks, 46 cows, 98 buffaloes, and 144 goats per village. Maximum amount of energy (274.50x105 kJha-1) was invested through manure (53.55 percent of the total energy), followed by chemical fertilizers (97.09 x105 kJha-1) and pesticides (82.88 x105 kJha-1), and minimum through seeds (15.15x105 kJha-1). In the form of useful outputs (grain and straw), a gross energy value of 10260.95 x105kJha-1 was harvested during summer cropping. The largest amount of energy was produced through fruit production (3246.60x105kJha-1), which was about 32 percent of the gross energy produced in one ha cropland during summer season. Gross energy output - input ratio of the tree-based fruit crops was the highest (61.291) of all the crops. Root and tuber crops showed comparatively higher energetic efficiency (17.833) than other vegetables (9.471). Amongst the food grain crops the maximum energetic efficiency (37.782) was recorded in amaranth-kidney bean cultivation followed by finger millet-pulses (23.884) and the minimum in soybean cultivation (3.438).

1. Introduction

Agriculture, concentrated mainly between 1000-2000 m altitude belts, is the primary occupation of about 80 percent people of Uttarakhand. This altitudinal range is also called the populated or "problem zone" of the region as most of the human population is settled in this belt. Agriculture in the Himalayan mountains is practiced as a mixed farming system, where the crops, livestock and forests are the integral parts of an agro-ecosystem. Summer cropping (the *Kharif* season) especially embraces a whole range of agro-biodiversity, including cropping patterns, large number of crops (cereals, millets, pseudo cereals, pulses, oil seeds, vegetables, *etc.*) and very large number of varieties of each crop. A strategy of agricultural development in mountain areas largely revolves round summer cropping. The summer cropping, so crucial in mountain agriculture, needs to be understood in its totality, including energy flow between different components of the agro-ecosystem. Some noted workers (*e*.g. Pandey and Singh, 1984a, 1984b; Singh, 1991; Singh and Dankelman, 1993; Singh, 1998; Singh, 2008; Tamta, 2010; Rastogi, 2012) have carried out energy flow related studies in mountain agroecosystems. Our current understanding of energy flow within a mountain agro-ecosystem, however, appears to be inadequate. No comprehensive energy analysis relating to the unique summer

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cropping system of the mountain agriculture has ever been made. The current energy flow analysis is an attempt to fill this gap. Energy, basically, is the capacity to do work. Energy input is a pre-requisite for the functioning of an ecosystem. The original form of energy, *i.e.* the light, is an extra terrestrial source, and this is the form of energy which is the primary source of life on Earth. When solar radiation strikes the Earth it tends to be degraded into heat energy. On account of the mechanism of photosynthesis carried out by green plants, however, a fraction of the same energy is converted into potential or food energy. It is thanks to this wonderful mechanism operated by green plants that entire energy received by the Earth is not wasted and a fraction of the light energy is converted in biochemical energy, the basis of food production. Every ecosystem has energy flow as one of its essential features and as an inevitability for its functioning. Lofty and fragile mountains of the Himalaya, as of Uttarakhand, attain some kind of ecological stability thanks to a variety of forests as the main natural resource of the region. The entire process of energy flow through an ideal forest ecosystem may be understood through (Mitra, 2000): i) acquisition of energy by the producers; ii) fixing of energy by the producers; iii) and transference of energy through trophic level. An agro-ecosystem in the Himalayan mountains, as operating in the Kumaun region of Uttarakhand, is an interesting example of overlapping ecosystems. Forest/ grassland/ rangeland, cropland, livestock and households' cluster called village, make inseparable components of an agro-ecosystem. Thus, an agro-ecosystem, as the one in the Himalayan mountains, is quite a heterogeneous and complex unit of nature managed by human beings. Here the major consumers are the human beings and, unlike in upland forest and open ocean ecosystems, it receives nature's subsidy either though natural means or through human management. Thus, an agro-ecosystem involves lot of energy input for its functioning. Functioning of a mountain agro-ecosystem would require energy input of various sorts, *viz.* i) direct solar energy which would be converted into potential energy by plants, ii) forest biomass in terms of manure through livestock, iii) seeds of a variety of crops, iv) animate energy of livestock and humans, v) crop residues as manure, and vi) livestock feeds, which are converted into draught power, milk and other products. An agro-ecosystem would produce energy in various usable forms, *viz.* i) crop residues used in livestock feeding, ii) food grains/ fruits/ other plant parts, such as roots, shoots, leaves, *etc.* of food value, iii) green grass, weeds and tree/ shrub leaves used as green fodder for livestock, iv) dung/ manure, v) milk and other animal products, and vi) calf crop. A quantitative estimate of energy flow through a mountain agro-ecosystem would help to gauge the energetic efficiency of the food production system. Energy output-input ratio is one of the major indicators of the functioning and performance of an ecosystem. Energetics being dependent on the inputs and outputs of an agro-ecosystem is also a useful indicator to suggest whether it is sustainable or not. This is, therefore, an important issue relating to the performance of an agro-ecosystem, which helps to understand the basic relationship of the production system with its environment (Singh and Sharma, 1993; Singh, 1998, Singh *et al.*, 2003).

2. Materials and Methods

2.1 The Study Area

The study area is located in the Pithoragarh district in the Kumaun Division of Uttarakhand. This district extends over a geographical area of 468293 ha out of which 47.8% is under forests. Cultivated barren land occupies 10.8%, fallow land 2.6%, uncultivated land 4.6%, other than agriculture 1.8%, pastures 11.0% and orchard 8.8% area. The net sown area reported is 12.4%. Cropping intensity is 170% (Teli, 2006).

2.2 Selection of Villages

Community land in mountain areas is shared by a cluster of villages called gramsabha, which is a local governing body. Selection of a Gramsabha thus is logical, for an agro-ecosystem receives energy and nutrients from a common uncultivated land which is looked after by the concerned Gramsabha. For this reason, Gramsabha Durlekh was purposely selected for the study. This Gramsabha has a cluster of five villages, *viz.* Bajani, Ajera, Hachila, Durlekh and Leemabhat. The selected agro-ecosystem is a typical case of mountain agriculture. The agro-ecosystem lies in the mid-altitude range (1400 to 2000). This is the altitude on which most of the mountain agriculture is concentrated.

2.3 Selection of Households

From each of the villages, ten farm families were selected randomly and required information was collected on the pre-structured format. In this way, a total of fifty households were selected for collecting detailed information.

2.4 Data Collection

The required information was collected from Government offices, Gramsabha office and from selected households. All agricultural outputs were recorded as per the estimates of the farmers, except for the amount of crop residues which was estimated based on the straw-grain ratio provided by Singh (1998).

2.5 Analysis of Data

All the inputs and outputs used in the summer cropping in mountain agriculture were converted into their calorific values using standard table for calorific values and published research work. The energy values for different agricultural operations for cultivation of different crops have been taken from Singh (1998) 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 standard values reported by Mitchell (1979) which have also been used by several workers, e.g. Pandey and Singh (1984a, 1984b), Singh *et al.* (1984), Negi *et al.* (1989), Ralhan *et al.* (1991), Singh (1991) and Maikhuri (1996). These values, summarised in Table 1, are expressed on fresh weight basis.

3. Results and Discussion

Data-based information about the cultivated land, area under different crops, and livestock population and composition in the purposely selected villages is presented in Tables 2, 3 and 4, respectively. Average landholding size (cultivated land per family) is quite meager (about 1.00 ha, Table 2). One striking features of mountain agriculture is this that no area of cultivated land is left fallow during summer cropping, while, during winter, a substantial chunk of the cultivated land is left fallow. In summer cropping the largest cultivated area is covered by upland (unirrigated) rice (about 36%) and and finger millet – pulses (29%) (Table 3). Amongst the bovine, cattle and buffaloes comprised almost 50 percent population each. There were no he-buffaloes in the study area. Farmers of these villages depended on other villages for the service of buffaloes to be met by he-buffaloes (Table 4).

Table 1. Energy values for different inputs and outputs

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); value for pesticides (insecticides) based on Ralhan *et al*. (1991)	

Table 2. Cultivated land in the study villages (ha)

Agricultural land	Bajani	Ajera	Hachila	Durlekh	Leemabhat	Overall
Total area	170.457	239.787	219.73	244.304	241.553	223.166
Cultivated area	48.65	97.67	72.57	75.22	94.76	77.774
Non agricultural land	121.802	142.116	147.16	168.784	156.793	147.331
Landholding size (cultivated land per family)	0.772	1.122	1.170	0.826	1.155	1.009

3.1 Crop Cultivation Inputs and Outputs

Crop cultivation requires certain inputs in appropriate quantities. It also gives certain inputs of critical consumptive value to human society. Input estimation was based on farmers' own experiences, while outputs were mainly based on the productivity of individual crops, but the figures were agreeable by the farmers. The input-output estimates are discussed under the following two subheads.

3.2 Input Estimation

Input energy used in crop production is: i) animate energy to be obtainable from human labour and bullock labour, and ii) energy to be provided by the other inputs, *viz.* seeds, manure, fertilizers, and pesticides. In animal production, the major input is feed and fodder. Outputs in crop production include food grains, straws, fruits and vegetables. In livestock production, outputs are milk, dung, and calf crop. The bullock and human work input depends upon the type of cropping system. Amongst the summer crops, the lowland rice demanded the highest number of bullock and human work hours to be invested in crop cultivation. On the other hand amaranth, a pseudo cereal, requires minimum number of bullock and human hours. The fruit crop, unlike food grain crops, did not need investment of bullock energy. Singh and Partap (2000) made a comprehensive study of bullock and human use in mountain agriculture. Their data for mid-altitude agriculture would also hold true in this case. We tried to testify their data while interviewing the farmers of the study area, which coincided with those already reported. So we opted to use the same data as reported by Singh and Partap (2000).

Table 3. Cultivated land in the study villages (ha)

Crops	Bajani	Ajera	Hachila	Durlekh	Leemabhat	Overall
Upland rice	16.0 (32.89)	48.5 (49.66)	25.0 (34.44)	18.0 (23.93)	31.0 (32.71)	27.7 (35.61)
Lowland rice	1.6 (3.29)	9.6 (9.82)	3.2 (4.40)	2.5 (3.32)	4.5 (4.79)	4.28 (5.50)
Finger millet + pulses	14.5 (29.80)	26.0 (26.62)	21.0 (28.93)	23.5 (31.24)	28.0 (29.55)	22.6 (29.05)
Barnyard millet	3.5 (7.19)	4.0 (4.09)	11.0 (15.16)	13.5 (17.95)	14.5 (15.30)	9.3 (11.96)
Amaranth + kidney beans	1.5 (3.08)	2.0 (2.05)	1.7 (2.34)	3.9 (5.18)	3.4 (3.59)	2.5 (3.21)
Soybean	4.5 (9.25)	5.5 (5.63)	4.0 (5.51)	6.5 (8.64)	7.8 (8.23)	5.66 (7.28)
Others*	7.05 (14.50)	2.07 (2.12)	6.67 (9.19)	7.32 (9.73)	5.56 (5.87)	5.73 (7.37)

Figures in parentheses are percentage of total cropped area

*Fruits, vegetables, roots and tubers

Table 4. Livestock population in the study villages

Livestock category	Bajani	Ajera	Hachila	Durlekh	Limabhat	Overall
Bullocks	64	68	61	73	56	64
Cows	35	42	35	64	55	46
Male calves	17	19	14	30	30	22
Female calves	21	14	12	32	32	22
Buffaloes	85	106	87	112	101	98
He buffaloes	-	-	-	-	-	-
Buffalo male calves	-	-	-	-	-	-
Buffalo female calves	41	47	53	58	46	49
Total bovines	263	250	262	369	321	302
Sheep	-	-	-	-	-	
Goats	299	89	33	43	108	144

Table 5. Bullock and human hours invested in summer cropping in the mountain agro-ecosystem

Summer crops	Bullock hours	Human hours
Upland rice	144	639
Lowland rice	180	1158
Finger millet + pulses	158	502
Barnyard millet	131	467
Amaranth + kidney beans	79	343
Soybeans	167	798
Fruits	-	400
Vegetables	80	872

Source: Singh and Partap (2000)

Amount of different inputs during summer (kharif) cropping on the basis of per ha cultivated land are presented in Table 6. An understanding of the input amount per unit area is essential to work out the energy value and finally energetics of the crop production. Rate of seed input for raising a particular crop is almost the same throughout the mountain region and in many cases it would be different from that in the plains. Farmers have their own perception of seed rate. Manure application, however, depends on many factors. Manure application rates are likely to vary from place to place depending upon livestock holding size, type of animals (*i.e.* kept on grazing or stall fed), family labour, *etc.* Fertilizer and pesticide use is seldom as per recommendations. Farmers do not apply these inputs under traditional system. It is only the lowland rice, soybeans and vegetable cultivation where fertilizer and pesticides are used.

Table 6. Amount of inputs (kg) per ha in summer cropping in study area

Crops	**Seeds**	**Manure**	**Fertilizer**	**Pesticides**
Upland rice	80	600	-	-
Lowland rice	60	300	120	5
Finger millet+pulses	30	350	-	-
Barnyard millet	25	350	-	-
Amaranth +kidney beans	12	100	-	-
Soybean	140	250	100	6
Fruits	-	500	-	10
Vegetables (fresh)	10	650	50	10
Roots and tubers	40	650	50	25

3.3 Output Estimation

Average productivity of individual crops is presented in Table 7. Amount of straw was estimated according to the straw-grain ratio of mountain crops provided by Singh (1998). It was observed that amongst the food grain crops lowland rice produced maximum yields on per ha basis. Amongst the other food crops fruit production was highest on per ha basis. Gross production of individual crops is presented in Table 8.

The figures have been derived by multiplying productivity of individual crop by the total cultivated area devoted to that crop in individual villages. Two outputs are of major human use, *viz.* main products that include food grains, vegetables, edible roots and tubers and fruits. The by-products serve as livestock feeds which are also of critical value. These feeds are eventually converted into milk and draught power by livestock. In addition, the by-products' energy is used in the maintenance and growth of livestock and a proportion of the feed voided as dung serves as a useful input for the soil.

Table 7. Average productivity (qha^{-1}) of summer crops at study site

Crops	**Grain**	**Straw**
Upland rice	24	31
Lowland rice	34	45
Finger millet+pulses	14+6	28+6
Barnyard millet	13	36
Amaranth+kidney beans	12+6	0+9
Soybean	18	0
Fruits	200	-
Vegetables (fresh)	50	-
Roots and tubers	120	-

4. Energy Audit of Crop Production

4.1 Input Energy

Every kind of biomass has its specific energy value. These values have been determined by different workers. Values provided by Mitchell (1979) are frequently used wherever applicable. Values of bullock work for different kind of operations in mountain agriculture have been deduced by Singh (1998) and Singh and Partap (2000). Ralhan *et al.* (1991) has used energy values of pesticides. The animate energy invested in the cultivation of summer crops per ha of land in the mountain agro-ecosystem studied are shown in Table 9.

The bullock energy and human energy input values are based on Singh (1998). These values have been found appropriate since they have been elicited by means of long-term experiments in mountain agro-ecosystems. Values of energy used through seeds, manure, fertilizer and pesticides have been presented in Table 10. The values have been deduced by multiplying the figures in Table 6 with those in Table 1.

Table 8. Total production (q) of different crops in the villages in study area

Crop	Bajani		Ajera		Hachila		Durlekh		Leemabhat		Total		Average	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
Upland rice	384	496	1164	1503.5	600	775.5	432	558	744	961	4068	4294	664.8	858.8
Lowland rice	54.4	72	326.4	432	108.8	144	85	112.5	153	202.5	727.6	828	145.52	192.6
Finger millet+pulses	203 87	406 87	364 156	728 156	294 126	588 126	329 141	658 141	392 168	784 168	1582 678	3164 678	316.4 135.6	632.8 135.6
Barnyard millet	45.5	126	52	144	143	396	175.5	486	188.5	522	6045	1674	120.9	334.8
Amaranth + kidney beans	18 9	0 13.5	24 12	0 18	20.4 10.2	0 15.3	46.8 23.4	0 35.1	40.8 20.4	0 30.6	150 75	0 112.5	30 15	0 22.5
Soybean	81	0	99	0	72	0	117	0	140.4	0	509.4	0	101.88	0
Fruits	800	-	150	-	750	-	800	-	350	-	2850	-	570	-
Vegetables (fresh)	150	-	70	-	130	-	150	-	140	-	740	-	148	-
Roots and tubers	200	-	100	-	150	-	180	-	150	-	780	-	156	-

Table 9. Bullock and human energy invested in the cultivation of summer crops (x10^5 kJha^{-1})

Summer crops	Bullock energy	Human energy
Upland rice	2.47	1.73
Lowland rice	3.09	3.13
Finger millet + pulses	2.12	1.36
Barnyard millet	1.79	1.26
Amaranth + kidney beans	1.24	0.93
Soybeans	2.59	2.15
Fruits	-	1.57
Vegetables	3.20	4.70
TOTAL	16.50	16.83

Source: Singh (1998)

Maximum amount of energy (274.50x10^5 kJha^{-1}) was invested through manure (53.55 percent of the total energy), followed by chemical fertilizers (97.09 x10^5 kJha^{-1}) and pesticides (82.88 x10^5 kJha^{-1}), and minimum through seeds (15.15x10^5 kJha^{-1}) during the production of summer crops in the mountain agro-ecosystem investigated during this study. Energy input in the form of chemical fertilizers and pesticides is imported one as these inputs are purchased from the market, unlike all other inputs which are produced within the system. Thus, the share of the imported energy input of the total energy input is considerable, 35.11 percent. Traditional agriculture tends to rely upon the inputs produced within the system. Many favourable areas of the mountains where agriculture has undergone considerable transformation, proportion of imported input energy is pretty high as has been revealed in a study of the Indian Central Himalaya (Singh, 1998).

4.2 Output Energy

Various outputs of human use were converted into their respective energy values as indicated in Table 1. The energy values for the output of various summer crops raised on one ha land area in the mountain agro-ecosystem under study are shown in Table 11. From the perusal of Table 11, we can find that in the form of useful outputs (grain and straw) a gross energy value of 10260.95 x10^5kJha^{-1} was harvested during summer cropping in the mountain agro-ecosystem under study. Out of this total energy, as much as 79 percent was harvested through grains only. Amongst the food grain crops, the largest share in total energy production was that of lowland rice. However, the largest proportion of energy was produced through fruit production (3246.60x10^5kJha^{-1}), which was about 32 percent of the gross energy produced in one ha cropland in summer cropping.

4.3 Energetic Efficiency

The output-input ratio of a production system is an important indicator of its efficiency. The energy budget shown in Table 12 would be indicative of the efficiency of the individual crop cultivation as well as of the entire agro-ecosystem. Ecosystems are the 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 the solar energy, the agro-ecosystems also use other forms of energy. The main forms of energy used in mountain agriculture can be broadly classified as direct energy (animate and biomass) and indirect energy (fertilizer and pesticide). Under this section we have analysed the overall energy budget of the crop production in the mountain agro-ecosystem and have discussed the efficiency of individual crop production in the overall energy scenario. The energy values for different crops were converted into kilo Joules (1 kWh = 860 kcal/h; 1 kcal = 4.186 kJ). Energy flow through summer crops per ha has been depicted in Figure 1. Gross energy output - input ratio of the tree-based fruit crops was the highest (61.291) of all the crops in the summer season. It is owing to the low input demand of tree crops. Deep-rooted trees fulfill virtually entire input needs the natural way. However, since the fruit crop is part of the socio-economic system, certain amounts of inputs, particularly in the form of human labour, are required. Manure on the floor of orchards is applied mainly for vegetable cultivation, but a considerable proportion is likely to be used by fruit crop. Root and tuber crops showed comparatively higher energetic efficiency (17.833) than other vegetables (9.471). Vegetables generally require chemical fertilizers and pesticides for their production, which narrow down their output-input ratios. Amongst the food grain crops the maximum energetic efficiency (37.782) was recorded in case of amaranth-kidney bean mixed crop cultivation. The next crop combination in energetic efficiency was finger millet and pulses (23.884). The poorest performance was recorded in case of soybean cultivation. Its narrow output-input ratio (3.438) was mainly because of very high amount of energy expended in soybean cultivation. This crop serves as a host of numerous insect pests which are controlled by the use of pesticides. The overall energetic efficiency of summer cropping is comparable with the one reported by Singh (1998) from four types of agro-ecosystems in the Central Himalaya. According to his report, the output - input ratios in the hill, transformed, and high Himalayan agriculture were 2.98, 3.81 and 2.51 times lower, respectively, than in the traditional mountain

Table 10. Energy investment through various inputs in the cultivation of summer crops (x105 $kJha^{-1}$)

Crops	Seeds	Manure	Fertilizer	Pesticides	Total energy
Upland rice	12.99	43.92	-	-	56.91
Lowland rice	9.74	21.96	36.41	7.40	75.51
Finger millet+pulses	4.87	25.62	-	-	30.49
Barnyard millet	4.06	25.62	-	-	29.68
Amaranth+kidney beans	1.95	7.32	-	-	9.27
Soybean	22.72	18.30	30.34	8.88	80.24
Fruits	-	36.60	-	14.80	51.40
Vegetables (fresh)	0.24	47.58	15.17	14.80	77.79
Roots and tubers	1.58	47.58	15.17	37.00	101.33
TOTAL ENERGY	58.15	274.50	97.09	82.88	512.62

Table 11. Energy values ($x10^5 kJha^{-1}$) of the useful outputs of summer crops in the mountains

Crops	Grain	Straw	Total energy
Upland rice	389.59	433.57	823.16
Lowland rice	551.92	629.37	1181.29
Finger millet+pulses	227.26+102.56	391.61+89.91	811.34
Barnyard millet	211.03	503.50	714.53
Amaranth+kidney beans	194.80+102.56	0+134.87	432.23
Soybean	292.19	0	292.19
Fruits	3246.60	-	3246.60
Vegetables (fresh)	811.65	-	811.65
Roots and tubers	1947.96	-	1947.96
TOTAL ENERGY	8078.12	2182.83	10260.95

agriculture. If only the main product (agronomic yields) is to be considered then these ratios, in the respective areas, were 3.53, 3.13 and 1.88 times lower than in the traditional agricultural areas. The high energy input compared to the energy output in the hills and transformed mountains and overall low energy output in the high Himalaya are attributable to the relatively lower energetic efficiency of the agriculture in these areas, according to Singh (1998). The energetic efficiency of the crops in which high amount of imported energy (chemical fertilizers and pesticides) is to be employed was lower than all other crops. For example, the output - input ratios for soybean crop in the mountain agro-ecosystem was lower than other crops. Non-availability of useful by-product from vegetable crops, as also from other crops, like soybean, further contributes to decline the output - input ratios for these crops. Amaranth too did not yield useful by-product (that is, their by-products were not usable in livestock feeding), but its output together with that of kidney bean was considerably higher than these crops because of saving on input energy. The output (biomass) - input ratio for maize in Mexico, Guatemala, Nigeria, Philippines and India were found to be 80.8, 11.2, 29.8, 14.3 and 13.3, respectively in a study (Reijntjes, 1992). The output - input ratios for selected crops in Nepal reported by Rijal *et al*. (1991) are comparable to those of ours in many cases.

Table 12. Energetic efficiency of summer crops at the study site (x10^5kJha^{-1})

Crops	Output (grain)-Input Ratio	Output (straw)-Input Ratio	Output (biomass)-Input Ratio
Upland rice	6.375	7.094	13.470
Lowland rice	6.752	7.700	14.453
Finger millet+pulses	9.709	14.174	23.884
Barnyard millet	6.447	15.387	21.831
Amaranth+kidney beans	26.342	11.789	37.782
Soybean	3.438	-	3.438
Fruits	61.291	-	61.291
Vegetables (fresh)	9.471	-	9.471
Roots and tubers	17.833	-	17.833

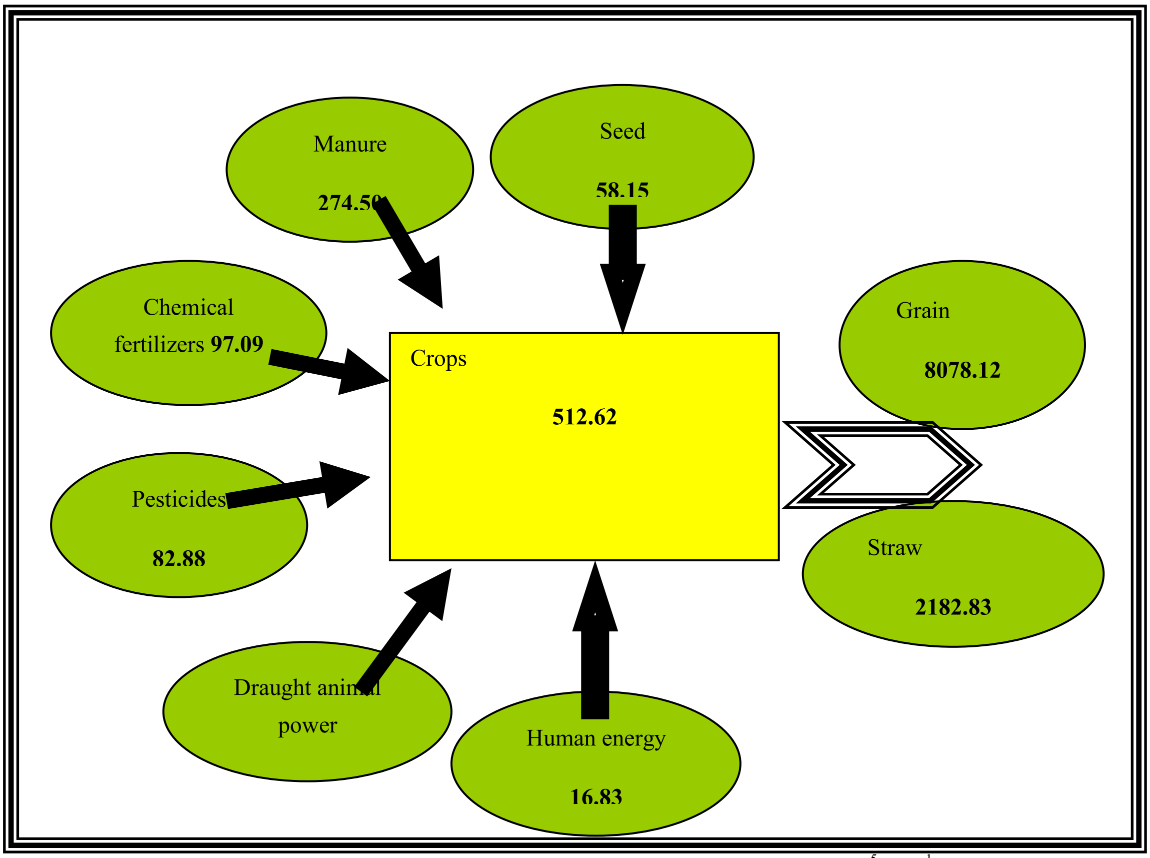

Figure 1. Energy flow through summer crops in a mountain agriculture (all figures are x 10^5kJha^{-1})

But our figures are higher (except for soybean) than those reported by Pandey and Singh (1984), Singh *et al.* (1984), Srivastava and Shah (1984), Negi *et al*. (1989) and Ralhan *et al.* (1991).

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