Energy Budget and Efficiency of Some Multiple Cropping Systems in Sikkim Himalaya

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ABSTRACT. Energy budgets of some multiple cropping system of Eastern Himalaya are investigated and compared with those of the Central Himalaya. Cropping pattern of irrigated fields was similar in both Himalayan regions but it was different in rainfed fields. Contribution of inputs among different crops was dissimilar in these regions. The contribution of seed input was higher in associated crops (ginger and soybean) than the main crops (maize and rice). The labour input was greater for main crops, however its contribution to the total energy input was lower than the associated crops. In Eastern Himalaya input of chemical fertilizer was greater than the Central Himalaya.

The patterns of rainfed fields were more productive than the irrigated fields. The system was most efficient for maize + soybean pattern with respect to agronomic production, and rice + soybean pattern with respect to total energy output. In comparison with the Central Himalaya, multiple cropping systems of the Eastern Himalaya were more efficient.

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INTRODUCTION

Multiple cropping is a common agricultural practice in the Sikkim (Eastern) Himalaya under both rainfed and irrigated field conditions. Energy efficiency of such systems has not been examined. This paper analyzes energy efficiencies of some common multiple cropping systems of the Eastern Himalaya, and compares these systems with multiple cropping practices of the Central Himalaya.

STUDY AREA AND METHODS

The study was carried out in Central Pandam of the East District of Sikkim in the Eastern Himalaya. Central Pandam is situated between 1000-1600 m elevation. Most cultivation is under rainfed conditions and practiced on terraces, with irrigated cultivation confined to valleys. The agriculture is permanent settled practice as in other regions of the Himalaya, except for the neighboring North-Eastern region where Jhum (slash and burn) is a common practice.

A detailed inventory of different inputs (seed, labour, farm manure and chemical fertilizer) and outputs (agronomic yield and crop by-produce) was prepared for each crop and cropping pattern following Sharma (1991). Various inputs and outputs were converted into energy using energy equivalents (Table 1), and efficiency was calculated as output:input ratio.

RESULTS AND DISCUSSION

Multiple Cropping Patterns

Rice (*Oryza sativa*) crop is cultivated on irrigated fields during the rainy season, while maize (*Zea mays*) and ginger (*Zingiber officinale*) are cultivated in rainfed fields. Soybean (*Glycine soza*) is common under both rainfed and irrigated conditions. The cropping pattern of irrigated fields (rice + soybean) is similar to that of the Central Himalayan region. Soybean plants were planted on the

Table 1. Energy equivalents for different inputs and outputs.

	Energy equivalent ($MJ\ kg^{-1}$)	Source
Maize (Zea mays)	14.29	Gopalan et al. 1985
Ginger (Zingiber officinale)	2.80	"
Soybean (Glycine soza)	18.01	"
Rice (Oryza sativa)	14.42	"
Straw (Rice)	13.63	Hurst & Rogers, 1983
Hay	14.42	Mitchell, 1979
Legume Hay	14.87	"
Farm manure	7.28	"
Nitrogen	78.72	Pimental et al., 1973
P_2O_5	13.90	"
K_2O	9.63	"
Human labour (MJ per hour)	1.50	Freedman, 1982
Bullock labour (MJ per hour)	1.00	Hurst & Rogers, 1983

bunds (the boundry of cropfields) of cropfields in similar fashion both in the present study sites and Central Himalayan case study by Sharma (1991). Cropping patterns of rainfed fields were different. In Central Pandam (present study) maize is the main crop and ginger and soybean are associated crops, while in Central Himalaya wheat (*Triticum aestivum*) and finger millet (*Elucine coracona*) are the main crops, however, soybean is a common associated crop in both studies. Dietary habits of the inhabitants of these regions determine the main crops grown. In Eastern Himalaya, wheat is not preferred while maize has multiple uses.

ENERGY BUDGET FOR CROPS

Among different crops (Table 2) total energy input ranged from 0.22 ha^{-1} (soybean of rainfed fields) to 12.52 GJ ha^{-1} (maize). For

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Table 2. Various energy inputs, outputs and output: input ratio for different crops grown in multiple cropping (GJ ha^{-1})

Input/Output	Rainfed fields			Irrigated fields	
	Maize	Ginger	Soybean	Rice	Soybean
Input					
Labour					
Human	0.41	0.16	0.04	0.16	0.05
Bullock	0.25	..	..	0.08	..
Seed/rhizome	1.41	5.53	0.18	0.84	0.20
Farm manure	3.60	-	-	0.73	..
Chemical fertilizer	6.85	.	.	2.31	..
Total	12.52	5.69	0.22	4.12	0.25
Output					
Agronomic	84.71	17.98 3.87*	1.78	23.72	2.20
Crop by product	46.59	22.37	3.67	26.80	4.53
Total	131.30	44.22	5.45	50.22	6.73
Output: Input Ratio					
Agronomic	6.76	3.84	8.09	5.75	8.8
Total output	10.48	7.77	24.77	12.26	26.92

* Additional output in the form of mother rhizome produced in off-season.

soybean, energy input was greater in irrigated conditions than the rainfed fields while this was reversed for the same crop in the Central Himalaya due to a greater seed input in rainfed condition.

The seed/rhizome input of different crops accounted for 11.3% to 97.2% of the total energy input. The contribution of this input was higher in associated crops (ginger and soybean) because this was the only material input for these crops, followed by input in the form of work (labour).

The labour input contributed from 2.8% (ginger) to 20% (rainfed soybean) of the total energy input. This contribution was similar for major crops (maize 5.3%, rice 5.8%), and associated crops (rainfed soybean 18.2% and irrigated soybean 20%), except ginger. Labour input was greater for the main crop, however, its contribution to the total energy input was lower than for associated crops. Among different crops, human labour input ranged from 0.04 GJ ha^{-1} (rainfed soybean) to 0.41 GJ ha^{-1} (maize), and bullock labour input from 0.08 GJ ha^{-1} (rice) to 0.25 GJ ha^{-1} (maize).

Yield-increasing inputs (farm manure and chemical fertilizer) were the chief constituent of total energy input in major crops (maize 83.4%, rice 73.8%), however, these inputs are not needed for associated crops. Input of chemical fertilizer (maize 6.85 GJ ha^{-1}, rice 2.31 GJ ha^{-1}) was greater than input of farm manure (maize 3.6 GJ ha^{-1}, rice 0.73 GJ ha^{-1}). This situation was reversed in the Central Himalaya where input of farm manure is greater than that of chemical fertilizer (Table 3). More use of chemical fertilizer might be due to the better soil moisture (due to more rainfall), and economic condition (ginger is a cash crop) in the present study than

Table 3. Comparison of different inputs (%) in some crops of Eastern and Central Himalaya.

Input	Eastern Himalaya			Central Himalaya*			
	Rice	Soybean		Rice		Soybean	
	I	R	I	R	I	R	I
Labour							
Human	3.9	18.2	20.0	10.2	6.2	18.3	33.9
Bullock	1.9	-	-	5.8	3.5	-	-
Seed	20.4	81.8	80.0	13.9	5.1	81.7	66.1
Farm manure	17.7	-	-	70.1	81.0	-	-
Chemical fertilizer	56.1	-	-	-	4.2	-	-

R = Rainfed, I = Irrigated,

* from Sharma (1991)

the hills of Central Himalaya where agriculture tends to be a subsistence living (Sharma, 1990).

Among different crops, total energy output ranged from 5.45 GJ ha^{-1} (rainfed soybean) to 131.3 GJ ha^{-1}) (maize). Energy output was greater under irrigated conditions than the rainfed conditions for soybean. Among the crops studied, maize was most productive (agronomic output 84.71 GJ ha^{-1}) and soybean in rainfed fields was least productive (1.78 GJ ha^{-1}). A typical practice was observed in the study area where ginger used as seed (mother rhizome) was dug out with care keeping the new ginger plants intact in the soil. The mother rhizome was sold in off-season at higher prices. This additional output was 3.87 GJ ha^{-1} which was about 10% of the total ginger output (Table 2).

The output (agronomic yield):input ratio, (0_a:I ratio), ranged from 3.84 (ginger) to 8.8 (irrigated soybean). The O (total energy): I ratio (O_t:I ratio) ranged between 7.77 (ginger) and 26.92 (soybean). The O:I ratios were greater for associated crops than main crops because associated crops required only seed and human labour inputs, except for ginger.

From the energy budget it is apparent that chemical fertilizer had a significant contribution to the crop production system (50% of the energy input in major crops). This situation is far different for crops grown in multiple cropping systems of Central Himalaya where it contributes 4-21% of the energy (Sharma, 1991).

ENERGY BUDGET FOR CROPPING PATTERNS

Among the different cropping patterns (Table 4) total energy input ranged on a per season basis from 4.37 GJ ha^{-1} (rice + soybean) to 18.21 GJ ha^{-1} (maize + ginger). The energy input of cropping patterns in rainfed fields was 3-4 times greater than the cropping patterns of irrigated fields. Among cropping patterns of rainfed fields, total energy input of maize + ginger pattern was greater than maize + soybean due to greater input of seed/rhizome (due to ginger) which contributes 38.1% of the total energy input. For other patterns, seed input contributed 12% to 24% of the total energy input.

For different cropping patterns, labour input accounted for less

Table 4. Various energy inputs, outputs and output: input ratios for different cropping patterns of multiple cropping system (GJ ha^{-1} $season^{-1}$)

Input/Output	Rainfed		Irrigated
	Maize+ginger	Maize+soybean	Rice+soybean
Input			
Labour			
Human	0.57	0.45	0.21
Bullock	0.25	0.25	0.08
Seed/rhizome	6.94	1.59	1.04
Farm manure	3.60	3.60	0.73
Chemical fertilizer	6.85	6.85	2.31
Total	18.21	12.74	4.37
Output			
Agronomic	106.56	86.49	25.92
Crop by product	68.96	50.26	31.33
Total	175.52	136.75	57.25
Output: Input Ratio			
Agronomic	5.85	6.78	5.93
Total output	9.63	10.73	73.10

than 7% of the total input. This was different from the Central Himalaya where labour input contributed 10% to 43% energy of the total energy input (Sharma, 1991). The labour contribution was greater in rainfed fields than irrigated fields in Central Himalaya while it was reversed in the present study. Among different cropping patterns human labour ranged from 0.21 GJ ha^{-1} (rice + soybean) to 0.57 GJ ha^{-1} (maize + ginger) and bullock labour from 0.08 GJ ha^{-1} to 0.25 GJ ha^{-1}.

Among various cropping patterns, yield-increasing inputs (farm manure and chemical fertilizer) accounted for 57% to 82% of the total energy input. This contribution is similar to that reported for the multiple cropping patterns of the Central Himalaya, but the difference is in the use of chemical fertilizer which is greater in the present study (Eastern Himalaya) than the reported for Central Himalaya. The input of farm manure and chemical fertilizer was 3-5 times greater in rainfed fields compared to irrigated fields.

Energy output (agronomic as well as total) was 3-4 times greater in rainfed fields compared to irrigated fields. Among different cropping patterns, agronomic output (energy) ranged from 25.92 GJ ha^{-1} (rice + soybean) to 106.56 GJ ha^{-1} (maize + ginger), and total energy output from 57.25 GJ ha^{-1}. Cropping patterns of rainfed fields were more productive than irrigated fields, which indicates that multiple cropping is more productive under rainfed conditions than irrigated conditions.

Maize + soybean pattern was most efficient when considering energy efficiency of agronomic production (O_a:I ratio 6.78), but rice + soybean pattern was observed to be more efficient (O_t:I ratio 13.10) based on total energy output. There was a large difference between input and output values of maize + ginger and rice + soybean patterns, but the output:input ratio for agronomic production was nearly equal for both (5.85 and 5.93, respectively). In comparison to the Central Himalaya, O:I ratios were generally higher in the Eastern Himalaya (present study) which indicates that the multiple cropping system of Eastern Himalaya (O_t:I ratio = 10.2 and 13.1, average for rainfed and irrigated, respectively) is more efficient than the Central Himalaya (O_t:I ratio = 8.3 and 3.1, average for rainfed and irrigated, respectively).

In Table 5, maize crop cultivation of Eastern Himalaya (present study) has been compared with the modernized cultivation of USA (Pimentel, 1980). The major difference in both type of cultivation was of the agricultural technology. In the hill agriculture of the Himalaya, the level of technology is low and farmers follow a simple type of traditional farming. Small landholdings, mostly rainfed cultivation and socio-economic conditions are the main barriers to check the advancement of technology in the hill region (Sharma and Singh, 1992). It is clear from the comparison of two studies (USA and Present) that more than 92% of the total energy input is due to the modernization of agriculture (machinery, chemicals, electricity, etc.) in the USA. The input of chemicals and seed in the present study were near to the rainfed cultivation of USA. The human

Table 5. Comparision of traditional maize cultivation of the Eastern Himalaya (Present study) and the modern cultivation of USA (Pimentel, 1980). All the values are GJ per ha.

Input/ Output	USA*		Eastern Himalaya
	Irrigated	Rainfed	Rainfed
Labour			
Human	0.02**	0.01**	0.41
Bullock	-	-	0.25
Machinery	4.13	4.13	-
Fuel	44.51	4.93	-
Chemicals	8.57	7.27	6.85
Farm Mnure	-	-	3.60
Seed	2.05	1.71	1.41
Irrigation	3.05	-	-
Biocides	4.26	2.97	-
Transportation	0.21	1.76	-
Electricity	10.95	0.87	-
Total Input	77.75	23.65	12.52
Output	102.45	74.86	84.71
Output:Input ratio	1.31	3.16	6.78

* Average of 5 and 8 cases for Irrigated and rainfed, respectively.

** Calculated by authors from the labour hours given by Pimentel (1980).

labour input in the present study was several times greater than the reported for USA. This is due to the use of labour saving devices in the latter while in former the main sources of power are human and bullock labour. The output and output:input ratio were also greater for the Eastern Himalaya than the rainfed cultivation of USA. The output in irrigated condition was greater in the USA than the Eastern Himalaya but due to a large quantity of fuel, electricity and other inputs the efficiency of the former system has been reduced dramatically as evidenced by the output:input ratio.

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