Energy input–output analysis and mechanization status for cultivation of rice and maize crops in Sikkim

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Abstract: Rice and maize are main cereal crops cultivated in Sikkim. In this paper energy input–output and the level of agricultural mechanization for cultivation of rice and maize in Sikkim state of India has been presented. The data were collected on area under rice and maize crops, sources of power and agricultural tools/implements used total production through village survey. It has been observed that the traditional practices of cultivation of rice and maize crops consumed an average energy input of 3,338.984 MJ ha^{-1} and 4,386.435 MJ ha^{-1} respectively. Data analysis showed that about 60% of the total input energy in the present cultivation practices comes from human and animal power sources. The output–to–input energy ratio was observed to be 7.66 and 5.86 for rice and maize, respectively. The observational estimate showed that average productivity of rice and maize crop in the region is only 924.0 kg ha^{-1} and 431.0 kg ha^{-1}, respectively, which is very low. Mechanization and machine energy indices were found to stand at a value of 0.3618 and 0.3244, respectively for rice crop cultivation, and 0.2612 and 0.2111, respectively for maize crop cultivation. The average farm power availability in the state has been estimated as 0.70 kW ha^{-1}.

Keywords: agricultural mechanization in Sikkim, energy input and output, rice and maize crops, grain productivity

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1 Introduction

The input energy has been a key input of agriculture since the age of subsistence agriculture. Agricultural production is positively correlated with energy input (Verma, 2006; Singh, 2001; Singh, 2006; Baruah and Bora, 2008). Sikkim is a small and beautiful state nested in the inner Himalayan mountainous ranges. It has elevations ranging from 300 to 7000 m above mean sea level. It lies between 27° and 28° N latitude and 88° and 89° E longitude. Nearly two third of its very high mountains territory is perpetually covered with snow. These mountains, including the third highest mountain in the world Kanchenjunga (8,598 m) are located in northwest Sikkim. The state is landlocked on its three sides by the international borders of China (Tibet), Bhutan and Nepal in the North–East, East and West Sikkim, respectively, and South by the Darjeeling district of West Bengal. Approximately, 11% of the total geographical area (7,096 km^2) is under agriculture. The state economy broadly depends on agriculture and animal husbandry, which provides livelihood and productive engagement to the majority of the population. Agriculture in the state is of mixed type and is still at the subsistence level rather than commercial level. Baruah and Bora have reported that though India has done well in agricultural development, north eastern region still needs special attention for agricultural development to address several socio–economic issues and is a typical example of

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economically backward rural India (Baruah and Bora, 2008).

The higher altitudes of the state are unfit for cultivation. Soils are loose, acidic and fragile. Table 1 presents the area, production and productivity of major agricultural produce in Sikkim during 2004–05 (Subba, 2006). The table indicates that productivity of all the crops is very low. The humid tropical zone foothills of Southern Sikkim dominate the maize cultivation. Paddy is cultivated in valleys and terraced field. Wheat is grown in southern and central part of the Sikkim.

Table 1 Area, production and productivity of major crops in Sikkim in 2004–2005

SN	Crop	Area /10^3 ha	Production /10^3 T	Productivity /kg ha^{-1}
1	Rice	14.74	21.19	1437.00
2	Maize	36.74	57.05	1554.50
3	Wheat	05.74	8.09	1409.41
4	Total cereals	64.59	92.96	1439.68
5	Total pulses	06.71	06.38	950.82
6	Total oil seed	09.95	07.44	747.74
7	Total fruits	07.62	11.52	1510.00
8	Total vegetables	08.52	41.89	4919.00
9	Large cardamom	24.71	33.52	142.00
10	Ginger	06.47	33.53	5186.00

It has been an established fact that the benefits of engineering inputs in terms of enhanced productivity is about 15% and reduction in cost of production by 20% (Chandra et al., 2011). The benefit includes increase in cropping intensity, timeliness in farm operations and reduction in drudgery of farm workers. Increased production and productivity achieved through mechanization is due to accurate application and better placement of inputs, conserving soil and water resources from further degradation, increasing irrigation potentialities and efficiencies, reducing losses of produce etc. The biggest challenge is to make agriculture profitable and sustainable. This will be possible only by reducing cost of cultivation through enhanced input use efficiency and by higher returns to the farmers through value addition in production catchments and adopting loss prevention measures. The mechanization of small farms, precision farming and post harvest technology will have to play a major role in future to increase production and productivity, to lower the cost of production, generate more income and employment opportunities in rural areas. Singh et al. has demonstrated that since last 25 years, the use of mechanical power in India has increased many folds from merely 0.32 kW ha^{-1} in 1965–66 and to 1.46 kW ha^{-1} in 2005–2006. However, it is needed to be increased to 2.0 kW ha^{-1} in to double the production to meet the increasing demand of food supply due to population growth (Singh et al., 2004).

The objectives of the present study were to assess the mechanization status of Sikkim state and find out its impact on production and productivity of rice and maize so that mechanization strategies for the state can be formulated in future to increase crop productivity with reduced human drudgery. The data required to analyze the indices of agricultural mechanization were collected through extensive survey of the region. Total energy use and mechanization index are the well adopted parameters to assess the mechanization status, therefore, these parameters were estimated based on the information available in the literature.

2 Materials and Methods

2.1 Sampling method

The state of Sikkim comprises of four districts i.e., East Sikkim, West Sikkim, North Sikkim and South Sikkim. The details of the sub–division and number of villages in each division were obtained from the Census Department, Government of India; Sikkim Centre based on the 2001 census and is shown in Table 2. Randomly 30 villages from all the nine sub-divisions and 10 families from each village were selected so as the total sample size was 300 families to represent whole state. While selecting the number of villages from each district, statistical tool of stratified sampling method (proportional allocation based on the number of villages in each sub–division) was used. Once the number of villages was ascertained, they were selected on the basis of their locations so that they can represent the total geographical area. Stratified sampling method as given in Equation (1) was used to decide the number of villages from each sub-division.

$$\frac{n_1}{n}=\frac{N_1}{N} \quad \text{or} \quad n=\frac{N\,n_1}{N_1} \qquad (1)$$

where, n is the number of sample size; N is the population size (30 in this case of study); n_1 is the population unit (in this study it was number of villages in the sub–division); and, N_1 is the number of sample units (in this study it is the number of villages in the state). Thus, the number of villages from each sub–division was calculated and is shown in Table 3.

Table 2 Details of districts and sub–divisions in Sikkim state

SN	Name of the district	Name of the sub–division	No of villages
1	East district, Gangtok	Gangtok (A)	85
		Pakyong (B)	28
		Rongli (C)	20
2	West district, Gyaishing	Gyaishing (D)	70
		Soreng (E)	51
3	North district, Mangan	Chungthang (F)	8
		Mangan (G)	45
4	South district, Namchi	Namchi (H)	98
		Ravong (I)	47
	Total villages		452

Table 3 Effective sampling size from each sub–division

Sub–division	No of villages in the sub–division	Effected sample size (no. of villages surveyed)
A	85	6
B	28	2
C	20	1
D	70	5
E	51	3
F	8	1
G	45	3
H	98	6
I	47	3
Total		30

2.2 Village survey

A questionnaire was prepared to interview households selected at random from the chosen villages. Farmers were personally interviewed to collect the information needed for the study. Data on area sown under rice and maize, sources of power utilized, number of hours needed for individual operation for a particular crop, and total crop production was obtained. Information on the cultivation practices adapted for both rice and maize crops was also collected. Traditional practices adapted for cultivation of rice and maize crops are presented in Section 2.3. The survey also included preparing an inventory of the major farm tools and implements used by the farmers. The list of commonly used hand tools in whole state is given in Table 4.

Table 4 List of the tools and implements commonly used in the Sikkim state

SN	Name of tool/ implement	Local name	Application
1	Country plough	Halo	Ploughing, puddling and sowing
2	Hand fork	Katto	Hoeing and cleaning
3	Plain sickle	Kachia	Cutting of grasses and crop
4	Serrated sickle	Hansia	Cutting of grasses and crop
5	Spade	Kodalo	Digging, ridge and furrow making
6	Hand hoe	Kodali	Hoeing
7	Axe	Khukhuri	Cleaning of jungle, bamboo work, cutting of fire wood, house making
8	Pick axe	Jumpher	Digging out stone plant root
9	Knife	Elachi chhuri	Harvesting of large cardamom

2.3 Traditional practices of rice and maize crop cultivation in Sikkim

In the state only transplanted rice is cultivated on carefully designed wet terraces. The terraces are made on hill slopes up to 80% or even more. The land preparation is carried out during on-set of south–west monsoon in the month of June. Two wet land ploughing with country plough followed by peg type wooden planker cum leveler for puddling and leveling of field is performed to prepare the land for transplanting of 25–30 days seedlings. Land leveling is also carried out by wooden hand leveler. Transplanting is done manually, and row and plant spacing are not maintained. Therefore, interculture operation is performed manually by hand uprooting of the weeds. Figure 1 shows some of photographic visuals of cultivation practices of rice in the state. The water coming from the upstream and highlands is tamed and made to stand behind the bunds. The flow of water is regulated from the perennial rivulets and is carefully carried from one terrace to the other and finally drained off in the downstream channels leading to the streams. Rice fields remain almost submerged throughout the growing season. The crop rotation systems followed in Sikkim are: rice–wheat, rice–mustard, rice–potato, rice–fallow, maize–rice–mustard, and maize–rice –fallow. Farmers intercrop rice with traditional varieties of soybean, rice bean and black gram on bunds. The popular local rice varieties are: *Attey*, *Masseey*, *Sikre*, *Krishnabhog*, *Kalshanti*, *Bhuidhan*, *Darmali*, *Tasrey* and *Dutkatti*.

Traditional hand tools used in Sikkim

Land preparation for rice cultivation

Land leveling before transplanting of rice

Land puddling for rice transplanting

Transplanting of rice seedlings

Growing rice crop on terraces

Figure 1 Traditional hand tools and various operation practices in cultivation of rice crop

Maize is extensively grown in Sikkim in the altitude ranging from 300 to 2,200 m above mean sea level, with more than 80% in the mid hills. It is also cultivated in paddy land prior to arrival of south–west monsoon season (pre kharif) at the lower hills up to an altitude of 900 m above mean sea level and during south–west monsoon season in the non–paddy land both as pure and mixed crops. The time of maize sowing varies with altitude and growing season is from mid February to April. Post kharif maize is sown from July to the first week of August along with pulses, beans and pulse–type beans. Land is prepared by two dry ploughing using country plough followed by planking and leveling. Sowing is done in furrows at a depth of 3–5 cm at a spacing of 30 cm between rows and plant spacing is not maintained. Organic manure is evenly spread and incorporated into the soil during land preparation. Interculture operations begin 10 days after sowing with the help of hand held fork. Earthing up process continues up to 15–20 days to flowering. Popular local cultivars such as *Sethia*, *Khukurey*, *Garbarey*, *Pahenli*, and *Lachung* are gradually getting replaced by improved varieties. At lower and mid hills, ginger is also cultivated as an intercrop. Turmeric and Lady's finger are also grown in the lower and mid hills.

2.4 Data analysis

Data collected through village survey was converted in terms of energy input and output. For conversion of inventory in to energy, energy equivalents as is suggested by Mittal and Dhawan (1989), Mittal et al. (1992), and Nassiri and Singh (2009), were taken into considerations. Table 5 shows the energy equivalents of various sources of energy input including machinery used i.e. hand tools in individual operations.

Table 5 Energy input equivalents

Sl. no.	Energy input source	Unit energy
1	Man (adult)	1.96 /MJ h^{-1}
2	Women (adult)	1.57 /MJ h^{-1}
3	Bullock pair (small)	8.07 /MJ h^{-1}
4	Rice grain	14.7 /MJ h^{-1}
5	Maize	14.7/MJ kg^{-1}
6	Rice seed	15.2/MJ kg^{-1}
7	Maize seed	15.2/MJ kg^{-1}
8	Rice straw	12.5/MJ kg^{-1}
9	Maize stalk	18.0/MJ kg^{-1}
10	Farm yard manure	0.30/MJ kg^{-1}
11	Farm machinery	62.7/MJ kg^{-1}

2.4.1 Mechanization index

The mechanization index and machinery energy ratio are internationally accepted indicator of mechanization status. Mechanization index is an index based on the ratio of the cost of use of machinery to the total animate and machinery cost for the estimation of the mechanization. A mechanization index based on the matrix of use of animate and machinery energy inputs was determined as is suggested by Singh (2006) and is presented in Equation (2).

$$I_{mi} = \frac{C_{EMi}}{(C_{EHi} + C_{EAi} + C_{EMi})} \quad (2)$$

where, I_{mi} is the mechanization index of the i_{th} crop; C_{EMi} is the cost of use of machinery in the i_{th} crop; C_{EHi} is the cost of use of human labour in the i^{th} crop; and C_{EAi} is the cost of use of animal labour in the i^{th} crop. In order to determine the mechanization index in the present case, the cost of use of machinery, human labour, and animal is taken as the amount of input energy and the unit cost of input energy is assumed as constant irrespective of their input source.

There is strong evidence to suggest that higher productivity requires more power. Farmers using sophisticated self–propelled machinery in advanced countries may require higher farm power per unit area. Developing countries relying on human and animal power operated equipment might achieve economical yield, if adequate irrigation, quality seeds and soil nutrients are available.

2.4.2 Machinery energy ratio (machine index)

The machinery energy ratio is an index which represents the fraction of the total energy inputs through the various tools and implements used in different operations for cultivation of the particular crop. The machinery energy was determined using Equation (3) as is suggested by Adrian et al. (2007).

$$MER = \left(\frac{M_{e(a,i)}}{T_{e(a,i)}} \right) \quad (3)$$

where, *MER* is the ratio of the machinery energy to the total energy input; $M_{e(a,i)}$ is the energy input through the various machines/implements; and, $T_{e(a,i)}$ is the total energy input (from human labour, animals, machine/hand tools, seed, and farm yard manures) for the production of crop 'i' in the production unit 'a'.

3 Results and Discussion

3.1 Operation wise energy input in rice and maize crops

Table 6 presents the energy input in various operations carried in cultivation of rice and maize crops. Total input energy required in cultivation of rice crop was observed as 3,338.984 MJ ha^{-1}. It is evident from the table that the land preparation operation required the highest energy input. Rice cultivation accounted 71.7% (3,147.3 MJ ha^{-1}) of total energy input followed by 50.0% (1,772.2 MJ ha^{-1}) in maize cultivation for land preparation

Table 6 Operation wise energy input in cultivation of rice and maize crops

Operation	Districts of Sikkim									
	East		West		North		South		Average	
	MJ ha^{-1}	%	MJ ha^{-1}	%	MJ ha^{-1}	%	MJ ha^{-1}	%	MJ ha^{-1}	%
Rice crop*										
Land preparation	3079.7	70.8	3100.7	72.4	3283.5	72.1	3125.2	71.6	3147.3	71.7
Transplanting	273.5	6.3	268.9	6.3	279.2	6.1	263.7	6.0	271.3	6.2
Weeding & interculture	213.2	4.9	220.9	5.2	226.1	5.0	215.9	4.9	219.0	5.0
Harvesting	195.3	4.5	199.1	4.7	184.2	4.0	168.4	3.9	186.8	4.3
Threshing	177.9	4.1	175.9	4.1	176.9	3.9	183.6	4.2	178.6	4.1
Maize crop										
Land preparation	1767.1	49.6	1797.7	49.9	1751.8	50.2	1772.3	50.2	1772.2	50.0
Sowing	615.6	17.3	615.6	17.1	615.6	17.6	615.6	17.4	615.6	17.4
Weeding & interculture	931.1	26.1	928.4	25.8	882.7	25.3	894.7	25.3	909.2	25.6
Harvesting & transportation	249.4	7.0	260.7	7.2	241.0	6.9	249.9	7.1	250.3	7.0

Note: The total of percentage energy input is not 100% because of the energy input required for raising the nursery is not included in rice cultivation.

only. The second highest energy input required in rice cultivation was transplanting operation, which accounted 6.2% (271.3 MJ ha^{-1}) followed by weeding and interculture operations. Harvesting and threshing operation of rice had consumed 4.3% (186.8 MJ ha^{-1}) and 4.1% (178.6 MJ ha^{-1}) of the total input energy respectively.

However, in cultivation of maize crop, 25.6% (909.2 MJ ha^{-1} energy was consumed for weeding and interculture operation which is the second highest energy consumption followed by the 17.4% (615.6 MJ ha^{-1}) for sowing operation. Harvesting and transportation had consumed about 7.1% (250.3 MJ ha^{-1}) of the total energy input.

3.2 Source wise energy input in rice and maize crops

Table 7 shows the source wise energy input and machine index in cultivation of rice and maize crops for all four districts of Sikkim. Figures 2 and Figure 3 present the source wise use of energy input for maize and rice crops, respectively. The average human energy use in Sikkim for cultivation of rice crop has been estimated as 1,543.526 MJ ha^{-1}, which alone contributed to 46.23% of total energy input. The use of animal energy in the rice cultivation was estimated as 367.202 MJ ha^{-1}, which contributed to 11.0% of the total input energy. Further, the use of machine energy had been found as 1,083.44 MJ ha^{-1}, which contributed to 32.45% of the total energy input. Seed and farm yard manure (FYM) energy remained constant in all four districts of the Sikkim, as the seed rate and manure application rate per unit area remains constant throughout the entire area. Seed and FYM energy contributed to 300.352 MJ ha^{-1} (9.0%) and 44.46 MJ ha^{-1} (1.3%), respectively in cultivation of the rice crop.

Table 7 Source wise energy input in cultivation of rice and maize crops

Districts	Human energy/MJ ha^{-1}	Animal Energy/MJ ha^{-1}	Machine energy/MJ ha^{-1}	Seed energy/MJ ha^{-1}	FYM energy/MJ ha^{-1}	Total energy/MJ ha^{-1}
Rice crop						
East	1556.356	368.1724	1083.163	300.352	44.46	3352.503
West	1585.678	375.8775	1093.733	300.352	44.46	3400.101
North	1502.834	358.7922	1074.752	300.352	44.46	3281.191
South	1529.234	365.968	1082.125	300.352	44.46	3322.14
Average	1543.526	367.2025	1083.443	300.352	44.46	3338.984
Maize crop						
East	1455.248	1145.91	905.8324	750.88	88.92	4346.791
West	1450.908	1108.269	881.3905	750.88	88.92	4280.367
North	1477.734	1247.23	989.9448	750.88	88.92	4554.709
South	1398.608	1195.974	929.4928	750.88	88.92	4363.875
Average	1445.624	1174.346	926.6651	750.88	88.92	4386.435

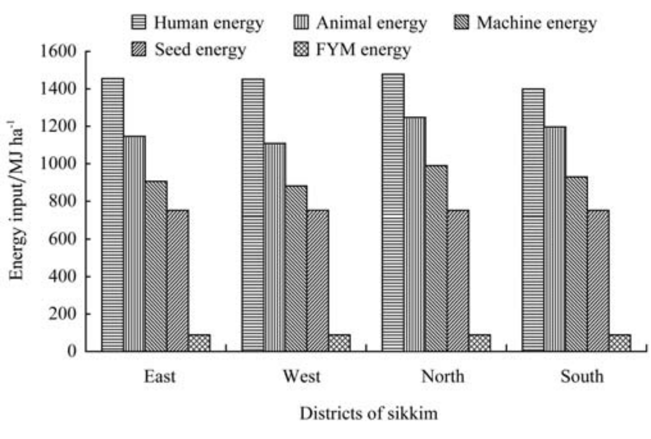

Figure 2 Source wise energy input in various districts in maize cultivation

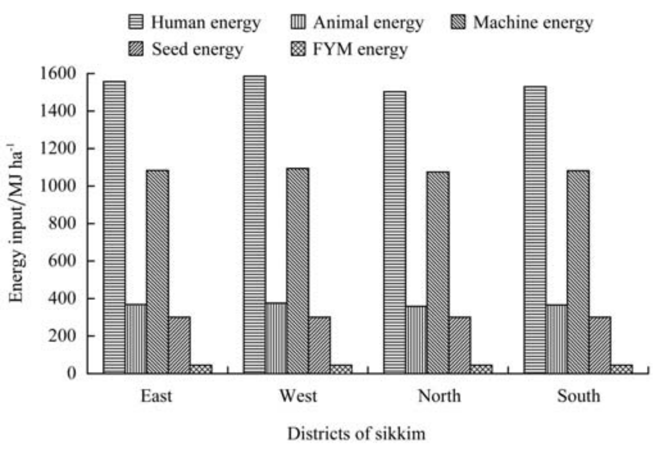

Figure 3 Source wise energy input in various districts in rice cultivation

The average human energy use in cultivation of maize crop has been estimated as 1,445.624 MJ ha^{-1}, which contributed to 32.95% of the total energy input. The use of animal energy in the maize cultivation was estimated as 1,174.346 MJ ha^{-1}, which is 26.78% of the total input energy. The use of machine energy had been found as 926.665 MJ ha^{-1}, which contributed to 21.1% of the total energy input. Seed and farm yard manure (FYM) energy again remained constant in all four districts of the Sikkim. Seed and FYM energy contributed to 750.88 MJ ha^{-1} (17.1%) and 88.92 MJ ha^{-1} (2.0%), respectively in cultivation of the maize crop.

It is clearly evident from the Figure 2 that the human energy has the highest share of input energy followed by animal, machine, seed and farm yard manure in the present cultivation practice of the rice.

Further, it is evident from Figure 3 that in the present cultivation practice of the maize crop, human energy has highest share followed by the machine, animal, seed and farm yard manure. Figure 4 presents the source wise energy inputs (human labour, animal labor, machine, seed and farm yard manure) in cultivation of rice and maize crops on the basis of MJ ha^{-1}.

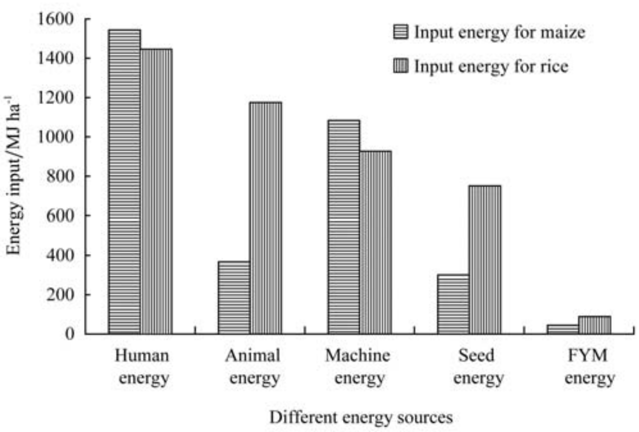

Figure 4 Source wise energy input (MJ ha^{-1}) in cultivation of rice and maize crops

Figure 5 shows the percentage share of different energy input sources in the current practice of maize cultivation in the state. The contribution of human energy, animal energy, machine energy, seed energy and fertilizer energy was found as 38%, 20%, 26%, 14% and 2%, respectively. The machine energy seems to be higher in comparison to animal energy. It is due to use of inefficient traditional tools having poor field capacity of indigenous tools, more and more man power is required to complete the operation. The machine energy input is only by the use of hand tools. The contribution of machine energy is very low against national average. This shows a wide gap and there is need for mechanization to improve crop yield and to reduce human drudgery in cultivation of crops.

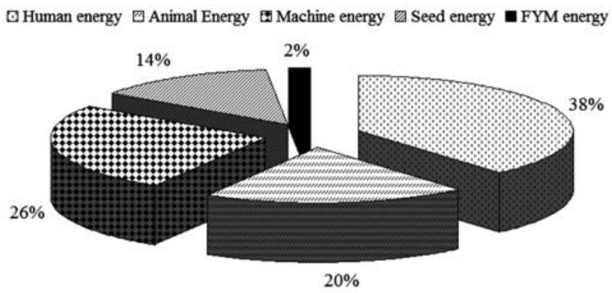

Figure 5 Percentage share of various energy input sources in maize cultivation

3.3 Productivity and input–output energy

Table 8 shows that the average rice and maize yield in Sikkim is about 924.0 kg ha^{-1} and 431.0 kg ha^{-1}, respectively. The average energy input in cultivation of rice and maize is about 3,338.984 MJ ha^{-1} and 4,386.435 MJ ha^{-1}, respectively. The output energy (from grain, straw/stalk) from rice and maize is about 25,594.8 and 25,700.9 MJ ha^{-1}, respectively. The observed productivity of rice and maize crops is very low against national average production yield.

Table 8 District wise rice and maize production yield and energy input–output in Sikkim

District	Input energy /MJ ha^{-1}		Grain yield /kg ha^{-1}		Output energy* /MJ ha^{-1}	
	Rice	Maize	Rice	Maize	Rice	Maize
East	3352.50	4346.79	1195	474	33101.5	28297.8
West	3400.10	4280.36	811	481	22464.7	28715.7
North	3281.19	4554.70	821	333	22741.7	19880.1
South	3322.14	4363.87	869	434	24071.3	25909.8
Average	3338.98	4386.43	924	431	25594.8	25700.9

Note:* Output energy is determined by taking into account grain as well as straw/stalk yields.

Rice cultivation in Sikkim is mostly rain–fed (only about 10% area is irrigated), therefore, energy required for irrigation has not been considered. The results revealed that the human energy contributes maximum input energy in all four districts of the state followed by animal energy, machine energy and fertilizer energy. The trend of energy use from different sources viz. human, animal, machine, seed and fertilizer was found almost similar in all the districts. However, in case of maize cultivation, the human energy played a vital role followed by machinery energy. Contribution of animal energy was found less than machine energy. It may be because only one or two ploughing is done for land preparation and sowing is carried out behind the country plough. Rest of the operation (interculture, harvesting and transportation) is done manually. In case of paddy, the animals are extensively used for land preparation and most of the animal energy is used for puddling. The machine energy input is only through the use of hand tools. Further, it has been demonstrated that the most traditional technologies practiced by use of human muscle power in crop cultivation are highly ineffective. It had been reported that in case of cassava cultivation in Nigeria, manual labour energy utilization for the same end product was approximately 83 times higher than that of energy required when using a tractor (Nkakini et al., 2006).

3.4 Mechanization index and machine energy ratio based on energy input

Mechanization index and machinery energy index gives clear picture of mechanization status of particular crop. Table 9 shows the observed values of output–input energy ratio along with the mechanization and machinery energy indices. The observed energy output/input ratio for rice and maize crop cultivation was 7.66 and 5.86, respectively. The mechanization index and machinery energy index in Sikkim for cultivation of rice crop was 0.3618 and 0.3244, respectively. However, in case of present practice of maize cultivation, mechanization index and machinery energy index was 0.2612 and 0.2111, respectively. The estimated values of mechanization and machinery energy indices are very poor in the region. The state's average estimated farm power availability is only 0.70 kW ha^{-1}. However, national average farm power availability was 1.70 kg ha^{-1} in year 2009–2010.

Table 9 Observed output/input energy ratio, mechanization index, and machine index in cultivation of rice and maize crops

District	Rice crop			Maize crop		
	Output/input ratio	Mechanization index	Machine index	Output/input ratio	Mechanization index	Machine index
East	9.87	0.3601	0.3230	6.51	0.2582	0.2083
West	6.60	0.3579	0.3216	6.70	0.2561	0.2059
North	6.93	0.3660	0.3275	4.36	0.2664	0.2173
South	7.24	0.3634	0.3257	5.94	0.2637	0.2129
Average	7.66	0.3618	0.3244	5.86	0.2612	0.2111

The productivity of crops had been found very low as compared to the national average. Sikkim is an organic state, thus, the major source of NPK is through farm yard manure the availability of which is limited due to less animal population. Therefore, there is great scope for producing organic fertilizers using agricultural and forestry based biomass. Another reason for low productivity of rice and maize yields might be due to loss of soil fertility during the crop cultivation duration because of run-off. The region has very high annual rainfall and the fields are at high and steep slopes, thus high soil erosion is very common, which removes top soils. Therefore, soil conservation practices should be promoted in the region to minimize the loss of soil fertility, which certainly will increase the crop productivity by retaining soil fertility and soil moisture.

Small land holdings of the farmers have been observed as a hindrance for use of machinery in the region. Researchers have demonstrated that due to the small land holdings, farmers in developing countries requires a system of selective mechanization due to many inherent constraints (i.e. low capital and poor technological environment) in the traditional system of agriculture (Aderoba, 1987). Moreover, it has been indicated that mechanization helps farmers to cultivate larger land areas and thus generate more income (Marrit

Van den Berg et al., 2007).

4 Conclusions

The analysis of the study revealed that approximately 60% of input energy in the present cultivation practices for rice and maize crops in the state is from human and animal sources only. The use of machinery energy had been found very limited and came only from human powered hand tools and animal operated tools, which had a share of about 25%–30%. This investigation has emerged that there is wide scope for introduction of small and efficient hand tools for the operations like weeding and interculture as most of the human energy is consumed in these operations. Introduction of improved tillage and puddling equipment will be highly helpful in reducing the human labour energy input. Land preparation alone consume about 50%–70% of total energy input in rice and maize cultivation. Therefore, introduction of lightweight power tillers and matching implements have high application potential for land preparation, sowing and tilling operations during crops cultivation practices. Furthermore, the introduction of improved and efficient farm tools may reduce human drudgery encountered during operation of hand tools and heavy implements.

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