



Intensification of maize (*Zea mays*) –based cropping sequence in rainfed ecosystem of Sikkim Himalayas for improving system productivity, profitability, employment generation and energy-use efficiency under organic management condition

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ABSTRACT

Three-year (2012–13, 2013–14 and 2014–15) fixed plot field experiment was conducted at Research Farm, ICAR Sikkim Centre, Tadong with five maize (*Zea mays* L.) – based crop sequences, viz. maize–fallow, maize–rajmash, maize–toria, maize–buckwheat and maize (green cob)–urdbean–buckwheat to identify the resource efficient cropping systems under resource scarce, rainfed conditions of Sikkim Himalayas at an altitude of 1 300 amsl. Results showed that all the intensified cropping systems were significantly superior over maize–fallow system under rainfed condition of Sikkim at mid-altitude in terms of productivity, production efficiency, profitability, land use efficiency, employment generation and energy-use efficiency. However, among the intensified cropping sequence, maize (green cobs)–urdbean–buckwheat system was most resource efficient and recorded significantly higher values of system productivity (8.89 tonnes/ha), relative system production efficiency (24.36 kg/ha/day), net return (303.4×10^3 ₹/ha), B:C ratio (2.59) and system employment generation (285 man-days/ha) over other cropping systems. With regards to the energetics, cultivation of three crops {maize (green cob)–urdbean–buckwheat} in a year recorded 188.9%, 192%, 25.8% and 6.5% higher gross energy return, net energy return, energy use efficiency and energy productivity, respectively, over maize–fallow rotation of the region. Contrarily, maximum value of specific energy (MJ/kg) was recorded with maize–fallow and least with maize (green cob)–urdbean–buckwheat. This indicated that for the production of unit amount of grain, higher energy was required in maize–fallow system as compared to other diversified sequences.

Key words: Cropping intensity, Diversification, Energetics, Hill agriculture, Organic, Profitability

Maize (*Zea mays* L.)–fallow is a predominant cropping sequence in the rainfed region of Sikkim Himalayas resulting in very low cropping intensity (about 118%). Productivity of rainfed mono–cropping system of Sikkim is very low and it is a high risk economic activity. Intensive natural resources mining, continuous degradation of natural resources and practice of mono–cropping under conventional agricultural practices in mountain ecosystems does not sustain the farm productivity and food security (Ghosh *et al.* 2010).

It is assumed that the present and future demand of food can be met through intensive crop production with increase in productivity per unit area and time especially under rainfed ecosystems of the region. Therefore, there is

need to intensify and diversify existing maize–fallow system by inclusion of more number of crops per unit area. But, the intensified production systems require increased use of energy and other production inputs. Under organic management condition of mountain regions, the relationship between energy and production agriculture is becoming more crucial with the intensification of the cropping systems. By and large energy productivity is diminishing with the escalating input costs without proportionate improvement in output of different crops. Sufficient availability of the right energy and its effective use are prerequisites for sustainable agricultural production. Energy analysis, therefore, is necessary for efficient management of scarce resources for improved crop production (Babu *et al.* 2014). It would identify production practices as economical and effective. It was realized that crop yields and food supplies are directly linked to energy (Stout 1990). The energy use pattern for unit production of crop varies under different agro-climatic zones and topography (Chaudhary *et al.* 2013). Hence, selection of appropriate vital crops in maize–based cropping system is required to harness the maximum

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returns and enhancing flexibility of cropping under limited moisture supply, without considerable modification in farming operations is of paramount importance for self-reliance in food and nutrition. In view of the limited scope for horizontal expansion to augment food production, the alternative is to proceed with vertical growth by increasing the productivity per unit of available land. It is pertinent to focus on the sequential cropping in monocropped areas and crop intensification for improved agricultural production. Improved productivity, profitability, employment-generation and energy use efficiencies also could be ensured by adopting scientific cropping sequences with 300% cropping intensity in rainfed mountain eco-system. Keeping these points in view present investigation was carried out during consecutive three years (2012, 2013 and 2014) at Research Farm, ICAR Sikkim Centre to intensify the maize-based cropping systems for improving the profitability, employment generation and energy use efficiency under organic management in rainfed region of Sikkim Himalayas.

MATERIALS AND METHODS

Fixed plot field experiment was undertaken during three consecutive years (2012–13, 2013–14 and 2014–15) at the experimental farm of ICAR Research Complex for NEH Region, Sikkim Centre, Tadong situated at latitude 27°32' N and longitude 88°60' E, at an altitude of 1 300 amsl. The experimental site received total rainfall of 3 102.5, 2 340 and 2 829.7 mm/annum for 2012, 2013 and 2014, respectively. The variation in maximum temperature was observed across the years; during 2012 maximum temperature was recorded in May (28.13 °C). However, the maximum temperature during 2013 and 2014 was recorded in September (28.22 °C) and July (28.2 °C), respectively. Although minimum temperature remained constant and lowest temperature in all the three years was recorded in January. The soil was clay loam in texture and initial content of pH, organic carbon, available N, P and K was 5.9, 20.6 g/kg, 235.3 kg/ha, 25.30 kg/ha and 204.7 kg/ha, respectively. Five maize-based cropping sequences, viz. maize–fallow, maize–rajmash, maize–toria, maize–buckwheat and maize (green cobs)–*pahenlo dal* (green seeded urdbean)–buckwheat was tested in four times replicated Randomized Block Design. With a view to avoid the mixing of soil in different plots, individual plots were thoroughly prepared by manual labour with the help of spade and power tiller in each season. The amount of organic manures applied in each crops has been given in Table 1. The average nutrients content in farmyard manure and vermicompost was 0.50 and 2.01 % N, 0.20 and 0.85% P₂O₅ and 0.50 and 1.20% K₂O, respectively. During all the years crops were grown under rainfed conditions with the recommended organic cultivation practices. Properly decomposed organic manures were applied and incorporated in the soil at the time of last tilling before the sowing of crops. The agronomic practices followed in different crops have been given in Table 1. Observations on yield were recorded as per the standard

Table 1 Time line of major agronomic activities and inputs used in different cropping systems

Cropping systems and cultivars	Date of sowing		Date of harvesting		Seed rate (kg/ha)		Spacing (cm)		Organic manure (t/ha)		Land used (days/year)
	Pre-kharif/kharif	Late kharif	Pre-kharif/kharif	Late kharif	Pre-kharif/kharif	Late kharif	Pre-kharif/kharif	Late kharif	Pre-kharif/kharif	Late kharif	
Maize (VQPM 9)–Fallow	21/02/1224/ 02/1321/02/14		23/06/1228/ 06/1326/06/14		20		50×25 VC@ 1.0		FYM @8+		125
Maize (VQPM9)–Rajmash (SKR57)	01/03/1226/ 02/1322/02/14	02/10/1204/ 10/1301/10/14	02/07/1229/ 06/1324/06/14	28/01/1301/ 02/1427/01/15	20	20	45×10		FYM @8 +VC@ 1.0	FYM@ 8.0	243
Maize (VQPM9)–Toria (M 27)	01/03/1202/ 03/1304/03/14	07/10/1206/ 10/1305/10/14	02/07/1230/ 06/1303/07/14	26/01/1327/ 01/1424/01/15	20	20	30×10		FYM @8 +VC@ 1.0	FYM@ 6.0	235
Maize(VQPM 9)–Buckwheat (Local Meethey)	10/03/1221/ 03/1319/03/14	16/11/1217/ 11/1314/11/14	07/07/1223/ 07/1318/07/14	04/03/1303/ 03/1401/03/15	20	20	30×10		FYM @8 +VC@ 1.0	FYM@4.0 +VC@0.5	230
*Maize (VQPM9)–urdbean (PD 3)–Buckwheat (Local Meethey)	16/04/1217/ 04/1322/04/1408/1301/08/1412/1315/12/1407/1315/07/1411/1326/11/1403/1430/03/15	03/08/1204/ 12/12/1213/	11/07/1213/ 29/11/1227/27/03/1329/	29/11/1227/27/03/1329/ 11/07/1213/	20	20	30×10		FYM @8 +VC@ 1.0	FYM@4.0 5.0 +VC@0.5	310

*Maize for green cobs, FYM, Farmyard manure; VC, Vermicompost.

Table 2 Formulae used for economics and energy analysis

Particulars	Formulae	Where
<i>Economic and land use efficiency</i>		
Total cost of production (₹)	$TC = f(H \times M \times F \times Ma \times S \times P)$	TC, total cost of production; H, human power; M, machine; F, fuel; Ma, manure; S, seed; P, bio pesticides
Gross return (₹)	$GR = \sum_{i=1}^n (RY + RBP)$	GR, gross return; RY, return from seed yield; RBP, return from stover/straw
Net return (₹)	$NR = \sum_{i=1}^n (GR - TC)$	NR, Net return; TC, total cost of production; GR, gross return
Benefit/Cost (B: C ratio)	$BC = \sum_{i=1}^n (GR / TC)$	BC, Benefit/Cost (B: C ratio); TC, total cost of production; GR, gross return
Maize equivalent yield (t/ha)	$MEY = Y_x (P_x) / P_m$	Y_x is the yield of crop x (t/ha of economic harvest), P_x is the price of crop x, and P_m is the price of maize
System production efficiency (kg/ha/day)	$SPE = Mey (kg/ha) / 365$	Mey is maize equivalent yield of the system
System profitability (₹/ha/day)	$SP = \frac{SNR/ha/year}{365}$	SNR is system net returns
Relative production efficiency (%)	$RPE = \frac{(EYD - EYE)}{EYE} \times 100$	EYD, equivalent yield under diversified system ; EYE equivalent yield of existing system
Land use efficiency (%)	$LUE = \frac{TDN(i)}{365} \times 100$	TND (i), total number of days field remained occupied under different crops (i=1...n)
Relative economic efficiency (%)	$REE = \frac{DNR - ENR}{ENR} \times 100$	DNR, net return obtained under diversified system; ENR, net return in the existing system.
Relative economic generation efficiency (%)	$REGE = \frac{MDD - MDE}{MDE} \times 100$	MDD, total man days require in diversified system; MDE, total man days require in existing system
<i>Energetics</i>		
Machine		
Fuel	$ME = \sum_{i=1}^n (T_m \times C_{vm})$	ME, energy output of machine (MJ); T_m , total machine operation (h); C_{vm} , caloric value of machine (h)
Total energy (MJ/ha)	$TE = \sum_{i=1}^n (C_1 \times C_2 + \dots C_i)$	TE, total energy (MJ/ha); $C_1 + C_2 + \dots C_i$, energy of each component (MJ/ha)
Energy use efficiency (%)	$EUE = \sum_{i=1}^n (EU / EI)$	EUE, energy use efficiency; EU, energy output (MJ/ha); EI, energy input (MJ/ha)
Specific energy (MJ/kg)	$SE = \sum_{i=1}^n (EU / CY)$	SE, specific energy (MJ/kg); EI, energy input (MJ/ha); CY, crop yield (kg/ha)
Energy productivity (kg/MJ)	$PE = \sum_{i=1}^n (CY / EI)$	PE, Energy Productivity (kg/MJ) EI, energy input (MJ/ha); CY, crop yield (kg/ha)
Net energy (MJ/ha)	$NE = \sum_{i=1}^n (CY / EI)$	NE, net energy (MJ/ha); EU, energy output (MJ/ha); EI, energy input (MJ/ha)

procedure. Cost of cultivation of each crop was computed based on the prevailing market price of the inputs during the respective crop season. System returns, B:C ratio, profitability, system production efficiency (SPE), relative production efficiency (RPE), land use efficiency (LUE), system profitability (SP), relative economic efficiency (REE) and relative employment generation efficiency (REGE) were calculated by the formulae presented in Table 2.

The inputs used for various operations in different crop sequences and output obtained in terms of yield were used for calculating energetics of systems. For the calculation of energy input, all inputs in the form of the labour, machinery, diesel, seed, organic manures and bio-pesticides used in all different operations were taken into consideration with the use of energy conversion factor. The different field operations involved in completion of each activity in the experiment was measured in terms of time taken by manual, machinery and fuel consumption and expressed as energy input in mega joules (MJ) and/or gigajoules (GJ) using corresponding conversion factors as given by Chaudhary *et al.* (2006); Beloborodko *et al.* (2013), Yadav *et al.* (2013) and Babu *et al.* (2014). The farm production (grain and straw/stover yield) was also converted in terms of energy output (MJ/GJ) using three year's average yield under different crops of selected sequences. Based on the energy equivalents of the inputs and output, energy use efficiency, energy productivity and specific energy were calculated by the formulae given in Table 2.

All the data obtained from different systems for consecutive three years was pooled and subjected to analysis of variance (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

System productivity (maize grain equivalent yield), production and land use efficiency

In general, all the intensified cropping systems were more productive over the farmer's practices (maize-fallow) of the region (Table 3). While comparing the total productivity of intensified cropping systems in terms of maize grain equivalent yield, significantly higher maize grain

equivalent yield (MEY) was recorded with more intensified cropping system {maize (green cobs)-urdbean-buckwheat} followed by maize-rajmash and maize-toria system (Table 3), whereas the lowest MEY (3.3 tonnes/ha) was recorded when the field was left fallow in consequent years after maize harvesting. This difference was mainly due to the higher amount of produce and higher sale price realized for these crops in the market. Correspondingly, maximum system production efficiency (24.36 kg/ha/day) was recorded with maize (green cobs)-urdbean-buckwheat system followed by maize-rajmash system (Table 3). Crop yield, duration and sale price of the produce greatly influenced the overall return and PE (production efficiency) of various systems (Mukherjee 2010) and resulted in higher production efficiency. However, the lowest PE was recorded in maize-fallow system. Similar results were also reported by Sharma *et al.* (2004) and Singh *et al.* (2007) with diversified systems over the existing systems. Similarly, relative production efficiency (RPE), i.e. the capacity of the system for production in relation to existing system was maximum (169.39%) with maize (green cobs) -urdbean-buckwheat system followed by maize-rajmash sequence. Land use efficiency (LUE) refers to the utilization of land in temporal dimension for cropping activity was recorded to be higher for the maize (green cobs)-urdbean-buckwheat system followed by maize-rajmash. This was due to higher crop duration which in turn recorded the highest LUE and efficient utilization of land over other systems. Similar observation on rice based cropping systems was also reported by Saha and Ghosh (2010). But the lowest LUE was recorded in maize-fallow system as the land was exploited very poorly in this system.

Economics and employment generation efficiency

Economic analysis (Table 4) showed that the highest cost was incurred in maize (green cobs) -urdbean-buckwheat cropping system (117.3×10^3 ₹/ha) followed by maize-rajmash (81.1×10^3 ₹/ha). The lowest cost was incurred in maize-fallow system (46.5×10^3 ₹/ha). This was because the highly intensified system involved more labour and other cost for managing the crop throughout the year. However, the net return (303.4×10^3 ₹/ha) and B:C ratio

Table 3 Effect of crop intensification on maize grain equivalent yield (MEY), system production efficiency (SPE), relative production efficiency (RPE) and land use efficiency (LUE). (Data pooled over 3 years)

Treatment	Yield of crops (t/ha)					MEY (t/ha)	SPE (kg/ha/day)	RPE (%)	LUE (%)
	Maize	Buckwheat	Rajmash	Toria	Urdbean				
Maize-fallow	3.30					3.30	9.04	0.00	34.25
Maize-rajmash	3.45		0.90			5.85	16.03	77.28	66.58
Maize-toria	3.53			0.85		4.91	13.45	48.79	64.38
Maize-buckwheat	3.59	1.05				5.15	14.11	56.06	63.01
Maize (green cobs) - urdbean-buckwheat	8.10	1.00			0.80	8.89	24.36	169.39	84.93
SEm±						0.18	0.52		
LSD (P=0.05)						0.56	1.59		

Table 4 Effect of cropping systems on system net returns, B:C ratio, profitability, relative economic efficiency, employment generation and relative employment generation efficiency (Data pooled over 3 years)

Treatment	Average cost of cultivation ($\times 10^3$ ₹/ha)	System net returns ($\times 10^3$ ₹/ha)	System B:C ratio	System profitability (₹/ha/day)	Relative economic efficiency (%)	System employment generation (Man-days)	Relative system employment generation efficiency (%)
Maize–fallow	46.5	87.0	1.87	238.4	0	106	0
Maize–rajmash	81.1	162.2	2.00	444.5	86.5	172	62.3
Maize–toria	71.4	132.1	1.85	361.9	51.8	162	52.8
Maize–buckwheat	76.9	138.3	1.79	378.9	58.9	167	57.5
Maize (green cobs)– urdbean –buckwheat	117.3	303.4	2.59	831.2	248.7	285	168.9
SEm±		2.83	0.03	4.57			
LSD (P=0.05)		8.57	0.10	13.80			

(2.59) recorded significantly higher with maize (green cobs)–urdbean–buckwheat system followed by maize–rajmash cropping system. This was due to higher system productivity of crops with growing three and two crops in a year, respectively. On the other hand, the lowest return and B:C ratio was recorded in maize–fallow cropping system. This may be attributed to variation in yield, cost of cultivation and prices of economic produce of component crops of cropping systems. Similar results were also reported by Walia *et al.* (2011) and Devkant Prasad *et al.* (2013). With regard to relative economic efficiency (REE), i.e. comparative measure of economic gains over the existing system, all the intensified systems had higher economic gain over the maize–fallow system. Among the intensified systems, maize (green cobs)–urdbean–buckwheat recorded the highest economic gain (248.7%) over others followed by maize–rajmash system (Table 4). Similarly, the maximum system profitability (831.2 ₹/ha/day) was recorded with maize (green cobs)–urdbean–buckwheat. On the contrary, minimum system profitability (238.4 /ha/days) was recorded with maize–fallow system. This corroborates the earlier findings of Mukherjee (2010), Shaha and Ghosh (2010) and Prasad *et al.* (2014).

When assessing the sustainability of cropping systems employment generation is a key indicator. It was evident from data (Table 4) that the intensification of the system adds to the employment generation and generated more employment as compared to maize–fallow cropping system, which generated only 106 man–days/ha to harvest the final produce. Among the intensified systems, maize (green cobs)–urdbean–buckwheat cropping system provided highest employment (285 man–days/ha) followed by maize–rajmash cropping system. Similar observations were also recorded by Chitale *et al.* (2011) with diversified rice–based cropping systems. Data related to relative system employment generation efficiency (REGE), i.e. additional man days required for a diversified system in relation to the existing system, showed that all the intensified systems had higher economic generation ability as compared to the prevailing system of the region. Among the cropping sequences, cultivation of maize (green cobs)

–urdbean–buckwheat resulted in maximum REE (168.9%) followed by maize–rajmash system. It was articulated from the economic analysis that under rainfed mountainous ecosystem, cultivating second and third crops is quintessence not only to increase the cropping intensity and profitability but also to generate employment opportunity for the resource poor tribal farmers.

Energy analysis

Energy analysis is the new tool for judging the system efficiency. A system is considered more efficient when it produces higher output energy and requires less input energy. Various intensified cropping systems required different levels of total energy inputs (Fig 1). The highest total energy input (15.5 GJ/ha) was recorded with maize (green cobs)–urdbean–buckwheat cropping system followed by maize–rajmash cropping system (12.3 GJ/ha). However, the lowest energy consumption (6.7 GJ/ha) was recorded for maize–fallow cropping system. This was due to higher input used for managing more number of crops in definite period of time as compared to mono cropping of maize. Concerning the energy output, there were significant differences between the intensified systems (Fig 1). Among the various cropping systems, maize (green cobs)–urdbean–buckwheat recorded the highest gross energy output (374.5 GJ/ha) followed by maize–rajmash cropping system (252.5 GJ/ha). This was because maximum maize grain equivalent yield was recorded in this system over the others. The output energy of agricultural production systems was determined by the amount and quality of harvestable biomass (Gelfand *et al.* 2010). Similarly, maize (green cobs)–urdbean–buckwheat cropping system recorded the highest net return of energy (359.1 GJ/ha) followed by maize–rajmash cropping system. However, the least return of net energy (122.9 GJ/ha) was recorded with maize–fallow system. Among the maize–based systems under study, significantly higher energy use efficiency (24.5%), i.e. the ratio of energy output to energy input was recorded with maize (green cobs)–urdbean–buckwheat cropping system followed by maize–buckwheat cropping system. This was because maximum energy was produced

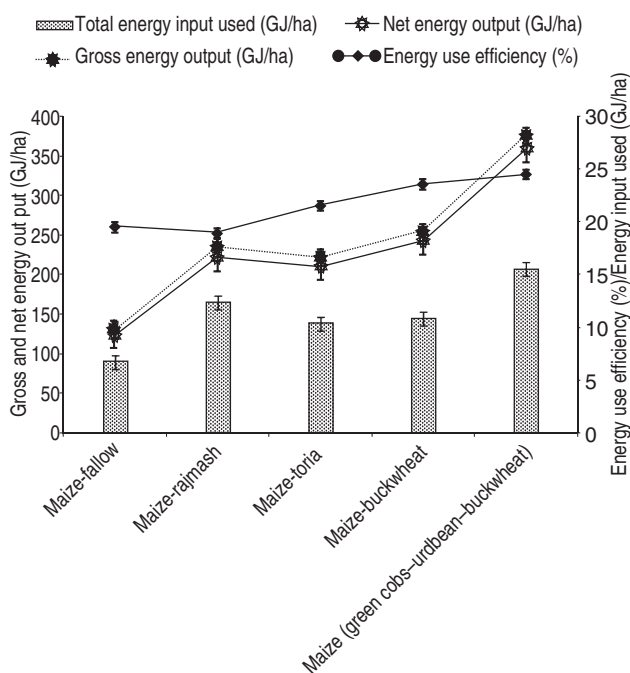


Fig 1 Energy input, gross/net energy output (GJ/ha) and energy use efficiency (%) of maize based cropping sequences on (Data pooled over 3 years). The vertical bars indicate LSD at $P = 0.05$.

in this system with least expenses of energy. These results are corroborated with the findings of Shahan *et al.* (2008) and Choudhary *et al.* (2013). However, maize-fallow system resulted in lowest energy use efficiency. This might be attributed to maximum energy being utilized to produce a unit product. Correspondingly, the energy productivity, i.e. kg of grain produced per unit of energy invested was higher under maize (green cobs)-urdbean-buckwheat cropping system and least with maize-rajmarsh cropping system. On the contrary, specific energy was measured highest for maize-fallow system and least with maize (green cobs)-urdbean-buckwheat system (Fig 2). This indicated that maximum quantum of energy was required to produce one unit of output in maize-fallow cropping system while the highest amount of product produced per unit of energy invested was under maize (green cobs)-urdbean-buckwheat cropping system.

Thus, on the basis of the above study it may be concluded that intensification of maize-fallow system under rainfed ecosystems of Sikkim Himalayas may enhance the profitability, employment generation and energy use efficiency. Therefore, it is recommended that growers can select maize (green cobs)-urdbean-buckwheat cropping system under rainfed conditions for sustaining their livelihood security especially in the mid hills of Sikkim Himalayas.

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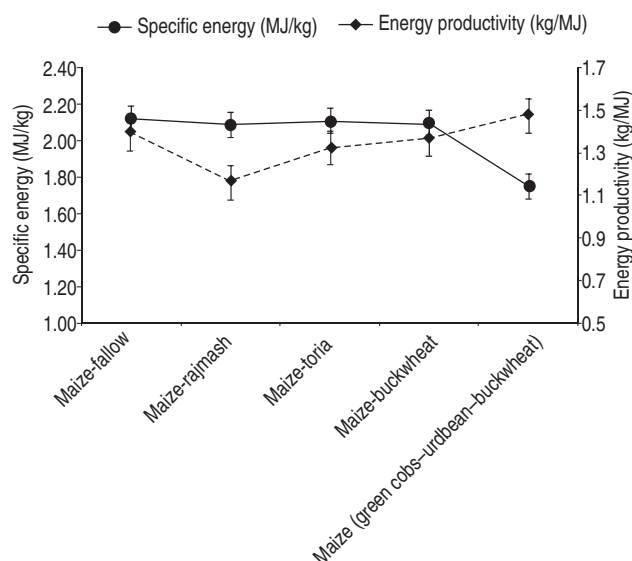


Fig 2 Specific energy (MJ/kg) and energy productivity (kg/MJ) of maize based cropping systems (Data pooled over 3 years). The vertical bars indicate LSD at $P = 0.05$.

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