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# Production potential, economic analysis and energy auditing for maize (*Zea mays*)–vegetable based cropping systems in Eastern Himalayan Region, Arunachal Pradesh

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ABSTRACT

A field experiment was conducted during 2008-11 to study the production, economics and energy auditing of maize (*Zea mays* L.)–vegetable cropping system. Maize was grown on terraces during rainy season and vegetables (tomato, okra, frenchbean, pea, potato, cabbage and cauliflower) were grown as sequential crops. Maize equivalent yield (MEY), production efficiency, return per rupee investment and marginal return to marginal cost ratio were recorded higher on maize–tomato cropping system followed by maize–cauliflower. However, the land use efficiency was recorded higher on maize–potato cropping system. Similarly, maize–tomato system generated employment for 175 days followed by maize-potato (150 days). Maize–potato system required highest energy input followed by maize–tomato. But the total output, net energy and output: input ratio of energy was recorded highest on maize–frenchbean system followed by maize–tomato. Specific energy was measured highest on maize–potato system (3.39 MJ/kg), while maize–cauliflower system recorded the highest energy productivity (1.14 kg/MJ). Similarly, maize–frenchbean system recorded highest energy-use efficiency (1257%) and the least energy-use efficiency was recorded on maize–potato system (223%). Maize-tomato system required highest direct energy and maize–potato system required highest indirect energy. However, maize–potato system largely depended on renewable and commercial energy, whereas maize-tomato system extensively relied on non-renewable and non-commercial energy.

**Key words:** Cropping system, Energy, Maize, Production, Profitability, Vegetables

The Eastern Himalayan Region (EHR) is bestowed with good rainfall, distributed throughout the year. Rice and maize are important rainy season crops along with some vegetables in the region. Growers mostly follow for cultivation of rice or maize as mono crop and leave the field fallow for remaining part of the year. Productivity of rainfed mono-cropping system in EHR of India is very low and it is a high economic risk activity. Intensive natural resources mining, continuous degradation of natural resources (soil, water, vegetation) and practice of mono-cropping under conventional agricultural practices will not ensure farm productivity and food security (Ghosh *et al.* 2010).

Maize (*Zea mays* L.) is the third most important cereal crop of the world after wheat and rice. The importance of maize in the state is visualized by its use as food for human beings, feed for livestock and poultry, forage for milch and security (Campos *et al.* 2004). Better management of soil and water offer an opportunity to take up second crop in the region. Introduction of high value crops like pulse, oilseed and vegetables in maize based cropping system under rainfed condition helps in enhancing the income to farmers. Arunachal Pradesh consumes 2.5 kg/ha of fertilizer, which led to obligation of adopting such practices which can restore the fertility status of the soil (Azam *et al.* 2008). Apart from these, availability of energy and its judicious use also play major role, because agriculture is continuous process of energy conversion (Alam *et al.* 2005, Khan *et al.* 2009). Sufficient availability of the right energy and its effective use are prerequisites for improved agricultural production. 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. Selection of maize based cropping system largely depends on availability of the resource and need of the farmers. Selection of suitable vegetables on maize based cropping system for harnessing the highest return generally

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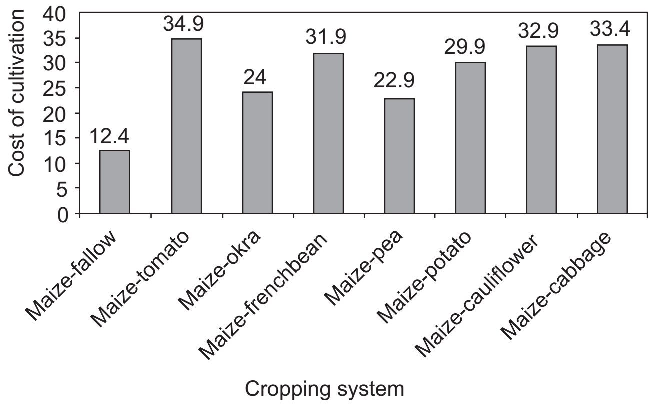


Fig 1 Cost of cultivation (in ’000 ₹/ha) of various maize based croping systems (mean of three years)

aimed at minimizing yield losses and enhancing flexibility of cropping under various climatic conditions, without much alteration in farming operations to have self sufficiency for food and nutrition.

## MATERIALS AND METHODS

The field experiment was carried out at the experimental farm of ICAR Research Complex for NEH Region, Arunachal Pradesh Centre, Basar, Arunachal Pradesh during 2008-11. The study area falls under the humid subtropical climate with 631 m above MSL. The daily temperature during a year varies widely between minimum 5.5°C and maximum 35°C. The experimental site received the total rainfall of 2590, 2400 and 2930 mm/annum for 2008–09, 2009–2010 and 2010–11, respectively. The soil texture was silt clay loam and initial content of pH, organic matter, available N, P and K were 5.3, 1.24 g/kg, 190, 9.5 and 203 kg/ha, respectively.

Maize cv All Rounder were sown during rainy (*kharif*) season with the row spacing of 60 cm × 30 cm during 1st week of May. Farmyard manure @ 10 tonnes/ha was applied at 15 days prior to sowing. Recommended 80 kg N, 60 kg $P_2O_5$ and 40 kg $K_2O$/ha were supplemented through urea, single super phosphate and muriate of potash, respectively. Nitrogen was applied in three equal doses; one-third at basal along with full of $P_2O_5$ and $K_2O$, one-third at 25 days after sowing and the rest one-third at 50 days after sowing. Other management practices were followed as and when required. During post rainy season, tomato var Rocky (120:100:100 kg N $P_2O_5$ $K_2O$/ha), okra var S 51 (100:80:60 kg N $P_2O_5$ $K_2O$/ha), french bean var Sel 9 (25:60:40 kg N $P_2O_5$ $K_2O$/ha), pea var Azad Pea 1 (20:60:40 kg N $P_2O_5$ $K_2O$/ha), potato var Kufri Jyoti (120:80:80 kg N $P_2O_5$ $K_2O$/ha), cabbage var Pride of India (60:40:40 kg N $P_2O_5$ $K_2O$/ha) and cauliflower var Snow Ball (60:40:40 kg N $P_2O_5$ $K_2O$/ha) were sown in 1st week of October and harvested in between February-March depends on their commercial maturity. Other cultural practices were followed as per the standard recommended practices for the region.

The yields of various crops of the respective cropping systems were recorded and converted to maize equivalent yield based on the price equivalent yield in the local market. Production efficiency in terms of kg/ha/day was calculated from the maize equivalent yield values of the system divided by the total duration of crops in the sequence. Crop intensification was measured by calculating land utilization efficiency by dividing the total duration of respective cropping systems by the number of days in a year (365 days) and expressed in percentage.

Return (Rs/ha/day) = Net return/ Total duration of system

Employment generation (%) = (Man-days (per ha) required in proposed cropping system- man-days (per ha) required in existing cropping system) × 100/ man-days (per ha) required in existing cropping system.

Statistical analysis was carried out to know the variance for different parameters, using SAS 9.2 and significance was identified in 5% level while non-significant results were denoted as NS.

## RESULTS AND DISCUSSION

*Equivalent yield, production and land-use efficiency*

The maize yield was recorded higher on maize–pea system followed by maize–frenchbean system (Table 1), whereas the lowest maize yield was recorded when the field was left fallow in consequent years after harvesting of maize. Cole crops based cropping systems were at par on their maize yield. The inherent ability of leguminous crops like pea and frenchbean to fix the atmospheric nitrogen induced the higher crop yield and helped the plant to provide more macro and micro elements through the increment in biological properties of soil (Angas *et al.* 2006 and Gill *et al.* 2008). Among the sequential crops, tomato recorded the highest crop yield with the corresponding maize equivalent yield, followed by cabbage. However, pea recorded lowest yield among the sequence crops, which was due to inherent potential yield capacity of various crops than any other external factors involved in the experiment. Irrespective of highest yield, potato based system recorded lower MEY than tomato, cauliflower and cabbage based cropping system. This difference was mainly due to the high sale price realized for these crops in the market than potato. Total crop duration was more in maize–potato followed by maize–tomato. Least days required to complete the total crop cycle was observed in maize–pea followed by maize–okra. Correspondingly, production efficiency (PE) was recorded higher in maize–tomato system followed by maize–cauliflower system (Table 1). PE follows the similar trend to that of MEY. Crop yield, duration and price of the produce greatly influenced the overall return and PE of various systems (Kumar *et al.* 2005 and Mukherjee 2010). However the lowest PE was recorded on maize–fallow system. Land use efficiency (LUE) was recorded higher for the maize–potato system followed by maize–tomato. This was due to higher

Table 1 Maize equivalent yield (MEY), production and land use efficiency of various maize based cropping systems (pooled data of three years)

| Crop sequence | Maize yield (tonnes/ha) | Sequential crop yield (tonnes/ha) | MEY (tonnes/ha) | Duration (days) | PE (kg/ha/day) | LUE (%) |
|---|---|---|---|---|---|---|
| Maize–fallow | 4.44[ab] | | 4.44[e] | 142 | 31.27[e] | 38.90[d] |
| Maize–tomato | 4.41[ab] | 19.40[a] | 23.81[a] | 142.4† +117.6§ = 260¶ | 91.58[a] | 71.23[a] |
| Maize–okra | 4.42[ab] | 8.20[c] | 13.56[d] | 141.1 + 102.8 = 244 | 55.57[c] | 66.85[bc] |
| Maize–french bean | 4.52[a] | 10.20[b] | 19.09[b] | 143.3 + 113.7 = 257 | 74.28[b] | 70.41[a] |
| Maize–pea | 4.60[a] | 6.60[d] | 12.41[d] | 143.5 + 96.5 = 240 | 50.58[cd] | 65.75[c] |
| Maize–potato | 4.40[ab] | 18.50[a] | 17.61[bc] | 140.1 + 122.9 = 263 | 66.96[bc] | 72.05[a] |
| Maize–cauliflower | 4.38[b] | 10.20[b] | 21.87[a] | 142 + 114.1 = 256 | 85.43[ab] | 70.14[ab] |
| Maize–cabbage | 4.38[b] | 11.60[b] | 20.95[ab] | 142 + 110 = 252 | 83.13[ab] | 69.04[ab] |
| LSD (*P*=0.05) | 0.21 | 1.57 | 2.50 | | 12.80 | 4.30 |

†: time required to harvest maize; §: time required to harvest sequence crops; ¶: total time required to the system; PE: Production efficiency; LUE: Land use efficiency; LSD: least significant difference; same letters in same column are not significant and different letters are statistically difference according to LSD (0.05)

crop duration which in turn recorded the highest LUE and efficient utilization of land over other systems. Similar observation was observed by Saha and Ghosh (2010) on rice based cropping system. But the lowest LUE was recorded on maize-fallow system, as land was utilized very poorly in this system.

Table 2 Energy analysis (Input and output of energy (MJ/ha) of the maize based cropping system (pooled data of three years)

| Crop sequence | Total input (MJ/ha) | Total output (MJ/ha) | Net energy (MJ/ha) | Output input ratio | Specific enegry (MJ/ha) | Energy productivity (kg/MJ) | Energy use efficiency (%) |
|---|---|---|---|---|---|---|---|
| Maize–fallow | 9 705.62[f] | 67 044.00[f] | 57 338.38[f] | 5.91[b] | 2.19[b] | 0.46[c] | 691[b] |
| Maize–tomato | 25 455.29[b] | 14 2445.00[b] | 11 6989.71[b] | 4.60[b] | 1.07[d] | 0.94[ab] | 560[c] |
| Maize–okra | 21 832.32[c] | 98 804.00[d] | 76 971.68[d] | 3.53[bc] | 1.61[c] | 0.62[c] | 453[d] |
| Maize–frenchbean | 16 835.20[de] | 21 1562.00[a] | 19 4726.80[a] | 11.57[a] | 0.88[d] | 1.13[a] | 1257[a] |
| Maize–pea | 15 923.80[e] | 95 266.00[d] | 79 342.20[c] | 4.98[b] | 1.28[c] | 0.78[b] | 598[c] |
| Maize–potato | 59 762.72[a] | 13 3040.00[c] | 73 277.28[e] | 1.23[d] | 3.39[a] | 0.29[d] | 223[f] |
| Maize–cauliflower | 19 119.49[c] | 74 298.00[e] | 55 178.51[g] | 2.89[c] | 0.87[d] | 1.14[a] | 389[e] |
| Maize–cabbage | 19 119.49[c] | 75 418.00[e] | 56 298.51[g] | 2.94[c] | 0.91[d] | 1.10[a] | 394[e] |
| LSD (*P*=0.05) | 21 34.00 | 1 858.10 | 1 483.30 | 1.61 | 0.50 | 0.21 | 48.01 |

LSD: least significant difference; same letters in same column are not significant and different letters are statistically difference according to LSD (0.05)

Table 3 Different energy consumption pattern in various maize based cropping system (pooled data of three years)

| Crop sequence | Direct† | Indirect¶ | Renewable§ | Non-renewable‡ | Commercial? | Non-commercial¤ |
|---|---|---|---|---|---|---|
| Maize–fallow | 1 035.67[c] (10.7)* | 8 669.95[g] (89.3) | 1 880.40[f] (19.4) | 7 825.22[f] (80.6) | 8 127.22[f] (83.7) | 1 578.40[d] (16.4) |
| Maize–tomato | 2 411.69[a] (9.5) | 23 043.60[b] (90.5) | 6 190.60[b] (24.3) | 19 264.69[a] (75.7) | 20 739.69[b] (81.5) | 4 715.60[a] (18.5) |
| Maize–okra | 2 263.79[b] (10.4) | 19 568.53[c] (89.6) | 4 413.60[cd] (20.2) | 17 418.72[c] (79.8) | 17 752.00[c] (81.3) | 4 080.32[b] (18.7) |
| Maize–french bean | 2 255.95[b] (13.4) | 14 579.25[d] (86.6) | 4 317.48[d] (25.6) | 12 517.72[e] (74.4) | 13 662.72[e] (81.2) | 3 172.48[c] (18.8) |
| Maize–pea | 2 255.95[b] (14.2) | 13 667.85[e] (85.8) | 3 709.08[e] (23.3) | 12 214.72[e] (76.7) | 12 751.32[e] (80.1) | 3 172.48[c] (19.9) |
| Maize–potato | 2 279.47[b] (3.8) | 57 483.25[a] (96.2) | 40 998.00[a] (68.6) | 18 764.72[b] (31.4) | 55 066.72[a] (92.1) | 4 696.00[a] (7.9) |
| Maize–cauliflower | 2 352.89[ab] (12.3) | 16 766.60[f] (87.7) | 4 558.80[c] (23.8) | 14 560.69[d] (76.2) | 15 062.69[d] (78.8) | 4 056.80[b] (21.2) |
| Maize–cabbage | 2 352.89[ab] (12.3) | 16 766.60[f] (87.7) | 4 558.80[c] (23.8) | 14 560.69[d] (76.2) | 15 062.69[d] (78.8) | 4 056.80[b] (21.2) |

†Includes human labour, Diesel; ¶Includes seeds, fertilizers, manure, chemicals, machinery; §Includes human labour, seeds, manure; ‡Includes diesel, chemical, fertilizers, machinery; ?Includes machinery, seeds, fertilizer, chemicals; ¤Includes human labour, manure; *values in parenthesis are percentage of respective cropping system

Same letters in same column are not significant and different letters are statistically difference according to LSD (0.05)

*Energy analysis*

Various energy parameters were calculated for different maize-based cropping systems (Table 2). The total energy input was recorded (515.8%) higher for maize–potato cropping system followed by maze–tomato cropping system (162.3%). However, the lowest energy consumption was recorded on maize–fallow cropping system. Among the various cropping system, maize–frenchbean recorded the highest total energy output (215.6%) followed by maize–tomato cropping system (112.5%). Similarly, maize–frenchbean cropping system recorded the highest net return of energy (239.6%) followed by maize–tomato cropping system (104.0%). The output input ratio was recorded higher in maize–frenchbean cropping system. This was due to maximum energy was produced with least expenses of energy in this system. Similar result was reported by Canakci *et al.* (2005) and Shahan *et al.* (2008). The lowest output input ratio was recorded on maize-potato cropping system. This might be due to maximum energy was utilized to produce unit product. Correspondingly, the specific energy was recorded higher in maize–potato cropping system followed by maize–fallow cropping system. However, maize–cauliflower, frenchbean and cabbage cropping system were most energy efficient cropping system among others (Canakci *et al.* 2005). In contrary, energy productivity was measured highest for maize–cauliflower followed by maize–frenchbean cropping system. However, the lowest energy productivity was recorded in maize–potato cropping system followed by maize–fallow cropping system. Similar finding was reported by Singh *et al.* 2007 and Esengun *et al.* 2007 in wheat based cropping system. Energy-use efficiency was recorded highest for maize–frenchbean cropping system followed by maize–fallow cropping system. However, the lowest energy use efficiency was recorded on maize–potato cropping system.

*Effect of direct and indirect energy on various systems*

The input of energy is designated as direct, indirect, renewable, non–renewable, commercial and non-commercial forms (Table 3). Direct energy was used (132.9%) more in maize–tomato cropping system followed by maize–cauliflower and cabbage (127.2%) over maize–fallow cropping system. However indirect energy and renewable energy consumption was recorded higher for maize–potato cropping system followed by maize–tomato cropping system (165.8 and 229.2%, respectively). Non-renewable energy consumption was recorded higher for maize–tomato cropping system (146.2%) followed by maize–potato cropping system (139.8%). This corroborates the earlier findings of Zentner *et al.* (2004). On the other hand, commercial energy was recorded higher for maize–potato cropping system and non-commercial energy consumption was recorded higher for maize–tomato cropping system. The maize–potato and maize–tomato cropping system required comparatively higher energy consumption among all other cropping systems. However the lowest energy consumption was recorded in maize-fallow cropping system (Khan *et al.* 2009). Observing the energy requirement in various form of cultivation is pre-requisite to carve out the sustainable production on maize based cropping system in the era of climate change and depletion of natural resources. Efforts should be taken to reduce the use of non

Table 4 Employment generation (%) and economic analysis (₹/ha) of various maize based cropping systems (pooled data of three years)

| Crop | Man-days (per ha) | Employment generation (%) | Gross return (₹) | Net return (₹) | B:C | Marginal cost (MC) | Marginal return (MR) | MR:MC | Return (₹/day/ha) | Income (% increase) |
|---|---|---|---|---|---|---|---|---|---|---|
| Maize–fallow | 40 | | 31 080 | 18 680 | 1.51[e] | | | | 131.6[f] | |
| Maize–tomato | 110 | 175 | 166 670 | 131 770 | 3.78[a] | 22 500 | 135 590 | 6.03[a] | 506.8[a] | 85.8 |
| Maize–okra | 92 | 130 | 94 920 | 70 920 | 2.96[cd] | 11 600 | 63 840 | 5.50[ab] | 290.7[de] | 73.7 |
| Maize–frenchbean | 88 | 120 | 133 630 | 101 730 | 3.19[bc] | 19 500 | 102 550 | 5.26[bc] | 395.8[bc] | 81.6 |
| Maize–pea | 88 | 120 | 84 980 | 62 080 | 2.71[d] | 10 500 | 53 900 | 5.13[c] | 258.7[e] | 69.9 |
| Maize–potato | 100 | 150 | 123 270 | 93 370 | 3.12[bc] | 17 500 | 92 190 | 5.27[bc] | 355.0[cd] | 80.0 |
| Maize–cauliflower | 80 | 100 | 153 090 | 120 190 | 3.65[ab] | 20 500 | 122 010 | 5.95[ab] | 469.5[ab] | 84.4 |
| Maize–cabbage | 80 | 100 | 146 650 | 113 250 | 3.39[b] | 21 000 | 115 570 | 5.50a[bc] | 449.4[ab] | 83.5 |
| LSD (*P*=0.05) | 78.8 | 21.2 | | | | | | | | |

Same letters in same column are not significant and different lettters are satistically difference according to LSD (0.05)

renewable energy sources in higher productivity systems like maize–tomato/cauliflower/cabbage cropping system is essential to reduce vagaries in climate.

*Economics analysis*

It was evident from Table 4 that maize–fallow cropping system generated 40 man–days/ha to harvest the final produce. Irrespective of crops, introduction of vegetable crops not only provide an additional income but also provided the employment to the farmers. Maize–tomato cropping system provided highest employment followed by maize–potato cropping system. Cauliflower and cabbage recorded similar employment generation pattern as observed in pea and frenchbean. It was lucid from the economic analysis that EHR where taking up of second crops is quintessence not only to increase the cropping intensity but also to generate employment opportunity thereby improve the socio-economic level of the tribal farmers.

Economic analysis showed that the highest cost was involved in maize–tomato cropping system (₹ 34 900/ha) followed by maize–cabbage (₹ 33 400/ha). The lowest cost was incurred in maize–fallow system (Table 4). However, the gross and net return was recorded higher on maize-tomato system (₹ 166 670 and 131 770/ha, respectively) followed by maize–cauliflower cropping system. The B:C ratio of maize–tomato cropping system was recorded higher (150.3%) followed by maize–cauliflower system (141.7%) over traditional maize–fallow system. On the other hand, the lowest return and B:C ratio was recorded on maize–fallow cropping system. Similarly, marginal return and MR:MC ratio was higher for the maize–tomato cropping system (₹ 135 590/ha and 6.03, respectively) followed by maize–cauliflower (₹ 122 010/ha and 5.95, respectively). Among the different cropping system, maize-tomato system recorded (285.1%) the higher return per ha/day and income increment (85.8%) followed by maize–cauliflower (256.8 and 84.4%, respectively) over maize–fallow cropping system. This corroborates the earlier findings of Mukherjee (2010) and Shah and Ghosh (2010).

The research outcome infers that maize equivalent yield, production efficiency, return per rupee investment were recorded higher on maize–tomato cropping system followed by maize-cauliflower. Similarly, the land use efficiency was recorded higher on maize–potato cropping system. But, total output, net energy, output: input ratio of energy and energy-use efficiency was recorded highest on maize-frenchbean system followed by maize–tomato. But, maize–potato system largely depends on renewable and commercial energy, whereas maize-tomato system extensively depends on non-renewable and non-commercial energy. Therefore, it is strongly recommended that among the various systems studied, the grower can select the maize-based cropping system, depends on the availability of resources and the market demand prevailing for various crops.

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