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Energy audit of rice production systems in different land forms in mid hills of Arunachal Pradesh

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ABSTRACT

A field study was carried out in four land forms of rice cultivation namely wetland (WRC), terrace wetland (TRC), upland (URC) and jhum land (JRC) in mid hills of Arunachal Pradesh during 2009 and 2010 to assess the energetics of rice cultivation in various land forms. It was found that the labour requirement was highest on JRC (122 man-days ha^{-1}) and least on URC (75 man-days ha ha^{-1}), whereas, the machine energy was required maximum on TRC (2015.58 MJ ha^{-1}). The highest seed rate (80 kg ha ha^{-1}) was used on URC followed by JRC (50 kg ha^{-1}). The fertilizer use was higher on WRC land form whereas, lower on URC. Uses of pesticides were higher on URC. As only traditional practices were followed by farmers, fertilizers and pesticides were not used in JRC. Total output-input energy ratio and energy productivity was recorded higher on JRC (17.67% and 0.45 kg MJ^{-1}, respectively) followed by WRC (13.86% and 0.38 kg MJ^{-1}). However, specific energy was recorded maximum on URC (3.43 MJ kg^{-1}) and least on JRC (2.21 MJ kg^{-1}). Nevertheless of higher cost for inputs, the net return and B:C ratio was higher on WRC followed by TRC form of rice cultivation.

Key words: *rice, land form, energy, audit, Jhum cultivation, terrace, economics*

Rice is being grown in wide ranges of topography in India. Northeast India is one of the important geographical areas, where rice is grown as staple crop (Mandal *et al.,* 2002). Arunachal Pradesh is the largest state among northeastern states of India and the productivity of rice is 1.40 t ha^{-1} which is lower than the national average (1.95 t ha^{-1}). Lower yield was due to various production factors like poor seed replacement rate, use of traditional varieties, unscientific cultivation and non adoption of mechanized technologies. Efficient utilization of available energy along with land and other resources are required to increase rice production to feed the ever increasing population and to meet other social and economic goals (Demircan *et al.,* 2006). Sufficient availability of the right energy and its effective and efficient use are prerequisite for higher agricultural production. It was realized that crop yields and food supplies are directly linked to energy (Stout, 1990). In the past decade, with an increase in energy inputs like improved seed, fertilizer, pesticide in agriculture, an equivalent increase in crop yields occurred in many parts of India (Kalbande and More, 2008). In the developed countries, increase in the crop yields was mainly due to increase in the commercial energy inputs in addition to improved crop varieties (Faidley, 1992). The energy use efficiency of Indian traditional cropping systems have been trending downward in the recent years due to energy inputs increasing faster than energy output as a result of the growing dependency on inorganic fertilizers and fossil fuels (Zentner *et al.,* 2004). The energy use pattern for unit production of crop varies under different agro-climatic zones and topography. Analysis of biophysical and energy in an agriculture ecosystem is necessary to make benefit in production and competency. Though some information is available in the energy audit of rice in other part of India, no systematic study was conducted in hilly, remote part of Arunachal Pradesh where *Jhum* cultivation is still practiced. It is therefore, essential to carry out energy analysis of crop production system and to establish optimum energy input at different levels of productivity. Keeping the above in mind, the present experiment was conducted to assess the energy audit of rice on various existing land forms.

MATERIALS AND METHODS

The study was conducted at ICAR Research Complex for NEH Region, Arunachal Pradesh Centre Basar, Arunachal Pradesh for two consecutive seasons during 2009 and 2010. The experimental site is >631 m above MSL. The maximum rainfall around 83% received from May to September from the average total rainfall of about 2400 mm annum^{-1}. There are four different major land forms *viz*., wet land rice cultivation (WRC), terrace wet land rice cultivation (TRC), upland rice cultivation (URC) and *Jhum* land rice cultivation (JRC) are followed to grow rice in Arunachal Pradesh. In each system, interestingly, the engagement of labourers and use of other critical inputs are profusely different. The data used in this study were collected from the experiment conducted at ICAR research farm, Gori and the farmers' field.

Among various land form of rice cultivation, input requirement is comparatively different with one another and their energy values. (Table 1). WRC, TRC and URC required labour for all the operations, machine for land preparation, seeds, manure, fertilizer, pesticides (insecticide and fungicide), whereas, JRC does not based on developed technologies it depends only on human labour and seeds. However, harvesting, threshing and transporting of rice are commonly done by human in all the land forms of cultivation.

Energy analysis was carried out by taking into account of all the forms of energy input and output to the production system to establish energy relationship for understanding the energy conversion process. Analysis of energy coefficients of rice was based on energy equivalents available for various inputs. The data were converted into suitable energy units and expressed in MJ ha^{-1}. The energy ratio in agricultural production in different land forms were calculated for the rice growing season. Energy ratio of output-input is determined by calculating energy equivalent yields harvested and energy consumed in production. Human, machinery, fuel, seed, manure, fertilizer and pesticide consumption and yield values of rice in all the land form have been included for calculating the energy ratio (Gholami and Sharafi, 2009).

Economics of rice cultivation was analyzed during the study period by taking into account of various input required and output realized from the study area as per the present market cost of input and output. Statistical analysis was carried out to know the variance for different parameters, using standard statistical package (SAS 9.2) and significance was identified in 5% level.

RESULTS AND DISCUSSION

It was observed that JRC method of cultivation required the highest labour (122 man-days) input followed by TRC (93 man-days). This may be due to the requirement of huge labour input in *Jhum* cultivation for slashing, burning, cleaning, fencing and tedious harvesting. Whereas, WRC and URC remained at par with each other on labour requirement as both the systems required labour for the same operations. The labour requirement in TRC (93 man-days) was comparatively more due to the labour investment in fencing and weeding. TRC utilized the power tiller for more hours (7 hours) compared to WRC (5 hours). It might be due to the fact that terrace lands were formed with narrow width where movements of machine (tractor or power tiller) were difficult, resulted into lowest diesel use efficiency whereas machine could easily move in WRC (Sarkar, 2000). Machines were not used in *Jhum* cultivation due to its topographical barrier and traditional method of cultivation. WRC, TRC and URC required 5 ton ha^{-1} of manure for rice cultivation, whereas, no external inputs were added in JRC. Tribal farmers in Arunachal Pradesh were wary of using fertilizer in any land form. However, use of fertilizer as the input for higher production (data not shown) was noticed on WRC (80:60:40 kg N, P_2O_5 and K_2O ha^{-1}) followed by TRC (80:60:40 kg N, P_2O_5 and K_2O ha^{-1}) and URC (50:40:25 kg N, P_2O_5 and K_2O ha^{-1}). Farmers relied on inherent soil fertility for rice growing in JRC land. Significant change in seed requirement was observed among different system of cultivation. Surprisingly, URC required the highest seed rate (80 kg ha^{-1}) followed by JRC (50 kg ha^{-1}), whereas, WRC and TRC (40 kg ha^{-1}) required lesser seed input. The variation in seed requirement was due to the method of sowing. Seeds were broadcasted in URC and dibbling of seeds has been followed in *Jhum* cultivation, whereas, transplanting of rice seedlings are common in WRC and TRC. Similarly, pesticides (insecticide and fungicides) consumption was comparatively more in URC (2 and 3 l ha^{-1}, respectively). This was due to the additional spraying of fungicide to control blast, brown leaf spot and false smut in that system.

Among the various inputs, highest energy contribution was from fertilizer and within fertilizer nitrogen was the major source of energy consumption in all the system except *Jhum* method of cultivation (Table 1). Nitrogen energy consumption was more and at par on WRC and TRC due to high dose of application of fertilizers. Second largest contributor on energy consumption in wetland system was from manure followed by diesel, whereas, in TRC diesel was the second largest contributor followed by manure. Seed was the major energy consumer in URC and JRC. This was due to higher seed rate in URC and the energy equivalent of this system on seed was almost double to other systems. Total input energy consumption was more for TRC which was on par with WRC. It was lucid from the table 1 that the energy requirement of *Jhum* cultivation was almost four times lesser than other system. The highest energy input was recorded on terrace wetland (24.1%) followed by wetland (15.4%) over upland rice cultivation (Fig 1).

Table 1. Energy consumption and energy co-efficient of various inputs and outputs of rice cultivation in different land forms (pooled data for 2009 and 2010)

Parameters	WRC	TRC	URC	JRC
A. Inputs (MJ ha^{-1})				
1. Labour	1191.68	1458.24	1176.00	1912.96
2. Machine	313.50	438.90	313.50	-
3. Diesel	1126.20	1576.68	1126.20	
4. Manure (FYM)	1500.00	1500.00	1500.00	-
5. Fertilizer				
Nitrogen	4848.00	4848.00	3030.00	-
Phosphorus	666.00	666.00	444.00	-
Potassium	268.00	268.00	167.50	-
6. Seed	588.00	588.00	1176.00	735.00
7. Insecticide	398.00	398.00	398.00	-
8. Fungicide	184.00	184.00	276.00	-
Total input (x10^{3}MJha^{-1})	11.08^a	11.93^a	9.61^b	2.65^c
B. Output (x10^4 MJ ha^{-1})				
1. Seed	6.17	5.73	4.12	1.76
2. Straw	9.19	8.17	6.27	2.92
Total output	15.36^a	13.90^{ab}	10.39^b	4.68^c
Output-input energy ratio for seed	5.57^b	4.81^c	4.28^d	6.66^a
Output-input energy ratio for straw	8.29^b	6.85^c	6.53^c	11.01^a
Total output-input energy ratio (%)	13.86^b	11.65^{bc}	10.81^c	17.67^a
Specific energy(MJkg^{-1})	2.64^b	3.06^{ab}	3.43^a	2.21^{bc}
Energy productivity (kg MJ^{-1})	0.38^b	0.33^c	0.29^d	0.45^a
Net energy (x10^{4}MJha^{-1})	14.25^a	12.71^a	9.42^b	4.42^c

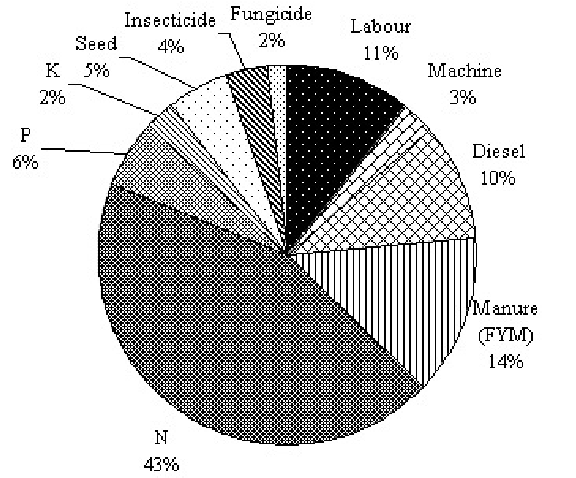
Different letter in superscript in the same row are statistically significant among the land forms at P<0.05 and similar letter were statistically similar.

WRC - wetland rice cultivation, TRC-Terrage wetland rice cultivation, URC-Upland rice cultivation, JRC-*Jhum* land rice cultivation

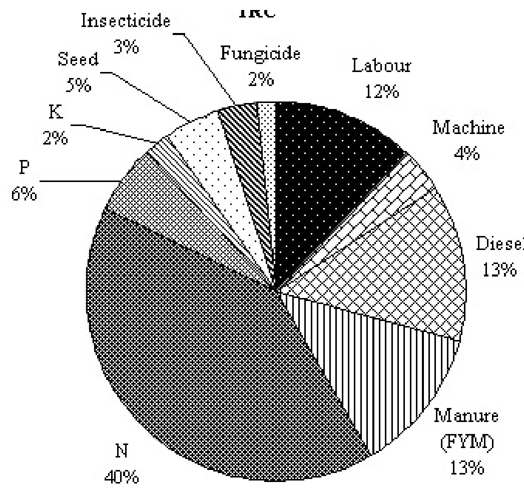
In general, irrespective of system the major source of output energy was from seeds and straw. The highest energy output came from the straw irrespective of the system of rice cultivation (Table 1). However, highest total energy output was recorded from the WRC (47.9%) followed by TRC (33.8%) over URC. The highest yield of rice on wetland and terrace wetland was due to better utilization of all the applied energy inputs. But the least output was observed from the JRC (1.2 and 2.0 ton ha^{-1} for grain and straw, respectively). The low yield of rice and unscientific method of cultivation in *Jhum* land led to very low total energy output. In addition, farmers traditionally leave the straw in the field after harvesting the panicle in *Jhum* cultivation which resulted into very low total energy output from JRC.

Energy equivalent of various inputs and output is presented in table 1. It was found that *Jhum* cultivation have recorded the highest output-input energy ratio for seed and straw (6.66 and 11.01%, respectively). However, URC recorded the least output-input energy ratio (4.28 and 6.53%, respectively). Total output-input energy ratio was recorded highest on *Jhum* cultivation (17.67%) followed by wetland (13.86%), whereas, the lowest total output-input energy ratio was recorded on upland rice cultivation (10.81%). This was due to the least energy involved in *Jhum* as compared to the share of output. The specific energy was higher when rice was grown under URC followed by TRC. Among the other energy parameters, energy productivity on *Jhum* system was recorded maximum with 0.45 kg MJ^{-1}. Net energy was recorded maximum

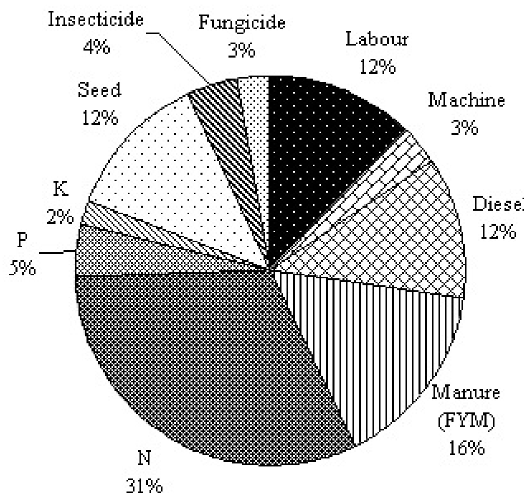
Fig. 1. Energy requirement of various inputs in all system of rice cultivation a) under wetland; b) under terrace; c) under upland and d) under *jhum* land



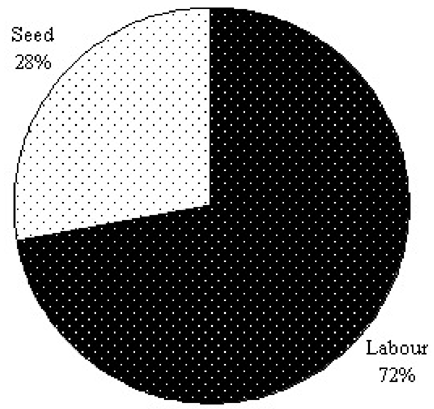
Wet land rice cultivation
(a)



Terrace wet land rice cultivation
(b)



Upland rice cultivation
(c)



***Jhum* land rice cultivation**
(d)

under WRC followed by TRC and URC. However, the lowest net energy was obtained under JRC. Better management practices coupled with right system of rice cultivation yielded more grain in wet land system of cultivation. Energy output, grain yield and net energy were recorded higher on WRC followed by TRC and URC.

The input of energy is designated as direct, indirect, renewable, non-renewable, commercial and non commercial forms (Table 2). The use of the direct energy was comparatively lower than the indirect energy for all the land forms. Similarly, renewable energy of WRC, TRC and URC was lower than the non renewable energy. Likewise, maximum commercial energy was used in WRC, TRC and URC than non commercial energy. Observing the energy requirement in various form of rice cultivation is pre-requisite to carve out the sustainable rice production system in the

Table 2. Various form of total energy input used in different land forms of rice cultivation (pooled data for 2009 and 2010)

Form of energy (x 10^3 MJ ha^{-1})	WRC	TRC	URC	JRC
Direct energy†	2.32^{b} (20.9)*	3.03^{a} (25.4)	2.30^{b} (24.0)	1.91^{c} (72.2)
Indirect energy¶	8.77^{a} (79.1)	8.89^{a} (74.6)	7.31^{b} (76.0)	0.74^{c} (27.8)
Renewable energy§	3.28^{c} (29.6)	3.55^{b} (29.7)	3.85^{a} (40.1)	2.65^{d} (100)
Non renewable energy‡	7.80^{b} (70.4)	8.38^{a} (70.3)	5.76^{c} (59.9)	0.00^{d}
Commercial energy🕮	8.39^{b} (75.7)	8.97^{a} (75.2)	6.93^{c} (72.1)	0.74^{d} (27.8)
Non commercial energy♋	2.69^{a} (24.3)	2.96^{a} (24.8)	2.68^{a} (27.9)	1.91^{b} (72.2)
Total energy input	11.08^{a}	11.93^{a}	9.61^{b}	2.65^{c}

†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 value, Different letter in superscript in the same row are statistically significant among the land forms at $P<0.05$ and similar letter were statistically similar.

era of climate change and depletion of natural resources. Though the *Jhum* cultivation was not utilizing any non-renewable energy and using totally renewable energy for rice cultivation, the effect due to slashing and burning was to be monitored closely which are not analyzed in this study. It was lucid that the grain and straw yield of rice was recorded higher on WRC followed by terrace wetland, whereas, JRC recorded the lower yield (Table 3). This might be due to the fact that WRC and TRC were highly evolved cultivation systems where use of external inputs encouraged the plants to grow well and in turn resulted into more yield attributing characters and finally higher yield (Munda *et al.,* 2009). *Jhum* cultivation used inherent fertility status of soil and no supplementary input has been provided. This ultimately reduced the growth and yield attributes to low yield of grain and straw.

Studying the economic analysis is essential prior to draw conclusion on supremacy of any system of cultivation. The cost of production under TRC and WRC were comparatively higher due to the cost involved in use of external inputs and land preparation activities (Table 3). Whereas JRC system of cultivation recorded an expenditure of Rs 13200 ha^{-1}, however, the net return and B:C ratio was obtained higher on WRC followed by TRC. Nevertheless of higher investment for production of rice under WRC and TRC system the higher return compensated the rupee invested. This was because of higher yield of grain and straw. It is interesting to note that the traditional and most popular system of rice cultivation i.e. *Jhum* cultivation recorded negative sign in net return and B:C ratio, which reflected that profitability of this system of rice cultivation was uneconomic. Therefore, it is high time to introduce modern agriculture technologies to the least productive system (Arunachalam *et al.,* 2002).

Table 3. Economic analysis of all land forms of rice cultivation (pooled data for 2009 and 2010)

Cost and returns components	WRC	TRC	URC	JRC
Grain yield (t ha^{-1})	4.20^{a}	3.90^{b}	2.80^{c}	1.20^{d}
Straw yield (t ha^{-1})	6.00	5.60^{b}	4.30^{c}	2.00^{d}
Sale price of grain (ha^{-1})*	42000	39000	28000	12000
Sale price of straw (ha^{-1})**	3150	2800	2150	1000
Total gross value of production (₹ ha^{-1})	45150	41800	30150	13000
Total cost of production (₹ ha^{-1})	21512	24412	21623	13200
Net return (₹ ha^{-1})	23638^{a}	17388^{b}	8527^{c}	-200^{d}
Benefit to cost ratio	2.10^{a}	1.71^{b}	1.39^{c}	0.99^{d}

*Price of rice grain ₹ 1000 ton^{-1}, **rice straw ₹ 500 ton^{-1}, Different letter in superscript in the same row are statistically significant among the land forms at $P<0.05$ and similar letter were statistically similar.

Among the four different types of rice cultivation system *Jhum* cultivation system was the most energy efficient but as for as profitability and net returns are concerned other systems like wetland and terrace wetland cultivation system are most profitable system of cultivation. Similarly, the use of non renewable energy was more in TRC and WRC irrespective of their higher output. Efforts should be taken to reduce the use of non renewable energy sources in higher productivity systems like WRC and TRC is essential to reduce vagaries in climate. Under these circumstances, an output-input analysis provides planners and policy-makers an opportunity to evaluate economic interactions of energy use in various system of rice cultivation. The negativity in net return clearly shows that *jhum* cultivation may be abandoned and those lands may be brought under TRC or other permanent rice cultivation system.

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