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Research Article

ASSESSING THE ECONOMIC AND ENERGY USE EFFICIENCIES OF DIRECT SEEDED AND TRANSPLANTED RICE (*Oryza sativa* L.) IN LAMJUNG, NEPAL

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Abstract

To meet the basic food needs of expanding human population a productive sustainable agricultural system must become a major priority in Nepal. An on-farm study was conducted to investigate the economic and energy use efficiencies of rice (Oryza sativa L.) under direct seeded (DSR) and transplanted (TPR) conditions at Lamjung campus. Five varieties of rice differing in phenology and growth (viz. US382, Sukha dhan, NR10676, NR10490 and Khumal10) were tested in Randomized Complete Block Design under DSR and TPR conditions with three replications. The statistical resulted revealed that the average grain yield was highest for TPR-NR10490 (7.52t ha^{-1}), whereas the lowest in DSR- NR10676 (1.96t ha^{-1}). The output energy obtained from grain and biomass yield was highest under TPR-NR10490 (2.05x10^{5}MJ ha^{-1}) followed by the lowest in DSR-NR10676 (7.35x10^{4}MJ ha^{-1}). In TPR-NR10490 the most energy use efficiency (output-input ratio of 9.22) was obtained whereas in TPR-Sukha dhan, energy use efficiency (output-input ratio of 1.01) was least. Partial-factor productivity and nutrient uptake was highest in TPR-NR10490 and the lowest in DSR- NR10676. The maximum productivity and profitability was recorded in TPR-NR10490 while reverse in DSR-Sukha dhan. The benefit cost ratio was found highest in TPR- NR10490 (4.45) and lowest in DSR-Sukha dhan (2.31). From above result, NR10490 was found to be the best variety under transplanted condition.

Keywords: DSR; Economic use efficiency; Energy use efficiency; Partial-factor productivity; TPR

Introduction

Rice is the most important food staple in the world with approximately 90% of the global supply grown in Asia and 29% produced in Southeast Asia (GRiSP, 2013). The importance of rice as a food staple will continue to increase with the growing global population. The productivity of rice farming in Southeast Asia has the potential to increase considerably, which will help meet increasing demands for food (Laborte *et al.*, 2012). The global rice production is 454.6 million ton annually, which has a yield of 4.25 ton/ha. In Nepal, the area of rice is about 1.42 million ha, producing 4.79 million tons with an average productivity of 3.35 ton/ha (MoAD, 2014). The crop is grown in all the three major agro-ecological regions i.e. Tarai and Inner Tarai, Hills and Mountains that include approximately 73%, 24% and 3% respectively of the total rice areas in the country. Rice is cultivated in the diverse eco-climatic ranges of Nepal at differing altitudes, topography, climate, in floods, deep water, water logged land, drought, in problem soil and with weed infestation, with disease and pests. Rice plays a significant role in the national economy, contributing 20% to the agricultural AGDP in the country. It accounts for 53 % of the total food grain production and more than 50% of the agricultural area. Rice also meets more than 50% of the total calories requirement and closely linked with the national economic growth.

Energy use is one of the key indicators for developing more sustainable agricultural practices (Streimikiene *et al.*, 2007) and efficient use of energy is one of the principal requirements of sustainable agriculture (Kizilaslan., 2009). Energy is one of the most important inputs in agricultural production process and is expended in every step starting from land preparation to value addition (Devasenapathy *et al.*, 2009). Agriculture is closely linked with energy and can as a consumer and supplier of energy in the form of biomass energy (Alam *et al.*, 2005). The energy consumption in the agricultural sector depends on soil type, tillage operation, fertilizers, harvesting, threshing operations and grain and biomass yield (Baishya and Sharma., 1990; Singh *et al.*, 1997). In future, agriculture not only growing demand for food supply does not meet demand, but fuel and livestock feed will also affect (Alam *et al.*, 2005). The efficient use of the energy resources is vital in terms of increasing production, productivity as well as sustainability of agriculture. Energy auditing is one of the most common approaches to examining energy efficiency. It enables to calculate output-input ratio, relevant indicators and energy use patterns in an agricultural activity and also, provides

sufficient data to establish functional forms to investigate the relationship between energy inputs and outputs. Estimating these functional forms is very useful for determining elasticity of inputs on yield and production (Hatirli *et al.*, 2006).

The input energy is also classified into direct, indirect and renewable, nonrenewable forms energy equivalents for different inputs and outputs in agricultural production. Indirect energy consists of seeds, chemical fertilizer, chemical poison, and machinery energy while direct energy covered human labor, water and diesel fuel used in the rice production. Non-renewable energy includes diesel fuel, chemical fertilizer, chemical poison and machinery and renewable energy consists of human labor, water and seed. Direct energy is required to perform various tasks related to crop production processes such as land preparation, irrigation, intercultural operations, threshing, harvesting and transportation of agricultural inputs and farm products (Singh 2000). Indirect energy consists of the energy used in the manufacture, packaging and transport of fertilizers, pesticides and farm machinery (CAEEDAC, 2000; Kennedy 2000). As the term addresses, indirect energy is not directly used on the farm. Major items for indirect energy are fertilizers, seeds, machinery production and pesticides. Calculating energy input in agricultural production is more difficult in comparison to the industry sector due to the high number of factors affecting agricultural production (Yaldiz *et al.,* 1993).

The cost of cultivation is equally important for the resource-poor farmers of many regions. Higher cost of cultivation relative to the returns from rice cultivation is a major concern among the rice farmers (Das *et al.*, 2014). Mechanization of cultivation system involves higher amount of energy expenditure but reduces cost of cultivation (Mandal *et al.*, 2002). Further, the mechanization ensures timeliness of agricultural operations, while increasing both the productivity and net returns over those performed by manual labor or draft animals. Therefore, it is important to identify efficient rice farming systems condition in terms of the EUE and the cost. The present study was undertaken with the objective to quantify the economic and energy use efficiencies of rice grown under DSR and TPR conditions. The hypothesis tested was that rice conditions which requires less tillage and inputs saves energy and reduces cost of cultivation.

The objective of our study was to quantify the economic and energy efficiencies of rice production under direct seeded and transplanted conditions of mid hill Nepal. These practices are existing practices in our contest but that cannot help to achieve food security and high return. This is due to increase in cost of cultivation and less yield due to inefficient use of input resources and traditional cultivation of rice under different conditions.

Materials and Method

The experiment was carried out at the Institute of Agriculture and Animal Science, Lamjung Campus, during the kharif season of 2015 (June- October) to study the economic and energy use efficiencies of rice in mid hill condition of Nepal. Geographically, it is located at elevation of 700m with the latitude of 28° 7' to 28° 10' N and longitude of 84° 24' to 84° 28' E. The experimental plot was cropped with rainfed rice when the field ploughed. Five varieties of rice differing in phenology and growth (viz. US382, Sukha dhan, NR10676, NR10490 and Khumal10) were tested in Randomized Complete Block Design under DSR and TPR conditions with three replications.

The various management practices followed and inputs used in DSR and TPR conditions. Manual labour is used for all agronomic operations except for land preparation, which is under taken with both manual labour and two wheel tractors. In DSR two ploughing operations were performed at 1 week before sowing. Line sowing performed manually with spade at 23rd June 2015. For TPR, nurseries were sown at same day. The 26 days old seedlings were transplanted at spacing of 20×20 cm. The seed rates were 20 kg ha^{-1} for US382 and 40 kg ha^{-1} for other treatments.

For a better nutrient management different fertilizers were applied. The fertilizer was applied in recommended dose of 100:30:30 NPK kg ha^{-1} whereas nitrogen was applied in 3 split doses. 50 % of nitrogen with all dose of P and K applied as basal dose during transplanting. Remaining 50% of nitrogen was applied in 2 split doses and top dressed at tillering and panicle initiation stages. The intercultural DSR and TPR plots were weeded by manually at 25 and 45 DAS and DAT respectively. Harvesting was done in 9-11 October 2015 for direct seeded and in 25-27 October 2015 for transplanted conditions. The net plots of area 18 m^2 were harvested and it was left two days in field for sun drying. Threshing was carried out manually which was locally adopted method of threshing.

The total energy input and output of DSR and TPR conditions were estimated by using the energy equivalents (Table 1) as suggested by Devsenapathy *et al.*, 2009. The energy input through land preparation, seed bed preparation, seed sowing, transplanting, fertilizer application, intercultural operations, harvesting and threshing expressed as human labour. Seed, fertilizer and fuel use for cultivation were calculated. The energy output was calculated by accumulating the main product and by-product produced.

The different energy indices parameters were calculated as below;

Energy use efficiency
EUE = Output energy (MJ ha^{-1}) / Input energy (MJ ha^{-1})

Net energy

Net energy = Output energy (MJ ha^{-1}) - Input energy (MJ ha^{-1})

Partial factor productivity

It was calculated by dividing economic yield with total NPK fertilizers applied to the different conditions.

Table 1: Energy equivalents for different inputs and outputs in rice production

Items	Unit	Energy equivalent (MJ/unit)
Inputs		
Seed	Kg	14.7
Fertilizers		
N	Kg	60.6
P	Kg	11.1
K	Kg	6.7
Fuel	L	56.3
Labour	Hr	1.96
Outputs		
Main product	Kg	14.7
By-product	Kg	12.5

(Devsenapathy *et al.*, 2009)

Nutrient uptake

The nutrient uptake was calculated on the basis of their respective dry matter yield at harvest and the system uptake NPK were estimated.

Economic analysis

The following economic parameters were calculated based on input and output costs were computed.

Cost of cultivation

Cost of cultivation was calculated on the basis of local market for different agro-inputs.

Gross return

Economic yield (grain + straw) of rice was converted into gross return (Rs. ha^{-1}).

Net return

Net return = (Product cost + Byproduct cost) – Input cost

B : C ratio

It was calculated by the formula, B:C ratio = Gross return / Cost of cultivation

Statistical analysis

The data obtained were statistically analyzed using SPSS and GenStat discovery software to compare the differences between means of different cultivation systems at 5% level of significance (P= 0.05).

Results and Discussion

The results obtained during the experiment were analyzed and are presented in this chapter with the help of the figures wherever necessary. The results obtained are discussed with possible reasons and literature support.

In input energy, these were not analyzed because the DSR and TPR showed significantly different. The DSR required lowest input than TPR. In TPR, extra human labour required in seedbed preparation and transplanting.Tillage operations used considerable amount of energy for land preparation. The energy requirement for land preparation was less in DSR condition, which is among its major advantages over the TPR. For seeding and transplanting, it required higher energy input than DSR because it used higher manpower to establish nursery as well as transplanting. So that, direct seeding reduced the energy input by 22% as compared to TPR because there was no need for nursery and tillage operation reduced (Das *et al.*, 2014).

The output energy produced by rice varieties TPR NR10490 (2.05×10^5 MJ ha^{-1}), TPR US382, TPR Kumal-10 was found to be significantly higher than that produced by other treatments. The treatments TPR Sukha and TPR NR10676 showed intermediate production of output energy while all other direct seeded rice varieties produced significantly low energy output. The TPR yielded the highest energy output because it produced the highest grain and plant biomass compared with the other treatments. Higher rice productivity under TPR than those under DSR condition (9.6%, Das *et al.*, 2014) have been reported in other studies. The yield advantage in TPR can be attributed to adequate moisture, low weed infestation and good crop establishment. The DSR methods produced the lowest total energy output because of poor crop establishment and poor productivity (Mandal *et al.*, 2015).
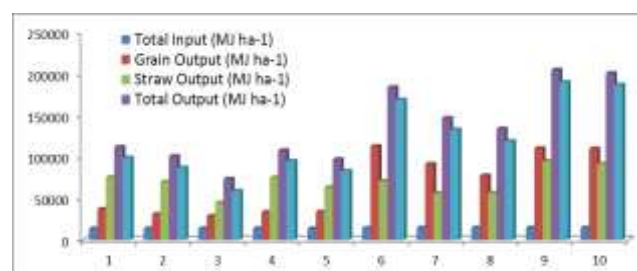

Fig. 1: Energy input, output and net output in DSR and TPR treatments. [Treatments: 1- DSR+US38, 2- DSR+Sukhadhan, 3- DSR+NR10676, 4- DSR+NR10490, 5- DSR+Khumal-10, 6- TPR+US382, 7- TPR+Sukhadhan, 8- TPR+ NR10676, 9- TPR+NR10490, 10- TPR+Khumal-10]

Net energy also showed significant variation among the treatments. Higher net energy was noted in transplanted treatments being highest in TPR NR10590 (1.9×10^5 MJ ha^{-1}) and TPR Khumal-10 (1.87×10^5 MJ ha^{-1}). Direct seeded treatments showed significantly lower net energy. The net

energy output was significantly lower in DSR than TPR due to lower productivity of main product and byproduct. Less productivity in DSR may be due to lower tillering, high weed infestation and bad crop establishment. Further, productivity of straw or biomass was more in TPR leading to a higher biomass energy production than that in the DSR condition. Net energy output in TPR conditions was higher than that in the DSR due to high productivity and good crop establishment (Mandal *et al.*, 2015).
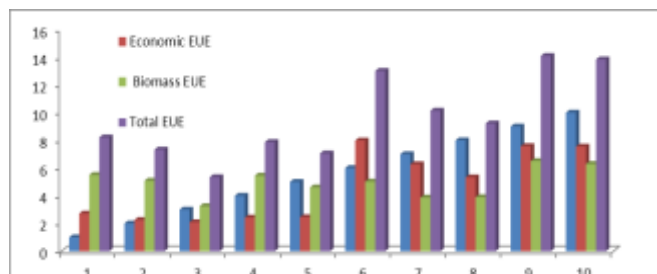

Fig. 2: Energy use efficiency (EUE) of DSR and TPR conditions. [Treatments: 1- DSR+US38, 2- DSR+Sukhadhan, 3- DSR+NR10676, 4-DSR+NR10490, 5- DSR+Khumal-10, 6- TPR+US382, 7- TPR+Sukhadhan, 8- TPR+ NR10676, 9- TPR+NR10490, 10- TPR+Khumal-10]

From the Fig. 2, TPR US382 gave the highest economic EUE (7.6) which was statistically at par with the treatments TPR NR10490 and TPR khumal-10. While the treatments DSR US382, DSR Sukha, DSR NR10676 (2.1), DSR NR10490 and DSR Khumal-10 yielded similar and lowest amount of rice. The economic EUE of rice treatments TPR NR10676, TPR Sukha lied intermediate with comparison the different treatments. DSR is both cost and labor saving but low productivity due to weed infestation and bad crop establishment although grain yield in DSR is comparatively less than that of TPR (Farooq *et al.*, 2006; Naklang *et al.*, 1996). This was also supported by Hasan *et al.*, 2011; TPR was the most effective method due to its effect on some yield components such as grain number per panicle, plant height and panicle length.

While biomass EUE was concerned, the treatment TPR NR10490 showed highest biomass EUE (6.5) being statistically at par with straw yields of other treatments DSR US382, DSR Sukha, DSR NR10490, TPR US382 and TPR Khumal-10. Biomass in case of DSR NR10676 was noted to be lowest (3.24). Similarly, other treatments DSR Khumal-10, TPR Sukhadhan and TPR NR10676 also showed lower biomass EUE to above mentioned treatments. Biomass is a function of vegetative growth. Balanced and optimum used of fertilizers and good crop stand increases plant height, green leaves/hill, tillers/hill and dry matter production which finally resulted in higher straw yield. Similar result was reported by Mirza *et al.*, 2010.

From the Fig. 2, significant result was found in energy use efficiency. The variety TPR NR10490 (14), TPR US382, TPR Khumal-10 showed the highest energy use efficiency. The DSR Sukha, DSR NR10676, DSR NR10590, DSR

Khumal-10 noted the lowest in comparison with other varieties. The other varieties like TPR Sukha, TPR NR10676 and DSR US382 lied intermediate among mentioned treatments in terms of energy use efficiency.TPR gave higher energy use efficiency as compared to DSR (Singh *et al.*, 2005) the high energy use efficiency under TPR condition was due to higher productivity resulting because of good crop stand and low weed infestation causes increase in tiller number, grain number per panicle, weight of grains and length of panicle.
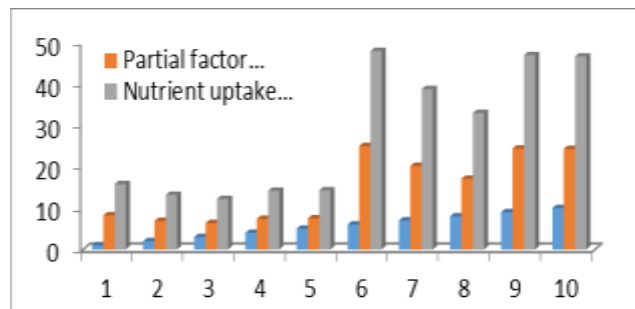

Fig. 3: Partial-factor productivity and nutrient uptake in DSR and TPR conditions. [Treatments: 1- DSR+US38, 2- DSR+Sukhadhan, 3-DSR+NR10676, 4- DSR+NR10490, 5- DSR+Khumal-10, 6- TPR+US382, 7- TPR+Sukhadhan, 8- TPR+ NR10676, 9-TPR+NR10490, 10- TPR+Khumal-10]

From the Fig. 3, TPR US382 was noted higher partial factor productivity (25) being statistically at par with TPR NR10490 and TPR Khumal-10 while the lowest was found in all DSR treatments. The TPR Sukhadhan and TPR NR10676 were showed the intermediate partial factor productivity among different treatments.

In terms of nutrient uptake, the treatment TPR US382 (48 kg ha^{-1}) were noted the higher nutrient uptake which were statistically at par with TPR NR10490, TPR Khumal-10. While the DSR treatments showed lowest and similar nutrient uptake. The intermediate nutrient uptake was noted in TPR Sukhadhan and TPR NR10676.

The input cost of all treatments was similar and there were no significant difference. In all treatments we had applied similar input. The input costs of DSR treatments were low as compared to TPR because of tillage operation and no preparation of seedbed.
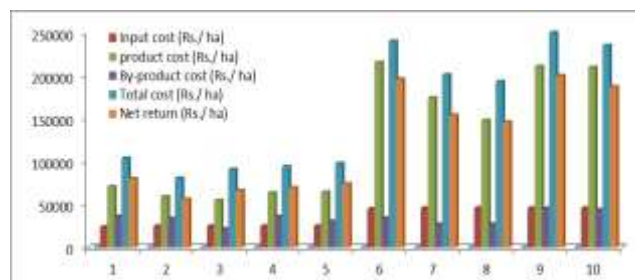

Fig. 4: Input cost, Total cost and Net return in DSR and TPR conditions of rice. [Treatments: 1- DSR+US38, 2- DSR+Sukhadhan, 3- DSR+NR10676, 4- DSR+NR10490, 5- DSR+Khumal-10, 6- TPR+US382, 7- TPR+Sukhadhan, 8- TPR+ NR10676, 9- TPR+NR10490, 10- TPR+Khumal-10]

From the Fig. 4, TPR NR10490(Rs.2.55×10^5) gave the highest output which was statistically at par with TPR Khumal-10 and TPR US382 while all the DSR treatments gave the lowest output. With comparison with other, treatment TPR Sukhadhan was noted intermediate treatment.

In terms of benefit, the highest benefit obtained from TPR NR10490 (Rs.2.55×10^5) which was statistically at par with TPR Khumal-10 and TPR US382. The lowest benefit was obtained from DSR US382, DSR Sukhadhan, DSR NR10676, DSR NR10490 and DSR Khumal-10. The TPR Sukhadhan, TPR NR10676 gave intermediate benefit among different treatments. The higher net benefit was found in TPR due to higher output of grain as well as straw yields due to low weed infestation and good crop establishment.
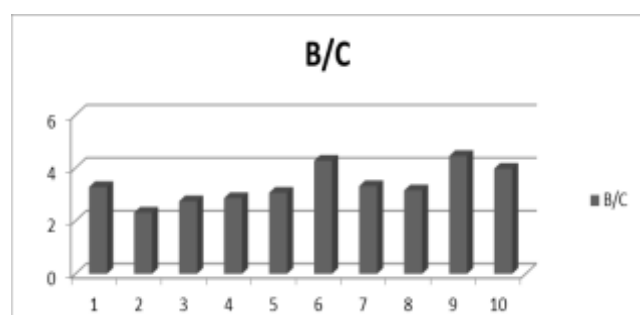

Fig. 5: Benefit cost ratio (B/C) of DSR and TPR conditions.

The highest benefit cost ratio was given by treatments TPR NR10490 (4.45) which were statistically at par with TPR US382 and TPR Khumal-10. The TPR Sukhadhan, TPR NR10676 and DSR US382 showed intermediate benefit cost ratio while DSR Sukhadhan (2.31), DSR NR10676, DSR NR10490 and DSR Khumal-10 gave lower benefit cost ratio.

Conclusion

The treatments TPR+NR10490 and TPR+Khumal-10 were showed best result in condition of EUE. The grain yield of US382 was higher due to genetic character. The increase in grain as well as straw which increases the output causes increase in energy use efficiency. In case of economic analysis, TPR+NR10490 and TPR+US382 were noted best result than other treatments of DSR and TPR. Despite of high input which resulted high output due to low weed infestation and good crop establishment in TPR condition.

According to result of this research, the economic and energy use efficiency, the condition of the management of energy consumption on DSR condition was more suitable. Despite of low energy consumption there was lower output. The TPR condition showed higher energy consumption as well as higher output which results highest net return than the DSR. So that TPR is better than DSR condition.

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