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Energy budgeting and global warming potential of traditional rice production system in Eastern Ghats region of Odisha

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Abstract

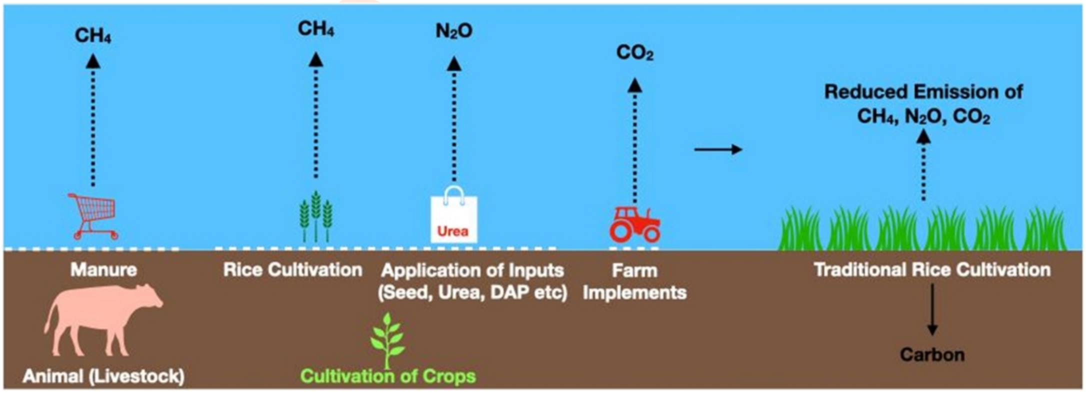
Aim: This study aims to focus on traditional agricultural practices which are gaining momentum around the globe as an energy efficient and sustainable approach in the changing climate condition. In this study, an attempt was under taken to quantify the energy use, green house gas emission and global warming potential of rice cultivated by traditional method in terraced low land.

Methodology: The data were collected through Focused Group Discussion (FGD) from farmers of the study area using the questionnaire. The sample size was calculated by Neyman method.

Results: Total input and output energy required for traditional rice production were 8513.0 MJ ha^{-1} and 77356.88 MJ ha^{-1}, respectively. Energy use efficiency was calculated as 9.01. Total global warming potential (GWP) was 610.19 CO$_2$ eq ha^{-1}. In this study, the output and input carbon were found to be 2580.48 and 164.75 kg C ha^{-1}, respectively and the carbon efficiency ratio was 15.66. Energy productivity of this traditional method of rice production system was approximately 1.21 to 3.64 times higher than that of other rice production system.

Interpretation: Rice is the staple food of tribal's habited in the highland region of Eastern Ghats Odisha, India, and these tribal people mostly cultivate rice by traditional method. This traditional rice production system can be considered as an environmental friendly and sustainable agricultural system in this changing climatic condition, and this system is also economical than the conventional rice cultivation practices.

Key words: Budgeting, Energy, Eastern Ghats, Green house gases, Global warming, Rice



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Introduction

Global warming is much talked upon topic of this century throughout the globe. The causes of global warming are mostly attributed to emission of green house gases like carbon dioxide, methane and nitrous oxide (Pathak *et al.,* 2007) as per the 6th IPCC report annual assessment. It was reported that since 2011 (measurements reported in AR5), the concentrations of green house gases have continued to increase in the atmosphere, reaching annual average of 410 ppm for carbon dioxide, 1866 ppb for methane, and 332 ppb for nitrous oxide in 2019, respectively, (IPCC, 2021). Currently, the emission of green house gases and consumption of high energy requiring inputs in agriculture (nitrogen and fossil fuels) are two important issues and will remain critical in future as there is a great challenge to achieve food and nutritional security for the ever-growing population. The reports suggest that the annual emission of green house gases from agriculture is 5.1-6.1 Pg CO_2 eq., contributing nearly 10-20% of the global green house gas emission (Smith *et al.,* 2007). In future, with increase in the population, demand for food grain will increase, thereby the emission of green house gases will increase proportionately, which is a very challenging task (Gilbert, 2011).

Rice is the lifeline of South-east Asian people. Out of 154 million ha of global rice harvested area, South-east Asia alone contributes 48 million ha (Yuan *et al*., 2022). It is the staple food of about 650 million people (Sabran *et al.,* 2023) of the South-east Asia region and feeding the population for over 4000 years. In Indian agriculture, rice occupies an important place as it is cultivated in 46.4 million ha of land and producing 130.3 million tons (Economic Survey, 2022-23). In India, the major rice producing states are Andhra Pradesh, Bihar, Uttar Pradesh, Madhya Pradesh, West Bengal and Odisha. In Odisha, the area under rice cultivation is 4.02 million ha with an average productivity of 2354 kg ha^{-1} rice (Odisha Economic Survey, 2022-23) and 6-7% of the area is cultivable under puddle rice. Rice constitutes a significant component of major food staples in the highland region of Eastern Ghats, Odisha. In this tribal dominated region, rice is cultivated across a range of agro-ecosystem, including upland and low land, irrigated and rain-fed landscapes, occupying 55% of the total cultivated land (Dash *et al*., 2019a).

In the Eastern Ghats highland region, the rice cultivation is mostly practiced in the terraced low land (locally known as *Jhola* land) through out the year, which are modified streambeds having good moisture condition. Reduction in energy inputs, thereby increasing energy use efficiency and reducing emission of green house gases are essential to ensure energy security and long-term sustainability of rice production. In Punjab state of India, it was observed that among various category of rice cultivating farmers, small farmers (land holding 1-2 ha) had a high energy ratio and a low specific energy requirement in comparison to large farmers land holding greater then 10 ha (Nassiri and Singh, 2009). In another study, it was reported that rice production in the Guilan and Mazandaran province, Iran used a total energy input of 39333 and 40624 MJ ha^{-1} and the energy ratio was 1.53 and 1.8, respectively (Pishgar-Komleh *et al.,* 2011 a; Firouzi *et al.,* 2016). The energy efficiency of rice production in the Mazandaran Province, Iran was 1.83 (Firouzi *et al.,* 2016). In China and Australia, the average energy use efficiency of rice cultivation was reported to be 2.75 and 6.7, respectively (Khan *et al.,* 2009; Khan *et al.,* 2010). Similarly, in India researchers have reported low energy use efficiency for rice production (Pawar *et al.,* 2018; Seal *et al.,* 2017). Not only low energy use efficiency of rice, it is considered as one of the most important sources of green house gases and have significantly contributed towards global warming. The average global warming potential of rice varied between 1865 and 8425 kg CO_2 eq. ha^{-1} under different management strategies in the Indo-Gangetic Plains of India (Gupta *et al.,* 2015). In the southern region of India, it was reported that the GWP of rice production ranged from 3439 to 5812 kg CO_2 eq. ha^{-1} under conventional and various modified rice cultivation system (Pathak *et al.,* 2003 and Oo *et al.,* 2018).

It is clear that global warming potential of rice will be a great concern in achieving the future food demand. Traditional agricultural practices are gaining importance around the globe as a sustainable approach in this changing climatic condition. The benefits of traditional agricultural systems include increase in crop production, protection and conservation of biodiversity, requirement of low energy inputs and climate change mitigation (Srivastava *et al.,* 2016; Singh and Singh, 2017). This terraced low land rice cultivation is considered as the rice bowl of the tribals. However, there has been no study on energy consumption and green house gases emission from this traditional rice production system till date. In this regard, study on this aspect will give more information related to traditional rice cultivation and will help in popularizing rice cultivation system to deal with climate crisis with respect to energy budgeting and global warming potential. Therefore, this study was conducted to estimate the energy use efficiency and determine the global warming potential of traditional rice production system under terraced low land in the highland region of Eastern Ghats. Previous studies were performed under conventional rice production system, however, in this study the energy budgeting and global warming potential was studied under traditional rice cultivation.

Materials and Methods

Study area: The Koraput district is the tribal dominated part of Eastern Ghats highland region of Odisha located between 81° 05´ to 83° 05´ East longitude and 18º 04´ to 19° 05´ North latitude (Fig. 1), and is popularly known as the land of aboriginals (Raut *et al.,* 2013). The district is home to as many as 25 different tribal communities. The monthly variation in rainfall, the maximum and minimum temperature of the study area are presented in Fig 2. The mean maximum and minimum temperatures of the study area are 36.2 ºC and 24.3 ºC (Adhikary *et al.,* 2015). The study area is bestowed with a good annual average rainfall of 1452 mm occurring over 70 days in a year. The agricultural production system in the area is mostly rain-fed and mono-cropped because the farmers are dependent on monsoon and mono cropping requires less cultural and management practices. Rain-fed up land and medium land are used for cultivation of upland paddy

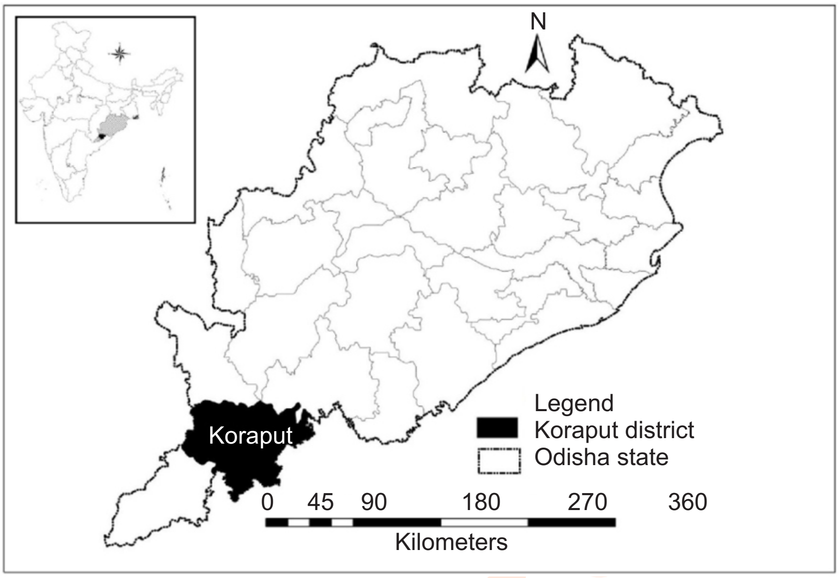

Fig. 1: Location map of the study area.

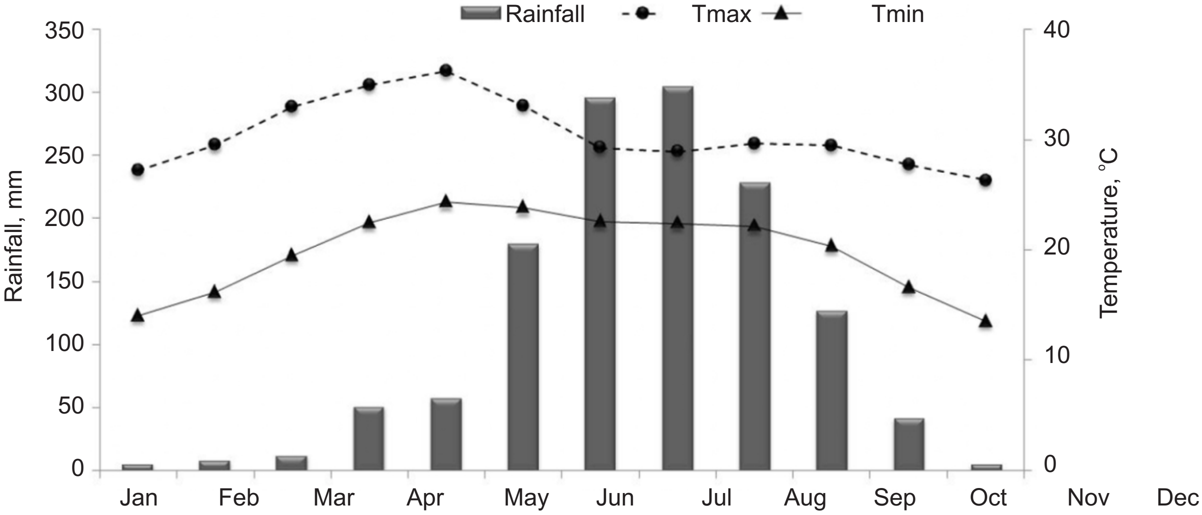

Fig. 2: Longterm (1901-2018) monthly variation of rainfall, maximum temperature and minimum temperature in the study area.

(*Oryza sativa*), maize (*Zea mays*), little millet (*Panicum sumatranse*) and finger millet (*Eleusine coracana*) during rainy season whereas niger (*Guizotia abyssinica*), and mustard (*Brassica juncea*) are cultivated during winter season. Soils are rich in organic carbon (0.5-0.7%), low to medium in available nitrogen (174-294 kg ha^{-1}), medium to high in soil available phosphorous (10.6-23.7 kg ha^{-1}) and low to high in available potassium content (91-345 kg ha^{-1}).

Data collection: The study was conducted in the Koraput district, Odisha and data was collected from 95 tribal farmers practicing traditional rice cultivation in terraced low land. The age of the respondent farmers varied between 25 to 62 years. A questionnaire was prepared and different information regarding rice cultivation practices, kinds of external and internal inputs used by these farmers for rice cultivation was collected through Focused Group Discussion (FGD). The sample size was

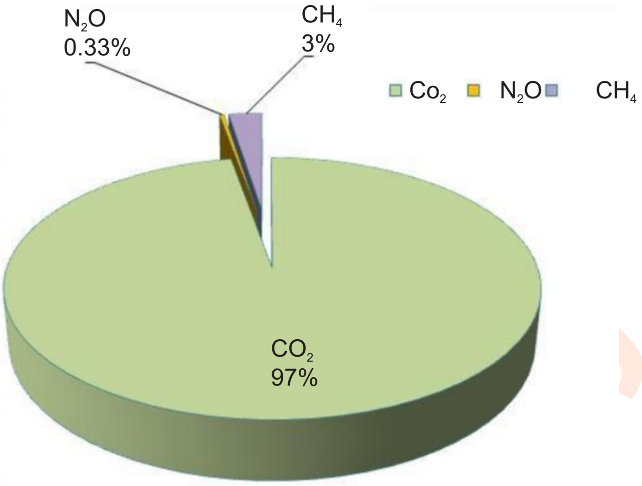

Fig. 3: Share of carbon dioxide (CO_2), nitrogen oxide (N_2O) and methane (CH_4) in traditional terraced low land rice production system.

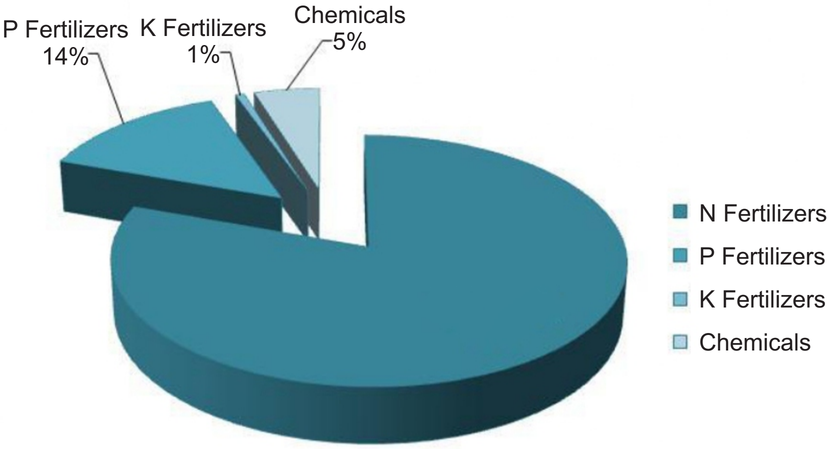

Fig. 4: Share of different chemical inputs (%) to total green house gas emission in traditional terraced low land rice production system.

calculated by the Neyman method (Yamane, 1967).

Land and crop management: Majority of the farmers prefer to prepare the land manually either with the help of a spade or use of bullocks or buffalos depending upon the availability of resources. Wooden or iron plough was used for ploughing the field by bullocks or buffalos. Transplanting was mostly carried out by women and supported by men in standing water. Only few farmers followed proper line spacing and in most cases, they followed random planting. Single seedling was planted on a hill for high yielding varieties (hybrid) and 2-3 seedlings for local varieties at 52.8 kg ha^{-1}. At the time of final land preparation, Gromor (28:28:0) was applied @ 100 kg ha^{-1} and within 8-10 days after transplanting when seedling stand was established and root development began, urea top dressing was done. Urea and Murate of Potash were manually applied @ 75 and 25 kg ha^{-1} after weeding. On an average, 34.5 kg N, 16 kg P and 11 kg K was applied per ha in the rice production system. Besides chemical fertilizers, about 271 kg ha^{-1} Farm Yard Manure was applied before land preparation. Pest and diseases were manged by chemical treatments. Harvesting of rice was done manually with locally available sickle. Women were employed for harvesting, bundling, transportation, while threshing and cleaning operations were carried out by males. Threshing was done by moving a group of bullocks tied together on spread out heap of harvested paddy.

Analysis of energy: The energy equivalents of inputs and output of traditional rice production system, were estimated using

Table 1: Energy equivalents of input and output in rice production systems

Inputs and Output	Unit	Equivalent energy	References
A. Inputs			
Labour			
Men	man-h	1.96	Yousefi and Mohammadi (2011)
Women	woman- h	1.57	Yousefi and Mohammadi (2011)
Animals	pair-h	10.1	Yousefi and Mohammadi (2011)
Chemical Fertilizers			
Nitrogen	kg	60.6	Ozkan *et al.* (2004)
Phosphorus	kg	11.1	Ozkan *et al.* (2004)
Potash	kg	6.7	Ozkan *et al.* (2004)
Farm Yard Manure	kg	0.3	Soltani *et al.* (2013)
Chemicals	kg	120	Demircan *et al.* (2006)
Seed	kg	15.7	Singh and Mittal (1992); Ozkan *et al.* (2004)
B. Output			
Rice Yield			
Grain	kg	14.7	Singh and Mittal (1992); Ozkan *et al.* (2004)
Straw	kg	12.5	Singh *et al.* (2019)

Table 2: Embodied energy and GHG emission of agricultural inputs

Input	Unit	Energy, (MJ)	CO_2	CH_4	N_2O	References
Internal input (Labour + animal)	MJ day^{-1}	43.0	3.20	0.00018	0.00123	Kongshaug (1998); West and Marland (2002)
Fertilizer Nitrogen	MJ kg^{-1}	49.5	2.60	0.003	0	Singh and Mittal (1992); Kongshaug (1998)
Phosphorus	MJ kg^{-1}	7.2	1.60	0.002	0	Ozkan *et al.* (2004); Ferrell (2006); Yousefi and Mohammadi (2011)
Potassium	MJ kg^{-1}	11.3	0.70	0.001	0	Ferrell (2006)
Chemicals	MJ kg^{-1}	358.0	25.10	0.036	0.0003	Liska *et al.* (2009)
Seeds	MJ kg^{-1}	9.7	0.70	0.000004	0.0003	Liska *et al.* (2009)

secondary information, which are presented in Table 1. Human and animal labour, diesel, chemical fertilizers, pesticides and seeds are important agricultural inputs whereas rice grain and straw are output. In this study, the environmental sources of energy such as solar energy, wind energy, rain, soil organic matter and soil were not considered. Energy indices such as energy use efficiency, energy productivity, specific energy and net energy were computed for traditional rice production system under terraced low land by the Equations given by Soltani *et al.* (2013).

$$\text{Energy use efficiency} = \frac{\text{Output energy (MJ ha}^{-1}\text{)}}{\text{Intput energy (MJ ha}^{-1}\text{)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

$$\text{Energy productivity} = \frac{\text{Crop output (kg ha}^{-1}\text{)}}{\text{Intput energy (MJ ha}^{-1}\text{)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

$$\text{Specific energy} = \frac{\text{Energy output (MJ ha}^{-1}\text{)}}{\text{Crop output (kg ha}^{-1}\text{)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

$$\text{Net energy} = \text{Energy output (MJ ha}^{-1}\text{)} - \text{Energy input (MJ ha}^{-1}\text{)} \ldots\ldots \text{(4)}$$

Inputs consumed in traditional rice production system under terraced low land were classified into direct energy and indirect energy, renewable energy and non-renewable energy sources and commercial energy and non-commercial energy (Yuan and Peng, 2017). Direct energy sources include human labour while indirect energy sources were seeds, chemical fertilizers and pesticides. Similarly, renewable energy included human labour and seeds whereas non-renewable energy included pesticides and chemical fertilizers. Commercial energy consisted diesel, pesticides, chemical fertilizers, seeds and non-commercial energy consisted of human labour. The input related to each group (direct energy, indirect energy, renewable energy, non-renewable energy and non-commercial energy) were calculated and finally different groups of energy were assessed.

Estimation of global warming potential: Global warming potential of rice under terraced low land was estimated from the internal and external inputs used in the production system using (Table 2). The amount of greenhouse gases emitted from chemical inputs per hectare were calculated by using. Emission

Table 3: Gaseous emissions (g) per unit of chemical sources and their global warming potential (Green 1987; Snyder *et al.*, 2009)

Input	CO_2	N_2O	CH_4
Fertilizers			
Nitrogen	3100	0.03	3.70
Phosphorus	1000	0.02	1.80
Potash	700	0.01	1.00
Chemicals	5100	0.02	0.01

Table 4: Energy inputs, output and their percentage in traditional terraced low land (jhola) rice production system

Input and Output	Quantity per unit area (ha)	Total energy equivalent	Percent
A. Inputs			
Human Labour			
Men	78.15	1225.39	14.28
Women	170.39	2140.10	24.94
Animals	35.26	1958.69	22.83
Total Internal Energy Input		5324.18	62.05
Chemical fertilizers			
Nitrogen	34.52	2091.912	24.38
Phosphorus	16.00	177.6	2.07
Potash	11.00	73.7	0.86
Farmyard manure	271.00	81.3	0.95
Chemicals	0.34	3.40	0.04
Seed	52.8	828.96	9.66
Total External Energy Input		3256.87	37.95
Total Input Energy (External)		8581.06	100.00
B. Output			
Rice Yield (Grain)	2580.4	37931.88	49.03
Rice Yield (Straw)	3154.0	39425.0	50.97
Total Output Energy		77356.88	100.00

coefficients of chemical inputs as presented in Table 3. Each greenhouse gas (CO_2, CH_4 and N_2O) has a global warming potential, which is the warming potential relative to that of CO_2. The gas emissions are measured in terms of a reference gas, CO_2. The gas emissions are measured in terms of a reference gas, CO_2 (IPCC, 1995). The GWP of CO_2, CH_4 and N_2O are 1, 21 and 310 respectively. The total greenhouse gas emissions were determined by the equation given by Kramer (1999).

$$\text{Green house effect} = \sum GWP_i \times M_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . \ (5)$$

where, M_i is the mass (kg) of the emission gas. The score is expressed in terms of CO_2 equivalents. The carbon efficiency ratio (CER) was calculated by using Eq. (6).

$$\text{Carbon efficiency ratio} = \frac{\text{Carbon content of yield (kg C ha}^{-1}\text{)}}{\text{Carbon emission (kg C ha}^{-1}\text{)}} \ldots\ldots\ldots \ (6)$$

The carbon content of yield was obtained by multiplying the rice yield with 0.45 (Bolinder *et al.,* 2007; Yosefi *et al.,* 2014). Similarly, the carbon emission was estimated by multiplying the total global warming potential of rice with 0.27.

Statistical Analysis: One-way ANOVA was calculated using the excel software of Microsoft. All the values were calculated in Excel and the mean values were used for interpretation.

Results and Discussion

Input used and output in rice production system, their energy equivalents and the percentage are presented in Table 4. Total internal and external energy inputs were 5324.18 MJ ha^{-1} and 3256.87 MJ ha^{-1}, respectively, where as the total input energy was 8581.06 MJ ha^{-1}. The results showed that among all the inputs used, the share of energy used by women labour was highest (25.14%), followed by nitrogen fertilizer (24.57%). The energy consumed by labour (includes men, women and animal) was nearly 62.5% of total energy because of traditional methods of paddy cultivation. All the fertilizers together contributed 27.53% to the total energy and this result is in accordance with the previous reports (Kazemi *et al.,* 2015; Yuan and Peng, 2017; Pawar *et al.,* 2018). Among the fertilizers, nitrogen in particular was the largest contributor followed by phosphorus, and the least was contributed by potash. Similar results were also reported by Pawar *et al.* (2018) for the Konkan region of Maharashtra and Soni *et al.* (2018) for the Indo-Gangetic Plain, India. In this study

Table 5: Energy use Indicators of energy use in traditional terraced low land (*jhola*) rice production system

Indicators	**Quantity**
Input Energy (MJ ha^{-1})	8581.06
Internal Energy Input (Labours) (MJ ha^{-1})	5324.18
External Energy Input (MJ ha^{-1})	3256.87
Output Energy (MJ ha^{-1})	77356.88
Rice Yield (kg ha^{-1})	2580.00
Energy Use Efficiency	9.01
Energy Productivity (MJ ha^{-1})	0.30
Specific Energy (MJ kg^{-1})	29.98
Net Energy (MJ ha^{-1})	68775.82
Internal to External Energy Input Ratio	1.63

Table 6: Total energy input in form of direct, indirect, renewable and non-renewable for rice production

Indicators	**Quantity**	**Percentage**
Direct Energy	5324.183	62.54
Indirect Energy	3256.87	38.26
Renewable Energy	6085.559	71.49
Non Renewable Energy	2427.912	28.52
Non Commercial Energy	3365.49	39.53

the lowest share of input energy was recorded from farm yard manure (1.0%). The rice and paddy straw yield were 2580.4 and 3154.0 kg ha^{-1} and their energy equivalents were 37931.88 MJ ha^{-1} and 39425.00 MJ ha^{-1}, respectively (Table 4). Hence, for natural farming the nitrogenous crops must be included in the field for fulfilling the nitrogen requirements. Various indicators of energy use in traditional rice production system are presented in Table 5. Energy use efficiency for rice production system was 9.01. The low energy use efficiency of rice is because of high-energy consumption in rice production due to high water requirement of the crop (Pathak and Bining, 1985; Yuan and Peng, 2017). Similar results on energy use efficiency was reported for rice-wheat cropping system in Indo-Gangetic plains (Soni *et al.*, 2018) and Doon valley of India (Diljun *et al.*, 2022). In another study energy use efficiency of rice varied between 5.4 to 11.53 in China (Yan *et al.,* 2023), 3.49 for rice cultivated in Konkan region (Pawar *et al.*, 2018), 2.07 in West Bengal of India (Seal *et al.*, 2017). In this study, the energy productivity for rice was 0.30 kg MJ^{-1} which indicated the rice yield per unit input energy to be 0.30 kg. The energy productivity of rice in the Eastern Ghats highland region was observed to be higher than those reported by other researchers around the globe. Energy the productivity value of 0.33 kg MJ^{-1} was reported for wet land rice cultivated in North-east India (Choudhary *et al.,* 2013). Similarly, Pawar *et al.* (2018) observed 0.11 kg MJ^{-1} as energy productivity for rice cultivated in the South-west India. The average energy productivity for rice was reported as 0.27 kg MJ^{-1} in Central China (Yuan and Peng, 2017). Similarly, a very low value of energy productivity (0.19 kg MJ^{-1}) for rice was reported by Khan *et al.* (2009) and Xiang *et al.* (2023). The net energy of this rice production system was 68775.82 MJ ha^{-1}. The net energy for rice cultivated in the South-western India was higher than the result obtained in this study.

Total energy input in the form of direct, indirect, renewable and non-renewable for rice production is given in Table 6. Direct and indirect energy inputs were 62.54 and 38.26 %, respectively. It is clear from the results that consumption of direct energy was higher than that of indirect energy in this traditional rice production system. Similar pattern of energy consumption was also recorded for renewable (71.48%) and non-renewable energy (28.52%). The result of this study was found to be similar to the reports of Choudhary *et al.* (2013) for wet land rice in North-east India. Seal *et al.* (2017) reported that there was consumption of 71% more renewable energy in case of organic rice farming than conventional farmers practice in West Bengal, India. In this study, the higher share of direct energy and renewable energy indicates lesser use of chemical fertilizers by the farmers in their field, which can be evidenced from work carried out by Dash *et al.* (2019a) and the reports published by the Government of Odisha reporting the fertilizer consumption rate in Koraput district, Odisha, India to be 67.88 kg ha^{-1} for the year 2019-20 (Odisha Economic survey 2022-23; 2023).

The traditional rice production system can be considered equivalent to organic cultivation and a promising production system towards sustainable agriculture. The total global warming potential estimated was 610.19 kg CO_2 eq ha^{-1} in this traditional terraced low land rice production system (Table 7). Different sources of chemical input that are applied in rice production system and the respective amount of green hous gas emission

Table 7: Energy and green house gases emission of agricultural inputs in traditional terraced low land (*jhola*) rice production system

Input	Total Energy (MJ ha^{-1})	Energy (MJ)	Energy	CO_2 Equivalent	GWP	Percent
Internal Input (per ha) (Labour+Animal)	5324.18	43.00	123.82	3.20	396.22	64.93
Fertilizers	2091.91	49.50	42.26	2.60	109.88	18.01
Nitrogen						
Phosphorus	177.60	7.20	24.67	1.60	39.47	6.47
Potash	73.70	11.30	6.52	0.70	4.57	0.75
Chemicals	3.40	358.00	0.01	25.10	0.24	0.04
Seeds	828.96	9.70	85.46	0.70	59.82	9.80
Total	8499.76	478.70	282.74	33.90	610.19	100.00

Table 8: Gaseous emissions from input (fertilizers and pesticides) and their global warming potential in traditional terraced low land (*jhola*) rice production system

Input (kg ha^{-1})	CO_2	N_2O	CH_4	CO_2	CO_2:N_2O:CH_4		
Fertilizers	125.90	0.00121	0.14907	128.80	97.27	0.29	2.44
Nitrogen	21.85	0.00043	0.03879	22.60	95.79	0.59	3.62
Phosphorus	0.99	0.00001	0.00142	1.03	96.67	0.43	2.90
Potash							
Chemicals	7.95	0.00003	0.00002	7.66	99.87	0.12	0.00
Total GWP (CO_2 equivalent)	156.69	0.0017	0.1893	160.09	97.18	0.33	2.49

are presented in Table 8. The amount of green house gases emission for CO_2, N_2O and CH_4 was 156.69, 0.0017 and 0.189 kg ha^{-1}, respectively (Table 8). Indian paddy fields contribute 4.09 ± 1.19 Tg CH4 y^{-1} and relatively 5% of the overall methane budget accounted by Indian agriculture (Gupta *et al.*, 2015). The eastern and the southern parts of the country have shown relatively higher GWP due to more emissions of CH_4 and N_2O as because large areas are under rice cultivation in these parts (Pathak, 2015). The average seasonal global warming potential of rice ranged from 1865 to 8425 kg CO_2 eq ha^{-1} under different management strategies in the Indo-Gangetic Plains of India (Gupta *et al.,* 2015). The higher global warming potential of the Indo-Gangetic Plains was mainly contributed by high emission of CO_2 from electric pump used for irrigation. Similarly, a much higher value of global warming potential was also reported from the work carried out in the Southern India, where the global warming potential of rice ranged from 3439 to 5812 kg CO_2 eq. ha^{-1} under conventional and various modified rice cultivation systems (Oo, 2018). It was observed that the highest share of green house gas emission was contributed from CO_2 (Fig. 3). Among the fertilizers, the highest share of green house gases emissions was from nitrogen fertilizer (80%), followed by phosphorus fertlizer (14%), chemicals (5%) and potash fertilizers (1%) (Fig. 4). The highest rate of green house gase emission (325 kg CO_2 eq ha^{-1}) for the production of potato was from chemical fertilizers (Pishgar-Komleh *et al.* 2012). Mohammadi *et al.* (2013) reported that contribution of irrigation to the total global warming potential was maximum (63%), followed by fertilization (34%). The lowest green house gase emissions in rice production system was from K fertilizers (1.03 kg CO_2 eq ha^{-1}). The results indicated that each kilogram production of rice in the study area would lead to GWP of 105.6 g kg^{-1} yield, , 60.5 g m^{-2} area of rice, 71.13 g CO_2 eq. MJ^{-1} of input energy and 8.79 g CO_2 eq MJ^{-1} of output energy. The average rice yield in the study area was 2580.4 kg ha^{-1} (grain) and 3154 kg ha^{-1} (straw) (Table 4). The carbon content in total yield of rice was as 2580.48 kg C ha^{-1} (Bolinder *et al.,* 2007).

The carbon content of input for rice production system was 164.75 kg C ha^{-1} and the carbon efficiency ratio was 15.66. It was reported that in USA. the amount of carbon efficiency ratio was 5.3 for corn production system (Lal, 2004). In a similar study, the carbon efficiency ratio was reported to be 10.95 for sugar beet, which had a high ratio due to high yield of sugar beet tuber (Yousefi *et al.,* 2014). Carbon sequestration could be an effective way to reduce atmospheric carbon dioxide which is the most important greenhouse gas. The carbon efficiency ratio of traditional rice production system is higher than that of corn and sugar beet, therefore this system of rice production which is practiced by tribal farmers is most efficient for reducing the atmospheric carbon, and this rice cultivation system can be considered more effective for carbon sequestration too.

Conclusion: In this traditional system, the consumed energy was 8581.06 MJ ha^{-1} and output energy was 77356.88 MJ ha^{-1}. The share of direct and indirect energy was 62.54% and 38.26% of total energy input while the share of renewable and non-renewable energy were 71.48% and 28.52%, respectively. The total emission of CO_2, N_2O and CH_4 from this production system was 610.19 kg ha^{-1}.

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