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Energy saving in shift crops cultivation: An analysis of paddy rice and upland crop production in Hau Giang province, Vietnam

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Abstract: Agricultural energy analysis and better energy use efficiency will contribute to sustainable development, adaptation to climate change and ensure maintainable production. A case study from Hau Giang province agriculture energy was conducted to compare the cultivation of paddy rice (PR) and upland crops, including corn, mungbean (MB), and black sesame (BS). The life cycle assessment methodology was used to estimate energy consumption and biomass energy production. Based on input-output energy inventoried results, the energy use efficiency, energy productivity, specific energy, and net energy were analyzed. Selected crops require 39,501–59,638 MJ ha^{-1} crop^{-1} that was higher than energy providing for PR. Crop cultivation required a large amount of energy from fossil fuels and electricity (12,946–34,375 MJ ha^{-1} crop^{-1}). Biomass production achieved 779,670 MJ ha^{-1} crop^{-1} through corn cultivation, follow by rice farming (198,723 MJ ha^{-1} crop^{-1}), BS and MB production (103,292 and 63,012 MJ ha^{-1} crop–1, respectively). Corn and PR reached the best energy analysis index because of their high biomass production. This study's results underlined the benefit of net energy from agricultural systems case study in Hau Giang province (19,380–720,032 MJ ha^{-1} crop^{-1}).

Key words: black sesame, corn, energy balance, life cycle assessment, mungbean, paddy rice

Varčevanje energije z menjavo gojenja različnih kultur: Analiza pridelave riža v poplavnih in suhih razmerah v provinci Hau Giang, Vietnam

Izvleček: Analiza porabe energije v kmetijstvu in njena boljša izraba bosta prispevali k trajnostnemu razvoju, prilagoditvam na podnebne spremembe in zagotovili predvidljivo pridelavo. Vzorčna raziskava, izvedena v provinci Hau Giang, je bila izvedena za primerjavo porabe energije pri pridelavi različnih poljščin in njene pretvorbe v biomaso pri gojenju riža v poplavnih razmerah (PR) in na suhem vključno s poljščinami kot so koruza, mungo fižol (MB) in črni sezam (BS). Za določanje porabe energije in njene pretvorbe v biomaso je bila uporabljena metodologija življenskih krogov. Na osnovi vnosa in vezave energije so bili analizirani parametri kot so učinkovitost izrabe energije, produktivnost energije, specifična energija in neto energija. Izbrane poljščine so zahtevale 39,501–59,638 MJ ha^{-1} poljščina^{-1}, kar je več kot je poraba energije pri gojenju poplavnega riža (PR). Pridelava poljščin je zahtevala veliko energije iz fosilnih goriv in elektrike (12,946–34,375 MJ ha^{-1} poljščina^{-1}). Količina energije v biomasi poljščin je znašala 779,670 MJ ha^{-1} poljščina^{-1} pri pridelavi koruze, temu je sledilo pridelovanje riža (198,723 MJ ha^{-1} poljščina^{-1}), mungo fižola (MB) in črnega sezama (BS) (103,292 in 63,012 MJ ha^{-1} poljščina^{-1}). Pridelovanje koruze in poplavnega riža (PR) je doseglo najboljše energetske indekse zaradi velike produkcije biomase. Rezultati te raziskave kažejo tudi prednost v izplenu neto energije pri načinu vzorca kmetovanja v provinci Hau Giang (19,380–720,032 MJ ha^{-1} poljščina^{-1}).

Ključne besede: črni sezam, koruza, energetska bilanca, določanje življenskih krogov, mungo fižol, poplavni riž

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1 INTRODUCTION

Research on agricultural energy has become vast and trendily to achieve sustainability and adaptation to climate change. The energy balance of agriculture is measured as agricultural activities' impact on the environment in the number of inputs and outputs measured in the equivalent of megajoule (MJ). The optimal and efficient energy usage in agriculture production will help succeed in the sustainable development goals (SDGs) under ensure sustainable consumption and production patterns (SDG12) through the sustainable reuse of agricultural residues. In Vietnam, solutions for using energy economically and efficiently in agricultural production have been stipulated in Article 22 of the Law on Economical and Efficient Use of Energy 2010 (The Vietnam National Assembly, 2010). The government, organizations, households, and individuals engaged in agricultural production carry out these energy-saving activities. In 2018, the Ministry of Agriculture and Rural Development of Vietnam also issued a circular guiding measures to use energy economically and efficiently in agricultural production (Vietnamese Ministry of Agriculture and Rural Development, 2018). The Vietnamese government has encouraged farming families to apply 4 leading solutions to use energy economically and efficiently in agrarian production. These groups proposed solutions focusing on the production stage, the processing, preservation, and transportation of farm products, and agricultural sector development. The most prominent of these regulations is encouraging scientific research results to production practices. Besides, using clean energy/renewable energy equipment and technology in production is a priority. Propaganda activities, dissemination of knowledge, and consultation on energy saving and efficiency for farmers are crucial.

The life cycle assessment (LCA) methodology is popularly used for agricultural energy analysis (Camargo et al., 2013; Del Borghi et al., 2022; Iriarte et al., 2010; Kaab et al., 2019; Ruviaro et al., 2012)we compare energy use and greenhouse gas (GHG. Almost all publications on paddy rice (PR) or upland crops have just focused on qualifying the energy requirement of farm inputs and output energy focus on grain or within straw (Elsoragaby et al., 2019a, 2019b; Kaur et al., 2021; Kazemi et al., 2015; Nandan et al., 2021; Soni et al., 2018; Truong et al., 2017) transplanting and broadcast seeding methods to investigate the energy pattern of rice production in Malaysia. The field under transplanting method in the main season showed 8.72% lesser mean total energy input, 6.25% higher mean machinery energy, 55.06% lesser mean seed energy and 23.01% higher mean output energy than the field under broadcasting method. Fertilizer the highest contributor of energy inputs it contributed by 62% in both transplanting and broadcasting methods and fuel was the second-highest contributor. The share of direct and indirect energy in the fields under the transplanting method were 19% and 81% and in the fields under the broadcasting method were 17% and 83% respectively. While the share of renewable and non-renewable energy in the fields under the transplanting method were 7% and 93% and in the fields under the broadcasting method were 14% and 86% respectively. The harvesting operation has the highest mechanization index level (0.99. However, producing energy from main products and byproducts is essential to calculate the energy balance and to evaluate energy efficiency.

Agriculture played an essential role in Vietnam's development, contributing 13.97–10.94 % of GDP (General Statistics Office of Viet Nam, 2021, 2022). Rice farming is a vital sector of Vietnam's agriculture, and the Mekong Delta (MD) is the largest cultivated area and the highest production density of paddy rice in the nation. The Vietnamese MD donates to over half of the total rice productivity of Vietnam. The rice area in 2021 was estimated at 7,240,000 ha and reached 43,880,000 tons (General Statistics Office of Viet Nam, 2021). However, PR monocultures would harm the environment long-term through a high source of greenhouse gas emissions and large energy requirement, while rotation could bring several benefits (Elbasiouny & Elbehiry, 2020; Kumar et al., 2022). Although, as mentioned above, energy-efficient usage will help countries achieve SDG12 and sustainable agricultural production, research on a comparison of PR and upland crop cultivation on the aspect of energy analysis in Vietnam's agriculture is a limitation.

PR and upland crop cultivation also require high energy for agricultural activities, from land reparation and crop care to harvest. Energy consumption of PR farming in Vietnam was estimated for product weight or growing area such as 2.8–2.9 MJ kg-rice^{-1} (Ogino et al., 2021), 24.813–32.793 MJ ha^{-1} (Truong et al., 2017), 12.500–15.300 MJ ha^{-1} (Winter-Spring) and 12.600–13.500 MJ ha^{-1} (Summer-Autumn) (Nguyen et al., 2022)two seasons of field trials were conducted to compare different crop establishment practices for rice production in the Mekong River Delta using environmental and economic sustainability performance indicators. The indicators including energy efficiency, agronomic use efficiency, net income, and greenhouse gas emissions (GHGEs. Energy consumption for vegetable cultivation in Vietnam was also limited only leafy vegetables (Napa cabbage, bok choy, and brown mustard), showing the results of energy provided for leafy vegetable cultivation was 44.118 MJ ha^{-1} and 2.68 MJ kg^{-1} (Liem & Phuoc, 2021). Fully understanding the energy balance from crop cultivation would successfully contribute to achieving advanced agriculture planning in VND.

2 MATERIALS AND METHODS

Research site selection: This research will compare the energy efficiency of rice farming and upland crop production. The research was applied several Participatory Rural Appraisal (PRA) activities in three sites (Chau Thanh A District, Long My District, and Vi Thanh City, Hau Giang Province) on farmers about the context of local crop system restructuring and their expectations. This research used a local gorverment recommendation on agricultural restructering process on replacing one rice farming growing season with another upland crop. Based on the discussion results with Department of Agriculture and Rural Development of Hau Giang Province staff members, this study chose Vi Thanh City and Chau Thanh A District to conduct field experiments on upland crops because agricultural restructuring was taking place from a triple rice model to double rice–one cash crop model. Based on energy balance aspects, the study will inform local authorities on which upland crops are suitable for this process. In Long My, our PRA results showed that people were uninterested in crop system restructuring. Therefore, an assessment of rice cultivation in the S–A growing season was necessary. The results of analyzing the cultivation models of corn, MB, and BS in Vi Thanh City and Chau Thanh A District will provide data for farmers' decision-making process in Long My District.

The on-farm experiments on corn (*Zea mays* L.), mung bean (*Vigna radiata* L.), and black sesame (*Vigna cylindrica* L. Skeels) were separately conducted in Chau Thanh A district and Vi Thanh city, which are located in Hau Giang province from March to June 2022. The total experiment area was 3.950 m^2 of corn, 1.800 m^2 of BS, and 2.350 m^2 of MB. We used the surface water from local canal for irrigation. The surface water quality index (WQI) of these canal were classified in "yellow" (Hau Giang Department of Science and Technology, 2022), indicating that it is suitable for agricultural irrigation and other similar purposes (Vietnam Ministry of Resources and Environment, 2019). Our experiments were set up on the classification soil of Gleyic Fluvisols (Hau Giang People Committee, 2022).

For collecting the PR cultivation data, this research randomly selected and interviewed 240 households from February to March 2022 in Long My district, Hau Giang province. The sample size accounted for 1.6 % total rice-farming household in research area.

This study applied a LCA methodology framework with the "cradle-to-farm gate". The research perspective was applied to estimate energy requirements to produce and apply all inputs applied for paddy rice/upland crops cultivation and all the necessary upstream processes. With the "cradle-to-gate" approach, the "cradle" is understood as where raw materials manufacturing place, and the "gate" is at the farm where those agricultural materials are used in the research area in Hau Giang. However, the scope of the study was limited by neglectable the stage of raw materials transportation from the manufacturer site to the farms. Thus, energy used for processing from raw material exploitation to the production of commercial agricultural inputs is estimated in this study.

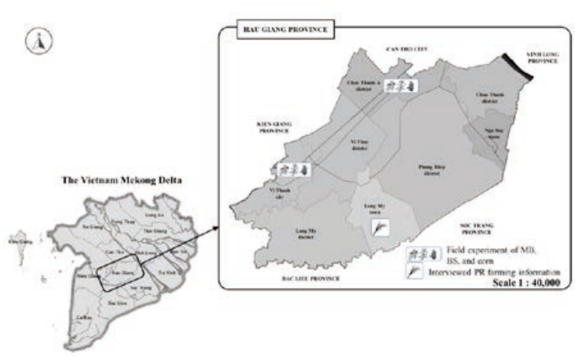

Figure 1: Research area.

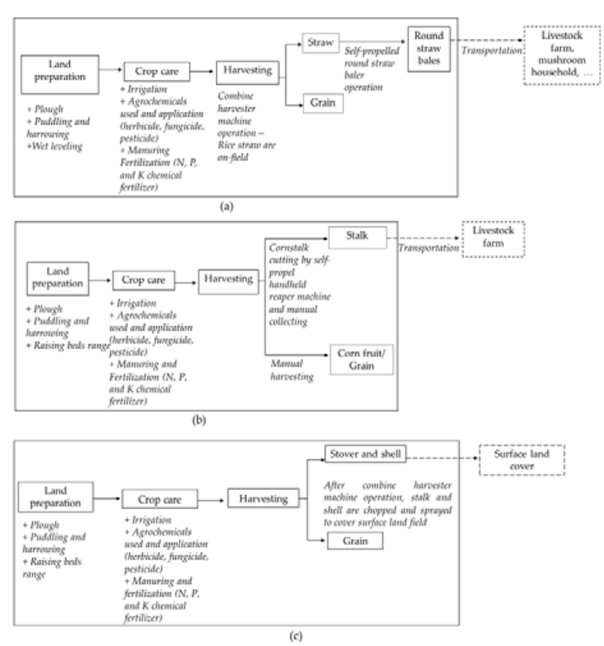

Figure 2: Life cycle assessment system boundary of paddy rice (a), corn (b), mungbean, and black sesame cultivation (c).

During the audit of farming materials, information about raw materials for production is collected, including the amount of fertilizer used (calculated by ingredients including nitrogen, phosphorus, and potassium fertilizers in kg-N, kg-P_2O_5, and kg-K_2O, respectively), amount of agrochemicals used (calculated by active ingredients including herbicide, pesticide, fungicide), amount of fuel/electricity used in tillage, irrigation and spraying agrochemicals. The system boundaries were set for farming activities under land preparation, crop care, and harvest stages presented in Figure 2. The functional unit is net energy in crop production per one hectare of growing area or one biomass tonnage in a growing season.

This study inventoried all agricultural inputs and output products. The mass of by-products was estimated based on the crop-to-residues ratio (CRR). In this study, straw, stover, cob, and shell of rice, corn, bean, and sesame were qualified through their dry grain. The CRRs are presented in Table 1.

This study applied several analysis of input-output energy that were popularly used in the field of agricultural production (Ali et al., 2019; Ghasemi-Mobtaker et al., 2020; Rajaeifar et al., 2014)intensive use of energy sources leads to environmental damages such as global warming and resources depletion. Hence, this study provided energy, environmental and economic overview of wheat cultivation in Hamedan province, Iran. The initial data were collected from 75 wheat farms applying face-to-face interview technique. The prepared data related to the 2017–2018 production cycle. The energy analysis results demonstrated that the total energy consumption and output energy in wheat cultivation were 43054.63 MJ ha^{-1} and 117407.13 MJ ha^{-1}, respectively. Energy productivity, energy use efficiency and net energy gain were computed as 0.12 kg MJ^{-1}, 2.73 and 74352.50 MJ ha^{-1}, respectively. Economic analysis showed that total value and cost of wheat production were 854.86 $ ha^{-1} and 366.57 $ ha^{-1}, respectively. Net return was 488.29 $ ha^{-1} and benefit to cost ratio computed as 2.33 in the investigated region. Wheat environmental impacts were evaluated by applying life cycle assessment methodology. Results of environmental impacts showed the largest emissions were related to marine aquatic ecotoxicity (319757.6377 kg 1,4-DB eq.:

Table 1: Crop to residues ratio (CRR)

Residue type	CRR	References
Rice straw	1.53	(Purohit, 2009)
Corn stover	2.5	(Soni et al., 2013)
Corn cob	0.15	(Honorato-Salazar & Sadhukhan, 2020)
MB stover	1.35	(Wang et al., 2013)
MB shell	0.323	(Soni et al., 2013)
BS stover	3.8	(Honorato-Salazar & Sadhukhan, 2020)
BS shell	1.86	(S. Ali & Jan, 2014)

Energy use efficiency = output energy (MJ ha^{-1}) / input energy (MJ ha^{-1})

Energy productivity (kg MJ^{-1}) = grain yield (kg ha^{-1}) / input energy (MJ ha^{-1})

Specific energy (MJ kg^{-1}) = input energy (MJ ha^{-1}) / grain yield (kg ha^{-1})

Net energy (MJ ha^{-1}) = output energy (MJ ha^{-1}) - input energy (MJ ha^{-1})

Output energy (MJ ha^{-1}) = main product energy (MJ ha^{-1}) + by-products energy (MJ ha^{-1}).

The conversion factors of energy equivalent was applied to calculate agricultural inputs and all types of product energy (Table 2).

Table 2: The energy equivalent of inputs and outputs

Note: *: we used the same data of groundnut shells as in Soni et al. (2013) and Paramesh et al. (2019).

3 RESULTS AND DISCUSSION

Agricultural energy is commonly estimated based on consumption rate and efficiency. All energy requirements will be changed to an ordinary unit (ha^{-1}, t^{-1}) in this research field. The energy required per crop unit or calorie production ratio will be known as energy efficiency (J/MJ per product mass calorie). Researchers usually use energy efficiency for standardized assessments between a diversity of crops. The agricultural biomass used for energy purposes is growing very fast, and because residual and waste biomass sources have largely been depleted, energy harvest from agriculture will be a significant factor in the further growth of biomass use for energy drives (Knápek et al., 2021). The energy analysis results of the crops cultivation are shown in Table 3.

Table 3: Input-Output energy and energy relationship of crops cultivation.

3.1 ENERGY REQUIREMENT

Corn cultivation was the highest energy consumption crop (59,638 MJ ha^{-1}), while rice cultivation was the lowest (31,478 MJ ha^{-1}). MB and BS were the second and third crops that consumed significant energy sources with 43,632 and 39501 MJ ha^{-1}, respectively. All selected crops consumed enormous energy from fuels-electricity

(41.1–57.6 %) and fertilizers (14.6–31.8 %) (Figure 3). Fuels-electricity provided 12,946–34,375 MJ ha^{-1}, while fertilizers supplied 5,753–18,941 MJ ha^{-1}. Corn cultivation required machine energy (3,566 MJ ha^{-1}) lower than other selected crops (5,936–13,104 MJ ha^{-1}). It was a higher agrochemicals energy provided for BS (3,432 MJ ha^{-1}) and MB (3,252 MJ ha^{-1}) than corn (2,160 MJ ha^{-1}) and PR (1,296 MJ ha^{-1}). Seed (0.3–5.6 %) and labor (0.3–1.6 %) were the lowest energy sources for crop cultivation (Figure 3). They provided 104–1,764 and 393–620 MJ ha^{-1}.

Farmers would improve energy input to get a better energy relationship. Fuels-electricity was the largest source of selected crop cultivation, similar to the previ-

Table 2: The energy equivalent of inputs and outputs

A. Inputs	Unit	MJ unit-1	References
1. Human labor	h	1.96	(Aghaalikhani et al., 2013; Heidari & Omid, 2011)
2. Agricultural machines	h	62.7	(Ali et al., 2019)
3. Fossil fuels			
3.1 Gasoline	L	40.9	(Japan Environmental Management Association for Industry - JEMAI, 2014)
3.2 Diesel	L	51.3	(Yousefi et al., 2014)greenhouse gas (GHG
4. Electricity	kWh	3.6	(Ghorbani et al., 2011; Yousefi et al., 2014)
5. Chemical fertilizers			
5.1 Nitrogen	kg N	66.1	(Ozkan et al., 2011)
6. Agrochemicals	kg-active ingredient (kg ai)	120	(Canakci & Akinci, 2006)
7. Seeds			
7.1 PR	kg	14.7	(Yadav et al., 2017)
7.2 Corn	kg	15.7	(Canakci et al., 2005)cotton, maize, sesame
7.3 MB	kg	14.7	(R. Kumar et al., 2021; Lotfi et al., 2021)
7.4 BS	kg	26	(Akpinar et al., 2009)
B. Outputs	Unit	MJ unit^{-1}	References
1. Rice product and by-products			
1.1 Grain	kg	14.7	(Yadav et al., 2017)
1.2 Straw	kg	14.87	(Biswas et al., 2017)
2. Corn product and by-products			
2.1 Grain	kg	14.7	(Parihar et al., 2017)
2.2 Stover	kg	18	(Soni et al., 2013)
2.3 Cob	kg	17.16	(Honorato-Salazar & Sadhukhan, 2020)
3. MB product and by-products			
3.1 Grain	kg	15.3	(Paramesh et al., 2019)
3.2 Stover	kg	12.5	(R. Kumar et al., 2021
3.3 Shell*	kg	11.23	(Sajjakulnukit et al., 2005)
4. BS product and by-products			
4.1 Grain	kg	25	(Akpinar et al., 2009)
4.2 Stover	kg	17.47	(Honorato-Salazar & Sadhukhan, 2020)
4.3 Shell*	kg	11.23	(Sajjakulnukit et al., 2005)

Note: *: we used the same data of groundnut shells as in Soni et al. (2013) and Paramesh et al. (2019).

ous study (Elsoragaby et al., 2019a; Kazemi et al., 2015; Yousefi et al., 2014)energy use pattern for rice production was analyzed and compared in different geographical regions, Golestan, Mazandaran and Guilan, northern pro-

Table 3: Input-Output energy and energy relationship of crops cultivation.

	PR	Corn	MB	BS
A. Inputs (MJ ha^{-1})	31,478	59,638	43,632	39,501
1. Human labor	108	393	545	620
2. Agricultural machines	5,936	3,566	7,524	13,104
3. Fossil fuels and electricity	12,946	34,375	24,358	16,488
3.1 Gasoline	0	389	307	0
3.2 Diesel	12,938	33,986	24,024	16,488
3.3 Electricity	8	0	27	0
4. Chemical fertilizers	9,428	18,941	7,585	5,753
4.1 Nitrogen	8,229	15,415	6,280	4,726
4.2 Phosphate	802	1,706	851	621
4.3 Potassium	396	1,820	455	405
5. Agrochemicals	1,296	2,160	3,252	3,432
6. Seeds	1,764	204	368	104
6.1 PR	1,764	-	-	-
6.2 Corn	-	204	-	-
6.3 MB	-	-	368	-
6.4 BS	-	-	-	104
B. Outputs (MJ ha−1)	198,723	779,670	63,012	103,292
1. PR product and by-product	198,723	-	-	-
1.1 Grain	78,001	-	-	-
1.2 Straw	120,722	-	-	-
2. Corn product and by-product	-	779,670	-	-
2.1 Grain	-	184,044	-	-
2.2 Stover	-	563,400	-	-
2.3 Cob	-	32,226	-	-
3. MB product and by-product	-	-	63,012	-
3.1 Grain	-	-	26,928	-
3.2 Stover	-	-	29,700	-
3.3 Shell	-	-	6,384	-
4. BS product and by-product		-	-	103,292
4.1 Grain	-	-	-	23,000
4.2 Stover	-	-	-	61,075
4.3 Shell	-	-	-	19,217
C. Energy relationship				
1. Energy use efficiency	6.31	13.07	1.44	2.61
2. Energy productivity (kg MJ^{-1})	0.17	0.21	0.04	0.02
3. Specific energy (MJ kg^{-1})	5.93	4.76	24.79	42.94
4. Net energy (MJ ha^{-1})	167,245	720,032	19,380	63,791

vinces of Iran. There is a significant difference among the three provinces in respect to input energy and agronomical managements such as crop rotation, transplanting date and land preparation. Data were collected from 50 farmers using a face to face questionnaire-based survey. The data collected belonged to the production period of 2012-2013 with the following results obtained. The energy use efficiency varied from 1.39 for Golestan to 1.67 for Guilan provinces. The research results revealed the main difference between energy consumption in three provinces comes from diesel fuel, chemical fertilizers and electricity. The net energy for paddy production was approximately higher in Guilan (36,927.58MJha-1. Changing from flooded to subsurface drip irrigation helps rice farming reduce power consumption (Coltro et al., 2017)mitigating GHG emissions in agriculture is fundamental to reduce its share of responsibility for the global climate change. Rice (paddy. The drip irrigation method achieved more efficient energy for upland crops than furrow and sprinkler irrigation (Kazemi & Zardari, 2020; Reddy et al., 2015)greenhouse gas (GHG. Specific energy is a significant factor that emphasizes the total energy demand to produce one product unit (Parihar et al., 2017)residue burning, decline in biomass productivity and water tables. In semi-arid regions, the climate-change-induced variability in rainfall and temperature may have an impact on phenological responses of cereals and pulses which in turn would affect biomass production, economic yield and energy and water-use efficiency (WUE. In agricultural production, a product with higher value of specific energy points that means it produce a lower total energy output from input energies (Chaudhary et al., 2017). By changing the current irrigation method to better practices, crop cultivation would save irrigation energy and achieve better total energy consumption and specific energy.

3.2 ENERGY OUTPUTS

Corn produced 779,670 MJ ha^{-1} through total biomass, 3.9 times higher than rice farming (198,723 MJ ha^{-1}), 7.5 times higher than BS cultivation (103,292 MJ ha^{-1}), and 12.4 times higher than MB cultivation (63,012 MJ ha^{-1}). Selected crops' by-products energy was higher than marketable products from 1.3 times (MB stover and shell/grain), 1.5 times (rice straw/grain), 3.2 times (corn stover and cob/grain), and 3.5 times (BS stover and shell/grain).

Government and policy-makers would plan to use the vast potential of by-products. Direct biomass energy source would be provided for surface soil by covering biomass debris from the stover and shell of MB and BS after the combine-harvester machine works. Corn stover and rice straw were used for several purposes, including feedstock, mushroom cultivation, and soil orchard mulching. In addition, by-product biomass sources could be used for gasification, biofuel, ethanol, and biochar production.

3.3 ENERGY RELATIONSHIP

Corn was the most energy efficiency cultivated crop when it produced 13.07 MJ based on one MJ input. One hectare of corn cultivation achieved a net energy of 720,032 MJ. On the other hand, corn also had benefits in energy productivity (the highest value, 0.21 kg MJ^{-1}) and specific energy (the lowest value, 4.76 MJ kg^{-1}). Rice was the second optimum selected crop, reaching 167,245 MJ net energy, and the energy efficiency index was 6.31. Rice cultivation needed 5.93 MJ input to produce one kg of rice grain. Parallelly, a one-hectare growing area had 0.17 kg of rice grain by providing one MJ through agricultural inputs. Although the net and effective energy of MB (19,380 MJ ha^{-1} and 1.44) was lower than BS (63,791 MJ ha^{-1} and 2.61), MB had energy productivity and specific energy value (0.02 kg MJ^{-1} and 42.94 MJ kg^{-1}) better than BS (0.04 kg MJ^{-1} and 24.79 MJ kg^{-1}).

Rice and corn play vital roles in worldwide food security. According to Li and Siddique (2020), MB will be an innovative food crop in the future. BS provides oil as the primary product and extracted oil meal for animals' feedstock as a secondary product. Selected crop cultivation has used high energy through several agricultural inputs. With a whole agricultural ecosystem of crop cultivation, it is possible to conclude that four selected crop cultivations had benefited energy net. Crop by-products provided a huge biomass source for secondary use - recycling activities that adapt to SDG12.

4 CONCLUSIONS

The optimal and efficient energy usage in agriculture production will help succeed in the SDGs under SDG12 through the sustainable reuse of agricultural residues. To explore the impact of farming activities, the LCA methodology was applied. Generally, all studied crops achieved benefits in energy targets. PR is the lowest-consumed energy crop but is the second-largest energy production crop. Upland crops require more energy than PR through labor, power (fossil fuels and electricity), and agrochemicals. Corn and PR reach the best energy analysis index because of their high biomass production, especially in cases of by-products. People must trade off energy to achieve nutrients from the grain. However, this study's results underline the benefit of produced energy from agricultural systems case study in Hau Giang province.

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