Quest Journals
Journal of Research in Agriculture and Animal Science
Volume 8 ~ Issue 10 (2021) pp: 56-60
ISSN(Online) : 2321-9459
www.questjournals.org

Research Paper

Agroecological and Economical Impact of Integrated Polyculture Paddy-Carp-Paddy in North Sumatra, Indonesia

Indah Mutiara Silalahi[1], Jongkers Tampubolon[1], Hotden L. Nainggolan[1], Yanto Raya Tampubolon[2], JuliRitha Tarigan[2]
[1]*Agribusiness Department, Agricultural Faculty, HKBP Nommensen University, Indonesia*
[2]*Agroecotechnology Department, Agricultural Faculty, HKBP Nommensen University, Indonesia*

ABSTRACT: *Agricultural intensification in Southeast Asia mainly increases the cropping index instead of increasing land productivity to produce certain crops (tons/ha). Various patterns developed, ranging from multiple cropping to different crops with animal husbandry up to fish culture. One pattern of intensification that has evolved in the irrigated agricultural area of North Sumatra, Indonesia, is the integrated polyculture of paddy-carp-paddy. This study aims to determine the impact of cultivation patterns in terms of (i) agroecology, (ii) economics and (iii) the contribution of income from fish culture to farmers' expenditure for input factor of paddy cultivation as the main commodity. The results of the study revealed that the paddy-carp-paddy cultivation pattern functions to maintain soil fertility through increasing organic matter from the decomposition of paddy waste which becomes carp feed. Fish culture contributes up to 18% of annual farm income and income from fish culture increases farmers' ability to purchase expensive input factors such as organic pesticides. In line with the research results, a future research agenda is suggested.*

KEYWORDS: *Agricultural Diversification, Asian Family Farming, Cropping Index, Integrated Farming, Integrated Polyculture, North Sumatra*

Received 13 October, 2021; Revised: 25 October, 2021; Accepted 27 October, 2021

I. INTRODUCTION

Population growth coupled with economic progress (increase in income per capita) has increased the demand for food. FAO [1] estimates that between 2012 and 2050, the demand for food and other agricultural products will increase by 50%. On the other hand, the availability of land for agriculture is increasingly limited.

Increased production through agricultural intensification can spur higher land productivity using technology, as has been applied in developed countries, has caused severe negative side effects on sustainable concerns. Pesticides and other chemicals are responsible for extensive environmental problems and health risks; over-reliance on synthetic fertilizers may cause soil degradation. Knowledge-based innovations responding to local conditions with local resources are to be preferred [2].

Southeast Asia, a well-known area with high population pressure, is inhabited by hundreds of millions of farmer families who manage small farmlands (less than 0.5 ha). In this region, agricultural intensification developed is multiple cropping, which aims to increase the cropping index rather than increase a particular crop's productivity per hectare of land. Various patterns of multiple cropping have been developed with various terms according to the combination of plants, livestock and fish culture in certain spatial areas at the same or different times [3]. Likewise, recent research shows that increasing the cropping index is better than opening new, less fertile land [4]. The ratio-temporal dynamics of multiple cropping intensity are of great significance to ensure food and ecological security [5].

One of the multiple cropping patterns practised in the irrigated area of North Sumatra, Indonesia, is paddy-carp-paddy rotation. In this system, after the rice is harvested, the rice fields will be flooded, and the rice fields will turn into ponds for carp culture. Organic material from the waste of the paddy plant will become fish feed. Towards the second rice planting season, the fields are drained, and fish are harvested. In this way, the preparation of the land becomes lighter because it does not require land clearing of shrubs that would grow if the soil is left fallow for two months.

This study aims to analyze the benefits of the paddy-carp-paddy polyculture pattern in terms of; (i) agroecological benefits, (ii) economic benefits and (iii) contribution of income from carp culture to the procurement of inputs for paddy farming.

II. METHODOLOGY

This study uses a descriptive approach to reveal the rationale of the application of the paddy-carp-paddy rotation pattern from an agroecological perspective that describes the benefits of the rotational pattern to maintain soil productivity/fertility, as well as the contribution of fish manure and the decomposition of rice plant residues as organic matter, which is usually burned when the land is left fallow in the transition between paddy planting seasons I and II.

The economic benefits of the paddy-carp-paddy rotation pattern will be analyzed using a farming business approach, which aims to obtain the income value of each business unit and as a whole, where gross margin (farm income) is the difference between revenue (the value of products) and explicit cost (which includes the use of inputs, capital depreciation and labour wages). Meanwhile, the contribution of income from carp culture to the use of inputs and the explicit cost of rice farming will be analyzed by simple linear regression, which is visualized in a trend line graph.

III. RESULTS AND DISCUSSIONS

3.1. The Origin of Terminology

Referring to ILACO [6], multiple cropping involves the cultivation of two or more crops in succession or with some overlap within a year. Furthermore, [3] categorized multiple cropping into three types, namely: (i) mixed cropping, which is the cultivation of various types of plants over the same area simultaneously, (ii) relay cropping (often also called allay cropping), which is a pattern of crop planting among previously existing crops, for example chilly, tomatoes or beans, among perennial crops such as oranges, and (iii) sequential cropping, where various crops are cultivated at different times in rotation on the same land.

Multiple cropping, as the name implies, focuses on plant variations. The combination of crops with livestock and fisheries either on the same or different parcels is referred to as agricultural diversification, e.g. [7] or polyculture, e.g. [8]. Furthermore, suppose there is a relationship between farming branches as input suppliers for other business branches, such as livestock as a provider of manure for vegetables under a farmer's management. In that case, this diversification pattern is referred to as agricultural integration [9]. By definition, the paddy-carp-paddy farming pattern in this study can be categorized as an integrated polyculture.

3.2. Agroecological Benefits of Paddy-Carp-Paddy Rotation

Irrigated land is used for the cultivation of paddy continuously throughout the year or alternately with other crops. Paddy field is not part of the swampland as found in the soil taxonomy. Even though it is flooded, but there are times of inundation and drying ([10] and [11]). The productivity of paddy fields may decrease as a result of (i) depletion, and nutrient deficits caused by harvesting, (ii) unbalanced fertilization, and (iii) a decrease in soil organic matter content. The general symptom seen is a decrease in the organic matter content of paddy fields due to the increase in the use of inorganic fertilizers. Facts in the field show that farmers generally still burn rice straw as crop residues and have not used it optimally to add organic matter. Each harvest yields waste an average of 1.5 times the product of grain. Research results by Kasno et al. [12], in 1,548 lowland soil samples in Indonesia, 17% had <1% organic C, 28% had 1–1.5% organic C, and 20% had 1.5–2% organic C. From the study results, [13] and [14] revealed that the C-organic status of paddy fields was low (< 2%), and only 34% had C-organic content > 2%. Burning straw results in nutrient losses of 94% C, 45% K, 75% K, 70% Ca, 30% Ca, and 20% Mg of the total nutrient content in straw.

The results of research by [15], on the chemical properties of the soil contained in two fish-pond bottoms, where pond 1; has a pH of 4.9 (acidic), organic matter 2.21% (high) and pond 2; has a pH of 5.7 (slightly acidic), organic matter 1.56% (medium). If the soil at the bottom of the fish pond is not appropriately managed, there will be an accumulation of solids (sediment) in the form of organic matter from food waste and fish faeces [16]. Furthermore, the results of [17], in rice fields that are rotated into fish ponds have moderate C-organic yields paddy production of 5.75 tons/ha, higher than unrotated rice fields with low C-organic with the production of 4.50 tons/ha. The difference in C-organic is that the paddy straw is not burned in the rotation of the fish pond but becomes a source of fish feed. On the other hand, faeces and fish feed waste also contribute to the organic matter at the bottom of the fish pond. This means that soil organic matter is very influential on the productivity and quality of paddy fields. If the organic matter content is low, the resistance of the soil will decrease to chemical, physical, and biological activities and vice versa if it is high, it can increase soil microbial activity to improve soil physical, chemical, and biological properties ([18] and [19]). In the study area, the rice-carp-rice cultivation pattern contributes positively to the fertility of paddy fields because the land can be

drained. This condition can be achieved due to the availability of technical irrigation systems that function correctly (figure 1).

Figure 1. Irrigation System and Paddy Cultivation as Primary Commodity

3.3. Economic Benefits of Paddy-Carp-Paddy Rotation Pattern

Farming business analysis was conducted by obtaining data from the interviews with 30 farmers who applied the paddy-carp-paddy rotation pattern, which had used this farming pattern for between 3 to 7 years. They are 56 years old on average and manage 0.16 to 0.6 ha of land with an average of 0.36 ha (small farmer, which is the hallmark of Southeast Asian farming).

Paddy harvest takes place five times in two years. Carp culture lasts two months, i.e. after the first season of rice harvest before planting the second season. Fish density 1,750 to 2,000 fishes per hectare with size when sowing 125 grams (8 fishes per kilogram). After being reared for two months, without additional feeding, the size of the fish when harvested became 500 grams each (two fishes per kilogram).

The transition of paddy fields from paddy cultivation to fish ponds does not require special treatment, the paddy stalks are not cut, water is directly put into the pond, and the water level is maintained at 40-50 cm or as deep as the existing paddy field. Water entering the pond is channelled through a pipe made of bamboo with a diameter of around 10 cm; its function is so that the shock of the shower water can produce the oxygen needed by carps.

The paddy-carp-paddy polyculture that increases the cropping index from 200 to 300% provides intangible benefits in the form of maintaining soil fertility conditions through the decomposition of organic matter from paddy waste that is processed by fish into faeces, in addition to controlling weed growth during the transition period for paddy cultivation due to flooded paddy fields, which in turn will facilitate land preparation for the next rice planting so that land processing costs are low. In addition, the carp culture also produces tangible benefits in the form of farm income, which contributes 18% to the total annual farm income. In table 1, the business analysis of paddy-carp-paddy farming is presented.

Table 1. Farm Business Analysis of Integrated Polyculture Paddy-Carp-Paddy (Per Farm Annually)

Description	Paddy Cultivation (two season)	Carp Culture
Area (ha)	0.70	0.35
Output (Kg)	8,770	300
Price (IDR/Kg)	4,300	30,000
Revenue (IDR)	37,711,000	9,000,000
Input (IDR)	2,459,635	2,000,000
Capital (IDR)	1,156,640	266,745
Wages (IDR)	3,724,940	114,665
Costs	7,341,215	2,381,410
Gross Margin (IDR)	30,369,785	6,618,590
R/C ratio	5,14	3,78
Farm performance (yearly):		
Farm Income (IDR)	36,988,375	
R/C ratio	4,80	

Source: Author Calculation

The results of the analysis show that an area of 0.35 ha will be able to provide an annual income of US$ 2,605 (exchange rate as of September 2021) with the absorption of 60 person-days of labour per year, of which 34 person-days are exclusively wage workers needed at the time of rice harvest. Thus, even though the

cropping index has reached 300%, family labours are still available to be allocated to off-farm employment activities, a common phenomenon in the farmer community of North Sumatra [20]. Carp culture does not significantly absorb labour and almost does not use hired labour. The correlation between fish farming areas and family employment is weak, with a correlation coefficient of + 0.39.

Additional income from fish culture increases farmers' opportunities to purchase inputs such as organic fertilizers and pesticides which are more expensive than synthetic fertilizers and pesticides. This is needed so that pesticide residues do not become toxic to carp that will be kept after rice harvest. Overall, income from carp rearing with farmers' expenditures for purchasing input factors for rice cultivation is positively correlated with a strong correlation (correlation coefficient + 0.77), and when the input factor is decomposed into seeds, fertilizers and pesticides, the correlation coefficients obtained are + 0.723, +0.808 and +0.515, respectively. This relationship is presented in figure 2.

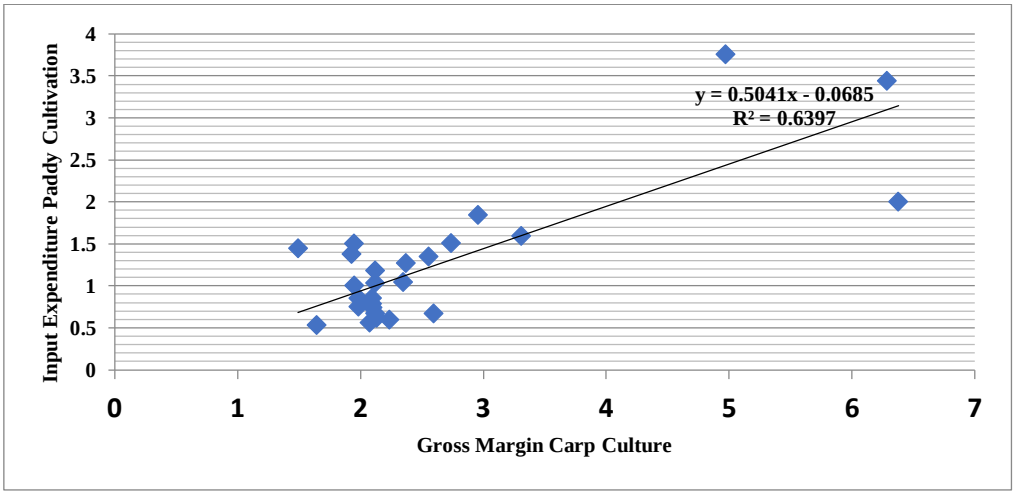

Figure 2. The Relationship Between Income from Carp Culture and Expenditures for Input Factors of Paddy Cultivation (in Million IDR)

The high correlation between income from fish culture and the use of fertilizers deserves special attention. It seems that the behaviour of farmers who practice integrated polyculture paddy-carp-paddy has not changed in the use of fertilizers even though their land conditions have become richer in organic matter. They still use the same fertilizer composition as the farming pattern that burns paddy straw. Tampubolon et al. [21] reported that reducing the use of fertilizers up to 50% was still able to increase production up to 70% on land, which is rich in organic matter in the rice intensification (SRI) system.

IV. CONCLUSIONS AND FUTURE RESEARCH AGENDA

The Paddy-Carp-Paddy integrated polyculture that is widely developed in technically irrigated agriculture areas in North Sumatra shows that this farming pattern, in addition to increasing the cropping index by up to 300% without significantly increasing labour absorption, also produces benefits in the form of:

Intangible benefits in the form of maintaining soil fertility by breaking down organic matter left over from paddy farming (straw) into the fish feed, which in turn produces faeces. In addition, saturated areas with a height of 40-50 cm for fish culture will suppress plant germination. Land preparation for rice farming as the primary commodity becomes lighter and costs less.

Tangible benefits are obtained by the gross margin of fish culture, which contributes about 18% to the annual farm income. This additional income increases the opportunity for farmers to finance input factors for rice farming in the form of certified seeds and organic fertilizers and pesticides, which are more expensive but more profitable for the environment.

As a further research plan, it is urgent to find out the optimum use of fertilizers in the paddy-carp-paddy integrated polyculture so that the increase in income from carp culture does not have to be followed by the overuse of fertilizers. It is considering that the organic component in paddy fields is higher than the rice cropping pattern, which burns rice waste instead of utilizing it.

REFERENCES

[1]. FAO. 2017. The Future of Food and Agriculture – Trends and Challenges. Rome: Food and Agriculture Organization of the United Nation.

[2]. Tripp, R. 2006. Is Low External Input Technology Contributing to Sustainable Agricultural Development? Natural Resource Perspective No. 102. Overseas Development Institute (ODI).

[3]. Beets, W.C. 1982. Multiple Cropping and Tropical Farming Systems. Gower.
[4]. Jiang, M. Li, X. Xin, L and Tan, M. 2019. Paddy Rice Multiple Cropping Index Changes InSouthern China. Journal of Geographical Science **29 (11):** 1773 – 1787.
[5]. Huimin, Y. Fang, L. Zhongen, N. Fengwe, G. and Yanzhao, Y. 2018. Changes Of Multiple Cropping InHuang-Huai-Hai Agricultural Region China. Journal of geographical Science **28 (11)**: 1685 – 1699.
[6]. ILACO. 1981. Agricultural Compendium for Rural Development in the Tropics and Subtropics. Elsevier.
[7]. Vyas, V.S. 1996. Diversification in Agriculture: Concept, Rationale and Approaches. Indian J. of Agric. Ec. **51 (4)**: 636-643.
[8]. Mangampa, S. 2014. PolikulturUdangWindu, Bandeng, NilaSrikandi dan RumputLaut di Tambak Tanah SulfatAsam. Prosiding Forum InovasiTeknologiAkuakultur pp 1 – 13.
[9]. Rana, S.S. and Chopra, P. 2013. Integrated Farming System. Dept of Agronomy, College of Agriculture, CSK Himacha Pradesh KoishiVisvavidyalaya.
[10]. Djaenudin D., Marwan H., Subagjo H., dan Hidayat, A. 2003. Petunjuk Teknis EvaluasiLahanuntukKomoditasPertanian. Edisi ke-1. BalaiPenelitian Tanah, Pusat Penelitian dan Pengembangan Tanah dan Agroklimat. Bogor.
[11]. Hardjowigeno, S. dan Rayes, M.L. 2005. Tanah Sawah. Bayu Media Publishing. Malang.
[12]. Kasno, A. Nurjaya, dan Setyorini, D. 2003. Status C-OrganikLahan Sawah di Indonesia. KongresHimpunanIlmu Tanah Indonesia (Hiti).Universitas Andalas, Padang.
[13]. Nurjaya, S. Rochayati, dan Pratiwi, E. 2015.Teknologi Pengelolaan Jerami Pada LahanSawahTerdegradasi. BalaiPenelitian Tanah. Bogor.
[14]. Suriadikarta, D.A., dan Adimihardja A. 2001, PenggunaanPupukDalamRangkaPeningkatanProduktivitasLahan Sawah. Pusat Penelitian dan Pengembangan Tanah dan agroklimat, Bogor.
[15]. Hasibuan, S. dan Syafriadiman (2013). KarakteristikFisik dan Kimia Profil Tanah Dasae Kolam Di DesaMesjidKabupaten Kampar. JurnalPerikanan dan Kelautan**18(1)**: 83-95.
[16]. BalaiPenelitianTanah , 2005. Analisis Kimia Tanah, Tanaman dan Air. Bogor.
[17]. Kemala, N. 2016. Pemetaan C-Organik di Lahan Sawah Daerah IrigasiPantoanKecamatanSiantarKabupatenSimalungun. Skripsi. Program StudiAgroekoteknologiFakultasPertanian Universitas Sumatera Utara. Medan.
[18]. Agus, D. Setyorini, A. Dariah. 2009. PelestarianLahan Sawah. BalaiPenelitian Tanah. Bogor.
[19]. Setyorini, D., S. Rochayati, Dan I. Las. 2007. Pertanian Pada EkosistemLahan Sawah. BalaiBesarLitbangSumberdayaLahanPertanian.
[20] Tampubolon, J. 2004. Multiple Employment as A Strategy of Labour Resource Management For Sustainable Food Security (Case Study In Peasant Community Of North Sumatra, Indonesia). J. of Agriculture and Rural Development in the Tropics and Subtropics **Supplement 80**: 33-40.
[21] Tampubolon, Y.R. Simanungkalit, F.J dan Tampubolon, J. 2020. IptekBagi Masyarakat UntukMeningkatkanKetahananPangan: PenerapanMetode Sri (System of Rice Intensification) di KecamatanNamorambe, Kabupaten Deli Serdang, Sumatera Utara.Logista-JurnalIlmiahPengabdianKepada Masyarakat **4 (2)**: 285-297.