RESR Revista de Economia e Sociologia Rural

ISSN 1806-9479

ARTICLE

System proximity index ratio (SPIR) accuracy in forecasting the sustainability of crop-livestock farming systems in Indonesian paddy fields

Precisión de la relación del índice de proximidad del sistema (SPIR) en el pronóstico de la sostenibilidad de los sistemas agrícolas de cultivos y ganadería en los arrozales de Indonesia

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How to cite: Sugandi, D., Purnamasari, N. R., Nurawan, A., Sutrisna, N., & Surdianto, Y. (2024). System proximity index ratio (SPIR) accuracy in forecasting the sustainability of crop-livestock farming systems in Indonesian paddy fields. Revista de Economia e Sociologia Rural, 62(2), e270959. https://doi.org/10.1590/1806-9479.2022.270959

Abstract: The crop-livestock farming system in paddy fields is integrated between rice crops and beef cattle (rice-beef cattle CLFS). Rice plants will produce straw and rice bran that can be used for animal feed, and livestock will produce compost/manure that can be used for rice nutrition. Some other benefits of implementing CLFS are increasing crop productivity, increasing the value of farmers' income, farming cost efficiency, and preserving the environment. The probability of the sustainability of CLFS application in paddy fields can be measured by calculating the system proximity index ratio using the SPIR formula. This research aims to demonstrate the accuracy of the SPIR formula in predicting the probability of CLFS sustainability in paddy fields. This study compares CLFS programs in several regions in Indonesia. It uses an independent sample t-test analysis tool with one-way rejection criteria to see the difference in SPIR scores on sustainable and unsustainable CLFS. The results showed that the SPIR formula could predict the sustainability of the CLFS program in Indonesia. However, further studies are needed to prove its ability to predict CLFS sustainability in other parts of the world.

Keywords: integration, SPIR, sustainability, crop, livestock.

Resumen: El sistema agrícola en cultivos de arroz es un sistema integrado entre cultivos de arroz y ganado vacuno (arroz-vacuno CLFS). Las plantas de arroz producirán paja y salvado de arroz que se pueden usar como alimento para animales, y el ganado producirá compost/estiércol que se puede usar para la nutrición del arroz. Algunos de los otros beneficios de implementar CLFS son el aumento de la productividad de los cultivos, el aumento del valor de los ingresos de los agricultores, la eficiencia de los costos agrícolas y la preservación del medio ambiente. La probabilidad de sostenibilidad de la aplicación de CLFS en los campos de arroz se puede medir calculando la relación del índice de proximidad del sistema utilizando la fórmula SPIR. El objetivo de esta investigación es demostrar la precisión de la fórmula SPIR para predecir la probabilidad de sostenibilidad de CLFS en arrozales. Este estudio compara los programas CLFS en varias regiones de Indonesia y utiliza una herramienta de análisis de prueba t de muestra independiente con criterios de rechazo unidireccionales para ver la diferencia en las puntuaciones SPIR en CLFS sostenible e insostenible. Los resultados mostraron que la fórmula SPIR puede predecir la sostenibilidad del programa CLFS en Indonesia. Sin embargo, se necesitan más estudios para demostrar su capacidad para predecir la sostenibilidad de CLFS en otras partes del mundo.

Palabras clave: integración, SPIR, sostenibilidad, cultivo, ganadería.

INTRODUCTION

Indonesian agriculture is still dominated by smallholder agriculture, with many farmers and a relatively small output per farming unit. Most of the agriculture is carried out by agricultural households in rural areas, mostly rice and secondary crops farming households.

Most of these food crop farming households are located on the island of Java. Java contributes 53.53% of the total rice production, 54.03% of the total corn production and 64.63% of the total soybean production (Indonesia Corporate Secretary Association, 2020). This percentage is lower than the potentially available land resources in Java, which is only around 40.81% of the total agricultural land in Indonesia (Prasada et al., 2022). If the available land area is compared to the number of farming households, then farming in Java is carried out on narrow land, which results in a low level of farmer income (Zhou et al., 2020).

Due to narrow land ownership and low income, farmers must exploit their land to maximize production. As a result, land productivity tends to decrease from year to year. This condition is consistent with the opinion that several factors cause the stagnation of rice production: (1) technological stagnation and degradation, (2) decreased soil fertility, (3) saturation of crop intensity, (4) decreased milled yield, (5) pest and disease attacks, and (6) abnormal climate (Rahmawati & Rozaki, 2021; Sawit, 2000; Souvannachith et al., 2017). The quality of land in Indonesia, especially paddy fields, tends to decline. Around 70% of the area is classified as diseased soil, and 20% has a C-organic content of less than 2% (Turmuktini et al., 2012). This condition has the potential to reduce plant productivity.

The continuous implementation of lowland rice farming in paddy fields with a high level of intensification will decrease productivity. The main causes of this decrease are: (1) increased salinity, water depletion, and acidity of the soil, (2) deficiency of soil microelements, (3) compaction of the subsoil, (4) decreased availability of micronutrients and nitrogen in the soil, and (5) an increase in disease disorders (Pingali & Rosegrant, 1994; Wan et al., 2019). For this reason, countermeasures need to be carried out through a crop-livestock integration system (CLFS) approach. This integration system will increase farming efficiency because it can utilize internal inputs. It will reduce external inputs (production costs) because rice farming will produce straw and rice bran, which can be the main feed for cattle. On the other hand, livestock can produce organic fertilizer that can be used as input for rice farming (Mukhlis et al., 2018).

There are eight advantages of implementing CLFS, namely (1) diversification of the use of production resources, (2) reducing risk, (3) efficient use of labor, (4) efficient use of production components, (5) reducing dependence on chemicals and biological energy, and also external inputs, (6) a more sustainable and less polluting (environmentally safe) ecology, (7) increasing output, and (8) developing a more stable agricultural household (Castillo et al., 2021; Devendra, 1993; Mukhlis et al., 2018). These advantages, especially point number 6, can economically increase an industry's competitiveness (Shrivastava, 1995). However, implementing CLFS, especially paddy-cattle CLFS, at the farm level in Indonesia is not easy. Some can maintain their sustainability, and some are not. Fortunately, the chances of maintaining CLFS implementation in paddy fields can be measured by calculating the system proximity index ratio using the SPIR formula. Therefore, this study aims to demonstrate the accuracy of the SPIR formula in predicting the probability of CLFS sustainability in paddy fields.

THEORETICAL FOUNDATION

CONCEPTS AND BENEFITS OF CLFS APPLICATION

The farming system is an arrangement or series of several farming components a farming household manages. It responds to physical, biological and socio-economic factors that adjust to the household's goals, interests and existing resources. The farming system can be in the form of food crops, trade crops, plantations or a combination of food crops and livestock, especially ruminants (Mukhlis et al., 2018).

Small-scale agriculture in several Asian countries implementing CLFS can potentially increase farmers' income. This condition is possible because livestock can be used as labor, while farming produces agricultural waste for animal feed. Types of livestock widely used as components in farming integration are ruminants such as cows and buffalo because they can graze themselves, eat from agricultural waste and require low labor (Bhattacharyya et al., 2022). Most farmers in India have incorporated crops and livestock into their farming systems. There, livestock has a complementary and additional role in agricultural production, as livestock can cope with risks and recycle biomass. So livestock can integrate well with various cropping systems (Bhattacharyya et al., 2022; Rangnekar, 2006).

The role of ruminants in small-scale integrated agriculture in South Asia is more important than other livestock because they can consume crude fiber from crop residues (Ramana et al., 2018). Although of low quality, animal feed from this material can be used as the main feed during the dry season. Ruminant livestock have a dual role; apart from producing meat and milk, they also make leather for the clothing industry and are the main input for plants. Livestock can also be a quick and strategic source of money and play a role in overcoming poverty and increasing household food security. A combination of crops and livestock is a more profitable farming business (Ryschawy et al., 2012). Livestock can be used to fill the free time of family workers and increase the use of by-products from farming (Sraïri & Ghabiyel, 2017).

Profits from livestock can increase with ownership of resources, especially land resources (Herrero et al., 2013). Livestock ownership, such as beef cattle, is usually also used as a status symbol and is generally an attractive investment because it is a multi-purpose item. They are used as savings and as labor for agricultural activities. Beef cattle are also a tool that produces services and semi-finished goods, as they are used in ploughing the land and the females can have calves that can be sold and provide additional income for farmers (Herrero et al., 2013). Therefore Farmers instinctively seek mixed farming or integrated farming system to improve their standard of living (Tumbo et al., 2018).

An integrated farming system organizes various biological production activities, both plants with plants and livestock, based on optimizing available natural resources (Mukhlis et al., 2018; Sraïri & Ghabiyel, 2017). The aim is to increase the income and labor efficiency of farming families. This approach suits Indonesian farmers, especially in Java, because the average land ownership is narrow (Brázdik, 2006). Crop and livestock farming (such as cattle) on the same land will complement and support each other.

OBSTACLES TO IMPLEMENTATION OF CLFS

Based on BPN data for 2019, the national rice field area is 7,463,948 ha. While the harvested area of paddy rice in 2018 and 2019 was 11,377,934 and 10,677,877 ha (Badan Pusat Statistik, 2019). Suppose the conversion rate of straw availability is 2.5 tons of dry matter per hectare, the available forage potential is 28,444,835 tons or the equivalent to feed for 6.4 million head of cattle (Ditjen Hortikultura, 2020). While the average land tenure per farmer nationally is around 0.65 ha, with details of 0.22 ha for paddy fields, 0.3 ha for fields/gardens, and 0.13 ha for areas. This condition is one of the inhibiting factors for the implementation of CLFS, in addition to limited capital ownership, low levels of technology utilization, limited supporting institutions such as extension workers and animal health workers, and the lack of readiness of farmers to implement CLFS. CLFS farms are usually scattered, small-scale, and far from the city center. This affects the marketing, production and transportation costs for purchasing production facilities generally located in urban areas.

CLFS SUSTAINABILITY OPPORTUNITIES IN THE PADDY FIELD

The concept of sustainability has been introduced in the literature for decades, and its definition has evolved to suit various fields (Mebratu, 1998). Sustainability in the agricultural context implies the ability to remain productive and maintain existing resources or means to continue indefinitely (Struik & Kuyper, 2017). The sustainability of farming can be seen from two sides, the ecological side and the economic side. From an ecological perspective, sustainability can be seen from the success in maintaining the quality of natural resources and increasing the ability of the agroecosystem as a whole. From an economic perspective, sustainability is measured by the success of maintaining production and income, conserving natural resources, and minimizing business risks (Mensah, 2019).

CLFS can be used as a solution to support the sustainability of farming, both in dry land and paddy fields. CLFS paddy-beef cattle is considered very relevant for paddy fields because the two types of business can be complementary. Beef cattle can produce manure which is needed as input for rice farming. On the other hand, rice farming has straw and bran, which can be used for animal feed. Manure is one component of sustainable agriculture because it can improve soil structure (Naveed et al., 2014). However, no matter how good the innovation concept offers will be in vain if farmers do not adopt it.

Farmers in West Java have applied the CLFS concept to their paddy fields since the late 1990s, either initiated by a government assistance program or independently. Factors thought to be motivating farmers to carry out these activities include government assistance programs in the form of livestock and labor training, the need for manure as a substitute for inorganic fertilizers, the availability of feed sources in the form of straw and bran, as well as the hope of obtaining additional income from livestock and increasing crop productivity. Applying CLFS in paddy fields can produce 6,050 kg/ha of rice in the first planting season (GS I), 5,280 kg/ha in GS II, and 300 kg/ha of corn straw. Manure production is around 1,413.9 kg/head/year. If the manure contains 1.65% N, the waste production can contribute as much as 23.32 kg of N (Prasetyo et al., 2002). Increasing farmers' income from CLFS can reach more than 50% compared to cropping patterns without livestock (Homann-Kee Tui et al., 2015).

Adoption in the agricultural extension process can essentially be interpreted as a process of changing behavior in the form of knowledge (cognitive), attitudes (effective), and skills (psychomotor) in a person after receiving innovations delivered by extension workers (Arisa et al., 2021). Factors that influence farmer behavior in farming include the condition of the individual farmer himself (level of education and experience), environmental conditions (arable area of land, etc.), income and extension programs (Uddin et al., 2014).

CLFS can sustainably adopt by farmers if it can provide real benefits, especially in increasing their income and improving their welfare (Wani et al., 2012). Increased revenue can be obtained by improving product quality so that selling prices rise, or by reducing production costs through efficiency. With low production costs, competitiveness with similar products also increases. The application of CLFS has been empirically proven to be able to create jobs. Thus it can be concluded that income level positively affects the sustainability of CLFS implementation.

Other factors that are thought to influence the level of sustainability of CLFS implementation in paddy fields are the level of education, age, and experience of farmers in raising livestock, as well as the area of land tenure, the number of livestock raised, the number of prospective family members, and whether there is a source of feed other than agricultural waste (Mwangi & Kariuki, 2015). These factors are internal variables of farmers that are closely related to the level of innovation adoption and external variables that are directly related to the needs of production implementation.

Other efforts that farmers can make to maintain the sustainability of CLFS paddy-beef cattle farming are to maximize the use of internal inputs (rice and beef cattle farming) and minimize the use of external inputs (production inputs from off-farm farming activities), such as inorganic fertilizers and chemical pesticides, that farmers have to buy from outside their farming system. This approach is commonly referred to as LEISA (Low External Input Sustainable Agriculture) (Altieri, 2018). These outputs or inputs can be tabulated into a formula called SPIR to predict whether CLFS can sustain or not. This formula calculates the proximity of all inputs and outputs produced by paddy and livestock.

METHODOLOGY

Primary and secondary data for this study were taken from sustainable and unsustainable CLFS located in Subang and Tasikmalaya Regencies in West Java Province and Seluma Regency in Bengkulu Province of Indonesia between 2010 and 2016. The government initiated the Subang and Bengkulu CLFS, while the farmer initiated the CLFS in Tasikmalaya. There were 360 farmers involved in interviews and field observations.

The interviews were based on a questionnaire of farmer identity, land and livestock ownership, and prices and types of inputs and outputs. Secondary data were obtained from government agencies where the farmers were located (Singarimbun & Pasandaran, 1989). Both data were then analyzed using accounting methods to tabulate profits, costs, total revenue, total production and total input (Fanani, 1998). Then, the T-test was used to compare the value of farm income, costs, and income between CLFS locations. The analysis software used was SPSS (Statistical Program for Social Science)

Internal input for paddy was livestock output and vice versa. Livestock output was labour, fertilizer and bio-urine, while paddy output was straw and bran. Measurement of the level of sustainability of CLFS in paddy fields in this study was carried out by calculating the system proximity ratio using the following formula (Sugandi, 2010):

$$SPIR = \left[\left(\frac{\sum^{n} PY_{TP}}{\sum_{1} HX_{IP}} \right) + \left(\frac{\sum^{m} PY_{PT}}{\sum_{1} HX_{IT}} \right) \right] \frac{1}{(n+m)}$$

SPIR: the system proximity ratio
Y_{TP}: Output of livestock (labour, fertilizer, bio urine) as internal input for paddy crops
Y_{PT}: Output of paddy (straw, bran) as input for livestock
X_{IP}: Internal input of livestock (kg)
X_{IT}: Internal input of crops (kg)
P: Output price (Rp)
H: Input price (Rp)
N: Number of input components from livestock for crops
M: Number of input components from crops for livestock
n + m: Total of input components in CLFS
SPIR scale: 0 < SPIR < 1
Hypothesis: SPIR ≤ 0,5 weak sustainability opportunities
SPIR > 0,5 strong sustainability opportunities

The System Proximity Ratio (SPIR) value reflects the closeness between two types of integrated farming, in this case, cattle and rice farming. The higher the SPIR value, the closer the relationship between the two types of farming, and the greater the chances of its application being sustainable. On the contrary, the lower the SPIR value, the weaker the closeness of the relationship between the two types of farming and the smaller the chance of its application being sustainable. An independent sample t-test analysis with one-tailed rejection criteria was performed to examine the relationship between the SPIR scores and the sustainability of CLFS implementation. The t-test analysis was carried out to see if there were differences in the SPIR values for sustainable and unsustainable CLFS.

RESULTS AND DISCUSSION

There were four areas of CLFS in this study, two of which are sustainable and two of which are not. CLFS organic beef cattle represented sustainable CLFS in Tasikmalaya District, West Java Province (Sugandi, 2010), and CLFS healthy & aromatic beef cattle in Seluma District, Bengkulu Province (Sugandi, 2016). SPIR values are 0.51 and 0.52, respectively. CLFS in both areas is still running today. CLFS rice cattle represented unsustainable CLFS in Binong District and Sagalaherang District, Subang Regency, West Java Province. The SPIR values are 2.4 and 2.8, respectively. The two regions no longer practice CLFS. In detail, the results of calculating SPIR values for those areas are presented in Table 1.

Table 1. SPIR for CLFS in three regions of Indonesia

No.	SPIR Level	Unsustainable CLFS Subang, West Java (Government Program)	Sustainable CLFS Seluma, Bengkulu (Government Program)	Sustainable CLFS Tasikmalaya, West Java (Non-government Program)
1.	SPIR average	0.26	0.51	0.52
2.	Maximum	0.42	0.69	0.70
3.	Minimum	0.25	0.28	0.29
4.	Deviation standard	0.04	0.13	0.14
	Total of samples	40.00	80.00	80.00

Source: Sugandi (2010, 2016)

Table 1 showed that the average SPIR value for unsustainable CLFS in Subang Regency was 0.26, lower than sustainable CLFS in Seluma, Bengkulu Regency (starting with the government assistance program), which was 0.51 and CLFS for the non-government program in Tasikmalaya Regency was 0.52. This proves that CLFS with low SPIR values tends not to be continued. On the other hand, CLFS with high SPIR has a great chance of continuing CLFS.

The results of the t-test analysis are presented in Table 2. It showed a strong relationship between the SPIR values and the sustainability of CLFS implementation. There were differences in the SPIR values for sustainable and unsustainable CLFS. The average SPIR level for unsustainable CLFS was 0.26, significantly different from sustainable CLFS in government program CLFS (0.51) and non-government program CLFS (0.52). This illustration showed that CLFS implementation's sustainability level can be measured using the SPIR. The higher the SPIR value, the greater the chance for CLFS sustainability.

Table 2. Results of the SPIR Difference Test between sustainable and unsustainable CLFS

No.	Variable	t	Significance
1.	Unsustainable CLFS - sustainable CLFS (Government Program)	-11,065	0,000
2.	Unsustainable CLFS - sustainable CLFS (Nongovernment Program)	-7,829	0,000
3.	Sustainable CLFS (Government program)- sustainable CLFS (Nongovernment program)	-1,851	0,068

Analysis by T-test at 95% confidence level (P < 0.05)

Table 2 implied that the SPIR value in the CLFS of government and non-government programs did not show a significant difference at the confidence interval α = 0.05. This means that at a certain SPIR level (SPIR ≥ 0.51), there was no difference in the effect of government and non-government programs on the sustainability of CLFS implementation. This situation implied that guidance on applying CLFS should be carried out until it reached the SPIR level of 0.51 because it was still prone to the possibility of failure in the lower phase. However, if it reached a number above 0.51, the opportunity for the sustainability of the CLFS implementation was very large. This can be seen in more detail in Figure 1.

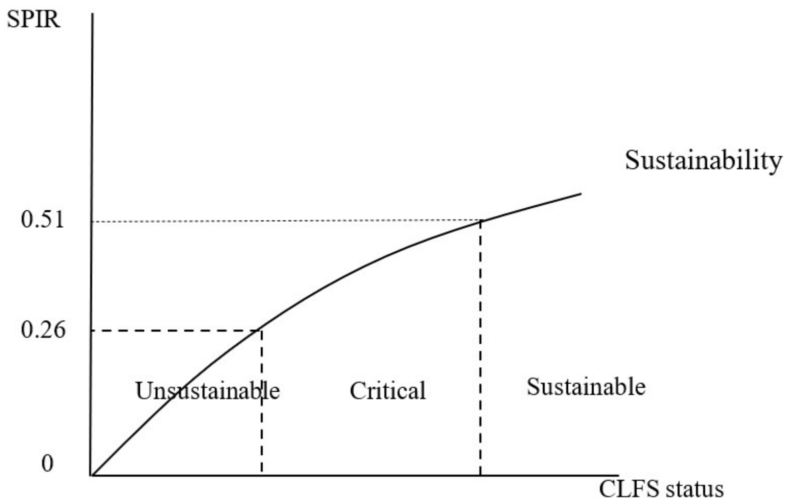

Figure 1. Sustainability level of CLFS implementation on paddy fields

Figure 1 shows the relationship between the SPIR level and the CLFS sustainability phase. At SPIR level 0 – 0.26, the CLFS position was unsustainable. Then at the SPIR level 0.26 – 0.51, the CLFS position was in a critical phase, meaning that in this phase, there was still a chance of failure. Efforts need to be made to save the implementation of CLFS. Meanwhile, at the SPIR level above 0.51, the CLFS position was already in the advanced/sustainable phase. At this phase, the rescue efforts by policymakers were no longer needed because farmers had reached an established level of awareness of the importance of implementing CLFS.

Another way to see the tendency of the relationship between the level of SPIR and the opportunity for the sustainability of the application of CLFS is to use a binary logit model regression analysis between sustainable CLFS (Yi = 1) and unsustainable CLFS (Yi = 0). The results of the analysis are presented in Table 3.

Table 3. The influence of SPIR level on the opportunity for the sustainability of the CLFS implementation

No.	Independent variable	Coefficient	Significance	Exp(B)
1.	SPIR level	16,470	0,000	14220177
2.	Constant	-5,076	0,000	0,006

Y_o = unsustainable CLFS, Y_i = sustainable CLFS, R^2 = 0,674, α = 0,01

The analysis showed that the SPIR level variable has a positive effect on sustainable CLFS and a negative effect on unsustainable CLFS in Indonesia, meaning that an increase will follow every increase in the value of SPIR in the opportunity for the sustainability of CLFS implementation. Thus, it was increasingly clear that the system proximity index ratio (SPIR) can be used to measure the chances of implementing CLFS sustainability in Indonesia. However, CLFS samples in this study were only taken in western Indonesia. Further studies are needed to prove its ability to predict CLFS sustainability in other parts of Indonesia and other parts of the world.

CONCLUSION

1. The sustainability of CLFS implementation in Indonesian paddy fields can be measured by calculating the system proximity index ratio using the SPIR formula. The higher the SPIR value, the greater the opportunity for the sustainability of the CLFS application.
2. Further studies are needed to test the SPIR formula in other parts of Indonesia and other parts of the world.

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Submitted on: January 08, 2023.
Accepted on: July 17, 2023.
JEL Classification: Q3.