Optimal use of tidal swampland by implementing technology innovation “Panca Kelola” to enhance farmer’s income in Central Kalimantan Indonesia

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Abstract. Rice production in swampland can increase farmers’ income through intensification activities based on local wisdom. This study aims to determine the household income of farmers by implementing the Innovation Technology “Panca Kelola”. This technology has components namely: water management, land preparation, amelioration and fertilization, high yielding variety and pest control. The method of data collection is done through a survey with direct interviews to farmers using a questionnaire. The results showed that the implementation of Technology Innovation “Panca Kelola” has economic prospects to be developed on a large scale with R/C> 1 and MBCR> 2. The increased income of cooperator farmers was 60.73% (IDR. 20,363,987,- household⁻¹ year⁻¹) compared to non-cooperative farmers.

1. Introduction
Utilization of acid sulphate tidal land is one of the options to address agricultural development problems in food production centers such as in Java, Bali, and Sumatra as a result of land degradation, sloping production, climate change, and land conversion. Swamp areas covered 33.4 million ha are found on the island of Sumatera (32.9%), Kalimantan (40.4%), Papua (21%), Sulawesi (5.7%) and the rests are in small areas [1]. The availability of tidal swampland for agriculture reaches 9.3 million ha [2].

Swampland development or reclamation had been carried out by the government since the 1970s through the Tidal Rice Field Development Project (Proyek Pengembangan Persawahan Pasang Surut, P4S) in Kalimantan and Sumatra [3] and until now it has not been given real impact, especially in supporting national food security. Its contribution is still low, around 1 to 1.5% of the total production of 62.56 million tons of dry unhulled rice [4].

Swampland development for agriculture, especially for crops, is not easy due to various obstacles. Problems from soil aspects are physical and chemical properties, fertility, and soil biological properties. From an environmental aspect, the problems are climate, topography, altitude from sea level, water systems, weeds, pests, and diseases. From the socio-economic aspect, it includes the availability and quality of manpower, regional accessibility, institutional and service mechanisms, capital, and marketing [5]. There are also social constraints caused by isolated residential conditions by water and congenital factors from the
farmers themselves, such as low levels of education and weak economic conditions since in their origin place, both local residents and transmigrants. Such conditions lead to low land productivity [6]. The low productivity of land due to degradation of soil fertility, water management is not optimal, low cropping index, land arrangement, commodity choice, lack of proper varieties, and applied imperfect agricultural model [7, 8]. In addition, water management technology is one of the main keys to the success of farming in tidal land because if the water is not controlled, it will not only result in failure but also cause various environmental damages, especially on tidal land with type B overflow [9]. The income of farmers in tidal swamplands in Central and South Kalimantan is an average of IDR 20,784,434 household^{-1}year^{-1} [10]. Furthermore, the income of farmers in Sidomulyo Village, Tamban Catur District, Kapuas Regency in 2015 was IDR 30,049,800 household^{-1}year^{-1} or IDR 2,504,150 month^{-1}household^{-1} [11]. Meanwhile, based on land ownership, with narrow (<1 ha), medium (1 to 1.5 ha) and wide (>1.5 ha) land ownership strata, respectively IDR 23,360,675 household^{-1}year^{-1}, IDR 28,973,970 household^{-1}year^{-1} and IDR 36,158,060 household^{-1}year^{-1}. The distribution of farmers' income per capita is categorized as medium with a Gini coefficient of 0.43 [12].

To increase farmers' income, optimal use of swamps is required. To increase support for the cultivation system, it is prioritized to develop adaptive, economical, inexpensive technology that is in line with the preferences and socio-culture of the community [13].

Many innovative technologies in the swamps field have been produced but have not been widely adopted by farmers. Technology adoption is strongly influenced by the level of farmers' social conditions, including farmer education, farmer capital, and the level of technology suitability [14 - 15]. The low application of technology is indicated by the large gap between the potential production of research results and the yield at the farmer level [6]. Furthermore, Bunch (2001) in [17] stated that the adoption of a technology can run quickly if the technology is able to increase farmers' income by at least 50 to 150%.

Many agricultural technologies have been produced by the Agricultural Research and Development Agency, but only partly adopted by farmers. Therefore, Balittra carried out demonstration farming activity of Environmentally Friendly Integrated Land and Plants Management Model in Acid Sulphate Tidal Field in Sidomulyo Village, Tamban Catur District, Kapuas Regency from 2015 to 2019 to produce "Panca Kelola" technology package for rice cultivation on acid sulphate land. The technological advantages of an applied package must be considered by farmers with the technology they are currently using. This paper aims to present information on the feasibility of introducing "Panca Kelola" technology in increasing farmers' income in tidal fields.

2. Materials and methods
The technology introduced research was carried out in the 2019 dry season and 2019 - 2020 rainy season in Sidomulyo Village, Tamban Catur District, Kuala Kapuas Regency, Central Kalimantan covering an area of 8 ha in 2019 dry season and 10 ha on 2019 - 2020 rainy season. The technology introduced research activities which were carried out are presented in table 1.

The technique of collecting data was the survey method. Primary data come from cooperator farmers and non-cooperators. The number of respondents each consisted of 10 cooperater farmers which selected purposely (the ones that implementing introduced technology) and 20 non-cooperator farmers who were randomly selected. Data were collected by means of interviews using a structured questionnaire. Primary data collected include: (a) Farming systems (cropping patterns, cultivation technology, land arrangement etc. on yards and business lands), (b) Resources owned by farmers (average area of land ownership, productive labor), (c) Inputs and outputs of rice farming and (d) Perception of farmers on one-way micro water systems.
Table 1. Model of Integrated Land and Crop Management in Acid Sulphate soils of Tidal Land.

| Utilized Technology       | Technology Introduced Package                                      | Farmers’ Pattern                  |
|---------------------------|------------------------------------------------------------------|-----------------------------------|
| Water Management          | One Way System                                                   | Two Way System                    |
| Land preparation          | Tractors and Agricultural Machine Tools                          | Tractors and Agricultural Machine Tools |
| Amelioration and fertilization | • Balanced (Soil nutrient status / DSS)                                 | Chemical Fertilizers               |
|                           | • Chemical / Biological Fertilizers (250 kg NPK Ponska, 100 kg Urea, 0.5 kg lime and 1 t of manure) |                                   |
| Use of Varieties          | Adaptive variety with Argo Pawon Siam                             |                                   |
| Pest control              | • Refugia plants                                                  | Use of chemical pesticides        |
|                           | • Light trap                                                      |                                   |
|                           | • Use of vegetal pesticides                                      |                                   |
|                           | • Use of chemical pesticides based on economic thresholds       |                                   |

Source: [26].

Perception data of the one-way micro water system was collected through a survey method for cooperators farmer. Data collection was carried out through individually interviews with farmers using a structured questionnaire. Measurement of one-way water system technology based on technological requirements criteria, namely relative advantage, technology suitability, ease of implementation, possibility to be tried, and possibility to be observed. Each indicator was developed in several statements. Respondents were asked to provide an assessment of all statements, using a rating scale with the terms score 1 = strongly disagree, 2 = disagree, 3 = doubt / don't know, 4 = agree, and 5 = strongly agree. The obtained data regarding perceptions were then distributed to different classes. Interval magnitude number class was determined based on the class interval formula. The score is displayed in the form of numerical value Suharyanto and Kariada [18] using a formula:

\[
\text{Highest Score} - \text{Lowest Score} \quad \text{Interval length} = \frac{\text{Highest Score} - \text{Lowest Score}}{\text{Number of class interval}}
\]

Based on the highest score of 5 then subtracting the lowest score of 1, then range value is 4. The interval length is obtained from the division between the range value and the number of class intervals which is 5, then the interval length is 0.8. So based on these data, the score intervals are 1 to 1.8 = very negative, > 1.8 to 2.6 = negative, > 2.6 to 3.4 = doubtful, > 3.4 to 4.2 = positive and > 4.2 to 5 = very positive.

The obtained data are tabulated and presented in table form, then financial analysis is carried out [19] with the following stages:

a. Total revenue is determined by subtracting total revenue with total costs, as follows:

\[
I = TR - TC
\]
Where:
I = Income (IDR/Season)
TR = Total Revenue (IDR/Season)
TC = Total Cost (IDR/Season)

b. Farming efficiency is assessed by using a ratio between total revenue and total costs, as follows:
R/C = Ratio between total revenue and total costs
TR = Total Revenue (IDR)
TC = Total Cost (IDR)

Decision Rule:
R / C ≥ 1 is economically efficient
RC < 1 is economically inefficient

c. To find out the possibility of new technology being developed on a wider scale (compared to the old technology), the Marginal Benefit Cost Ratio (MBCR) analysis was used. New technologies will be feasible to develop if the MBCR value is > 2 [20].

3. Results and discussion

3.1 Land characteristics
The research location is a tidal field with overflow type B. In the tidal area of overflow type B, tide range to the land is affected by large tidal overflows which occur twice a month, namely at full moon and dead moon. The condition of the water management infrastructure has not been yet perfect, some of the gates are damaged and are not functioning, there is sedimentation in the secondary and tertiary channels, so that water traffic entering and leaving the land cannot be managed properly. Based on soil classification, the demonstration plots were classified into Typic Sulfaquents and Typic Endoaquepts. The pyrite content in the upper layer of 0 to 30 cm ranges from 0.1 to 0.56 % and is said to be high if it is found in layers > 100 cm [30]. The pattern of pyrite content is the same as reported by Markus et al. [21]. Acid sulphate soils in South Kalimantan generally have pyrite in the oxidation layer between 0.09 to 0.32 percent and lower than the reduction layer which ranges from 0.17 to 1.91 %. From the characteristics and evaluation of tidal lands in Tamban Catur district shows that they are classified as quite suitable (S2) and marginally suitable (S3) for rice plants [17]. The cropping pattern at the farm level is local rice - bero. Rice cultivation in the dry season uses local Siam varieties with 2.1 to 3.5 t ha⁻¹ production.

3.2 Characteristics of farmers
The characteristics of farmers in Sidomulyo Village, Tamban Catur District are presented in Table 2. Table 2 shows that the average age of cooperator farmers is 45 years, and the level of education from elementary school to junior high school. Average farming experience is 26 years. Likewise, the age of the non-cooperator farmers is 46 years old and the education level is 9 years. The productive workforce owned by cooperator farmers is 2.30 people per family on average and 2.25 people per family for non-cooperators. The average area of land owned by cooperator farmers is 2.16 ha per family and non-cooperator 2.14 ha family⁻¹. With a total workforce of 2.28 people household⁻¹ year⁻¹, related to the area of land owned and the availability of machine tools such as hand tractors, thresers, the increase in planting intensity in tidal land using existing technology using local varieties is 2 times a year.

The average capital ownership of cooperator farmers is IDR 21,043,830 household⁻¹ year⁻¹. This value represents the difference in income of IDR 53,894,190 household⁻¹ year⁻¹ and food and non-food expenditures of IDR 32,850,366 household⁻¹ year⁻¹, while for non-cooperators, capital ownership is IDR...
1,883,703 household\(^{-1}\)year\(^{-1}\) from IDR 33,530,203 household\(^{-1}\)year\(^{-1}\) of income minus IDR 31,646,500 household\(^{-1}\)year\(^{-1}\) of expenses.

Table 2. Characteristics of cooperator and non cooperator farmers in Sidomulyo Village, Tamban Catur District, Kapuas Regency, 2020.

| Characteristics                      | Cooperator | Non Cooperator |
|---------------------------------------|------------|----------------|
| **Average**                           |            |                |
| Age (years)                           | 45         | 46             |
| Education (years)                     | 8          | 9              |
| Farming experience (years)            | 26         | 22             |
| Productive workforce (person household\(^{-1}\)) | 2.30       | 2.25           |
| Land ownership area (ha)              | 2.16       | 2.14           |
| **Range**                             |            |                |
| Age (years)                           | 33 – 64    | 33 – 56        |
| Education (years)                     | 6 – 12     | 6 – 12         |
| Farming experience (years)            | 3 – 50     | 2 – 35         |
| Productive workforce (person household\(^{-1}\)) | 1 – 3      | 1 – 3          |
| Land ownership area (ha)              | 1.25 – 11  | 1.0 – 2.75     |

3.3 Cost and income analysis

3.3.1 Rice production. The analysis results of farming costs under introduced technology and existing technology is presented in Table 3.

Table 3. Analysis of costs and income for rice farming with introduced technology and farmer technology in Sidomulyo Village, Tamban Catur District, Dry Season 2019 and Rainy Season 2019 to 2020.

| No. | Description     | Introduced Technology | Existing Technology |
|-----|-----------------|------------------------|---------------------|
|     |                 | Physical Value (IDR)   | Physical Value (IDR) | Total Value (IDR) | Physical Value (IDR) | Total Value (IDR) |
| 1.  | Production      | 5,530 ton 30,415,000   | 5,250 ton 26,250,000 | 56,665,000         | 2,922 ton 18,993,000  |
| 2.  | Production cost | 12,817,400             | 10,434,400           | 23,251,800         | 8,770,300             |
|     | Production Means| 3,420,000              | 3,500,000            | 6,920,000          | 1,167,500             |
|     | Seed 25 kg 225,000 | 25 kg 225,000       | 25 kg 225,000        | 450,000            | 10 kg 70,000          |
|     | Urea 100 kg 220,000 | 100 kg 220,000      | 100 kg 220,000       | 440,000            | 50 kg 110,000         |
|     | NPK 250 kg 675,000 | 250 kg 675,000       | 250 kg 675,000       | 1,350,000          | 175 kg 472,500        |
|     | KCI 100 kg 500,000 | 100 kg 500,000       | 100 kg 500,000       | 1,000,000          | 50 kg 350,000         |
|     | Manure 1000 kg 500,000 | 1000 kg 500,000   | 1000 kg 500,000      | 1,000,000          | -                    |
|     | Biotara 25 kg 300,000 | 25 kg 300,000      | 25 kg 300,000        | 600,000            | -                    |
|     | Lime 1000 kg 900,000 | 1000 kg 900,000     | 1000 kg 900,000      | 1,800,000          | 50 kg 45,000          |
|     | Herbicide 1 L 60,000 | 1 L 60,000          | 1 L 60,000           | 120,000            | 1.0 L 60,000          |
|     | Botanical pesticide 40 ml 40,000 | -                 | -                 | 40,000             | -                    |
|     | Drugs -          | -                    | -                  | 120,000            | -                    |
|     | Labor manday 55.5 | 9,397,400 23         | 9,397,400 23        | 16,331,800         | 7,602,800            |
| 4.  | Income manday 55.5 | 17,597,600 23       | 17,597,600 23       | 33,413,200         | 10,222,700            |
| 5.  | R/C             | 2.37                 | 2.52               | 2.43               | 2.16                 |
| 6.  | MBCR            | 2.60                 |                    |                    |                      |

Source: Primary Data
3.3.2. Farmers household income. The household income of cooperator and non-cooperator farmers comes from agricultural and non-agriculture resources, which is presented in Table 4. The farming system at the farm level, namely in the yard, is partly cultivated for poultry and large livestock such as cows. The rice fields and vegetable farming, generally cultivated for their own needs and the rest is sold. Meanwhile, non-agricultural income comes from service activities, civil servants, and working as construction workers.

Table 4 shows that the household income of cooperators in 2017 was IDR 53,894,190 household\'-year\'-1 and non-cooperators IDR 33,530,203 household\'-year\'-1. The income of cooperators comes from agriculture (rice, livestock and annual crops/vegetables) 88.61% and non-agriculture 11.39%. Meanwhile, non-cooperator farmer household income comes from agriculture 72.18% and non-agriculture 27.82%. The contribution of rice to the source of income for cooperators was 86.44% and non-cooperators was 65.24%. If the household income of cooperators is compared to non-cooperators, there is an increase of IDR 20,363,987 household\'-year\'-1 or 60.73%.

Table 4. Income of cooperator and non-cooperator farmers in Sidomulyo Village, Tamban Catur District, Kapuas Regency, 2020.

| No. | Description | Cooperator | | | Non Cooperator | |
|-----|-------------|------------|---|---|----------------|---|
|     | Value (IDR household\'-year\'-1) | % | Value (IDR household\'-year\'-1) | % |
| 1.  | Agriculture | 47,754,190 | 88.61 | 24,202,703 | 72.18 |
|     | Rice | 46,585,860 | 86.44 | 21,876,578 | 65.24 |
|     | Livestock | 618,330 | 1.15 | 1,700,625 | 5.07 |
|     | Other plants | 550,000 | 1.02 | 625,500 | 1.87 |
| 2.  | Non Agriculture | 6,140,000 | 11.39 | 9,327,500 | 27.82 |
|     | Total (1+2) | 53,894,190 | 100.00 | 33,530,203 | 100.00 |

An increase in income is also followed by an increase in expenditure. The expenditure for cooperators is IDR 32,850,360 household\'-year\'-1 and non-cooperators is IDR 31,646,500 household\'-year\'-1. Even though the expenditure is quite high for cooperators, there is still a surplus of income, namely IDR 21,043,830 household\'-year\'-1 and non-cooperator IDR 1,883,703 household\'-year\'-1 (Table 5).

Table 5. Household income and expenditure of cooperator and non-cooperator farmers in Sidomulyo Village, Tamban Catur District, Kapuas Regency, 2017.

| No. | Farmer | Income (IDR household\'-year\'-1) | Expenditure (IDR household\'-year\'-1) | Income Surplus (IDR household\'-year\'-1) |
|-----|--------|----------------------------------|---------------------------------------|-----------------------------------------|
|     |        | Food | Non Food | Food | Non Food | |
| 1.  | Cooperator | 53,894,190 | 20,982,000 | 11,868,366 | 21,043,830 |
| 2.  | Non Cooperator | 33,530,203 | 20,740,000 | 10,906,500 | 1,883,703 |

Source: Primary Data

3.3.3. Farmer household income performance. Research activities were carried out in 2015 - 2019. Table 6 shows the cooperator farmer household income from 2015 to 2019. The household income of cooperators from 2015 to 2019 has seen an impressive increase in 2017. This is because the contribution of
farmers’ income from rice is quite high, then in 2018 is decreased. The decrease in income from rice is due to the once-a-year planting activity that is only during the dry season. Then in 2019 the contribution of income from rice increased because the yield of rice cultivation was quite high. The rate of increase / decrease was between 37.69 to 60.59%. Or average increase of 21.12% year\(^{-1}\).

Table 6. Income and expenditure of cooperator farmer households in Sidomulyo Village, 2015 to 2019.

| No. | Description                  | Income and Expenditure (IDR household\(^{-1}\)year\(^{-1}\)) in Year | 2015\(^1\) | 2016\(^2\) | 2017\(^3\) | 2018\(^4\) | 2019\(^5\) |
|-----|------------------------------|-----------------------------------------------------------------|-----------|-----------|-----------|-----------|-----------|
| 1.  | Agriculture                  |                                                                 | 25,049,800| 26,858,920| 37,278,168| 23,428,887| 47,754,190|
|     | Rice                         |                                                                 | 19,346,500| 15,544,830| 26,337,925| 19,315,272| 46,585,860|
|     | Livestock                    |                                                                 | 4,903,300 | 11,173,636| 8,867,576 | 2,975,153 | 618,330 |
|     | Vegetables and fruit         |                                                                 | 800,000   | 140,454   | 2,072,667 | 1,138,462 | 550,000  |
| 2.  | Non Agriculture              |                                                                 | 5,000,000 | 8,950,000 | 16,579,999| 10,130,769| 6,140,000|
| 3.  | Total income                 |                                                                 | 30,049,800| 37,308,920| 53,858,167| 33,559,656| 53,894,190|
| 4.  | Income increase / decrease (%)|                                                                 |            | 24.15     | 44.36     | 37.69     | 60.59    |
| 5.  | Spending                     |                                                                 | 28,231,330| 30,419,082| 42,210,272| 31,762,095| 32,850,360|
| 6.  | Income increase / decrease (%)|                                                                 |            | 7.75      | 38.76     | 24.75     | 3.43     |
| 7.  | Income surplus               |                                                                 | 1,818,470 | 6,889,838 | 11,647,895| 1,797,561 | 21,043,830|

Source: [11, 17, 25, 26]

3.4. Farmers perception towards one-way water system technology

Water management is one of the keys to the success of farming in tidal swamps field. For tidal land overflow type C, the availability of water in the dry season is badly needed, while in land types A and B, the availability of water during the rainy season needs to be managed to avoid flooding. Water that smoothly enters and leaves the fields will wash out the toxic materials for plants. In this research activity carried out the application of one-way water system, namely water management that regulates water intake through the inlet door and water discharge through the outlet door. In order for the system to run properly, the conservation "tabat" system (SISTAK), which is a floodgate model that combines a swing door that is used at high tide and a stoplog door that is used to hold water at low tide, is installed in the outlet channel. In tidal swampland, water management should be accommodated by water user farmer groups or P3A groups. In Sidomulyo Village there is Kencana Tirta Makmur, a P3A organization, which has the management structure of a chairman, treasurer and secretary. The P3A institution Kencana Tirta Makmur has not been functioning. The P3A group needs to be activated because water management problem is a major problem in rice farming. Water regulation is not only to reduce or increase surface water availability but also to reduce soil acidity, prevent salinity, and wash out toxic substances that accumulate in the root zone [13]. According to WA Yusuf [27], one-way water management compared to two-way flow systems can increase yields of 46% in the dry season and 55% in the rainy season.

The perception of cooperative farmers about a one-way water system with variable relative benefits, suitability to farmer needs, ease of implementation, possibility to try, and possibility to be observed is very positive. Respondents' perceptions of water management technology are very positive because they get
higher yields and income by using a one-way water system compared to using rice technology with the two-way water system they previously used. The technology recommended is relatively simple, as needed, and not complicated, easy to understand, and easy to try with little risk. Therefore, respondents put suitability to their needs and ease of testing with a small risk, each of which has the highest value, namely 4.67, then the second place is relative advantage, and third is ease of implementation. The existence of a common perception among farmers allows good communication among farmers. Farmers' perceptions of a technology are determined by technological characteristics and individual personal characteristics [28]. The characteristics of the technology have relevance to the habits of society, then applying and the benefits obtained. Soekartawi [29] emphasizes this with his statement that agricultural technology innovation will be quickly accepted if it is more profitable, in accordance with the habits and needs of farmers, easy to understand, allows it to be tried with less risk and is easily observed and felt.

The complete farmer's perception of the one-way water system technology in Sidomulyo Village, Tamban Catur District is presented in table 7.

Table 7. Average score of farmers' perceptions of one-way water systems in Sidomulyo Village, Tamban Catur District, Kapuas Regency, Dry Season 2020.

| No. | Technology Characteristics                        | Average score of perception | Category       |
|-----|--------------------------------------------------|-----------------------------|----------------|
| 1.  | Relative advantages of micro water management technology | 4.62                        | Very positive  |
| 2.  | Compliance with farmers' needs                   | 4.67                        | Very positive  |
| 3.  | Ease to implement                                | 4.56                        | Very positive  |
| 4.  | Possibility to try                               | 4.67                        | Very positive  |
| 5.  | Possibility to be observed                       | 4.53                        | Very positive  |

Information: 1.0 to 1.8 = very negative, > 1.8 to 2.6 = negative, > 2.6 to 3.4 = doubtful, > 3.4 to 4.2 = positive, and > 4.2 to 5 = very positive. Source: Primary Data.

4. Conclusions
Panca kelola technology on tidal fields resulting in rice productivity of 268.9% higher for cooperator farmers than non-cooperator farmers. Economically, the rice-rice pattern is profitable and feasible to be developed on a large scale as indicated by the MBCR value > 2. Cooperator farmer household income compared to non-cooperator increased by IDR 20,363,987 household^{-1}year^{-1} or 60.73%. The rate of increase in household income of cooperator farmers (2015 to 2019) was higher (21.12% household^{-1}year^{-1}) than expenditure (6.30% household^{-1}year^{-1}).

The farmer cooperator's perception of the introduced one-way water system technology is very positive, so it is an internal supporting factor for farmers to increase the cropping index from once to twice a year.

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