Farmers’ perception towards water and soil management in the irrigated paddy field in North Sumatera, Indonesia

Wasito¹, V W Hanifah¹ and Sukardi²

¹Indonesian Center for Agricultural Technology Assessment and Development, Bogor, Indonesia
²Faculty of Economics and Management, Sumatera Utara University, Medan, Indonesia

E-mail: wasito63@yahoo.co.id

Abstract. Integrated Crop Management (ICM) had been introduced in North Sumatra Province since 2002. This study aimed to explore how farmers’ perception on intermittent irrigation and balanced fertilization of ICM. The assessment was obtained using cross-sectional and field survey in Serdang Bedagai and Deli Serdang Regency. Primary data were initially collected through observation toward community surrounding the watershed. The farmer respondents were selected purposively based on their roles as innovators or early adopters. Secondary data was collected from the review of previous studies. The results showed that after its first introduction in 2002, most farmers had not applied intermittent irrigation and balanced fertilization such as the use of compost and leaf colour chart (BWD) in farming practice. Farmers perception was low regarding technological characteristics that did not correspond with adoption level. High understanding on complexity, comparative advantage, and compatibility were not followed by high level of adoption, resulting innovation dissonance to occur. Farmers in downstream area were unsatisfied of irrigation institution (P3A) particularly in dry season. Therefore, it is recommended to consider institutional (P3A) approach to stimulate behaviour changes among farmers in surrounding watershed area despite hard effort to do so.

1. Introduction
Irrigation needs to be done intermittently to strengthen the roots and to support the process of growing paddy tillers. This is part of the technology component of Integrated Crop Management (ICM). In addition, the components of soil macro nutrient management in ICM include balanced fertilization and provision of organic matter through returning straw, compost, and manure to the fields.

NPK fertilizers and organic matter are one of the important nutrients for rice farming. The Five Right principles (right on place, on quantity, on type, on time, and on price) need to be pursued at the farmer level, so that rice production is optimal. According to Makarim and Suhartatik [1], the use of N fertilizer in Indonesia is quite high, where the ratio of N: P₂O₅: K₂O is much higher than Vietnam (the ratio is 4.9: 0.8: 1 and 3: 1: 1, respectively). According to Arsana [2], the use of inorganic fertilizer in rice farming is unbalanced for N and P. Urea which is given excessively can cause S or Zn nutrient deficiency, as a result, rice plants become sensitive to pests and diseases, and easily collapse, or can increase crop damage and prolong plant life [3]. The use of urea continuously as the main source of N causes deficiency of nutrient S [2].

According to Roger and Shoemaker [4] in regards to the adoption theory, the acceptance stage is described when someone has used a new idea regularly on a broader scale, after the awareness, interest,
judgment, and experimental stages. Further, the developing model were: (1) the adoption process allows adoption or rejects adoption, (2) the five stages do not always occur sequentially, and (3) after the adoption stage there are still other stages. Rogers, Singhal and Quinlan [5] refined these stages into the recognition, persuasion, decision, application, and confirmation stages. Adoption according to Mardikanto [6] is the behaviour change process, either in the form of knowledge, attitudes, and skills in a person who has received the innovation delivered by extension agents. The formation of attitudes and behavior is based on perception. Perception according to Rakhmat [7] is the process of interpreting objects, events, people that involve the senses, or the process of interpreting objects based on the gap between true or false statements or questions. Perception is the process by which sensory information is translated into something meaningful. The meaning of perception is an assessment, or process of giving meaning, or meaning carried out by individuals, groups, or society. That impression then forms the meaning of good - bad, understand - do not understand (evaluation), strong - weak (potential), or active - passive (activity).

This study was conducted to explore that intermittent irrigation, inorganic fertilizers and organic materials have already applied on irrigated rice farming, in accordance with the perception of farmers on efficient water management, balanced fertilization, and the system of ecological balance in the watershed of Ular River in Deli Serdang and Serdang Bedagai Regencies.

2. Materials and methods

2.1. Study area

The locations at the village level was selected based on the watershed area (DAS) of the Ular River, except for Sunggal Subdistrict (Deli Serdang) which was similarity in the above sea level altitute and water balance as the main problem on planting index (IP) for rice farming. This study used primary and secondary data, and reviewed research results particularly in the study area, covering the existing conditions of intermittent irrigation systems, fertilization patterns, adoption, and farmers' perceptions of using intermittent irrigation systems, inorganic fertilizers and organic matter.

2.2. Methods

The study format was cross-sectional with a field survey method. Primary data assessment started with observing and engaging in natural settings in rural communities [8]. The next step was to determine the purposive sampling of pioneer farmers or innovators or early adopters in each village, as respondents and key informants, so that there were 50 respondents. The next stage was to conduct Focus Group Discussions (FGD) and in-depth interviews with a participatory approach, with respondents who had been divided into two sub-groups (i. farmers and institutional roles = 25 respondents, ii. farmers = 25 respondents).

2.3. Perception measurement

Perception measurement referred to Saifuddin [9], in the form of Likert scale and Semantic differentials with range of: 0 = no knowledge, 1 = less knowledge, 2 = some knowledge, 3 = good knowledge, 4 = excellent knowledge. According to Catrileo theory [10], cultural similarity provides a perception of an object that is almost the same. Differences in culture, values, and terms of reference (heterophiles are the result of differences in experiences and environments. On the other hand, cultural similarity (homophily) is adapted to the measurement of perception and adoption.

Adoption and perception of balanced fertilization and organic matter referred to ICM model released by Minister of Agriculture Decree number 40/2007 regarding recommendations for fertilization of paddy fields in specific location, and recommendations from the local governments of Deli Serdang and Serdang Bedagai Regencies.
2.4. Data analysis

Data analysis was simply done by editing, coding, and tabulating data, arranged into groups or categorizations [11] for interpretation. In addition, the probability theory [12] used in this study was set theory: the intersection operation, where the slice of set A (village 1) and set B (village 2) = A ∩ B = (X : x ∈ A and x ∈ B), A and B were not separated from each other as shown in Figure 1. For example, when there is an intersection, meaning that the two sets are simultaneous; meanwhile, when no intersection, the two sets are unconnected.

![Intersection](image)

**Figure 1.** Intersection operation of set A and set B.

3. Results and discussion

3.1. Perception on intermittent irrigation system

The Field School of Integrated Crop Management (FS-ICM) which was started in 2008 was an effort to increase rice production focusing on implementation, and has succeeded in being one of the triggers in increasing rice production [13]. The result of the study showeed the increase of rice production from 2008 to 2011 is about 2.78%. Meanwhile, in 2012 the FS-ICM activities continued on an area of 3,500,000 ha for non-hybrid rice, hybrid rice, and upland rice, according to Yahya [14]. The implementation of FS-ICM in 2012 received facilitation/support for the provision of seeds for non-hybrid rice, hybrid rice, upland rice, and hybrid maize through Direct Seed Assistance (BLBU).

In order to meet the needs of irrigation water for rice plantations, the water discharge in the watershed area must be more than enough to be channelled to the main, secondary, and tertiary canals that have been prepared in the rice planting area. For this reason, the distribution of irrigation water to an area of rice land can be properly regulated based on an agreement between the irrigation manager and the P3A or GP3A. Based on the controlled distribution of water, the problem of irrigation water need to be resolved without causing conflict or turmoil in farming communities as user of irrigation water.

Intermittent irrigation was mostly not applied by farmers in the study area neither in Deli Serdang nor Serdang Bedagai. The same condition was found in the area where ICM on the lowland rice program began in Lubuk Bayas Village, Lubuk Saban Village, and Tanah Merah Village. This continued in the Farmer School (FS) – ICM on paddy program which run for the period of 2008 to 2012. The adoption of intermittent irrigation was in line with the perception of farmers who were less than 0.4 to 0.8 (table 1).

Based on the result on farmers’ perception about intermittent irrigation, it is concluded that all farmers had not adopted this technology due to some reasons as follow: (a) rotating irrigation water was not always available, especially during the dry season; (b) regulation of water from all groups of P3A/GP3A was not fair and most farmers objected to implement because it raised some problems; (c) required a workable rice field with a high topography or swale land, but it cannot be applied for paddy fields, because the water cannot be discharged; and (d) farmers filled as they wish to avoid growing weeds, unless they want to fertilize, then reduce the water (table 3), in line with the perceived value of perception in the range of 0.5 to 0.9. The number of perception showed that farmers agreed with the reasons abovementioned. The higher number means that the level of agreement was also high.
Table 1. Perceptions of intermittent irrigation technology was not applied by farmers in the surrounding Ular River watershed.

| No. | Technology (Regency) | Areas | Average Perception | Adoption |
|-----|----------------------|-------|--------------------|----------|
| 1.  | Lowland rice ICM (2002–2004) | L. Bayas, L. Saban, T. Red (Interception) | 0.4 | 0.0 |
| 2.  | FS-ICM lowland rice | Kec. Perbaungan, T. Noni, Sei Buluh | 0.7 | 0.0 |
| 3.  | ICM, FS-ICM lowland rice | Kec. Merbau fence, Banyan, T. Morawa | 0.8 | 0.0 |

Table 2. The intermittent irrigation technology was not applied by farmers outside the Sungai Ular watershed.

| No. | Technology (Regency) | Area | Perception | Adoption |
|-----|----------------------|------|------------|----------|
| 1.  | ICM, FS-ICM lowland rice | Kec. Sunggal | 0.6 | 0.0 |

Table 3. Perceptions of intermittent irrigation technology that are not adopted.

| No. | Reasons not adopted | Perception |
|-----|---------------------|------------|
| 1.  | P3A, GP3A | 0.5 |
| 2.  | There is no agreement between the P3A/GP3A management - farmers didn’t adopt because it was difficult to manage, both in rainy or dry season | 0.5 |
| 3.  | The irrigation water intake and discharge system was difficult to adopt intermittent, either rainy or dry season | 0.6 |
| 4.  | The topography of paddy fields in both P3A/P3A was difficult to manage Farmer or Between Farmers | 0.6 |
| 5.  | Continuous waterlogging irrigation systems reduced grass growth | 0.9 |
| 6.  | When fertilizing rice, the volume of water in the fields was reduced | 0.8 |
| 7.  | Paddy field topography among farmers was difficult to adopt intermittent | 0.8 |

P3A or GP3A are in a relatively good condition and strong, but the institutional capacity need to be strengthened. Moreover, they were less successful in the application of intermittent irrigation technology, due to many factors as listed in table 3. When the dry season arrived, farmers usually faced great difficulties due to limited water availability. There were two solutions to overcome water shortages in dry seasons: the first, was to carry out water management appropriately, and the second was to initiate efficient water usage. In addition, there were problems with the distribution of irrigation water across several districts, especially in downstream (isolated) areas, where the water supply was always less than demand. In these conditions, it is very important to manage water sources and irrigation supply systems. For example, the farming community needs to hold an initial meeting to prepare a plan for the distribution of water.

3.2. Perceptions of balanced fertilizer
The fertilizer subsidies by the government did not drive farmers to reduce the dosage of fertilizer. This means that the imbalance use of inorganic fertilizers was assumed as the cause of soil nutrient depletion, resulting in rice yields. In the use of urea, farmers did not apply as recommended by IRRI using the leaf colour chart (BWD) once every 7 days because BWD tools were not available in the local area. On a non-technical basis, they had experience in applying urea fertilizer by looking at the greenness of rice
leaves without BWD. Farmers were never done soil analysis. The use of single N, P, K fertilizers (urea, SP36) or compound (Ponska) in the study villages was still excessive and not in accordance with the principle of balanced fertilization. This seems that farm practice changes were difficult to occur. According to Saifuddin [9], collective values determine thought patterns, behaviour patterns, and have the power to urge members of community groups to adopt these behaviours.

The adoption of balanced fertilization according to dosage, type and time in this study was not analyzed in depth because the use of urea, SP36, and Ponska fertilizers in the study village was not in accordance with the principle of balanced fertilization. The adoption of high balanced fertilization technology was generally carried out by cooperative farmers in government programs, for example the Integrated Rice Productivity Improvement Program (P3T) with Integrated Crop Management (ICM) in Bengkulu, Bali, East Lombok [2], or the FS-ICM program in the field laboratory unit. The level of farmer adoption was also influenced by the carrying capacity of the agro-system, motivation, attitude, consistent action, availability of capital and production inputs.

The adoption of inorganic fertilizers and manure rates in the study villages did not comply with the recommendation of Permentan 40/2007 about ICM for lowland rice, in line with their perceptions of balanced fertilization and its benefits, which mostly in the range of no or less knowledge (perception score 0-1). This score was very different from those who have good knowledge or excellent (perception score 3-4) that have applied the practice of using inorganic fertilizers and did not differ significantly between villages. For farmers, high fertilization rates can increase rice yields. Based on set theory [12], there is an intersection of small slices (heterophily) between the perception and adoption of farmers on ICM recommendations as stated in Permentan 40/2007 as shown in figure 2.

According to Wahid [3], the adoption of appropriate fertilization technology, either type, dose, or application, can increase the efficiency of N, P, and K fertilization (40 to 50%). Applying fertilizers to rice plants appropriately will not only reduce the cost of using fertilizers, but also will make the plants to be healthier as it could reduce nutrients dissolved and the accumulation of N in water that is very dangerous to human health. Excessive application of N fertilizers can damage the environment because of N2O gas emissions. Granular urea fertilizer provides the highest N2O gas emissions, and the lowest is tablet urea fertilizer.

Farmers' perceptions on balanced fertilization technology were not in line with the level of adoption, because high understanding of the level of complexity, relative advantage, conformity was not followed by high adoption rates, then there was dissonance of innovation. Farmers' perceptions of the properties of this technology are in line with the adoption of the hand tractor in [15]. The application of balanced fertilization technology did not only change the existing technology but also the community concerned. The impact of its application did not end at the production system because it also addressed the economic, social, cultural, and systemic ethical tools [4]. The community must be able to determine how to apply the technology sustainably in realizing planting index for rice.

3.3. Perception of organic matter
There was a difference perception between farmers who have good or excellent knowledge (perception score 3 to 4) and no or less knowledge (perception score 0 to 1) about the adoption of organic material, returning paddy straw in the form of compost, or manure decomposes. They did not adopt organic materials according to these recommendations due to some reasons, including: it was less or not available in the location, the adoption costs and the labour costs were more expensive, the application
was less practical, and there was large intersection and operation of large sections (homophily). On the other hand, there was an intersection and operation of small slices (heterophily) to understand the negative impact (-) toward the plants and the harmful for human health. In addition, the manure production from cattle owned by farmers in the location did not correspond with the recommendation of Permentan 40/2007 (2 t ha\(^{-1}\) planting season\(^{-1}\)). Each cow (with live weight 250 to 275 kg) produces wet dung of about 4% of live weight (10 to 11 kg) per day. After the processing step into ready-to-use manure, the yield produced is 45 to 50% (4.5 to 5 kg head\(^{-1}\) day\(^{-1}\)).

In terms of the benefits of providing organic materials, farmers who have good or excellent knowledge (perception score 3 to 4) were significantly having different behaviour from those who no or less knowledge (perception score 1 to 2). The main benefits are considered as follow: can improve soil structure and fertility, save the use of inorganic fertilizers, can increase rice yields that then showed an intersection and large slice operations (homophily). Another benefit in term of saving water use showed an intersection and operation of small sections (heterophily). The provision of organic matter can significantly increase the yield of dry un-hulled rice, improve the environment for plant growth, and increase fertilization efficiency.

The application of manure and inorganic fertilizers gave higher yields (10 to 15%) than inorganic fertilizers in ICM, or 23 to 27% in Non ICM. The application of cattle manure (2 to 3 t ha\(^{-1}\)) increased rice production by ± 15% (0.8 to 1.0 t), saved urea (40 to 70 kg ha\(^{-1}\)) and SP36 (35 to 50 kg ha\(^{-1}\)), in addition, on irrigated rice fields increased GKP production by 15% [16]. Meanwhile, the application of rice straw compost increased rice production and fertilizer efficiency, for instance, by putting 2 t ha\(^{-1}\), 1 to 2 t ha\(^{-1}\) and 3 t ha\(^{-1}\) increased rice production, respectively 765 kg ha\(^{-1}\), 1 to 1.5 t ha\(^{-1}\), and 2 times as much. A study by Wasito et al. [17] in Blora showed that most farmers had applied organic matters to their fields even though still far from recommendation dozes.

### Table 4. Organic matter content of lowland soils in Deli Serdang Regency.

| No. | Sub-District, Village | Level of C-organic (%) | Level of organic content (%) |
|-----|-----------------------|------------------------|-------------------------------|
| 1.  | Medan Senembah,       | 0.69 (very low)        | 1.19 (low)                    |
| 2.  | Pardamean,            | 0.79 (very low)        | 1.36 (low)                    |
| 3.  | Telaga Sari,          | 0.62 (very low)        | 1.07 (low)                    |
| 4.  | Wonosari,             | 0.11 (very low)        | 0.19 (very low)               |
| 5.  | Naga Timbul,          | 0.35 (very low)        | 0.60 (very low)               |
|     | Beringin,             |                        |                               |
| 1.  | Araskabu,             | 0.71 (very low)        | 1.22 (low)                    |
| 2.  | Kelapa,               | 0.46 (very low)        | 0.79 (very low)               |
| 3.  | Sidodadi,             | 0.64 (very low)        | 1.10 (low)                    |
| 4.  | Karang Anyar,         | 0.14 (very low)        | 0.24 (very low)               |
|     | Hamparan Perak        |                        |                               |
| 1.  | Payabakung,           | 0.74 (very low)        | 1.27 (low)                    |
| 2.  | Paluh Manan,          | 0.96 (very low)        | 1.65 (low)                    |
| 3.  | Hamparan Perak,       | 0.87 (very low)        | 1.49 (low)                    |
|     | Sunggal,              |                        |                               |
| 1.  | Medan Krio,           | 0.82 (very low)        | 1.41 (low)                    |

Source: [18]

According to Rauf [18], rice fields in Deli Serdang Regency have a much lower level of organic matter than the required content of ideal soil (5%) (table 4). The rice fields in the location as shown in table 4 are used intensively, have low to very low levels of organic matter so that the carrying capacity of plant production was also low. Paddy soil with an organic matter content of less than 2% is classified as critical soil because the energy source or organic matter is also very low. Low content of organic
matter meant that there was buffering capacity and weak aggregation as the ability to absorb and provide available nutrients is too low.

Furthermore, Rauf [18] said that soil organic matter is very important in supporting soil and plant productivity because it plays a role in improving all aspects of soil productivity or all soil properties and behavior. Organic matter also plays a role in increasing soil porosities (loose), increasing the value of the Cation Exchange Capacity (CEC/KTK) so that soil can absorb more nutrients, also improve the life of soil microorganisms (biological properties). Sufficient and good quality (high nutritional value and balanced) of organic material will stimulate growth and increase in microbial diversity in the soil. High levels of microbes will help the dissolution of mineral and organic matter (nutrients) in the soil so that sufficient nutrients are available for plants.

4. Conclusions

Since the initial introduction of ICM on rice (2002), FS-ICM program for lowland rice generally did not apply neither intermittent irrigation technology nor balanced fertilization system. Generally, farmers perception concerned with technological characteristics (complexity, relative advantage, compatibility); however this did not comply with the perception on the two technologies abovementioned (intermittent irrigation technology nor balanced fertilization system). Thus, there was dissonance of innovation.

Farmers' perceptions were dissatisfied with the condition and irrigation institutions (P3A), especially in the downstream (isolated) areas in the dry season. Paddy soil in Deli Serdang has a content of organic matter (<1.5%) which was much lower than the ideal soil organic matter content (5%). Therefore, rice straws needs to be returned to paddy fields to increase soil levels of K$_2$O. Perceptions on this ecological aspect were influenced by experiences and social culture in the farming community. This study recommended to consider institutional (P3A) approach to stimulate behaviour changes among farmers in surrounding watershed area, particularly in order to manage irrigation.

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