

## Managing Movement of Returning Rice Straw into Soil (RRIS): A Solution to Land Degradation

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### ABSTRACT

Concern on rice production in Indonesia is escalating since the production of rice tends to be levelling off for more than a decade. Soil degradation in lowland is among the main challenges. Soil encounters continuous decreasing organic matter and organic carbon content because the biomass from the rice plants was not returned to the land sufficiently. Most of the biomasses went out of the land or were burned by rice producers since there was not enough time to decompose the biomass before returning into the soil of lowland or it need additional cost to do so. Most farmers preferred to return the rice straw after burning, but it will not improve the condition. Otherwise, burning of rice straw caused air pollution since it released at least three kg particulate matter consisting of CO, SO<sub>2</sub>, CO<sub>2</sub>, and ash. Using interpretive structural modeling (ISM) this paper is trying to find the important factors with sequential solution. The result shows that encouraging rice producers to return rice straw into soil (RRIS) should start with Provision of Immediate Decomposing Technology and assistance program and Credit and Assistance Program.

Keywords : ISM, managing soil degradation, organic matter, rice straw

### INTRODUCTION

Intensive farming system develops as the solution of increasing agriculture production amid limited agriculture land. Continual increase of agriculture production is a critical way to keep people getting food. Intensive farming in lowland areas refer to increase planting round from one to two, two to three, even three to four planting rounds a year. Intensive farming is also marked with excessive use of agrochemical for decades. This is made worse with the application of monoculture system. Such intensive farming will also ignore fallow period or a rest time of land. Normally, a land needs a rest time or no cultivation period at which the land has a break time from soil nutrient exploitation. Otherwise, the land has a chance to give microbes to decompose and analyze biomass and compounds into available substances. Fallow is also beneficial to cut

off disease and pest which attack the similar plants previously.

Fallow, therefore, has a function to restore land fertility naturally. Plant residues will be decomposed by nature within months of fallow. Naturally, fertile land will not only reduce fertilizer use but also provide healthy soil with good structure and lots of beneficial microbes. This conducive condition will support plant to grow well and give optimum yield.

Such fallow application will be found only in the once or twice planting round where the time between the two planting rounds is long enough. If one rice planting round need about four months then the fallow time is the rest months within one year long, which is really a long fallow. If the rice producers apply two planting rounds a year, then the fallow time will be three to four months. In the intensive farming, fallow between the first planting round in rainy season to the next planting round in

the dry season cannot be applied, since the interval time from harvest to the next planting round is very short. The rice producers will be busy to prepare for the next planting round, and the residues of rice plants have not enough time to decompose. For that reason, the rice producers tend to burn the rice straw, the main residue of the rice plants.

At another interval time from second planting round in dry season to the first planting round in rainy season, fallow is possible because it has about three months long before the rice producers start to the first planting round. Unfortunately, in the fallow period the rice producers cannot let the rice straw to decompose to restore some fertilizers, repair soil structure, and activating beneficial microbes to work. Most rice producers tend to burn the rice straw to avoid the accumulate plant residue from rat to make nest in the biomass. The rice producers also have own confidence that ash from the rice straw can be utilized as fertilizers. The use of fallow system in the rice production in lowland areas will be scarcer at the three planting rounds or more.

The above-mentioned condition makes the lowland areas are degrading in the quality of soil, which is not conducive to increase production. Otherwise, the production tends to be stagnant, even with more fertilizer uses. Degraded land does not happen only in Indonesia but it has been a global problem. Bekuzarova *et al.* (2020) shows that the global areas of degraded and diseased soils exceeded 1.2 billion hectares, which is about 22% of the world's agricultural lands, while the losses from damaged soils account for 25% of the global crops.

The main efforts to make restoration to damaged soil should be addressed to returning rice straw into soil (RRIS). Returning rice straw is the most rational effort because it is available at field. Besides improving land condition, such effort will avoid emission from rice straw burning. Burning of rice straw emits at least 3 kg particulate matter consisting of CO, SO<sub>2</sub>, CO<sub>2</sub>, and ash. Therefore, there are some factors need to be worked to return rice straw into lowland soil.

Objectives of the paper is to give description on rice cultivation practice recently, impact to soil condition, and arranging the best sequence of factors supporting RRIS. The results of the research will show the government on how to do with the factors, which are the factors that should get first attention and the factors which have important roles to resolve other factors. Some factors will get strong and capable of resolving all the factors.

## MATERIAL AND METHODS

The paper was written based on literature review and field assessment in Lombok, West Nusa Tenggara. Respondents interviewed including seven officers of agriculture bureau, 5 agriculture extension officers, and agronomy and socio-economic researchers.

Field study was carried out in Teruwai Village, Pujut District. The location is shown in the map of Central Lombok Regency (Figure 1).

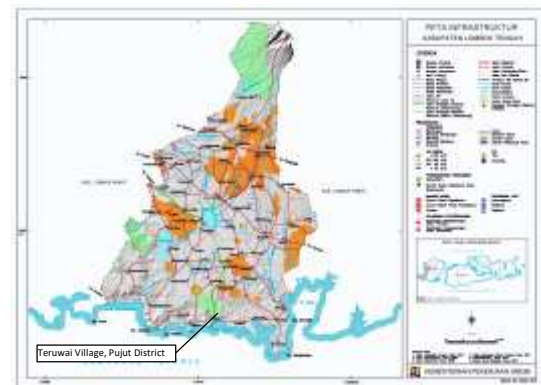


Figure 1. Map of Central Lombok showing the Teruwai Village, Pujut District

Interpretive Structural Modeling (ISM), developed by J. Warfield in 1997, is employed to make the sequence of the factors supporting RRIS. ISM is used to construct appropriate sequential steps of RRIS. ISM will also develop a relationship between driving power and dependence condition, in which the factors will reside. It will be classified into 4 sectors, where sector 1: Weak Driver - Weak Dependent Variable (OTONOMOUS); sector 2: Weak Driver Variable - Highly Dependent (DEPENDENT); sector 3: Strong Driver-

Strongly Dependent Variable (LINKAGE); and sector 4: Strong Driver - Weak Dependent (INDEPENDENT).

## RESULT AND DISCUSSION

### Degradation of lowland soil

Use of fertilizers and pesticides for rice farming in lowland has happened for decades. Worst practice particularly occurs among intensive rice farming. Intensive rice farming which applies more than two planting rounds in which use of fertilizers as well as pesticides more frequent than conventional farming. The rice producers who mostly have small size field tend to use excessive fertilizers, with the purpose of obtaining more yield.

Although chemical fertilizer has supported to increase production, chemical fertilizer has been determined to be the second cause of soil degradation after soil erosion (Abad, 2018). The over use of chemical fertilizer has resulted to hardened soil, decreased in fertility, low soil quality, increased used of pesticide and herbicide, polluted air and water, and also produces greenhouse gasses. It also contains salt as well as other acidic materials which is one of the most critical characteristics of chemical Fertilizer and is expected to damage the soil in the long run (Abad, 2018).

Over use of fertilizers in lowland rice farming is possible since irrigation water can supply some fertilizers, including macro nutrients (K, Ca, and Mg) and micro nutrient (Si) which are solved in irrigation water. The amount of the substance brought by irrigation water often exceed quantity needed by rice plants (Setyorini *et al.*, 2011).

Besides chemical fertilizer, organic matter supply into soil makes the soil degrade. Research results carried out by Agency of Agriculture Research and Development in 2006 showed that 65% of 7.9 million hectares of lowland areas in Indonesia have low to very low organic matter of below 2% (Setyorini *et al.*, 2011), whereas organic matter has incredible function in soil.

Several soil organic matter functions as follows: produces small colloids with large surface area, stores nutrients used by plants which is done through humus particle size and its own chemical makeup, holds six times weight in water, and helps sandy soils by increasing their water - and nutrient - holding capacity (DeBusk, 2020), and the major source of organic carbon. Soil organic matter content has positive correlation with lowland rice productivity: the lower soil organic matter content the lower land productivity (Erfandi and Nurjaya, 2014).

At the condition of degraded lowland, uses of more fertilizers in rice farming will not increase the production. The chemically damaged soil also affects the cation exchange capacity of the soil. Likewise, the nutrient storage and nutrients exchange capability have also diminished as the organic matter drops. The chemical fertilizer applied to the farm escapes to the ground water in the absence of sufficient soil organic matter to catch and store these nutrients (NPK).

Although the above-mentioned impact of fertilizer uses, the contribution toward the degradation of lowland cannot be identified exactly. On the other hand, organic matter depletion has various consequences which contribute to lowland degradation. The magnitude of fertilizer consequence also depends on the sufficiency of organic matter.

The concentration of soil organic matter (SOM) or soil organic carbon (SOC) is seen as an important determinant of soil remediation. Increased levels of SOM have been reported as improving crop nutrition, aggregate stability (soil structure), water retention and ease of cultivation and seedbed preparation. Soil organic matter has also been linked to improved soil aeration and supporting the resistance of a soil to compaction and enhanced soil biodiversity. Therefore, a quantity of SOM contributes to soil quality/health (Jangir *et al.* (2019); Spink *et al.*, 2010).

Activities of various biological community such as microorganism, microflora, and soil fauna support each other for cycles process sustainability, form biogenic soil structure, which control processes of physics, chemical, and

biological soil. Rice straw is able to reduce soil compaction and increasing water absorption capacity, porosity and decreasing bulk density. Meanwhile, rice straw influence soil physical characteristics such as humidity of soil, aggregate form bulk density, hydraulic conductivity (Erfandi and Nurjaya, 2014).

#### **Concern on lowland soil remediation**

The main causes of lowland degradation are indicted a combination of long-term use of inorganic fertilizers, which is less or more has left residues because of over use, and SOM and SOC depletion. Most SOM content is below 2%. Therefore, the simple and effective ways of restoring the degradation soil is putting more organic matter into the lowland soil. Obviously, RRIS should be chosen as it is available in the field.

Awareness of RRIS has appeared in the last 40 years, when SOM was relatively sufficient. The government through extension officers reminded rice producers the benefits of rice straw for soil improvement and providing organic fertilizers. The government has also provided decomposer to accelerate rice straw to decompose and ready to apply. Promotion of RRIS was also motivated to avoid rice straw burning, which polluted air. Unfortunately, promotion of RRIS did not carry out completely with strong program and involving all prime stakeholders.

Returning rice straw will increase soil organic matter, organic carbon, and microbes. Soil microbes together with organic matter is important components in soil and role as soil biological buffer which maintain nutrient provision in balance amount for plants (Erfandi and Nurjaya, 2014). Microbes that are important in lowland areas are those tethering N from air, P element solvent, and the microbe that change S into available sulphate for rice plants.

Nevertheless, better decomposer microbe is required to accelerate rice straw to decay and ready to apply in the lowland. Some efforts to find strong decomposer have been carried out by researchers although more supports are still needed. So far, research on soil microbiology has resulted superior inoculants from the microbes and

has been packed as biological fertilizers (Setyorini *et al.*, 2012).

Local knowledge performed by rice producers toward rice straw through burning can be considered beneficial for soil fertility. However, it is not effective because it can damage soil structure and reduce soil microbe activities. Burning rice straw will loss 80% of N, 21% of K, 4-60% of S, and all organic matter (Erfandi and Nurjaya 2014). Therefore, it is essential to inform the right knowledge to the rice producers intensively through assistance, extension, and training.

Government efforts to make lowland remediation in terms of increasing SOM and SOC is through the use of organic fertilizers. Organic fertilizers are embedded in the package of fertilizer subsidy with the purpose of ensuring rice producers to use it. It is expected that the use of organic fertilizers will help restore SOM and SOC gradually. However, the program of RRIS does not work well since the rice producers are not interested in using the fertilizer. Organic fertilizers produced by a fertilizer company does not give good benefit to rice plants as expected.

Soil experts realize that the benefit of organic fertilizers produced by national big company is not suited since the company needs to concern on the durability of the fertilizers, which enable to be resistant from early damage. Durability is related with high temperature treatment, which will kill beneficial microbes. The living organism is in fact very important in organic matter as has been stated earlier. The production of organic fertilizer which is centralistic could be the main factors of the unwilling organic quality. Therefore, there is a need to decentralize the production of the fertilizer to ensure of better quality, easier distribution, and cheaper. Organic fertilizer can be produced at each sub district or district by local-state enterprises.

#### **Factors Supporting returning rice straw into soil (RRIS)**

##### *Identification of the factors*

Based on literature review, expert judgment, and field assessment, there are nine factors potentially support RRIS program. The factors are as follows crushing machine support (Machine), labor availability

(Labor), time for decomposing (Time), provision of immediate decomposing technology (Technology), promotion through plot demonstration (Promotion), credit and assistance program (Credit), institution capability of rice straw returning service (Capability), capital availability (Capital), rice producer motivation (Motivation).

#### ***Crushing Machine Support (Machine)***

Support of rice straw crushing machine is considered important in a precondition for subsequence processing (QiangHe, 2015) which can be the factor motivating the rice producers to return rice straw into soil. Small parts of rice straw will be decomposed much faster, even without specific treatment. Such practice appeared in the use combine harvester which left small parts of rice straw spread across the field. The rice producers let the crushed rice straw grind with soil through plowing. No complaint was appearing during the growing period. This showed that fresh small part rice straw immersed into soil will not bother the rice plant growing.

A rice producer told at field visit that fresh rice straw made the rice plant leaves turned into yellowish at several days after replanting from nursery. However, it did not matter at all afterwards. Therefore, support of rice straw crushing machine will help the rice producers to return the biomass into soil.

#### ***Labor Availability (Labor)***

Labor availability refers to the family labors who are now very limited in villages. Young rice producer family members tend to urbanize or are not ready to work in agriculture sector (Christiaensen et al., 2020; Besuspariene and Butvilaitė, 2019). They go out of the villages to get job in non-agriculture sectors, especially industry and services. The availability of family labors is crucial to reduce cash cost.

The rice producer has no enough time to work in decomposing and RRIS. Soon after rice harvest, the rice producers need to dry the husky rice on the sun. Some of the rice harvested is for sale and the rest for own consumption. Some farmers sell rice at field, while others sell the rice after drying. They

also have to contact tractor owner to plow the land, buy seed, prepare nursery and its maintenance.

#### ***Provision of Immediate Decomposing Technology (Technology)***

Since the time interval between harvesting and the next land cultivation is very short, the technology of immediate decomposing rice straw with simple in application is crucial to be provided. So far, the technology of immediate decomposing has yet to introduce by the government, although the product from produced by private has appeared recently.

In order to support the rice producers to return rice straw in soil, provision of immediate decomposing technology is important. Previous technology of decomposing rice straw developed by government's research centers need 15 days, which is not capable of overcoming the short interval. However, with continual research, Balittanah has been successful to produce a decomposer which can decompose rice straw less than a week. A current product which can immediately decompose rice straw are Dekomposer Super Aktif (DSA) which decompose rice straw only 5-7 days.

#### ***Time for Decomposing (Time)***

Time interval after harvest to the next land cultivation in irrigated lowland area is usually very tight because irrigation water needs to be utilized immediately, or it will be scarce, otherwise. In watering all lowland areas from irrigation water, the irrigation authorization divides rice lowland areas into five blocks of irrigation schedule. First block will get first irrigation water for two weeks, in which the irrigation water will fulfil the block. After the first block has get full water within two weeks, the water will be inverted to the second block also for two weeks. The same will be applied to other blocks. Within the two weeks of getting irrigated, the rice producers must be ready with land plowing and planting.

This tight time available make the producers have no time to decompose rice straw. According to rice producer information, composing rice straw needs at least 45 to 60 days (Cybex Pertanian, 2019).

The rice straw needs to be decomposed before being returned into soil. Returning fresh rice straw will spoil rice plant growing because decomposing rice straw will release hot energy which bother the rice plant.

#### ***Promotion through Plot Demonstration (Promotion)***

Seeing is believing concept is always effective to ensure rice producers in doing new things. Promotion through plot demonstration needs to be developed in several locations, which enable people can watch the process and the yield. The demonstration plot should give detailed information technically and financially, which make rice producer can calculate the cost and the benefit with the family labor available.

The plot demonstration can continue to field study for those interested in doing the same. Plot demonstration is effective to give information and invite to apply the innovation (Khan *et al.*, 2009; Sseguya *et al.*, 2021). Agriculture extension officers can also give more information about the plot demonstration.

#### ***Credit and Assistance Program (Credit)***

Most rice producers cultivate less than 0.3 ha of land are considered poor community. Therefore, provision of soft credit will help the rice producers to apply the technology (Chandio *et al.*, 2017). However, the application of technology should be accompanied with assistance, and the agriculture extension has the capability of doing so.

#### ***Institution Capability of Returning Rice Straw Service (Capability)***

Institution capability is needed to organize the RRIS program. According to Merriam-webster dictionary, the meaning of capability is the quality or state of being capable. Capability is at the upper level of capacity which is commonly should be embedded in an institution. The capable institution is required to overcome the scarcity of labor and efficiency of machine use. The capability of the institution in the returning service will affect the program acceleration. The larger the more capable the institution the faster the effect to returning

program, with the assumption that the higher level of lowland organized is sub district.

The institution to establish should come from local capable people and institution at subdistrict or district level. Village-owned enterprise (BUMDES) has been developed in every village in Indonesia, some of which have run businesses successfully (Soejono *et al.*, 2021). Some BUMDES in Lombok make collaboration local state-owned enterprise (BUMDA) at province level.

#### ***Capital Availability (Capital)***

Capital availability is essential developing program. Capital availability is directed to the institution which organize RRIS program. Capital availability is to equip organizing institution in RRIS program.

#### ***Rice Producer Motivation (Motivation)***

Rice producers have high motivation to improve soil fertility (Nakamura *et al.*, 2015). Since the purpose of RRIS is also to improve soil fertility, the motivation of rice producers will increase with the successful of the program. The rice producers, theoretically, should have higher motivation if RRIS will get additional income.

#### **Result of ISM**

ISM method shows that technology of decomposition and credit are determining factors in the sequence of steps of RRIS. Decomposition technology provided is the technology which can decompose rice straw less than a week. The existing decomposition technology has the capability of decomposing less than two weeks. At the same time, credit is needed to support the application of the technology. Credit may be meaning of free of charge decomposer. Small scale rice farms are considered poor sector which avoid cash expense.

When technology and credit factors have been available, promotion factor of RRIS can be developed. Promotion factor is through plot demonstration. Plot demonstration is to show step by step returning rice straw through the yield of the practice. It may need several planting rounds within several years.

The promotion factor will facilitate capital availability factor to work. Capital availability factor is intended to the institution which organize RRIS program. Afterwards, the capital factor will enable the capability factor of the returning rice straw service institution to function. The Capability factor at the same time activates motivation factor of rice producers to perform. Capability and motivation factors will make other factors of machine, labor, and time to perform.

The sequence of factors supporting the RRIS shows that Provision of Immediate Decomposing Technology, Credit and Assistance Program, Promotion through Plot Demonstration, and Capital Availability need to get earliest solution. The factors are powerful driver which can support other factors to work. Technology which has been invented need to spread out among farmers with the support of credit, which enable the farmers to buy and use the technology. Obviously, Figure 2 is the structural model showing the sequence of resolving the factors for optimum resolution. At the first level, credit and technology are the factors that should be initially resolved. Other factors at upper level will be resolved if the factors at first level is done.

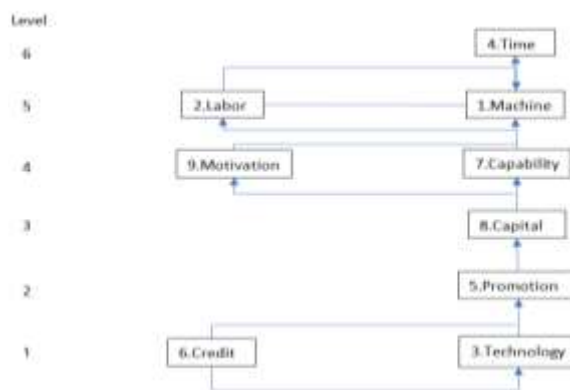


Figure 2. Diagram of structural model

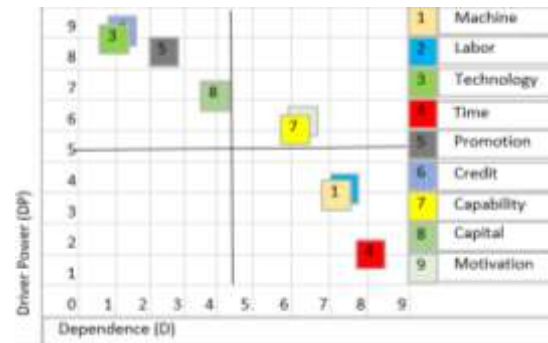


Figure 3. Diagram of driver power and dependence of the factors supporting RRIS

On the other hand, Figure 3 shows the power and dependence of the factors toward the rest factors. Credit, technology, promotion and capital have high driver power with low dependence, which have the capability of resolving other factors together.

**CONCLUDING REMARKS**

Cultivation practice by rice producers has yet to pay attention on the soil health in the long term, especially by not returning rice straw into soil where the rice is growing. Such a practice has made the SOM as well the SOC deplete much lower than minimum level.

Structural modeling shows the arrangement the best sequence of factors supporting RRIS, as the guidance for the government to make a program on land degradation solution. According to the results of the model shows that Technology and Credit should get firstly resolved in order to resolve other factors.

The model also shows that Credit, Technology, Promotion and Capital have high driver power with low dependence have the capability of resolving other factors together.

In the practice of movement, the government can provide the technology and credit to the rice producers by involving Bumda (Local government-owned enterprise) and Bumdes (Village government-owned enterprise), the existing institution that is closest to farmers. If the technology and credit are available, then RRIS program can develop.

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