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Anticipate of Climate Change Impacts In Rainfed Lowland Rice Through Applying Appropriate Technology

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Abstract. Rainfed lowland covers about 2.1 million ha in Indonesia that are generally distributed in Java, Sumatera, Kalimantan, Sulawesi, and Nusa Tenggara. Rainfed lowland ecosystems have great potential to be more productive agriculture to avert possible food shortage. However, productivity of rainfed lowland rice is low due to low soil fertility, lack of water resources and its infrastructure, high weeds infestation, drought stress, and susceptible to climate change. The higher rainfed lowland rice yields can be attained by implementing appropriate crop and soil management technique. Incorporating 5 ton cattle manure per ha into soil significantly increased grain yield of DSR, also improve soil tillage and supply nutrients required by rice plants. The application of composted organic matter, slow release materials, and direct seeded system could reduce greenhouse gas emissions, and water harvesting could be used as adaptation of climate change. During the TPR and the upland crops, the crops often suffer from severe drought, resulting in drastic yield reduction. One of the alternatives to solve drought stress is to collect excess water during the water surplus rainy season in on-farm reservoirs (OFR) and use the water for the dry season crops.

1. Introduction
National food stability recently is faced on population increase and conversion of fertile lowland rice to non-agricultural function for housing, industry, and dynamic of environmental change such as climate change and degradation of agricultural land resources. Food requirement always increases which follows population growth. For example, rice production in 2010 was 66.5 million tons and increase to 75.4 million tons in 2015 [4]. Rice is most of national food consumption so national food requirement could be contributed from irrigated and rainfed lowland rice. Optimization of rainfed lowland rice areas should be necessary by considering that rainfed lowlands areas in Indonesia are more than 2.848 million hectare (ha) which are generally distributed in Java, Sumatera, Kalimantan, Sulawesi, and Nusa [4]. Rainfed lowland ecosystems have great potential to be agriculturally more productive to avert possible food shortage.
However, productivity of rainfed lowland rice is low due to low soil fertility, lack of water resources and its infrastructure, high weeds infestation, and drought stress.

Rainfed lowland rice encounters an environment more complex and unpredictable than most crops. It is grown in bunded fields without water control, and it therefore experiences hydrological conditions fluctuating from complete submergence of the crop to drought, often during the same growing season. The alternating periods of soil oxidation and reduction resulting from changing hydrologic conditions lead to a gaseous loss of nitrogen and immobilization of other nutrients, together with changes in soil acidity and concentration of toxic iron and aluminum. The effect of drought may be compounded by poor nutrition and soil chemical toxicities.

To increase cropping intensity in rainfed lowland area, the general cropping pattern adopted by farmers is direct seeded rice (gogorancah rice) in rainy season followed by transplanted rice (walik jerami rice) in early dry season and followed by neither upland crops nor fallow. The average grain yield is 4.0 – 4.5 t ha\textsuperscript{-1} in DSR, 2.0 – 2.5 t ha\textsuperscript{-1} in TPR, and 0.7 t ha\textsuperscript{-1} in soybean, respectively [13]. Farmers generally use such cropping pattern to anticipate erratic rainfall and unpredictable pattern. In dry season, about 60,000 ha of rainfed lowland area in the Rembang and Pati districts of Central Java suffer from water scarcity.

Contrary, lowland rice could be as source of greenhouse gas emission especially methane (CH\textsubscript{4}) and nitrous oxide (N\textsubscript{2}O) which cause global warming and climate change. Besides that, inappropriate agrochemical materials use in intensive lowland rice causes their accumulation in soil and crops that disturb human health. Some adaptive technologies improve crop productivity such as water harvesting technology and high yielding rice variety. By being combined with mitigation effort, some mitigation technologies can suppress greenhouse gas emission such as integrated and balanced fertilization, incorporation of compost into soil, and planting system with direct seeded. This paper informs that application of appropriate technologies that synergize adaptation actions with mitigation effort on climate change impact in rainfed lowland rice areas.

2. Agricultural Practices with Environment Friendly
Application of crops culture with environmental friendly approach is one of forms of sustainable agriculture. Sustainable agriculture is define as an integrated systems of integrated system of plant and animal production practices having a site specific application that will, over the long term: (a) satisfy human food and fiber needs; (b) enhance environmental quality; (c) make efficient use of non-renewable resources and on-farm resources and integrate appropriate natural biological cycles and controls; (d) sustain the economic viability of farm operations; and (e) enhance the quality of life for farmers and society [6,10]. Sustainable agriculture integrates ecological aspect with social-economical aspect in systems of agricultural production that could be used as model in giving a solution related to land degradation and environment problems.

Sustainable agriculture refers management and conservation of natural resources, and orientation of technology and institution changes so that could guarantee human fulfill requirement sustainably for present and future generations [5]. Sustainable agriculture integrates some aspects to maintain soil and crop productivity and reduce agricultural problems, i.e. increasing or maintaining cycle systems, increasing organic farming, improving soil health, managing residue and wastes, and reducing agrochemical materials. According to [8], providing of agricultural technologies with environment friendly contributes sustainability of production systems which have been applied since 1980 such as
conservation agriculture, integrated pest management, integrated crop management, integrated crop-livestock, and low external input supply agriculture (LEISA).

There are some constraints in managing rainfed lowland rice areas, i.e. nutrient, weed, water, and crops. Through applying environment friendly concept, management of rainfed rice should integrate components of nutrient, weed, water, and crops, so that high productivity will be maintained without reducing environmental quality.

3. Nutrient Management

The soil fertility of rainfed lowland could be improved by applying fertilizers combined with organic amendment. Application of organic materials such as farmyard manure, composted materials could alleviate the problem associated to low soil fertility. Besides providing essential nutrients, organic materials could enhance good soil physical conditions and enable the soil to retain moisture as well as nutrients. However, organic materials application id submerged lowland rice could be source of greenhouse gas emission especially methane ($\text{CH}_4$). Application of composted organic materials emit low methane compared with fresh ones. [2] found that application of composted rice straw into soils decreased methane emission in range of 31.4-66.4% than fresh straw (52.9±4.5 kg $\text{CH}_4$ ha$^{-1}$ season$^{-1}$). The composted straw could increase higher grain yield ± 6% than fresh straw.

Tablet urea application enhances nitrogen supply into plant tissues especially stem, so that it accelerates roots generation which is sink of N nutrient and N accumulation in plant stems to be relatively faster. The increase of tablet urea rate increase rice grain yield and N uptake of transplanted rice under rainfed lowland area (Figure 1). Application of tablet urea reduce methane ($\text{CH}_4$) emission and nitrogen loss in form of nitrous oxide ($\text{N}_2\text{O}$).

The averaged rice grain yield ranges 4.52-6.02 t ha$^{-1}$ in DSR and 2.20-2.75 t ha$^{-1}$ in TPR, respectively. Application of K fertilizer could yield grains higher than without applying K fertilizer. The application of FYM also yields grains higher than without applying K fertilizer (Figure 3). The application of potassium fertilizer or farmyard manure (FYM) could increase K uptake of IR64 compared with application of NP only. The K fertilizer increases 53 kg K ha$^{-1}$ in DSR and 41 kg K ha$^{-1}$ in TPR. The NP fertilizer combined FYM 5 t ha$^{-1}$ increases K uptake as much as 77 kg K ha$^{-1}$ in DSR and 28 kg K ha$^{-1}$ in TPR (Figure 2). Application of potassium fertilizer improve rain fed rice yield and could reduce methane emission. As shown in Table 1, application NPK in rainfed rice field emitted methane lower than NP.

Without applying potassium fertilizer in rainfed lowland rice field, rice plant is more susceptible to several important rice diseases like brown leaf spot ($\text{Helminthosporium oryzae}$), stem rot ($\text{Helminthosporium sigmoideum}$), and bacterial leaf blight ($\text{Xanthomonas campestris}$). The severe infestation of brown leaf spot can reduce grain yield up to 50% (Suparyono et al. cit Wihardjaka et al., 1998). Impact of climate change in rainfed areas is fast development of blast fungal diseases ($\text{Pyricularia oryzae}$).
Table 1. Combination of farmyard manure and inorganic fertilizer for rainfed rice cultivation at Central Java, Indonesia

| Organic materials | kg CH₄ per ton grains |
|-------------------|----------------------|
|                   | No inorganic fertilizer | N P | N P K |
| Without FYM       | 7.11                  | 11.82 | 2.68 |
| With FYM          | 3.49                  | 2.99  | 5.45 |

Rate of fertilizers for direct seeded rice of IR64 was 120 kg N, 18 kg P2O5, 75 kg K2O, 5 t farmyard manure (FYM) per hectare.

Source: Wihardjaka and Abdurachman (2007)
The average grain yield and K uptake are consistently larger in the DSR, both because of a higher yield potential in the earlier season due to more favorable temperature and solar radiation regimes, and because the TPR is more prone to water deficit, especially during the later growth stages. The low grain yield of rainfed lowland rice is due to water limiting in reproductive and ripening growth stages. Rice plant requires 700 mm per season or 200 mm per month so that it needs additional supply from water reservoir. Rice plant is relatively more sensitive on water limiting during reproductive growth stage than vegetative growth stage.

4. Water management

On-farm reservoir or embung is one alternative to overcome drought and to increase land productivity in rainfed areas in Indonesia. On-farm reservoir is an adaptive technology to climate change impact. In Central Java, farmers adopt cropping pattern of direct seeded rice (DSR) in rainy season followed by transplanted rice (TPR) in dry season followed by neither upland crops nor fallow. During the TPR and upland crop seasons, the crops often suffer from severe drought, resulting in drastic yield reduction. On-farm reservoir could collect excess water during the water surplus rainy season and could be used to irrigate the dry season crops.

OFRs in Indonesia are locally simple ponds and generally could be constructed in 0-20% slope. A steeper slope enables the runoff water from the catchment area to flow easily to the OFR, and the stored water to irrigate easily the crops in the lower part of the field. OFRs in Indonesia area easily built using human labor and simple tools such as a hoe. The size of OFRs in Pati and Rembang districts varies from small (<50 m²) to medium (100-200 m²) to large (>500 m²). The large OFR potentials to achieve high yield of TPR by using OFR water, especially during reproductive growth stage. Farmers can decide whether to use OFR water for TPR or to conserve it for upland crops that will be grown after harvesting rice crops. If the water is used for TPR, water should be applied during the most critical stage of crop growth i.e. flowering and grain filling [9]).

The water balance in OFR is calculated as the accumulated water depth, which is equal to water inflow minus the outflow. Water inflows are contributed by direct rainfall, runoff water, and groundwater, while the outflows are basically contributed by processes such as evaporation, seepage, percolation irrigation, and overflow that cause the volume of water in the OFR to decrease (Figure 3).

![Figure 3. Schematic of inflow and outflow in the rainfed lowland rice (Source: Syamsiah et al., 1994)](image-url)
Based on research in OFRs during 1991-1994 using OFR construction of 100 m² size, farmers could obtain additional income from the OFR (Table 2). The FR increased farmer gross return by about 50% [9]. It also created more land use and employment opportunity. An OFR could increase the groundwater level, which can be used by people for agricultural and daily domestic consumption.

Table 2. Production and gross return from a 0.5 ha land before and after construction of 100 m² size OFR

| Component                  | Before     | After      | Difference in gross returns (US$) |
|----------------------------|------------|------------|-----------------------------------|
|                            | Yield (kg) | Return (US$) | Yield (kg) | Return (US$) |                                      |
| DSR (gogorancah)           | 2,500      | 304.90     | 2,450      | 298.80       | -6.10                                |
| TPR (walik jerami)         | 1,000      | 121.90     | 960        | 117.10       | -4.80                                |
| DS seed watermelon         | 0          | 0          | 200        | 195.10       | 195.10                               |
| Banana (bunch)             | 0          | 0          | 20         | 19.50        | 19.50                                |
| Fish                       | 0          | 0          | 20         | 14.60        | 14.60                                |
| Total gross returns        | 426.80     |            | 645.10     |              | 218.30                               |

Cost of construction = US$48.00; lifetime = 15 yr Av of 20 samples; DSR = direct seeded rice; TPR = transplanted rice; DS = dry season
Source: Syamsiah et al. (1994)

5. Crop Management

Appropriate crop management could improve crop productivity and maintain quality of soil and environment. Some practices are applied in rainfed lowland rice areas, i.e. using direct seeded system and high yielding variety with low emission. Compared with transplanting systems, direct seeded could reduce methane from 123 to 82 kg CH₄ ha⁻¹ season⁻¹, increase N uptake of Ciherang from 85 to 105 kg N ha⁻¹ and grain yield from 4.12 to 7.26 t ha⁻¹ [14].

Some adaptive rice varieties could be cultured in rainfed areas such as high yielding variety with low emission, and drought tolerance variety. Rice plants develop an intercellular gas space system, the aerenchyma, which provides roots with oxygen (O) submerged in inundated soils. This gas space system also enables the transport of other gases, including CH₄, N₂O and carbon dioxide (CO₂) from the soil/sediment to the atmosphere [12]. It is not clear how the aerenchyma system varies among these cultivars and how the gas transfer capacity in the root–shoot transition zone influences GHG emissions associated with the yield increase [3].

Utilization of high yielding rice variety is an adaptive technology in rainfed lowland rice areas. Some researchers have tested greenhouse gas emissions, especially in some rice varieties. For example Kartikawati et al. (2017) who tested methane flux from rice variety of Ciherang, Dendang, Inpari 31, Inpari 24 from rainfed rice fields. According to them, averaged dry grain yield from Ciherang, Dendang, Inpari 31, Inpari 24 was 5.92; 7.10; 6.06; 7.41 t ha⁻¹, respectively with methane flux of 232, 319, 300, 405 kg CH₄ ha⁻¹ season⁻¹, respectively. The difference in methane flux among rice varieties is influenced by plant morphology and physiology, root exudation, availability of organic substrate in roots, and physicochemical soil in rhizosphere [7].
6. Conclusion
Rainfed lowland rice production is generally low due to erratic rainfall, drought stress, and low soil fertility. Management of rainfed rice culture could be done with using environmental friendly concept which integrates management of water, nutrient, and culture practices. Rainfed lowland productivity could be increased through nutrient and water management combined with appropriate weeds control and high yielding variety with low emissions. Application inorganic and organic fertilizers could increase rice grain yield, and water use from farm reservoir could prevent the transplanted rice and upland crops from drought periods. Introduction of adaptive rice variety that is neither tolerance to drought stress nor early maturity is needed to maintain high rainfed lowland production in supporting national food consumption requirement.

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