The characteristics of swampland rice farming in South Sumatra: local wisdom for climate change mitigation

N P S Ratmini1,2 and Herwenita1

1South Sumatra Assessment Institute for Agricultural Technology, Jl. Kol. H. Burlian No. 83 Km.6 Palembang, 30153, Indonesia
2Corresponding author: nps_ratmini@yahoo.com

Abstract. Swampland has been used for agriculture for hundreds of years, yet most still use traditional ways. In general, rice farming in swampland is cultivated once a year before the dry season depending on land classification. This paper presents the swampland rice farming system's role as local wisdom that needs to be maintained for environment preservation and climate change mitigation. Data was collected through interviews with farmers and extension workers and reviews of relevant experimental studies and articles. The success of rice farming in swampland is primarily determined by nature such as sudden flood and drought. Swampland is divided into three typologies, namely shallow swampland, mid swampland, and deep swampland. The nursery system and rice variety selection are key for successful rice farming in swampland. There are dry and floating nursery systems in South Sumatra. The dry nursery is carried out in dry land and field beds, usually done for shallow swampland; floating nursery is carried out in higher water level swampland using rafts made from waterweeds. Some of superior adaptive varieties in swampland are Inpara-1, Inpara-2, Inpara-4, Batutegi, Limboto, Inpari-1, Inpari-4, Inpari-6, Inpari-9 and Mekongga which may increase production in swampland.

1. Introduction
The rapid population growth of 1.3% growth rates per year requires higher food supply, while planted area and plant production are decreasing [1]. Land depreciation is estimated to reach an average of eight thousand hectares per year [2]. Thus, crop production must be increased to meet food needs and anticipate climate change and extreme weather [3]. Swampland is one of the agro-ecosystems for agricultural land development, particularly for food crops [4]. It also serves as an alternative reserve for rice production interruption during fallow season, mainly in intensive rice fields [5]. Swampland is an inland swamp with relatively concave topography, always experiencing inundation for at least three months with water level of more than 50 cm to 200 cm [2][6]. Moreover, its water regime is also affected by rain and overflow water from the upstream [7][8][9].

The main problems faced by swampland are inundation, soil fertility, and infrastructure [2][5][7][10]. The flood period and drainage time are also unpredictable which affects planting schedule. It is often found that high stagnant water may harm plant growth and causes low yield so that planting system adjustment is needed. Local people of South Sumatra generally adjust the nursery system in order to avoid harvest delay. The nursery pattern is carried out using multilevel/gradual system. The initial nursery is done in dry land for dry nurseries or using rafts made from waterweeds for floating nursery in higher inundation land, and then followed by second nursery in the field when water began to recede. Other problems encountered in swampland rice farming are drought in dry season, uncertified seed thus lower quality of seed, and unbalanced fertilization [11]. These resulted in rice yield's low production.
from 2.7 tons/ha to 3 tons/ha only [12]. However, this number may still be improved using adaptive and high yield varieties [11].

In general, swampland as agricultural land is utilized once a year which is dominated by rice commodities. The impact of extreme climate change has resulted in productivity decrease in swampland due to flood and drought, leading to crop failure [13]. Unfavorable climatic conditions indeed require adjustment and innovations to overcome obstacles and reach favorable production. This paper presents the swampland rice farming system's role as local wisdom that needs to be maintained for environment preservation and climate change mitigation.

2. The characteristic of swampland
Swampland has special characteristics of water conditions in which abundant and stagnant for several months in rainy season depends on its physiography. The inundation is not caused by high tide but caused by surface water runoff stored in basin areas with poor drainage. It is affected by rainfall from upstream as well as local rainfall. Based on water level and inundation time, swampland is classified into three types, namely shallow swampland, middle swampland, and deep swampland [2][14]. Figure 1 presents a schematic cross-section of swampland [2].

Shallow swampland is characterized by higher hydro topography than other swampland types, located near the river dyke, and has less than 50 cm water level with minimum of 3 months of inundation time per year. Middle swampland has lower topography than shallow swampland with 50-100 cm water level and 3-6 months inundation time. While deep swampland has the lowest topography, compare to shallow and middle swampland. It has more than 100 cm of water level and the longest inundation time for more than 6 months or even throughout the year.

Furthermore, each type of swampland's characteristics are different in terms of physical, chemical, and biological; so different management is needed to be able to utilize it for agricultural use. In general, shallow swampland towards the river dyke is dominated by sand fraction while the finer fraction will be settled towards the deeper swampland. This happens since sand has bigger particle size that allows it to be settled before the dust and clay.

Swampland is strongly affected by climate, especially rainfall. The water level of inundation is very unpredictable because of water discharge from upstream [8][15]. Four peak floods in swampland happen in months of November, December, mid-February, and May as shown in figure 2; that hinders the planting time. Farmers will begin tilling and planting after water recedes and may predict the nursery time in normal climatic condition.

Types of soil commonly found in swampland are alluvial soils in the form of mineral and peat soil. Mineral soil comes from river sediment characterized by undeveloped to moderate level of soil development, clogged to severely stunted clogged, and its texture consists of dusty clay at the top part
while clay and sandy clay at the bottom part [16][17]. Clay mineral types determine the chemical characteristic of swampland. In general, chemical properties of South Sumatra swampland is characterized by acid to strong acid soil reaction, high to very high organic carbon © content, moderate to very high of total nitrogen (N), low of available phosphorus (P), low to moderate exchangeable cations for calcium (Ca) and magnesium (Mg), moderate to high content of potassium (K) and sodium (Na), low to moderate soil cation exchange capacity (CEC), and low to high base saturation [16][18]. In terms of chemical characteristics and soil fertility, middle swampland and deep swampland in South Sumatra are more fertile than shallow swampland which is not found in Kalimantan. In Kalimantan, shallow swampland is the most fertile among middle and deep swampland [15]. Based on peat thickness, swampland can be divided into peatland (20-50 cm peat layers), shallow peat (50-100 cm peat layers), middle peat (100-200 cm peat layers), and deep peat (200-300 cm peat layers) [19].

The swampland’s chemical properties are strongly affected by soil types, soil parent material, and upstream sediments or old sediments from bottom layers of the sea. This is due to heavy rains that happened upstream that bring sediments deposited in the basin area of swampland, making it moderately fertile but rich in mineral materials. The swampland’s nutrient contents depend on the contribution of sediment nutrients carried by runoff water from upstream. The swampland spatial competitiveness in South Sumatra is high because of its flat expanse land, all-time water availability, and rich in antioxidant mineral deposits to produce functional health food [20][21].

**Figure 2.** The dynamics of rainfall and high inundation in swampland, from August 1999 to July 2000.

### 3. Rice farming system in swampland

Swampland is potential as agricultural land in terms of land size. There are 1.55 million hectares that have been cleared most by the local community that utilized residential and agricultural use [15]. In South Sumatra, there are 1.1 million hectares of swampland in which 296,900 hectares of it has been utilized for agriculture that spread out in downstream areas of Musi River, Ogan River, and Komering River. Most of that area is used for rice farming: 148,08 thousand hectares once a year rice farming, 6.71 thousand hectares twice a year rice farming, and 142,11 thousand hectares is untapped [22][23].

Farming systems developed in swampland are rice farming, secondary crops, vegetables, fisheries, swamp buffalo, and ducks [23][24], with rice farming as the most widely practiced. The secondary crops
that are commonly planted are corn, soybeans, peanuts, and mung beans; while vegetables are chilies, mustard greens, eggplant, cucumbers, and long beans. There are more than 27 kinds of fish in terms of fisheries that can be cultured in swampland using catch fisheries or aquaculture [25]. The swamp buffalo raising is commonly done with traditionally grazed swampland at days while caged at nights. The swamp buffalo is one of the genetic resources that must be preserved, considering its limited existence that only 3,623 left [26].

![Figure 3. Estimated swampland rice farming calendar and some problems faced by the farmers.](image)

Farmer in swampland in South Sumatra holds local wisdom in utilizing swampland for agricultural use. The planting time begins at the early dry season when water in the fields starts to recede, while the second planting time is done during rainy season; thus, it is known as “padi salah tahun” or “mistaken year rice”. The delay of planting time will result in crop failure due to drought. The estimation schedule of farming system in swampland is presented in figure 3 [27], while the common practice of the farming system applied in swampland are:

### 3.1 The nursery

Farmer in swampland has implemented environmentally friendly local wisdom for their rice farming, such as nursery system to deal with high inundation and planting delay. Dry nursery is applied for shallow swampland by sowing the seeds in field beds called “ngerencam” in local dialect. In middle swampland or deep swampland, the seeding is done when water still high uses raft beds or called floating nursery. The seedling beds use rafts of 1.5 m x 3 m made from waterweeds or “lanting”. It takes 6 to 7 lanting to cover seed need for 1 hectare field. In the next step, the seeds will be moved to the edge part of the rice field at 10 to 14 days after planting using large number of seeds per planting plot or known as “najar”. After 10 to 14 days planted in najar, the seeds then moved and planted to the field to consider water level. The nursery system in swampland is presented in figure 4.

The problem faced during nursery is when the water has not yet begun to recede, but the seed is mature enough to be planted that causes failure seedling. Thus, farmers have to replant the nursery. Floating nursery is not only suitable for rice seed but also can be done for other commodities, particularly vegetables such as spinach [28], water spinach “kangkong” [29] and chilies [30]. This kind of nursery is also developed in Bangladesh for vegetables as many as 23 types and 5 types of spices [31].
3.2 Land preparation
Land is begun to be prepared along with first stage of nursery. The first step of land preparation is weed rolling, known as “melulan”. The rolled weeds are stacked in the field for one to two weeks, depending on the inundation condition, and then moving to the field beds afterward. Neither herbicide applications nor land is burning in land preparation in swampland. These environmentally friendly activities are the local wisdom implementation for climate change mitigation, especially swampland on peatland. Swampland contributes CO₂ emissions from 1.214–3.126 g C/m² per year and CH₄ emission from 3.0–18.0 mg C/m² per year [32]. Land clearing from land preparation makes other water plants grow, such as water lettuce (Pistia stratiotes) or known as “kiambang” in local dialect. This waterweed serves as soil cover as well as fertilizer with high N.

3.3 Varieties use
In general, farmers choose local varieties that have adapted well to local conditions yet with long life and low yield. However, the condition of climate change and advanced technologies require farmers to cultivate higher yield varieties so that rice variety selection is needed to get an adaptive and tolerant varieties particularly from inundation pattern change and water level change. Some local varieties planted by farmers are Siputih, Padi Rampak, Padi Bone, Pegagan, Petek, Padi Rantai, and Sawah rimbo [20][33]. But, farmers nowadays begin to switch to new superior varieties with higher yield and short life. Still, not all varieties may adapt well in swampland due to flood and drought land characteristics. Plants that are flooded will experience lack of oxygen and results in physiological and physical damage. Furthermore, the unbalanced production and consumption of assimilation effects disrupted leaf elongation and even death for longer periods of immersion [34]. Very low concentration in the root zone happens during inundated conditions, which then interfere with metabolic activity and energy production [35]. Immersion resistance varieties are characterized by high phosphofructokinase enzymes, pyruvate decarboxylase, and alcohol dehydrogenase [36].

Meanwhile, in terms of dryness, plants’ photosynthetic process will be disrupted when experiencing drought [37]. In dealing with water stress, plant with moderate water stress survival is called strain avoidance while severe water stress survival called strain tolerance is presented in figure 5 [38]. In addition, the morphology and physiology of drought-resistant varieties are characterized by the proline content and number of tillers [39].

Tolerant varieties of environmental change are needed to obtain favorable yield due to such environmental conditions of floods and droughts. Various experiments and studies has been carried out to find varieties that adapted well in swampland such as Inpara-1 (7.43 tons/ha), Inpara-2 (7.4 tons/ha) and Inpara-4 (7.6 tons/ha) [11][40], Batutegi (6.05 tons/ha), Limboto (5.5 tons/ha) [41], Inpara-1 (6.2 tons/ha), Inpara-4 (7.2 tons/ha), Inpara-6 (7.8 tons/ha), Inpara-9 (7.7 tons/ha), and Mekongga (6.1 tons/ha) [11][42]. To anticipate and mitigate climate change, CH₄ emissions of a variety is also considered aside from its high yield. The CH₄ release of paddy is high during vegetative phase at 6–7 weeks after planting, while the highest CO₂ release happens at 50–60 days after plant. Several varieties that can reduce GHG emissions are Punggur, Batanghari, Air Tenggulang, and Banyuasin; while Martapura is the variety that has the highest GHG emission contribution [32].
4. Conclusions
Swampland is potential to be developed for agriculture area. Swampland is characterized by its moderate level of soil fertility divided into three types: shallow swampland, middle swampland, and deep swampland. Local wisdom applied in swampland is a multilevel/gradual nursery system that consists of dry nursery and floating nursery. This local wisdom is environmentally friendly and considered as an effort for climate change adaptation. Swampland with its conditions of flood and drought has attempted to use adapted varieties. Some of those varieties are Inpara-1, Inpara-2, Inpara-4, Batutegi, Limboto, Inpari-1, Inpari-4, Inpari-6, Inpari-9 and Mekongga.

References
[1] Sulaiman A A, Sulaeman Y and Minasny B 2019 A framework for the development of wetland for agricultural use in Indonesia Res. 2019 8 Resources 2019 8 34.
[2] Neilson J and Wright J 2017 The state and food security discourses of Indonesia: Feeding the nation Geogr. Res. 55 131–43.
[3] Noor M 2007 Swampland ecology, utilization and development (Jakarta: PT. Raja Grafindo Persada).
[4] Neylor R L, Battisti D S, Vimont D J, Falcon W P and Burke M B 2007 Assessing risks of climate variability and climate change for Indonesian rice agriculture Proc. National Academic Science 104 7752–7757.
[5] Djafar Z R 2013 Agronomical activities to increase the potential of the swampland for food sources J. Lahan Suboptimal 2 58-67.
[6] Syahbuddin H, Noor M, Anwar K, Alwi M, Hamada M, Indrawati L, Mawardi and Wakhid N 2010 Development of crop calendar in swampland (Banjarbaru: Synthesis Balittra Policy).
[7] Haryono, Noor M, Syahbuddin H and Syiarwani M 2013 Swampland research and development Indonesia agency for agricultural research and development (Jakarta: IAARD Press).
[8] Efendi D S, Abidin Z and Prastowo B 2014 Acceleration of swamp land development based on innovation Agricultural Innovation Development 7 177-86.
[9] Waluyo S S 2008 Inundation fluctuation in swampland and its benefit for agriculture in Ogan.
Komering Ilir *J. Hidrosfir Indonesia* 3 57-66.

[9] Wakhid N and Syahbuddin H 2010 The Dynamic of rice planting time in swampland of Borneo Island *Agrin* 23.

[10] Suryana S 2016 The potency and opportunity for developing area-based integrated farming in swampland *J. Litbang Pertanian* 35 57-68.

[11] Suparwoto and Waluyo 2019 Cultivation and adaptation of new superior varieties paddy in lebak swampy lands in South Sumatra *J. Litbang Pertanian* 38 13-22.

[12] Soehendi R and Syahri 2013 The suitability of new superior rice varieties in South Sumatra *Proc. of the National Seminar on Location-Specific Agricultural Technology* (ICATAD) Medan 6-7 June 2013.

[13] Lindiana, Lakitan B, Herlinda S, Kartika, Widuri L I, Siaga E and Meihana 2016 Rice cultivation images by local farmers in Pemulutan District, Ogan Ilir, South Sumatra *J. Lahan Suboptimal* 5 153-158.

[14] Widjaja-Adhi I P G, Suriadikarta D A, Sutriadi M T, Subiksa I G M and Suastika I W 2000 Management, utilization and development of swampland in *Adimihardja A, et al.*, (eds) Indonesian Land Resources and Management ISRI Page 127-164.

Subagyo A 2006 *Swampland characteristics and management* (Bogor: Indonesian Centre for Agricultural Land Resources Research and Development).

[15] Alwi M and Tapakrisnanto C 2007 *Swampland farming system and development* (Bogor: IAARD Press).

[16] Waluyo and Djamhari S 2011 Soil chemical properties and land suitability in each typology of swamplands for rice farming, the case in Tanjung Elai Village, Ogan Komering Ilir. *J. Sains dan Teknologi Indonesia* 13 204-09.

[17] Puspitahati 2015 Characteristics of swampland in Pemulutan Ogan Ilir District in *Proc. of the national seminar on suboptimal land* 2015, Palembang 8-9 October 2015 ISBN: 979-587-580-9.

[18] Djamhari S 2010 Waters as an auxiliary land in agricultural development in swamplands *J Hidrosfir Indonesia* 5 1-11.

[19] Achmadi dan Las I 2006 Technology innovation for swampland development *Proc. of the national seminar on integrated land management*, Banjarbaru 28-29 July 2006.

[20] Waluyo, Akasuma, Susilawati and Suparwoto 2012 Spatial inventory of potential competitiveness swampland for agricultural development in South Sumatera *J. Lahan Suboptimal* I 64-71.

[21] Subowo G, Ratmini N P S, Waluyo and Purnamayani R 2005 Competitiveness potential and prospects of the functional rice development in South Sumatra swampland *Proc. of the National Seminar on development Research in the era of the global market* SOROPADAN Agro Expo Magelang 2005.

[22] Subiksa I G M and Ratmini N P S 2008 Soil and water management technology for the development of dry season rice on tidal lowland in South Sumatra *Proc. of the Indonesian Soil Science Association Annual Scientific Meeting*, Palembang 17-18 December 2008.

Sudana W 2005 Potential and prospect of swampland as a source of agricultural production. *Agricultural policy analysis* 3 141–151.

[23] Suparwoto and Waluyo 2009 Increasing farmers income in swamplands through commodity diversification *J. Pemb. Manusia* 7.

[24] Noor M, Anwar K and Kartiwa B 2007 *Polder system for sustainable agricultural development in lowland swamps. In book of Swamplands agricultural system and its development* (Bogor: IAARD Press).

[25] Mutmainah D 2013 Fisheries activity in swamp water as livelihood in Jungkal Village *J. Pemb. Manusia* 7.

[26] Muhakka, Riswandi and Ali A I M 2013 Morphological and reproductive characteristics of pampangan buffalo in South Sumatra Province *J. Sain Peternakan Indonesia* 8.

[27] Irmawati, Eharah, Suwignyo R A and Sakagami J I 2015 Swamp rice cultivation in South
Sumatera Indonesia: an Overview *Trop Agr. Develop*. 59 35—39.

[28] Syafrullah 2014 Floating farming system from plastic waste in spinach cultivation (Amaranthus ticolor L.) in swampland *Klorofil* 9 80 – 83.

[29] Bernas S M, Pohan A, Fitri S N A and Kurniawan E 2012 Bamboo floated-cultivation model for upland kangkong (*Ipomoea reptans Poir.*) in tidal lowland area *J. Lahan Suboptimal* 1 177 - 85.

[30] Hasbi H, Lakitan B and Herlinda S 2017 Farmer perception to chili cultivation in floating agricultural system in Pelabuhan Dalam Village Ogan Ilir *J. Lahan Suboptimal* 6 126-33.

[31] Haq A H M R, Ghosal T K and Ghosh P 2014 Cultivating wetlands in Bangladesh Leisa India 6.

[32] Nursyamsi D, Alwi M, Noor M, Anwar K, Matfuah E, Khairullah I, Ar-Riza I, Raihan S, Simatupang R S, Nurginayuwati and Jumberi A 2014 *General guidelines for swampland management for sustainable agriculture* (Bogor: IAARD Press).

[33] Suparwoto 2019 Production and income of rice farming in swampland, Ogan Komering Ilir District, South Sumatra *J. Socio-Economics of Agriculture and Agribusiness* 13.

[34] Suwignyo R A 2007 Plant resistance to submerged conditions, understanding the physiological characters to obtain tolerant rice cultivars in swampy areas *West Indonesian Regional Science Congress Palembang*, 3-5 June 2007

[35] Dennis E S, Dolferus R, Ellis M, Rahman M, Wu Y, Hoeren F U, Grover A, Ismond K P, Good A G and Peacock W J 2000 Molecular strategies for improving waterlogging tolerance in plants *J. Exp. Bot.* 51 89-97.

[36] Gibbs J, Morrell S, Valdez A, Setter T L and Greenway H 2000 Regulation of alcoholic fermentation in coleoptiles of two rice cultivars differing in tolerance to anoxia *J. Exp. Bot.* 51 785-96.

[37] Jaleel C A, Manivannan P, Wahid A, Farooq M, Al-Juburi H J, Somasundaram R and Panneer selvam R 2009 Drought stress in plants : A review on morphological characteristics and pigment composition. *Inter. J. of Agri. & Bio* 11 :100-05.

[38] Mundree S G, Baker B, Mowla S, Peters S, Marais S, Willien C V, Govender K, Maredza A, Muyanga S, Farrant J M and Thomson J A 2002 Physiological and molecular insights into drought tolerance *African J. of Biotechnology* 1 28-38.

[39] Sulistyono E, Suwarno and Lubis I 2012 Morphological and physiological characterization for resulting morphological and physiological marker for drought tolerant low rice (-30 kPa) with high productivity (> 8 ton/ha) *J. Ilmu Pertanian Indonesia* 17 96-102.

[40] Suparwoto dan Waluyo 2011 Technological innovation for new superior varieties in increasing rice production and farmers' income in swampland *J. Pemb. Manusa* 5 39-49.

[41] Suparwoto dan Waluyo 2015 Superior rice varieties production and farming in shallow swampland of South Sumatra *J. Pemb. Manusa* 9 89-100.

[42] Suparwoto, Waluyo dan Setiawan S 2016 Display of Inpari variety in two typologies of swampland in Ogan Ilir Distric, South Sumatra *Proc. of the National Seminar on Building Sustainable Modern and Innovative Agriculture in Support of the AEC* Indonesian Center for Agricultural Technology Assessment and Development, AIAT Jambi, 31 May 2016.