Suboptimal Land Series - Part 1

An Introduction to Sustainable Agriculture Practice on Suboptimal Land

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INTRODUCTION

It might be possible to address food security in 2050 without producing more food. Today's food production is suggested to be enough to feed 10 billion people (Holt-Giménez et al., 2012). However, this calculation would only be sensical if the food is produced at the same rate in the next three decades. Among others, major constraints come from agriculture land conversion (ALC) or cropland loss due to increasing human population. The rate of farmland loss in Indonesia is around 140,000 – 187,000 hectares per year due to residential and industrial purposes (Rondhi et al., 2019; World Bank, 2008). Three-quarters of those losses occurred in high-yield farmlands in Java Island.

The combination of ALC and climate change will surely decrease agricultural production. This leads to insufficient food supply to feed all of the people. It is inevitable to expand new farmland. Intensification has a limited capacity to produce up to the maximum yield, even if it continues to surpass the limit, the land would degrade. Urban farming such as hydroponic could only produce a low amount of food. Thus, land-based agriculture is more visible in terms of cost production and productivity. Creating new farmland or extensification, if well managed, can work better than intensive agriculture and boost food production (Horrocks et al., 2014). Available arable lands for agriculture are shrinking over time since most of them are already cultivated or converted. It is important to segregate farmland expansion with deforestation because many abandoned and degraded areas can be enhanced for farming. One of potential areas for creating new farmland is on suboptimal land.

SUBOPTIMAL LAND DEFINITION

This article will firstly discuss the conditions of land that can be defined as suboptimal. The simplest way to identify it is when the land produces less than maximal crop yield (Levitt, 1978). The "sub" term is a prefix indicating the land inhibits the growth of crops since the amount of water, light, or nutrients below the optimum. The "suboptimal land" term was started to be widely used to describe the typical character of land with low productivity, reduced economic return, and/or severe limitations for agricultural use. In this context, the usage of the "land" is broader than just soil or terrain layer. These include the atmosphere, geology, hydrology, soil, and the whole living things on it, including human activities such as drainage, terracing, and irrigation.

Different names are connected and used to describe the suboptimal land – infertile, marginal, low potential, resource-poor, fragile, vulnerable, or degraded. This type of land is naturally difficult to be cultivated into productive agricultural land. It has several limitations that are caused by human activities, for example, mismanagement of the previous utilization (Lakitan & Gofar, 2013); or naturally-occurred such as (1) lack of water availability, (2) acidic soil condition (low pH), (3) unpredicted tidal inundation, (4) seawater intrusion, (5) pyrite poisoning, (6) poor soil nutrients, and (7) thin layer of soil (rocky ground).

TYPES OF SUBOPTIMAL LAND

Based on its dominant characteristics, there are only two types of suboptimal land: dryland and wetland. Principally, if the land is too dry or too wet, especially under flooded conditions, it would hamper the crops growth. There are five types of suboptimal lands in Indonesia, namely (1) acidic dryland, (2) dryland on the dry climate, (3) tidal swampland, (4) lowland swamp, and (5) peatland (Mulyani & Sarwani, 2013). The determination of suboptimal land types based on soil types, rainfall, and landform. In total, 78.2 percent or two-third of Indonesia's land area is suboptimal land (Mulyani et al., 2016). Referring to Table 1, the acidic dryland contributes to over half of Indonesia's land area, followed by peatland, lowland swamp, dryland on the dry climate, and tidal swampland.

Dryland, both acidic and under dry climate, is never inundated by freshwater or even lack of water. Low water presence in dryland is due to low rainfall and high evaporation. In Indonesia, the area with rainfall below 2,000 mm per year and never inundated by freshwater or seawater falls into dryland. In extreme conditions where rainfall becomes rare, dryland is changing into deserts, shrublands, grasslands, savannas, or woodlands.

Acidic dryland characterized by high acidity on the soil which appears from the rapid mineral corrosion process. The process washes out the substances and leaves only its non-essential nutrients within the soil that can be toxic for the plant. This kind of land generally has less than 5.5 pH, poor nutrients, and can lead to Aluminum (Al) poisoning. Moreover, dryland situated in dry climates has a small precipitation rate with rainfall below 2,000 mm per year with the dry month (rainfall <100 mm per month) over 7 months a year. Because of the longer dry condition, the weathering of rocks is low. The impact on the soil layer in the dry climate of dryland is thin and mixed with rock. The dry condition made the land only have a thin layer of soil that is hard to plant the crops. This type of land formed by a combination of low precipitation, drought, and heat wave. Unsustainable farming also can create dryland conditions such as land burning, livestock grazing, forest utilizing, and soil cultivation. Some of the lands have a boulder-strewn subsoil and thin topsoil over the surface.

Tidal swampland, also known as *lahan pasang surut*, can be found along the coastline. Tidal swampland characterized by all year water inundation. Some of the

Table 1. Suboptimal land distribution in Indonesia

Island	Dryland		Wetland			Total
	Acidic	Dry climate	Tidal swampland	Lowland swamp	Peatland	
Sumatra	30,781,437	429,035	2,501,888	3,988,301	6,436,646	44,137,307
Java	7,294,213	1,682,498	94,756	0	0	9,071,467
Bali & NT	82,904	5,077,737	0	0	0	5,160,641
Kalimantan	39,094,313	0	2,301,410	2,944,085	4,778,005	49,117,813
Sulawesi	7,187,383	2,382,556	318,030	706,220	0	10,594,189
Maluku	1,999,401	0	74,395	88,159	0	2,161,955
Papua	18,174,276	1,179,055,	2,262,402,	3,916,123	3,690,921	29,222,777
Indonesia	104,613,927	10,750,881	7,552,881	11,642,888	14,929,416	149,489,993

Source: Mulyani et al. (2016)

swampland contains saline (salty) water, others are brackish (somewhat salty), and the rest are freshwater. Many challenges to cultivate this land are pertinent to the water-management, pyrite soil existence, thick peat soil layer, and saltwater intrusion.

Lowland swamp or known locally as *rawa lebak*, is formed by rainfall that was trapped on land cavities. Based on the land depth, there are three types of swamp: (1) shallow swamp (50cm - 100cm); (2) medium swamp (100cm - 200cm); (3) deep swamp (200cm - 300cm). Among those types, the shallow swamp has the highest potential to be cultivated into productive agriculture. While it has an extra nutrient layer that is deposited from the upstream flow, the challenge comes from the difficulties of predicting and managing water level and acidity level. Similarly, peatland is an accumulation of organic matter that is formed in an anaerobic condition which drives long-process yet partial decomposition. Because of its unique characteristic, in this article, the peatland is differentiated from lowland swamp. Peatland can be found in high latitudes of the northern hemisphere, coastal environment, and moist tropical areas with wet climate. As peat layers become thicker over time, the level of the undecomposed organic matters will also increase which causes the land to have higher levels of acidity and low nutrient availability (Craft, 2016).

STRATEGIES FOR PRACTICING AGRICULTURE IN SUBOPTIMAL LAND

The challenge in managing the suboptimal land starts with the unique features of the land itself. Like other landscapes, suboptimal lands provide essential ecosystem services and support the communities in their vicinity since the locals have benefited from the lands for timber to build houses, wild food, and medicinal plants to be utilized, and access to clean water (Hergoualc'h et al., 2018). Multiple studies have been implemented to identify the effective ways to properly convert them into productive land. Siaga et al. (2018) and Purba et al. (2020) highlighted the suitability of riparian wetland and tidal swamp to grow chilli pepper, and rubber-corn intercropping. Mwenzwa (2011) and Singh et al. (2016) examined the role of dryland agriculture to strengthen the food security in Kenya and India, both emphasized the soil water conservation practices employed by dryland farmers, their efficacy, and to what extent locally available organic fertilizer is used in dryland farming. Utilization of suboptimal land for agriculture cannot be achieved without overcoming the existing limitations. The practice requires additional investment in land

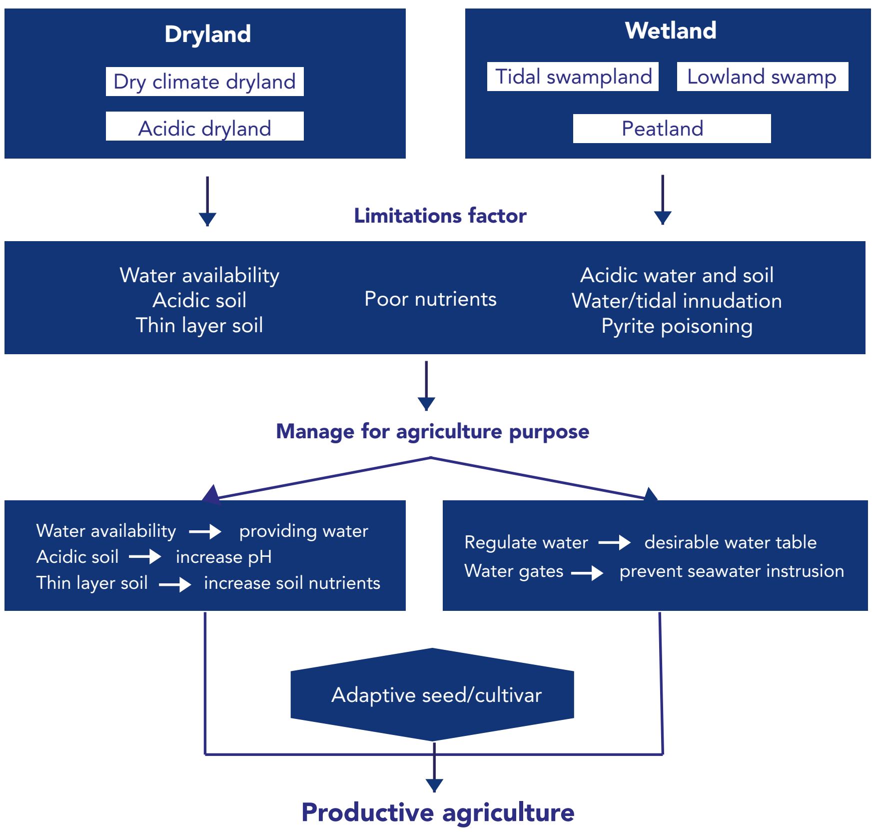

Figure 1. Suboptimal Land Conversion into Productive Agricultural Land Flow. Modified from Lakitan & Gofar (2013)

preparation. In general, the preparation to use suboptimal land for agriculture is determined by three following factors:

1. Land management to handle soil acidic condition, poor nutrient, thin layer of soil, and pyrite poisoning.

2. Water management, this aspect is crucial in both dryland and wetland. On dryland, it aims to provide water for irrigation, while on wetland it serves to regulate water.

3. Cultivar selection, to make crops adaptive in suboptimal condition.

The chart above indicates that engineering measures application such as ameliorants, fertilizer, and proper water management can bring a significant change in the production yield of suboptimal land (Fig. 1). To increase soil pH, ameliorants are commonly applied. Lime (e.g. calcite, dolomite, and calcium oxide), ash, salt, rice husk, sawdust ash, weed biomass can be used to raise the pH and enable the land utilization for agriculture production (Hendronursito et al., 2019). Furthermore, application of fertilizer is essential for optimum yield, the soil nutrient needs to be managed by controlling the application of organic and chemical fertilizer to boost the productivity (Sulaeman et al., 2017). For example, rice farming requires approximately 200 - 250 kg per hectare of Nitrogen fertilizer; lower dose would result in declining harvest (Abu et al., 2017).

Dryland agriculture mostly rainfed crops, where it depends on rainfall. Hence, it is only productive during the rainy season or once a year planting period. Development of the irrigation system will boost the yield since it enables the cultivation all year-round. In the areas without irrigation systems, the crops rely on cultivars that adapt with low water availability.

While in dryland the challenge lies on crops watering, wetland is more about regulating excess water on soil and maintaining the moist condition. In wetland, regulating the water system is as important as managing the land. The right amount of water level in the soil defines the ability of the land to perform. A well-regulated water management system is necessary to control the quantity and quality of water throughout the phases of agriculture production without harming the ecosystem. Different species of plants will have different water requirements in different phases. The water management is not only meant for regulating its availability but also functioned to reduce soil acidity, prevent pyrite layer being exposed and oxidized, and avoid flooding and drought. On an inundated suboptimal land, aquaculture and fishery have the potential to be developed. In lowland swamp, aquaculture can be done by a fence system, beje pond, or surjan (alternating bed) system. There is also the potential for duck farming in lowland swamp using feeder treatment technology, semi-intensive, and intensive maintenance. Rice and maize production in the tidal flood crops can be optimized using the suitable rice variety. There is also a paludiculture approach, which is a wet intercropping, and wet agroforestry that could provide food for communities (Budiman et al., 2020).

Even though the water and soil are well-managed, sometimes the cultivar cannot grow well in such condition. The use of adaptive cultivar becomes necessary. Many researches have been deployed to expand the list of adaptive varieties. Local cultivars from various locations of lowland swamp are collected and are used as germplasm as a genetic source of selective breeding. Particularly, local genetic sources are vital to construct new varieties that are submergence/flood-tolerant. Considering particular characteristics of suboptimal land, there are also rice varieties with high tolerance of Fe and Al (high acidity) like IR64, and pest-resistant such as Mekongga and Pak Tiwi (Fawzi & Qurani, 2020). In dryland, the method of farming is using drought-resistant crops and conserving the soil moisture. Cultivar adaptation in suboptimal conditions will give a significant amount of productivity. Drought and Al poisoning tolerant of rice variety on dryland will produce 3.46 ton/ha (Yullianida et al., 2019).

FUTURE PROSPECT

Enhancing agricultural productivity in suboptimal land can contribute to the betterment of the state of food security. Instead of solely relying on land intensification, the sustainable use of abandoned or degraded land can be part of the solution to secure the food supply. The crop yield that is produced in the formerly suboptimal lands will increase the availability and accessibility of food, especially for the surrounding area.

Knowing the varied characteristics of suboptimal land, there are three inseparable aspects that should be employed simultaneously. First, the state of the soil that needs to be improved in all aspects including physical, chemical, and (micro) biological. Second, the water resource that should be regulated by implementing water management both in dryland or wetland. And the last is the expansion of adaptive agricultural crop cultivars that are necessary to yield the optimum harvest.

It must be underlined that these planned measures will only succeed through the inclusive engagement of all relevant stakeholders in the various processes of the measure, from improving the technical knowledge aimed for high productivity, to enhancing the value chain of the produced commodities. Intense cooperation between the involved stakeholders where they can exchange information and form complex social networks will affect the decision-making to institutionalize the whole process. Further elaboration on challenges to ensure sustainable agriculture in suboptimal lands and specific study cases for each land type will be delivered on upcoming issues.

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ABOUT TJF

Tay Juhana Foundation (TJF) is a nonprofit organization dedicated to promote the advocacy of the conversion and cultivation of suboptimal lands into productive lands, through the most environmentally, economically, and socially sustainable manner.

CONTACT US

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