Management and development of oil palm cultivation in swamplands in perspective of limitation and sustainability

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Abstract. Development of oil palm plantations in swamps in the last ten years has progressed rapidly as a result of limited availability of fertile lands. Due to the nature of the environment, productivity over swamp land is quite different from other ecosystems. Studies reported that average productivity of oil palm in swamps ranges from 0.8-1.2 tons fresh fruit bunch (FFB)/ha/month (equivalently 9-10 t FFB/ha). Economic analysis shows that this productivity level does not provide a benefit to the farmers. It was reported, however, that with the intervention and introduction of good management and technology, productivity of swamp land can reach 25-27 t FFB/ha and on peat soil it can reach 19 t FFB/ha. Socio-economic factors such as capital, knowledge, technology, labor, physical infrastructure or other facilities significantly affect palm oil productivity. Identification of economic, socio-political, and ecological aspects drive a concept of sustainable development for oil palm plantation. This paper reviews results related to this development in the perspective of limiting issues related to sustainability. Development of oil palm plantations expects high productivity and stability, yet promoting equality and local wisdom towards sustainable environment. Good management of soil and water is the key for oil palm farming in swamp lands. There are four properties of sustainable agroecosystems, namely productivity, stability, sustainability and equity.

1. Introduction

Indonesian oil palm plantation in 2020 is approximately 14.60 M ha over 26 provinces, marking the largest palm oil producer in the world. As recorded by Directorate General of Plantations at the Ministry of Agriculture, Riau Province has the largest community-based plantation reaching 1.8 M ha, followed by North Sumatra (730 thousand ha), Jambi (688 thousand ha) and South Sumatra (674 thousand ha).

Oil palm is currently the most economical annual crop for swampland if properly managed. Main obstacles to the development include unstable soil aggregates, permeability, low organic matter, alkalinity, and pH. Presence of high toxic elements provides the limiting factor, i.e. reduction of SO₄²⁻ and Fe (III) oxides by iron and sulfate reducing bacteria in flooded condition. Both soil properties, iron and sulfate, could form a compound called pyrite. There has been a cautious issue that increasing oil palm plantation, especially in swamps, ignores the principles of sustainability, which in turn, potentially contribute to the loss of forest cover, biodiversity and disruption of ecosystem balance, increasing greenhouse gas emissions, and emerging social conflicts around plantations. This was anticipated by the issuance of Minister of Agriculture Regulation No. 19/OT.140/3/2011 concerning Indonesian Sustainable Palm Oil (ISPO/Indonesian Sustainable Palm Oil) which has been updated through Minister of Agriculture Regulation No. 11/OT.140/3/2015, then updated again in 2020 in the Minister of Agriculture Regulation No. 38 of 2020 concerning the Implementation of Plantation Certification and Presidential Regulation Number 44 of 2020 about the Indonesian Sustainable Oil Palm Plantation Certification System. The implementation was expected to increase economic activities without further
damaging the environment and to produce sustainable palm oil. This paper reviews research results related to development of oil palm in swamps in the perspective of sustainable plantations.

2. Limiting factors
Utilization of swamp lands for plantation crops is constrained by various factors such as high acidity, low fertility, peat thickness, presence of sulphidic materials, soil layer under peat (substratum) in the form of quartz sand and water management systems which result in sub-optimal plant productivity. Soil acidification in swamps occurs due to oxidation of pyrite compounds. This process produces sulfuric acid leading to acidification process. Pyrite as FeS2 compound is stable under aerobic conditions in swampy soils (acid sulfate and peat). Over-drainage in the channels and beyond pyrite depth layer results in pyrite oxidation.

Oxidized pyrite produces jarosite shown by a rust or reddish yellow color in standing water or a yellowish rust color on outcrops. It increases water acidity, often around pH 3 or pH 2, and causes the solubility of Fe and Al in water to increase. When pyrite is oxidized, iron contained in pyrite changes its shape and is toxic to plants. Acidic soil is due to the release of hydrogen (H) ions, which are the determinants of the acidity level of the soil. Furthermore, acidic soil causes aluminum (Al) ions present in the soil to be released and are toxic to plants.

Soil saturated with iron and aluminum ions due to pyrite oxidation, acts like a magnet looking for nearby metals and immediately attaches them. Saturated iron and aluminum ions in the soil attract phosphate ions (PO4) in the soil; hence, they are unavailable to plants. As a result, lacking of phosphorus (P) is generally evident; plants suffer during the formation of flowers and fruits.

To obtain optimum soil conditions for plant growth, a balanced fertilization is needed. Critical nutrient levels in plants are required as the basis for applying fertilizer. Plants respond well to fertilizers if nutrient levels are below the critical limit. In principle, balanced fertilization is ruled according to the ability of soil to naturally provide nutrients, sustainability of production systems, and adequate profits for farmers. Balanced fertilization signifies applying sufficient nutrients for plants site-wise, depending on soil characteristics and amount of nutrients needed by plants. Dobermann et al. [1] and Makarim et al. [2] argued that site-specific nutrient management considers the ability of soil to appropriately provide nutrients, in terms of the amount, type, and timing of application, taking into account plant requirements and land capacity to supply nutrients to restore previously utilized nutrients.

3. Socio-cultural conditions of farmers
Oil palm productivity in swamps is generally low, only 0.8-1.2 tons/ha/month on the average. Based on economic analysis, this level of productivity is not profitable for farmers [3, 4]. Additional problem is high emission of greenhouse gases (GHG). This is possible due to low adoption of oil palm cultivation technology rooted from limited capital, risk factors and uncertainty [5], so that application of environmentally friendly oil palm cultivation requires institutional supports such as markets, supply of production inputs, and farmer groups as well as socio-economic factors. Austin [6] reported that socio-economic factors such as capital, knowledge, technology, labor, physical infrastructure or other facilities significantly affect productivity. Meanwhile, institutional factors such as existence of supporting institutions (agricultural production facilities, marketing, finance and processing), inter-institutional relationships and inter-institutional linkages and farmers improve institutional form of production and distribution systems [7].

Fauzi [8] estimated cost for establishing oil palm plantation up to juvenile phase (Tanaman Belum Menghasilkan, TBM, about three years) containing 136 seedlings around Rp. 18,662,716 per hectare, while for mature plants (Tanaman Menghasilkan, TM) ca. Rp. 1,649,011. Generally, capital for the development comes from internal or extended households occupying all costs including inputs, labor, equipment and investments of new technology, both mechanical technology and biological chemical technology [9]. Abilities to accept risks differ among farmers, influenced by the amount of capital available, farmer’s age, experience and local social environment [10]. These suggest that farmer’s decision to adopt new technology is based on various criteria.

4. The concept of sustainable oil palm plantation
Sustainable oil palm plantation development can be identified through economic, socio-political and ecological perspectives. It is expected that plantation development to gain high productivity and
stability, yet to promote equality and high values of local wisdom towards the environment. Law no. 9 of 1995, article 27, letter (a) explains that plasma-core pattern is "a partnership between small and medium or large businesses as the core that fosters and develops small businesses that become their plasma through the provision of land, production facilities, technical guidance on business and production management, acquisition of mastery and improvement of technology needed to increase business efficiency and productivity".

In fact, the right pattern to avoid conflict is needed to synergize all parties involved in the partnership, namely productive partnership pattern. Development of natural resources must also pay attention to various life aspects such as increasing prosperity and economic welfare of the inhabitant, while keeping ecological sustainability, in particular land and water conservation and regional socio-cultural systems.

Plasma-core partnership binds land owners (farmers) with a profit share scheme. They surrender land to core company to obtain the rights to cultivate (Hak Guna Usaha, HGU); in return, farmers receive 20% of total profit of the concession. During its development, plasma-core pattern has been refined into an integrated partnership pattern. This pattern involves several parties, namely (1) farmers/farmers groups or small businesses, (2) large or medium enterprises as core company, and (3) banks. Plasma-core program in oil palm plantations requires commitment from all parties.

Prospect of smallholder oil palm plantations is said to be good if it can improve people's welfare. It is, therefore, a necessity to increase plant productivity. However, a price improvement should be sought by providing good quality of the produce, in which, the role of cooperatives is vital.

Recently, Indonesian government designed the Indonesian Sustainable Palm Oil (ISPO) to guide sustainable palm oil development, based on the 4th amendment of the 1945 Constitution. The article 3 paragraph (4) dictates "The national economy is organized on economic democracy, with the principles of togetherness, efficiency, justice, sustainability, environmental insight, independence and by maintaining a balance of progress". The objectives of establishing ISPO include positioning oil palm development as an integral part of nation's economic development, strengthening basic attitude of Indonesian people to produce sustainable palm oil, and supporting Indonesia's commitment to preserving natural resources and environmental functions. Principles and criteria as governed by Directorate General of Plantations in 2011 cover 1) permit systems and plantation management; 2) application of technical guidelines for oil palm cultivation and processing; 3) environmental management and monitoring; 4) responsibilities to workers; 5) social and community responsibility; 6) empowerment of community economic activities; and 7) continuous business improvement.

5. Technologies and innovations

Oil palm productivity is influenced by environmental and genetic factors, as well as plant cultivation techniques. Environmental factors include abiotic (rainfall, rainy days, soil, topography) and biotic aspects (weeds, pests, total plant population/ha). Genetic factors (innate) cover variety of seeds and plant age. Factors of cultivation techniques include fertilization, soil and water conversion, control of weeds, pests, and plant diseases as well as other maintenance activities. These factors are interrelated and influence each other [11].

Beside tidal fluctuations, main obstacle into developing oil palm plantations in tidal land is diversity of physico-chemical soil properties, for instance low water pH and soil pH, low fertility, aluminum (Al) and Iron (Fe) toxicity and bio-physical constraints, such as rapid weed growth, pests and water stress [12]. Innovations developed to overcome existing obstacles have been in forms of (1) water management; (2) land preparation; (3) amelioration and fertilization; (4) nurseries; (5) pest/disease controls.

Water management in swamps uses a one-way flow pattern (one follow system) with conservation blocks and elbow pipes and pumps which aim to regulate the entry and exit of water and to maintain water quality. Water management in swamps is developed to avoid excessive flooding/inundation in rainy seasons while preventing drought in dry seasons. The latter is critical to minimize chance of drying out in acid sulfate lands and peatlands. In macro-scale water systems, drainage and irrigation canals are usually divided into primary, secondary, and tertiary channels.

During land preparation, community plantations have a commitment to "environmental sustainability" in accordance with Government Regulation no. 28 of 1995 concerning the development of national plantations. To support aforementioned policy, “zero burning”, i.e. land clearing for plantations without burning, is obliged to be applied. This approach has several advantages, including
(1) maintaining biodiversity (flora and fauna), (2) preventing air pollution as smoke, (3) maintaining soil nutrients from decomposed forest waste, (4) preventing fire spread accessing community lands and gardens.

The level of soil fertility is to fit biological, physical and chemical balance of the soil and to prevent excessive application of fertilizers. Applying fertilizers is usually done in dry season. Good fertilizers should be able to improve soil acidity and stimulate roots. Therefore, fertilizing procedure must also be addressed to maximize outcome through balanced fertilization based on soil nutrient status. This level of fertilization efficiency is taken to achieve economic and yield benefits, while minimizing natural resources and environmental risks.

The success of CPO production is largely determined by the use of certified, superior seeds, as well as the quality (type of seed and growth rate) and quantity of oil palm seeds. Seed quality also determines whether harvesting can start at the age of 30 months. Seed quality is influenced by, among others: a) varieties and sources of seeds or their genetic potential; b) nursery process (technical culture) during planting and maintaining seedlings; c) selection of seeds; and d) age of seedlings when transplanted.

6. Conclusion

Development of oil palm plantations is expected in the future. In addition to having high productivity and stability, the development should also promote a sense of equality and highly regard local wisdom towards the environment. Four properties of sustainable agroecosystems need to be maintained, namely productivity, stability, sustainability, and equity.

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