MODULE 2

COMMUNITY SUSTAINABLE LIVELIHOOD AND USE ON PEAT

In collaboration with

Measurable Action on Haze-Free Sustainable Land Management in Southeast Asia (MAHFSA) Programme

Content

1. Getting To Know Peatland

Peatland has many benefits, among the most important are to prevent flooding during rainy season and to prevent drought during dry season. Peatland has an extraordinary capacity to store water during rainy season. This water will then be gradually released during dry season. Other benefits include being the habitat for various species of animals and plants, providing land for agricultural cultivation, farming, and fisheries which can be profitable when managed properly. For particular type of peatland, agricultural cultivation can be quite profitable. While for other types of peatland, it can be challenging and very costly, hence a loss.

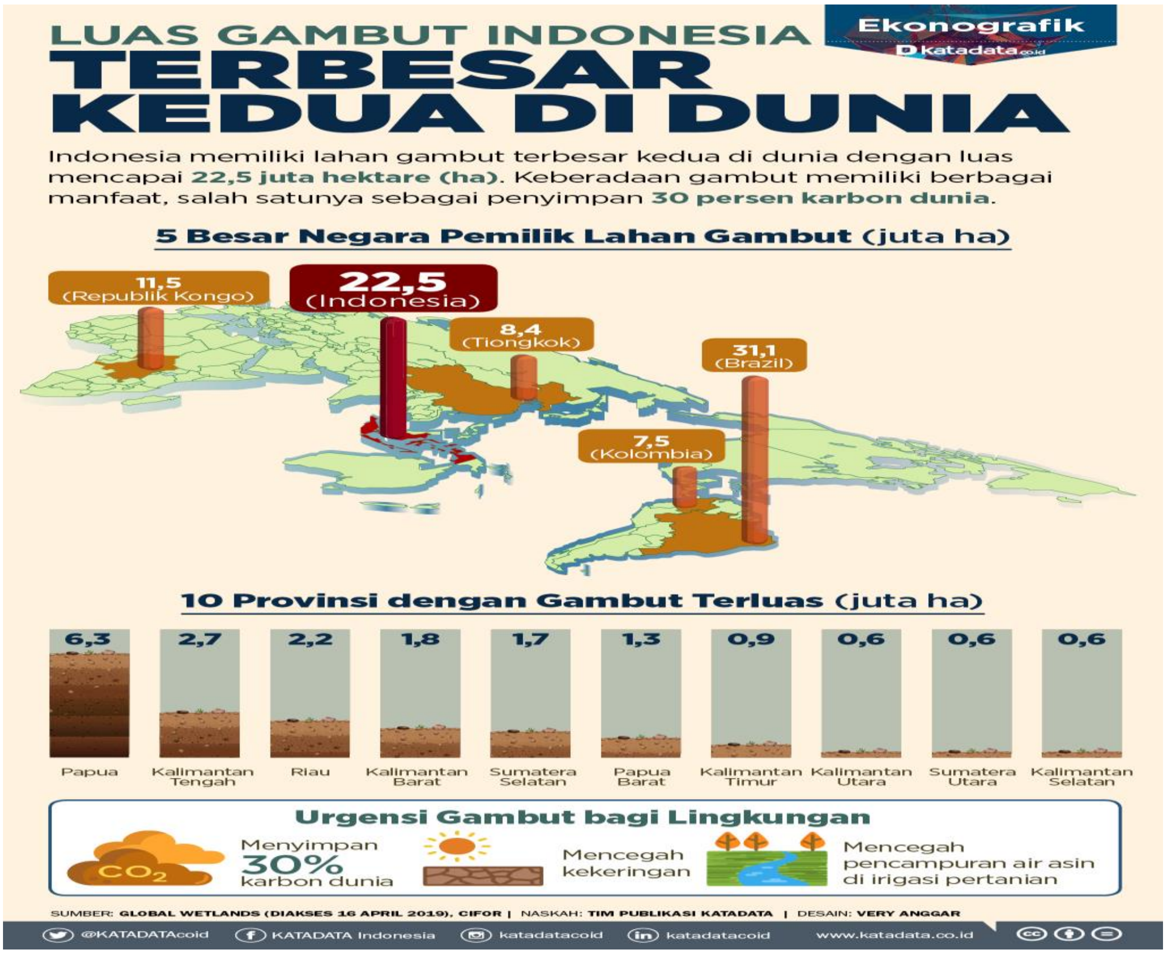

Figure 1. Distribution of Indonesia’s Peatlands, Source: Kata Data

1.1. Peatland Physiography

Peatland in Indonesia normally takes the shape of a peat dome. The sides of the dome are dominated by woods that still obtain nutrients from groundwater and rivers, hence there are different types and usually have large diameters. This kind of forest is called mixed swamp forest.

Towards the middle, the location of the groundwater is already too deep that the roots of forest wood plants cannot reach it. As a result, the forest vegetation only gets nutrients solely from rain water. The forest vegetation slowly changes, the types of forest wood species are getting less and less, the forest vegetation is relatively thin with a small diameter. This type of forest vegetation is called *hutan padang*. The thick peat that is formed is generally acidic and poor in nutrients so that it has low to very low natural fertility. Changes from peat periphery areas which are relatively rich in nutrients to areas of poor ombrogen peat are estimated to occur at peat depths of between 200-300 cm (Suhardjo dan Widjaja-Adhi, 1976).

Indonesia has the largest peatland in Southeast Asia with an area of 20.2 million hectares (ha). This amount is equivalent to 88% of the total peatlands in Southeast Asia. Peatlands in Indonesia reportedly store 57 gigatons of carbon. This amount is 20 times more than the carbon stored in ordinary tropical rain forests or mineral soils. Apart from Indonesia, Malaysia is also noted to have relatively large peatlands on the scale of Southeast Asia, which is 2.56 million ha. The following is a breakdown of peatland areas in Southeast Asian countries: 1) Indonesia: 20.2 million ha, 2) Malaysia: 2.56 million ha, 3) Brunei Darussalam: 90.9 thousand ha, 4) Thailand: 64.5 thousand ha, 5) Vietnam: 24 thousand ha, 6) Philippines: 20.2 thousand ha, 7) Myanmar: 11.2 thousand ha, 8) Cambodia: 9.8 thousand ha, and 9) Myanmar: 1.0 thousand ha.

Peat swamp area in the lowlands is located at an altitude of 0 to several meters above sea level, so that the topography or shape of the swamp land area (relatively close to the coast) is somewhat flat to flat. In some places there are differences in the configuration of the ground surface. Some of the land in the basin is always inundated with water, some are rather high and never flooded, but the groundwater is generally shallow.

The main physiographic units found in peatland areas are usually influenced by the marine environment, the river environment (alluvial riverine), and peat (peat dome, which occupies the basin). In areas affected by a combination of freshwater and seawater environments, alluvial/fluviatile physiography (the result of river deposits), peat (which occupies depressions), and marine physiography (formed in a marine environment) are found.

In the upstream part of the river, due to the strong influence of freshwater river currents, a river embankment is formed on the edge of the river, with the parent material in the form of river sediment/fluviatile above the marine sediment. The location of the plain behind the river embankment is lower and is already a marine deposit, namely sedimentary material formed by the marine/marine environment. The closer to the estuary and closer to the shoreline, the influence of the river decreases, river embankments are not formed and the influence of the sea/marine is increasingly dominant, so that the entire plain is a marine deposit. The small islands that are part of the river delta are formed entirely from marine deposits.

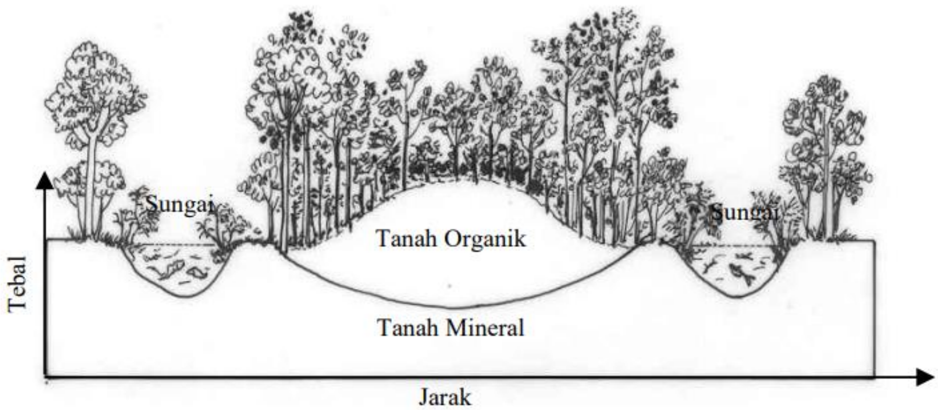

Figure 2. Peatland with the top of the dome in the middle

Peatlands occupy the basin between two major rivers. If the horizontal distance between the two major rivers is quite far, for example several tens of kilometers, the peatlands usually form a fairly large peat dome pattern. In a peat dome like this, at the edges is shallow peat and further towards the center towards the top of the dome, the peat soil level gradually rises. The height of the peak of the peat dome varies, it can reach 3-8 m above the river water level. In deep peat, the center of the peat dome can reach 8-13 m, the ground water is stagnant and very poor in nutrients. Around the top of the peat dome or at the edges is sloping peat, shallower and more mixed with mineral materials, so the fertility level is higher. Peat soil that occupies depressions or narrow basins, is usually thin peat (0.5–1 m) to medium peat (1–2 m).

1.2. Formation Process

Peat is a wetland ecosystem characterized by the accumulation of organic matter that lasts for a long time. This accumulation occurs due to the slow rate of decomposition compared to the rate of accumulation of organic matter on the forest floor of the wetlands. The process of peat formation almost always occurs in flooded forests with large amounts of organic matter production.

The formation of peat in several coastal areas of Indonesia is estimated to have started since the late glacial period, around 3,000 - 5,000 years ago. The process of formation of inland peat is even longer, around 10,000 years ago (Brady, 1997 in Murdiyarso et al, 2004). Like other tropical peats, peat in Indonesia is formed by the accumulation of tropical vegetation residues that are rich in lignin and cellulose content (Brady, 1997 in Murdiyarso et al., 2004). Due to the slow decomposition process, in the peat swamp ecosystem, large stems, branches and roots can still be found.

In general, peat formation and maturation go through three processes, namely physical ripening, chemical ripening and biological ripening. The speed of the process is influenced by climate (temperature and rainfall), composition of organic matter, activity of organisms, and time (Andriesse, 1988).

Peat maturation through physical, chemical, and biological maturation processes can be described as follows:

1. Physical maturation occurs with the release of water (dehydration) due to drainage, evaporation (evaporation), and being sucked in by roots. This process is characterized by subsidence and discoloration of the soil;
2. Chemical maturation occurs through the decomposition of organic materials into simpler compounds. This ripening process will release organic acids that are toxic to plants and make the soil acidic. Peat that has undergone chemical ripening completely will eventually form a new organic material called humus;
3. Biological maturation is a process caused by the activity of soil microorganisms. This process will usually occur more quickly after making drainage because of the availability of oxygen which is quite favorable for the growth of microorganisms.

1.3. Properties of Peat Soil

Peat soil properties can be grouped into two, namely physical and chemical properties. The physical and chemical properties of peat are not only determined by the level of decomposition of organic matter but also by the type of vegetation from which the organic matter originates.

Physical Properties

Physical properties of peat that are important to know include maturity level, specific gravity, water holding capacity, bearing capacity, soil settlement, hydraulic conductivity, and color.

Peat Maturity Rate

Since it is formed from different materials, environmental conditions, and time, the level of maturity of peat varies. Peat that has matured will tend to be smoother and more fertile. On the other hand, the immature ones contain a lot of crude fiber and are less fertile. Coarse fiber is the portion of peat that does not pass through a 100 mesh (100 holes/square inch) sieve. Based on the level of maturity/decomposition of organic matter, peat is divided into three, namely:

1. Fibric, i.e. peat with early weathering (still young) and more than of its volume in the form of fresh (coarse) fiber. Characteristically, when the peat is squeezed with the palm of the hand in a wet condition, the fiber content left in the palm after the squeeze is three-quarters or more (>¾);
2. Hemic, i.e. peat that has a moderate level of weathering (half-cooked), some of the material has undergone weathering and partly is in the form of fiber. When squeezed with wet palms, the peat passes easily between the fingers and the fiber content remaining in the palms after squeezing is between less than three quarters to a quarter or more (¼ and <¾)
3. Sapric, i.e. peat that has advanced weathering (mature). When squeezed, the peat passes easily between the fingers and less than a quarter of the fiber remains in the palm of the hand (<¼).

To accelerate peat maturity, cassava plants are usually used, application of manure or compost, application of liquid organic fertilizer, and drainage. Cassava plants are resistant to high acidity, and microorganisms (microorganisms) found in their roots will accelerate peat maturation. Likewise, microorganisms found in compost, manure, and liquid organic fertilizer. While adequate drainage will provide a good atmosphere for the proliferation of microorganisms [note: drainage must be carried out with extra care, namely by maintaining the water level of the peat soil according to plant needs. Over-drainage conditions will be very dangerous, because in addition to peat will become dry and vulnerable to fire, there is also subsidence in the peat soil which can uproot plants on it as a result of roots sticking out to the surface of the peat].

Colour

Even though the material from peat is gray, brown or reddish in color, after decomposition, dark colored compounds appear so that peat is generally brown to black in color. Peat color is an indicator of peat maturity. As it matures, the peat becomes darker in color. Fibric is brown, hemic is dark brown, and saprik is black (Darmawijaya, 1990). In wet condition, the color of the peat is usually darker.

Bulk Density/BD

Peat has a much lower specific gravity than alluvial soil. The more mature the peat, the greater the specific gravity. Wahyunto et al, 2003 classified the value of the specific gravity or bulk density of peat soils in Sumatra as follows: sapric peat has a density of about 0.28 gr/cc, hemic 0.17 gr/cc and fibric 0.10 gr/cc. Due to its light density, dry peat is easily eroded/floated by the flow of water.

The general value of bulk density in peatlands is 1.1 gr/cm^3 - 1.6 gr/cm^3. In accordance with the opinion of Radjagukguk, (1997) which stated that the volume of peat soil ranges from 0.1 gr/cm^3 - 0.3 gr/cm^3, and the value of bulk density of peat is largely determined by the level of peat maturity. The low value of bulk density will affect the ease of plant roots to penetrate into the peat soil layer, however the penetration of these roots will be limited by waterlogging and the level of soil acidity, in addition, low bulk density will affect the strength of the soil to hold plant stems. This causes plant stems in peat areas to tend to grow crookedly as a result of the soil not being able to hold the plant stems (Nugroho, 2018), therefore peatland management efforts in cultivating need to pay attention to the height of the bunds to the depth of water, so that peatland plants have a percent grow tall, and the stems of the plant grow straight. To calculate the need for fertilizer or water, a bulk density value is needed which can be based on the weight of the soil per hectare. (Harjdowigeno, 2003).

Water Holding Capacity

Peat has a high porosity so that it has a very large water absorption capacity. When saturated, the water content of sapric, hemic and fibric peat is <450%, 450-850%, and >850% of its dry weight or 90% of its volume (Suhardjo and Dreissen, 1975). Therefore, peat has the ability as a reservoir that can withstand flooding during the rainy season and release water during the dry season so that seawater intrusion during the dry season can be prevented.

Irreversible Hydrophobia

Peatlands that have been cleared and have been drained by making ditches or canals, the water content decreases excessively. The decrease in surface water will cause the peatlands to become dry. Peat has irreversible dryness. This means that peat that has experienced extreme drying will find it difficult to absorb water again. Peat that has experienced extreme drying has a very light density so that it is easily washed away by rainwater, its structure is loose like a sheet of litter, easy to burn, and difficult to replant.

Hydraulic Conductivity

Peat has a hydraulic conductivity (water distribution) horizontally that is fast so that it accelerates the leaching of nutrients into the drainage channel. In contrast, peat has very slow vertical (upward) hydraulic power. As a result, the top layer of peat is often dry, even though the bottom layer is wet. This also makes it difficult to supply water to the root layer. The hydraulic power of the water up is only about 40 - 50 cm. To overcome this behavior, it is necessary to make efforts to maintain the groundwater level at a certain depth. For annual crops, the ideal depth of groundwater table is less than 100 cm. As for perennial plants, it is recommended to maintain the water table at a depth of 150 cm. Peat compaction is often done to reduce soil porosity.

Carrying capacity

Peat has a low carrying capacity or bearing capacity because it has a large pore space so that the soil density is low and its weight is light. The total pore space for fibric/hemic materials is 86 - 91% (volume) and for hemic/sapric materials 88 - 92%, or an average of about 90% by volume (Suhardjo and Dreissen, 1977). As a result, the trees that grow on it fall down easily. The low bearing capacity will be a problem in the construction of irrigation canals, roads, settlements and paddy fields (except peat with a depth of less than 75 cm).

Subsidence

After drainage or reclamation is carried out, the peat will gradually deflate and experience subsidence, namely a decrease in the soil surface, this condition is caused by the peat maturation process and reduced water content. The duration and speed of the subsidence depends on the depth of the peat. The thicker the peat, the faster and longer the decline. The average rate of decline is 0.3 - 0.8 cm/month, and occurs for 3 - 7 years after drainage and cultivation.

The problem of peat subsidence in perennial crops is usually addressed in the following ways:

1. Planting annual crops is preceded by planting seasonal crops at least three times the planting season.
2. Compaction before planting annual crops.
3. Make a multilevel planting hole.

Flammable

Peatlands tend to burn easily due to their high organic matter content and their irreversible dryness, high porosity and low vertical hydraulic conductivity. Fires in peat soil are very difficult to extinguish because they can penetrate below the soil surface. The embers that were thought to have been extinguished were actually still hidden in the ground and spread to the surrounding areas without realizing it. Coals in deep peatlands can usually only be extinguished by heavy rains. Therefore, peat fires must be prevented by not burning the land, not throwing the slightest embers such as cigarette butts carelessly, especially in the dry season, and maintaining the moisture of the peat soil by not making excessive drainage.

Forest and peatland fires have negative ecological impacts in the form of the destruction of most sources of biodiversity; the killing of hundreds of wild animals such as orangutans and bears; air pollution that causes health problems, economic activities, and transportation. The resulting air pollution directly increases the number of patients of respiratory tract infections (ARI).

Chemical Properties

The chemical properties of peat that are important to know are the level of fertility and the factors that affect the fertility.

Peat Fertility

Peat fertility is divided into three levels, namely Eutrophic (fertile), mesotropic (moderate), and oligotropic (infertile). In general, topogenous peat that is shallow and influenced by groundwater and rivers is generally classified as mesotropic to eutropic peat so that it has better natural fertility potential than ombrogen peat (fertility is only affected by rainwater) which is mostly oligotropic.

Ash content is a good indicator to determine the state of the natural fertility level of peat. Suhardjo and Driessen (1975) and Suhardjo and Widjaya-Adhi (1976) have investigated the ash content of peat soils for the purpose of land reclamation in the Riau area. In general, shallow peat (<1 m) found on the edge of the dome has an ash content of about 15%, the slopes with a depth of 1-3 meters contain about 10% ash, while in the center of the dome which is more than 3 meters deep, the ash content is less than 10% and sometimes even less than 5%. This corresponds to enrichment by river or sea water or contact with the bottom of the depression. The indicative chemical properties of ombrogenous and topogenous peat in Indonesia are presented in Table X.

Table 1. Nutrient content of three peat typologies

Peat Type	**Content (percentage of dry weight of peat)**			
	Ash	**P2O5**	**CaO**	**K2O**
Eutrophic	>10	>0,25	>4,0	>0,10
Mesotrophic	5-10	0,20 - 0,25	1 - 4,0	0,10
Oligotrophic	2-5	0,05 - 0,20	0,25 – 1	0,03 – 0,1

Source: Polak (1941; 1949)

Peat soils generally have low fertility, characterized by low pH (acidic), availability of a number of macro (K, Ca, Mg, P) and micro (Cu, Zn, Mn, and Bo) nutrients that are low, contain organic acids. which is toxic, and has a high Cation Exchange Capacity (CEC) but low Base Saturation (KB).

High CEC and low KB cause low pH and a certain amount of fertilizer applied to the soil is relatively difficult for plants to take. In general, tropical peatlands have a pH between 3 - 4.5. Shallow peat has a higher pH (pH 4.0 - 5.1) than deep peat (pH 3.1 - 3.9). Al content in peat soils is generally low to moderate, decreasing with decreasing soil pH. Total N content is high, but generally not available to plants, due to the high C/N ratio.

Decomposition of organic matter in an anaerobic atmosphere produces organic compounds such as proteins, organic acids, and humus-forming compounds. These organic acids are black in color and make the soil acidic and toxic to plants. The pH range of peat soil is between 3 to 5. This low pH causes a number of nutrients such as N, Ca, Mg, K, Bo, Cu, and Mo to be unavailable to plants. Phosphate macronutrients are also in low quantities because peat is difficult to bind to these elements so that they are easily washed off. High acidity (low pH) also causes the inactivity of microorganisms, especially soil bacteria, so that mold growth is rampant and soil reactions supported by bacteria such as nitrogen fixation and peat mineralization are inhibited. The ideal pH level for nutrient availability in peat soil is 5 to 6.0 (FAO, 1997). But making the pH of peat soil more than 5 requires a very large cost, so the number 5 is used as a reference for agricultural cultivation.

Other fertility factors are Cation Exchange Capacity (CEC) and Base Saturation (KB). CEC is the ability of the soil to bind (absorb) and exchange cations expressed in milliequivalents per 100 grams of soil. While base saturation is the percentage of base cations (Ca, Mg, K, and Na) that can be exchanged against its CEC value. The CEC of peat soils is generally high and increases with increasing organic matter content. But the KB is low because the number of base cations is low. Low KB causes low pH and some of the fertilizer applied to the soil is difficult for plants to take. The addition of ingredients containing Ca, Mg, K and Na will increase KB, increase pH, and repel organic acid compounds.

Factors Affecting Fertility

The level of peat soil fertility is influenced by various things, namely the thickness of the peat, the material of origin, water quality, maturity of the peat and the condition of the soil under the peat. In general, peat from soft-trunked plants is more fertile than peat from woody plants. Mature peat is more fertile than immature peat. Peat that receives overflowing river water or brackish water is more fertile than peat that only receives overflow or rainfall. Peat that is formed on a layer of clay/mud is more fertile than that found on a layer of sand. Shallow peat is more fertile than deep peat.

The formation of shallow peat is influenced by river flooding which carries a lot of nutrients, so it is more fertile than deep peat which only comes from rainwater and the decomposition of the vegetation debris on it. Research by Leiwakabessy and Wahyudin (1979) showed that on peaty soils (about 20 cm thick) to medium peat (180 cm thick), dry grain production decreased with increasing thickness of peat. The thicker the peat, the lower the ash content, the lower the Ca and Mg content and the more acidic the soil reaction.

Table 2. Fertility Limiting Factors in Peat

Category	Traits/Behavior
Physical Properties	Peat maturity varies
	Low specific gravity
	High water holding capacity, but when dry it is difficult to reabsorb water
	Low vertical water conductivity
	Low bearing capacity
	Experiencing land subsidence
	Under the peat there is often a layer of sand or pyrite
Chemical Properties	Low fertility
	a. Low pH
	b. High CEC
	c. Low base saturation
	d. Availability of macro nutrients (N, Ca, Mg, K) is low
	e. Availability of micro nutrients (Cu, Mo, Zn, Mn, Fe) is low

1.4. Problems related to Unsustainable Peat Cultivation

1.4.1. Peatland Degradation

Land degradation is a process in which the biophysical environmental conditions change due to human activities on a land. Changes in environmental conditions tend to be destructive and undesirable. Until now, some of the peatlands have been cleared and used for agricultural land either through government, private, or non-governmental programs. Of these cleared areas, apart from being successful in a sustainable manner, many have also become abandoned and damaged lands (Subiksa, et al., 2010). The driving factors for the destruction of agricultural land on peatlands include land fires, construction of drainage channels and land management.

Peatland degradation can occur due to peat fires, rapid decomposition processes, and dehydration. Fire and decomposition processes produce high CO_2 emissions. Decomposition occurs when long carbon chains are degraded into compounds with shorter carbon chains. This process is mainly triggered by the construction of drainage channels which increases the redox potential of the soil. Drainage and water management systems in a peatland can be seen from changes in the hydrological conditions of the area as a whole. Wosten in Hooijer et al., (2006) and Agus et al., (2010) say that several drainage systems clearly affect CO_2 emissions.

Excessive drainage will accelerate peatland degradation through decomposition and drying processes. This process also causes the peat soil layer to become thinner. If the substrate is quartz sand or pyrite layer, the soil becomes more acidic and has the potential to be poisoned by iron and Al. Damage to the peat ecosystem has a major impact on the local environment (in-situ) and the surrounding environment (ex-situ). The occurrence of flooding in the downstream watershed or the increase in air temperature is the impact of the destruction of the peat ecosystem.

Some of Indonesia's peatlands have been cleared and used for agricultural land either through government, private, or non-governmental programs. The tendency to expand the use of peatlands is very significant in several provinces that have large peat areas, such as Riau, Jambi, West Kalimantan and Central Kalimantan. Research results from WWF (2007) show that the rate of deforestation of peat forests in Riau is very high, from 50 thousand ha in 1982-1988 to 180 thousand ha in 2005-2006.

1.4.2. Carbon Emission

Peat soils store much higher C than mineral soils. One gram of dry peat stores about 180-600 mg of carbon, whereas every one gram of mineral soil contains only 5-80 mg of carbon. In the tropics, the carbon stored by tillage and plants on peatlands can be 10 times the carbon stored by soils and plants on mineral soils (Agus and Subiksa, 2008). Peatlands cover only 3% of the world's total land area, but store 550 Gigatonnes C or the equivalent of 30% of soil carbon, 75% C of all atmospheric C, equivalent to all C contained in the biomass (total mass of living things) on land, and equivalent to twice of the C storage of all forests worldwide (Joosten, 2009). Indonesia's peatland area covers 10% of its total land area or about 20 million ha (Rieley, 1996). Jaenicke et al. (2008) estimated the carbon stored on peatlands in Indonesia at around 55 Gigatonnes.

Under natural conditions, carbon storage in peatlands is relatively stable. Peat thickness can increase up to 3 mm year-1 (Parish et al., 2007). However, if these natural conditions are disturbed, there will be an acceleration of the weathering process (decomposition), so that carbon stored in peatlands will be emitted to form greenhouse gases (GHG) especially CO_2 gas, as a result of the drainage process that always accompanies the land use process. Based on data released by BAPPENAS (2009), it is estimated that the average annual emission from peatlands in Indonesia in 2000-2006 is around

903 million t CO_2, including emissions that may occur from peat fires. Whereas in the state of natural forest, peatlands emit emissions of 20-40 t CO_2-eq ha-1 year-1 (Rieley et al., 2008).

1.4.3. Peatland Fire

Data on forest and land fires in Indonesia as reported in https://sipongi.menlhk.go.id/ shows that during the 2014-2019 period, the area of forest and land where fires occurred was highest during the long dry season in 2015 and 2019. In 2015, forest and land fires amounted to 2,611,411.44 Ha. In 2019 there was a fire covering an area of 1,592,010.00 Ha. Most of the fires that occur in forests and land occur outside the forest area. Around 70-80 percent of fires occur outside forest areas, while about 20-3 percent are inside forest areas. Fires in the territory of Indonesia are specific because many occur on peatlands which cause haze problems (BNPB, 2013). Fires in Indonesia are recurring fires that occur during the dry season (Putra et al., 2018).

Forest/peatland fires affect the degradation of environmental conditions, human health and socio-economic aspects for the community. The environmental conditions of peatlands in the event of fire will reduce the porosity of the peatlands and the water content of the peatlands, as well as disrupt the decomposition process of peatlands due to microorganisms that die due to fires.

The World Bank reported that Indonesia's total losses due to forest and land fires throughout 2019 reached US$ 5.2 billion or equivalent to Rp 72.95 trillion (exchange rate of Rp 14,000). This figure is equivalent to 0.5% of Indonesia's Gross Domestic Product. Based on the publication of the World Bank under the title Indonesia Economic Quarterly Reports (IEQ), the calculation of this economic loss is based on massive forest fires that occurred in eight priority provinces, namely, Central Kalimantan, South Sumatra, South Kalimantan, Riau, West Kalimantan, Jambi, East Kalimantan and Papua.

2. Peatland Utilisation

Despite the unique and vulnerable nature of peatlands, they have many benefits. Among them are to prevent flooding in the rainy season and prevent drought in the dry season; as carbon sinks and stores so that they can play a role in controlling world climate change; as a habitat for the life of various kinds of animals, plants, and microorganisms; and profitable agricultural land.

2.1. Zero burning farming of red ginger in Temiang Village

Ginger is a medicinal plant in the form of quasi-trunked clump. Ginger comes from Asia Pacific which spread from India to China. Both countries use ginger as an ingredient in drinks, cooking spices and traditional medicines. Ginger belongs to the gathering tribe (Zingiberaceae), a family with other findings such as temu comedy (Cucuma xanthorrizha), black ginger (Curcuma aeruginosa), turmeric (Curcuma domestica), kencur (Kaempferia galanga), galangal (Languas galanga) and others.
In Indonesia, there are various names for ginger, including ginger (Aceh), beeuing (Gayo), bahing (Batak Karo), sipodeh (Minangkabau), jahi (Lampung), ginger (Sunda), jae (Java and Bali), jhai (Madura), melito (Gorontalo), mobila (Ternate), in Riau Province are still called ginger as well as Temiang Village. There are various types of ginger commonly traded in Indonesia, including elephant ginger, emprit ginger and red ginger, of the three types of ginger big ginger still occupies the highest productivity. It was recorded that in 2011 the harvested area reached 5,491 ha, with a production of 94,133 tons and a productivity of 13.11 tons/ha (BPS, 2011).

The Makmur Jaya Women Farmers Group in Temiang Village manages peatland without burning through the cultivation of Red Ginger. The land management activity without burning is currently supported by the Peat Foundation, WWF Indonesia Foundation and the Peat Restoration Agency.

a. Seed Preparation

Quality seeds should meet the requirements of genetic quality, physiological quality (high growth percentage) and be free from pests and diseases. In conducting the nursery, the Makmur Jaya Women's Farmer Group chose seeds that were old, over 9 months old, and the rhizome skin was not injured or blistered. Before planting, the ginger rhizome is dipped in a fungicide to prevent disease.

b. Land Preparation and Planting

For land preparation, the Makmur Jaya Women's Farmer Group chose to use 10 kg sacks filled with peat soil, and pay attention to the pH of the peat soil as a prerequisite for red ginger plants. Before planting, the sacks filled with soil are left for 1 week and then ginger is planted.

c. Maintenance

The maintenance of ginger plants is carried out after the plants are a month old, the Makmur Jaya Women Farmers Group routinely cleans the grass that grows around the ginger plants, the aim is to reduce the impact of competition for nutrients between plants. Fertilization is done every 3 months as much as 200 grams of NPK per sack, watering plants is done almost every day except rainy days.

d. Harvesting

Harvesting is done after the ginger plant is 9 months old. From the experience of the Makmur Jaya Women's Farmer Group, in one sack a minimum yield of 3 kg is obtained. The results can be greater if you use a larger sack.

e. Farming Analysis

I. Assumption

1. The land used is privately owned and not by burning.

2. As many as 1,000 units of sacks are provided.

3. The seeds obtained are healthy seeds.

II. Cost

1. Investment Cost

Component	Unit		Price (Rp)	Total cost (Rp)
Farming Tools	1	set	200.000	200.000
Water hose	1	set	500.000	500.000
Sacks	1.000	pack	1.200	1.200.000
Watering can	3	Pc	75.000	225.000
Total Investment Cost				**2.125.000**

2. Fixed Cost

Description	Usage time		Cost (Rp)	Depreciation (Harvest time)	Total cost (Rp)
Farming tools depreciation	36	Month	800.000	9	200.000
Water hose depreciation	48	Month	500.000	9	93.750
Sacks depreciation	24	Month	1.200.000	9	450.000
Watering can depreciation	36	Month	600.000	9	150.000
Total Fixed Cost					**893.750**

3. Variable Cost

Description	Unit		Cost (Rp)	Total Cost (Rp)
Red ginger seeds	1.000	Unit	8.000	8.000.000
NPK fertiliser	10	Sack	450.000	4.500.000
Total Fixed Cost				**12.500.000**

4. Total Operating Costs Per Period

Total Operating Cost = Total Fixed Cost + Total Variable Cost

= Rp 893.750 + Rp 12.500.000

= **Rp 13.393.750**

III. Income and Profit

- Income Per Period

Income = Total Yield x Average Local Market Price in Bengkalis

= 3.000 Kg x Rp 20.000

= **Rp 60.000.000**

- Profit Per Period

Profit = Income – Total Operating Cost

= Rp 60.000.000 – Rp 13.393.750

= **Rp 46.606.250**

In one planting period of 9 months, from the profits obtained by farmers if divided per month, the farmer's income from 1,000 ginger seeds managed is around Rp 5 million.

IV. Feasibility

- R/C Ratio

R/C Ratio = Revenue : Total Operating Cost

= Rp 60.000.000 / Rp 13.393..750

= **4,48**

R/C 4.48 means that each additional capital of one rupiah will provide an income of Rp 4.48

2.2. Coffee Agroforestry on Peatland

Coffee is the third plantation commodity in Indonesia which has a fairly high share as a foreign exchange earner after timber and rubber. In Indonesia, Robusta and Arabica coffee are more popular, but actually there is one other type of coffee that has a distinctive taste, namely Liberika coffee. Liberika coffee is known as peat specialty coffee because of its ability to adapt well to peat soil.

Liberica coffee (Coffea liberica) is a type of Liberoid coffee originating from Liberia which is considered to have less economic value compared to Arabica and Robusta because of its low yield. However, Liberika coffee has several advantages, including being more tolerant of disease and adapting well to peatlands. Liberica coffee is widely cultivated in the Meranti Islands where according to BPS data for Meranti Islands in 2019, Liberica coffee production in the Meranti Islands is 1,881 tons per year.

The Makmur Jaya Women's Farmer's Group in Temiang Village together with the Gambut Foundation and support from the Global Environment Center carried out Liberika Coffee Agrofrestry activities in the Rubber Garden on peatlands.

Peatland Liberica Coffee Cultivation Experience

Nursery

The Makmur Jaya Women's Farmer Group in the village of temiang carried out 5000 liberica coffee seedlings, the seeds of the Liberian coffee variety were obtained from the Meranti Islands, the nursery was carried out on beds that were provided with shade. Coffee in the nursery is watered every day except in the rainy season. Then the coffee seeds that have grown are moved into polybags after 2-3 months.

Figure 3. Liberika Coffee Seeds in Temiang Village

Coffee Agroforestry Planting

Land clearing is carried out on the planting path between rubber trees, the distance for planting coffee trees is 3 x 2.5 meters, the coffee planted by the Makmur Jaya Women's Farmer Group is a liberica coffee seed that is adaptive to grow on peatlands. Coffee plants need shade, so planting is done between rubber trees to get natural shade from rubber trees. As well as part of efforts to increase the economic value of rubber plantations managed by the community.

Figure 4. Coffee planting on the sidelines of a rubber plantation in Temiang Village

2.3. Peatland management through Harapan Jaya Village government policy

Harapan Jaya Village in an effort to manage peatlands applies several strategies including:

1. Sustainable Management of Village Areas through a Participatory Approach

In planning the management of the village, the Village Government involves the community to conduct participatory mapping of the village administration area and the topography of the village area, then issues various village regulations related to the management of the village area and forms a community that cares about peatland management.

2. Village Area Management Plan

Efforts and area management plans are the most important thing so that the community becomes the real manager and receives the best benefits from their village area, including if they are in peat areas. Efforts made by the village government include:

a. Mapping the village administration area

b. Mapping the topography (contour) of the village area

c. Building a Village Spatial Plan (RTRWDes)

d. Issue village regulations on forest and land fire prevention

e. Building a Fire Danger Rating System

f. Building canal blocking (Channel Blocking)

g. Forming a Fire Care Community Group

h. Ensure that village regulations, warning boards, canal barriers, and Fire Care Community Groups are used as material in the preparation of the Village Medium Term Development Plan (RPJMDes)

3. Participatory Mapping of Village Administration Areas

The participatory mapping of the village area became the starting point for the planning and management process of Harapan Jaya Village. Through participatory mapping, villagers become more familiar with their village, territorial boundaries and land potential. Participatory mapping is primarily intended to build a sense of ownership of the planning and management processes. Activities carried out in participatory mapping include:

a. Gathering village history information

b. People practice using GPS (Global Positioning System) and process the data into maps

c. Socialization with neighboring villages regarding the mapping activity plan

d. The participatory map provides information on village boundaries, agricultural areas, sub-village divisions, roads and village canal networks.

e. The results of the participatory mapping are conveyed to the district government

f. Carry out contour mapping on peatlands to analyze the hydrology of peatlands in village areas

4. Develop a Village Spatial Plan (RTRW Desa)

After the topographic map and the contours of the area, it is necessary to make a Village Spatial Plan. The purpose of making RTRWDes is to manage the water system in the village and plan the direction of development and village development in the future.

In the RTRWDes, especially for peat areas, the canals that have been the cause of drought during the dry season and flooding during the rainy season will be normalized. RTRWDes also underlies an integrated design for regional development based on land use that follows the rules of water management in peat areas.

5. Land and Forest Fire Prevention

Some of the efforts made by the Harapan Jaya Village government in preventing forest and land fires include:

a. Issue a Village Regulation on procedures for sustainable peatland management and strict sanctions for residents who burn land and then harm other residents

b. Forming a Fire Care Community Group (MPA) and equipping it with equipment and capacity building for members

c. Installing a fire hazard warning board (Fire Danger Rating System/FDRS)

d. Building canal blocks in fire-prone areas

e. Ensure that all landowners are responsible for safeguarding their land from fire hazards

3. Water Management in Peatlands

3.1. Construction of Canal Blocks

Canal blocking is one of the efforts that needs to be done to increase the water capacity of peatlands, by constructing canal blocks to reduce the rate of outflow of peatlands, it will be difficult to burn. In carrying out the construction of canal blocks in Indonesia, referring to government regulations no. 71 of 2014 concerning the protection and management of peat ecosystems where in peat areas there are cultivation zones and protected zones, we need to do an area analysis first and evaluate community social activities and determine the construction of joint canal blocks. But still refers to the type of canal blocking in the peat zone.

The selection of canal blocking type can be grouped according to the function of the peat ecosystem, whether protection or cultivation. For a peat ecosystem with a protected function, a no-spillway canal type can be used and for a peat ecosystem with a cultivation function, a spillway can be used.

In the case that there is use of canals by the community in Peat Ecosystem having protection function, the development of wetting infrastructure can apply the type of bulkhead with spillway, by setting the spillway height not exceeding 0.4 meter from the ground surface. However, if wetting infrastructure is built in the form of canal blocking without spillway, then the community's access to the canal can use a ramp/roller. Selection of the type of canal blocking is adjusted to the location conditions, the dimensions of the canal and the availability of raw materials and as much as possible using local natural materials.

With reference to the Regulation of the Director General of Pollution and Environmental Damage Control Number: P.3/PPKL/PKG/PKL.0/3/2018 regarding Guidelines for Wetting Infrastructure Development for Peat Ecosystem Recovery, there are several designs and types of canal blocking including:

1. Plank Dam (single-ply wood block)

The single-ply wood block type (plank dam) is generally used for blocking canals or ditches with small dimensions (canal width less than 2 meters), with relatively very low discharge and water velocity. Single layer bulkheads may be equipped with spillway and/or non-spillway devices. For canal blocks of the Plank dam type, the piles must penetrate the mineral soil layer so that water does not leak through the peat soil layer below the canal block and reduce the effectiveness of the block in retaining water.

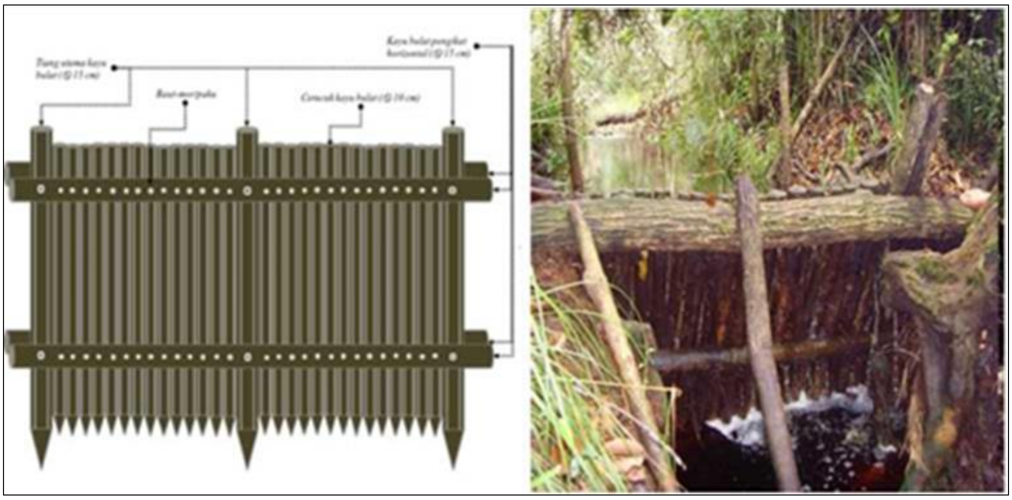

Figure 5. One layer bulkhead type without overflow (non-spillway)
(Photo and illustration by: Alue Dohong)

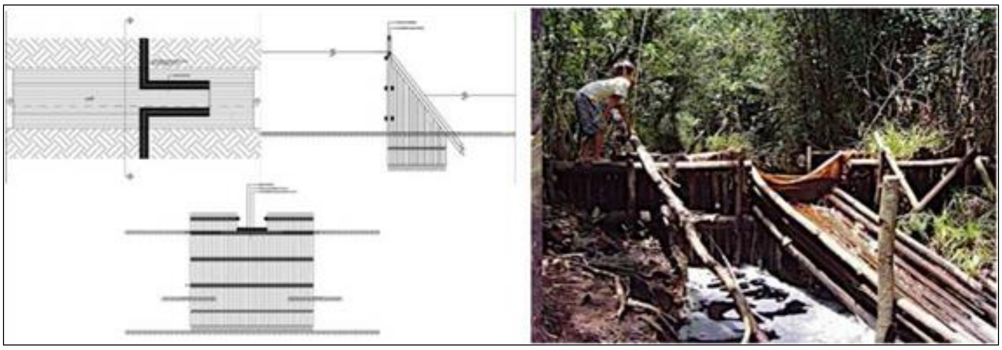

Figure 6. Example of a one-layer bulkhead type with overflow (design: Lola C and photo: Alue Dohong)

2. **Multiple-Sheet Piles Dam**

Wooden blocks with a multi-layered wooden structure are wooden blocks (generally logs) built in vertical rows/arrangements of logs (more than one arrangement) and between the vertical rows of logs are filled with sacks of soil or mature peat soil (hemic/sapric). The purpose of making a multi-ply wooden structure is to be able to withstand relatively greater water pressure and water discharge. The multi-ply wooden block type is generally used to block canals with large dimensions (canal width >5 meters).

The multi-ply log screen type can be equipped with or without overflow devices. It is recommended to fill in the voids between layers of wooden blocks using mineral soil or mature peat soil (hemic/sapric). It is not recommended to use sand because generally sand will be carried away by water currents when the sacks (sacs) of soil that cover it peel off and rot. In addition, sand cannot be used as a good planting medium for woody plants if there is a plan for planting wood as reinforcement above the wooden blocks. It is recommended that before the earthen sacks are filled, the two and multi-layer canal partitions should be lined with geotextile or tarpaulin along the inner walls of the canals to prevent/reduce seepage of water through the existing soil sacks.

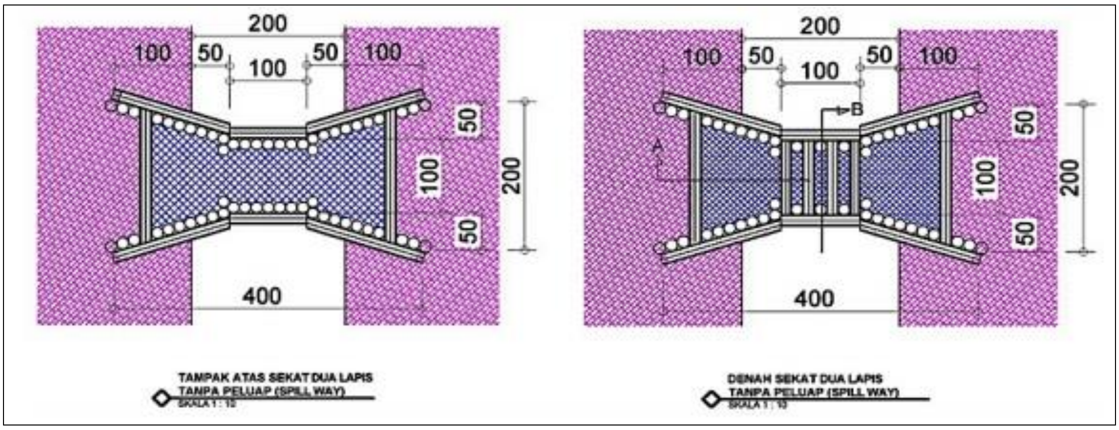

Figure 7. Sample of Two Ply Wooden Blocks without Spillway

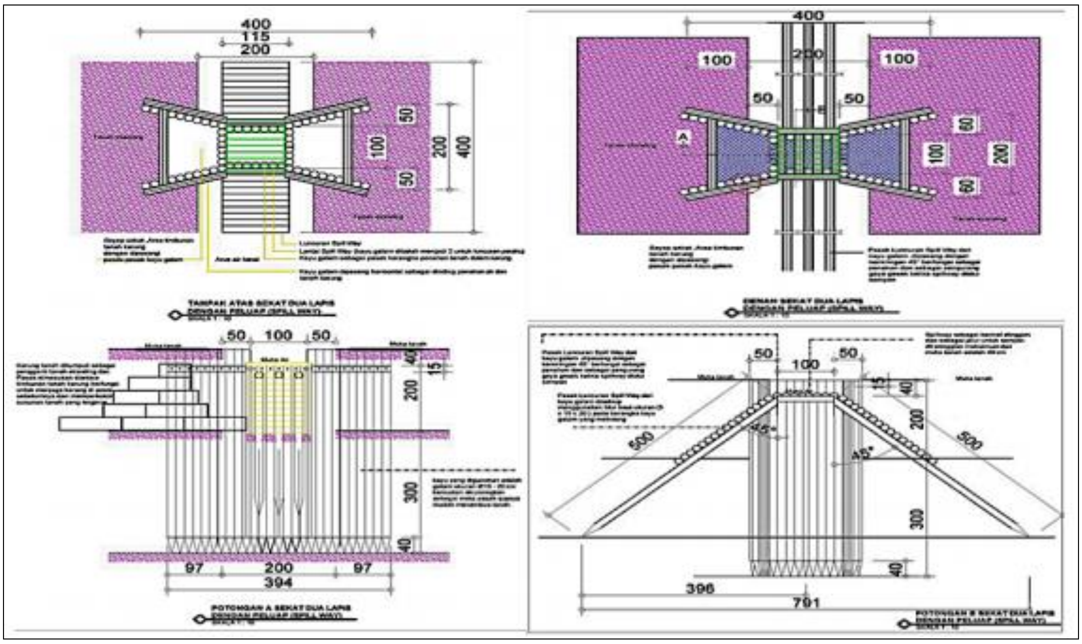

Figure 8. Example of Design Drawing of Two Ply Wood Block with Spillway System

Figure 9. The canal blocking built by the community in Rambaian Village, Indragiri Hilir Regency

3. Soil bags Dam

The type of canal blocking with sacks of soil is a quantity of soil (mineral/ripe peat) that is filled into sacks (jute or plastic) which are then put inside the canal body to a certain height with the aim of impeding the flow and maintaining the water level. The use of earthen sack type canal blocking is recommended only for canals with small dimensions (<2 meters) and shallow ones. The sacks of soil must be placed deep into the peat soil, so that no scouring of the peat occurs at the bottom of the canal or on the left and right sides of the canal body.

Figure 10. Types of Soilbags Dam (Photo: Ng Kok Seng, 2011)

4. Block from compacted peat

The type of block constructed from compacted peat is constructed by piling excavated peat soil in the body of the canal and then compacting it using a bucket excavator or stamper or other compaction device, to a level of density and stability capable of holding back the current and maintaining the desired water level. The dimensions of the compacted peat must be relatively large, proportional to the size of the canal so that the construction is strong and able to hold water.

Compacted peat soil material is recommended to use mature peat (hemic/sapric) and not peat soil that has experienced repeated drought because such peat soil will refuse to absorb water (hydrophobic). Blocks made of compacted peat are predicted to be very cheap and efficient because the materials for the blocks are locally available and the construction steps are not too complicated. This type of block can be constructed in canals with medium to large dimensions (> 5 meters).

Figure 11. Example of compacted peat canal blocking (Photo: Deltares)

5. Concrete Block

Concrete block is used for canals that are large/wide (> 15 meters) in locations with medium-thin peat depth and the layer beneath the peat is mineral (alluvial), where the carrying capacity of the soil is relatively strong to withstand the load of the concrete structure. The concrete block/concrete dam aims to withstand the relatively high discharge and flow of water and maintain the maximum water level.oncrete blocks can be equipped with water level control devices in the form of overflow or non overflow. Concrete blocks are recommended to be built in canals that are close together and empty into rivers or beaches. Concrete blocks have a relatively long life and strong construction durability compared to compacted wood or peat blocks, however, the cost of constructing concrete blocks is relatively expensive and the construction process is somewhat more complicated and takes longer time.

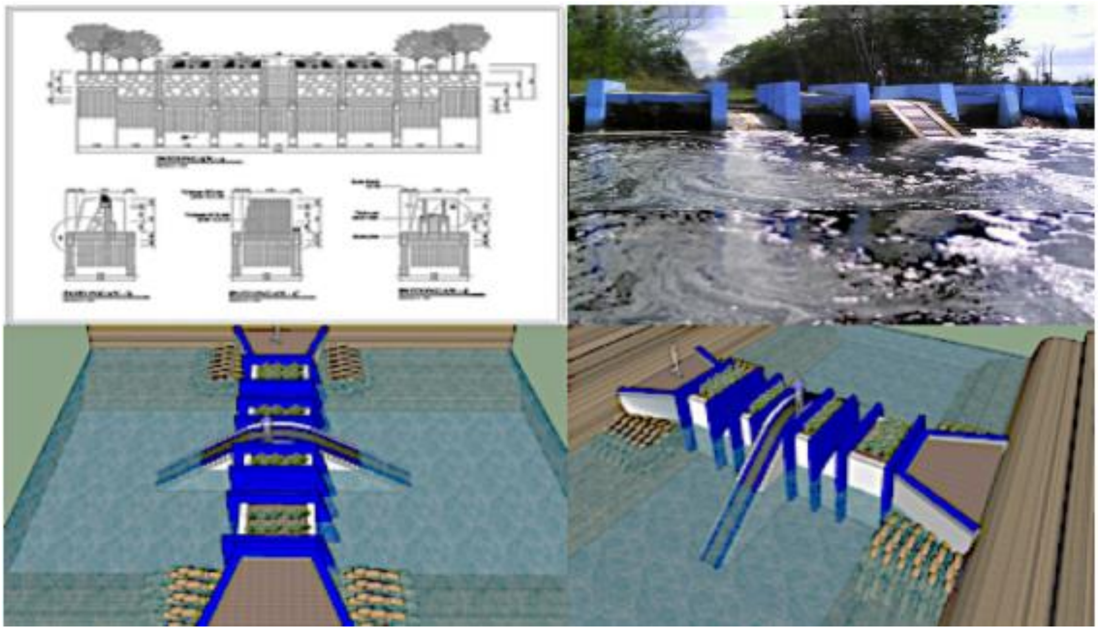

Figure 12. Type of Concrete Block built by ex PLG by Balai Swamp PU (Triadi, 2015, 2016)

3.2. Paludiculture in Peatlands

The word Paludiculture comes from the Latin word (palus) which means swamp. Swamp forest ecosystems (including peat swamps) are forests that grow in areas that are always inundated with fresh water, not affected by climate, but can be affected by tides. Paludiculture means the productive use of swamp land (and peat swamps) in ways that protect the peat. The condition of swamps and peat swamps that are saturated with water is maintained without making drainage, even in conditions that have already been drained. Attempts will be made to cover drainage or water canals so that the peat will be wet again (Joosten et al., 2012).

The development of paludiculture in Indonesia is one way to restore the sustainability of the peat ecosystem which is in line with the interests of the people living around the peatlands. Where to develop a paludiculture that will be applied by the community must consider the economic value and still maintain the ecological function of peatlands. So that the selection of the types of paludiculture is carried out by considering the benefits obtained, the sago plant is a type of food plant that is developed by means of paludiculture in Riau Province.

Table 3. Types of flora that grow naturally in swamp and peat lands, grouped based on benefits

No	Benefit	Type

1	Food producers (including fruit, sources of carbohydrates, protein, spices and fats/oils)	Sago (Metroxylon spp.), asam kandis (Garcinia xanthochymus), kerantungan (Durio oxleyanus), pepaken (Durio kutejensis) , kasturi mango (Mangifera casturi), kueni mango (Mangifera odorata), rambutan (Nephelium spp.), nipah (Nypa fruticans), elakai (Stenochlaena palustris), tengkawang (Shorea stenoptera, S. macrophylla)
2	Fiber producer (as a substitute for pulp and paper raw materials)	Geronggang (Cratoxylum arborescens), Terentang (Campnosperma auriculatum), gelam (Melaleuca cajuputi)
3	Bio-energy sources (wood pellets, briquettes, bio-ethanol)	Gelam (Malaleuca cajuputi), sago (Metroxylon sago), nipah (Nypa fruticans)
4	Rubber/latex producer	Jelutung (Dyera polyphylla), nyatoh (Palaquium leiocarpum), sundi (Payena spp., Madhuca spp.)
5	Source of medicines	Akar kuning (Coscinium fenestratum), pulai (Alstonia pneumatophora)
6	Other associated forest products	Gaharu (Aquilaria sp.), gemor (Alseodaphne sp.), purun tikus (Elaeocharis dulcis), irit rattan (Calamus trachycoleus)
7	Timber of conservation value	Ramin (Gonystylus bancanus), red meranti (Shorea macrantha, Shorea balangeran)

Source: (Hesti dan Adi, 2016)

3.2.1. Sago Paludiculture in Riau

Sago is a type of the Arecaceae family with a fairly wide natural distribution, starting from Sumatra (Riau and Jambi), West Kalimantan, Java, Sulawesi, Maluku and Papua (Rostiwati et al., 2008). It grows naturally in the lowlands to an altitude of 300 m above sea level (asl), in swampy areas along the coast and along stagnant rivers. Sago grows on mineral soils, tidal swamp areas, and peat soils with shallow to medium depths. Although tolerant of salt water up to a certain level of salinity, sago palms grow better in fresh water (Schuiling & Flach, 1985).

Sago cultivation is carried out generatively (seeds) and vegetatively (shoots). The age of sago trees from germinating to fruiting varies from 8-17 years. Sago trees only flower and bear fruit once in their lifetime. After the fruit ripens on the tree and is harvested or falls from the tree, the sago tree will die. During this process, side shoots will grow as vegetative propagation. Sago grows in clumps, with 1-3 mature trees (Schuiling & Flach, 1985).

Figure 13. Sago Cultivation in Sungai Tohor Village

In intensive cultivation, sago seedlings are planted at a spacing of 7 x 7 m, in which the canopy will close in the fifth year and side shoots will only maintain one shoot per tree. Harvesting is done every 18 months from one stem per clump so that sago stem production is 136 stems/ha/year. (Schuiling and Flach, 1985).

The sago area in Riau Province in 2015 reached 82,713 Ha, consisting of smallholder plantations covering 62,513 Ha (75.57%) and large private plantations covering 20,200 Ha (24.43%). The distribution of sago areas in Riau Province is in 5 districts, one of which is Meranti Islands Regency which has the widest area of sago plants, namely 41,130 Ha and is used as a national food security development area (Disbun Riau 2016).

Sago as the largest starch producer promises starch production throughout the year. Each stalk can produce around 200 kg of wet sago flour per year, or 25 to 30 tons per hectare (Dishutbun Kepulauan Meranti 2014). Productivity (starch) of sago growing on shallow peat is higher than sago on deep peat. In addition, sago trees that grow on shallow peat mature faster than those that grow on deep peat (Karyanto, 2015).

Potential of Sago Cultivation in Sungai Tohor, Riau Province

The area of the Sago Plant belonging to the people of Sungai Tohor Village is around 2,650 Ha. Sago is a native plant of Sungai Tohor Village since 1904 when the Sungai Tohor Village was formed. Then in the mid-1970s sago began to be cultivated en masse. At first, people planted sago only to meet their food needs. However, along with the increasing economic value of Sago, the community began to develop sago into various kinds of processed foods that are typical of Sungai Tohor Village such as Sago Noodles, Sago Fat, Sago Eggs, and Sago Crackers.

347 households in Sungai Tohor are capable of producing wet sago reaching 600-700 tonnes/1.4 billion rupiah/month. Wet Sago production is processed by 14 Sago Refinery, with a price per kilogram of wet sago Rp 1,800.-. Sago plants that are harvested must be over 10 years old, under 10 years old they are not harvested because the quality is still low. In general, Sago Sungai Tohor is sent to Batu Pahat, Malaysia.

Sago Cultivation by Farmers in Sungai Tohor Village

Sago farmers in the Tohor River generally plant one hectare of sago seedling land by planting 150 seeds with a spacing of 8x8 meters. After the sago is planted there is no treatment for the application of fertilizer to the sago plants. Treatment carried out by Sungai Tohor sago farmers is only cutting the grass around the sago plants from the beginning of planting until they are 6 years old, cutting the grass is done every 6 months. The most common type of sago cultivated in the Sungai Tohor Village is thorn sago.

Figure 14. Sago Cultivation on Peatlands in Sungai Tohor, Groundwater Level 0 cm (Paludiculture)

The sago planted by the community, at the age of 6 months there are up to 5 sago tillers around the planted sago, sago is harvested after the sago plants are 10 years old. 1 hectare of sago plants that can be harvested as many as 70 stems, harvesting is done once a year. In 1 day farmers are able to harvest as many as 7 sago stems, then 1 sago plant is cut into 10 tuals, 1 tual sago 42 inches (105 cm) long. So that in a day farmers are able to get 70 Tual Sago. To harvest 70 sago stalks it takes 10 working days which are carried out by 2 sago harvesters.

Figure 15. The harvested Sago which has become *Tual* (105 cm), is transported away from the sago garden using the canal route

The Economic Value of Sago Plants for the Sungai Tohor Community

Every year the sago farmers get as much as 700 *Tual* of Sago, then the *Tual* Sago is sold to factories in Sungai Tohor at Rp 35,000, for 1 *Tual* Sago. Therefore the total income of sago farmers in a year is Rp 24,500,000, - or Rp 2,041,667 per month. This income is calculated from the lowest price fluctuation, the pertual price range for sago ranges from RP 35,000 to RP 45,000.

The total income is calculated if the sago farmers harvest the sago themselves, if it is done by harvesters, the farmer's income is reduced by RP 10,000/Tual. So that the total annual income is Rp 17,500,000, - or Rp 1.458.333,- per month.

The harvest of 700 Tual is obtained if the conditions of the farmers' sago land are wet, so that currently the people of Sungai Tohor maintain the condition of their sago fields in wet conditions through the construction of canal blocks around the sago gardens.

Sungai Tohor Village has 14 Sago Factory, 1 Day Sago Factory can produce 100 Tual Sago to 3,000 Kg of Wet Sago, 1 Tual Sago on average produces 30 Kg of Wet Sago. The number of Sago Factory Workers in general is 3 people to produce Wet Sago every day.

Figure 16. Wet Sago produced at the Sungai Tohor Community Sago Factory

To produce sago, the sago factory obtains raw materials from sago farmers, at a buying price of RP 35,000 for 1 *tual* sago. 1 *tual* sago produces 30 kg of wet sago with a selling price of RP 1,800 for 1 kg. The sago factory produces wet sago up to one holding tank full, generally reaching 30 tons. The wet sago is then exported to Batu Pahat Malaysia. Based on survey results in 2019, the total selling value of sago production in Sungai Tohor reaches up to RP 1.4 billion.

Figure 17. Wet Sago Rafting Process to be Exported to Malaysia

Based on the results of an interview with Cik Manan, a resident of Sungai Tohor, the following is a comparison of the yield of processed sago products in 1 hectare which produces 70 stalks of sago to 700 *tual* sago.

Product Type	Wet Sago	Dry Sago	Sago Noodles	Fat Sago	Egg Sago	Liquid Sugar
Price/kg	1.800	5.000	6.000	6.000	10.000	20.000
Hasil (Kg)	21.000	14.700	14.000	16.800	17.000	17.000
Total Sales	37.800.000	73.500.000	84.000.000	100.800.000	170.000.000	340.000.000

Table 4. Comparison of the Economic Value of Sharing Processed Sago Production (Numbers in Rupiah)

Bibliography

Agus, F. dan I. G. M. Subiksa. 2008. Lahan Gambut: Potensi untuk Pertanian Dan Aspek Lingkungan. Balai Penelitian Tanah Dan World Agroforestry Centre (ICRAF). Bogor. Indonesia. 36 hal.

Andriesse, J. P. 1997. The reclamation of peatswamps and peat in Indonesia. Widiatmaka (ed.). Center for Wetland Studies, Faculty of Agriculture, Bogor Agriculture University.

Brady, M.A. 1997. Organic matter dynamic of coastal peat deposit in Sumatera, Indonesia. Phd thesis. The University of British dalam Mudiyarso dkk, 2004. Petunjuk Lapangan: Pendugaan cadangan Karbon pada lahan gambut. Proyek Climate Change, Forests and Peatlands in Indonesia. Wetlands International – Indonesia Programme dan Wildlife Habitat Canada. Bogor, Indonesia.

Darmawijaya, M. I. 1990. Klasifikasi Tanah, dasar teori bagi peneliti tanah dan pelaksana pertanian di Indonesia. Gadjah Mada University Press, Yogyakarta, 441p.

FAO. 1997. FAO Technical Guidelines for Responsible Fisheries. Roma, Italy.

Hardjowigeno, S. 2003. Ilmu Tanah. IPB.Bogor

Hooijer A, M Silvius, H Wosten and S Page. 2006. Peat-CO2. Assessment of CO2 Emission from Drained Peatlands in SE Asia. Delft Hydraulies Report Q3943.

Joosten H. 2009. Peatland status and drainage related emissions in all countries of the world. The Global Peatland CO2 Picture. Wetlands International.

Joosten, H., Dommain, R., Haberl, A., Peters, J., Silvius, M., & Wichtmann, W. (2012). Implementation. In: Joosten, H., Tapio-Bistrom, M.L., & Tol, S. (eds). Peatlands – guidance for climate change mitigation through conservation and sustainable use. 2nd ed. pp:9-21. Rome: FAO and Wetlands International

Karyanto, O. (2015). Smallholder sago farming on largerly undrained peatland: Meranti Island District, Riau Province, Indonesia. Rome: FAO. [Fact Sheet].

Leiwakabessy, F.M., dan M. Wahyudin. 1979. Ketebalan gambut dan produksi padi. Makalah A3. Third Symp. on Tidal Swamp Land Development Aspects, Palembang February 5-10, 1979.

Nugroho, Y. 2018. Budidaya Sengon Laut (Paraserianthes Falcataria (L) Nielson di Lahan Rawa. Laporan Penelitian. Banjarbaru Kalimantan Selatan.

Parish, F., Sirin, A., Charman, D., Joosten, H., Minayeva, T., and Silvius, M. (Eds.). 2007. Global Environment Centre, Kuala Lumpur and Wet Land International, Wageningen.

Putra, D. W. T. and Putra, J. J. (2018). Perancangan sistem informasi pencarian lowongan pekerjaan. Jurnal TeknoIf, 6(1).

Radjagukguk, B. 1997. Peat Resource of Indonesia: Its Extent, Characteristics anda Development Possibilities. Paper Presented at the Third Seminar on the Geening with Peat Held at Waseda University. Tokyo

Rieley, J.O., R.A.J. Wüst, J. Jauhiainen, S.E. Page, H. Wösten, A. Hooijer, F. Siegert, S.H. Limin, H. Vasander and M. Stahlhut. 2008. Tropical peat lands: carbon stores, carbon gas emissions and contribution to climate change processes. pp. 148-182.In M. Strack (Ed.) Peat Lands and Climate Change. International Peat Society, Vapaudenkatu 12, 40100 Jyväskylä, Finland.

Rostiwati, T., Lisnawati, Y., Bustomi, S., Leksono, B., Wahyono, D., … & Haska, N. (2008). Sagu (Metroxylon spp.): Sebagai Sumber Energi Bioetanol potensial. Badan Penelitian dan Pengembangan Kehutanan. Jakarta.

Suhardjo, H. and P.M. Driessen. 1977. Reclamation and use of Indonesian Lowlaand peats and their effects on soil conditions. p419-424. Proc. Third Asean Soil Conf., Kuala Lumpur, Malaysia.

Suhardjo, H., dan IPG Widjaja-Adhi. 1976. Chemical characteristics of the upper 30 cms of peat from Riau. p74-92. In Soil Research Institute.

Schuiling, D.L., & Flach, M. (1985). Guidelines for the cultivation of sago palm. Departemen of Tropical Crop Science. The Netherlands: Agricultural University Wageningen. 34 p.

Wahyunto, S. Ritung, K. Nugroho, Y. Sulaiman, Hikmatullah, C. Tafakresnanto, Suparto, dan Sukarman. 2013a. Peta Arahan lahan Gambut Terdegradasi di Pulau Sumatera Skala 1:250.000. Badan Litbang Pertanian, Kementerian Pertanian. Bogor.