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Alternative waste management: composting and biochar conversion for metal remediation

Eny Dyah Yuniwati[1*], Dwi Rizki Novitasari[2], And Ali Kamran[3]

[1] Universitas Wisnuwardhana Malang, Indonesia
[2] Yayasan Assyfa Learning Centre (YALC) Pasuruan, Indonesia
[3] Medical diagnostic Sonographer, Gunnedah Diagnostic Imaging Alpenglow Pty, Australia
[*] Corresponding author: nieyuniwati@gmail.com

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ABSTRACT Palm oil agribusiness drives agricultural economic growth the greatest. Developing palm oil agriculture can solve financial issues. Despite low productivity, swamp areas can be used to grow oil palm plants to increase palm oil production. Due to low plant cultivation technology use from sowing to harvest and soil amelioration, plant productivity needs to be maximised. This study will qualitatively synthesise all research data to investigate biochar and organic materials as soil fertility and productivity supplements in swamp terrain. This study summarises primary research using a systematic review. Peer-reviewed PDF-formatted scientific literature. Journal articles in Indonesian and English on Instagram's usefulness as a digital socialisation medium, especially in government institutions, were chosen. The Harzing Publish or Perish software searched Google, ScienceDirect, and Emerald for relevant papers from the past five years. This literature review was synthesised using a narrative method to group similar retrieved data by outcomes measured to meet objectives. According to the results, palm oil biomass waste as compost or biochar is a realistic way to manage organic waste. Biochar can sink atmospheric carbon as a soil amendment by converting biomass into aromatic carbon, which degrades less. This article discusses how waste management increases biological decomposition.

1. INTRODUCTION

Palm oil agribusiness is the subsector that contributes the most to the agricultural sector's positive economic development. Hence, establishing a palm oil agribusiness represents a potential resolution to financial challenges. This method is regarded as more effective when cultivating oil palm on swamp land as part of developing an oil palm agribusiness (Dahliani & Maharani, 2018; Mujtaba, 2020; Setyawan, 2022). The potential of utilising wetland land for oil palm cultivation is perceived as a means to increase palm oil production even though this land's productivity still needs to improve. Swamp land is defined as an area that experiences year-round saturation with water, resulting from factors such as precipitation, river overflows, or the impact of marine tides (Hariyadi, 2020; Oladele, 2020; Zemp, 2019). The existence of water is primarily attributable to flat to concave physiographic forms that impede rapid drainage, resulting in stagnant water and reductive conditions (Chaivatamaset, 2011; Dahliani & Elban, 2019; Santika, 2019). Consequently, the atmosphere transitions from a reductive to an oxidative state, while the soil becomes acidified in preparation for converting wetlands into cultivated biomass.

This attempt demands hard work, according to the facts. This effort has several challenges. Farmers struggle to manage oil palm plantations because they lack knowledge of cultivation techniques, plant maintenance, and the ideal number of production facilities (Chandrasekaran & Bahkali, 2013; Jekayinfa, 2013; Santika, 2021). Coconut plants need a suitable atmosphere to thrive and produce. Environmental elements include sunlight, temperature, rain, humidity, soil, and wind speed. Climate also affects coconut plant growth (Bentivoglio, 2018; Dahliani et al., 2022; Ibrahim, 2020). Oil palm production in the marsh area is hindered by unstable ground carrying capacity, permeability, poor organic matter and alkalinity, and acidic soil pH of 3.5 to 4.0. Due to hazardous ingredients, iron and sulfate-reducing bacteria reduce SO42- and Fe (III) oxide in flooded environments. Iron and sulfate make pyrite (Dahliani & Saputra, 2018; Liew, 2018; Mahmud, 2019). Oil palm plantations in swamp terrain have a complicated and dynamic agroecology. System dynamics result from vegetation, nutrient cycles, and hydrological interactions (M. Sanyang, 2015; M. et al., 2016; Sari & Malik, 2023). Due to limited plant cultivation technology, from sowing to harvest and soil improvement, most plant productivity needs to be maximised.

Moreover, the above factors suggest that oil palm plant productivity, especially in marshy environments, depends on nutritional balance. Fertilisation must include soil nutrient conditions and plant needs for optimal and sustainable yield. De Menezes (2000) said the outermost layer should comprise at least 2% organic matter (C-total) for optimal plant growth. Biochar can improve marsh soil fertility. Biochar reduces soil acidity (pH) and optimises inorganic fertiliser use, increasing agricultural yield. Oil palm plants can be fed agro-industrial waste compost, reducing their need for chemical fertilisers (Araya et al., 2021; Nata, 2021; Palmas, 2021). Organic components improve granulation and aggregate stability by decreasing clay's fluidity, cohesion, and stickiness through the humic fraction.

Fertilisation, a combination of coal organic compounds, can significantly boost the productivity of oil palm plants. Combining biochar with organic materials can improve the soil's chemical properties, and its Cation Exchange Capacity (CEC) can be increased, resulting in a mutually beneficial consequence (Hu, 2020; M. Huang, 2019; Liang, 2021). As a result, this will reduce the chances of nutrient leakage, especially for potassium and N-NH4. —Frequent fertiliser applications heighten the soil's vulnerability to rainfall. Using palm oil shells as a soil amendment shows excellent potential for expanding plantations. The utilisation of palm oil shell biochar as a soil amendment is attributed to its high macronutrient content and remarkable water retention capacity (Dissanayake, 2020; B. C. Huang, 2018; Premarathna, 2019). Palm oil waste, such as palm oil shells and dry decanted sludge (DDS), can be utilised as valuable resources for producing biochar and organic compounds. Integrating biochar with organic resources will have a positive and mutually reinforcing effect on improving soil chemical properties and increasing oil palm productivity. It will also help capture carbon in land-use systems as part of sustainable oil palm production.

By synthesising all qualitative research findings regarding the potential of biochar and organic materials as ameliorants to increase soil fertility and productivity in swamplands, this article endeavours to achieve this objective. The studies above were carried out by (Wang, 2019) and (Hao, 2013). Recent studies have shown that applying biochar to immobilise metals effectively mitigates soil contamination in wetland areas. Implementing Rice Husk Biochar in conjunction with agricultural waste decomposition into preexisting marshland can potentially increase soil pH, reduce methane (CH4) emissions, enhance grain productivity by up to 27.6%, and mitigate the presence of the detrimental element Fe (Budai, 2014; Liu, 2014). As a soil amendment, biochar can function as an atmospheric carbon reservoir by converting biodegradable carbon (biomass) into aromatic carbon, a more durable carbon form (Azhar et al., 2023; Febrinda et al., 2023; Feng, 2020; Sugiono et al., 2023).

The present study differentiates itself from previous investigations by utilising a systematic review approach to combine primary research results between 2018 and 2023. This research uses biochar and organic materials derived from oil palm biomass as amendments to improve soil fertility. The discussions revolve around agriculture's progress and oil palm biomass production. This is achieved by illustrating Indonesia's growth in palm oil areas from 2018 to 2023. It is worth noting that previous studies only focused on the period up to 2020. Afterwards, the discussion moved on to using palm biomass as biochar and compost material for improvement and explaining the early decomposition process. These compounds, such as chlorophyll found in plants and epidermal tissue found in skin, undergo fast decomposition. This research aims to examine the effects of chelated aluminium-based compounds on enhancing soil fertility in swamplands. More precisely, it investigates the impact of oxidised pyrite on water acidity, leading to a significant decrease in pH levels to as low as three or even two. Consequently, this process may produce iron (Fe) and aluminium (Al) solubility in the water. Moreover, enhance. The soil is enriched with iron and aluminium ions due to pyrite oxidation, acting like a magnet that quickly attracts and binds any nearby metal it detects. The iron and aluminium ions existing in the soil will form complexes with the phosphate ions (PO4) that are already there, causing them to be attracted and bound together. Plant roots in the ground do not absorb it. Therefore, this study is of utmost importance and will be reviewed via the conclusion of previous investigations.

2. METHOD

The study technique used was a thorough literature evaluation, as described by (Yuniwati, Darmayanti, et al., 2023). The ongoing inquiry employs systematic methodologies to carefully choose, assess, and analyse certain research discoveries from pre-existing scientific literature. The study results that have been selected are evaluated and examined, and judgments are drawn about their importance to the targeted research goals. Subsequent steps are executed methodically, as previously established. The data used in this study falls under the secondary data classification since it was acquired indirectly from prior investigations. This study uses a systematic review methodology to integrate primary research findings from 2018 to 2023. The primary objective of this study is to investigate the efficacy of biochar and organic compounds obtained from oil palm biomass as soil amendments for enhancing soil fertility. The research presents a series of steps in the Systematic Literature Review Media (SLRM), as shown in Figure 1 (Ahmed et al., 2021).

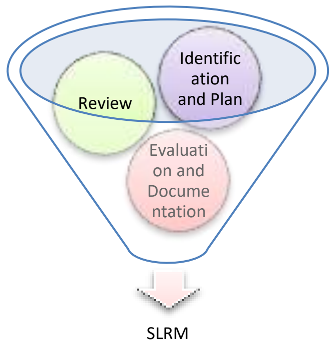

Figure 1. depicts the initial step utilised

Figure 1 illustrates the early processes used, which include identification. Identification involves developing inquiries on the function of the ameliorant agent. The planning process is the second phase. The planning process entails identifying issues about using biochar, organic materials, oil palm biomass, soil fertility, and soil amendment materials. It involves the formulation of research objectives and the subsequent selection of suitable approaches and strategies. Gather relevant literature about the subject of the review. The third component pertains to executing a thorough and systematic evaluation or appraisal. This process involves the selection of research papers that are relevant to the issue under discussion. Next, do a qualitative analysis and synthesis. This evaluation rigorously assesses scientific articles or databases pertinent to the study topic and then categorises them according to the research framework. The fifth aspect is documentation. The fourth aspect pertains to concerns about documentation. In the third and fourth stages, specific literature is gathered and elucidated. The acquired findings serve as the foundation for addressing the indicated issues. After completing stages one to five, proceed to prepare the paper.

After devising a procedure, researchers performed an extensive literature search utilising the Google Scholar, Garuda, and Willey WOS databases. A qualitative research methodology was used, explicitly using the review technique (Putra et al., 2023). This study examines scientific publications in international and national journals from 2018 to 2023 (Hudha et al., 2023). Utilising Harzing's Publish or Perish service enhances the availability of research publications, therefore enhancing the efficiency of performing literature searches that will subsequently be transformed into an article.

3. RESULT AND DISCUSSION

Swampy soil restrictions are best addressed with organic soil additions like biochar. Oil palm fruit bunches outnumber palm shells and other palm oil waste on oil palm plantations. Landfilling and factory burning of large amounts of oil palm empty fruit bunch biomass would harm the environment. Alternative waste management methods like composting and biochar production boost marsh soil fertility and productivity. It may also clean up metal-polluted areas.

A new research found that biochar immobilises metals in wetlands, reducing soil pollution. Supplying rice husk Biochar made from agricultural waste compost may improve soil pH, decrease Fe levels, reduce methane (CH4) emissions, and increase grain yield by 28% in the marsh (Hariati et al., 2017; Yuniwati, 2005; Yuniwati, Prasetya, et al., 2023). Biochar may store atmospheric carbon by converting biomass into aromatic carbon when applied as a soil addition. The combination of earlier research revealed six relevant texts for qualitative analysis. This study examined how biochar and organic materials may improve marsh area soil fertility and production (Fitriana et al., 2020, 2021; Muddarisna et al., 2021; Muddarisna, Yuniwati, Masruroh, & Oktaviansyah, 2019; Nurul et al., 2021; Yuniwati, Utomo, et al., 2020). Figure 2 displays the analysis results.

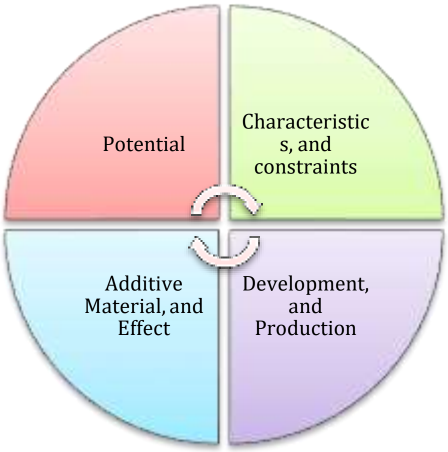

Figure 2. Displays the analysis results

Figure 2 displays the outcomes of the conducted analysis, which provides five conversation components. The five components of the conversation are as follows:

3.1. Ppotential of "tidal" swamp land in Indonesia for oil palm cultivation

Oil palm growth is promising in Indonesian tidal swamps. Marginal Indonesian tidal wetlands provide oil palm production potential. Maximum agricultural productivity requires overcoming several challenges, such as poor drainage, high salinity, and pyrite. Tidal marshes are coastal or riverine wetlands that are periodically flooded by tides. Variable with tides. Tidal marshlands were first used for agriculture in the early 1800s. Due to research projects including P4S, SWAMP I, II, ISDP, and SUP, agricultural land was expanded. Land clearing programmes like PLG and PLG Revitalization have also encouraged agricultural growth in littoral wetland areas. Rising sea levels might flood irrigation canals that service coastal agricultural districts in rivers near estuaries. Thus, tidal rice fields get water even without precipitation. Indonesia has a vast littoral area.

Estimate that wetland land will cover 20.11 million hectares, or 33.4 million hectares, in 2023 (Budi et al., 2016; Muddarisna, Yuniwati, Masruroh, & Aulia, 2019; Yuniwati, Darmawan, et al., 2020). Swamp areas—lowland swamps and tidal wetlands—have great potential as agricultural land. The bulk of Indonesia is swampy. Indonesia has 33.4 million hectares of wetland, 20.1 million of which are tidal swamps (Asikin et al., 2012; Faudin et al., 2016; M. S. Koesrini & Thamrin, 2018). In South Kalimantan, 67% of the 1.14 million hectares of marshland might be arable (Antarlina, 2007; Karolinoerita, 2021; Subagyo, 2006).

A specialised study is needed to determine the best tidal marsh areas for oil palm growth. Tidal marsh terrain is ideal for oil palm development because it provides consistent water, reducing drought risk. The flat topography of the tidal marsh will also make oil palm farming easier. Java's oil palm agriculture may be improved. Certain soil types are unsuitable for oil palm growth (Muddarisna et al., 2020; Muddarisna, Yuniwati, Masruroh, & Aulia, 2019; Yuniwati, Darmawan, et al., 2020). Oil palm farming is best around 24–28 degrees Celsius and 1–500 metres above sea level. For optimum growth, 80–90% relative humidity is desirable. Peatlands have poor fertility because of their low nutrient content and varied organic acids, some of which are phytotoxic (Ilham, 2020; Tjahjono et al., 2020; Yuniwati & Afdah, 2021).

These chemicals significantly affect peat soil's nutrient retention. Wetlands and floodplains may have weathered soil from organic matter breakdown. This soil is permeable owing to its high water content. Topography and land area determine whether oil palm may be grown on coastal terrain. Stagnation from blocked drainage is the main issue. A 50–75 cm dry stratum, preferably 100 cm, is needed for optimum root growth (Cholily et al., 2022; Muddarisna et al., 2021; Nurul et al., 2021). A drop in groundwater levels might cause caustic sulphate soils to oxidise pyrite minerals, especially in the proximal layer. Pyrite mineral depth measurements are needed to reduce water levels and assess tidal wetland suitability for oil palm root growth. Oil Palm Businesses Oil palm agriculture on littoral land would face land administration issues, agricultural methods, and infrastructure development investments due to soil characteristics (Martunis et al., 2023; Pratiwi et al., 2023; R. Saleh et al., 2021). Thus, developing tidal marsh property requires adequate technology, notably in land and water management, careful design, efficient use, and effective management. These programmes promise to turn tidal marshes into environmentally viable croplands (Ardianto et al., 2020; K. Koesrini & Anwar, 2017; Prayudi, 1995).

3.2. Characteristics and constraints of "tidal" swamp land management

The flat terrain makes tidal marsh areas prone to flooding. Widjaja-Adhi et al. (1992) categorised tidal swamp terrain into brackish/saline and freshwater zones based on water tidal range. To use these two zones, the land aspect (land typology) must be linked to the water aspect (overflow type), which has more unique features. The brackish tidal zone has a land type. Saline has a high Na exchange rate, more than eight me/100g soil, and is near the seashore. This area is mainly utilised for rice growing. Rice and coconut are often grown together in tabukan surjan or tukungan. The brackish/saline water zone has less land type than the freshwater tidal zone.

Typological classification of freshwater zone land by sulfidic material depth, pyrite oxidation, and peat thickness. This led to eight land typologies: actual acid sulphate land (SMA), potential SMP, SMPG, P, GDK, GSD, GDL, and GSDL.

Besides land typology, water overflow type affects agricultural appropriateness (Dias, 2019; Moerman, 2023; Zakharin, 2021). Figure 3 divides tidal swamp area into four types by overflow type.

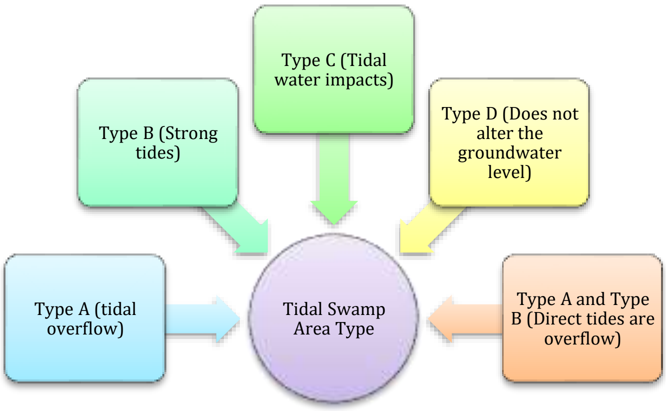

Figure 3. Tidal Swamp Area Type

Figure 3 shows that Type A tidal overflow, the initial tidal swamp region, may flood with high and low tides. Second, Type B overflow may only occur during strong tides and cannot enter rice fields at low tides. The third is Type C overflow, which is when tidal water impacts groundwater levels less than 50 cm from the surface but does not flood. Fourth is Type D, where tidal water does not alter the groundwater level but does affect it at depths more than 50 cm. Last, direct tides are overflow kinds A and B, whereas indirect tides are types C and D.

Tidal terrain has shallow groundwater levels and poor drainage, ranging from blocked to inundated. Tidal land is usually part of marine and peat physiography. Water is available year-round, reducing water shortages. Poor drainage might hinder drainage and cause frequent or chronic floods. Obstructed drainage conditions decrease root growth owing to suppressed respiration and soil chemical changes, reducing plant nutrition availability (Moumtaz, 2019; Verkempinck, 2018; Zhu, 2020). This illness may cause nitrogen and other nutritional deficits in oil palm trees, causing pale discolouration and stunted development. Developing oil palm plantations on tidal marsh terrain requires substantial technical attention and significant land preparation expenditure (Azizah et al., 2023; Hizqiyah et al., 2023; Nurdiani et al., 2021). Pyrite content is another tidal land feature. Pyrite oxidises to sulfuric acid and iron sulphide, making the soil unsuitable for farming. The acidity and H+, Al, Fe3+, and Mn concentrations in oxidised pyrite soil harm plants. This situation usually has poor P and other macronutrient availability (Andriese and Sukardi, 1990 in Suriadikarta, 2005). Indonesia has 2 million hectares of acid sulfate soil in Sumatra, Kalimantan, and Papua (Hakim et al., 1986). Oil palm development in tidal swampland is limited by the pyrite (sulfidic layer) (Anisah, 2021; Kavitha, 2018; Kurnianto et al., 2022). Acid sulphate soil has sulfidic particles and a sulfuric horizon. Acid sulphate soil requires treatment because pyrite mineral oxidation lowers soil pH, disrupting oil palm plant development. In an oxidised state, pyrite turns into iron sulphide, which sharply increases soil acidity, inhibits plant growth and becomes toxic to plants through several mechanisms, including damage to plant cells due to increased H+ ions, increased solubility of toxic Fe, Al, and Mn, decreasing exchangeable cation concentrations like K, decreasing P availability, inhibiting root growth and water uptake, and abnormalities in biotic fact (Nurkanti et al., 2020; Wulandari et al., 2023; Yustiani et al., 2021).

3.3. Development of agriculture and oil palm biomass production

Palm oil exports and production have climbed in Indonesia for 22 years. Indonesia and Malaysia produce 87% of palm oil, according to USDA (2007) and Yacob (2008) (Hairani & Raihana, 2017; Mamat & Noor, 2018; Pribadi et al., 2021; Silva, 2022; SUBAGIO & INDRAYATI, 2015; Umar & Alihamsyah, 2014; Widjaja-Adhi, 1986). Oil palm plants fuel the palm oil industry. Oil palm plants and crude palm oil output increased 10.55–16.47 per cent annually from 2015–2022. Waste increased when oil palm farms extended 14.99 million hectares till 2023. The following data on production growth, domestic consumption and palm oil exports can be seen in Figure 4.

	2021 (juta ton)	2022 (juta ton)	Growth (%)
Produksi (CPO +PKO)	15.25	16.47	8.00
Konsumsi Minyak Sawit Domestik	6.07	6.13	0.99
Industri Pangan	3.18	2.52	- 20.75
Industri Oleokimia	0.68	0.72	5.88
Industri Biodiesel	2.22	2.88	29.73
Stok Akhir	3.27	6.10	86.54
Ekspor			
Nilai (USD Miliar)	10.47	12.56	19.97
Volume (juta ton)	10.90	8.88	-18.55
Crude	1.16	0.22	-80.78
Refined PO	8.38	7.35	-12.30
Product Palm oil based	1.35	1.30	- 3.83

Figure 4. Source: GAPKI; BPS; data processed by PASPI, 2022

According to ESCAP (1997), Malaysia's waste is 54.5% palm oil, 16.77 million tonnes. Forest product waste is lowest at 2.2% (0.676 million) (Alwi, 2014; Kurnain & Irfansyah, 2015; Mayasari, 2019; Simatupang & Susanti, 2017). Palm oil waste may be composted or burned to improve soil and plant nutrition. We call flammable organic materials in soil and water biomass, primarily plants and animals. From agriculture and plant processing, biomass comprises straws, husks, cobs, stems, leaves, and shells. (Ar-Riza Rumanti, 2014) define biomass as biodegradable organic matter containing carbon, hydrogen, oxygen, and nitrogen. Tree age and planting density influence oil palm biomass. Oil palm trees produce biomass from fruit, leaves, stems, and roots. Leaf midrib supplies 78% and declines with age, whereas stem biomass increases from 11% to 56%. Root biomass averages 16%. Hafiyyan, (2017) found that 1.5-year-old oil palm plants with 148 trees/ha produce 10.4 t/ha of biomass, rising to 90 t/ha.

The most frequent year-round waste is empty oil palm bunches and fronds containing cellulose, hemicellulose, and lignin. Uneven brown empty palm oil bunches weigh 3.5 kg and are 130 mm thick. Depending on fresh palm bunches, they are 170-300 mm long and 250-350 mm broad (Hidayat, 2000; Noor & Nazemi, 2021; William, 2007). (Mukhlis & Prayudi, 2001) state that oil palm fronds may be 9 m long, 7 kg, and 15-20 cm wide. Recycling soil organic waste reduces intensive agriculture environmental risks (Ordonez et al., 2006). Instead of organic fertiliser, 23% of palm oil waste is empty bunches. Open oil palm fruit bunch compost improves plant growth, chemistry, and biology. One of the palm oil industry's solid wastes, palm oil shells, are biomass from green leaf grains' photosynthesis, which converts carbon dioxide and water into carbon, hydrogen, and oxygen. Chemistry can create palm kernel shell charcoal from solid palm oil shell biomass. (M. Saleh, 2019) computed solid waste of 3.0-3.6 tons/hour and 2.1-2.7 tonnes from a palm oil manufacturing method that generates 30 tonnes of fresh fruit bunches per hour. Palm shells hourly. Palm fruit fibre averages 3.3 tons/hour, and palm oil shells 2.4 tons/hour. The majority of palm fruit fibre is boiler fuel.

Palm oil shell boiler fuel burns 1.5 tonnes/hour, and palm fruit fibre 0.9 tonnes/hour. The 24-hour palm oil manufacturing method yields 21.6 tons/hour of shells for different applications. Palm oil industry waste might create valuable, eco-friendly biomass. Composting industrial waste improves soil structure and nutrients (Boer, 2008; Dewi et al., 2020; Rahmadani & Rosa, 2021). Composting may decrease mixture volume by 40–50%, kill pathogens with metabolic heat in the thermophilic phase, break down vast quantities of harmful organic pollutants, and produce soil amendment or fertiliser (Riset & Indonesia, 2023; Septinar & Putri, 2018; Sobatnu et al., 2016). High-lignin organic compounds are ideal biochar sources because they decompose slowly. Ash has more lignin. It binds water and has a weaker cellulose bond than hemicellulose. Gasification, quick pyrolysis, and low-resource thermochemical conversion are suitable for agriculture. Environmental, genetic, and plant culture practices affect oil palm yield (Amara et al., 2020; Asikin et al., 2021; Irwandi, 2015). Rain, rainy days, soil, topography, weeds, pests, and plant populations/ha affect oil palm production. Genetic variables include oil palm seed variety and age. Culture includes fertilisation, water conservation, weeding, pain management, disease prevention, and other upkeep. Palm oil biomass is a renewable raw resource that can be produced. Its economic value will rise as fossil fuel prices rise, and it does not emit CO2 and has low sulphur (Adistya et al., 2023; Mursyidin, 2018; Wahdah & Langai, 2011).

Biochemical, thermochemical, and physicochemical methods convert palm oil waste biomass into bioenergy. The thermochemical process converts palm oil waste biomass into gas, making it suited for synthesis. Humanity needs energy. Indonesia, like other rising nations, needs power to grow. The government must oversee biomass extraction, usage, and sustainability. They are expanding biomass utilisation for energy and chemical food processing. Several methods may generate sustainable energy from agricultural products and plants. Multiple energy conversion methods create bioethanol, biodiesel, and biogas. Better biomass-based renewable energy is required (Annisa, 2016; Noor & Rahman, 2015; Perwira et al., 2023). Energy developer-producer integration requires improvement. Unsafe raw materials may disrupt forest biomass supply. Small farmers and communities need competence. Therefore, agriculture has human resource constraints. We need more educated individuals. Thus, rural processing skills are required. Otherwise, small agricultural tools and machinery are employed. Improve agricultural waste-to-renewable energy conversion. It must control utilisation to prevent sectoral biomass overlap. Regulation across sectors, agencies, ministries, and manufacturers is crucial. Regions, agencies, and religions use and manage their interests under this agreement.

3.4. Utilization of palm biomass as amenity materials such as compost and biochar

Palm shell biochar is chemical-exposed soil. Fertility deterioration reduces land productivity. Indonesia has more crucial land each year. Thus, soil amendments are required to speed its recovery. Biochar has long been used in agriculture to improve soil physical and biological qualities and boost production. Biochar has been shown to benefit soil. Since biochar leaves no residue on or off agricultural land, it promotes sustainable and ecologically friendly agriculture. Biochar is made from hard-to-decompose organic materials burnt incompletely (pyrolysis) or without oxygen at high temperatures. After boiling, biological charcoal will create active carbon with minerals like Ca and Mg and inorganic carbon. The carbonisation technique and organic material origin determine biochar's organic component quality. Soil amendment purpose: Stabilising soil aggregates to avoid erosion and pollution changes hydrophobic and hydrophilic characteristics, boosting soil water-holding and cation exchange capacity (CEC).

Figure 5. Palm biomass production
Source: https://www.bpdp.or.id/biomassa-sawit-sumber-energi-terbarukan

Using biochar: Organic material improves soil qualities when used with mineral soil additions like zeolite. Some soil additives provide nutrients. The levels are modest, and plants may not consume all nutrients in soil additions. Benefits of Biochar: Increases water retention, minimising runoff and nutrient leaching. Biochar enhances soil structure, porosity, and aggregate formation. By enhancing soil's physical qualities, plant roots may access more nutrients and water, simplifying growth. Biochar is commonly utilised to improve soil quality, exceptionally marginal soil, due to its organic and inorganic constituents. Biochar affects soil microbes. Biochar increases plant-beneficial rhizobacteria and fungi. Biochar increases enzyme composition and activity surrounding the roots. Material selection for soil amendment:

Cheap, in situ, and renewable soil amendment materials are still preferred. Environmental impacts must be considered while using mineral-correcting materials. Additionally, availability, quality, and pricing must be believed. Synthetic soil additives are costly and environmentally harmful. Thus, they should be avoided.

Advantages of Palm Shell Biochar: Palm shell biochar includes macronutrients and holds water, making it a soil improver. With excellent water retention, soil moisture is maintained. Maintaining soil moisture allows bacteria to grow. High soil microbe populations provide high organic matter. Biochar from palm kernel shells supports a larger bacterial population than compost, improving soil structure and microbial life. Palm oil shell biochar is a viable soil supplement because Indonesia has enough palm oil shells to develop agricultural land and achieve food sovereignty.

Figure 6. Utilization of palm biomass as amenity materials
Source: https://dinpertanpangan.demakkab.go.id/?p=3031

3.5. The effect of palm waste-based additives on swamp land soil fertility

The effect of palm waste-based additives on swamp land soil fertility is Swamp land is still unsuitable for plantation crops due to high acidity, low fertility, peat thickness, sulphidic materials, quartz sand soil under the peat, and the water management system, which reduces plant productivity. Pyrite oxidation acidifies swampland soil. Sulfuric acid from pyrite compound oxidation causes significant acidification. Under aerobic circumstances, Pyrite, a FeS2 compound, is stable in marshy ground (acid sulphate and peat). Pyrite oxidation occurs when channel drainage exceeds the depth limit of the pyrite layer.

Oxidised pyrite produces Jarosite poison, turning water puddles rusty or reddish yellow or soil outcrops yellowish rusty. Water acidity will rise to pH three or even 2 with oxidised pyrite, increasing Fe and Al solubility. Pyrite's iron changes form and is poisonous to plants when oxidised. The pyrite oxidation also increases soil acidity by releasing hydrogen ions (H). Aluminium ions (Al) in acidic soil are poisonous to plants and are eliminated.

Iron and aluminium ions generated by pyrite oxidation in the soil act like a magnet, continually searching for and binding metal. Saturated iron and aluminium ions attract and secure phosphate ions (PO4) in soil. Plant roots cannot absorb it underground. Even though plants require phosphorus (P) to create blossoms and fruit, the earth will be deficient. Organic resources may lower harmful element solubility in swamp terrain. Composting empty palm oil bunches produces organic material. Wholly decomposed organic material increases soil pH in swamp terrain by releasing OH- and consuming H+, decreasing H+ ion activity, and increasing soil Fe2+. Organic material added to the ground stimulates Fe3+ to Fe2+ reduction, which raises soil pH and Fe2+ concentration. Additionally, organic material is essential because marsh land oxidation adds to the burden. Adverse soil may chelate Fe2+ to lower soil concentration. Focusing on ground Fe2+ concentrations helps plants flourish in marsh areas, which may be hazardous to food crops.

Decomposing organic material has a negative charge, and the carboxyl and phenolic groups provide the negative control for chelation. Chelation response depends on these two functional groups. The carboxyl group dissociates at pH=3, leaving a negative charge. The phenolic group dissociates at pH=9, creating a significant negative demand. The pyrite oxidation process releases hydrogen ions (H), which increase soil acidity. Aluminium ions (Al) in acidic soil are poisonous to plants and are eliminated.

Iron and aluminium ions generated by pyrite oxidation in the soil act like a magnet, continually searching for and binding metal. Saturated iron and aluminium ions attract and secure phosphate ions (PO4) in soil. In the earth, roots cannot absorb it. Even though plants require phosphorus (P) to create blossoms and fruit, the world will be deficient. Organic resources may lower harmful element solubility in swamp terrain. Composting empty palm oil bunches produces organic material. Applying fully decomposed organic material in swamp land raises soil pH by releasing OH- and consuming H+, decreasing H+ ion activity, and increasing Fe2+ concentration. These two functional groups determine the chelation reaction. Tan (2003) said that the amount of carboxyl and phenolic groups represents the overall acidity, the total edge indicates the negative charge of the humic substance, and humic acid chelates metals better than fulvic acid.

Biochar increases water retention in soil, improving its physical qualities. It also increases soil aggregate, structure, and porosity (Lehmann & Joseph, 2010) and plant roots' reach to help plants get water and nutrients fast. Therefore, biochar directly affects plant production. Biochar quality depends on input components, combustion reaction circumstances, and procedure. Biochar often raises soil pH, P, and CEC in swamps. Biochar reduces metal ion activity in soil solution, which relies on quality, improving soil properties and plant productivity, particularly in marshy soil (Annisa et al., 2021). Biochar can adsorb toxic elements in swamp land by forming a surface complex (inner sphere complex) where metal elements react with functional groups (- OH, - SH, and - COOH) on the biochar (Shan, 2020; Xu, 2018; Yuniwati et al., 2016).

It contains carbon and holes that elevate pH since it is ash and works as a liming agent, but it does not contain macro and micro nutrients required by plants. Yuniwati, (2019) say the optimal biochar is determined by its adsorption capacity and CEC, with lower adsorption capacity and greater CEC. Nutrient-enriched biochar increases soil fertility, particularly in swamplands, lowering fertiliser use and environmental effects emissions while improving plant yield. Hawari et al., (2021) found that biochar without nutrients like nitrogen (N) did not boost crop yields.

The atmosphere's CO2 content has risen steadily because more CO2 gas is entering than leaving. Thus, soil carbon storage and amendment are essential. The high carbon concentration of biochar makes it resistant to oxidisation and stores carbon for an extended period. Biochar production is a dynamic carbon sequestration process. Carbon sequestration involves absorbing CO2 gas from the atmosphere and storing it in the ground for an extended period to prevent its concentration from rising. In the environment, biochar absorbs NO3- and NH4+ ions, which are readily lost owing to leaching carbon sequestration, which reduces soil greenhouse gas production, heavy metals and pesticides.

4. CONCLUSION

Indonesia's marginal tidal marsh region provides oil palm growth potential. Inferior drainage, excessive salinity, and probable pyrite concentration must be addressed to maximise plant output. Vegetative observations of 2-year-old oil palm plants in Pitu swamp (80-100 cm pyrite depth) indicate that water management at 20-40 cm yields a larger leaf area (2.93 m2) than 0-20 cm (2.40 m2) and 40-60 cm (2.21 m2) below ground surface. Oil palm productivity in the 1998 planting year in Betung Krawo was greater in locations with deep than shallow pyrites. Assessing site suitability classes before creating gardens, excellent water management, and enhancing soil chemical characteristics may optimise plant growth and production on tidal swamp land. Biochar or compost made from palm oil biomass waste is an efficient way to manage organic waste. Biochar may sink atmospheric carbon as a soil amendment by converting biomass into aromatic carbon, which degrades less. Waste management methods like composting accelerate organic waste's biological and physiochemical breakdown. By boosting pH, organic matter content, soil CEC, and toxic element solubility, biochar and compost as soil additives might increase swamp area plant production.

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