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Environmental Ethics in Agricultural Research Through Vegetation Study of Oil Palm Seedlings

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Abstract. Agriculture is a dominant ecosystem globally in 2023, farmland and pastureland occupied nearly 50 % (about 48 million km2) of habitable terrestrial land. Since the early 2000s, rates of global agricultural expansion have fallen, but agriculture is still expanding rapidly in the tropics. Expansion of tropical agriculture has been driven by a growing human population, increases in per capita consumption rates for agricultural-derived resources, and the high economic value of agriculture in many tropical countries. While tropical agricultural production can increase food security and support human health and livelihoods, conversion of natural tropical habitat to farms and pastures has had severe environmental consequences and changed social dynamics. The research employed a quantitative approach with a case study method. This method was chosen because it provided an opportunity to conduct an in-depth analysis of the application of environmental ethics in agricultural practices and to systematically examine the effects of these ethics on the growth of oil palm seedlings. The application of environmental ethics in agricultural research, particularly in the study of oil palm seedling vegetation, is crucial for achieving sustainability and ecosystem balance. This research demonstrates that sustainable agricultural practices address not only economic outcomes but also social and environmental impacts. In the context of the palm oil industry, the application of ethical principles such as responsibility, intergenerational equity, and community participation is key to addressing issues of deforestation, pollution, and conflict with local communities. The analysis identified challenges in the application of environmental ethics, such as low public awareness and conflicts of interest among stakeholders. However, multi-stakeholder collaboration and enhanced moral education can be a solution to raise awareness and a shared commitment to environmental sustainability

Keywords: Environmental; Agricultural; Vegetation; Oil Palm

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INTRODUCTION

Agriculture is a dominant ecosystem globally (Ramankutty et al., 2018; Song et al., 2018); in 2023, farmland and pastureland occupied nearly 50 % (about 48 million km2) of habitable terrestrial land. Since the early 2000s, rates of global agricultural expansion have fallen, but agriculture is still expanding rapidly in the tropics (Ramankutty et al., 2018; Song et al., 2018). Expansion of tropical agriculture has been driven by a growing human population, increases in per capita consumption rates for agricultural-derived resources, and the high economic value of agriculture in many tropical countries (Curtis et al., 2018; Ramankutty et al., 2018). While tropical agricultural production can increase food security and support human health and livelihoods, conversion of natural tropical habitat to farms and pastures has had severe environmental consequences and changed social dynamics (Drescher et al., 2016; Santika et al., 2020).

In recent years, substantial research activity has aimed to identify strategies to make tropical agriculture more sustainable, i.e., to maintain or increase levels of food production in the long-term while mitigating the ecological and sociocultural impacts of cultivation (Luke et al. 2020). A key first step is identifying how cultivation affects local ecological and sociocultural dynamics. Although this has been done in many tropical contexts, large research gaps remain From a spatial perspective, this is especially true in the African tropics. For example, a recent meta-analysis on the impacts of tropical agriculture on biodiversity found roughly 1.5 and 2.6 times more studies in the American and Asian tropics, than in the African tropics, respectively (Oakley and Bicknell, 2022). Traditional on-the-ground data collection (e.g., field surveys) is key to overcoming this knowledge gap and identifying the impacts of agriculture in poorly studied tropical regions. Yet, such data are often rare, owing to the challenge of collecting high-quality field data in remote or isolated areas and limited resources and availability of long-term funding in these regions.

Oil palm Elaeis guineensis Jacq. is widely reviled for causing large-scale deforestation in the species-rich tropics. With 18.7 million hectares of industrial-scale oil palm plantations in 2017 (Meijaard et al., 2018), it is ranked 3rd in terms of planted area for an oil crop, behind soy and rapeseed (4th if maize is considered an oil crop). Currently oil palm produces about 35% of global vegetable oils on <10% of the total land under oil crops. Given the demand and profitability (Byerlee et al., 2017), expansion will continue. Such expansion, if it involves forest loss, or the replacement of other important natural vegetation types, will harm biodiversity. Overall, direct conversion to industrialscale oil palm development appears associated with <0.5% of global deforestation, but surpasses 50% in specific regions such as Malaysian Borneo (Meijaard et al., 2018). This forest loss is the main direct impact on biodiversity. Furthermore, human-wildlife conflict often increases following the establishment of largescale plantations, with species like orangutans and tigers being displaced when forests are cleared, causing conflict with people, and concurrent harm to animals. Other indirect environmental impacts of oil palm include greenhouse gas emissions related to deforestation and peat decomposition and the additional influences of land-cover change on local climates and hydrology, the use of fire in land clearing and resulting smoke-haze, fertilizer, and pesticide usage and runoff, downstream water quality and freshwater species diversity, spill over effects (e.g., from high densities of rats), invasive species, and modified access for hunters, farmers and others (Dislich et al., 2017; Meijaard et al., 2018).

When compared to similar areas of old growth rain forests, all these impacts from oil palm plantings on the environment and biodiversity at local scales can be summed up as negative. In terms of global outcomes, however, it needs to be assessed to what extent the negative impacts can be reduced or avoided, for example by planting in areas already deforested (something that has long been more common than is widely recognised, (Gaveau et al., 2016), and are potentially offset by, for example, reduced expansion of other oil crops elsewhere. A more complete accounting should consider not just the environmental aspects but the influence on poverty, hunger, and all the factors considered under the 17 UN-Sustainable Development Goals (SDGs) (United Nations, 2017).

Results and Discussion should be written as a series of connecting sentences, however, for manuscript with long discussion should be divided into subtitles. Results should be clear and concise.

Thorough discussion represents the causal effect mainly explains for why and how the results of the research were taken place, and do not only re-express the mentioned results in the form of sentences, not repeat them. Concluding sentence should be given at the end of the discussion.

MATERIALS AND METHODS

The research employed a quantitative approach with a case study method. This method was chosen because it provided an opportunity to conduct an in-depth analysis of the application of environmental ethics in agricultural practices and to systematically examine the effects of these ethics on the growth of oil palm seedlings.

The research was conducted at an oil palm experimental plantation located in Aek Pancur, Tanjung Morawa District, Deli Serdang Regency, North Sumatra. This location was chosen because it has climate, soil, and vegetation characteristics that support oil palm growth. The plantation also implements sustainable agricultural practices relevant to this study.

RESULTS AND DISCUSSION

Overview of Oil Palm Seedling Vegetation

Understory vegetation in oil palm plantations is a crucial component of the plantation ecosystem, playing a role in maintaining soil stability, nutrient cycling, and microclimate balance. This vegetation consists of various types of herbs, grasses, shrubs, and ferns that grow beneath the canopy of the main plant. Its presence is often considered competition for oil palm plantations, but ecologically, understory vegetation functions to maintain soil moisture, suppress the growth of certain weeds, and provide habitat for other organisms. The diversity of understory vegetation is strongly influenced by the age or year of the oil palm plantation because it is related to changes in canopy structure and light intensity reaching the ground surface. In the young plant phase, the canopy is still open, resulting in relatively high light intensity, allowing various types of vegetation to grow well. This results in a higher number of species and a higher level of vegetation diversity compared to older plants. Conversely, in established plants, the canopy becomes denser, reducing light penetration and allowing only shade-tolerant species to survive, resulting in a tendency for vegetation diversity to decrease (Dislich et al., 2017; Meijaard et al., 2018).

Research results show that understory vegetation in young oil palm plantations has a greater number of species than in young and older plantations. Species such as Ageratum conyzoides are dominant in the young phase due to their adaptability to high light conditions and their ability to compete for water and nutrients. In the juvenile phase, dominance shifts to species capable of growing in moderate shade, such as Asystasia gangetica, which has good ground cover capabilities. Meanwhile, in the mature phase, the understory vegetation is dominated by highly shade-tolerant species such as Peperomia pellucida, which thrives in humid conditions and low light intensity. Overall, the level of understory vegetation diversity at various oil palm plant ages is in the moderate category based on the Shannon-Wiener index value. The highest diversity is found in young plants, then decreases slightly in young plants, and is lowest in older plants. This condition indicates that changes in canopy structure and light intensity are the main factors shaping the composition of understory vegetation in oil palm plantations. Thus, the general picture of understory vegetation reflects the ecological dynamics of oil palm plantations that change with the growth of the main crop (Corciolani et al., 2019).

Agricultural Research Practices in Oil Palm Seedling Vegetation Studies

Oil palm seedling vegetation studies are conducted to determine the growth and environmental factors that influence seedling quality during the nursery phase. Research is typically conducted in pre-nursery and main nurseries using controlled experimental designs such as Completely Randomized Designs (CRD) or Randomized Block Designs (RBD). Observed parameters include plant height, leaf number, stem diameter, leaf area, root length, and dry and wet plant weight (Sinaga et al., 2022).

Various studies have shown that nutritional factors, growing media, and water management significantly influence seedling growth. For example, the application of fertilizer and organic ameliorants can increase plant height and stem diameter in oil palm seedlings. Furthermore, the application of growth-promoting rhizobacteria (PGPR) and nanosilica has been shown to increase leaf number, root length, and dry weight of oil palm seedling crowns (Sinaga et al., 2022).

Other research also shows that watering intervals and planting medium types affect photosynthesis and transpiration rates in oil palm seedlings, thus significantly determining seedling quality before planting in the field (Corciolani et al., 2019). Therefore, studies of oil palm seedling vegetation should not only examine plant growth but also environmental factors and nursery management that influence long-term plant productivity.

Policy reforms should focus on three main aspects: land governance, social sustainability, and environmental conservation. First, land governance must be reformed to reduce ownership inequality and accommodate the rights of indigenous communities and smallholder farmers. Regulations related to land permits must be tightened to prevent land grabbing and ensure that plantation expansion does not compromise existing ecosystems. The government needs to implement equitable land redistribution, provide access to capital for smallholders, and establish collective ownership mechanisms or cooperatives that can improve farmer welfare without relying on large corporations (Pambudi, 2025).

Second, social sustainability must be a priority in this industry by improving the protection of workers' rights and ensuring their welfare. This includes ensuring proper company practices, social security, and healthy

and humane working conditions. Transparency in the supply chain must also be strengthened so that smallholders receive fairer prices and are not subordinated to large corporations (Pambudi, 2025).

Third, environmental conservation efforts must be strengthened by adopting regenerative economic principles, namely industrial practices that not only reduce negative impacts but also improve ecosystem conditions. The government should mandate the implementation of agroforestry, a plantation system that integrates oil palm plantations with native trees to reduce deforestation and maintain biodiversity. Furthermore, sustainability certifications such as the RSPO and ISPO must be strengthened, with stricter monitoring mechanisms to ensure companies truly comply with sustainability standards (Pambudi, 2025).

Implications of Environmental Ethics for the Sustainability of Agricultural Research

Permaculture ethics offer scientific solutions for environmental and economic sustainability, helping to alleviate anxiety among organic farmers. Permaculture Ethics: Permaculture is a systems design concept for agriculture that emphasizes ecological and economic balance. It is not only about increasing production but also about gaining agricultural knowledge from the local environment and culture. Permaculture ethics include "Care for the Earth," "Care for People," and "Fair Share."

a. Environmental Sustainability: The application of permaculture ethics in Hanif Garden demonstrates good environmental sustainability, as evidenced by several indicators
b. Soil Fertility: The physical, biological, and chemical properties of the soil indicate that it is fertile. These include good soil texture, granular structure, dark brown color (indicating organic matter), and moderate porosity. The soil pH is neutral (6-6.5), which is ideal for the growth of bacteria and fungi that decompose organic matter. The soil also has a high cation exchange capacity (CEC) due to its fine texture.
c. Zero Waste: Hanif's farm operates on a zero-waste principle, where all waste is recycled into animal feed or agricultural inputs such as compost and organic matter for the soil.

The implications of environmental ethics for the sustainability of agricultural research are crucial because they emphasize the need to maintain ecosystem balance and respect the intrinsic value of nature. In the context of the Cingcowong tradition in the Luragung Landeuh community, environmental ethics demands collective and sustainable management of natural resources, including water and plants, which are considered vital elements for life. This approach emphasizes that sustainability relates not only to economic aspects but also to moral and spiritual aspects, which must be integrated into modern agricultural practices. Furthermore, ecocentric ethics, which places nature as a moral subject, encourages researchers and farmers to adopt environmentally friendly and sustainable methods, avoiding overexploitation that can damage ecosystems and threaten the future sustainability of natural resources (Waniatri et al., 2025).

The implications of environmental ethics for the sustainability of agricultural research are crucial because they emphasize the need to consider the ecological relationships and moral values of environmental elements such as soil, water, and air. By integrating environmental ethics, agricultural research focuses not only on productivity but also on preserving the integrity, stability, and beauty of biotic communities, as well as preventing ecological damage that could threaten the sustainability of agroecosystems. This approach encourages the development of ecologically and morally responsible agricultural systems, thus supporting long-term sustainability and reducing environmental degradation caused by conventional agricultural practices. Furthermore, the incorporation of moral philosophy into agricultural research can help uncover the underlying assumptions of the current system and open up opportunities for more sustainable, innovative solutions (Congreves, 2025).

Application of Environmental Ethics in Research Activities

Key principles include intergenerational equity, ecological responsibility, environmental rights, and an ecocentric approach that views nature as an entity of intrinsic value, not merely an object of exploitation. This integration is necessary in policy planning to balance economic growth with ecosystem preservation, in line with SDGs such as SDG 13 (Climate Change) and SDG 15 (Terrestrial Ecosystems).

Integration in Policy: The journal highlights the integration of environmental ethics into Indonesian public policies, such as the 2020-2024 National Medium-Term Development Plan (RPJMN) and Law No. 32/2009 on the Environment, emphasizing the involvement of indigenous communities and local wisdom as partners in conservation. Local wisdom, such as the practices of the Belu community or the ngembang tradition in Banten, serves as an ethical model that supports human-nature harmony.

Implementation Challenges: Key obstacles include weak institutional capacity, low ecological awareness, the dominance of economic and political interests, and conflicts with regional autonomy and the free market, which often override moral considerations. However, the opportunity for a paradigm reorientation to ecocentrism is recommended for inclusive policies that involve local cultural values (Saputra et al., 2025).

CONCLUSION

The application of environmental ethics in agricultural research, particularly in the study of oil palm seedling vegetation, is crucial for achieving sustainability and ecosystem balance. This research demonstrates that sustainable agricultural practices address not only economic outcomes but also social and environmental impacts. In the context of the palm oil industry, the application of ethical principles such as responsibility, intergenerational equity, and community participation is key to addressing issues of deforestation, pollution, and conflict with local communities. The analysis identified challenges in the application of environmental ethics, such as low public awareness and conflicts of interest among stakeholders. However, multi-stakeholder collaboration and enhanced moral education can be a solution to raise awareness and a shared commitment to environmental sustainability.

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CONFLICT OF INTEREST

There is no conflict of interest and takes full responsibility for the content of the article, including the implications of AI-generated content.

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