



## **Organic Fertilization Practices and Coconut Productivity in Smallholder Plantations: Evidence from Nabire Regency, Indonesia**

**Kartinus Obed Satia<sup>1)\*</sup> , Kristian Hoegh Pride Lambe<sup>2)</sup> , Johannes Baptista Halik<sup>3)</sup>**

<sup>1,2,3)</sup> Master of Management Department, Universitas Kristen Indonesia Paulus, Makassar, Indonesia

E-mail: [kartinusobedsatia@gmail.com](mailto:kartinusobedsatia@gmail.com)

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### ***Abstract***

Coconut is an important smallholder plantation commodity in Nabire Regency, Indonesia, yet its productivity remains suboptimal due to traditional cultivation practices, aging trees, irregular maintenance, and limited technical capacity. This study examines coconut cultivation conditions and productivity, identifies organic fertilization practices, and assesses their contribution to coconut productivity in smallholder plantations. A descriptive field study was conducted using field observations, productivity measurements, semi-structured interviews, and documentation. Productivity was assessed based on the number of fruits per tree, coconut flesh weight, harvest intervals, and plant growth conditions. The findings indicate that organic fertilizers, including livestock manure, compost, plant residues, leaves, and grass, are already used by farmers, but application practices remain inconsistent in terms of dosage, frequency, processing, and application techniques. Organic fertilization contributes positively to soil conditions, plant growth, and the potential improvement of coconut productivity. However, its effectiveness depends on complementary cultivation practices, including proper maintenance, quality planting materials, pest and disease management, and the rejuvenation of aging trees. The study highlights the need for standardized fertilization practices, stronger agricultural extension services, farmer capacity building, and sustainable integration of livestock and plantation resources.

**Keywords:** coconut productivity; Nabire Regency; smallholder plantations; sustainable agriculture; organic fertilization

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✉ Corresponding author : Kartinus Obet Satia

Email Address : [kartinusobedsatia@gmail.com](mailto:kartinusobedsatia@gmail.com)

## 1. INTRODUCTION

Coconut (*Cocos nucifera* L.) remains an important tropical plantation commodity because of its contribution to food systems, household income, and rural livelihoods. The crop is predominantly cultivated by smallholders, making improvements in coconut productivity particularly relevant not only from an agronomic perspective but also from the perspective of rural economic development. Recent literature describes coconut as a crop with substantial livelihood significance in tropical regions, while its production is increasingly expected to move beyond traditional products toward diversified and higher-value uses (Nair et al., 2022). In Indonesia, this importance is reflected in the scale of the national coconut sector. Data from the Directorate General of Estate Crops show that Indonesia had approximately 3.27 million ha of coconut area and an estimated production of 2.77 million tons in 2025. However, national production declined from 2.86 million tons in 2020 to 2.77 million tons in 2025, while productivity decreased slightly from 1,119 to 1,110 kg/ha during the same period (Directorate General of Estate Crops, 2026).

This situation suggests that expanding or maintaining coconut production cannot rely solely on the availability of land. Productivity improvement requires better management of existing plantations, particularly smallholder plantations where production practices are often influenced by farmers' access to inputs, technical knowledge, labor, and extension services. The productivity of perennial crops such as coconut is also shaped by a combination of plant age, genetic materials, soil fertility, nutrient availability, climatic conditions, pest and disease pressure, and cultivation practices. Evidence from coconut-growing areas in Indonesia demonstrates that pests and diseases can substantially affect plant performance, highlighting the fact that productivity improvement cannot be attributed to a single agronomic factor (Papona et al., 2023).

Among the agronomic factors that can be directly managed, nutrient management occupies a central position. Coconut is a perennial crop that continuously removes nutrients from the soil through vegetative growth and fruit production. Consequently, inadequate nutrient replenishment can gradually reduce soil fertility and constrain plant growth and yield. Fertilization is therefore not merely an input intended to increase short-term production; it is also part of maintaining the productive capacity of the soil over time. This consideration has become increasingly important as sustainable agriculture places greater emphasis on nutrient recycling, soil health, efficient use of agricultural resources, and the reduction of dependence on external inputs.

Organic fertilization offers one possible pathway for addressing these concerns. Organic fertilizers derived from livestock manure, compost, plant residues, and other locally available biomass can supply nutrients while simultaneously contributing organic matter to the soil. A global meta-analysis covering 219 studies found that organic amendments increased several indicators of soil microbial diversity and functionality and were positively associated with crop yields (Shu et al., 2022). Similarly, a global meta-analysis by Wang et al. (2024), based on 211 studies and 852 observations, found

that replacing part or all of inorganic fertilizer with organic substrates increased crop productivity and soil biofertility, although the magnitude of the response varied according to environmental and management conditions. These findings are important because they indicate that the value of organic fertilization extends beyond nutrient supply; its effectiveness may also operate through changes in soil biological and physicochemical conditions.

The relationship between organic fertilization and productivity, however, should not be interpreted as universally linear or automatic. The effectiveness of organic amendments depends on the type and quality of material, application rate, timing, frequency, soil characteristics, climate, and the way the amendment is integrated with other cultivation practices. A meta-analysis of organic amendments in upland cropping systems, for example, found that combining organic materials with mineral fertilizer generally produced stronger improvements in crop yield and soil quality than relying on organic materials alone (Wang et al., 2021). This finding reinforces an important point for coconut production: the presence of organic fertilizer in a farming system does not necessarily guarantee higher productivity unless its application is technically appropriate and accompanied by adequate plantation management.

Evidence from coconut-specific studies provides further support for examining fertilization practices in greater detail. Risandi et al. (2020), for example, found that combinations of inorganic and liquid organic fertilizers affected the vegetative growth of young kopyor coconut plants, although the response differed across growth indicators and fertilizer combinations. More recent research on coconut seedlings has likewise examined manure, rock phosphate, and mycorrhizal biofertilizers, demonstrating that nutrient-management strategies can influence early coconut growth, particularly plant height, leaf development, and root colonization (Kaewnoo et al., 2023). Thus, the literature supports the agronomic relevance of organic inputs, but it also indicates that the outcome depends on how those inputs are applied and the stage and conditions of coconut cultivation.

The issue becomes particularly relevant in Nabire Regency, Central Papua, where coconut is cultivated predominantly through smallholder plantations. According to Nabire Regency in Figures 2025, coconut production in 2023 reached 3,515.5 tons, with coconut plantations distributed across several districts. Production was particularly concentrated in Kepulauan Moora, Makimi, Napan, Wanggar, and Teluk Kimi. The official statistics therefore confirm that coconut is not a marginal crop in Nabire but forms part of the region's plantation economy (BPS-Statistics of Nabire Regency, 2025).

The following table summarizes several empirical facts that establish the rationale for the present study.

**Table 1.** Empirical Evidence Underlying the Research Problem

| Evidence                           | Recent data/finding                                                                                                                            | Implication for the research                                                                            |
|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| <b>National coconut production</b> | Indonesia's coconut production decreased from <b>2.86 million tons in 2020 to 2.77 million tons in 2025</b> , a decline of approximately 3.21% | National coconut productivity remains an important issue requiring improvement in plantation management |

| <b>Evidence</b>                       | <b>Recent data/finding</b>                                                                                                                                                                           | <b>Implication for the research</b>                                                                                            |
|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| <b>National coconut productivity</b>  | Productivity decreased from <b>1,119 kg/ha in 2020 to 1,110 kg/ha in 2025</b>                                                                                                                        | Increasing production requires more efficient management of existing productive land                                           |
| <b>Coconut production in Nabire</b>   | Nabire produced approximately <b>3,515.5 tons of coconut in 2023</b>                                                                                                                                 | Coconut constitutes an economically relevant plantation commodity at the local level                                           |
| <b>Spatial distribution in Nabire</b> | Coconut production was distributed across multiple districts, with particularly high production recorded in Kepulauan Moora, Makimi, Napan, Wanggar, and Teluk Kimi                                  | Productivity improvement requires attention to smallholder plantation practices across different local production environments |
| <b>Organic fertilization evidence</b> | Recent meta-analyses indicate that organic amendments can improve soil biological functions, soil quality, and crop productivity, although responses vary by management and environmental conditions | Organic fertilization is promising but requires context-specific assessment                                                    |
| <b>Coconut-specific evidence</b>      | Studies on coconut indicate that organic or biologically based fertilizer strategies can influence plant growth and development                                                                      | More empirical evidence is needed concerning practical application under mature smallholder coconut plantations                |

*Source: Directorate General of Estate Crops (2026); BPS-Statistics of Nabire Regency (2025); Shu et al. (2022); Wang et al. (2024); Risandi et al. (2020).*

The local situation documented in the present study indicates that the challenge in Nabire is not simply the absence of organic fertilizer. Organic materials are available locally, including livestock manure, compost, leaves, grass, plant residues, and agricultural and livestock waste. The more fundamental problem concerns how these materials are utilized. The study documents that organic fertilization practices vary in terms of fertilizer type, dosage, frequency, processing, timing, and application method. Dosage decisions are frequently based on farmers' experience, while application frequency is generally around one to two times per year or depends on the availability of fertilizer and labor. This indicates a transition problem between the availability of local organic resources and their systematic use as a component of productive plantation management.

The cultivation context further complicates this issue. Field observations reported in the study show variation in plantation maintenance, including differences in weed management and plant condition. Some coconut trees remain productive and grow relatively well, whereas others are already old and show declining production. The study also identifies differences in plantation management and highlights plant age, soil fertility, maintenance, fertilization, rainfall, pests and diseases, and farmers' technical capacity as factors associated with differences in productivity. These conditions are consistent with the broader literature, which cautions against treating fertilizer application as an isolated determinant of agricultural productivity.

Despite the growing literature on soil health and organic amendments, an important empirical gap remains. Much of the recent evidence concerning organic fertilization is derived from annual crops, controlled experiments, or broad meta-analyses. These studies are valuable for establishing general mechanisms, but their findings cannot automatically be transferred to smallholder coconut systems, particularly in geographically remote and ecologically distinctive regions.

Coconut-specific research also tends to focus on particular fertilizer treatments, seedling growth, or controlled agronomic responses. For example, Risandi et al. (2020) examined the response of young kopyor coconut plants to combinations of inorganic and liquid organic fertilizers, while Kaewnoo et al. (2023) focused on fertilizer treatments during the coconut seedling stage. Research in Indonesian coconut-producing regions has also addressed other constraints, such as pest and disease incidence, but this literature remains geographically concentrated in established coconut-producing areas such as North Sulawesi (Papona et al., 2023).

Consequently, there is still limited empirical evidence concerning how organic fertilization is actually practiced within smallholder coconut plantations in Nabire, what forms of organic fertilizer are locally utilized, how dosage and application practices are determined, and how these practices relate to coconut productivity under actual field conditions. The present study addresses this gap by bringing together three dimensions that are rarely examined simultaneously in the local context: **(1) the condition of smallholder coconut cultivation and productivity, (2) the actual practices of organic fertilization, and (3) the contribution of those practices to supporting coconut productivity.** The focus on Nabire is important because local agricultural conditions, resource availability, farmer practices, plantation age, and institutional support may differ substantially from those reported in established coconut-producing regions.

Importantly, this study does not assume that organic fertilization alone determines coconut productivity. Rather, it examines organic fertilization as one component of an interconnected plantation management system. This positioning is consistent with recent evidence showing that the productivity effects of organic amendments depend on soil properties, climate, fertilizer characteristics, and complementary management practices (Wang et al., 2024). It also provides a more realistic interpretation of organic fertilization in smallholder systems, where technical practices, resource availability, labor, farmer knowledge, and institutional support jointly shape the feasibility of recommended technologies.

The urgency of this research lies in the need to transform the use of locally available organic resources from an informal and experience-based practice into a more systematic component of sustainable coconut plantation management in Nabire. National data indicate a gradual decline in coconut production and productivity, while Nabire remains an important local production area with substantial coconut resources. At the farm level, the challenge is not simply to introduce organic fertilizer, but to establish application practices that are technically appropriate, locally feasible, and compatible with the characteristics of smallholder plantations. Understanding the existing pattern of organic fertilization is therefore essential for developing realistic recommendations concerning dosage, frequency, application techniques, farmer capacity, extension support, and the utilization of agricultural and livestock waste. Such

evidence can contribute not only to improving coconut productivity but also to strengthening resource recycling and the sustainability of smallholder plantation systems. The emphasis is particularly relevant for Nabire because the availability of organic materials, including livestock and agricultural residues, creates an opportunity to develop a more integrated crop-livestock resource system rather than treating plantation waste as an underutilized by-product.

Based on the background, empirical evidence, research gap, and urgency described above, this study addresses the following research questions:

1. What are the current cultivation conditions and productivity levels of coconut in smallholder plantations in Nabire Regency?
2. How is organic fertilization currently practiced in coconut plantations in Nabire Regency in terms of fertilizer type, dosage, frequency, timing, processing, and application method?
3. How does the application of organic fertilizer contribute to supporting coconut productivity under smallholder plantation conditions in Nabire Regency?

## **2. LITERATURE REVIEW**

### ***2.1 Coconut Cultivation and Productivity***

Coconut (*Cocos nucifera* L.) is an important tropical plantation crop with substantial economic and livelihood value, particularly for smallholder farming communities. Coconut productivity is influenced by the interaction between genetic characteristics, plant age, soil fertility, water availability, climatic conditions, pest and disease pressure, and plantation management. Consequently, productivity cannot be attributed to a single agronomic input but should be understood as the outcome of an integrated production system.

In smallholder plantations, inadequate maintenance, aging trees, limited access to production inputs, and insufficient technical knowledge can constrain productivity. The present study similarly identifies traditional cultivation practices, aging coconut trees, irregular maintenance, limited facilities, and technical constraints as important conditions underlying suboptimal coconut productivity in Nabire Regency. Productivity in this study is assessed using practical indicators, including the number of fruits per tree, coconut flesh weight, harvest intervals, and plant growth conditions.

### ***2.2 Organic Fertilization and Soil Improvement***

Organic fertilization is an important component of sustainable soil management because organic materials can improve soil physical, chemical, and biological properties. Organic amendments contribute to soil organic matter, improve soil structure and moisture retention, and provide substrates for soil microorganisms. These processes can create more favorable conditions for root development and nutrient uptake. A meta-analysis of 219 studies found that organic amendments increased soil microbial diversity and functionality and were positively associated with crop yields (Shu et al., 2022).

However, the benefits of organic fertilizer depend on the characteristics of the material and its nutrient-release dynamics. Geisseler et al. (2021), based on 113 datasets,

demonstrated substantial variation in nitrogen mineralization among different organic fertilizers and composts. This finding indicates that the type, quality, decomposition characteristics, and application conditions of organic materials are important considerations in nutrient management.

In Nabire, farmers utilize locally available organic materials, including livestock manure, compost, leaves, grass, plant residues, and agricultural and livestock waste. Nevertheless, application practices remain inconsistent, particularly with respect to dosage, frequency, processing, and application techniques.

### ***2.3 Organic Fertilization and Coconut Productivity***

The relationship between organic fertilization and coconut productivity can be explained through improvements in soil conditions and nutrient availability. Better soil structure, moisture conditions, biological activity, and nutrient supply can support root development and plant growth, which subsequently contribute to flowering and fruit development. Empirical evidence from coconut plantations also suggests that integrated nutrient management involving organic materials can improve soil properties and production performance.

For example, Shinde et al. (2021) reported higher coconut yields under an integrated nutrient management system involving organic recycling, vermicompost, and other nutrient sources. Similarly, Pawar et al. (2024) found that the integrated use of manures and fertilizers improved soil physicochemical properties and was associated with higher coconut yield. These findings suggest that organic fertilization can be an important component of coconut productivity management, particularly when integrated with other appropriate cultivation practices.

The evidence from Nabire is consistent with this general mechanism. Field observations indicate that coconut plants receiving better organic matter management and more regular maintenance tend to have looser soil conditions, healthier vegetative growth, and better canopy development. However, the study does not establish organic fertilization as the sole determinant of productivity.

### ***2.4 Factors Affecting Coconut Productivity and Research Gap***

Coconut productivity is affected by multiple interacting factors. Besides fertilization, plant age, planting material, soil fertility, water availability, plantation maintenance, pest and disease management, environmental conditions, and farmer technical capacity can influence production outcomes. Therefore, the contribution of organic fertilization should be considered within an integrated plantation management perspective rather than as an isolated production factor. The findings of the present study support this perspective, as productivity differences are also associated with plant age, seedling quality, rainfall, pests and diseases, plantation cleanliness, rejuvenation, and farmer capacity.

Despite growing evidence concerning organic amendments and coconut production, empirical research specifically addressing organic fertilization practices in Nabire Regency remains limited. Previous studies have generally been conducted in established coconut-producing regions and have frequently emphasized soil properties, vegetative growth, or general nutrient management. The thesis identifies a particular

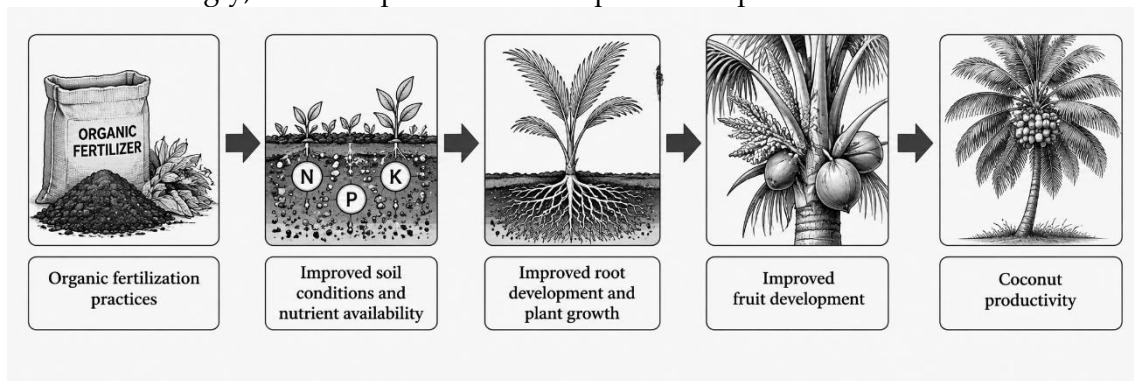
gap in empirical evidence concerning coconut flesh productivity in Papua, especially Nabire Regency.

This study therefore contributes localized evidence by examining existing organic fertilization practices and their contribution to coconut productivity in smallholder plantations in Nabire. Rather than assuming a direct causal effect, the study focuses on the practical relationship between fertilization practices, plantation conditions, and observed productivity.

## 2.5 Conceptual Framework

Based on the literature, organic fertilization can contribute to coconut productivity through a sequential agronomic mechanism. The application of organic materials can increase soil organic matter and biological activity, improve soil structure and moisture conditions, and enhance nutrient availability. These improvements can support root development and nutrient uptake, which in turn facilitate vegetative growth, flowering, fruit formation, and fruit development.

Accordingly, the conceptual relationship can be expressed as:



**Figure 1.** Conceptual Framework

However, this relationship operates within a broader production system. Plant age, planting material, environmental conditions, pest and disease pressure, plantation maintenance, and farmer capacity may strengthen or constrain the contribution of organic fertilization. This integrated framework is consistent with the conceptual framework developed in the original study.

Thus, the present study conceptualizes organic fertilization not as an independent cause of productivity improvement, but as an important agronomic practice that can support coconut productivity when appropriately integrated with other plantation management practices.

## 3. RESEARCH METHODS

This study employed a field-based quantitative descriptive design to examine organic fertilization practices and their contribution to coconut productivity in smallholder plantations in Nabire Regency, Central Papua Province, Indonesia. The study combined direct field observation, productivity measurement, semi-structured interviews, and documentation to obtain both quantitative and contextual evidence. The quantitative component focused on observable productivity indicators, whereas

interviews and field observations were used to provide contextual information regarding cultivation practices and organic fertilizer application. This design was selected because the study aimed to describe actual plantation conditions and examine patterns associated with organic fertilization under real smallholder farming conditions rather than relying solely on controlled laboratory observations. The original research design also specified a field experiment using a Randomized Block Design, with five fertilizer treatments consisting of an unfertilized control, livestock manure, compost, biofertilizer, and a combination of livestock manure, compost, and biofertilizer.

The experimental component was structured to account for possible heterogeneity in field conditions, particularly differences in soil fertility, moisture, texture, and other environmental characteristics. The five treatments were coded as P1 for the control, P2 for livestock manure, P3 for compost, P4 for biofertilizer, and P5 for the combined organic fertilizer treatment. The planned design consisted of four blocks, resulting in 20 experimental units, with treatments randomly allocated within each block. However, because the reported empirical findings are primarily based on field observations, productivity measurements, and interviews, the present article interprets the experimental framework descriptively and avoids claiming a statistically established causal effect where corresponding inferential results are not reported. This approach is also consistent with the broader evidence that organic amendments can improve soil biological functioning and crop productivity, while their effects vary according to amendment type and environmental conditions (Shu et al., 2022).

The population comprised productive coconut trees located in smallholder coconut plantations within the study area in Nabire Regency. Productive trees were defined as coconut plants that had entered the fruit-bearing stage and were still actively producing. The sample was selected from productive trees aged approximately 5–15 years, with relatively homogeneous growth conditions, healthy physiological status, comparable planting distances and land characteristics, and broadly similar management histories. Trees showing severe pest or disease damage were excluded in order to reduce excessive variation unrelated to the fertilization treatments.

Purposive sampling was used to select the coconut trees included in the field observations and experimental component. This technique was considered appropriate because the study required trees that met specific agronomic criteria rather than a randomly selected cross-section of all coconut trees in the area. The selection criteria were intended to improve comparability among observations and reduce variation arising from differences in plant age, health status, spacing, and plantation conditions.

In addition to the plant-level observations, the study incorporated eight institutional informants from the Nabire Regency Livestock and Plantation Service. The informants represented organizational leadership, technical plantation and livestock divisions, extension infrastructure, program and finance, and general and personnel administration. They were selected purposively on the basis of their responsibilities, experience, and knowledge concerning coconut development, organic fertilization, agricultural extension, production facilities, planning, and farmer support. All eight interviews were conducted on 23 June 2026. This institutional perspective complemented the field-level observations by providing information concerning

technical practices, extension support, organic fertilizer resources, and institutional constraints.

The research was conducted in smallholder coconut plantations in Nabire Regency, Central Papua Province, Indonesia. The location was purposively selected because coconut is an important plantation commodity for local communities, particularly in rural and coastal areas, while plantation management in many locations remains relatively traditional. The setting therefore provides an appropriate context for examining the practical application of locally available organic fertilizers and their relationship with coconut productivity under smallholder conditions.

The field research was planned for approximately two months, from May to June 2026, with the timing adjusted to the growth and harvesting period of coconut. The research activities included field preparation, site observation, selection of study plants, implementation of the planned fertilization treatments, productivity observation, data collection, and subsequent data processing. The timing was intended to ensure that observations corresponded with the prevailing production cycle and provided field-based information relevant to coconut productivity. The institutional interviews were conducted on 23 June 2026, providing additional contextual information on cultivation practices and the implementation of organic fertilization in Nabire.

Data were obtained through field observation, productivity measurement, documentation, and semi-structured interviews. Field observation covered the physical condition of the plantation, coconut tree condition, cultivation practices, organic fertilizer application, plant growth, and environmental factors that could influence productivity. Productivity was assessed using the number of fruits per tree, coconut flesh weight, harvest interval, and plant growth characteristics. Growth observations included indicators such as the development of new fronds, stem condition, and canopy characteristics. These measurements were conducted periodically using consistent observation procedures.

Semi-structured interviews were used as supplementary evidence to capture information that could not be directly measured in the field, including farmers' cultivation experience, fertilization habits, types of organic fertilizer used, constraints in applying organic fertilizers, perceptions of coconut production, and expectations concerning productivity improvement. The study also used photographs, field notes, and relevant secondary information as documentary evidence. Triangulation was applied by comparing observations, productivity measurements, documentation, and interview information to strengthen the credibility and consistency of the findings.

The data were analyzed primarily using descriptive analysis. Quantitative observations of coconut productivity were organized according to the principal indicators, namely fruit number per tree, coconut flesh weight, harvest interval, and plant growth condition. The results were compared descriptively across the observed fertilization practices and treatment conditions to identify patterns in soil condition, plant growth, and productivity. This analytical approach was complemented by qualitative interpretation of interview and observation data, allowing the study to connect measurable productivity characteristics with information concerning fertilizer type, application practices, maintenance, and environmental constraints. The analysis therefore emphasized patterns and practical relationships rather than unsupported

causal claims. The use of multiple sources of evidence was consistent with the study's triangulation procedure.

The interpretation of the relationship between organic fertilization and productivity was guided by the agronomic mechanism proposed in the literature, namely that organic amendments can improve soil conditions and microbial functioning, which may subsequently support nutrient availability and plant growth. Evidence from a global meta-analysis of 219 studies indicates that organic amendments can enhance microbial diversity, microbial functionality, and crop yields, although the magnitude of these effects depends on amendment characteristics and environmental conditions (Shu et al., 2022). Evidence from coconut-specific field research likewise indicates that integrated manure and fertilizer management can improve soil physicochemical properties and coconut yield, although the highest yield in the cited experiment was obtained from an integrated nutrient treatment rather than organic fertilizer alone (Pawar et al., 2024). These findings support the present study's decision to interpret organic fertilization as one component of an integrated coconut management system.

Overall, the analytical procedure followed a sequence of data organization, descriptive comparison, interpretation of field observations, integration of interview evidence, and triangulation of findings (Miles et al., 2021). This procedure enabled the study to identify the prevailing organic fertilization practices, describe variation in coconut productivity, and assess the contribution of organic fertilization within the broader context of plantation management. Because the available study evidence does not provide a complete set of inferential test results, the article deliberately uses cautious expressions such as *contributes to*, *is associated with*, *supports*, and *tends to improve*, rather than presenting organic fertilization as an experimentally proven sole cause of increased coconut productivity.

## 4. RESULTS

### 4.1 Cultivation Conditions and Coconut Productivity

Field observations indicated that coconut cultivation in Nabire Regency is predominantly characterized by smallholder plantation management, with substantial variation in the level of field maintenance and plant condition. Some plantations were relatively well maintained, whereas others showed limited maintenance, including the presence of weeds and other vegetation around coconut trees. The observed coconut stands also varied considerably in age and physiological condition. Productive trees with relatively good growth were found alongside older trees showing declining production. These differences were reflected in variation in the observed productivity indicators, including fruit production, coconut flesh weight, harvest intervals, and general plant growth conditions.

The productivity observations did not indicate a uniform production pattern across coconut trees. Variation was associated with differences in plant age, soil fertility, maintenance intensity, fertilization practices, and general plant condition. The findings also indicated that better-maintained plantations tended to have healthier plants and

better fruit production than plantations receiving less intensive management. The eight institutional informants consistently identified plant age, planting material, soil fertility, maintenance, rainfall, pest and disease pressure, and farmer technical capacity as factors contributing to differences in coconut productivity.

The findings therefore suggest that the productivity problem in Nabire is not primarily attributable to the absence of a suitable agroecological environment. Rather, a gap exists between the productive potential of the coconut-growing environment and the intensity and consistency of plantation management. The study identified traditional cultivation practices, aging trees, irregular maintenance, limited production facilities, and uneven technical knowledge as important constraints.

#### ***4.2 Organic Fertilization Practices***

Organic fertilization was already practiced by some coconut farmers in Nabire. The materials identified through field observations and interviews included livestock manure, compost, leaves, grass, plant residues, and other locally available agricultural and livestock wastes. The availability of these materials indicates that the local production system has considerable potential for developing organic nutrient sources without relying entirely on externally purchased inputs.

However, the application practices were not standardized. Fertilizer dosage was generally determined according to farmers' experience rather than a consistent technical recommendation. The frequency of application commonly ranged from once to twice a year, although some farmers applied organic fertilizer only when sufficient material was available. Application was generally concentrated around the root zone and was often conducted when soil moisture was adequate or before the rainy season.

The quality and preparation of organic fertilizer also emerged as an important issue. Livestock manure from cattle, goats, pigs, and poultry was considered a potentially valuable fertilizer source, but informants emphasized that manure should preferably undergo maturation or composting before application. Differences in farmers' knowledge concerning processing, dosage, timing, and application distance resulted in substantial variation in the quality of organic fertilization practices.

The findings further identified a combination of technical and institutional constraints. Limited knowledge, inadequate processing equipment, labor availability, transportation costs, distance between organic material sources and plantations, and insufficient extension support constrained more consistent adoption. Conversely, the existence of livestock activities, agricultural residues, farmer groups, extension personnel, and government programs represented important enabling conditions for wider adoption.

#### ***4.3 Observed Contribution of Organic Fertilization to Coconut Productivity***

The field observations indicated that coconut trees receiving organic materials more regularly tended to exhibit better soil conditions, healthier vegetation, and more favorable canopy development. Soils associated with better organic matter management were observed to be relatively looser and better able to retain moisture. Plant growth

was also comparatively better, particularly in terms of leaf condition and canopy development.

The observed contribution of organic fertilization was therefore more apparent through changes in the growing environment and plant condition than through a demonstrable statistical increase in productivity. Organic materials contribute organic matter to the soil, improve soil structure and moisture retention, and provide substrates for biological activity. These processes can create more favorable root-zone conditions and support nutrient acquisition, thereby providing a plausible pathway toward improved plant growth and fruit development.

The findings also indicate that organic fertilization should not be viewed as an isolated determinant of coconut productivity. Informants consistently emphasized that fruit production is also influenced by plant age, planting material, rainfall, pest and disease management, plantation sanitation, rejuvenation of old trees, and farmer competence. Thus, the contribution of organic fertilization appears to depend on its integration with other plantation management practices.

## 5. DISCUSSION

### *5.1 Cultivation Conditions and Productivity Constraints*

The first important finding is that the relatively low and uneven productivity of coconut in Nabire cannot be adequately explained by environmental suitability alone. The study found that the area has considerable potential for coconut cultivation, yet productivity remains inconsistent because plantation management is still predominantly traditional and varies substantially among farmers. This finding is important because it shifts the interpretation of the productivity problem from a purely resource-based issue toward a management-capability problem. The gap lies not simply in whether coconut can grow in Nabire, but in whether farmers have the technical, material, and institutional capacity to manage productive coconut stands consistently.

The variation associated with plant age is particularly important. Coconut is a perennial crop, meaning that productivity cannot be improved solely through short-term fertilizer application when a substantial proportion of the plantation consists of aging trees. The findings show that some trees are already old and have experienced declining production. Consequently, fertilization may improve the growing environment of productive trees, but it cannot fully compensate for the biological limitations associated with aging stands. This explains why better fertilization alone is unlikely to eliminate productivity differences among plantations.

This interpretation is consistent with the integrated management perspective reported by Shinde et al. (2021). Their long-term coconut field experiment demonstrated that higher productivity was associated with integrated nutrient management involving organic recycling, vermicompost, biofertilizers, and other agronomic practices, rather than with organic inputs considered in isolation. Their integrated treatments produced yields of approximately 141.28 and 126.33 nuts palm<sup>-1</sup> year<sup>-1</sup> under different nutrient combinations.

The implication is that coconut productivity in Nabire should be understood as an outcome of multiple interacting management conditions. Organic fertilization is one component of this system, alongside plant rejuvenation, planting material, weed

management, pest and disease control, and farmer technical capacity. This finding provides an important qualification to simplistic claims that organic fertilizer alone can solve low coconut productivity.

### ***5.2 Local Organic Fertilization Practices and the Problem of Standardization***

The second major finding concerns the paradox between the availability of organic resources and the limited standardization of their use. Nabire has access to livestock manure, plant residues, leaves, grass, compostable materials, and other agricultural wastes. Nevertheless, these resources have not yet been translated into a consistently managed nutrient supply system. Farmers generally determine dosage based on experience, apply fertilizers irregularly, and use different preparation and application practices.

This finding helps explain why the presence of organic materials does not automatically produce higher productivity. Organic fertilizer is not a homogeneous input. Its nutrient concentration, carbon-to-nitrogen ratio, decomposition rate, moisture content, maturity, and nutrient release characteristics can differ substantially according to the source and processing method. Consequently, simply increasing the quantity of organic material does not necessarily guarantee an equivalent increase in nutrient availability.

This interpretation is supported by the broader evidence synthesized by Shu et al. (2022). Their meta-analysis of 219 studies found that organic amendments enhanced soil microbial diversity and functionality and were positively associated with crop yields, but the response varied according to amendment type, microbial community characteristics, soil pH, and other environmental conditions. Importantly, their analysis indicated that soil abiotic properties and microbial functionality had stronger relationships with crop yields than microbial diversity alone.

The Nabire findings therefore add an important **implementation dimension** to the agronomic literature. Previous research largely demonstrates what organic amendments can do under defined management conditions. The present study shows why those benefits may not be fully realized in smallholder settings where dosage, timing, processing, and application techniques remain dependent on farmer experience. In other words, the critical issue is not merely the availability of organic fertilizer, but the quality of its management.

### ***5.3 Organic Fertilization and Coconut Productivity***

The third research question concerns the contribution of organic fertilization to coconut productivity. The study found a consistent positive pattern: trees receiving organic materials more regularly tended to have better soil conditions, healthier vegetation, and more favorable growth characteristics. The observed pathway can be expressed as:

**organic fertilization → improved soil organic matter and soil condition → better root-zone environment → improved nutrient availability and uptake → healthier plant growth → improved fruit development → potential productivity improvement.**

This pathway is biologically plausible and is strongly supported by recent evidence. Shu et al. (2022) found that organic amendments increased microbial diversity

and functionality and were positively associated with crop yields across a large global evidence base. Wang et al. (2024), based on 211 papers and 852 observations, similarly found that replacing part of inorganic fertilizer inputs with organic substrates increased crop productivity by approximately 3.04% and improved several indicators of soil biofertility. However, the authors also emphasized that the response depended on environmental and management conditions.

Evidence specific to coconut further supports this interpretation. Pawar et al. (2024) found that integrated use of manures and fertilizers improved soil physicochemical properties in a coconut orchard, while the highest coconut yield was obtained under an integrated treatment involving recommended fertilizer, micronutrients, and pest-management components. This is particularly relevant to the present study because it demonstrates that organic manure contributes to soil improvement but does not necessarily mean that organic fertilizer alone will maximize coconut yield.

The findings from Nabire are therefore consistent with, but also more cautious than, previous experimental studies. The present research does not demonstrate a statistically significant treatment effect. Instead, it identifies a consistent field pattern in which better organic matter management is accompanied by better soil and plant conditions. The novelty lies in showing how this agronomic relationship operates under a smallholder context where fertilizer application is informal, resource availability is uneven, and institutional support influences adoption.

#### ***5.4 Why the Contribution of Organic Fertilization Is Conditional***

An important finding emerging from the study is that the contribution of organic fertilization is conditional rather than automatic. The effectiveness of organic fertilizer depends on fertilizer type, maturity, dosage, application frequency, timing, placement, plant age, soil condition, rainfall, pest and disease pressure, and the quality of other cultivation practices.

This explains why two farmers using apparently similar organic materials may obtain different outcomes. A mature compost applied at an appropriate rate and time can provide a different nutrient-release pattern from fresh manure or undecomposed plant residues. Similarly, fertilizer applied to an appropriate root-zone location is more likely to contribute to nutrient acquisition than material distributed without consideration of the active root system.

The findings are consistent with Wang et al. (2024), who reported that the productivity response to organic substitution varies with environmental variables and the level of organic substitution. Their global synthesis suggests that organic nutrient management should be adapted to site-specific conditions rather than treated as a universally transferable prescription.

This conditional relationship is particularly relevant for Nabire because farmers operate within resource constraints. The problem is therefore partly agronomic and partly institutional. Limited access to processing equipment, labor, transportation, and extension services can prevent farmers from applying technically appropriate practices even when organic resources are locally abundant. The study thus extends the

conventional agronomic explanation by demonstrating that technical effectiveness and adoption capacity are interdependent.

### ***5.5 Novelty and Theoretical Implications***

The novelty of this study should not be claimed as the discovery that organic fertilizer improves soil or coconut growth. That relationship has already been demonstrated by previous experimental and meta-analytic research. Rather, the contribution of this study lies in identifying the contextual mechanism through which organic fertilization is translated, or fails to be translated, into productivity improvement in smallholder coconut plantations in Nabire.

The study demonstrates that organic fertilization operates within an interconnected production system consisting of local resource availability, farmer knowledge, fertilizer preparation, application consistency, plantation maintenance, plant age, extension services, infrastructure, and institutional support. This extends the integrated nutrient management perspective by incorporating the human and institutional conditions required for agronomic practices to become effective at farm level. The thesis itself identifies this broader relationship, emphasizing that productivity improvement depends not only on organic fertilization but also on planting material, productive plant age, maintenance, pest and disease control, environmental conditions, and farmer skills.

Theoretically, the findings therefore support an integrated farm-management perspective rather than a single-input productivity model. Organic fertilizer should be conceptualized as an enabling component of soil and plant management, not as an independent determinant of productivity. This interpretation is consistent with evidence from coconut systems research showing that integrated combinations of organic recycling, mineral nutrients, biofertilizers, and other agronomic practices can produce stronger productivity outcomes than isolated interventions.

A second theoretical contribution concerns the distinction between resource availability and resource utilization capability. Nabire possesses substantial potential sources of organic fertilizer, but the existence of resources does not guarantee their effective utilization. The findings suggest that farmer knowledge, technical standardization, extension support, and institutional infrastructure function as enabling conditions that determine whether locally available organic resources can be converted into productive agricultural inputs. This provides a more nuanced explanation of why organic-fertilization potential may remain underutilized in smallholder systems.

### ***5.6 Practical Implications***

The practical implication is that policy intervention should move beyond simply distributing or promoting organic fertilizer. The first priority should be the development of locally appropriate fertilization guidelines, including recommendations for fertilizer preparation, maturity, dosage, application frequency, timing, and placement according to plant age and local soil conditions. Such standardization is necessary because the current practice remains largely experience-based.

Second, agricultural extension should become more practice-oriented. Rather than relying exclusively on classroom-based information, extension programs should

incorporate field demonstrations, demonstration plots, compost-production training, and direct guidance on fertilizer application. This is especially important because the study found that farmer knowledge and technical capacity remain uneven and that extension access is not yet consistent.

Third, the study identifies a strong opportunity for livestock–coconut integration. Livestock manure can be processed into organic fertilizer, while crop residues can become inputs for compost production. Such integration could simultaneously address waste management, fertilizer availability, and production costs. The institutional position of livestock and plantation activities within the same local government agency further strengthens the feasibility of developing an integrated program.

Finally, productivity improvement programs should combine organic fertilization with rejuvenation of aging coconut trees, improved planting material, plantation sanitation, pest and disease management, and farmer capacity building. This is important because the study clearly indicates that organic fertilizer cannot compensate for all structural constraints affecting coconut productivity. The most appropriate policy approach is therefore an integrated coconut productivity program, with organic fertilization positioned as one strategic component rather than a standalone intervention.

## **6. CONCLUSION**

The main findings of this study are: (1) the central constraint to coconut productivity in Nabire is not the absence of organic resources, but the gap between resource availability and effective agronomic utilization. Coconut plantations have access to locally available manure, compost, plant residues, and other organic materials, yet their use remains largely experience-based and insufficiently standardized in terms of dosage, frequency, material preparation, and application practices. (2) organic fertilization should therefore be understood as a supporting component of an integrated coconut management system rather than as a stand-alone productivity solution. Its contribution is most meaningful when combined with appropriate plant maintenance, suitable planting materials, pest and disease management, and the rejuvenation of aging trees. The observed relationship between more regular fertilization and better soil and plant conditions supports this integrated interpretation. (3) the key development opportunity for Nabire lies in institutionalizing locally available organic resources into a more reliable production system. This requires locally appropriate fertilization recommendations, practical extension, farmer capacity development, processing facilities, stronger farmer groups, and closer integration between livestock and coconut production.

Taken together, the study shifts the discussion from whether organic fertilizer is available to whether farmers and local institutions have the capacity to use it effectively. This distinction is important because the productivity challenge identified in Nabire is simultaneously agronomic, human-capacity, infrastructural, and institutional. The implication is that improving coconut productivity requires a system-level intervention rather than a single-input intervention.

### **Limitations of the Study**

This study has several limitations that should be considered when interpreting its findings. First, the research employed a descriptive field-based approach combining observation, productivity measurements, documentation, and semi-structured interviews, with eight institutional informants from the Nabire Regency Livestock and Plantation Service. Consequently, the findings provide strong contextual insight into fertilization practices and their perceived contribution, but they should not be interpreted as evidence of a statistically established causal effect of organic fertilization on coconut productivity. Second, the study was conducted within a relatively specific geographical and institutional context, which limits the direct generalization of the findings to other coconut-producing regions with different soil, climatic, socioeconomic, and management conditions. Third, variation in fertilizer materials, application practices, tree age, plantation maintenance, and other production conditions makes it difficult to isolate the contribution of organic fertilization from other determinants of productivity. The study itself indicates that coconut productivity reflects the interaction of plant age, planting material, soil fertility, maintenance, environmental conditions, pest and disease management, and farmer capability.

### **Suggestions for Future Research**

Future research should move beyond descriptive assessment toward controlled and longitudinal field experimentation. In particular, experimental studies should compare different types, maturity levels, application rates, application frequencies, and combinations of organic fertilizers under comparable coconut-growing conditions. Productivity should be monitored using objective indicators such as nuts per palm, flesh weight, flesh thickness, harvest interval, and productivity per hectare over multiple production cycles. The comparison of manure, compost, vermicompost, liquid organic fertilizer, and integrated organic-inorganic nutrient management would be particularly valuable for identifying technically effective and economically feasible fertilization strategies for Nabire. These recommendations are also consistent with the original study's proposed direction for subsequent research.

Future studies should also incorporate soil and plant measurements, including soil organic carbon, nutrient availability, soil moisture, microbial activity, and plant nutrient status, to clarify the mechanisms linking organic inputs to coconut productivity. A longer observation period would be important because changes in soil quality and productivity in perennial crops such as coconut may not be adequately captured within a short study period. In addition, economic analysis should be incorporated to determine whether locally produced organic fertilizers can reduce production costs and improve farm profitability. This would allow subsequent research to move from identifying the potential contribution of organic fertilization toward establishing evidence-based, locally optimized fertilization recommendations.

The most important implication of this study is that Nabire does not primarily face a shortage of organic resources; it faces a shortage of standardized knowledge, implementation capacity, and institutional support for converting those resources into consistent agronomic practice. Organic fertilization can become a meaningful pathway to more productive and sustainable coconut farming, but only when it is embedded

within an integrated system of farmer capability, technical guidance, appropriate infrastructure, and continuous plantation management. This is where the real opportunity for improving smallholder coconut productivity in Nabire lies.

## BIBLIOGRAPHY

- BPS-Statistics of Nabire Regency. (2025). *Nabire Regency in figures 2025*. BPS-Statistics of Nabire Regency.
- Directorate General of Estate Crops. (2026). *Performance accountability report of the Directorate General of Estate Crops 2025*. Ministry of Agriculture of the Republic of Indonesia.
- Geisseler, D., Smith, R., Cahn, M., & Muramoto, J. (2021). Nitrogen mineralization from organic fertilizers and composts: Literature survey and model fitting. *Journal of Environmental Quality*, 50(6), 1325–1338. <https://doi.org/10.1002/jeq2.20295>
- Kaewnoo, T., Chaovanapong, P., Munmai, S., Reuncharoen, S., Thaweenut, N., Wiwatwittaya, P., Jinjakam, P., Thanjun, K., Pongthai, T., & Hrunheem, P. (2023). Effect of manure, rock phosphate fertilizer and mycorrhiza biofertilizer on growth of coconut seedling. *Journal of Technology and Agricultural Innovation*, 1(1), 34–42. <https://li02.tci-thaijo.org/index.php/jtai/article/view/162>
- Li, P., Li, Y., Xu, L., Zhang, H., Shen, X., Xu, H., Jiao, J., Li, H., & Hu, F. (2021). Crop yield-soil quality balance in double cropping in China's upland by organic amendments: A meta-analysis. *Geoderma*, 403, 115197. <https://doi.org/10.1016/j.geoderma.2021.115197>
- Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). SAGE Publications.
- Papona, A. T., Tondok, E. T., & Istiaji, B. (2023). Identification of pests and diseases on coconut (*Cocos nucifera* L.) in Sangihe Island Regency, North Sulawesi Province, Indonesia. *Agriprima: Journal of Applied Agricultural Sciences*, 7(2), 142–153. <https://doi.org/10.25047/agriprima.v7i2.520>
- Pawar, S. S., Bankar, R. T., & Khobragade, N. H. (2024). Effect of integrated use of manures and fertilizers on physico-chemical properties of soil and yield of coconut (*Cocos nucifera* L.). *International Journal of Plant & Soil Science*, 36(7), 908–919. <https://doi.org/10.9734/ijpss/2024/v36i74803>
- Risandi, F. H., Ariyanti, M., & Soleh, M. A. (2020). Respons pertumbuhan tanaman kelapa kopyor (*Cocos nucifera* L.) belum menghasilkan terhadap pemberian pupuk anorganik yang dikombinasikan dengan pupuk organik cair. *Jurnal Kultivasi*, 19(1), 1069–1076. <https://doi.org/10.24198/kultivasi.v19i1.23607>
- Shinde, V. V., Ghavale, S. L., Wankhede, S. M., Haladankar, P. M., & Maheswarappa, H. P. (2021). Systems approach in coconut for higher productivity and profitability in coastal ecosystem of Maharashtra. *Journal of Eco-Friendly Agriculture*, 17(1), 15–22. <https://doi.org/10.5958/2582-2683.2021.00003.4>
- Shu, X., He, J., Zhou, Z., Xia, L., Hu, Y., Zhang, Y., Zhang, Y., Luo, Y., Chu, H., Liu, W., Yuan, S., Gao, X., & Wang, C. (2022). Organic amendments enhance soil microbial

diversity, microbial functionality and crop yields: A meta-analysis. *Science of the Total Environment*, 829, 154627. <https://doi.org/10.1016/j.scitotenv.2022.154627>

Wang, X., Liu, M., Ciampitti, I. A., Cui, J., Fang, K., Zhao, S., He, P., & Zhou, W. (2024). Benefits and trade-offs of replacing inorganic fertilizer by organic substrate in crop production: A global meta-analysis. *Science of the Total Environment*, 925, 171781. <https://doi.org/10.1016/j.scitotenv.2024.171781>