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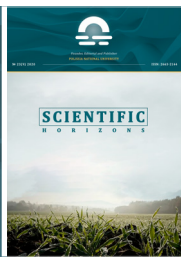

Analysis of tobacco production in Indonesia: A deterministic approach

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Abstract. Improving production input efficiency is crucial for enhancing productivity and sustainability in Indonesia's tobacco farming. This study examined the effects of land area, number of seeds, fertiliser use, pesticide application, and labour on tobacco production using multiple linear regression with natural logarithm transformation. Data were collected from tobacco farmers in East Java, Central Java, and West Nusa Tenggara through purposive sampling. The results showed that land area negatively affected tobacco production ($\beta = -0.242$, $p = 0.0001$), indicating inefficiency on larger land areas, possibly due to uneven land quality or problems in land management. In contrast, number of seeds ($\beta = 0.512$, $p < 0.0001$), fertiliser use ($\beta = 0.206$, $p < 0.0001$), and pesticide application ($\beta = 0.139$, $p < 0.0001$) had a positive and significant effect on yield. Labor had no significant effect ($\beta = 0.0003$, $p = 0.9819$), although it made a small contribution to production efficiency. Most farmers manage small to medium scale land (10.5% own 0.30 ha), plant 8,500 seedlings (8.4%), and use 600 kg of fertiliser (8.1%) and 400 ml of pesticide (11.7%). This emphasises the significance of efficient input allocation to support greater productivity. Additionally, the findings reflect farmers' tendency to manage resources conservatively due to cost or knowledge constraints. Overall, these findings confirmed the need to optimise the use of inputs, especially quality seeds, and efficient use of fertilisers and pesticides, to increase productivity while reducing adverse environmental impact and supporting the implementation of sustainable agricultural practices. The present study recommended adopting agricultural technology, farmer training, and crop diversification to improve productivity

Keywords: land area; number of seeds; number of fertilisers; pesticides; labour

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INTRODUCTION

Tobacco production in Indonesia plays a crucial role in the national economy, supporting millions of farmers and contributing significantly to government revenue. However, the industry faces challenges in balancing economic benefits with public health concerns and environmental sustainability. The present study employed a deterministic approach to analyse tobacco production, aiming to improve agricultural practices, improve farmers' welfare, and support sustainable policies. B. Prasetya *et al*. (2025) stated that tobacco cultivation is a primary source of income for many farmers, contributing between 40-80% of their total earnings. As the key raw material for cigarette manufacturing, tobacco is essential for the industry, making it a focal point for both economic stakeholders and tobacco control advocates. The Indonesian government has designated the tobacco industry as a national priority sector due to its economic impact. A 45% increase in tobacco taxes since 2019 is projected to boost economic output by USD 5.11 bn, increase household income by USD 1.46 bn, and create approximately 400,300 jobs (Bella *et al*., 2024). As an agrarian nation, the economy and livelihood heavily depend on agriculture, with natural processes at its core to meet both food and economic needs.

Indonesia, with its rich natural resources, depends on agriculture as the foundation of its economy. Globally, eleven countries – China, Brazil, India, the United States, Turkey, Zimbabwe, Indonesia, Italy, Greece, Malawi, and Argentina – produce nearly 80% of the world's tobacco, with China alone accounting for 33% of global production (World Bank, n.d.). D. Nuryunarsih *et al*. (2021) noted that tobacco, derived from the *Nicotiana* genus, is widely used in clove cigarettes, filter cigarettes, cigars, and other tobacco products. The economic significance of tobacco is clear in its impact on agricultural productivity and export earnings. J. Smith and J. Fang (2020) also noted its role in job creation and economic benefits. Countries like China, India, and Indonesia dominate global production, contributing significantly to rural employment and government revenue through excise taxes. According to E. Fukase and W. Martin (2020), government investment in agriculture enhances productivity, enables efficient resource allocation, and promotes poverty reduction. Despite these benefits, the sector faces challenges such as declining employment, income instability, and opportunity costs linked to unpaid family labour and health risks, as emphasised by D. Samaan *et al*. (2023). Indonesia's diverse agricultural landscape, characterised by varying land conditions across provinces, influences tobacco production strategies and yields. A. Chikowore and A. Chawarika (2024) highlighted that land types markedly affect production outcomes, emphasising the need for tailored development strategies. Land transfer and improved accessibility can enhance economic value and farming systems.

M. Naeem *et al*. (2020) suggested that sustainable agricultural practices, including intensive land management, seed selection, and organic fertiliser use, help maintain productivity, especially in hilly areas. While pesticides are essential for pest control, E. López Dávila *et al*. (2020) warned that their excessive use poses environmental and health risks. To enhance resilience in tobacco farming, M. Shammi *et al*. (2020) proposed implementing crop diversification as an effective adaptation strategy. Labour is another critical factor in tobacco production. M.Z. Rahman *et al*. (2020) emphasised that labour-intensive cultivation provides employment opportunities, benefiting both the government and the market. Z.N. Kebede (2021) highlighted the significance of working capital in enhancing agricultural profitability, particularly for smallholder farmers. Considering these challenges and opportunities, understanding the determinants of tobacco production is essential for improving efficiency, addressing climate challenges, and reducing agricultural poverty.

The purpose of the present study was to identify key determinants of tobacco production in Indonesia and develop a framework for optimising agricultural practices, enhancing farmers' welfare, and promoting sustainable policies in the tobacco sector. By examining variables such as seed quantity, land area, fertiliser use, and labour, the research sought to improve production yields sustainably while balancing economic and environmental considerations.

LITERATURE REVIEW

Tobacco production is increasing in low- and middle-income countries, which creates complications for tobacco control efforts. A. Appau *et al*. (2020) emphasised the need to understand and address global tobacco leaf supply as a means to reduce tobacco consumption and improved farmers' livelihoods. The expansion of tobacco land has significantly affected the land distribution of urban construction as the continued growth of tobacco market demand has driven increased land use for tobacco farming. D.C. Midamba *et al*. (2024) explored the impact of tobacco cultivation on land use and the livelihoods of smallholder farmers in Uganda, indicating that land area influences total tobacco production. The relationship between land area and total tobacco production is evident, considering that most of tobacco is grown by smallholders on small plots of land, where small land area is the principal characteristic of tobacco cultivation. Nevertheless, Indonesia continues to be one of the world's major tobacco producers due to the high intensity of manual labour and local adaptation to agronomic conditions.

However, this needs to be considered as the research findings by J. Shao *et al*. (2024) on tobacco farming in Yunnan Province, China, indicated that the expansion of tobacco land can seriously threaten

biodiversity. This finding emphasises the relevance of regulation to maintain a balance between tobacco farming expansion and environmental conservation. This is also relevant for Indonesia, where the expansion of tobacco growing can have analogous impacts on biodiversity and soil quality. The number of seedlings planted has a direct relationship with the yield of tobacco production. Increasing the number of seeds can increase yields, but it needs to be adjusted to land conditions and the availability of other resources. Tobacco seeds were separated into three weight groups of 76 mg, 65 mg, and 50 mg/1,000 seeds. Germination was tested at 20°C in light and in darkness without disturbance. Adoption of the latest technologies and the use of recommended tobacco varieties can markedly increase yields and farmers' income. T.M. Yola *et al.* (2023) indicated that the adoption of innovative technologies and the use of superior seed selection in tobacco varieties can reduce production costs and increase farmers' profits compared to the use of non-superior seeds.

Tobacco plants require high amounts of pesticides, insecticides, and fertilisers. The role of fertiliser application in tobacco is known to be key for efficient nutrient uptake in application in poor sandy soils as this will result in increased yield and quality of tobacco leaves (Lisuma *et al.,* 2023). Pesticides are chemicals and other materials used to control pests, diseases, and weeds in plants. Their function also includes regulating and stimulating plant growth, but not as fertilisers. According to G.M.V. Lengai *et al.* (2020), pesticides reduce crop yield losses before and after harvest enhancing agricultural productivity their use increases yields and profits but involves costs and potential risks a cost-benefit analysis is essential to optimise their effectiveness. However, in other studies, intensive use of fertilisers and pesticides gradually reduces soil fertility (Sultana *et al.*, 2020).

M.Y. Ali *et al.* (2023) highlighted that while tobacco farmers contribute economic benefits, there are major social and environmental impacts in Bangladesh. This suggests that the government's role in tobacco regulation should involve strategic steps that balance economic benefits with social and environmental considerations. A comparable situation exists in Indonesia, where tobacco is primarily cultivated by smallholders with limited land, relying heavily on family labour and restricting mechanisation. G.A. Sahadewo *et al.* (2020) further observed that in Indonesia, Kenya, and Zambia, household labour costs exceed those of hired labour for both tobacco and non-tobacco farming, with tobacco farming incurring significantly greater household labour costs compared to non-tobacco farming.

By adopting the latest systems and technologies, Indonesia can increase tobacco productivity while addressing labour-related constraints. This step is crucial to ensure the sustainability and efficiency of tobacco production in the future. Current tobacco farmers typically allocate more labour – both from household members and hired workers – for crop cultivation compared to former tobacco farmers. Tobacco farming employs millions of small-scale tobacco farmers worldwide, most of whom are casual farmers dependent on the tobacco industry (Martins-da-Silva *et al.*, 2022). Tobacco farming usually involves various labour-intensive activities, such as planting and harvesting tobacco leaves, drying the leaves, and packaging and transporting the finished product. According to R. MacKenzie *et al.* (2021), tobacco production causes deforestation, soil erosion, and water pollution due to intensive farming practices, while the curing process also contributes to greenhouse gas emissions. These environmental impacts are most evident in Indonesia's major tobacco-producing regions, where deforestation continues to rise alongside the expansion of tobacco farmland.

This plant can thrive in various types of climates, ranging from tropical to sub-tropical regions, and is utilised to produce a variety of products, such as cigarettes, cigars, and snuff (Ndlangamandla *et al.*, 2024). The average productivity of tobacco is still relatively low. Virginia tobacco productivity only reaches 1.3 tonnes per hectare, lower than its optimal potential of 2 tonnes per hectare. This low production is thought to be related to the lack of pure superior varieties used, suboptimal land management, and the absence of the application of pruning technology (World Bank, n.d.). Technological innovations that combine the use of high-yielding varieties, proper fertilisation, and balanced pruning have been proven to increase the productivity and quality of Virginia tobacco in several regions, such as Bojonegoro and Bondowoso (East Java), and East Lombok (West Nusa Tenggara). Commercially viable quality tobacco is only produced in certain regions. Some of the principal areas producing local Virginia tobacco include West Nusa Tenggara (NTB) and East Java. Local Virginia tobacco notably contributes to the regional and national economy, such as being one of the sources of state revenue through cigarette excise. Time trends reflecting technological improvements are expected to positively influence the amount of tobacco production.

MATERIALS AND METHODS

Data collection. This study employed a quantitative approach to analyse the factors that influence Virginia tobacco production in Indonesia (Fig. 2). The variables used in this study included the amount of tobacco production, land area, number of tobacco seeds, amount of fertiliser, pesticides, and the number of workers. Despite their influence on the level of production, some variables that can affect production were omitted, namely, rainfall, land conditions, plant age, season, because this study was conducted in three provinces and the timing of the season could not be predicted. Therefore, that these variables were assumed to be homogeneous for all respondents. Three provinces in Indonesia such as East Java, Central Java, and West Nusa Tenggara were

selected for this study as they are among the most significant areas with Virginia tobacco cultivation capacity and are the largest contributing areas in the tobacco sector in Indonesia.

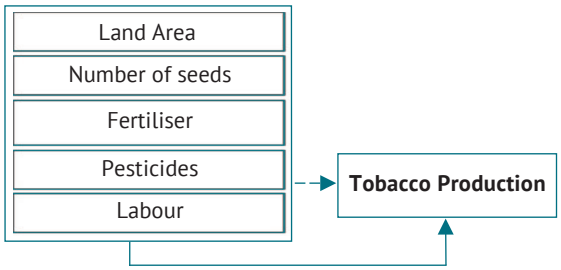


***Figure 1**. Research design*
***Source:** created by authors of this study based on (World Bank, n.d.)*

Sampling. This study was conducted from April to August 2024, following the planting and harvesting seasons among tobacco farmers, labourers, and entrepreneurs in Indonesia. Research participants were selected from three provinces with the largest tobacco production over five consecutive years and significant contributions to the national economy, based on data from the Directorate General of Estates, as presented in Table 1. A purposive sampling method was employed to select participants, with the most respondents coming from East Java, West Nusa Tenggara, and Central Java. To qualify as research participants, individuals had to be actively involved in the tobacco sector, whether as full-time workers, part-time workers, or entrepreneurs. An offline survey was distributed, containing an explanation of the research objectives and a questionnaire, to 418 selected respondents. Participation was conducted anonymously, and all respondents provided informed consent before taking part. This study strictly followed the ethical standards for research involving human subjects (The Declaration of Helsinki, 2013), ensuring that participation was voluntary and free from coercion. To validate the questionnaire used, three experts in the fields of tobacco farming and economics were involved. These experts had over 10 years of experience in their respective fields at the time of study and provided input to ensure the research tools aligned with the study's context and objectives.

The questionnaire was designed to collect information on tobacco farming practices, covering aspects of production and challenges faced by farmers. Respondents provided personal data, land ownership status, as well as the size and number of plots used. The questions covered the type and quantity of seedlings planted, seedling mortality rates, and replanting methods. The use of fertilisers and pesticides was also examined, including their types, quantities, and application during production. Additionally, the questionnaire highlighted labour requirements at each stage of cultivation, harvest yields, sales methods, agricultural equipment, as well as obstacles and efforts made by farmers to improve production outcomes.

Table 2 outlines the distribution of 418 respondents across three provinces: East Java, Central Java, and West Nusa Tenggara (NTB). East Java had the greatest number of respondents (200), followed by NTB (118), and Central Java (100). The selection of these provinces aligned with their status as the top tobacco-producing regions in Indonesia, as evidenced by the production data in Table 1. The distribution reflected the study's focus on areas with pronounced tobacco farming activities, ensuring that the research captures insights from key stakeholders in the industry. The total number of respondents (418) provided a robust sample size for analysing tobacco farming practices and challenges in these regions.

***Table 1**. Distribution of respondents in three provinces in Indonesia*

No.	Province	Number
1	Jawa Timur	200
2	Jawa Tengah	100
3	Nusa Tenggara Barat	118
Total		**418**

***Source:** created by authors of this study based on data from the Directorate General of Estates (2021, 2022, 2023)*

Table 2 presents a detailed breakdown of respondents by subdistrict within the three provinces. In East Java, respondents were evenly distributed across four subdistricts: Bojonegoro, Jember, Pamekasan, and Sumenep, with 50 respondents in each. In Central Java, Temanggung had the largest number of respondents (50), followed by Rembang (30), and Boyolali (20). In West Nusa Tenggara, respondents were concentrated in Lombok Tengah (50) and Lombok Timur (68). This distribution ensured representation from various subdistricts known for tobacco farming, enabling a comprehensive analysis of regional differences in farming practices, challenges, and outcomes. The focus on specific subdistricts highlighted the localised nature of tobacco cultivation and its economic significance in these areas.

***Table 2**. Distribution of respondents in three provinces in Indonesia (by Subdistrict)*

Province	Municipality	N
East Java	Bojonegoro	50
	Jember	50
	Pamekasan	50
	Sumenep	50
Central Java	Temanggung	50
	Rembang	30
	Boyolali	20
West Nusa Tenggara	Lombok Tengah	50
	Lombok Timur	68

***Source:** created by authors of this study based on data from the Directorate General of Estates (2021, 2022, 2023) and World Bank (n.d.)*

Data analysis. To analyse the magnitude of the influence between variables, an econometric estimation model was employed. Regression analysis was applied to predict the causal relationship between variables. Additionally, tobacco farmers differed in the amount of input used in managing their farms. To estimate the regression coefficient, it is necessary to calculate the natural logarithm (Ln) of each variable that has an unequal unit of measure when entered into the model. This process will result in the following equation being obtained:

$$Ln\_TProduction_i = \alpha + \beta_1 Ln\_LA_i + \beta_2 Ln\_NS_i + \\ + \beta_3 Ln\_NF_i + \beta_4 Ln\_Pest_i + \beta_5 Ln\_Labour_i + \mu, \quad (1)$$

where Ln is the natural logarithm (e = 2.718); TProduction is the total production of tobacco (kg); LA is the land area (ha); NS is the tobacco seedlings (pcs); NF is the fertiliser requirement (kg); Pest is the pesticide (ml); Labour is the total labour (person). The subscript i denotes the cross-sectional unit of observation, referring to each individual farmer included in the sample. The term α represents the intercept of the regression equation, indicating the expected log of tobacco production when all explanatory variables are at their base levels. Coefficients β_1 to β_5 represent output elasticities, measuring the percentage change in output due to a 1% change in each input. The error term μ accounts for unobserved factors influencing production.

Impact assessment framework. Figure 2 illustrates various factors influencing tobacco production in Indonesia, where each factor has sub-factors contributing to production efficiency. The horizontal axis in the diagram represents the primary production factors, namely land area, number of seedlings, amount of fertiliser, pesticide use, and labour. The vertical axis shows the derivative elements of each primary factor that determine the success of tobacco production.

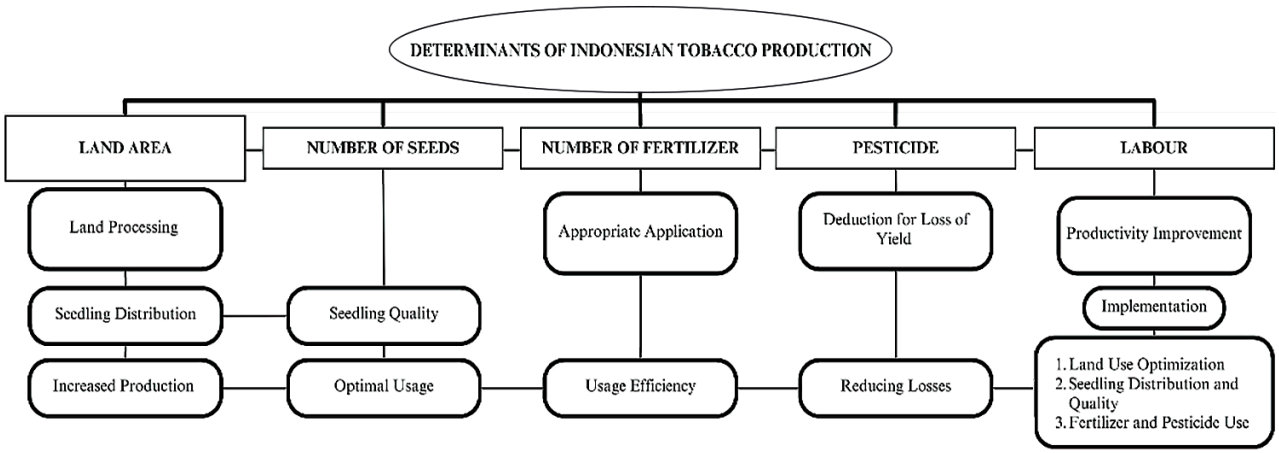


***Figure 2**. Framework of determinants of tobacco production in Indonesia*

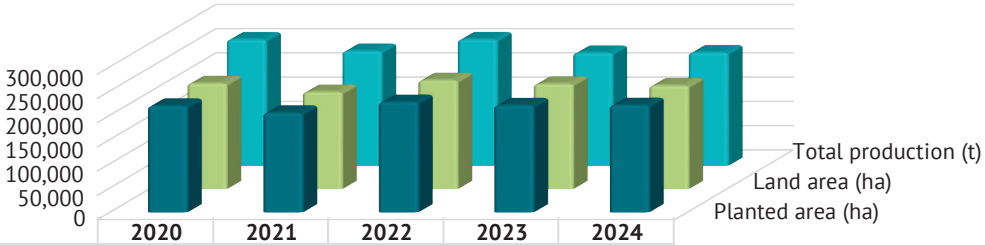
***Source:** compiled by authors of this study based on N.N. Sultana et al. (2020), G.A. Sahadewo et al. (2020), M. Yahui et al. (2021), R. MacKenzie et al. (2021), T.M. Yola et al. (2023), World Bank (n.d.)*

This study was conducted following the ethical principles outlined in the Declaration of Helsinki (2013). Although this study was not funded by any institution or agency and therefore did not involve formal ethical approval documents from an ethics committee, the authors of this study ensured that all research procedures were designed to protect participants' rights, privacy, and well-being. Participation in this study was

voluntary, with all respondents providing consent upon receiving sufficient information regarding the objectives, procedures, and their right to withdraw from participation at any time without any negative consequences. The authors of the present study emphasise that no coercion or pressure was applied to participants during the research process. The authors are strongly committed to confidentiality and data protection. All collected data were anonymised when necessary to prevent participant identification, and strict measures were implemented to secure sensitive information. The identities of all respondents were strictly safeguarded, with access to personal data restricted only to authorised researchers and solely for the purposes of this study.

RESULTS AND DISCUSSION

Overview of tobacco production. Indonesia's tobacco production has fluctuated in recent years due to weather, technology, and policy factors. As presented in Figure 1, output peaked at 261,018 tonnes in 2020 but declined to 234,138 tonnes by 2024. East Java, the top producer, saw a drop from 128,919 tonnes (2020) to 109,539 tonnes (2024) due to climate change, soil degradation, and land access challenges.



	2020	2021	2022	2023	2024
Planted area (ha)	219,774	205,406	227,673	220,830	221,290
Land area (ha)	218,476	200,626	224,905	217,275	213,883
Total production (t)	261,018	237,116	261,208	233,255	234,138

***Figure 3**. Planted area, land area, and tobacco production in Indonesia*
***Source:** created by authors of this study based on data Directorate General of Estates (2021, 2022, 2023)*

Table 3 presents tobacco production data (in tonnes) across various provinces in Indonesia from 2020 to 2024. The data reveals significant variations in production levels among provinces. East Java consistently dominates tobacco production, with figures ranging from 128,919 tonnes in 2020 to 109,539 tonnes in 2024, despite a gradual decline. Central Java and West Nusa Tenggara (NTB) also contribute substantially, with Central Java producing between 57,643 tonnes (2020) and 50,439 tonnes (2024), and NTB ranging from 57,065 tonnes (2020) to 56,667 tonnes (2024). Other provinces, such as North Sumatra, Lampung, and South Sulawesi, show fluctuating but relatively lower production levels. Notably, provinces like South Sumatra and Central Sulawesi have minimal contributions, with production below 100 tonnes in some years. This data highlights the concentration of tobacco production in specific regions, particularly Java and NTB, which are key contributors to Indonesia's national tobacco output.

***Table 3**. Tobacco production data by province in Indonesia*

Provinces	Production (tonnes)				
	2020	2021	2022	2023	2024
Aceh	2.255	2.110	2.273	2.244	2.339
Sumatera Utara	1.740	1.754	1.754	1.613	1.807
Sumatera Barat	245	123	247	250	314
Jambi	166	177	167	159	180
Sumatera Selatan	61	114	61	38	30
Lampung	910	812	916	700	497
Jawa Barat	8.035	7.435	8.096	7.773	8.721
Jawa Tengah	57.643	57.645	58.082	52.151	50.439
D.I Yogyakarta	744	835	750	671	471
Jawa Timur	128.919	110.814	129.901	114.013	109.539
Bali	350	307	353	323	307
Nusa Tenggara Barat	57.065	53.122	57.500	50.718	56.667
Nusa Tenggara Timur	830	749	836	714	754
Sulawesi Tengah	107	107	107	79	65
Sulawesi Selatan	1.948	1.012	165	1.809	2.008

***Source:** created by authors of this study based on data Directorate General of Estates (2021, 2022, 2023)*

The Figure 4 illustrates the concentration of tobacco production in three key provinces of Indonesia: East Java, Central Java, and West Nusa Tenggara (NTB). East Java recorded the largest production at 109,539 tonnes, solidifying its position as the national hub for tobacco production. Central Java contributed 50,439 tonnes, while NTB produced 56,667 tonnes, making both regions major players in the tobacco industry. This data indicates that tobacco production in Indonesia is concentrated in these three provinces, with East Java leading the way. This concentration reflects the crucial role of the tobacco sector in the regional and national economy, supported by geographical, climatic, and agricultural traditions that favour tobacco cultivation in these areas.

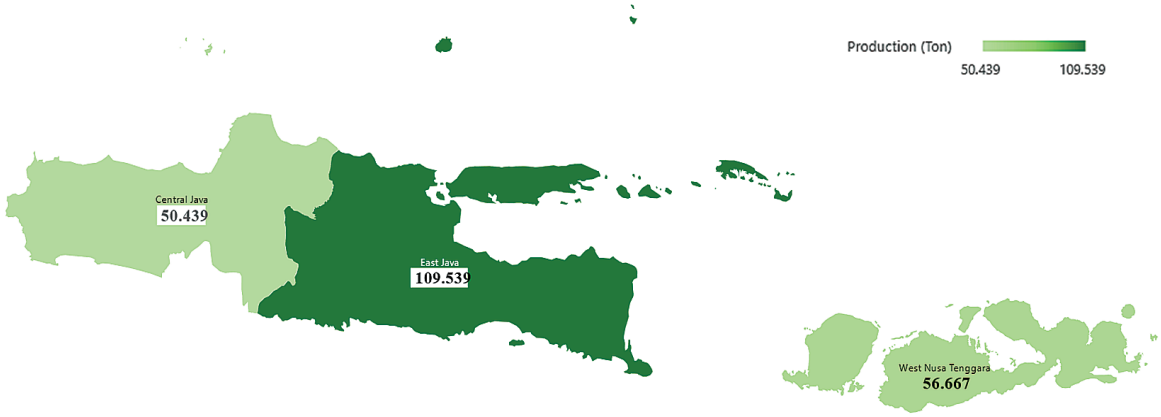


***Figure 4**. Distribution of tobacco production in Indonesia (top three largest provinces)*
***Source:** created by authors of this study based on Directorate General of Estates (2021, 2022, 2023) and World Bank (n.d.)*

Tobacco variants in Indonesia are remarkably diverse, which can be identified from their morphology or characteristics. This is related to the long adaptation of tobacco in various agroecologies of plantation areas spread across 15 provinces, from dryland to irrigated and from lowland to upland. Tobacco was introduced in Indonesia more than four centuries ago and is mostly used for cigarettes. The significance of research into production determinants cannot be underestimated, considering its valuable contribution to the national economy (Sahadewo, 2023). The survey involved 418 active tobacco farmer households located in the key tobacco producing provinces of East Java, Central Java, and West Nusa Tenggara. In the next stage of the study, various key selected sub-districts in Indonesia were randomly sampled for farmers based on the amount of tobacco production (Table 3). The graph below (Fig. 5) presents the data of tobacco land area and a brief explanation of the distribution of land area owned (in hectares).

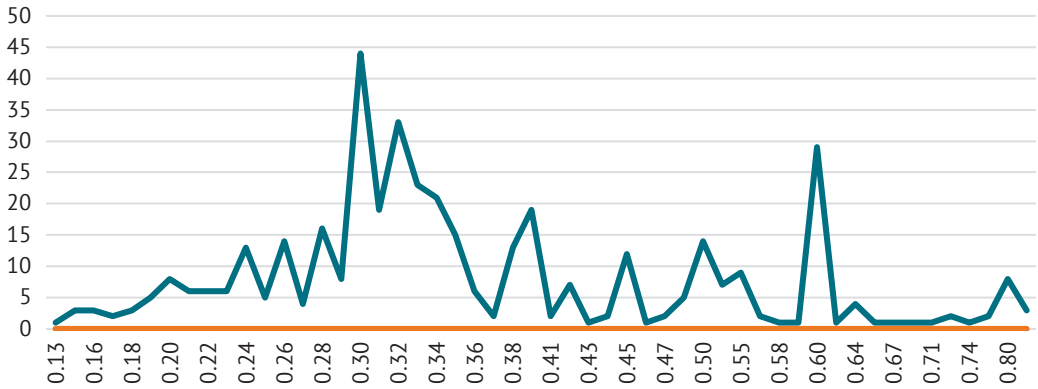


***Figure 5**. Distribution of tobacco land area (Ha) based on respondent data*
***Source:** created by authors of this study*

The distribution of the size of land owned by the 418 respondents shows that the majority owns relatively small plots of land, with the most widespread land size being 0.30 ha, owned by 44 respondents (10.5%). The other dominant groups included landholders with 0.32 ha (33 respondents or 7.9%) and 0.60 ha (29 respondents or 6.9%). Most respondents owned land that ranged within 0.20-0.40 ha, indicating that land distribution was concentrated in this category. In contrast, certain land sizes such as 0.13 ha, 0.43 ha, 0.46 ha,

0.58 ha, and a few others were owned by only 1 respondent (0.2%), indicating the rarity of land ownership at these sizes. This reflects that most farmers own small to medium-sized landholdings, which was relevant for analysing tobacco production in Indonesia.

Data on the distribution of the number of tobacco seedlings planted (Fig. 6) shows that most farmers plant within 7,000-8,500 seedlings. The most dominant number of seedlings was 8,500 pcs, which is planted by 35 farmers (8.4%), followed by 8,000 pcs with 34 farmers (8.1%). Additionally, 7,000 and 7,500 seedlings also showed a strong number, with 24 farmers (5.7%) and 31 farmers (7.4%) respectively. In contrast, the number of seedlings under 6,000 pcs or over 10,000 pcs tended to have a lower frequency. Only 1 farmer (0.2%) planted 3,000 seedlings, while only 10 farmers (2.4%) planted 15,000 seedlings.

At exceedingly high numbers, such as 25,000 seedlings, there was only 1 farmer (0.2%). This pattern reflected that most farmers choose an intermediate seedling quantity between 7,000 pcs and 8,500 pcs, which may reflect farming practices that are compatible with land capacity or yield optimisation strategies. Farmers with exceedingly small or large seedling numbers reflect the diversity of tobacco farming scale, which may be influenced by factors such as land size, resource availability, or financial capability. The distribution data of the amount of fertiliser used by tobacco farmers in kilograms (Fig. 7) shows that most farmers use fertiliser within 500-600 kg. The largest amount of fertiliser used was 600 kg with a frequency of 34 farmers (8.1%), followed by 590 kg with a frequency of 27 farmers (6.5%). Additionally, 750 kg of fertiliser was also used by 19 farmers (4.5%).

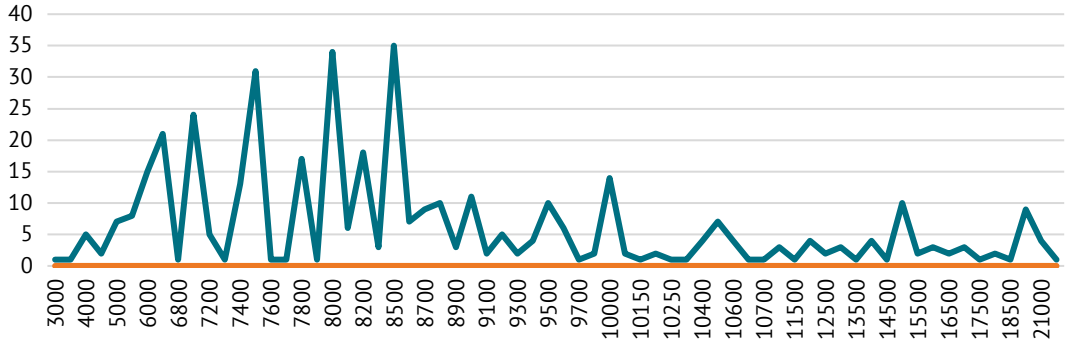


***Figure 6**. Distribution of quantity of tobacco seedlings (pcs) based on respondent data*
***Source:** created by the authors of this study*

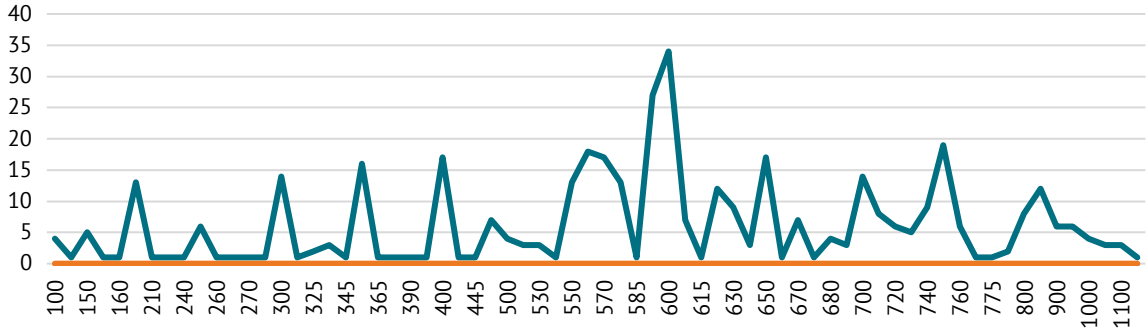


***Figure 7**. Distribution of fertiliser amount (kg) based on respondent data*
***Source:** created by the authors of this study*

Fertiliser usage below 200 kg or above 800 kg had a lower frequency, indicating that most farmers are in the moderate fertiliser usage category. For example, only 1 farmer (0.2%) used 120 kg or over 1,000 kg of fertiliser, respectively. This trend illustrates a relatively concentrated pattern of fertiliser use around the optimal number that supports tobacco yields. Fertiliser usage within 400-750 kg shows a significant pattern, such as the use of 400 kg by 17 farmers (4.1%) and 650 kg by 17 farmers (4.1%). This data reflects farmers' efforts to balance the nutritional needs of the plants with the capacity of their land. Additionally, variations in fertiliser use may be explained by differences in farming practices, land type, and accessibility to fertilisers.

Based on the data on the use of pesticides in millilitres (ml) in Figure 8, there are variations in the frequency of use with concentrations at certain amounts. The most frequently used amount of pesticide was 400 ml with a frequency of 49 respondents (11.7%), indicating that most farmers chose this amount as the main dose.

Additionally, the use of 200 ml was also significant with a frequency of 41 respondents (9.8%). The frequency of pesticide use in the 300-600 ml range was fairly evenly distributed, with frequently used amounts such as 500 ml (24 farmers or 5.7%), 350 ml and 370 ml (19 farmers or 4.5% each), and 340 ml and 600 ml (18 and 19 farmers, respectively, about 4.3-4.5%). In contrast, the use of pesticides at under 100 ml or over 800 ml was extremely low. For example, only 1 farmer (0.2%) used 900 ml or 1,000 ml of pesticides, reflecting that extreme use is rare. This could be explained by the efficient use of pesticides tailored to crop needs or awareness of environmental impacts. This distribution shows that most farmers tend to use moderate amounts of pesticides (200-500 ml). This pattern indicates a consistency in pesticide application methods. However, there are also small variations that may be influenced by land conditions, crop type, or accessibility to pesticides.

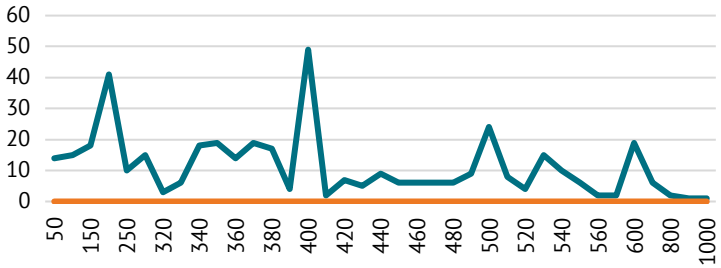


***Figure 8**. Distribution of pesticides (ml) based on respondent data*
***Source:** created by the authors of this study (2024)*

Data on the distribution of labour use (Fig. 9) showed that most tobacco farmers employed labour in the range of 8 to 15 people, with 9 people being the most dominant (14.8%), followed by 8 people (12.7%). This reflects the tendency of small to medium-scale enterprises to maximise labour efficiency in this range. Additionally, the use of a workforce of 10 people (7.9%) and 14 and 15 people (7.2% each) was also quite significant, indicating that operations were centred on a moderate number of workers. In contrast, labour numbers below 6 people or above 30 people were rare, involving only a handful of businesses. A small number of workers (5 to 7 people) was only used by around 5.5% of businesses, while the use of a large number of workers such as 72 to 97 people was exceedingly rare. This pattern indicated that most farmers operated with an efficient labour structure suitable for the needs of lower-middle-scale businesses.

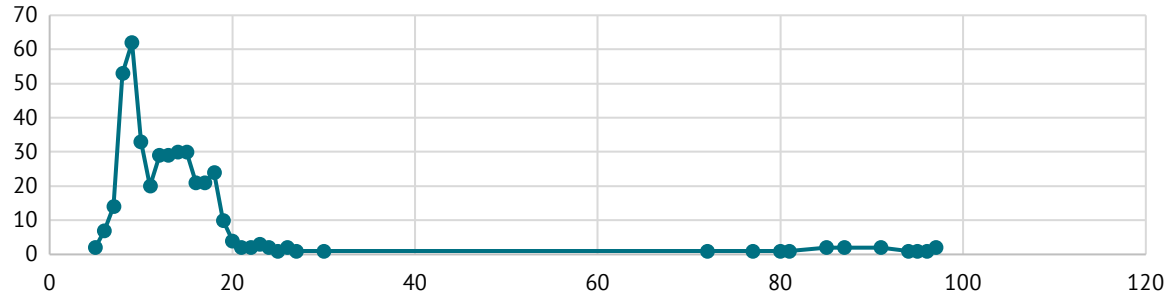


***Figure 9**. Distribution of labour usage (person) based on respondent data*
***Source:** created by the authors of this study (2024)*

The regression results (Table 4) indicate that land area (Ln_LA) had a significant negative effect on tobacco production, with a coefficient of -0.242433 and a probability of 0.0001. This implies that a 1% increase in land area reduces production by approximately 0.242%, potentially due to inefficiencies in land use or uneven land quality. This finding contrasts with the results presented by M. Yahui *et al.* (2021), who emphasised land suitability for yield improvement, and aligned with J. Shao *et al.* (2024), who warned against unregulated land expansion due to its environmental and productivity risks. The study highlighted that tobacco cultivation is often more effective on smaller plots, as larger areas may lead to inefficiencies. Despite these challenges, Indonesia continues to be a major global tobacco producer, supported by intensive manual labour and local adaptation to agronomic conditions.

Tobacco seeds (Ln_NS) significantly and positively affect production, with a coefficient of 0.512401 and a probability of 0.0000, indicating that a 1% increase in seed quantity can raise production by approximately 0.512%. This highlights the critical role of high-quality seedlings in boosting productivity. However, seed effectiveness depends on land conditions and the adoption

of adequate technologies. Increasing the number of seeds can enhance yields, but this must be balanced with resource availability and sustainable practices. The adoption of superior seed varieties and the latest technologies can reduce production costs and increase farmers' income, as supported by T. Yola *et al.* (2023). Still, the expansion of tobacco farming must be carefully managed to avoid adverse environmental impacts, such as threats to biodiversity and soil quality, as highlighted by J. Shao *et al.* (2024). Sustainable practices are essential to balance production growth with environmental conservation.

***Table 4**. Regression analysis results*

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.323571	0.625316	-0.517453	0.6051
Ln_LA	-0.242433	0.060379	-4.015215	0.0001
Ln_NS	0.512401	0.058356	8.780566	0.0000
Ln_NF	0.206108	0.036447	5.655008	0.0000
Ln_PEST	0.139687	0.025096	5.566184	0.0000
Ln_LABOUR	0.000311	0.013673	0.022735	0.9819

***Source:** created by the authors of this study*

The amount of fertiliser (Ln_NF) also has a significant positive effect on production with a coefficient of 0.206108 and a probability of 0.0000. This means that a 1% increase in fertiliser use will increase production by about 0.206%. This result indicates the significance of fertiliser use in supporting the productivity of tobacco plants, so that the management of fertiliser needs must be considered optimally. Fertiliser usage shows a significant positive effect on tobacco production, consistent with the findings of J.B. Lisuma *et al.* (2023), who highlighted the relevance of fertiliser application in improving crop quality and yield. However, inadequate fertiliser use can adversely impact soil fertility in the long term, as warned by N.N. Sultana *et al.* (2020). Therefore, effective fertiliser management is necessary for sustainability. Pesticide (Ln_PEST) has a significant positive effect on production with a coefficient of 0.139687 and probability of 0.0000. A 1% increase in pesticide use can increase tobacco production by approximately 0.14%. Tobacco requires high pesticide and fertiliser use, with fertilisers improving yield and leaf quality, especially in poor soils. Pesticides reduce crop losses and increase productivity, according to G.M.W. Lengai *et al.* (2020), but excessive use can degrade soil fertility. Balancing their application with sustainable practices is crucial for long-term productivity and environmental health.

Total labour (Ln_LABOUR) showed no significant effect on production with a coefficient of 0.000311 and probability of 0.9819. This result indicates that changes in the amount of labour have no significant impact on tobacco production, which may suggest that labour input is less relevant than other input factors. Production optimisation is better focused on the use of significant inputs such as seeds, fertilisers, and pesticides. Tobacco farming provides economic benefits but also creates social and environmental challenges, as highlighted by M.Y. Ali *et al.* (2023). Analogous trends in Kenya and Zambia showed greater household labour costs than hired labour, especially in tobacco farming (Lencucha *et al.*, 2022). Strategic government action is needed to balance economic benefits with social and environmental sustainability. Various studies have consistently reported proportionally greater agricultural input costs for tobacco crops compared to non-tobacco crops grown in the same geographical area in the same season (Hussain *et al.*, 2020). Strong supply chains, such as in tobacco-producing countries, allow farmers to access essential inputs such as seeds, fertilisers, and pesticides. In this study, these inputs were shown to significantly affect production outcomes. For example, in Kenya, the government does not provide resources for research related to tobacco farming, and therefore information on tobacco cultivation depends entirely on the industry (Appau *et al.*, 2020). Through contractual arrangements, farmers can borrow essential inputs such as seeds, fertilisers, and pesticides, with repayment made after their tobacco crop is sold to the lender (Nguenha *et al.*, 2021).

The study revealed significant insights into the determinants of tobacco production in Indonesia, focusing on land area, seed quantity, fertiliser use, pesticide application, and labour input. The regression analysis indicated that land area has a significant negative effect on production, suggesting that larger landholdings may lead to inefficiencies. In contrast, the quantity of seeds and the use of fertilisers and pesticides have significant positive effects on production, highlighting their critical roles in enhancing yield. Specifically, a 1% increase in seed quantity, fertiliser use, and pesticide application can raise production by approximately 0.512%, 0.206%, and 0.14%, respectively. However, labour input does not significantly influence production, indicating that other factors such as seed quality and input management are more crucial for optimising yields. The obtained findings underscore the value of sustainable practices in tobacco farming, balancing productivity with environmental and social considerations. This aligns with

global trends where efficient input management and technological adoption are key to improving agricultural outcomes.

CONCLUSIONS

The present study highlighted that tobacco production in Indonesia is significantly influenced by several key factors, including land area, the number of seeds, fertiliser use, pesticide application, and labour. The findings reflected a strong relationship between the efficient use of production inputs and the amount of output produced. Specifically, the regression analysis revealed that land area (Ln_LA) had a significant negative effect on production, with a 1% increase in land area reducing production by approximately 0.242%. In contrast, the number of seeds (Ln_NS), fertiliser usage (Ln_NF), and pesticide application (Ln_PEST) had significant positive effects, with a 1% increase in these inputs raising production by 0.512%, 0.206%, and 0.14%, respectively. Labor input (Ln_LABOUR), however, showed no significant impact on production, suggesting that other factors such as seed quality and input management are more critical for optimising yields.

As a strategic commodity, tobacco plays a vital role in the regional economy, particularly in key production areas such as East Java, Central Java, and West Nusa Tenggara, which have long been the centres of national tobacco production. The survey data revealed that most farmers own small to medium-sized landholdings, with 44 respondents (10.5%) owning 0.30 ha, the most widespread land size. Additionally, most farmers plant between 7.000-8.500 seedlings, use 500-600 kg of fertiliser, and apply moderate amounts of pesticides (200-500 ml). These findings align with the significance of quality seeds, as highlighted in previous studies, which found that seed weight affects germination rates and crop quality. Analogously, fertilisers and pesticides are crucial for increasing yields, although excessive use can have adverse environmental impacts, as noted in other studies. Labour, while not statistically significant in the regression analysis, continues to be an essential factor in production efficiency, particularly in Indonesia's labour-intensive tobacco sector. The findings emphasised the significance of optimised production input management and adequate policy support, such as improved access to agricultural technology, training for farmers, and sustainable farming practices. This not only enhances yields but also ensures the long-term sustainability of the tobacco sector in the face of economic and environmental challenges. For instance, adopting superior seed varieties, efficient fertiliser and pesticide management, and labour training can markedly improve productivity while minimising environmental degradation.

Future research should explore the long-term environmental impacts of tobacco farming, particularly the effects of intensive fertiliser and pesticide use on soil health and biodiversity. Additionally, studies could investigate the socio-economic implications of tobacco farming on rural communities, including labour conditions and income stability. Further analysis could also focus on the adoption of innovative technologies, such as precision agriculture, to optimise input use and reduce environmental footprints. Finally, comparative studies between tobacco and alternative crops could provide insights into diversifying agricultural practices in tobacco-producing regions, ensuring both economic viability and environmental sustainability.

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CONFLICT OF INTEREST

The authors of this study declare no conflict of interest.

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Аналіз виробництва тютюну в Індонезії: Детерміністичний підхід

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Анотація. Підвищення ефективності виробничих ресурсів має вирішальне значення для підвищення продуктивності та стійкості тютюнового господарства в Індонезії. У цьому дослідженні було проаналізовано вплив площі земельних угідь, кількості насіння, використання добрив, застосування пестицидів та робочої сили на виробництво тютюну за допомогою множинної лінійної регресії з використанням натурального логарифмічного перетворення. Дані були зібрані від тютюнових фермерів у Східній Яві, Центральній Яві та Західній Нуса-Тенггара за допомогою цілеспрямованої вибірки. Результати показали, що площа земельних угідь негативно впливала на виробництво тютюну (β = -0,242, p = 0,0001), що вказує на неефективність на більших площах, можливо, через нерівномірну якість землі або проблеми в управлінні земельними ресурсами. Натомість кількість насіння (β = 0,512, p < 0,0001), використання добрив (β = 0,206, p < 0,0001) та застосування пестицидів (β = 0,139, p < 0,0001) мали позитивний і значний вплив на врожайність. Праця не мала значного впливу (β = 0,0003, p = 0,9819), хоча все ж мала невеликий внесок у ефективність виробництва. Більшість фермерів обробляють невеликі та середні ділянки землі (10,5 % володіють 0,30 га), висаджують 8500 саджанців (8,4 %) та використовують 600 кг добрив (8,1 %) і 400 мл пестицидів (11,7 %). Цей висновок підкреслює важливість ефективного розподілу ресурсів для підвищення продуктивності. Крім того, результати дослідження відображають тенденцію фермерів до консервативного управління ресурсами через обмеження у витратах або знаннях. Загалом, ці результати підтверджують необхідність оптимізації використання ресурсів, особливо якісного насіння та ефективного використання добрив і пестицидів, для підвищення продуктивності при одночасному зменшенні негативного впливу на навколишнє середовище та підтримці впровадження стійких сільськогосподарських практик. Це дослідження рекомендує впровадження сільськогосподарських технологій, навчання фермерів та диверсифікацію культур для підвищення продуктивності

Ключові слова: площа землі; кількість насіння; кількість добрив; пестициди; робоча сила