JURNAL AGROEKOTEKNOLOGI TERAPAN
Applied Agroecotechnology Journal

Agroteknologi Universitas Sam Ratulangi **e ISSN:2797-0647**

A Model for Forecasting Production in Large-Scale and Smallholder Plantations in Indonesia

Ellen Grace Tangkere*, Maya Hendrietta Montolalu, Caroline Betsy Diana Pakasi, Maelani Ai Kaban.

Faculty of Agriculture, Sam Ratulangi University, Manado, 95115, Indonesia

*Corresponding author:
ellentangkere16@gmail.com

Manuscript received: 23 Nov. 2024. Revision accepted: 14 Dec 2024.

Abstract

This study aims to develop a model that can predict the production of large plantation crops and smallholder plantations in Indonesia. The results are expected to contribute to the agricultural management strategy in Indonesia that allows this sector to continue to be one of the backbones of the national economy. The data collection method involves the annual report of the Indonesian Central Statistics Agency and global data published by the Food and Agricultural Organization from several decades ago to the present. Data analysis will involve time-series modeling, especially Auto Regressive Integrated Moving Average (ARIMA) and the latest machine-learning approach. The assessment of predictive ability is carried out through Receiver Operating Curves (ROC) curve analysis. The final model is selected based on the ability to predict the output of the simulation data. The ARIMA and NNAR models generally support the continued increase in palm oil seed production on large plantations in Indonesia at least until 2030. Meanwhile, coconut production, on the other hand, tends to continue to decline. These results indicate that the community that is the backbone of smallholder plantations needs to think in the long term to try to farm other production crops. This is because coconut plants, without changes in market demand, technological changes, or economic intervention, will continue to decrease in production in the coming years.

***Keywords**: Production, Large Plantations, Smallholder Plantations*

INTRODUCTION

The agricultural sector in Indonesia consists of large plantations owned by the state or private companies and smallholder plantations owned by individual farmers. Large plantations typically focus on key export commodities such as oil palm and rubber (Tiesnamurti et al., 2024), while smallholder plantations concentrate on crops such as rice, soybeans, maize, fruits, and vegetables (N. Setianto et al., 2025). Balancing production between large plantations and smallholder plantations is essential to ensuring the sustainability of the agricultural sector as a vital contributor to Indonesia's economy (Wenzel et al., 2024). The plantation sub-sector is one of the important components of agriculture, and its role is equally significant compared to other sub-sectors in contributing to the Gross Regional Domestic Product (GRDP). Various commodities produced by the plantation sub-sector, including rubber, oil palm, coconut, cinnamon bark, and robusta coffee, serve as raw materials for industry and are widely accepted in international markets (Yanita et al., 2024). The plantation sub-sector has also traditionally been an important source of foreign exchange for the country. Most plantation crops are cultivated by smallholders, while the remainder are managed by large plantations owned by either the government or private enterprises (Abdi & Mohamed, 2025).

Indonesia's abundant fertile soils are a fundamental driver of its rich variety of tropical agricultural products. While the agricultural sector's contribution to the country's Gross Domestic Product (GDP) has declined over the last fifty years, it continues to serve as the main source of income for most Indonesian households. In 2012, approximately 49 million people were employed in agriculture, representing around 41 percent of the national workforce. Although the absolute number of agricultural workers has continued to rise, their share of total employment has dropped considerably, falling from about 55 percent in the 1980s to 45 percent in the

1990s and now standing below 40 percent. Between the mid-1960s and mid-1980s, around 21 percent of Indonesia's total land area was devoted to agriculture. This share increased to roughly 25 percent from the mid-1980s to the late 1990s. Since 1998, land use has expanded rapidly to approximately 30 percent, largely due to the development of large-scale plantations, especially oil palm (Indonesia Investments, 2015).

Building on the preceding discussion and considering the plantation sub-sector's role in driving Indonesia's economic growth, this study aims to develop a prediction model for production in both large-scale and smallholder plantations in Indonesia. The research is intended to support agricultural management strategies that will enable the sector to remain a key pillar of the national economy.

Data collection will draw on annual reports from Indonesia's Central Bureau of Statistics and global datasets published by the Food and Agriculture Organization, spanning several decades to the present. The analysis will employ time-series modeling techniques, particularly Auto Regressive Integrated Moving Average (ARIMA) models, alongside advanced machine learning approaches. Predictive performance will be assessed using the Receiver Operating Characteristic (ROC) curve analysis. The final model will be selected based on its predictive accuracy on simulated data and subsequently validated against real-world observations.

Smallholder Plantations and Large-Scale Plantations

Plantations refer to activities that involve cultivating specific crops within suitable ecosystems, followed by processing and marketing the resulting goods and services. Indonesia is known for its fertile soils, which are highly suitable for a variety of plantation crops. These include oil palm, coffee, rubber, tobacco, cocoa, sugarcane, and others. Plantations in Indonesia are commonly classified based on ownership structure and scale of operation:

- Smallholder plantations are cultivation activities managed by individual farmers, typically on limited land areas, with most of the production intended for sale. These operations are not established on land with cultivation rights (HGU). Examples of smallholder plantations include rubber, coffee, coconut, and tobacco (Mustofa, 2021).
- Large-scale plantations are cultivation enterprises operated by state-owned enterprises or private companies, with all production intended for large-scale commercial sale. Examples include oil palm, cocoa, coffee, and tobacco plantations (wulandari & kemala, 2016).

According to Indonesia's Plantation Law, plantations serve three primary functions. First, there is the economic function, which involves improving public prosperity and welfare, as well as strengthening regional and national economic structures. Second, the ecological function includes enhancing soil and water conservation, acting as a carbon sink, supplying oxygen, and supporting protected areas. Third, the socio-cultural function emphasizes fostering national unity.

Future development of plantation crops faces the challenge of selecting species well-suited to local environmental conditions while also ensuring strong market prospects. Plantation crops are essential commodities that support industrial needs, serve as a source of foreign exchange earnings, and contribute to public welfare. Thus, there is significant importance placed on the sustainable development of plantation crops.

Plantations are considered one of several sub-sectors within agriculture. The definition used in this study follows Law No. 18 of 2004 on Plantations, which describes plantations as all activities involving the cultivation of specific crops

on land or other suitable growing media within an appropriate ecosystem, processing and marketing the resulting goods and services, with the application of science and technology, capital investment, and management practices to improve the welfare of plantation business actors and society.

Plantations are managed based on the principles of utility and sustainability, integration, cooperation, transparency, and equity. The objectives of plantation management include: (1) increasing community income; (2) boosting state revenue; (3) increasing foreign exchange earnings; (4) providing employment opportunities; (5) enhancing productivity, added value, and competitiveness; (6) meeting domestic consumption needs and supplying raw materials for local industries; and (7) optimizing the sustainable management of natural resources.

Indonesia is widely recognized as an agrarian country, relying on outputs from the agricultural and plantation sectors both as primary sources of livelihood and as essential pillars of development. The agriculture and plantation sectors are among the most important contributors to household income in Indonesia, given that the majority of the population is engaged in farming and plantation activities.

In the 21st century, agriculture and plantations in Indonesia must be seen as economic sectors equal in importance to others. These sectors should no longer be treated merely as supporting players in development, but must take on a leading role comparable to that of industry. For this reason, the agriculture and plantation sectors must be developed to be competitive, modern, efficient, and capable of achieving excellence (P. Setianto & Susilowati, 2014).

Plantation Commodities

A priority (or flagship) commodity is defined as a key commodity with strategic importance, determined by both technical factors (such as soil and climate suitability) and socio-economic and institutional considerations (including technological mastery, human resource capacity, infrastructure, and local socio-cultural conditions. The development of priority commodities should consider three main aspects—ecological, economic, and social—to ensure the sustainability of the production system in a given region. Furthermore, the availability of technological innovations is a critical factor in developing regional priority commodities, helping to accelerate agricultural development in each area and deliver tangible welfare benefits to communities.

The term plantation commodity generally refers to a group of specific crops or commodities. According to the Minister of Agriculture Decree No. 511/KPTS/PD 310/9/2006 on the Types of Crops Managed by the Directorate General of Plantations, Directorate General of Food Crops, and Directorate General of Horticulture, the scope of plantation commodities includes 124 crop types plus two groups of supporting plantation crops. Plantation commodities cover crops other than food crops and horticulture. Among these 124 plantation commodities, the main ones include oil palm, coconut, rubber, sugarcane, tobacco, cinchona, tea, coffee, and cocoa (Evizal, 2014).

Efforts to improve technological innovation are key drivers of competitiveness for agricultural commodities, including those produced in the plantation sector within a given region. Developing priority commodities is essential for the sustainable growth of agribusiness in the era of globalization. In many regions, development is planned through the designation of plantation-based production zones.

Plantation commodities are commonly grouped based on the type of product or its use. Examples include oil

crops such as coconut and oil palm; beverage crops such as coffee, cocoa, and tea; spice crops such as pepper, nutmeg, and cinnamon; and sweetener crops such as sugarcane. There is no formal criterion yet for classifying plantation crops as "major" or "minor," but such groupings are typically based on long-term statistical production data. Coconut remains one of the largest contributors to Indonesia's economy among plantation commodities (Wachjar, 2019).

RESEARCH METHOD

Study Design, Setting, and Period

This research adopts an observational design using secondary data analysis. The primary data source consists of survey results published by Indonesia's Central Bureau of Statistics (Badan Pusat Statistik, BPS). The dataset includes annual information covering multiple years. The study population comprises smallholder plantations in Indonesia, with the sample drawn from all available observations in the BPS data. The unit of analysis is defined as annual observations. The planned study period is nine months, from proposal preparation in February 2023 to final reporting in December 2023.

Data Collection Approach

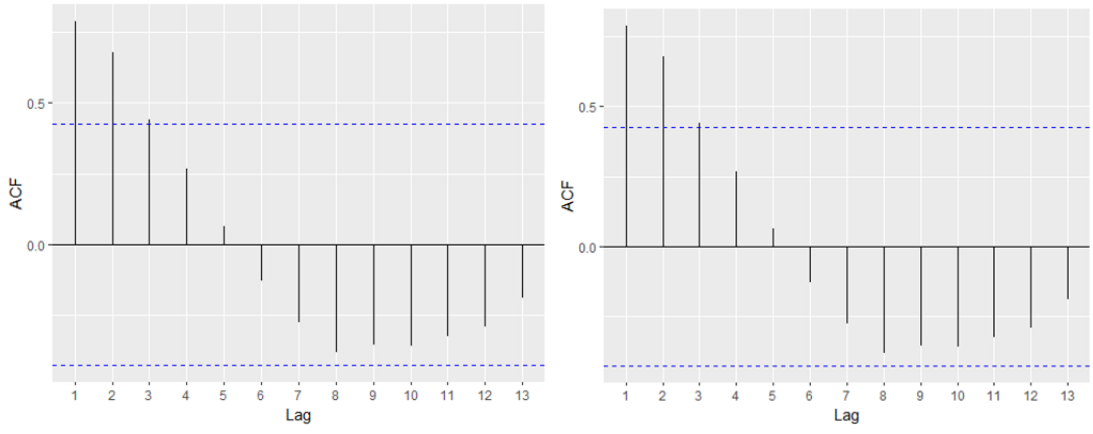
Data were collected from annual reports produced by Indonesia's Central Bureau of Statistics (BPS) and global datasets provided by the Food and Agriculture Organization (FAO), spanning multiple decades through to the present.

Statistical Analysis

The statistical analysis comprises time-series modeling, particularly employing Auto Regressive Integrated Moving Average (ARIMA) models, alongside advanced machine learning approaches. Model performance will be assessed through Receiver Operating Characteristic (ROC) curve analysis, with the final model selected based on its predictive accuracy on simulated data and validation against real-world data.

RESULTS AND DISCUSSION

Figure 1 presents the correlogram of palm oil seed and coconut production. This analysis serves as a guide for subsequent model specification. The augmented Dickey-Fuller test indicates the presence of unit roots in the production data for both plantation crops, suggesting the need for models that account for non-stationarity. Residual autocorrelation assessment using the Ljung-Box test supports the best-fit ARIMA(0,1,1) model with drift for palm oil seed production from 1995 to 2021. The same test subsequently supports the use of an ARIMA(1,2,0) model for coconut production.



(I) (II)

Figure 1. Autocorrelation Function Of The Original Palm Seed (I) And Coconut (II) Production Datasets

Table 1. Forecast Of Palm Seed and Coconut Productions For 2030 From ARIMA and Neural Network Autoregression (NNAR) Models

Production	Model	Forecast	Lower 95%	Upper 95%
Palm seed (ton)	ARIMA(0,1,1) with drift	7747.738	5513.216	9982.260
	NNAR(15,8)	8416.749	8384.610	8448.102
Coconut (kiloton)	ARIMA(1,2,0)	2633.575	1098.424	4168.726
	NNAR(15,8)	2772.535	2772.276	2772.795

Table 1 presents the projected production of palm oil seeds, representing large-scale plantations, and coconut, representing smallholder plantations, for the year 2030. These projections are generated using the optimal ARIMA models for each crop and the neural network autoregression (NNAR) model. The results indicate that the NNAR estimates tend to be slightly higher, but with significantly narrower prediction intervals compared to the ARIMA models..

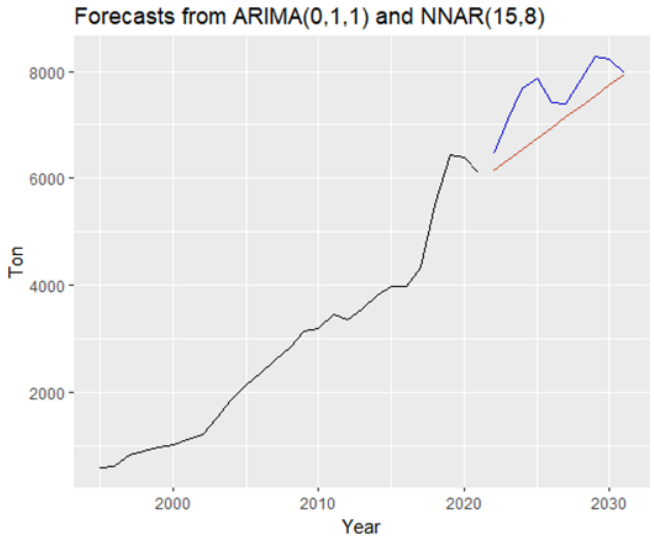


Figure 2. Observed Palm Seed Production In 1995-2021 And Forecast For 2022-2030 From ARIMA (0,1,1) And NNAR (15,8) Models.

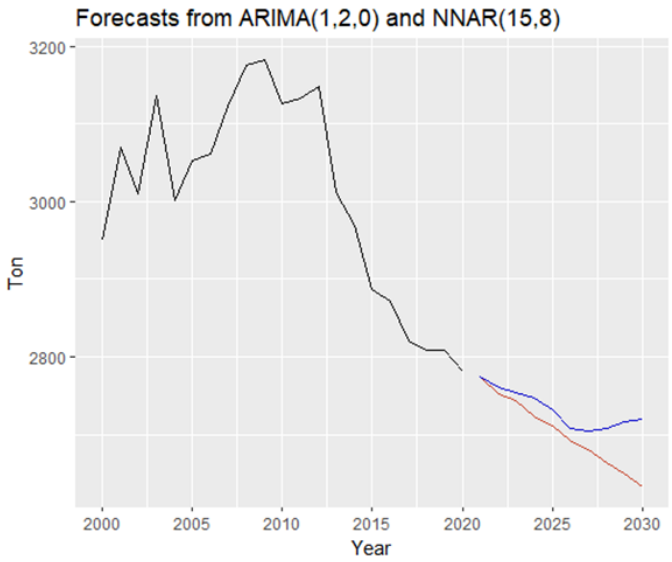


Figure 3. Observed Coconut Production In 2000-2020 And Forecast For 2021-2030 From ARIMA (1,2,0) And NNAR (15,8) Models

In general, both the ARIMA and NNAR models support the projection of continued growth in palm oil seed production from large-scale plantations in Indonesia, at least through 2030. In contrast, coconut production is expected to continue declining. This suggests that smallholder farmers, who form the backbone of the smallholder plantation sector, need to consider long-term strategies for shifting to alternative crops. Without changes in market demand, technological improvements, or economic interventions, coconut production is likely to decline further in the coming years.

CONCLUSIONS

Based on the results of this study, it can be concluded that both the ARIMA and NNAR models generally indicate a continued increase in palm oil seed production from large-scale plantations in Indonesia through 2030. In contrast, coconut production, which represents smallholder plantations, is projected to continue declining. Smallholder coconut farmers, who form the backbone of this sector, should begin considering long-term strategies to diversify into other crops with better economic prospects. Likewise, the government should proactively prepare and implement long-term policies to support the transition of smallholder plantations. Such efforts are essential to improve rural prosperity and ensure the sector's continued strategic role in generating foreign exchange for the country.

ACKNOWLEDGEMENTS

Gratitude is extended to the Indonesian government via LPPM Sam Ratulangi University for the allocation of the research grant DIPA in 2024..

REFERENCES

Abdi, A., & Mohamed, A. (2025). Determinants of agricultural exports in Somalia: the impacts of exchange rates, foreign direct investment, and institutional quality. *Cogent Economics & Finance*, *13*. https://doi.org/10.1080/23322039.2024.2445755

Evizal, R. (2014). Dasar-Dasar Produksi Perkebunan. In *Buku: Vol. Graha Ilmu*. Graha Ilmu.

Indonesia Investments. (2015). *Agriculture Sector of Indonesia - Indonesian Agriculture Products | Indonesia Investments*. Indonesian-Investments. https://www.indonesia-investments.com/culture/economy/general-economic-outline/agriculture/item378

Mustofa, R. (2021). Komparasi Usahatani Perkebunan Kelapa Sawit Rakyat Di Kabupaten Rokan Hilir. *Media Bina Ilmiah*, *15*(11), 5667–5674.

Setianto, N., Nur Wakhidati, Y., & Subagyo, Y. (2025). Systems analysis of smallholder dairy farming in Banyumas, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *1476*, 12028. https://doi.org/10.1088/1755-1315/1476/1/012028

Setianto, P., & Susilowati, I. (2014). Komoditas Perkebunan Unggulan yang Berbasis Pada Pengembangan Wilayah Kecamatan di Kabupaten Banjarnegara Provinsi Jawa Tengah. *Jurnal Wilayah Dan Lingkungan*, *2*(2), 143. https://doi.org/10.14710/jwl.2.2.143-156

Tiesnamurti, B., Handiwirawan, E., Santoso, S., Tresia, G., Shiddieqy, M., Fanindi, A., Ibrahim, A., & Romjali, E. (2024). The adaptability of Garut sheep grazing on oil palm and rubber plantations in tropical conditions of Indonesia. *Veterinary World*, *17*, 1889–1903. https://doi.org/10.14202/vetworld.2024.1889-1903

Wachjar, A. (2019). Kriteria, Bentuk Usaha, dan Pola Pengembangan Tanaman Perkebunan Utama. *Jurnal Agritec*, *4*(2), 1–24. https://pustaka.ut.ac.id/lib/wp-content/uploads/pdfmk/LUHT434503-M1.pdf

Wenzel, A., Westphal, C., Ballauff, J., Berkelmann, D., Brambach, F., Buchori, D., Camarretta, N., Corre, M., Daniel, R., Darras, K., Erasmi, S., Formaglio, G., Hölscher, D., Iddris, N., Irawan, B., Knohl, A., Kotowska, M., Krashevska, V., Kreft, H., & Grass, I. (2024). Balancing economic and ecological functions in smallholder and industrial oil palm plantations. *Proceedings of the National Academy of Sciences of the United States of America*, *121*, e2307220121. https://doi.org/10.1073/pnas.2307220121

wulandari, siti abir, & kemala, nida. (2016). Kajian Komoditas Unggulan Sub-Sektor Perkebunan Di Provinsi Jambi. *Jurnal Ilmiah Universitas Batanghari Jambi*, *16*(1), 134–141.

Yanita, M., Napitupulu, D., Rahmah, K., Alamsyah, Z., Fauzia, G., Herlambang, N., & Tanaka, M. (2024). Contribution of the agricultural sector to embody Sustainable Development Goals (SDGs) in Jambi Province. *IOP Conference Series: Earth and Environmental Science*, *1302*, 12143. https://doi.org/10.1088/1755-1315/1302/1/012143