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Socio-economic and agroecological factors influencing sacha inchi productivity in West Java, Indonesia

MUHAMAD NURDIN YUSUF[1,♥], DADI[2], JETI RACHMAWATI[1], BENIDZAR M. ANDRIE[1], SAEPUL AZIZ[1], MOCHAMAD ARIEF RIZKI MAULADI[1]
[1]Department of Agribusiness, Faculty of Agriculture, Universitas Galuh. Jl. R. E. Martadinata No. 150, Mekarjaya, Baregbeg, Ciamis 46274, West Java, Indonesia. Tel.: +62-265-776787, ♥email: muhamadnurdinyusuf@unigal.ac.id
[2]Department of Biology Education, Faculty of Education and Teacher Training, Universitas Galuh. Jl. R. E. Martadinata No. 150, Mekarjaya, Baregbeg, Ciamis 46274, West Java, Indonesia

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Abstract. *Yusuf MN, Dadi, Rachmawati J, Andrie BM, Aziz S, Mauladi MAR. 2026. Socio-economic and agroecological factors influencing sacha inchi productivity in West Java, Indonesia. Asian J Agric 10 (1): g100140. https://doi.org/10.13057/asianjagric/g100140.* The high economic value of sacha inchi has attracted many farmers to cultivate it, despite the fact that it remains a relatively new crop with limited available information. We examined the effects socio-economic and agroecological factors on the sacha inchi productivity. The research was carried out using a survey based quantitative analysis involving 78 sacha inchi farmers in West Java Province, Indonesia, selected through a census approach. The data analyzed were primary data collected directly from respondents through structured interviews using questionnaires, in-depth interviews with key informants, and Focus Group Discussions (FGDs). Factors affecting the productivity of sacha inchi were analyzed using inferential statistics through a multiple linear regression model. The results at the 95% confidence level indicated that age, education, experience, family responsibility, soil acid, and altitude had a significant effect on sacha inchi productivity when tested simultaneously. Partially, age, education, soil acid, and altitude significantly influenced productivity, whereas farming experience and family responsibility did not have a significant effect. The novelty of this research resides in the comprehensive analysis of the interaction between farmers' social conditions and the biophysical characteristics of land in determining sacha inchi productivity, an aspect that has been scarcely explored in prior studies.

Keywords: Agroecology, conservation agriculture, farmers education, regression analysis, soil acidity

INTRODUCTION

Climate change has led to substantial losses among farmers due to unpredictable rainy and dry seasons, rising air temperatures, droughts, floods, and the increasing intensity of pest and disease outbreaks, all of which have adversely affected the agricultural sector, particularly food crops (Li et al. 2019; Malau et al. 2023). The agricultural sector serves as a major source of employment for approximately 20 million farming households in rural Indonesia (Hafizah et al. 2020; Yusuf 2024). The capacity of this sector to directly contribute to economic growth and the welfare of farming households depends largely on farm income levels and the surplus generated within the sector itself (Muraoka et al. 2018; Kassy et al. 2021).

According to Oskorouchi and Sousa-Poza (2021), the frequent occurrence of floods has resulted in the loss of livelihoods for farmers, particularly those dependent on a single source of income. Such events contribute to reduced productivity, lower household food security, and diminished community welfare, especially in developing countries (Hirabayashi et al. 2013; Arnell and Gosling 2016; Hapsari and Rudiarto 2017; Opaluwa et al. 2018). One strategy to enhance household food security among farmers is to cultivate crops that provide added value with low production costs, exhibit resilience to climate change, and possess high nutritional content (Cisneros et al. 2014; Sterbova et al. 2017; Muraoka et al. 2018; Mishenin et al. 2023).

One such high-value functional food crop with multiple benefits is *Plukenetia volubilis* (sacha inchi), native to the Amazon basin. This crop is well-adapted to tropical regions, can perform well even in the absence of intensive management practices, and remains productive for up to 18 years without replanting (Cachique et al. 2018; Kodahl 2020; Van et al. 2022; Sari et al. 2024). Sacha inchi is nutritionally rich, containing 45.2% omega-3, 36.8% omega-6, 9.6% omega-9, and 7.7% saturated fat, making it a potential functional food crop substitute for soybean, with the added advantages of ease of cultivation and environmental friendliness (Cisneros et al. 2014; Kodahl and Sorensen 2021; Yanti et al. 2022). Although numerous studies have been conducted on sacha inchi, most have focused on its use as a herbal product, cosmetic ingredient, or its nutritional profile (Chavan et al. 2013; Sytar et al. 2018; Rodzi and Lee 2022; Ishak et al. 2024; Sari et al. 2024). Yanti et al. (2022) revealed that sacha inchi contains polyunsaturated fatty acids, high sucrose levels, and that its residues retain resveratrol and omega-3 content. In the pharmaceutical field, studies by Rodzi and Lee (2022) and Rahman et al. (2023) have demonstrated its beneficial effects in various neuroprotective, dermatological, antidyslipidemic, antioxidative, and anti-inflammatory activities, as well as its antiproliferative and antitumor modulation properties, and its potential in reducing obesity, diabetes, and hypertension.

As with other crops, the productivity of sacha inchi is influenced by environmental factors such as temperature, altitude, cultivation methods, seasonal variations, and socio-economic conditions (Yaqoob and Nawchoo 2017; Gong et al. 2018; Azkiyah and Tohari 2019). Cachique et al. (2018), in their study on vegetative propagation of sacha inchi, demonstrated that selecting rootstocks resistant to pests and diseases results in healthier plants with greater resistance to such threats. However, research examining crop productivity in relation to farmers' socio-economic factors remains scarce. The considerable economic potential of sacha inchi has motivated many farmers to cultivate it intensively, despite its status as a relatively new crop with limited research and information available.

This lack of integrative socio-economic and agroecological analysis constrains a comprehensive understanding of how their complex interactions jointly influence sacha inchi productivity, thereby revealing a critical research gap in the development of context specific and sustainable production strategies. The novelty of this study lies in the integration of socio-agroecological aspects, encompassing socio-economic factors (age, education, farming experience, and family dependents) and agroecological factors (soil acidity and altitude), in analyzing the productivity of sacha inchi. Although crop productivity is influenced by the chemical, physical, and biological properties of soil, soil acidity serves as the primary controlling factor governing nutrient availability, microbial activity, and nutrient uptake efficiency. Given the sensitivity of sacha inchi to soil acidity, this study prioritizes soil acidity as the main explanatory variable under relatively homogeneous site conditions, aiming to produce focused and practically applicable findings while leaving broader soil interactions for future research. This comprehensive approach has rarely been applied in previous studies, thereby offering a new perspective on how the interaction between farmers' social conditions and the biophysical characteristics of the land simultaneously influences the productivity of sacha inchi. Therefore, this study aims to examine analyze the influence of socio-economic and agroecological factors on sacha inchi productivity, both simultaneously and partially. From a practical perspective, this study provides an evidence base for government decision making in designing more targeted, cost effective, and easily adoptable agricultural development policies and extension programs to enhance productivity, improve farmers' incomes, and promote the sustainable management of land resources.

MATERIALS AND METHODS

Study area

This research was conducted in West Java Province, Indonesia, which administratively comprises 27 districts/municipalities. According to the Central Statistics Agency (Badan Pusat Statistik (BPS 2025)), West Java, as a buffer zone for the national capital, covers an area of 37,040.04 km² and hosts the largest population in the country, totaling 50.35 million inhabitants or 17.88% of the national population. The province exhibits diverse agroecological zones, ranging from lowland to highland areas. Five districts Ciamis, Tasikmalaya, Garut, Cianjur, and Bandung were purposively selected due to their heterogeneous agricultural landscapes and their designation as conservation satellite models of Universitas Galuh, West Java, which is actively promoting the cultivation of sacha inchi (Figure 1).

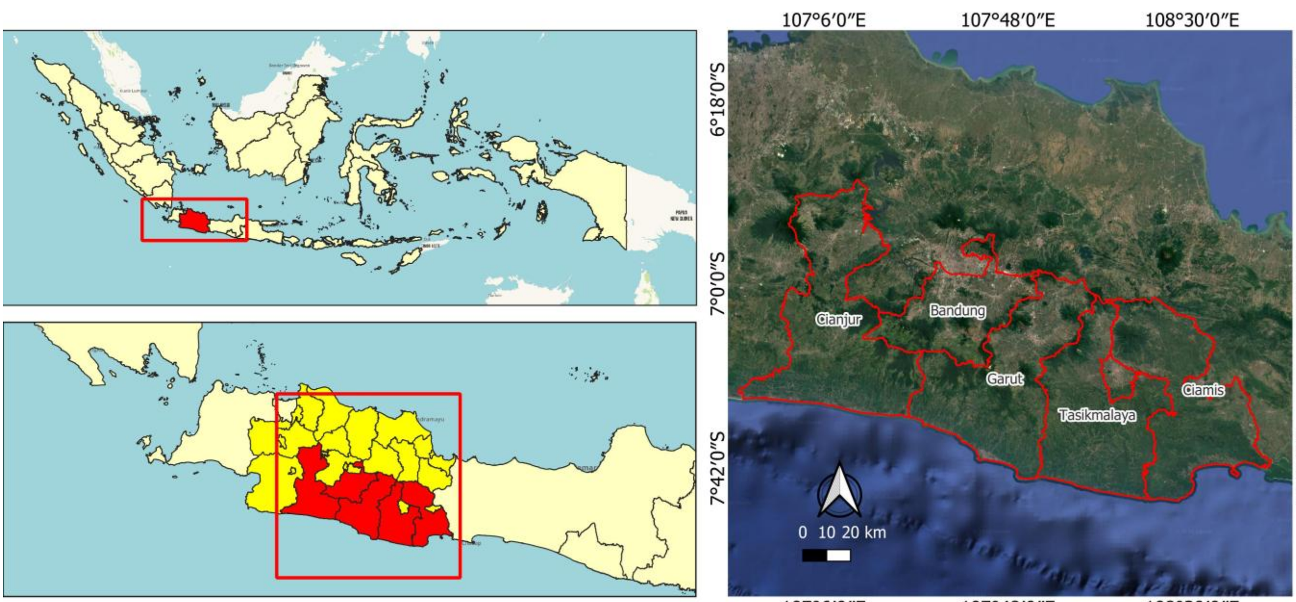

Figure 1. Map of research locations in West Java, Indonesia

Sampling technique

The population of sacha inchi farmers fostered by -Universitas Galuh is 78 people spread across Ciamis, Tasikmalaya, Garut, Cianjur, and Bandung District, which was taken by census. All farmers included in the sample were organized within a group known as the conservation satellite model. This model represents a partnership framework that emphasizes the integrated development of sacha inchi along the entire value chain, from upstream cultivation to downstream processing and marketing. Within this model, Universitas Galuh functions as the core institution, providing technical guidance, research-based innovations, and institutional support to strengthen both the production system and market linkages.

Method of data collection

The study was designed quantitatively using a survey method intended to provide an overview of age, education, experience, family dependents, soil acidity, altitude, and sacha inchi productivity. The data analyzed in this study are primary data obtained directly from respondents through structured interviews using questionnaires, in-depth interviews with respondents, key informants, and FGD.

Data analysis

Factors that influence sacha inchi productivity are analyzed using inferential statistics with multiple linear regression models whose computation uses the SPSS Ver.16. (Hair et al. 2010), multiple linear regression models are used to determine the influence between two or more independent variables on one dependent variable which can then be used as a prediction model.

The influence of age, education, experience, family dependents, soil acidity, and altitude on sacha inchi productivity using the following equation model:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + e$$

Where:
Y: Productivity, tonnes per hectares;
β_0: Constant;
βi: Regression coefficient of the independent variable;
X_1: Age; year
X_2: Education; year
X_3: Experience; year
X_4: Family dependents; person
X_5: Soil acidity; pH
X_6: Altitude; meters
e: Error term

However, because multiple linear regression is a parametric statistical approach, before the data is processed, classical assumption tests must first be carried out, including tests for normality, linearity, and multicollinearity. The testing of classical assumptions in multiple linear regression models is essential to ensure that the resulting model is valid and scientifically accountable. Such testing guarantees the validity of the model, the reliability of statistical inferences, and the accuracy of predictions. By examining assumptions such as normality, homoscedasticity, absence of multicollinearity, and absence of autocorrelation, researchers can ascertain that the estimated parameters are unbiased, consistent, and efficient (Greene 2018; Wooldridge 2025). Consequently, the results obtained from the model can be confidently interpreted, defended in academic discourse, and utilized for evidence-based decision-making. Simultaneous hypothesis testing was carried out using the F test and partially using the t test at a 5 percent error rate.

RESULTS AND DISCUSSION

Farmers characteristics

Farmers characteristics in this research consist of age, education, experience, family dependents, and land area (Table 1). Table 1 shows that the farmers' ages ranged from 40 to 69 years, with an average of 50 years, thus classifying them within the productive age group (73%). Education in this study was measured based on the highest level of formal education attained by the farmers. The majority had completed elementary education (59%), followed by those with junior education (37%), while the proportion with senior education was the smallest (4%). The predominance of farmers with only elementary level education indicates a generally low level of educational attainment, even though, as reported by Djuliansah et al. (2024), education is a crucial factor in enhancing farmers' knowledge. Experience generally influences decision making processes for farmers, it plays a crucial role in farm management, ultimately leading to better profitability. A total of 56 farmers (72%) had less than 2 years of experience in sacha inchi cultivation, 20 farmers (25%) had 2-4 years of experience, and the remaining 2 farmers (3%) had more than 4 years of experience. The farmers' experience in cultivating sacha inchi varied between 1 and 5 years, with an average of 2.4 years. The relatively short duration of experience was primarily due to the fact that they were introduced to sacha inchi farming through social media and were attracted by its high market price. The number of dependents per household ranged from 1 to 5 persons, with an average of 3 persons. Farmers with 1-3 family dependents constituted the majority (93%), whereas only a small proportion (7%) had 4-6 dependents. Dependent family members in this context refer to household members or relatives living under the same roof whose needs rely on the farmer's income. The relatively small number of dependents reflects a decline in the traditional rural belief that "having many children brings abundant fortune". According to Emmanuel et al. (2025), the number of family members can be considered a form of household capital in agricultural enterprises. A larger family provides additional labor, enabling farmers to reduce the need for hired labor and minimize operational costs, which can ultimately support more efficient farm management and productivity. The farmers' cultivated land was predominantly used for plantation crops, with sizes ranging from 0.14 to 1 ha. The majority of farmers (55%) cultivated sacha inchi on land ranging from 0.14 to 0.42 ha, while 41% managed plots of 0.43-0.71 ha, and only 4%

cultivated sacha inchi on areas of 0.72-1.00 ha. The average landholding among the farmers was 0.20 ha, which classifies their landholdings as small-scale.

Classical assumption testing

The classical assumption test is conducted before the research hypothesis testing process with aim that the resulting model is truly accurate and reliable. Test is conducted using SPSS Ver.16 program as follows:

Normality test

Normality test aims to test whether in regression model, the residual value has a normal distribution pattern or not. According to Hair et al. (2010), a regression model with a normal residual distribution is a good model so that it can be said the data is normally distributed if significance value is ≥0.05. Results of the residual normality test were carried out using Kolmogorov-Smirnov test statistics (Table 2).

Table 2 shows the test results using SPSS Ver.16 obtained a significance value of Asymp.Sig (2-tailed) greater than 0.05 age (0.086), education (0.102), experience (0.092), family dependents (0.211), soil acidity (0.243), altitude (0.171), and productivity (0.265) so it can be said that the data is normally distributed. This is consistent with Hair et al. (2010) and Wooldridge (2025), who stated that when the significance value (Sig.) is greater than 0.05, the data can be considered normally distributed.

Liniertiy test

Linearity test is carried out by finding the equation regression line of independent variable against dependent variable. Based on the regression line that has been made, the significance of regression line coefficient and its linearity are then tested (Table 3).

Table 3 shows that based on the test result, the deviation value from linearity of variables age, education, experience, family dependents, planting location, and altitude is greater than 0.05, age (0.094), education (0.184), experience (0.743), family dependents (0.324), soil acidity (0.136), and altitude (0.274) so that it can be concluded that there is a linear relationship between the independent variables and their dependent variables. This shows that regression assumption that the independent variables and dependent variables must have a linear relationship has been met.

Multicolierity test

Multicollinearity test or statistical technique used to test whether there is a high or perfect correlation between independent variables in the regression model. This test aims to test whether there is a correlation between independent variables in the regression model. If a high correlation is found between independent variables, then it can be stated that there are symptoms of multicollinearity. Based on the rules of Variance Inflation Factor (VIF) and tolerance, if the VIF value is more than 10 or tolerance the less than 0.10, then it is stated that there are symptoms of multicollinearity. Conversely, if the VIF value is less than 10 or tolerance more than 0.10, then it is stated that there are no indication of multicollinearity (Hair et al. 2010; Greene 2018). The results of multicollinearity test can be seen in Table 4.

Table 1. Characteristics of sacha inchi farmers' in West Java, Indonesia

Variable	Frequency	Percentage (%)
Age (year)		
40-49	47	60
50-59	15	10
60-69	16	21
Mean	50	
Education level		
Elementary	46	59
Junior	29	37
Senior	3	4
Experience (years)		
< 2	56	72
2-4	20	25
> 4	2	3
Mean	2.4	
Family dependents (persons)		
1-3	73	93
4-6	5	7
Mean	3	
Land area (hectares)		
0.14-0.42	43	55
0.43-0.71	32	41
0.72-1.00	3	4
Mean	0.2	

Source: Results of primary data processing (2024)

Table 2. Results of normality using Kolmogorov-Smirnov test

Variable	Asymp. Sig. (2-tailed)
Age	0.086
Education	0.102
Experience	0.092
Family dependents	0.211
Soil acidity	0.243
Altitude	0.171
Productivity	0.265

Source: Built by the authors based on the results of the research

Table 3. Deviation from linierity

Independent Variable	Sig.
Age	0.094
Education	0.184
Experience	0.743
Family dependents	0.324
Soil acidity	0.136
Altitude	0.247

Source: Built by the authors based on the results of the research

Table 4 shows that all independent variables are not correlated with each other, as indicated by the tolerance value each independent variable being more than 0.10, age (0.189), education (0.541), experience (0.682), family dependents (0.253), soil acidity (0.959), and altitude (0.836) and VIF value being less than 10, age (1.638), education (2.431), experience (2.976), family dependents (5.348), soil acidity (1.042), and altitude (6.548) so it can be said that there are no indication of multicollinearity.

Multiple linier regression models

According to Hair et al. (2010), multiple linear regression model that involves more than one independent variable. Multiple linear regression analysis is carried out to determine direction and how much influence the independent variable has on dependent variable. Simultaneously, all independent variables studied, consisting of age, education, experience, family dependents, soil acidity, and altitude, had a significant effect on sacha inchi productivity (Table 5).

Partially, age, education, planting location, and altitude have a significantly effect on sacha inchi productivity, while the effect of experience and family dependents are not significant on sacha inchi productivity. Table 6 shows the results of testing using multiple linier regression analysis, namely planting location and altitude on sacha inchi productivity.

Based on the analysis results, a regression equation can be created as follows:

$$Y = 0.116 + 0.748 X_1 + 1.650 X_2 + 0.832 X_3 + 0.932 X_4 + 0.856 X_5 - 1.036 X_6 + e$$

The results of the regression analysis showed that statistically age (p-value=0.000), education (p-value=0.000), Soil acidity (p-value=0.000), and altitude (p-value=0.012) had a significant effect on sacha inchi productivity, while experience (p-value=0.103) and family dependents (p-value=0.241) did not have a significant effect on sacha inchi productivity (ceteris paribus).

The value of coefficient correlation shows that the model built sufficiently describes dependency sacha inchi studied productivity. The coefficient determination value (R^2=0.798) shows that around 80% of the variation changes in sacha inchi productivity it highly dependent on changes in age, education, experience, family dependents, planting location, and altitude, the remaining 20 percent is influenced by other factors not included in model.

Discussion

General condition of sacha inchi farming in West Java

Sacha inchi farming is generally conducted using simple practices; however, optimal growth and productivity require specific agronomic conditions. Land preparation typically involves soil tillage, starting with the construction of raised beds and planting holes. Raised beds are generally arranged in rows, with widths ranging from 80 to 90 cm, while their lengths are adjusted according to the available land area. Farmers usually incorporate farmyard manure mixed with dolomite into each planting hole and leave it for approximately two weeks to facilitate decomposition while waiting for the seedlings to grow in the nursery. According to Van et al. (2022), sacha inchi farmers in Vietnam commonly apply 1 kg of organic fertilizer and 0.5 kg of NPK per planting hole to promote optimal plant growth.

Before sowing, seeds are soaked in warm water for 24 hours to facilitate germination, as unsoaked seeds take longer to germinate and have a relatively high failure rate. Lubis et al. (2014) and Van et al. (2022) noted that soaking enhances germination in plants with hard seed coats that hinder imbibition and gas exchange. Sacha inchi seeds generally germinate about 20 days after soaking, after which they are transplanted into polybags for nursery growth. Planting is usually carried out in the morning, when sunlight is less intense. Farmers transplant sacha inchi seedlings after 50 days in the nursery, when the plants have reached a height of approximately 20-30 cm. The common spacing between plants ranges from 1 to 2.5 m, with an average of 1.6 m. Planting typically requires 58-65 male labor days per hectare, with an average of 63 labor days per hectare, at a wage rate of IDR 70,000 per day.

Several maintenance activities are carried out by farmers, including replanting, trellis installation, weeding, fertilization, irrigation, and harvesting. Replanting aims to replace dead or poorly growing plants to maintain uniform crop stands. This aligns with Nisa et al. (2017), who reported that sacha inchi, originating from tropical regions, is well adapted to the Indonesian climate, with arthropod populations dominated by decomposers that do not cause economic damage. In contrast, Van et al. (2022) reported that plant mortality in Vietnam was due to root rot (2.1-5.3%) and leaf wilt (3.1-4.8%). Based on farmers' interviews, no disease incidence was observed in sacha inchi during the study period, which may be attributed to its status as a relatively new crop that has not yet developed an established pest and disease complex in the study area.

Table 4. Collinierity statistics

Independent variable	Tolerance	Variance Inflation Factor
Age	0.189	1.638
Education	0.541	2.431
Experience	0.682	2.976
Family dependents	0.253	5.348
Soil acidity	0.959	1.042
Altitude	0.836	6.548

Source: Built by the authors based on the results of the research

Table 5. Simultaneous test results

Indicator	Value	Indicator	Value
R	0.893	F (148.350)	0.005
R-squared	0.798	P-value (F)	0.000
Durbin-Watson	2.438	Std. Error of estimate	0.210

Source: Built by the authors based on the results of the research (α=0.05)

Table 6. Results of regression analysis of factors influencing sacha inchi productivity

Indicator	Coefficient	Std. Error	t-ratio	P-value	Conclusion
Const	0.116	0.119	0.581	0.563	-
Age (X_1)	0.748	0.241	10.221	0.000	Significant
Education (X_2)	1.650	0.037	18.612	0.000	Significant
Experience (X_3)	0.832	0.429	1.236	0.103	Not significant
Family dependent (X_4)	0.932	0.142	1.612	0.241	Not significant
Soil acidity (X_5)	0.856	0.069	16.162	0.000	Significant
Altitude (X_6)	-1.036	0.021	-2.574	0.012	Significant

Note: Statistically significant indicator for reliability 0.05. Source: Built by the authors based on the results of the research

As a climbing plant, sacha inchi requires proper support structures for optimal growth. Farmers typically use bamboo poles for climbing support; however, some use living stakes such as *Gliricidia sepium* and *Moringa oleifera* to provide more durable support, as these grow alongside the crop. Wires are usually stretched between poles to guide the vines, though a few farmers use metal poles. Trellises are generally installed at the time of planting, but some farmers install them two to three weeks after planting, once the plants begin producing new shoots.

Weeds around the crop can hinder growth and reduce yields; however, as the sacha inchi canopy becomes denser, sunlight penetration to the soil surface decreases, making weed growth minimal. Farmers generally avoid the use of chemical fertilizers in sacha inchi cultivation, as they may reduce fruit quality and lower market value. During the vegetative growth stage, organic fertilizer application ranges from 2 to 3 kg per plant (average 2.5 kg), repeated every two months, with increasing doses as plants mature. The organic fertilizer used by the farmers consisted of animal manure derived from cattle and goats, which is widely available in the study area. According to Widhiningsih (2020) and Shah et al. (2023), organic fertilizers are highly recommended for restoring soil fertility, although their initial application requires relatively large amounts.

Water availability is another critical factor in sacha inchi cultivation. Irrigation is conducted during the early growth stage, with a frequency of one to two times per day, either in the morning or evening, depending on weather conditions. The first harvest occurs eight months after planting, but yields at this stage are relatively low, at about 0.1-0.3 kg per plant, depending on soil fertility. Harvesting is typically conducted weekly or at least three times per month, when the fruits are mature and dark brown in color. Cai et al. (2012) and Yang et al. (2014) noted that flowering onset in sacha inchi varies with the length of the vegetative phase, occurring at 240-480 days after planting, with harvest possible 120 days thereafter. Van et al. (2022) reported that sacha inchi in Vietnam began flowering at 108-125 days after planting, with the first harvest at 244-250 days, achieving productivity levels of 2.66-3.07 per ha.

Socioeconomic and agroecological determinants of sacha inchi productivity

The results of the study show that the average age of the farmers surveyed fells within the productive age range. The higher the proportion of farmers in this productive age group, the higher the productivity of the cultivated crops. Farmers within the productive age group are generally more capable of managing their farming activities intensively, as they possess greater physical strength and endurance to perform labor-intensive tasks. This demographic advantage not only facilitates the adoption of improved cultivation practices but also enhances their ability to cope with production challenges. In line with this, our findings demonstrate that sacha inchi productivity it significantly higher among farmers of productive age compared to their older counterparts in the non-productive age group. These results suggest that age plays an important role in determining farm performance, highlighting the need for strategies that support aging farmers while maximizing the potential of younger, more physically capable farmers. Tong et al. (2024), it was found that farmer aging negatively affects productivity in several regions and farming scales, primarily due to physical limitations, reduced technology adoption, and decreased efficiency in resource allocation. This is primarily because farmers in their productive years still possess strong motivation and good physical strength, enabling them to manage their farming activities more optimally. According to Ifeanyi-Obi et al. (2024) and Dyanty et al. (2025), farmers of productive age tend to interact more frequently, allowing them to exchange experiences with other farmers regarding their farming practices. Similarly, Djuliansah et al. (2024) reported that soybean farmers within the productive age bracket more often discuss potential technological applications in farming with peers. In this study, higher sacha inchi productivity was recorded among farmers of productive age compared to their less productive counterparts. Although sacha inchi does not require special maintenance, farmers in their productive years were observed to cultivate it more intensively, as reflected in their frequent visits to the field even if only to weed or prune unproductive branches that could hinder plant growth. As noted by Cachique et al. (2018), Kodahl (2020), and Kodahl and Sorensen (2021), pruning water shoots facilitates plant growth by allowing sunlight to penetrate dense canopies, which in turn inhibits fungal growth that could damage crops.

Farmer education has a positive and significant effect on sacha inchi productivity. According to Cordaro and Desdoigts (2021), Afful and Mabena (2024), and Djuliansah et al. (2024), education is a factor that can facilitate farming activities, as higher education levels generally enhance knowledge and understanding. Although most farmers in this study had only completed basic formal education, they actively participated in informal activities such as agricultural extension programs. The findings reveal that farmers typically meet with their business partners at least once a month to discuss sacha inchi cultivation techniques. As highlighted by Sharp (2019), Siphesihle and Lelethu (2020), Afful and Mabena (2024), Hoxha and Ramadani (2024), Ifeanyi-Obi et al. (2024), and Teele and Nkoane (2024), the training provided through extension activities delivered practical knowledge that can be directly implemented, including the use of locally available and environmentally friendly organic fertilizers to enhance productivity.

Experience, defined as the result of human activities acquired over time (Setshedi and Modirwa 2020; Siphesihle and Lelethu 2020; Djuliansah et al. 2024), did not have a significant effect on sacha inchi productivity in this study. This is understandable, as sacha inchi is a relatively new crop introduced to these farmers in recent years from social media platforms such as YouTube, Facebook, Instagram, and TikTok. Farmers' interest in cultivating sacha inchi was driven primarily by its high selling price rather than technical knowledge of its cultivation. As noted by Nmadu et al. (2012), Hirabayashi et al. (2013), Macours (2013), Sulewski and Kloczko-Gajewska (2014), Mazwan et al. (2020), and Kodahl and Sorensen (2021), the substantial risks associated with the high dependence of the agricultural sector on natural conditions require farmers to have a strong understanding of cultivation techniques in order to achieve high productivity.

Family dependents comprising the spouse and unemployed children are theoretically expected to encourage farmers to take farming more seriously in order to achieve higher productivity and profits. Djuliansah et al. (2024) found that in large families, members often assist with farming activities. However, the statistical analysis at a 95% confidence level (α=0.05) indicated no significant influence of family dependents on sacha inchi productivity. This aligns with field observations that sacha inchi farming is not the farmers' main occupation, and most family members neither participate in nor wish to work in agriculture. The majority of farmers primarily cultivate rice, with sacha inchi serving as a supplementary crop, while family members often prefer industrial work even in informal roles perceiving agriculture as less promising. According to Tong et al. (2024), the decline in young labor participation in the agricultural sector is a global phenomenon, commonly referred to as the aging of farmers. Yet, as Djuliansah et al. (2024) noted, large rural families can be an asset since smallholder farmers often rely on unpaid family labor, which can reduce production costs and potentially increase productivity.

Statistical analysis at a 95% confidence level (α=0.05) showed that soil acidity significantly affects sacha inchi productivity. The study area featured diverse soil types, including calcareous soils, podzols (spodosols), volcanic soils (andisols), and highly weathered red soils classified mainly as ultisols and oxisols. Podzols and red soils (ultisols and oxisols) are the most widely cultivated across both lowland and highland areas. Farmers used organic fertilizers derived from cattle, goats, sheep, rabbits, or poultry manure, depending on local availability. Organic fertilizers were preferred to avoid potential quality degradation from chemical fertilizers, with application rates ranging from 2.4-3.0 tons ha^{-1} (mean 2.6 tons ha^{-1} or ~2 kg tree^{-1}). In addition to solid organic fertilizers, liquid organic fertilizers were applied twice: during the vegetative phase (three months after planting) and again during the generative phase (three months later) at an average dose of 22.4 liters/ha, sprayed with a hand sprayer. Farmers noted that red soils, being less fertile, required higher organic fertilizer application to restore soil fertility. This is consistent with Shah et al. (2023), who reported that organic fertilizers can improve crop yields and restore soil health.

In addition to human capital factors, soil chemical properties and topographic conditions played important roles in shaping productivity. Soil pH in the study sites ranged from 4 to 8.6, with an average of 6 (neutral). Farmers generally lacked knowledge about the soil pH of their plots or the optimal pH for sacha inchi cultivation. Soil pH is widely recognized as a critical determinant of nutrient availability and plant growth, with optimal pH ranges enhancing nutrient uptake and overall yield potential, while strongly acidic or alkaline conditions can limit crop development (Xing et al. 2025). Soil pH plays a crucial role in determining nutrient availability and overall plant performance. The closer the soil pH is to neutral, the more optimal the conditions become for nutrient solubility and root uptake, which in turn supports physiological processes and biomass accumulation. Conversely, soils that are too acidic (pH <5.5) or alkaline (pH>7.5) often restrict the absorption of essential nutrients such as nitrogen, phosphorus, and potassium, thereby limiting plant growth. As a result, maintaining a near-neutral soil pH creates more favorable conditions for plant development, ultimately leading to increased productivity (Fageria et al. 2008). According to Nisa et al. (2017) and Sterbova et al. (2017), soils that are too acidic or alkaline can inhibit plant growth and development.

Statistical analysis at a 95% confidence level (α=0.05) also indicated that altitude significantly affects sacha inchi productivity, with higher altitudes yielding higher productivity. The cultivation sites ranged from 180-735 m above sea level (mean 220 m). Most farmers planted sacha inchi under tree canopies (e.g., mahogany, *Manglietia*) to provide shade, which reduced light intensity, although some cultivated in open fields to maximize sunlight exposure. To optimize land use, intercropping was common, particularly with horticultural crops such as chili. As noted by Cachique et al. (2018), Van et al. (2022), and Yanti et al. (2022), sacha inchi is a tropical forest plant that can tolerate shade and does not require full-day sunlight. Furthermore, altitude influences microclimate and soil attributes, which in turn affect crop growth environments. Variations in elevation create differences in temperature regimes, moisture dynamics, and related soil fertility gradients that can alter the suitability of sites for specific crops, as documented in studies on altitudinal effects on soil nutrient dynamics and fertility constraints in agricultural landscapes.

Sacha inchi productivity in the study area ranged from 1.2-2.5 tons/ha, averaging 1.5 tons/ha still far below yields in other countries. Van et al. (2022) reported yields of 2.66-3.07 tons/ha for 2-3-year-old sacha inchi in Vietnam. The relatively low productivity observed here was attributed to the young age of the plants and suboptimal maintenance practices, such as the lack of pruning. The relatively low productivity of sacha inchi can be largely attributed to farmers' limited knowledge of appropriate cultivation techniques. Insufficient understanding of key agronomic practices, such as soil management, pest control, and post-harvest handling, hinders the optimization of crop performance. Therefore, capacity building and the dissemination of technical knowledge are essential to enhance farmers' skills and, consequently, improve productivity. According to Cai et al. (2012), Lei et al. (2014), Nisa et al. (2017), Cachique et al. (2018), Gong et al. (2018), Van et al. (2022), and Sari et al. (2024), pruning allows sunlight to penetrate the canopy, aiding photosynthesis however, inadequate fertilizer application may reduce productivity, as an adequate nutrient supply is essential for plant growth. Nevertheless, although sacha inchi grown at higher altitudes had lower productivity compared to lowland cultivation, the quality of seeds produced was superior. Lowland agroclimatic conditions, characterized by warmer and more stable temperatures and higher solar radiation, enhance photosynthetic activity and photosynthate accumulation during the seed-filling stage, thereby promoting efficient seed development and lipid synthesis. Optimal temperatures in lowland environments also facilitate flowering, fertilization, and seed filling, reducing the incidence of empty or poorly developed seeds. In contrast, cooler and more variable highland conditions may constrain plant metabolism and disrupt fatty acid biosynthesis, leading to inferior seed quality. Additionally, greater soil microbial activity in lowland areas improves nutrient availability through mineralization, further supporting superior physical and chemical seed quality. Overall, these findings highlight temperature and solar radiation as key environmental determinants of sacha inchi seed quality. Frequent interactions among farmers as farming practitioners constitute an effective learning mechanism for enhancing their knowledge, particularly in the presence of limited technical knowledge related to cultivation practices (Djuliansah et al. 2024). The results indicate that frequent interactions among farmers play a crucial role in enhancing farmers' knowledge of sacha inchi cultivation. Given the limited access to formal training and technical information, farmer-to-farmer interactions function as an effective informal learning mechanism. Knowledge exchange through peer discussions enables farmers to share practical experiences related to cultivation techniques, pest management, and input use, thereby improving their overall farming practices. This finding underscores the importance of social learning processes in supporting the adoption and sustainability of sacha inchi farming systems.

In conclusion, the results of this study indicated that, simultaneously, age, education, farming experience, number of dependents, soil pH, and altitude have a significant effect on sacha inchi productivity. However, partial analysis shows that only age, education, soil acidity, and altitude exert a significant influence. Age and education have a positive effect, suggesting that farmers in a more productive age range and with higher education levels tended to achieve greater productivity. Soil pH also shows a significant positive effect, indicating that more neutral pH conditions favor sacha inchi productivity. Conversely, altitude has a significant negative effect, implying that higher elevations are associated with lower productivity levels. In contrast, farming experience and number of dependents do not significantly affect sacha inchi productivity. Taken together, the empirical evidence from the field supports the conclusion that both socio-economic characteristics (age and education) and agroecological factors (soil pH and altitude) collectively determined sacha inchi productivity. Sacha inchi development should consider socio-economic factors of farmers, such as age and education, along with agroecological conditions, particularly soil acidity and altitude, to improve productivity. These multifaceted relationships highlight the need for integrated agronomic and extension strategies that address farmer knowledge, soil management, and site suitability to optimize yield outcomes.

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REFERENCES

Afful DB, Mabena PP. 2024. Agricultural extension practitioners' use of information communication tools in the Capricorn District, Limpopo, South Africa: A perception study. S Afr J Agric Ext 52 (3): 175-196. https://doi.org/10.17159/2413-3221/2024/v52n3a15904.

Arnell NW, Gosling SN. 2016. The impacts of climate change on river flood risk at the global scale. Clim Chang 134 (3): 387-401. https://doi.org/10.1007/s10584-014-1084-5.

Azkiyah DR, Tohari. 2019. Pengaruh ketinggian tempat terhadap pertumbuhan, hasil dan kandungan steviol glikosida pada tanaman stevia (*Stevia rebaudiana*). Vegetalika 8 (1): 1-12. https://doi.org/10.22146/veg.37165. [Indonesian]

Badan Pusat Statistik (BPS). 2025. Statistik Demografi Indonesia (Hasil Sensus Penduduk 2020). Badan Pusat Statistik, Jakarta. [Indonesian]

Cachique DH, Solsol HR, Sanchez MA, Lopez LA, Kodahl N. 2018. Vegetative propagation of the underutilized oilseed crop sacha inchi (*Plukenetia volubilis* L.). Genet Resour Crop Evol 65 (7): 2027-2036. https://doi.org/10.1007/s10722-018-0659-9.

Cai ZQ, Jiao DY, Tang SX, Dao XS, Lei YB, Cai CT. 2012. Leaf photosynthesis, growth, and seed chemicals of sacha inchi plants cultivated along an altitude gradient. Crop Sci 52 (4): 1859-1867. https://doi.org/10.2135/cropsci2011.10.0571.

Chavan JJ, Gaikwad NB, Kshirsagar PR, Dixit GB. 2013. Total phenolics, flavonoids and antioxidant properties of three *Ceropegia* species from

Western Ghats of India. S Afr J Bot 88: 273-277. https://doi.org/10.1016/j.sajb.2013.08.007.

Cisneros FH, Paredes D, Arana A, Cisneros-Zevallos L. 2014. Chemical composition, oxidative stability and antioxidant capacity of oil extracted from roasted seeds of sacha inchi (*Plukenetia volubilis* L.). J Agric Food Chem 62 (22): 5191-5197. https://doi.org/10.1021/jf500936j.

Cordaro F, Desdoigts A. 2021. Bounded rationality, social capital and technology adoption in family farming: Evidence from cocoa-tree crops in Ivory Coast. Sustainability 13 (13): 7483. https://doi.org/10.3390/su13137483.

Djuliansah D, Noor TI, Noormansyah Z, Yusuf MN. 2024. Rationality of soybean farmers: The findings from rainfed field agroecosystems. Agric Resour Econ 10 (3): 248-269. https://doi.org/10.51599/are.2024.10.03.10.

Dyanty T, Agholor IA, Nkambule TB, Nkuna AA, Nkosi M, Ndlovu SM, Mokoena JJ, Nkosi PN, Nkosi NP, Makhubu TH. 2025. Socio-economic determinants of climate change adaptation strategies among smallholder farmers in Mbombela: A binary logistic regression analysis. Climate 13 (5): 90-117. https://doi.org/10.3390/cli13050090.

Emmanuel OE, Nnenna OM, Nkiruka BCG, Henry AK, Ebuka OJ, Ogbuji EC, Thankgod EK, Chinenyenwa TAA, Ugochukwu NE, Jerry UE, Chibueze NF. 2025. Vulnerability determinant of rice farmers to climate change in Ebonyi State, Nigeria. Asian J Agric 9 (1): 23-30. https://doi.org/10.13057/asianjagric/g090103.

Fageria NK, Baligar VC, Li YC. 2008. The role of nutrient efficient plants in improving crop yields in the twenty first century. J Plant Nutr 31: 1121-1157. https://doi.org/10.1080/01904160802116068.

Gong HDE, Geng YJ, Yang C, Jiao DY, Chen L, Cai ZQ. 2018. Yield and resource use efficiency of *Plukenetia volubilis* plants at two distinct growth stages as affected by irrigation and fertilization. Sci Rep 8 (1): 80. https://doi.org/10.1038/s41598-017-18342-6.

Greene WH. 2018. Econometric Analysis. 8th ed. Pearson Education Limited, London.

Hafizah D, Hakim DB, Harianto H, Nurmalina R. 2020. The role of rice's price in the household consumption in Indonesia. Agriekonomika 9 (1): 38-47. https://doi.org/10.21107/agriekonomika.v9i1.6962. [Indonesian]

Hair JF, Black WC, Babin BJ, Anderson RE. 2010. Multivariate Data Analysis. 7th ed. Pearson Prentice Hall, New York.

Hapsari NI, Rudiarto I. 2017. Factors influencing food vulnerability and security and their policy implications in Rembang Regency. Jurnal Wilayah Lingkungan 5 (2): 125-140. https://doi.org/10.14710/jwl.5.2.125-140.

Hirabayashi Y, Mahendran R, Koirala S, Konoshima L, Yamazaki D, Watanabe S, Kim H, Kanae S. 2013. Global flood risk under climate change. Natl Clim Chang 3 (9): 816-821. https://doi.org/10.1038/nclimate1911.

Hoxha S, Ramadani R. 2024. The impact of intrinsic motivation on the sustainable extra-role performance with the mediating role of job engagement. Sustainability 16 (17): 7643. https://doi.org/10.3390/su16177643.

Ifeanyi-Obi CC, Henri-Ukoha A, Familusi LC. 2024. Analysis of climate change knowledge and capacity needs of rural women farmers in Southern Nigeria. S Afr J Agric Ext 52 (3): 132-157. https://doi.org/10.17159/2413-3221/2024/v52n3a15659.

Ishak I, Ismail NE, Yahaya NS, Khaironi J, Musa N, Teh AH, Ghani MA. 2024. Reduction of saturated fat in dark chocolate using sacha inchi (*Plukenetia volubilis*) oil oleogel. Jurnal Gizi Pangan 19 (1): 111-118. https://doi.org/10.25182/jgp.2024.19.Supp.1.111-118. [Indonesian]

Kassy WC, Ndu AC, Okeke CC, Aniwada EC. 2021. Food security status and factors affecting household food security in Enugu State, Nigeria. J Health Care Poor Underserved 32 (1): 565-581. https://doi.org/10.1353/hpu.2021.0041.

Kodahl N, Sorensen M. 2021. Sacha inchi (*Plukenetia volubilis* L.) is an underutilized crop with a great potential. Agronomy 11 (6): 1066. https://doi.org/10.3390/agronomy11061066.

Kodahl N. 2020. Sacha inchi (*Plukenetia volubilis* L.) from lost crop of the Incas to part of the solution to global challenges? Planta 251 (4): 80. https://doi.org/10.1007/s00425-020-03377-3.

Lei Y, Zheng Y, Dai K, Duan B, Cai Z. 2014. Different responses of photosystem I and photosystem II in three tropical oilseed crops exposed to chilling stress and subsequent recovery. Trees 28 (3): 923-933. https://doi.org/10.1007/s00468-014-1007-0.

Li Y, Yi F, Wang Y, Gudaj R. 2019. The value of El Niño-Southern Oscillation forecasts to China's agriculture. Sustainability 11 (15): 4184. https://doi.org/10.3390/su11154184.

Lubis YA, Riniarti M, Bintoro A. 2014. Pengaruh lama waktu perendaman dengan air terhadap daya berkecambah trembesi (*Samanea saman*). Jurnal Sylva Lestari 2 (2): 25-32. https://doi.org/10.23960/jsl2225-32. [Indonesian]

Macours K. 2013. Volatility, agricultural risk, and household poverty: Micro-evidence from randomized control trials. Agric Econ 44: 79-84. https://doi.org/10.1111/agec.12052.

Malau LRE, Rambe KR, Ulya NA, Purba AG. 2023. The impact of climate change on food crop production in Indonesia. Jurnal Penelitian Pertanian Terapan 23 (1): 34-46. https://doi.org/10.25181/jppt.v23i1.2418. [Indonesian]

Mazwan MZ, Ibrahim JT, M Fadlan WA. 2020. Risk analysis of shallot farming in Malang Regency, Indonesia. Agric Soc Econ J 20 (3): 201-206. https://doi.org/10.21776/ub.agrise.2020.020.3.3.

Mishenin Y, Koblianska I, Yarova I, Kovalova O, Bashlai S. 2023. Food security, human health, and economy: A holistic approach to sustainable regulation. Agric Resour Econ 9 (4): 50-78. https://doi.org/10.51599/are.2023.09.04.03.

Muraoka R, Jin S, Jayne TS. 2018. Land access, land rental and food security: Evidence from Kenya. Land Use Policy 70: 611-622. https://doi.org/10.1016/j.landusepol.2017.10.045.

Nisa K, Wijayanti R, Muliawati ES. 2017. Keragaman arthropoda pada sacha inchi di lahan kering. Caraka Tani J Sustain Agric 32 (2): 132-141. https://doi.org/10.20961/carakatani.v32i2.16330. [Indonesian]

Nmadu JN, Eze GP, Jirgi AJ. 2012. Determinants of risk status of small scale farmers in Niger State, Nigeria. Br J Econ Manag Trade 2 (2): 98-108. https://doi.org/10.9734/bjemt/2012/1284.

Opaluwa HI, Oyibo FO, Jimoh FA. 2018. Determinants of food security among farming households in Akure North local government area of Ondo State. J Asian Rural Stud 2 (2): 164-172. https://doi.org/10.20956/jars.v2i2.1479.

Oskorouchi HR, Sousa-Poza A. 2021. Floods, food security, and coping strategies: Evidence from Afghanistan. Agric Econ 52 (1): 123-140. https://doi.org/10.1111/agec.12610.

Rahman IZ, Hisam NS, Aminuddin A, Hamid AA, Kumar J, Ugusman A. 2023. Evaluating the potential of *Plukenetia volubilis* Linneo (sacha inchi) in alleviating cardiovascular disease risk factors: A mini review. Pharmaceuticals 16 (11): 1588. https://doi.org/10.3390/ph16111588.

Rodzi NA, Lee LK. 2022. Sacha inchi (*Plukenetia volubilis* L.): Recent insight on phytochemistry, pharmacology, organoleptic, safety and toxicity perspectives. Heliyon 8 (9): e10572. https://doi.org/10.1016/j.heliyon.2022.e10572.

Sari NM, Aryani F, Wartomo W, Paurru P, Lumbanraja GP, Astuti RP, Rudito R. 2024. Potensi pemanfaatan tumbuhan invasif daun sacha inchi (*Plukenetia volubilis*) sebagai antioksidan. ULIN Jurnal Hutan Tropis 8 (1): 61-66. https://doi.org/10.32522/ujht.v8i1.13203 . [Indonesian]

Setshedi KL, Modirwa S. 2020. Socio-economic characteristics influencing small-scale farmers' level of knowledge on climate-smart agriculture in Mahikeng local municipality, North West Province, South Africa. S Afr J Agric Ext 48 (2): 139-152. https://doi.org/10.17159/2413-3221/2020/v48n2a544.

Shah MN, Wright DL, Hussain S, Koutroubas SD, Seepaul R, George S, Ali S, Naveed M, Khan M, Altaf MT, Ghaffor K, Dawar K, Syed A, Eswaramoorthy R. 2023. Organic fertilizer sources improve the yield and quality attributes of maize (*Zea mays* L.) hybrids by improving soil properties and nutrient uptake under drought stress. J King Saud Univers Sci 35 (4): 102570. https://doi.org/10.1016/j.jksus.2023.102570.

Sharp H. 2019. Bricolage research in history education as a scholarly mixed-methods design. Hist Educ Res J 16 (1): 50-62. https://doi.org/10.18546/herj.16.1.05.

Siphesihle Q, Lelethu M. 2020. Factors affecting subsistence farming in rural areas of Nyandeni local municipality in the Eastern Cape Province. S Afr J Agric Ext 48 (2): 92-105. https://doi.org/10.17159/2413-3221/2020/v48n2a540.

Sterbova L, Hlasna Cepkova P, Viehmannova I, Huansi DC. 2017. Effect of thermal processing on phenolic content, tocopherols and antioxidant activity of sacha inchi kernels. J Food Process Preserv 41 (2): 1-8. https://doi.org/10.1111/jfpp.12848.

Sulewski P, Kloczko-Gajewska A. 2014. Farmers' risk perception, risk aversion and strategies to cope with production risk: An empirical study from Poland. Stud Agric Econ 116 (3): 140-147. https://doi.org/10.7896/j.1414.

Sytar O, Hemmerich I, Zivcak M, Rauh C, Brestic M. 2018. Comparative analysis of bioactive phenolic compounds composition from 26 medicinal plants. Saudi J Biol Sci 25 (4): 631-641. https://doi.org/10.1016/j.sjbs.2016.01.036.

Teele T, Nkoane MM. 2024. Reimagining agricultural advisors and educators as agricultural bricoleurs towards enhanced skills transfer: An adult learning perspective. S Afr J Agric Ext 52 (3): 16-35. https://doi.org/10.17159/2413-3221/2024/v52n3a13288.

Tong T, Ye F, Zhang Q, Liao W, Ding Y, Liu Y, Li G. 2024. The impact of labor force aging on agricultural total factor productivity of farmers in China: Implications for food sustainability. Front Sustain Food Syst 8: 1434604. https://doi.org/10.3389/fsufs.2024.1434604.

Van QV, Thi NY, Thi TN, Van MN, Van T Le, Thi BNV, Thi BH. 2022. Variation in growth and yield of sacha inchi (*Plukenetia volubilis* L.) under different ecological regions in Vietnam. J Ecol Eng 23 (8): 162-169. https://doi.org/10.12911/22998993/150659.

Widhiningsih DF. 2020. Young farmers' motivation and participation in horticultural organic farming in Yogyakarta, Indonesia. Intl J Soc Ecol Sustain Dev 11 (1): 45-58. https://doi.org/10.4018/IJSESD.2020010104 .

Wooldridge JM. 2025. Introductory Econometrics: A Modern Approach. 8th ed. Cengage Learning, Boston.

Xing Y, Wang X, Mustafa A. 2025. Exploring the link between soil health and crop productivity. Ecotoxicol Environ Saf 289: 117703. https://doi.org/10.1016/j.ecoenv.2025.117703.

Yang C, Jiao DY, Geng YJ, Cai CT, Cai ZQ. 2014. Planting density and fertilisation independently affect seed and oil yields in *Plukenetia volubilis* L. plants. J Hortic Sci Biotechnol 89 (2): 201-207. https://doi.org/10.1080/14620316.2014.11513069.

Yanti S, Agrawal DC, Saputri DS, Lin HY, Chien WJ. 2022. Nutritional comparison of sacha inchi (*Plukenetia volubilis*) residue with edible seeds and nuts in Taiwan: A chromatographic and spectroscopic study. Intl J Food Sci 2022 (1): 9825551. https://doi.org/10.1155/2022/9825551.

Yaqoob U, Nawchoo IA. 2017. Impact of habitat variability and altitude on growth dynamics and reproductive allocation in *Ferula jaeschkeana* Vatke. J King Saud Univ Sci 29 (1): 19-27. https://doi.org/10.1016/j.jksus.2015.10.002.

Yusuf MN. 2024. Determinants of household food security: An evidence from small farmer in swamp agroecosystem in Ciamis Indonesia. Agrisocionomics Jurnal Sosial Ekonomi Pertanian 8 (1): 166-182. https://doi.org/10.14710/agrisocionomics.v8i1.17988. [Indonesian]