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Adoption Rate of Modern Alsintan and Challenges of Indonesian Agricultural Modernization Based on the Agricultural Census for the 2003, 2013, and 2023 Periods

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A B S T R A C T

Agricultural modernization through the use of agricultural tools and machinery became one of the important pathways to improve farm efficiency, especially as Indonesia's agricultural sector faced pressures from land conversion, an aging farming population, and the weak regeneration of agricultural labor. This article aimed to analyze the level of modern agricultural machinery adoption among Agricultural Business Households (RTUP) in Indonesia and to interpret the challenges of agricultural modernization based on the Agricultural Census data from 2003, 2013, and 2023. This study used a descriptive-comparative quantitative approach by relying on secondary data from publications of Statistics Indonesia, policy documents, and related scientific articles. The analysis was carried out through data tabulation, percentage change calculations, growth rate analysis, and interpretation of factors that hindered technology adoption. The findings showed that the number of RTUP declined from 31.23 million in 2003 to 26.14 million in 2013, before increasing to 28.42 million in 2023. At the same time, the use of modern technology among farmers/RTUP in 2023 only reached around 46.84%, indicating that more than half of agricultural business actors had not been adequately reached by modernization. The low adoption of agricultural machinery was associated with the dominance of older farmers, limited land ownership, lack of capital, low digital literacy, limited infrastructure access, and uneven extension services and machinery assistance. These findings indicated that agricultural modernization could not rely merely on the distribution of machinery, but also required institutional strengthening, operator training, financing schemes, and strategies to encourage the regeneration of young farmers.

KATA KUNCI

Adopsi Teknologi, Alsintan, RTUP, Sensus Pertanian, Modernisasi Pertanian

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A B S T R A K

Modernisasi pertanian melalui penggunaan alat dan mesin pertanian (alsintan) menjadi salah satu jalan penting untuk meningkatkan efisiensi usaha tani, terutama ketika sektor pertanian Indonesia menghadapi tekanan alih fungsi lahan, penuaan petani, dan rendahnya regenerasi tenaga kerja. Artikel ini bertujuan menganalisis tingkat adopsi alsintan modern pada Rumah Tangga Usaha Pertanian (RTUP) di Indonesia serta menafsirkan tantangan modernisasi pertanian berdasarkan data Sensus Pertanian 2003, 2013, dan 2023. Penelitian menggunakan pendekatan kuantitatif deskriptif-komparatif dengan data sekunder dari publikasi Badan Pusat Statistik, dokumen kebijakan, dan artikel ilmiah terkait. Analisis dilakukan melalui tabulasi data, perhitungan perubahan persentase, growth rate, serta interpretasi faktor penghambat adopsi teknologi. Hasil kajian menunjukkan bahwa jumlah RTUP turun dari 31,23 juta pada 2003 menjadi 26,14 juta pada 2013, kemudian naik menjadi 28,42 juta pada 2023. Pada saat yang sama, penggunaan teknologi modern pada petani/RTUP pada 2023 baru mencapai sekitar 46,84%, sehingga lebih dari separuh pelaku usaha pertanian masih belum tersentuh modernisasi secara memadai. Rendahnya adopsi alsintan berkaitan dengan dominasi petani usia lanjut, keterbatasan penguasaan lahan, modal, literasi digital, akses infrastruktur, dan belum meratanya layanan penyuluhan serta bantuan alsintan. Temuan ini menegaskan bahwa modernisasi pertanian tidak cukup dilakukan melalui distribusi alat, tetapi perlu disertai penguatan kelembagaan, pelatihan operator, skema pembiayaan, dan strategi regenerasi petani muda.

1. Introduction

Agriculture is still a strategic sector for Indonesia because it is directly related to food security, labor absorption, and household livelihoods in rural areas [1]. However, in the last two decades, this sector no longer faces production problems alone. Changes in the structure of agricultural businesses, narrowing of land

tenure, aging of farmers, and low interest of the younger generation show that Indonesian agriculture is in a phase of transformation that is not simple [2], [3].

One of the important instruments for reading these changes is the Agricultural Census. The Central Statistics Agency (BPS) conducts the Agricultural Census every ten years [4], while FAO through the World Programme for the Census of Agriculture places the agricultural census as the basis for providing agricultural structure data that can be compared periodically [5]. In the Indonesian context, the 2003, 2013, and 2023 Agricultural Census data provide an opportunity to read long-term changes, especially in the number of Agricultural Business Households (RTUP), Individual Agricultural Enterprises (UTP), the age composition of farmers, and the use of agricultural technology.

The changes in Indonesia's agricultural sector over the past two decades can not only be seen from the number of agricultural business households, but also from the pressure on land, the aging of farmers, changes in business scale, and the slow adoption of technology. The results of the 2023 Agricultural Census show that the number of Agricultural Business Households (RTUP) reached 28.419.398 households, an increase of 8.74% compared to 2013. At the same time, Individual Agricultural Enterprises (UTP) were recorded at 29.342.202 units, down 7.45% compared to 2013 [4]. This pattern shows that the agricultural sector still survives as a livelihood base, but its business structure is facing pressure to change.

Modernization of agriculture through the use of agricultural tools and machinery (alsintan) is an important issue because the need to increase productivity cannot continue to depend on manual labor. Ministerial Regulation Number 21 of 2023 places agricultural tools and machinery as a means to increase farmers' income, production quality and quantity, and national food security [6]. Alsintan can accelerate land cultivation, planting, harvesting, and post-harvest, while reducing yield losses and labor costs [7]. Several studies have shown that mechanization can increase the efficiency and income of farmers, especially in rice farming [8], [9]. However, the use of alsintan at the farmer level is not even because it is influenced by the scale of the business, capital, access to services, and the ability of farmers to operate technology [10].

This condition is increasingly challenging because the agricultural sector is confronted with demographic problems. The proportion of older farmers continues to dominate, while the interest of the younger generation to work in agriculture is relatively weak [11], [12]. In addition, converted agricultural land and spatial restrictions threaten the sustainability of agricultural production [13]. Strategic policy interventions and structural transformation are needed so that agricultural development is not only oriented towards physical output, but also towards the welfare and capacity of farmers [14], [15].

Based on this background, this article aims to: (1) analyze the development of the structure of RTUP and Indonesian agricultural businesses in the period 2003–2023; (2) describe the level of adoption of modern alsintan in agricultural business actors; and (3) discuss factors related to the slow adoption of modern alsintan in Indonesia. With this design, the article is expected to contribute as a secondary data-driven study that remains relevant to the formulation of agricultural modernization policies [16].

2. Research Method

This study uses a descriptive-comparative quantitative approach. A descriptive approach is used to describe the condition of research variables in the form of absolute numbers, percentages, and distributions. A comparative approach was used to compare changes between census periods, namely 2003, 2013, and 2023. The selection of this design is adjusted to the aggregate character of census data, so it is more appropriate to read patterns, tendencies, and structural changes than to test causal influences directly [17].

The main data used are secondary data from the BPS Agricultural Census publication, especially related to RTUP, UTP, farmer age composition, land area, and the use of modern equipment/technology. Supporting data was obtained from policy documents, including Law Number 19 of 2013 concerning the Protection and Empowerment of Farmers, Law Number 41 of 2009 concerning the Protection of Sustainable Food Agricultural Land, and Regulation of the Minister of Agriculture Number 21 of 2023 concerning Agricultural Equipment and Machinery Taxis. In addition, previous research was used to strengthen the interpretation of the results.

The analysis was carried out through four stages. First, the data is compiled and arranged in a comparison table. Second, the calculation of changes between periods is carried out using the growth rate formula on Equation 1, with Xt as the value in the final period and Xt-1 as the value in the previous period. Third, the results of the calculation are interpreted to see the direction of change, whether it is increasing, decreasing, or stagnating. Fourth, descriptive results are associated with supporting and inhibiting factors for alsintan adoption based on relevant literature and policies.

$$Growth\ Rate = ((Xt - Xt1)/Xt1)x\ 100\% \quad (1)$$

The limitation of this study lies in the availability of aggregate census data. Therefore, this article does not use regression or causal relationship tests. The term 'related factors' in this article is understood as a factor that is conceptually and empirically related in the literature to the adoption of alsintan, rather than as evidence of direct statistical influence. These

restrictions are important so that the analysis remains proportional to the type of data available.

3. Result and Discussion

3.1. Changes to the RTUP and Agricultural Business Structure

The number of RTUPS in Indonesia has changed quite sharply over the past two decades. As can be seen on Table 1 from a report, in 2003, the number of RTUP was recorded at 31,232,184 households. This figure dropped to 26,135,469 households in 2013, then increased again to 28,419,398 households in 2023 [4]. The number of RTUP in 2023 increased by 8.74% compared to 2013. These changes show that the agricultural sector is still an important livelihood space, but it is also experiencing strong structural pressures.

Table 1. Changes to the RTUP according to the 2003, 2013, and 2023 Agricultural Census [4]

Indicator	2003	2013	2023
RTUP	31,232,184	26,135,469	28,419,398
UTP (unit)	31,170,000	31,705,295	29,342,202
Land area (ha)	30,419,582	25,751,267	27,802,434

The 2003-2013 period showed a decrease in RTUP of 16.32%. This decline can be read as the impact of urbanization, land conversion, and the shift of labor to the non-agricultural sector. In the same period, the area of agricultural land also decreased by around 15.35%, so the pressure on the agricultural production base looks quite consistent. Land degradation can impact the scale of businesses, incomes, and the ability of farmers to invest in technology.

In 2013-2023, the RTUP increased by 8.74%, but the UTP actually decreased by around 7.45% [4]. This condition indicates that the increase in the number of agricultural households is not always followed by the strengthening of more productive business units. One possible interpretation is the fragmentation of businesses, the survival of small-scale businesses, or the increase in households that remain dependent on agriculture but with limited production capacity.

3.2. Calculation of RTUP and UTP Growth Rate

To clarify the changes between periods, this article uses the calculation of growth rates on two main indicators, namely, the number of RTUP and UTP. The formula used can be seen on Equation (2), where X_t is the value of the variable in a given observation period, and X_(t-1) is the value of the variable in the previous period.

$$Grwth\ Rate = \frac{X_t - X_{t1}}{X_{t1}} \times 100\% \quad (2)$$

Table 2. Calculation of RTUP and UTP Growth Rate [4]

Indicator	2003-2013	2013-2023	2003-2023
RTUP	-16.32%	8.74%	-9.01%
UTP	1.75%	-7.49%	-5.87%
Remarks	RTUP drops sharply, UTP rises slightly	RTUP partially recovers, UTP weakens	The base of households and agricultural business units has not yet returned to 2003

The calculation results show that the amount of RTUP decreased by 16.32% from 2003 to 2013, then increased by 8.74% from 2013 to 2023. The decrease in the 2003–2013 period occurred along with land conversion, urbanization, and structural shift of labor from agriculture to the non-agricultural sector [13]. Conversely, the increase in the number of RTUPs in the 2013–2023 period shows that agriculture remains an important safety valve for rural communities, especially during economic uncertainty and the COVID-19 pandemic [14].

However, the increase in the number of RTUP was not automatically accompanied by an increase in individual business scale. Data from the 2023 Agricultural Census shows that Individual Agricultural Enterprises (UTP) reached 29,342,202 units, down 7.45% from 31,705,295 units in 2013 [4]. This phenomenon indicates that although the number of households engaged in agriculture is increasing, business consolidation at the individual level has not taken place strongly. Most farm households remain smallholders with land ownership of less than 0.5 hectares [2].

3.3. Adoption Rate of Modern Alsintan

In its implementation in Indonesia, the types of alsintan operated in cultivation activities, especially in the food crop subsector, are very diverse and adjusted to the needs of each production phase. These tools are distributed both through self-procurement schemes by farmers and through government intervention programs aimed at accelerating modernization at the grassroots level.

Table 3. Types of Modern Alsintan and Their Functions [6], [8]

Types of Alsintan	Main Functions	Remarks
Two-wheeled tractor	Cultivating soil on rice fields or small-medium scale dry land	Helping smallholders reduce manual labor
Four-wheeled tractor	Tillage of the soil on a wider expanse	More suitable for large land or rental services
Water pump	Helps with irrigation when irrigation is limited	Important when drought or growing season is unstable
Rice transplanter	Planting rice seedlings faster and more uniformly	Encouraging efficiency in rice farming
Combine harvester	Harvesting and harvesting rice in one process	Reduces harvest time and potential yield loss
Hand sprayer electric	Spraying pesticides or liquid fertilizers	Improve the efficiency of maintenance work
Cultivator	Cultivating the soil or ridge on certain commodities	Relevant for horticulture and drylands

In the food crop subsector, the application of alsintan tends to be easier to do because each stage of rice cultivation has a clear and interrelated schedule. Tillage must be completed before the planting period begins, planting is carried out simultaneously, while harvesting needs to be carried out on time so that yield loss can be suppressed. In these conditions, the use of tractors, water pumps, rice transplanters, and combine harvesters is very important to increase the efficiency of the cultivation process. This finding is in line with research which states that alsintan plays an important role in increasing production, productivity, and supporting food security, especially when land area and the availability of agricultural labor are increasingly limited [8].

Agricultural modernization can be seen from the use of modern equipment and technology in farming activities. Based on the ST2023 data used in this study, around 46.84% of farmers/RTUP have used modern technology, while 53.16% have not used modern technology adequately. If the number of farmers in 2023 is estimated at 28.19 million people, then modern technology users are around 13.20 million people, while those who have not used modern technology are around 14.99 million people.

Table 4. The Use of Modern Technology [4], [7]

Categories of use of modern technology	Percentage	Estimated number of farmers
Using modern technology/alsintan	46.84%	±13.20 million
Not yet using modern technology/alsintan	53.16%	±14.99 million

This figure shows that agricultural modernization has not yet become the dominant practice for most farmers. This is not to say that the mechanization program has failed completely, but it does suggest that the adoption of technology still faces obstacles at the level of agricultural households. Conceptually, the adoption of alsintan requires technical, economic, institutional, and social readiness [10]. Available equipment without trained operators, affordable maintenance costs, and a clear institutional model are at risk of not being used optimally [10]. These findings are in line with the research which shows that farmers view alsintan as beneficial for improving efficiency, but cost barriers and usability still arise [8]. Again, other research also emphasizes that the use of alsintan in rice farming can support food efficiency, but requires adequate infrastructure and farmer capacity [7]. Thus, the main issue is not only the availability of tools, but also the connectivity between tools, farmers, institutions, and support services.

3.4. Factors Related to the Slow Adoption of Alsintan

First, the age structure of farmers is an important factor. Young farmers tend to be more adaptive to technology because they are more familiar with digital devices, online information, and technical learning [11]. In contrast, older farmers more often maintain conventional ways of working, not because they resist change, but because experience, risk, and limitations of mentoring make the use of new technologies feel more difficult. show that the aging of farmers is a serious threat to the sustainability of Indonesian agriculture [3].

Second, the land area and business scale affect the feasibility of using alsintan. Farmers with larger land are more likely to benefit economically from mechanization because the cost of tools can be spread over larger production areas. On the other hand, smallholder farmers or farmers with narrow plots tend to face higher costs per unit of land. Under these conditions, the model of individual ownership is less realistic; joint use through farmer groups, Alsintan Service Units (UPJA), cooperatives, or rental schemes have become more relevant [8], [10].

Third, limited capital is still the main obstacle. The price of alsintan, maintenance costs, fuel needs, and the risk of damage make many smallholders hesitant to adopt the technology [10]. Law Number 19 of 2013 actually places financing and empowerment of farmers as an important part of farmer protection, but the implementation of access to financing is still uneven [18]. People's Business Credit Programs, equipment assistance, or subsidies need to be designed to really reach small farmers, not just groups that already have better administrative capacity [10], [18].

Fourth, technology literacy and the quality of counseling determine the success of adoption. Modern tools require technical knowledge, from operation, maintenance, to adjustment to land conditions [7]. Law Number 16 of 2006 concerning the Agriculture, Fisheries, and Forestry Extension System is an important basis for increasing the capacity of farmers [19]. However, in practice, extension often faces limitations in the number of extension workers, regional coverage, and training materials that do not always keep up with the latest agricultural technology developments [15].

Fifth, infrastructure and regional context also have an effect. Not all regions have access to farming roads, alsintan workshops, internet networks, or adequate technical services [13]. In narrow, scattered, or hard-to-access land, the use of large alsintan becomes less efficient [7]. Therefore, agricultural modernization cannot be standardized. Policies need to pay attention to the type of commodity, agroecological conditions, topography, land tenure structure, and local institutional capacity [20].

3.5. Implications of Agricultural Modernization Policy

The results of the study show that agricultural modernization needs to be understood as a socio-economic process, not just a distribution of technology. Alsintan assistance is important, but its effectiveness depends on who the recipient is, how the mechanism of use is, who cares for it, and how the operational costs

are covered. Without strong institutions, tools are at risk of not being used optimally or only used by certain groups [10]. A more appropriate strategy is to strengthen the region-based alsintan service model. The government can encourage UPJA, farmer cooperatives, or farmer groups as providers of equipment rental services at affordable rates [10]. This scheme makes more sense for smallholder farmers because they don't have to buy the tools themselves [8]. In addition, the training of local operators and alsintan maintenance workshops needs to be expanded so that the tools can be used sustainably [7].

Farmer regeneration must also be placed as part of modernization. Young farmer programs do not stop at training, but need to be linked to land access, financing, markets, and digital technology [11], [12]. Young farmers can be a driver of technology adoption if they are given space as equipment operators, agricultural service providers, farm data managers, or digital marketing liaison [12]. In this way, agricultural modernization not only increases production efficiency, but also opens up new job opportunities in rural areas [1].

Finally, the use of census data needs to be strengthened as the basis for evidence-based policies. The ST2023 data can be used to map areas with predominance of old farmers, narrow land, or low levels of technology use [4]. The mapping is important so that the assistance of alsintan is not general, but directed to areas and groups that really need support. Thus, the agricultural census is not only a statistical report, but also a tool for drafting more targeted modernization interventions [1], [16].

4. Conclusion

The analysis of Agricultural Census data from 2003, 2013, and 2023 demonstrates that while the number of Agricultural Business Households (RTUP) experienced a partial recovery in 2023 to 28.42 million, overall adoption of modern agricultural tools and machinery (*alsintan*) remains constrained at 46.84%. This limited adoption is heavily influenced by structural constraints, including narrow land tenure, an aging farmer demographic where 34.20% are over 55 years old, capital limitations, and institutional deficiencies in custom hiring services like UPJA. Addressing these bottlenecks requires a shift from simple machinery distribution to comprehensive institutional strengthening, expanded custom renting services, targeted capital access, and active youth farmer regeneration strategies.

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