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Optimization Of Agricultural Mechanization To Support The Development Of Horticultural Areas In Hulu Sungai Tengah Regency

Suhermanto[1*], Nur Inayah Ariyani[2], Fahrina Roli[3]

[1,2,3] D4 Study Program of Horticultural Crop Production Technology, Politeknik Murakata.

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ABSTRACT

Agricultural mechanization is one of the main pillars of agricultural sector modernization that significantly contributes to productivity improvement, labor efficiency, and competitiveness of agricultural products. Hulu Sungai Tengah (HST) Regency in South Kalimantan Province possesses enormous horticultural potential with an area of approximately 8,750 hectares; however, the adoption rate of agricultural machinery and equipment (alsintan) remains relatively low at 42.3%, far below the national average of 68.5%. This study aimed to: (1) analyze the existing condition of horticultural agricultural mechanization in HST Regency; (2) identify inhibiting and driving factors of alsintan adoption; (3) analyze the relationship between mechanization level and farming productivity and efficiency; and (4) formulate a comprehensive mechanization optimization strategy. The study employed a quantitative descriptive method with surveys conducted on 120 horticultural farmers selected through purposive stratified random sampling in four major production sub-districts. Data were analyzed using the Agricultural Mechanization Index (AMI), Analytic Hierarchy Process (AHP), SWOT analysis, and Quantitative Strategic Planning Matrix (QSPM). Results indicated that the main inhibiting factors for alsintan adoption were capital constraints (78.3%), land topography incompatibility (65.0%), and insufficient technical knowledge of farmers (61.7%). Regression analysis confirmed a significant positive relationship between mechanization level and productivity ($r = 0.723$; $p < 0.01$), where farmers with full mechanization achieved 35.6% higher productivity and 28.4% better cost efficiency compared to conventional farming. Five recommended optimization strategies include: development of appropriate technology alsintan based on local wisdom, strengthening of Farmer Group Alsintan Brigade, subsidized financing schemes, farmer human resource capacity building, and development of supporting infrastructure. Integrated strategy implementation is projected to increase horticultural productivity by 35% and reduce production costs by 28% within the next five years.

Corresponding Author: **Suhermanto**

Author: Suhermanto, Nur Inayah Ariyani, Fahrina Roli
D4 Study Program of Horticultural Crop Production Technology, Politeknik Murakata
Jl. Surapati No. 3, Barabai Timur 71313, South Kalimantan, Indonesia

Email: gedesuher.yt@gmail.com

INTRODUCTION

The agricultural sector is the backbone of the Indonesian economy, serving not only as a food provider but also as a source of employment for approximately 38.9 million people, or about 29.3% of the total national workforce [1]. Amid the increasingly complex dynamics of national development, the horticultural sub-sector has emerged as a leading sector with high economic value, diverse commodities, and promising export potential. In 2022, the national horticultural production value reached IDR 187.4 trillion, or approximately 21.7% of the total national agricultural production value [1].

Hulu Sungai Tengah (HST) Regency, located in the heart of South Kalimantan Province at coordinates 2°20'–2°51' South Latitude and 115°17'–115°50' East Longitude, is one of the horticultural production centers with very significant development potential. With elevations ranging from 100 to 1,894 meters above sea level, the agroclimatic conditions in this regency highly support the growth of various lowland and highland horticultural commodities [2]. Based on HST BPS data [2], agricultural land area in this regency reaches 28,450 hectares, with a dedicated horticultural zone of 8,750 hectares spread across various sub-districts.

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HST Regency's leading horticultural commodities include cayenne pepper (Capsicum frutescens L.) with production of 4,328 tons/year, shallot (Allium cepa L. var. aggregatum) at 2,156 tons/year, tomato (Solanum lycopersicum L.) at 1,847 tons/year, and various other vegetables such as mustard greens, water spinach, spinach, yard-long beans, and eggplant totaling 3,215 tons/year [2]. These commodities have wide market reach, from local markets within HST Regency and surroundings to regional markets in Banjarmasin and Banjarbaru cities.

Nevertheless, horticultural productivity in HST Regency remains below its optimal potential. One of the fundamental root causes is the low adoption rate of agricultural mechanization. Based on data from the HST Regency Department of Agriculture and Horticulture [29], the Agricultural Mechanization Index (AMI) for the horticultural sector in this regency has only reached 42.3%, far behind the national average which has already reached 68.5% [13]. This condition causes the production process to remain highly dependent on manual labor, which is increasingly scarce and expensive due to the ongoing urbanization trend.

Research on horticultural agricultural mechanization in the Kalimantan region remains very limited. Most agricultural mechanization studies in Indonesia focus on food crops, particularly rice and corn in Java and Sumatra [3], [10], [13]. Research specifically examining mechanization optimization to support horticultural area development in regions with diverse topographic characteristics such as HST Regency has rarely been conducted. This research gap serves as the primary motivation for this study.

This study aimed to: (1) comprehensively analyze the existing condition of horticultural agricultural mechanization in HST Regency based on production stages and areas; (2) identify and rank the inhibiting and driving factors of alsintan adoption using the AHP approach; (3) analyze the causal relationship between mechanization level and horticultural farming productivity and efficiency; and (4) formulate measurable, applicable, and sustainable mechanization optimization strategies to support the development of horticultural areas in HST Regency.

LITERATURE REVIEW

Concept and Urgency of Agricultural Mechanization

Agricultural mechanization is broadly defined as the application of engineering principles and technology in agricultural activities, encompassing the use of agricultural machinery and equipment (alsintan) and efficient management systems to replace or assist human and animal labor in agricultural production processes [7]. FAO [7] distinguishes agricultural mechanization into three levels: (1) simple mechanization (hand tools and animal traction), (2) advanced mechanization (motorized equipment), and (3) precision mechanization (precision agriculture with sensors, GPS, and drones).

In the context of modern agriculture, mechanization is not merely the replacement of human labor with machines, but a systematic effort to increase production capacity, improve output quality, reduce losses, and ultimately improve farmer welfare [4]. A meta-analysis study by Kuntariningsih and Mariyono [19] of 47 studies in Indonesia showed that mechanization adoption on average can increase productivity by 28–42% and reduce production costs by 18–35% compared to manual systems.

Horticultural Agricultural Mechanization: Characteristics and Challenges

Horticultural mechanization has fundamentally different characteristics compared to food crop mechanization. According to Sudirman [8], there are at least four main differentiating aspects. First, commodity diversity – unlike rice or corn which are relatively uniform, horticultural commodities vary greatly in terms of plant morphology, cultivation systems, and handling requirements, so no single type of alsintan can be applied universally. Second, susceptibility to mechanical damage – fresh horticultural products such as chili, tomatoes, and leafy vegetables are very prone to bruising or physical damage from improper mechanical processes, which directly impacts reduction in selling value. Third, small and fragmented farming scale – the average horticultural land ownership per farmer in Indonesia is only 0.36 hectares [13], making large-scale alsintan uneconomical to use. Fourth, topographic variation – horticultural land is often located in hilly areas or on slopes with gradients that do not allow the use of standard alsintan.

Wicaksono et al. [20] in their research in Kalimantan found that the level of suitability of commercially available alsintan with the needs of local horticultural farmers was only around 43–58%, indicating a significant technology gap between mass-produced alsintan and the actual needs of horticultural farmers in the field.

Theory of Agricultural Technology Innovation Adoption

Understanding mechanization adoption cannot be separated from the theoretical framework of innovation adoption. Rogers [9] in his monumental Diffusion of Innovations states that the decision to adopt an innovation is influenced by five innovation characteristics: (1) relative advantage – the extent to which the innovation is perceived as better than what it replaces; (2) compatibility – the alignment of the innovation with adopter values, experience, and needs; (3) complexity – the degree of difficulty of the innovation to understand and use; (4) trialability – the possibility of trying the innovation first before full adoption; and (5) observability – the extent to which the results of using the innovation can be observed by others.

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In the context of agricultural mechanization in Indonesia, Hendriadi [10] developed a more contextual adoption model by adding structural factors such as credit accessibility, subsidy policies, and farmer institutional capacity. Suharsono [12] through his research in Central Java found that cognitive factors (farmer knowledge and perception) have equal influence to economic factors (capital) in determining alsintan adoption decisions.

Policy for Horticultural Area Development in Indonesia

The Indonesian government has established agricultural area development policies based on leading commodities through Minister of Agriculture Regulation No. 56 of 2016 [15]. This policy promotes the formation of integrated horticultural areas, encompassing land consolidation, cultivation standardization, value chain integration from upstream to downstream, and application of agricultural technology including mechanization [17]. The Directorate General of Horticulture [17] has set a target to increase the national AMI for the horticultural sector from 68.5% in 2022 to 80% by 2027 as part of the Indonesian Agricultural Mechanization Roadmap 2021–2025 [13].

Research by Badrudin et al. [21] on the technical efficiency of cayenne pepper farming in HST Regency revealed that the average technical efficiency level only reached 0.64, far from the achievable frontier. One of the determining factors of this inefficiency was the low use of alsintan, particularly in the land preparation and plant pest control stages. These findings reinforce the argument that mechanization optimization is an appropriate and urgent intervention to be carried out in the study area.

METHODS

Research Location and Time

This research was conducted in Hulu Sungai Tengah Regency, South Kalimantan Province, during the period of February–June 2024 (5 months). Location selection was performed purposively considering: (1) HST Regency is the second largest horticultural production center in South Kalimantan based on production volume; (2) the regency is in the process of developing an integrated horticultural area supported by regional and national budget programs; (3) there is significant variation in mechanization levels between areas, enabling meaningful comparative analysis; and (4) there is full support from the HST Regency Department of Agriculture and Horticulture in the form of data access and research permit facilitation.

The research covered four sub-districts which are the largest horticultural production centers in HST Regency: Barabai Sub-district (horticultural area 2,840 ha), Pandawan Sub-district (2,310 ha), Labuan Amas Utara Sub-district (1,975 ha), and Haruyan Sub-district (1,625 ha). These four sub-districts collectively represent 98.3% of the total horticultural area of HST Regency.

Population, Sample, and Sampling Technique

The study population consisted of all active horticultural farmers registered in farmer groups in the four research sub-districts, totaling 2,340 farming household heads based on data from the HST Regency Department of Agriculture and Horticulture in 2023 [29]. Sample inclusion criteria included: (1) farmers actively cultivating at least one horticultural commodity during the last two planting seasons; (2) holding horticultural cultivated land of at least 0.10 hectares; and (3) willing to be respondents and provide information honestly.

Sample size was determined using the Slovin formula with a tolerable error level (e) of 9%, yielding a minimum sample size of 106 respondents. To anticipate the possibility of incomplete data or withdrawn respondents, the sample size was rounded up to 120 respondents. The sampling technique used purposive stratified random sampling, with proportional distribution based on the horticultural area of each sub-district: Barabai 35 respondents (29.2%), Pandawan 30 respondents (25.0%), Labuan Amas Utara 28 respondents (23.3%), and Haruyan 27 respondents (22.5%).

Data Collection Methods

Primary data were collected through three complementary methods. First, structured interviews using questionnaires that had undergone validity and reliability testing (Cronbach's Alpha = 0.847 > 0.70). The questionnaire comprised 78 question items gathering information on farmer characteristics, farming conditions, ownership and use of alsintan, perceptions toward mechanization, and factors influencing adoption decisions. Second, field observations for three days in each sub-district to directly observe the condition and use of alsintan in the production process. Third, Focus Group Discussions (FGD) conducted four times (once per sub-district) with 8–12 participants consisting of farmer group administrators, field agricultural extension workers (PPL), and local Agriculture Department officials.

Secondary data were obtained from various sources, including: agricultural statistics data from HST Regency BPS [2], annual reports of the HST Regency Department of Agriculture and Horticulture [29], alsintan inventory data from the Center for Agricultural Mechanization Development (BBP Mektan), and various relevant research reports and scientific publications.

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Data Analysis Methods

Data analysis in this study used four complementary analytical approaches. First, the Agricultural Mechanization Index (AMI) was calculated based on the ratio of the mechanized area to the total harvested area for each production stage. The overall AMI was obtained from the weighted average AMI per stage, with weights determined based on each stage's contribution to total production costs.

Second, Analytic Hierarchy Process (AHP) was used to determine factors influencing alsintan adoption. AHP involved 15 experts (5 researchers, 5 senior agricultural extension workers, and 5 experienced farmers). Assessment consistency was tested using the Consistency Ratio (CR) with a tolerance limit of $CR \leq 0.10$. Third, multiple regression analysis was used to measure the effect of mechanization level on farming productivity and efficiency, with control variables including land area, farming experience, and farmer education level. Fourth, optimization strategies were formulated through SWOT analysis and priority strategy selection using the Quantitative Strategic Planning Matrix (QSPM) [16].

RESULTS AND DISCUSSION

Respondent Profile and Characteristics of Horticultural Farming

The sociodemographic characteristics of 120 horticultural farmer respondents in HST Regency are presented in detail in Table 1. In terms of age, the majority of respondents (71.7%) were in the productive age group of 25–55 years, with an average age of 42.3 years. Only 8.3% of respondents were above 60 years of age, indicating that horticultural farming in HST Regency is still attractive to younger age groups. The average horticultural farming experience was 18.4 years (range 3–41 years), showing that most respondents had adequate empirical knowledge of horticultural cultivation.

The formal education level of respondents was still relatively low, dominated by elementary school graduates (45.8%) and junior high school graduates (30.0%). Only 5.8% of respondents had diploma or undergraduate-level education. This condition has implications for farmers' capacity to absorb increasingly complex mechanization technology innovations, so technology dissemination approaches need to be adjusted to existing literacy level characteristics.

Table 1. Sociodemographic Characteristics of Horticultural Farmer Respondents in HST Regency, 2024

Characteristic	Category	Number (persons)	Percentage (%)
Age	< 25 years	7	5.8
	25–40 years	42	35.0
	41–55 years	44	36.7
	56–60 years	17	14.2
	> 60 years	10	8.3
Education	Did not complete primary school	10	8.3
	Primary school (SD)	55	45.8
	Junior high school (SMP)	36	30.0
	Senior high school (SMA)	12	10.0
	Diploma/Bachelor's (D3/S1)	7	5.8
Farming Experience	< 5 years	8	6.7
	5–10 years	19	15.8
	11–20 years	52	43.3
	> 20 years	41	34.2
Land Area (ha)	< 0.25 ha	22	18.3
	0.25–0.50 ha	45	37.5
	0.51–1.00 ha	38	31.7
	> 1.00 ha	15	12.5
Land Status	Freehold (Hak Milik)	82	68.3
	Leased	26	21.7
	Cultivated/Other	12	10.0

Source: Primary data processed (2024)

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Existing Condition of Horticultural Agricultural Mechanization

The overall Agricultural Mechanization Index (AMI) measurement results for the horticultural sector in HST Regency show a figure of 42.3%, confirming that the mechanization condition still lags behind the national average of 68.5% [13]. Table 2 presents mechanization levels in detail by production stage and comparison with the national average.

Table 2. Level of Horticultural Agricultural Mechanization by Production Stage in HST Regency

Production Stage	AMI HST Reg. (%)	National AMI (%)	Gap (%)	Main Alsintan Types Used
Land Preparation	61.7	75.2	13.5	Hand tractors, rotovators, cultivators
Planting	28.3	52.4	24.1	Transplanters, seed drills
Irrigation/Watering	54.2	71.8	17.6	Water pumps, drip/sprinkler systems
Fertilization/Crop Protection	42.5	60.3	17.8	Power sprayers, motorized knapsack sprayers
Harvesting	34.2	58.7	24.5	Mechanical harvesting tools, conveyors
Post-harvest & Packaging	38.5	67.4	28.9	Grader/sorter, portable cold storage
Overall Average (AMI)	42.3	68.5	26.2	–

Source: Primary data processed; Ministry of Agriculture RI (2023) in [13]

Table 2 shows that the largest mechanization gap occurs at the post-harvest stage (gap 28.9%) and harvesting stage (gap 24.5%). This condition is critical given that post-harvest losses in Indonesian horticulture remain very high, ranging from 20–40% of total production [17]. These high post-harvest losses directly reduce farmer income and hamper the competitiveness of HST Regency's horticultural products in the regional market.

Spatial analysis shows significant variation in mechanization levels between sub-districts. Barabai Sub-district has the highest AMI (48.6%), which correlates with better infrastructure accessibility and proximity to the regency capital as the alsintan distribution center. In contrast, Haruyan Sub-district shows the lowest AMI (35.8%) due to more hilly terrain and still-limited farm road access.

Table 3. Comparison of Agricultural Mechanization Index (AMI) between Horticultural Production Centers in HST Regency

Sub-district	Area (ha)	Number of Farmers	AMI (%)	Average Productivity (tons/ha)	Production Cost (IDR million/ha)
Barabai	2,840	35	48.6	12.4	18.7
Pandawan	2,310	30	43.2	10.8	21.3
Labuan Amas Utara	1,975	28	39.7	9.6	23.1
Haruyan	1,625	27	35.8	8.9	24.8
Average	2,187.5	30	42.3	10.4	22.0

Source: Primary data processed; HST Regency Department of Agriculture and Horticulture (2023) [29]

Inhibiting and Driving Factors of Alsintan Adoption

AHP analysis involving 15 experts successfully determined the ranking of factors influencing horticultural alsintan adoption in HST Regency. Assessment results from all experts showed a good level of consistency (CR < 0.10). Complete analysis results are presented in Table 4.

Table 4. AHP Analysis Results of Inhibiting Factors for Horticultural Alsintan Adoption in HST Regency

Rank	Inhibiting Factor	AHP Weight	Affected Farmers (%)	Category
1	Capital limitations and access to formal financing	0.287	78.3	Economic
2	Incompatibility of land topography with conventional alsintan	0.198	65.0	Technical
3	Insufficient technical knowledge and skills of farmers	0.176	61.7	Human Resources
4	Limited after-sales service and spare parts	0.142	53.3	Infrastructure
5	Mismatch of alsintan size/scale with small land areas	0.118	47.5	Technical
6	Low farmer awareness and motivation to change	0.079	38.3	Social

Source: AHP analysis, primary data processed (2024); CR = 0.068 (consistent)

Capital limitations dominated as the main inhibiting factor with an AHP weight of 0.287, affecting 78.3% of respondents. The average investment value required for one hand tractor unit in the current market ranges from IDR 28–45 million, far exceeding the financial capacity of small-scale horticultural farmers who earn an average net income of

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IDR 2.8–4.2 million per month per hectare from their farming [21]. Farmer access to formal credit is also very limited, with only 31.7% of respondents having ever utilized People's Business Credit (KUR) for the agricultural sector.

The topographic factor (weight 0.198) became the largest technical obstacle, particularly in Haruyan and Labuan Amas Utara Sub-districts which have land slopes > 15%. Standard alsintan available on the market is generally designed for flat land, so it cannot be operated safely and efficiently on hilly terrain. Rachman et al. [11] in their research found that only about 42% of total horticultural land in the Kalimantan highlands is suitable for conventional alsintan use without modification.

On the driving side, AHP analysis identified that farmers' desire to increase income (weight 0.324) became the strongest motivation, followed by awareness of increasingly scarce labor efficiency (weight 0.251), availability of government alsintan assistance programs (weight 0.198), and positive demonstration effect from farmers who have already adopted alsintan (weight 0.155).

Relationship between Mechanization and Farming Productivity and Efficiency

Multiple regression analysis showed a positive and significant relationship between mechanization level (AMI) and horticultural farming productivity ($r = 0.723$; $R^2 = 0.523$; $p < 0.01$). This means 52.3% of productivity variation can be explained by the mechanization level, after controlling for land area, farming experience, and education variables. Every 10 percentage point increase in AMI correlates with an average productivity increase of 3.8 tons/ha/season.

Table 5. Productivity and Efficiency of Horticultural Farming by Mechanization Level in HST Regency

Mechanization Category	AMI (%)	Productivity (tons/ha)	Production Cost (IDR mil/ha)	Net Income (IDR mil/ha)	Number of Farmers
Very Low (manual)	0–25	6.8	27.4	18.6	18
Low	26–50	9.2	23.8	26.4	52
Medium	51–70	12.1	20.1	34.7	31
High (full)	> 70	16.9	19.5	51.9	19
Overall Average	42.3	10.4	22.0	28.8	120

Source: Primary data processed (2024)

Table 5 shows a very clear pattern: farmers with full mechanization (AMI > 70%) achieve an average productivity of 16.9 tons/ha, or 148.5% higher compared to fully manual farmers (6.8 tons/ha). In terms of production costs, full mechanization can reduce costs from IDR 27.4 million/ha to IDR 19.5 million/ha, or an efficiency of 28.8%. Overall, the net income of fully mechanized farmers reaches IDR 51.9 million/ha/season, or 2.8 times the income of still-manual farmers (IDR 18.6 million/ha/season).

The greatest efficiency from mechanization is obtained in the land preparation stage, where using a hand tractor can save 68% of labor costs compared to manual preparation with a hoe. In the crop protection stage, using motorized power sprayers saves 41% costs compared to manual hand sprayers, while also improving pesticide application uniformity thereby reducing the risk of pest and disease control failure. Meanwhile, the use of drip irrigation systems has been proven to save 35–50% of water use and 20–30% of soluble fertilizers through a precise fertigation system [7].

SWOT Analysis of HST Regency Horticultural Mechanization

Based on the synthesis of primary and secondary data, the SWOT analysis of HST Regency's horticultural mechanization resulted in the identification of strategic factors. Strengths include: extensive horticultural land potential (8,750 ha) with supportive agroclimatic conditions; commodity diversity providing farming flexibility; relatively active farmer groups (178 groups) as an institutional base; and local government commitment reflected in the RPJMD. Weaknesses include: low AMI (42.3%) with high inter-sub-district variation; limited farmer capital and low credit access; farmers with low educational backgrounds; and inadequate farm road infrastructure.

Opportunities that can be leveraged include: central government alsintan assistance programs (national budget) that continue to increase; increasingly diverse and affordable small-scale alsintan technology development; fresh horticultural market demand continuously growing at 8–12% per year; and integrated horticultural area development policies that provide program legitimacy. Threats to anticipate include: urbanization causing agricultural labor scarcity; climate change increasing farming risks; competition from horticultural products from other regions; and unpredictable commodity price fluctuations.

Horticultural Agricultural Mechanization Optimization Strategies

Based on SWOT analysis results and QSPM selection, five priority strategies for optimizing horticultural agricultural mechanization in HST Regency with the highest Total Attractiveness Scores (TAS) were identified. These five strategies are then detailed in action programs implementable in the short term (1–2 years), medium term (3–4 years), and long term (5 years and above).

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Strategy 1: Development of Locally-Adapted Appropriate Technology Alsintan (TAS = 6.84). This program encompasses identification and documentation of traditional alsintan still used by local farmers, followed by development or modification based on modern technology to improve efficiency and capacity. Collaboration among farmers and farmer groups, agricultural extension workers, Politeknik Murakata, Agricultural Extension Centers, the HST Regency Department of Agriculture and Horticulture, and alsintan business actors or distributors, is key to the success of this strategy.

Strategy 2: Strengthening of Farmer Group-Based Alsintan Brigade (TAS = 6.71). The Alsintan Brigade model is a system of collective alsintan ownership and management by farmer groups, where each member can access alsintan through an affordable intra-group rental system. Revenue from rental services is used for operational costs, maintenance, and revolving capital for purchasing new alsintan. The regency government plays a role in providing starter pack alsintan assistance and management mentoring for Brigade operations.

Strategy 3: Innovation in Alsintan Financing Schemes (TAS = 6.58). This program involves negotiation with banks and microfinance institutions to design special alsintan credit products for horticultural farmers with low interest, light collateral, and long terms (3–5 years). The regency government can serve as credit guarantor through the Food and Energy Security Credit (KKPE) scheme or revolving funds sourced from the regional budget. Additionally, agricultural leasing schemes with alsintan distributor companies also need to be developed as an acquisition alternative without direct purchase.

Strategy 4: Strengthening Farmer and Operator Human Resource Capacity (TAS = 6.43). A comprehensive horticultural mechanization training program needs to be designed and implemented in a structured manner, encompassing: technical training in alsintan operation (theory and practice), training in alsintan maintenance and minor repairs, Alsintan Brigade management training, and study visits to advanced horticultural mechanization centers in East Java or North Sumatra. Training is conducted by the Agricultural Extension Center (BPP) in collaboration with alsintan distributors who provide direct demonstrations.

Strategy 5: Development of Mechanization Supporting Infrastructure (TAS = 6.27). Without adequate infrastructure, alsintan adoption will not be optimal even if farmers already have financial and technical capabilities. Priority infrastructure programs include: improvement and expansion of farm roads so they can be traversed by tractors and harvest transport vehicles; construction of integrated alsintan workshops in each sub-district functioning as service centers, spare parts supply points, and technical consultation facilities; and development of piped irrigation systems compatible with drip irrigation equipment.

Table 6. Summary of Horticultural Mechanization Optimization Strategies and Achievement Targets in HST Regency

No.	Strategy	TAS	Implementation	5-Year Achievement Target
1	Development of Locally-Adapted Appropriate Technology Alsintan	6.84	Short-term	3 adaptive alsintan prototypes; AMI increase 8–10%
2	Strengthening of Farmer Group Alsintan Brigade	6.71	Short-medium term	50 active Brigades in 4 sub-districts; 60% farmers served
3	Innovation in Alsintan Financing Schemes	6.58	Medium term	500 new alsintan units; credit NPL < 3%
4	Strengthening Farmer & Operator HR Capacity	6.43	Short-long term	1,200 trained farmers; 80 certified operators
5	Development of Supporting Infrastructure	6.27	Medium-long term	120 km farm roads; 4 sub-district alsintan workshops

Source: QSPM analysis results, primary data processed (2024)

Projected impact of integrated implementation of all five strategies, validated through expert judgement with 10 agricultural mechanization and agricultural economics experts, shows an AMI increase from 42.3% (2024) to 72.5% by 2029. This AMI increase is estimated to produce: (1) an average horticultural productivity increase of 35% from 10.4 tons/ha to 14.0 tons/ha; (2) a production cost decrease of 28% from IDR 22.0 million/ha to IDR 15.8 million/ha; (3) an average farmer net income increase of 89% from IDR 28.8 million/ha to IDR 54.4 million/ha; and (4) reduction of post-harvest losses from 32% to below 15%.

CONCLUSIONS

This research yields four main conclusions. First, the condition of horticultural agricultural mechanization in HST Regency is still at a low level with an average AMI of 42.3%, far below the national average of 68.5%, with the largest gaps in the post-harvest stage (gap 28.9%) and harvesting stage (gap 24.5%). The variation in AMI between sub-districts is quite significant, from 48.6% in Barabai Sub-district to 35.8% in Haruyan Sub-district, influenced by infrastructure accessibility and regional topographic characteristics.

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Second, the inhibiting factors for horticultural alsintan adoption identified through AHP—in order from most to least dominant—are: capital limitations and access to formal financing (weight 0.287; 78.3% of affected farmers), land topography incompatibility (0.198; 65.0%), insufficient technical knowledge (0.176; 61.7%), limited after-sales service (0.142; 53.3%), alsintan scale mismatch with small land areas (0.118; 47.5%), and low motivation for change (0.079; 38.3%).

Third, there is a positive and significant causal relationship between mechanization level and productivity ($r = 0.723$; $p < 0.01$) and production cost efficiency of horticultural farming. Farmers with full mechanization (AMI > 70%) have 148.5% higher productivity and 2.8 times the net income compared to fully manual farmers.

Fourth, five optimization strategies were successfully formulated through SWOT-QSPM analysis, in order of priority: (1) development of locally-adapted appropriate technology alsintan; (2) strengthening of Farmer Group Alsintan Brigade; (3) innovation in alsintan financing schemes; (4) strengthening farmer and operator human resource capacity; and (5) development of mechanization supporting infrastructure. Integrated implementation of these five strategies is projected to increase AMI to 72.5% within five years, increase productivity by 35%, and reduce production costs by 28%.

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CONFLICT OF INTEREST STATEMENT

The authors sincerely declare that there is no conflict of interest in the writing and publication of this scientific article. The research was conducted independently without pressure or intervention from any party, and did not receive funding from alsintan producer or distributor companies that could affect the objectivity of the research results.

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