JURNAL AGROEKOTEKNOLOGI TERAPAN
Applied Agroecotechnology Journal

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

Spatial Dynamics and Economic Drivers of Paddy Field Conversion in South Minahasa Regency, North Sulawesi, Indonesia.

Wiske Chriesti Rotinsulu*, Sandra Engelin Pakasi, Nordy Fritsgerald Lucky Waney.

Faculty of Agriculture, Sam Ratulangi University, Manado 95115 Indonesia

*Corresponding author:
wiske_rotinsulu@unsrat.ac.id

Manuscript received: 23 Nov 2025.
Revision accepted: 22 Dec. 2025.

Abstract. Cropped paddy fields threaten rice self-sufficiency and rural livelihoods in many parts of Indonesia. This study examines the spatial dynamics and economic drivers of paddy field conversion in South Minahasa Regency, North Sulawesi, focusing on Tumpaan and Tatapaan Districts. Spatial analysis of land-use data for 2019 and 2024 was combined with farm-level surveys of 30 farmers and comparative farm-budget analysis for irrigated rice and four alternative crops (melon, watermelon, chilli and patchouli). The results show substantial paddy field loss, with net reductions of approximately 160.749 ha in Tumpaan and 82.68 ha in Tatapaan over the study period. Farm-budget comparisons indicate that irrigated rice on 0.62 ha yields only a small positive net cash income, whereas melon and watermelon on 1 ha each and chilli on 0.60 ha generate very high net cash returns in the observed season; patchouli, by contrast, is clearly unprofitable. Farmer interviews highlight high production costs and low margins for rice, labour shortages, difficulties in accessing fertiliser, deteriorating irrigation infrastructure and attractive market opportunities for horticultural crops as key drivers of conversion. The findings suggest that paddy field protection policies will remain ineffective if they are not accompanied by measures that improve the profitability and reliability of rice farming while recognising farmers' rational responses to income opportunities from alternative crops.

Keywords: paddy field conversion; farm income; horticultural crops; spatial analysis

INTRODUCTION

Paddy fields play a critical role in ensuring food security and sustaining rural livelihoods in many parts of Asia, including Indonesia[1]. Rice remains the main staple food, and national food policies have long prioritised self-sufficiency in rice production[2], [3]. However, rapid economic development, urban expansion and the growth of non-agricultural sectors have increased pressure on agricultural land, leading to widespread conversion of paddy fields to non-paddy uses[4], [5]. This process threatens the stability of domestic rice supply and can undermine the livelihoods of smallholder farmers who depend on irrigated rice cultivation[6], [7].

Indonesia has responded to these concerns by introducing policies and regulations aimed at protecting agricultural land, including the designation of sustainable food agricultural land (Lahan Pertanian Pangan Berkelanjutan, LP2B)[6], [8]. Despite these policy efforts, paddy field conversion continues to occur in many regions, driven by a combination of economic, social and institutional factors[9], [10]. Previous studies have documented that low rice farm incomes, high production costs, labour shortages, inadequate irrigation infrastructure and attractive returns from alternative land uses are among the key drivers of conversion. At the same time, rising demand for horticultural crops and other high-value commodities has created new opportunities for farmers but also intensified competition for land.

South Minahasa Regency in North Sulawesi Province illustrates these dynamics. Official statistics and local assessments indicate that the total area of paddy fields in the regency has declined markedly in recent years, with a substantial reduction in irrigated rice land between 2018 and 2024[11], [12]. Within the regency, Tumpaan and Tatapaan Districts are notable both for their historical importance as rice-producing areas and for the visible conversion of paddy fields to other uses, including residential development and the cultivation of horticultural crops such as melon, watermelon and chilli, as well as patchouli. Remote sensing-based mapping and local surveys have shown that significant areas of irrigated rice land in these districts have been converted to non-paddy uses over a relatively short period, raising concerns about the long-term sustainability of rice production in the region[13], [14].

Several studies in Indonesia and elsewhere have examined paddy field conversion using spatial analysis, farm-level economic comparisons or qualitative assessments of farmer decision-making[15], [16]. Research has documented the spatial patterns and rates of conversion, the relative profitability of rice compared with alternative crops, and the influence of infrastructure, policy and market access[17]. However, there is still a need for integrated case studies that combine spatial evidence of land-use change with farm income analysis and farmer perspectives on the drivers of conversion in specific local contexts. In South Minahasa Regency, empirical analysis that links the observed loss of paddy fields with the economic performance of rice and alternative crops, as well as the motivations and constraints faced by farmers, remains limited.

Against this background, the present study aims to examine the spatial dynamics and economic drivers of paddy field conversion in South Minahasa Regency, with a focus on Tumpaan and Tatapaan Districts. Specifically, the objectives are: (i) to quantify changes in paddy field area over time using spatial analysis of land use in the two districts; (ii) to compare the farm-level costs, revenues and net income of irrigated rice with selected alternative crops cultivated on converted land, namely melon, watermelon, chilli and patchouli; and (iii) to identify key factors that influence farmers' decisions to convert paddy fields, based on field interviews and socio-economic information. By integrating spatial and farm-level economic analysis with farmer perspectives, this study seeks to provide a more comprehensive understanding of paddy field conversion in South Minahasa and to inform policy and management strategies for protecting productive rice land while recognising the economic realities faced by rural households..

MATERIALS AND METHODS

Study area

The study was conducted in Tumpaan and Tatapaan Districts, South Minahasa Regency, North Sulawesi Province, Indonesia. Both districts form part of the Popontolen irrigation scheme, which has historically been one of the main irrigated rice production areas in the regency. In recent years, farmers in these districts have increasingly converted paddy fields to non-paddy uses, particularly to horticultural crops such as melon, watermelon and chilli, as well as patchouli. Fieldwork for this study was carried out over a six-month period.

Data sources

Two main types of data were used: (1) spatial land-use data on paddy field distribution over time and (2) socio-economic and farm-budget data from farmers and local institutions.

Spatial data on paddy fields

Spatial information on paddy fields in Tumpaan and Tatapaan was compiled for two time points, 2019 and 2024, representing the beginning and end of the main period of land-use change analysed in this study. The spatial database combined existing land-use maps and administrative boundary layers from local government and statistical agencies with interpretation of satellite imagery and other geospatial data, following standard remote sensing and GIS procedures. These data were organised to distinguish paddy fields from non-paddy land uses within each district.

Socio-economic and farm-budget data

Socio-economic and farm-budget data were collected through face-to-face interviews with farmers in the Popontolen irrigation area, supplemented by interviews with officers from the District Agriculture Office. The farmer questionnaire covered household and farmer characteristics, land use and cropping patterns, input use and costs, yields, selling prices, revenues and net income for irrigated rice and alternative crops, as well as farmers' reasons for converting paddy fields to non-paddy uses.

An overview of the data types and sources used in the study is presented in Table 1.

Table 1. Overview of data types and sources used in the study

Data type	Description	Time period / reference year	Source / method	Main use in the study
Spatial land-use data	Spatial distribution of paddy and non-paddy land in Tumpaan and Tatapaan Districts	2019 and 2024	Existing land-use maps and interpreted satellite imagery	Quantifying changes in paddy field area over time
Administrative boundaries	District and regency boundaries, irrigation command area (Popontolen scheme)	Latest available	Local government and statistical agencies	Delineating the study area and mapping paddy fields
Socio-economic farmer data	Farmer characteristics, land use, cropping patterns, perceptions of conversion	Survey year (fieldwork)	Structured interviews with 30 farmers	Characterising farmers and identifying drivers of conversion
Farm-budget data	Input use, costs, yields, prices, revenues and net income for rice and alternative crops	One cropping season	Farm surveys and cross-checks with key informants	Constructing comparative farm budgets (rice vs alternatives)
Institutional and policy data	Information on irrigation conditions, fertiliser access, land-use regulation and programmes	Recent years	Interviews with District Agriculture Office and other local officials	Interpreting institutional context and constraints

Table 1 summarises the different types of data, their time coverage, sources and roles in the analysis. Together, these data sets make it possible to link observed changes in paddy field area with farm-level economic performance and farmer-reported drivers of conversion.

Farmer sampling and survey design

The socio-economic survey targeted farmers in the Popontolen irrigation area who cultivated irrigated rice and/or had converted paddy fields to alternative crops. A purposive sampling strategy was used to ensure that both rice farmers and farmers planting alternative crops on former paddy land were included. In total, 30 farmers were selected as respondents.

Structured interviews were conducted using a questionnaire that collected quantitative information on land area, input use, costs, yields and prices, and qualitative information on perceptions and motivations. On the basis of these survey data and discussions with key informants, representative farm budgets were constructed for one irrigated rice farm and for four alternative crop farms. Representative farm areas were 0.62 ha for irrigated rice (average of the 30 surveyed rice farmers), 1.00 ha for melon, 1.00 ha for watermelon, 0.60 ha for chilli and 1.00 ha for patchouli.

The representative farm types used in the farm income analysis are summarised in Table 2.

Figure 1. Bar chart of the number of coffee garden insects at each height. Numbers followed by different letters indicate significant differences based on the f table 1%.

Farm type / crop	Representative farm area (ha)	Basis of construction	Notes
Irrigated paddy rice	0.62	Average cultivated area of 30 rice farmers in the Popontolen irrigation area	Represents a typical smallholder irrigated rice farm in the study area
Melon	1	Farmer survey and key informant information	Alternative crop on converted paddy fields
Watermelon	1	Farmer survey and key informant information	Alternative crop on converted paddy fields, similar practices to melon
Chilli	0.6	Farmer survey and key informant information	High-value, labour-intensive crop on converted paddy land
Patchouli	1	Farmer survey and key informant information	Perennial alternative crop requiring high initial investment

Table 2 clarifies the scale and origin of the farm budgets used in the comparative income analysis, making it clear that they are based on typical farm sizes observed in the study area rather than hypothetical plot sizes.

Data analysis

Spatial analysis of paddy field change

Spatial analysis was conducted using a geographic information system. Land-use layers for 2019 and 2024 were harmonised and clipped to the boundaries of Tumpaan and Tatapaan Districts. Within each district, paddy fields were delineated as a separate land-use class.

For each district and time point, total paddy field area was calculated as:

$$A_{d,t} = \sum_{j \in \text{paddy}} a_{j,d,t}$$

where $A_{d,t}$ is the total area of paddy fields in district d at time t, and $a_{j,d,t}$ is the area of the j-th paddy polygon in that district and year. Net change in paddy field area between 2019 and 2024 was computed as:

$$\Delta A_d = A_{d,2024} - A_{d,2019}$$

and percentage change as:

$$\%\Delta A_d = \frac{A_{d,2024} - A_{d,2019}}{A_{d,2019}} \times 100$$

These calculations were performed separately for Tumpaan and Tatapaan to quantify the extent of paddy field loss in each district.

Farm income analysis

Farm income analysis was carried out using a partial budget approach for irrigated rice and each of the four alternative crops.

For each representative farm type, total revenue (TR) was calculated as:

$$TR = Y \times P$$

where $Y$is yield per farm (kilograms per season) and $P$is the farmgate selling price (Indonesian Rupiah per kilogram).

Total production cost (TC) was defined as the sum of cash costs incurred by the farmer during one cropping season, including land rent, interest on capital, hired labour, seeds or planting material, fertilisers and agrochemicals:

$$TC = C_{\text{land}} + C_{\text{capital}} + C_{\text{labour}} + C_{\text{seed}} + C_{\text{fertiliser}} + C_{\text{agrochemical}}$$

Net farm income (cash profit) was then calculated as:

$$\pi = TR - TC$$

Separate budgets were prepared for irrigated rice and for melon, watermelon, chilli and patchouli, using the representative farm areas given in Table 2. The analysis focuses on cash-based net income, reflecting the actual cash flow available to farmers from each crop within one season. Although the inclusion of non-cash or implicit costs (such as imputed land rent and the opportunity cost of own capital) was considered, the main comparative results are based on cash costs only, due to inconsistencies in the recorded non-cash items. This ensures that profitability comparisons rest on a consistent and empirically reliable set of figures.

Analysis of drivers of paddy field conversion

Factors influencing farmers' decisions to convert paddy fields to non-paddy uses were analysed qualitatively and descriptively. Responses from the 30 farmers were grouped into thematic categories, including production cost and profitability considerations, labour availability and cost, access to fertilisers and other inputs, irrigation conditions and water availability, pest and disease pressures and perceived market opportunities for alternative crops.

The frequency with which each factor was mentioned was tabulated, and illustrative quotations were used to enrich the interpretation. These qualitative findings were then discussed alongside the spatial patterns of paddy field loss and the farm income comparisons in order to build an integrated picture of the economic drivers of paddy field conversion in South Minahasa Regency.

RESULTS AND DISCUSSION

Spatial patterns of paddy field conversion

At the regency level, South Minahasa has experienced a pronounced decline in paddy field area, from 5,491 ha in 2018 to 3,078.63 ha in 2024, indicating substantial loss of irrigated rice land over six years. Within this broader trend, Tumpaan and Tatapaan Districts show clear evidence of paddy field conversion to non-paddy uses, including horticultural crops and other land uses. Spatial analysis for 2019–2024 indicates net paddy field losses of approximately 160.749 ha in Tumpaan and 82.68 ha in Tatapaan.

These figures confirm that even in an irrigation command area historically designated for rice production, paddy fields are being converted at a notable scale. The spatial evidence is consistent with previous GIS-based work in the same region and with national studies documenting ongoing rice field conversion despite land protection policies such as LP2B.

Table 3 highlights that paddy field loss is more pronounced in Tumpaan than in Tatapaan, reflecting stronger land-use pressures and a more rapid shift away from irrigated rice in that district. Although the study does not provide a full time series of annual change, the combined spatial and field evidence suggests that paddy field conversion has been substantial over a relatively short period and is likely to continue unless more effective protection and incentive mechanisms are implemented.

Cost structure of irrigated rice farming

Rice farming in the Popontolen irrigation area is characterised by relatively small farm sizes and high dependence on hired labour and rented land. The 20 rice farmers in the sample cultivate a total of 12.4 ha, with an average farm size of 0.62 ha. The main input costs and their distribution are summarised in Table 4.

Table 3. Estimated paddy field loss in Tumpaan and Tatapaan Districts, 2019–2024

Data type	Description	Time period / reference year	Source / method	Main use in the study
Spatial land-use data	Spatial distribution of paddy and non-paddy land in Tumpaan and Tatapaan Districts	2019 and 2024	Existing land-use maps and interpreted satellite imagery	Quantifying changes in paddy field area over time
Administrative boundaries	District and regency boundaries, irrigation command area (Popontolen scheme)	Latest available	Local government and statistical agencies	Delineating the study area and mapping paddy fields
Socio-economic farmer data	Farmer characteristics, land use, cropping patterns, perceptions of conversion	Survey year (fieldwork)	Structured interviews with 30 farmers	Characterising farmers and identifying drivers of conversion
Farm-budget data	Input use, costs, yields, prices, revenues and net income for rice and alternative crops	One cropping season	Farm surveys and cross-checks with key informants	Constructing comparative farm budgets (rice vs alternatives)
Institutional and policy data	Information on irrigation conditions, fertiliser access, land-use regulation and programmes	Recent years	Interviews with District Agriculture Office and other local officials	Interpreting institutional context and constraints

Table 4. Input use and costs for irrigated paddy rice farming (0.62 ha representative farm)

Cost item	Total cost (IDR)	Average cost per farmer (IDR)
Land rent	37,200,000	1,860,000
Interest on capital	19,300,000	965,000
Hired labour	114,350,000	5,717,500
Seed	5,700,000	285,000
Fertilisers	19,950,000	997,500
Agrochemicals	4,155,000	207,750
Total (20 farmers)	**200,655,000**	–

Note: Average farm area = 0.62 ha; representative cash cost = labour + seed + fertiliser + agrochemicals; cash+inkind cost adds land rent and interest.

Table 4 shows that labour is the largest single cost component for rice farming, followed by land rent and fertilisers. This reflects the labour-intensive nature of irrigated rice cultivation and the fact that many farmers either rent land or account for an implicit land rental cost. High labour and land costs reduce margins and make rice relatively less attractive compared with crops that can generate higher output values per unit of land. These findings are consistent with other studies that identify rising input costs and labour shortages as key constraints on rice profitability in Indonesia.

Cost structure of alternative crops on converted paddy land

On converted paddy fields, farmers cultivate melon, watermelon, chilli and patchouli. The cost structure of these alternative crops is summarised in Table 5.

Table 5. Input costs for melon, watermelon, chilli and patchouli farming

Cost item	Melon (IDR/ha)	Watermelon (IDR/ha)	Chilli (IDR/0.60 ha)	Patchouli (IDR/ha)
Land rent	3,000,000	3,000,000	3,600,000	6,000,000
Interest on capital	1,173,500	1,173,500	1,556,750	3,175,000
Hired labour	11,100,000	11,100,000	18,250,000	24,300,000
Seed / planting mat.	1,500,000	1,500,000	7,000,000	30,000,000
Fertilisers	6,600,000	6,600,000	1,310,000	2,235,000
Agrochemicals	1,270,000	1,270,000	975,000	965,000
Total cost	**24,643,500**	**24,643,500**	**32,691,750**	**66,675,000**

Melon and watermelon have identical total costs per hectare, with labour and fertilisers as the dominant components. This reflects similar cultivation practices and input requirements for these two fruit crops. Chilli is more costly on a per-farm basis (0.60 ha), driven primarily by high labour and seed costs, confirming that chilli is a labour-intensive and capital-demanding enterprise. Patchouli has the highest total cost per hectare among all alternative crops due to very high planting material and labour costs, making it a high-risk investment.

From an economic perspective, these cost structures imply different risk and capital profiles: melon and watermelon require moderate investment with relatively balanced cost components, chilli requires substantial upfront spending on labour and seed, and patchouli requires very high initial capital, especially for planting material.

Comparative farm income: irrigated rice versus alternative crops

To assess the economic incentives for paddy field conversion, farm budgets were constructed for a representative irrigated rice farm and for farms cultivating each alternative crop. The analysis focuses on cash-based net income, using actual cash expenditures and revenues observed in one production season. The results are shown in Table 6.

Table 6. Comparative cash-based farm budgets for rice and alternative crops

Farm type	Farm area (ha)	Cash cost (IDR)	Revenue (IDR)	Net cash income (IDR)
Irrigated paddy	0.62	7,207,750	8,123,500	915,750
Melon	1	20,470,000	160,000,000	139,530,000
Watermelon	1	19,200,000	160,000,000	140,800,000
Chilli	0.6	27,535,000	105,000,000	77,465,000
Patchouli	1	57,500,000	28,600,000	-28,900,000

In cash terms, irrigated rice on 0.62 ha generates a small positive net income of IDR 915,750 per season. By contrast, melon and watermelon on 1 ha each generate net cash incomes of about IDR 139.5 million and IDR 140.8 million, respectively, while chilli on 0.60 ha generates IDR 77.5 million. Patchouli, however, yields a substantial cash loss of IDR 28.9 million per hectare in the observed season.

If the net incomes are expressed per hectare, the contrast becomes even sharper:

irrigated rice yields roughly 1.5 million IDR per hectare, chilli about 129 million IDR per hectare, and melon and watermelon around 140 million IDR per hectare. Patchouli remains clearly unprofitable even before accounting for non-cash or opportunity costs. These comparisons indicate that, under the price and yield conditions prevailing in the study season, melon, watermelon and chilli provide extremely strong financial incentives for farmers to convert paddy fields to horticultural uses, whereas patchouli does not.

A critical point is that these results are based on one cropping season and on representative budgets rather than a full distribution of outcomes over multiple years. High returns from melon, watermelon and chilli are partly driven by favourable prices and successful harvests, and may not be guaranteed in every season. Price volatility, production risk and input price shocks could reduce profits in less favourable years. Nevertheless, for farmers observing such large income differences in recent seasons, it is rational to perceive horticultural crops as much more attractive than rice and to reallocate land accordingly.

It is also important to note that the original Indonesian draft attempted to extend the analysis to a “cash + inkind” concept using a second set of income figures. However, the recorded revenues for that scenario (approximately IDR 8.123.501–8.123.504 for all alternative crops) are clearly inconsistent with the observed cash revenues and are almost certainly data entry errors. For this reason, the present article restricts the comparative analysis to the cash-based budgets in Table 6, which are internally consistent with the cost data in Table 5 and with the narrative interpretation of farm profitability.

Drivers of paddy field conversion from the farmers’ perspective

Farmer interviews provide additional insight into why paddy fields are being converted despite their importance for local food security. The main factors reported by farmers are summarised in Table 7.

Table 7. Main farmer-reported drivers of paddy field conversion

Factor category	Description of farmer statements
Production costs	Rice cultivation is perceived as costly; land rent, tractor hire and labour are expensive.
Labour availability	It is increasingly difficult to find agricultural labour; many villagers prefer salaried work in nearby factories.
Fertiliser access	Subsidised fertilisers (especially NPK and urea) are scarce; non-subsidised fertilisers are expensive.
Irrigation and water	Irrigation canals are damaged; the water users’ association (P3A) is not functioning well, leading to uneven water distribution and water shortages in some plots.
Pest and disease pressure	Farmers mention outbreaks of pests such as brown planthopper and mite-related diseases as reasons to break the rice cycle.
Profit expectations	Farmers believe alternative crops, especially melon, watermelon and chilli, offer higher income and better market opportunities than rice.
Experimentation and risk	Some farmers are motivated to try patchouli due to stories of high prices, despite the high capital requirement and risk.

These qualitative findings align closely with the farm-budget results. High production costs and low margins in rice, combined with the very large profits observed for melon, watermelon and chilli, create powerful economic incentives to convert paddy fields. Fertiliser scarcity and high non-subsidised prices further erode rice profitability, echoing results from other regions where fertiliser constraints have been shown to depress rice yields and incomes. At the same time, deteriorating irrigation infrastructure and weak local water governance reduce the reliability of rice production, making crops that are less dependent on continuous flooding or precise water control more attractive.

Labour market changes also play a significant role: the presence of factories offering non-farm employment in the study area draws labour away from agriculture, increasing rural wage rates and making labour-intensive rice cultivation more difficult to sustain. In this context, switching to high-value horticultural crops may be seen as a way to maximise income from limited land and labour, even if these crops themselves are labour-intensive. Farmers' decisions to experiment with patchouli, despite its poor financial performance in the observed season, illustrate how expectations and information flows about "profitable" crops can sometimes lead to high-risk choices that do not necessarily improve household welfare.

Taken together, the spatial analysis, farm-budget comparisons and farmer narratives provide a coherent picture: paddy field conversion in South Minahasa Regency is driven by a combination of economic incentives (large income gaps between rice and certain horticultural crops), input and infrastructure constraints (fertiliser access, irrigation, labour) and changing livelihood opportunities. At the same time, the analysis relies on a relatively small number of representative farm budgets and a single season of price and yield data, so the results should be interpreted as indicative rather than as definitive long-term averages. From a policy perspective, the findings suggest that protecting paddy fields through zoning alone is unlikely to be effective unless accompanied by measures that improve rice profitability, secure fertiliser supply and maintain irrigation infrastructure, while also recognising farmers' rational responses to market signals.

CONCLUSION

This study analysed the spatial dynamics and economic drivers of paddy field conversion in South Minahasa Regency, North Sulawesi, with a focus on Tumpaan and Tatapaan Districts. Spatial analysis for 2019–2024 showed substantial loss of paddy fields, with net reductions of approximately 160.749 ha in Tumpaan and 82.68 ha in Tatapaan, confirming that conversion is occurring even within an irrigation command area traditionally dedicated to rice production. These findings are consistent with the broader regency-level decline in paddy area from 5,491 ha in 2018 to 3,078.63 ha in 2024 and highlight the vulnerability of irrigated rice land to competing land uses.

Comparative farm-budget analysis revealed large differences in profitability between irrigated rice and the main alternative crops cultivated on converted paddy fields. In the study season, irrigated rice on 0.62 ha generated only a modest positive net cash income, whereas melon and watermelon on 1 ha each, and chilli on 0.60 ha, produced very high net cash returns, on the order of tens of millions of Indonesian Rupiah per season. Patchouli, in contrast, generated a substantial cash loss, reflecting its high capital requirements and risk. These results indicate that under prevailing price and yield conditions, melon, watermelon and chilli offer very strong economic incentives for farmers to convert paddy fields to horticultural uses, while patchouli is not financially attractive.

Farmer interviews helped to explain why these economic incentives translate into actual land-use change. Farmers emphasised high production costs and low margins for rice, labour shortages due to non-farm employment opportunities, difficulties in accessing subsidised fertilisers and the high cost of non-subsidised fertilisers, deteriorating irrigation infrastructure and unreliable water supply, as well as pest and disease pressures in rice. At the same time, they perceived strong market opportunities and higher expected incomes from horticultural crops such as melon, watermelon and chilli. Together, these factors create a rational motivation to convert paddy fields, even though such conversion may undermine local rice production and food security in the longer term.

From a policy and management perspective, the findings suggest that zoning and land-use protection measures alone are unlikely to halt paddy field conversion if they are not accompanied by improvements in the economic viability of rice farming and the reliability of irrigation and input supply. Efforts to maintain paddy fields in South Minahasa Regency need to address key constraints identified by farmers, including irrigation rehabilitation, better functioning of water user associations, more predictable access to subsidised fertilisers and support for labour-saving technologies. At the same time, policy instruments should acknowledge farmers' legitimate pursuit of higher incomes and explore options for integrating high-value crops into farming systems without permanently removing land from rice production.

The study is subject to several limitations. Spatial analysis was conducted for two time points only, and farm-budget calculations are based on representative budgets for a single season rather than multi-year panel data. The income comparison therefore reflects observed conditions in one period and cannot fully capture inter-annual variability in prices and yields. In addition, the farm sample is relatively small and purposively selected, so the findings are not statistically generalisable to all farmers in South Minahasa. Nevertheless, by combining spatial evidence, farm-level economic analysis and farmer perspectives, the study provides a coherent picture of the processes and incentives underlying paddy field conversion in Tumpaan and Tatapaan Districts and offers empirically grounded insights for policies aimed at balancing rice land protection with the economic realities of smallholder households.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the Research and Community Service Institute (LPPM), Universitas Sam Ratulangi, for funding this study through the 2025 DIPA Unsrat programme.

The authors also thank the farmers in Tumpaan and Tatapaan Districts who generously shared their time and experience during the field interviews, as well as the officers of the South Minahasa District Agriculture Office and other local stakeholders who provided valuable information on irrigation conditions, input supply and land-use changes in the study area. Their support and collaboration were essential for the completion of this research.

REFERENCES

[1] D. Pribadi, K. Saifullah, L. O. Iman, M. Nurdin, and A. Putra, "Urban Transition in Monsoon Asian Megacity: Will Paddy Fields in the Rural–Urban Fringe Persist? Insight from Jakarta-Bandung Mega Urban Region, Indonesia," 2023, pp. 107–124. doi: 10.1007/978-981-99-2695-4_7.

[2] Z. Sjamsir, B. Dahliana, and S. R, "ANALYSIS OF FOOD SECURITY AND SELF-SUFFICIENCY IN FOOD IN SOUTH SULAWESI," *Multidiscip. Indones. Cent. J.*, vol. 2, pp. 1676–1684, Apr. 2025, doi: 10.62567/micjo.v2i2.626.

[3] N. Idris and N. Nazarudin, "Barriers to Sustainable Rice Farming and Food Security in Malaysia's Primary Granary Zones," *Int. J. Res. Innov. Soc. Sci.*, vol. IX, pp. 621–637, Jun. 2025, doi: 10.47772/IJRISS.2025.915EC0043.

[4] H. Fandani and R. Harini, "Impact and economic value of agricultural land conversion in sub-urban of Bantul Regency," *E3S Web Conf.*, vol. 200, p. 3005, Jan. 2020, doi: 10.1051/e3sconf/202020003005.

[5] Z. Xie, D. Zhu, W. Wei, C. Ye, H. Wang, and C. Li, "Phosphorus leaching risk from black soil increased due to conversion of arid agricultural land to paddy land in northeast China," *Chem. Biol. Technol. Agric.*, vol. 10, Jul. 2023, doi: 10.1186/s40538-023-00420-9.

[6] E. Amrullah, H. Takeshita, and H. Tokuda, "The productivity and income effects of adopting improved rice varieties by smallholder farmers in Indonesia," *J. Agribus. Dev. Emerg. Econ.*, May 2024, doi: 10.1108/JADEE-11-2023-0282.

[7] E. Amrullah and H. Tokuda, "The impact of agricultural extension access on the technical efficiency of smallholder rice farmers in Banten, Indonesia," *J. Agribus. Dev. Emerg. Econ.*, Jun. 2025, doi: 10.1108/JADEE-09-2024-0298.

[8] D. Cahyaningrum, "Pelindungan Hukum Terhadap Lahan Pertanian Pangan dari Pengalihan Fungsi untuk Non Pertanian Pangan (Legal Protection of Food Agricultural Land from Conversion to Non-Food Agricultural Land)," *Negara Huk. Membangun Huk. untuk Keadilan dan Kesejaht.*, vol. 10, pp. 27–48, Sep. 2019, doi: 10.22212/jnh.v10i1.1218.

[9] S. Kasimin, I. Zais, A. Deli, and L. Hakim, "Evaluation of paddy field conversion rate and its impact on farmers' income in Aceh Besar regency," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1510, p. 12021, Jun. 2025, doi: 10.1088/1755-1315/1510/1/012021.

[10] G. Ummah, B. Wijimulawiani, and M. D. Fadlli, "Analysis Of Factors Influencing The Community In The Conversion Of Paddy Fields In The West Nusa Tenggara Province," *Int. J. Econ. Bus. Innov. Res.*, vol. 4, pp. 905–921, Mar. 2025, doi: 10.63922/ijebir.v4i02.1661.

[11] N. Rombe, P. Rogi, F. J. Paat, and J. Paulus, "Spatial Mapping And Analysis Of The Harvest Time Determination Of Paddy (Oryza sativa L.) Using The Thermal Unit Of The Southeast Minahasa Regency," *J. Agroekoteknologi Terap.*, vol. Vol. 5, pp. 26–36, Jan. 2024, doi: 10.35791/jat.v5i1.54044.

[12] W. Kumolontang, L. Karamoy, J. Rondonuwu, and R. Kawulusan, "Testing of the N, P, and K nutrients in rice soil in the Kalawarat district of North Minahasa Regency," *J. Agroekoteknologi Terap.*, vol. 5, pp. 75–81, Feb. 2024, doi: 10.35791/jat.v5i1.54506.

[13] D. Sudiana *et al.*, "A CNN-RF Hybrid Approach for Rice Paddy Fields Mapping in Indramayu using Sentinel-1 and Sentinel-2 Data," *IEEE Access*, vol. PP, p. 1, Jan. 2025, doi: 10.1109/ACCESS.2025.3537818.

[14] Z. Liu, J. Liu, Y. Su, X. Xiao, J. Dong, and L. Luo, "A General Model for Large-Scale Paddy Rice Mapping by Combining Biological Characteristics, Deep Learning, and Multisource Remote Sensing Data," *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.*, vol. PP, pp. 1–11, Jan. 2025, doi: 10.1109/JSTARS.2025.3573750.

[15] L. Nel, "Complex evaluation of ecosystem services in agricultural landscapes," 2024. doi: 10.13140/RG.2.2.13483.35360.

[16] I. Hasmi, "Analysis of Paddy Field Conversion Using Geographic Information System (GIS) in

Labuhanbatu Utara Regency, Indonesia," *J. Environ. Dev. Stud.*, vol. 4, pp. 122–131, May 2023, doi: 10.32734/jeds.v4i01.9209.

[17] A. Fauzan and A. Kurnia, "A Machine Learning Approach to Spatial Analysis of Paddy Field Conversion Using Multispectral Sentinel-2A Imagery," *JOIV Int. J. Informatics Vis.*, vol. 9, pp. 2029–2039, Oct. 2025, doi: 10.62527/joiv.9.5.3617