International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 6, 2025
https://www.theaspd.com/ijes.php

Agricultural Land Conversion Drivers And Irrigation Conflict Impacts In Sustainable Land Protection Areas: A Case Study From Muara Beliti, Indonesia

Indarwanto*[1], Yuwana[2], Atra Romeida[3], Gungung Senoaji[4]
[1]Natural Resources Doctoral Study Program, Faculty of Agriculture, Bengkulu University, Indonesia
[2]Agricultural Industrial Technology Study Program, Faculty of Agriculture, Bengkulu University, Indonesia
[3]Agroecotechnology Study Program, Faculty of Agriculture, Bengkulu University, Indonesia
[4]Forestry Study Program, Faculty of Agriculture, Bengkulu University, Indonesia

ABSTRAK
Agricultural land conversion threatens food security and undermines Sustainable Agricultural Land Protection (SALP) policies in Indonesia. This study investigates the socio-economic and resource-based drivers of land-use change and the exacerbating role of irrigation conflicts in Muara Beliti District, Musi Rawas Regency. A mixed-methods design combined multiple regression analysis of 60 farmer households with in-depth interviews of key local stakeholders. Independent variables included farmer age, gender, ethnicity, farming experience, irrigation availability, crop type, farm income, and labor input. Regression results demonstrate that irrigation availability, farm income, and labor supply are the primary determinants of land conversion, whereas socio-demographic factors are statistically insignificant. Limited irrigation access compels farmers to shift from rice cultivation to higher-return alternatives such as aquaculture, oil palm, rubber, or residential development. Qualitative evidence indicates that upstream fish pond constructions significantly reduce downstream water flows, provoking crop losses, social tensions, and occasional sabotage of irrigation infrastructure. These interactions create a reinforcing cycle: water scarcity accelerates land conversion, and the expansion of aquaculture intensifies competition over water, amplifying both ecological and social risks. The findings underscore that effective protection of agricultural land depends on equitable water governance, economic incentives to maintain productive farmland, and sufficient rural labor. Policy interventions should prioritize investments in irrigation infrastructure, targeted income support for farmers, and participatory water management mechanisms to mitigate conflicts. Without coordinated measures addressing both economic and hydrological constraints, the sustainability of protected agricultural land remains jeopardized.
Keywords: *Land Conversion, Irrigation Conflicts, SALP*

1. INTRODUCTION

Agricultural land conversion has emerged as a strategic issue in national development, as it directly affects food availability, farmer welfare, and environmental sustainability. Over the past two decades, Indonesia has experienced a significant increase in farmland conversion driven by population growth, urban expansion, infrastructure development, and the expansion of non-food cash crops (Azadi *et al.*, 2018; Batubara *et al.*, 2024; Kurnia *et al.*, 2022; Oktavia *et al.*, 2024). This phenomenon reflects the growing economic pressure and short-term land-use demands that undermine the long-term sustainability of agricultural production systems. As a result, national food security faces mounting challenges, with declining productive agricultural land threatening the stability of rice production and other staple commodities (Alaerts, 2020; Ansari *et al.*, 2023; Sutardi *et al.*, 2022)

The drivers of agricultural land conversion are multifaceted, involving both socioeconomic and structural dimensions. Socioeconomic factors such as farmers' age, farming experience, labor availability, crop type, and household income strongly influence farmers' decision-making in either maintaining or converting agricultural land (Moghaddam *et al.*, 2025; Prayitno *et al.*, 2021; Y. Zhang & Xie, 2019; Z. Zhang *et al.*, 2023). Meanwhile, structural factors such as weak spatial planning enforcement, limited economic incentives for farmers, and policy biases favoring non-agricultural sectors accelerate the pace of land conversion (Anggalini *et al.*, 2020; Wahyuningrat *et al.*, 2019). These findings highlight that land conversion is not merely an agrarian or economic issue but rather the outcome of a complex interplay among social, economic, institutional, and environmental variables, necessitating an integrated and evidence-based policy response.

In addition to reducing food-producing areas, land conversion often exacerbates irrigation-related conflicts, particularly in regions where water resources are already under pressure. Changes in land use such as the shift from paddy fields to plantations, aquaculture, or residential development tend to alter water allocation patterns, increase competition between sectors, and weaken community-based irrigation governance systems (Meinzen-Dick, 2014; Nouri *et al.*, 2023; Sanchis-Ibor *et al.*, 2019). As irrigation is a critical factor in sustaining agricultural productivity, conflicts arising from unequal water distribution, reduced access for smallholder farmers, and competing demands between agriculture and non-agriculture users can further undermine rural livelihoods and food security. Therefore, examining both the socioeconomic drivers of land conversion and the subsequent irrigation conflicts is essential for designing sustainable land and water governance strategies in Indonesia and beyond.

The availability of irrigation water constitutes a critical determinant in sustaining agricultural land, particularly in rice-based farming systems that form the backbone of Indonesia's food security. Irrigation water is not only essential for ensuring productivity but also for stabilizing cropping intensity and maintaining the resilience of rural livelihoods. However, irrigation distribution is often uneven due to inadequate infrastructure, deterioration of canal networks, and competing demands among upstream and downstream users (Christoforidou *et al.*, 2023; Ingrao *et al.*, 2023; Palatnik *et al.*, 2025). These imbalances create structural vulnerabilities in water governance, reducing farmers' ability to secure reliable access to irrigation and threatening the long-term viability of food production landscapes.

Water-related inequalities frequently trigger irrigation conflicts that directly influence farmers' land-use decisions. When water becomes scarce or access is contested, farmers tend to reduce planting intensity, shift toward less water-demanding cash crops, or even convert their farmland into non-agricultural uses that promise higher and more stable returns (Bryła *et al.*, 2025; Hensengerth, 2024; Yong, 2022). Consequently, irrigation conflict is not merely a technical challenge of resource distribution but also a socio-economic driver of agricultural land conversion. Understanding this dynamic is therefore essential for designing integrated policies that simultaneously address the drivers of land conversion and mitigate the escalation of irrigation conflicts in rapidly transforming agrarian landscapes.

Muara Beliti Subdistrict in Musi Rawas Regency exemplifies the dual challenges of agricultural land conversion and irrigation conflicts in Indonesia's Sustainable Food Agricultural Land zones. Although formally designated as protected farmland, the area continues to face pressures from settlement growth, infrastructure expansion, and the rise of non-food plantations, reflecting broader national trends where land protection policies struggle against market-driven demands (Appelt *et al.*, 2022; J. Liu *et al.*, 2020; Widyatmanti & Umarhadi, 2022). At the same time, limited and uneven irrigation distribution has triggered recurring water disputes between upstream and downstream farmers, shaping land-use decisions and accelerating farmland conversion (Akmal & Mohammadi, 2025; Ricks, 2017). This study therefore seeks to analyze the socio-economic and water-related drivers of land conversion and to assess the role of irrigation conflicts in influencing conversion dynamics, with the goal of informing more effective policies for sustainable land protection in Indonesia.

2.MATERIALS AND METHODS

This research was conducted in Muara Beliti Subdistrict, Musi Rawas Regency, South Sumatra Province, Indonesia. The study area was selected purposively (*purposive sampling*) based on two main considerations: first, Muara Beliti represents one of the key rice-producing regions in the regency, and second, it is simultaneously experiencing an increasingly rapid rate of agricultural land conversion despite its formal designation as a Sustainable Food Agricultural Land (LP2B) area. From the 14 villages in the subdistrict, four villages were chosen as the research sites, namely Air Satan, Satan Indah Jaya, Suro, and Air Lesing. These villages were selected due to their relatively high intensity of land conversion, either toward non-rice agricultural commodities or non-agricultural uses such as residential development.

The study involved 60 farmer households as respondents, each of whom owned or managed rice fields and had directly engaged in land conversion. The forms of land-use change considered included shifts from rice cultivation to alternative crops such as maize, oil palm, and rubber, as well as aquaculture and residential construction. Respondents were purposively chosen on the basis that they play a direct role in decision-making regarding land management, ensuring that the collected data accurately represent the dynamics of conversion processes.

Both primary and secondary data were collected. Primary data were obtained through structured interviews using questionnaires designed to capture farmers' socio-economic characteristics, land-use history, and the driving factors of land conversion. In-depth interviews were also conducted with selected farmers and community leaders to gain deeper insights into irrigation-related conflicts, water distribution mechanisms, and their implications for land-use decisions. Secondary data were sourced from government reports, agricultural statistics, policy documents related to LP2B, and relevant academic literature.

The analytical framework combined quantitative and qualitative approaches. The dependent variable in the quantitative analysis was the extent of land conversion (hectares). Independent variables included: farmer's age (years), gender (1 = male, 2 = female), ethnicity (1 = Malay, 2 = Javanese, 3 = Sundanese, 4 = Balinese), farming experience (years), irrigation water availability (1 = available, 2 = not available), type of conversion commodity (maize, oil palm, rubber, fishponds), farm income (Rupiah), and labor use (man-days). Multiple linear regression was employed with the model:

$$Y = a + b1X1 + b2X2 + b3X3 + b4X4 + b5X5 + + b6X6 + b7X7 + b8X8 + e$$

where Y denotes land conversion (ha), aaa is the constant, b1—b8 are the regression coefficients, X1 = age of farmer (years), X2 = gender (1 = male, 2 = female), X3 = ethnic group (1 = Malay, 2 = Javanese, 3 = Sundanese, 4 = Balinese), X4 = farming experience (years), X5 = availability of irrigation water (1 = available, 2 = not available), X6 = type of commodity in land-use conversion (maize, oil palm, rubber, fish), X7 = farm income (Rupiah), X8 = labor (workdays/Man-Days), and e = error term.

To complement the regression results, qualitative thematic analysis was applied to the interview data to examine the impacts of irrigation conflicts. Interview transcripts were coded, categorized, and analyzed to identify major themes related to the causes of disputes, patterns of upstream–downstream interactions, and their consequences for farmers' land-use strategies. By integrating quantitative and qualitative methods, this study aims to provide a comprehensive understanding of both the socio-economic drivers of land conversion and the critical role of irrigation conflicts in accelerating agricultural land-use change within LP2B areas.

3. RESULTS

3.1. Respondent Characteristics Results

Based on the characteristics of respondents presented in Table 1, agricultural land conversion in Muara Beliti is predominantly driven by farmers in the productive age group, particularly those aged 40–59 years (64%), who generally possess substantial farming experience, with 45% cultivating land for more than 25 years. This age distribution suggests that land-use decisions are largely influenced by experienced farmers who combine traditional knowledge with practical considerations of farm productivity and profitability. The majority of farmers had relatively low formal education levels, with 71% completing only elementary or junior high school, indicating potential limitations in exposure to advanced agricultural practices or awareness of sustainable land management policies. Ethnic composition was dominated by Javanese farmers (56%), reflecting historical transmigration programs, followed by Malay (21%), Balinese (18%), and Sundanese (3%), which may shape cultural approaches to land management and social cohesion in cooperative farming or irrigation arrangements.

Most respondents (80%) owned relatively large landholdings (≥10,000 m^2), providing them with both the capacity and flexibility to diversify or convert crops for higher economic returns. More than half of the respondents (55%) reported annual farm incomes above Rp 30,000,000, highlighting that economic considerations are central drivers of land-use change, with profitability often outweighing regulatory or environmental constraints. In terms of land conversion patterns, the majority (81.7%) shifted their rice fields to maize, oil palm, or rubber plantations, reflecting a preference for cash crops that promise higher and more stable returns. A smaller proportion (16.6%) converted land into fish ponds, while only 1.7% allocated land for residential purposes. These patterns indicate that agricultural land conversion in Muara

Beliti is primarily oriented toward alternative commercial farming rather than purely non-agricultural development, emphasizing the interplay of market incentives, resource availability, and traditional agricultural experience in shaping land-use decisions.

Table 1. Characteristics of Respondents

Characteristics	**Category**	**Frequency**	**Percentage (%)**
Age	20–29 years	3	5.0
	30–39 years	5	8.0
	40–49 years	16	27.0
	50–59 years	22	37.0
	60–69 years	10	17.0
	70–79 years	4	6.0
Education Level	Elementary	15	25.0
	Junior High	28	46.0
	Senior High	16	26.0
	Bachelor	1	3.0
Ethnic Group	Malay	13	21.0
	Javanese	34	56.0
	Sundanese	2	3.0
	Balinese	11	18.0
Farming Experience	< 25 years	33	55.0
	≥ 25 years	27	45.0
Farm Size	< 10,000 m^2	12	20.0
	≥ 10,000 m^2	48	80.0
Farm Income	< Rp 30,000,000	27	45.0
	≥ Rp 30,000,000	33	55.0
Land Conversion Decision	Maize, Oil Palm, Rubber	49	81.7
	Fish Pond	10	16.6
	Building (House)	1	1.7

3.2. Drivers of Agricultural Land Conversion

Model Summary

The model summary results (Table 2) show that the regression model has good explanatory power, with an R^2 of 0.528 and an adjusted R2 of 0.453. This means that approximately 52.8% of the variance in agricultural land conversion can be explained by the selected independent variables, while the remaining variance is influenced by other factors not included in the model. The correlation coefficient (R=0.726) indicates a strong relationship between the predictors and the dependent variable.

Table 2. Model Summary

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of Estimate**
1	0.726	0.528	0.453	0.400

ANOVA Test

The ANOVA test (Table 3) further confirms the robustness and significance of the regression model, yielding an F-value of 7.118 with a probability value of <0.001. This indicates that, collectively, the independent variables such as farmers' age, gender, ethnic group, farming experience, availability of irrigation water, type of commodity in land-use conversion, farm income, and labor input have a substantial and statistically meaningful influence on agricultural land conversion decisions in Muara Beliti. In other words, these factors are not random but jointly contribute to explaining variations in land-use change, highlighting the importance of both economic and resource-based determinants. The results underscore that while demographic and socio-cultural characteristics have relatively minor effects, structural and economic factors such as water access, farm profitability, and labor availability are critical drivers of land-use decisions, providing a strong empirical basis for targeted policy interventions to support sustainable agricultural land management.

Table 3. ANOVA

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	9.108	8	1.138	7.118	0.000
Residual	8.157	51	0.160		
Total	17.265	59			

Regression Coefficients

The regression coefficient analysis (Table 4) provides detailed insights into the specific factors influencing agricultural land conversion in Muara Beliti. Among the variables examined, three demonstrate statistically significant effects: irrigation water availability ($\beta = 0.330$, $p = 0.033$), farm income ($\beta = 0.748$, $p = 0.001$), and labor availability ($\beta = 0.635$, $p < 0.001$). These results indicate that the decision to convert land is primarily driven by economic incentives and the accessibility of critical resources, rather than socio-demographic characteristics. Factors such as gender, age, ethnic group, and farming experience were found to have no significant impact, suggesting that structural and resource-based conditions outweigh individual attributes in determining land-use changes. Irrigation water availability emerges as a key determinant, reflecting the crucial role of water security in sustaining rice cultivation and preventing conversion to other land uses. Similarly, higher farm income and sufficient labor supply reduce the pressure to convert land to alternative uses, highlighting the importance of economic viability and workforce availability in maintaining agricultural land. These findings underscore the necessity for policies that enhance irrigation infrastructure, support farm profitability, and ensure adequate labor resources, as a means to curb unsustainable land conversion and promote long-term agricultural sustainability in the region.

Table 4. Regression Coefficients

Variable	B	Std. Error	Beta	t	Sig.
Constant	-0.339	0.589	–	-0.575	0.568
Gender	-0.044	0.218	-0.020	-0.201	0.842
Age	-0.007	0.007	-0.143	-1.031	0.308
Ethnic Group	-0.031	0.054	-0.057	-0.573	0.569
Farming Experience	0.008	0.006	0.180	1.251	0.217
Irrigation Availability	0.371	0.169	0.330	2.194	0.033*
Commodity Type	-0.078	0.049	-0.345	-1.584	0.119
Farm Income	0.287	0.078	0.748	3.688	0.001**
Labor	0.005	0.001	0.635	5.361	0.000**

Note : * Significant at $p < 0.05$; ** Significant at $p < 0.01$

3.3. Irrigation Conflicts and Their Impacts

Findings from the in-depth interviews revealed that irrigation conflict constitutes one of the most pressing challenges affecting the sustainability of agricultural land within the Sustainable Agricultural Land Protection area of Muara Beliti. Farmers consistently reported that irrigation water distribution is frequently inequitable, largely due to the conversion of rice fields into fishponds. Fishpond owners often construct barriers or small dams within primary irrigation channels to maintain pond water levels, which significantly diminishes water flow for downstream rice fields. As one farmer lamented, "We downstream farmers get no water because it is blocked for the fishponds. The paddy fields dry out." This indicates that irrigation conflicts directly compromise water access and undermine traditional water-sharing arrangements, which are vital for maintaining rice cultivation in the region.

The immediate consequence of these conflicts is a notable decline in rice productivity. Farmers reported that the volume of irrigation water supplied to their fields is often only about 20% of the required amount, leading to severe crop failures or significantly reduced yields. Such production losses are particularly alarming because these lands are designated under Sustainable Land Protection Areas to safeguard local food security. Beyond the agronomic impacts, irrigation conflicts also generate social tensions between rice farmers and fishpond owners. Community leaders described recurrent disputes, including verbal confrontations and retaliatory actions, such as the installation of counter-barriers to redirect water flow, highlighting that water resource competition disrupts both agricultural activities and social cohesion.

Moreover, persistent irrigation conflicts have accelerated the pace of land conversion from rice paddies to fishponds. Faced with limited water availability and increasing risk of crop failure, farmers perceive aquaculture as a more viable and profitable alternative. One respondent noted, "If we keep planting rice, we suffer losses. It is better to switch to fishponds." This trend directly contradicts the objectives of the Sustainable Land Protection Areas program, which seeks to preserve agricultural land for long-term food production.

In the long term, the irrigation conflicts in Muara Beliti create a dual threat: the erosion of regional food security and the weakening of policy implementation for land protection. Weak institutional oversight of land use changes, combined with low awareness among fishpond owners about the collective function of irrigation systems, has led to the gradual displacement of productive rice fields. These findings underscore that sustainable land protection cannot rely solely on regulatory frameworks; effective management requires integrated approaches that include participatory water governance, conflict resolution mechanisms, and local stakeholder engagement to balance agricultural production needs with community interests.

4. DISCUSSION

The findings of this study reveal that land-use change in Muara Beliti District is primarily driven by structural and economic factors, while socio-demographic characteristics play only a marginal role. Regression analysis identified irrigation availability, farmers' income, and labor availability as significant determinants of land conversion, whereas socio-demographic variables such as gender, age, ethnicity, and farming experience showed no significant influence. This indicates that broader structural pressures, rather than individual attributes, are the main drivers shaping farmers' decisions regarding land use.

The significant role of irrigation availability ($p = 0.033$) underscores the centrality of water resources in sustaining agricultural land. Farmers with reliable access to irrigation are more likely to maintain rice cultivation, while those facing scarcity tend to shift toward alternative land uses such as aquaculture or residential development. These findings align with previous research emphasizing irrigation as a cornerstone for agricultural productivity and farmland preservation (Hussain & Hanjra, 2004; Mupaso *et al.*, 2023). Irrigation infrastructure thus functions not only as a productivity enhancer but also as a protective barrier against farmland conversion. However, once irrigation reliability declines, the economic calculus of farmers rapidly shifts toward more profitable non-rice uses. This dynamic highlights the dual role of irrigation as both an economic and environmental determinant, where secure water supply strengthens farmers' resilience against external pressures such as market fluctuations, urban expansion, and climate variability (He & Rosa, 2023; Rosa & He, 2025). Moreover, insufficient irrigation can trigger conflicts among farmers over water allocation, further accelerating land abandonment and conversion, particularly in areas where institutional regulation and governance of water resources are weak (Ferreira *et al.*, 2018; Gain *et al.*, 2020). In this sense, irrigation availability is not merely a technical issue of infrastructure, but also a socio-political factor shaping patterns of land use change and rural livelihoods (Hoffmann & Villamayor-Tomas, 2023; Wang *et al.*, 2020).

Farmers' income also emerged as a strong predictor ($p = 0.001$). Higher agricultural returns reduce the likelihood of conversion, while lower profitability encourages transitions to more lucrative alternatives such as oil palm, rubber, or aquaculture. This trend is consistent with studies in Southeast Asia showing that income disparities across commodities strongly shape land-use transformations (Jouf & Lawson,

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 6, 2025
https://www.theaspd.com/ijes.php

2022; West *et al.*, 2025). Market fluctuations and global commodity integration further amplify this effect, highlighting how local decisions are embedded in broader economic systems (Lambin & Meyfroidt, 2010; Liao *et al.*, 2022). In Muara Beliti, aquaculture was often perceived as economically superior to rice cultivation, especially in contexts of water scarcity, thereby directly linking market incentives with land conversion. Similar findings have been reported in Indonesia and Vietnam, where the comparative profitability of cash crops and aquaculture relative to staple crops has accelerated farmland transition (Chu *et al.*, 2021). Moreover, the volatility of rice markets compared to globally integrated commodities such as oil palm or rubber increases farmers' exposure to income risks, pushing them toward more financially secure land uses (Reich & Musshoff, 2025). This suggests that land conversion is not merely a household-level adaptation strategy, but also a manifestation of structural pressures arising from global value chains, trade liberalization, and shifting consumer demand (Garrett *et al.*, 2013). Ultimately, farmers' income operates as both a micro-level driver of household decision-making and a macro-level reflection of how local agricultural landscapes are shaped by broader political economic forces.

Labor availability also played a critical role ($p < 0.001$). A shortage of agricultural labor, driven by youth migration to urban and industrial sectors and the aging of the farming population, reduced the sustainability of labor-intensive rice cultivation. This pattern accelerated land conversion to aquaculture or less labor-demanding land uses, reinforcing broader agrarian transition processes documented across Asia (Z. Liu *et al.*, 2025; Rigg *et al.*, 2016; Zou *et al.*, 2024). The demographic restructuring of rural communities thus functions as both a direct and indirect driver of agricultural land decline. The migration of young laborers not only decreases the household workforce but also limits knowledge transfer and adoption of improved agronomic practices, thereby affecting long-term productivity and resilience (Hao & Tang, 2023). Furthermore, labor scarcity interacts with other structural pressures, including irrigation reliability and market incentives, creating a compound effect that favors land uses requiring less labor input (Norbu *et al.*, 2021). This interplay suggests that demographic factors are not isolated influences but are embedded within wider socio-economic and environmental systems that collectively shape patterns of land-use change.

Beyond these structural drivers, in-depth interviews revealed how irrigation conflicts are tightly interlinked with land conversion dynamics. Farmers in upstream areas often constructed small dams to maintain water levels for aquaculture, diverting flows away from downstream rice fields. As a result, irrigation water availability downstream sometimes dropped to only 20% of the required demand, leading to repeated harvest failures. In turn, downstream farmers facing declining productivity expressed a greater willingness to convert their rice paddies into alternative uses, such as fishponds or non-agricultural land. This cycle illustrates a feedback mechanism: water scarcity induces land conversion, while expanded aquaculture further intensifies competition over water, deepening conflict. In several cases, tensions escalated into canal sabotage or deliberate obstruction of water flows, highlighting the fragility of local governance systems. These findings corroborate Ostrom (1990) theory of common-pool resource management, which posits that weak or absent institutions foster rivalry and conflict. Moreover, this evidence aligns with subsequent research emphasizing the importance of equitable water governance, collective action, and institutional capacity in mitigating resource conflicts (Haeffner *et al.*, 2024; Soliman *et al.*, 2021; van Aalderen *et al.*, 2024). The Muara Beliti case demonstrates how local-level competition over irrigation resources not only affects agricultural productivity but also drives land-use transitions, illustrating a tightly coupled socio-ecological system in which water governance, economic incentives, and demographic pressures intersect to shape land conversion outcomes.

The linkages between land conversion and irrigation conflicts in Muara Beliti can therefore be understood as a reinforcing cycle. Reduced water access triggers farmland conversion, while conversion to aquaculture increases upstream demand for water, exacerbating conflicts and further undermining downstream agricultural resilience. This cyclical relationship demonstrates that farmland protection policies cannot be separated from water governance strategies. Effective interventions require integrated approaches that combine investment in irrigation infrastructure, stabilization of farm incomes, rural labor revitalization, and participatory institutions for water management. Without such integrative measures, both the sustainability of agricultural land and the stability of local communities remain under significant threat.

5. CONCLUSIONS

This study reveals that agricultural land conversion in Muara Beliti is significantly influenced by irrigation availability, farmers' income, and labor supply, while socio-demographic characteristics such as age, gender, ethnicity, and farming experience show no significant effect on land-use decisions. Irrigation availability emerged as the most crucial determinant of farmland sustainability, as limited access to water strongly encourages farmers to convert land into alternative uses such as fish ponds, oil palm, rubber plantations, or housing. Findings from in-depth interviews highlight that irrigation conflicts between upstream and downstream farmers further exacerbate land conversion dynamics. Upstream farmers often build small dams to secure water for fish ponds, which reduces water availability downstream, leading to crop failures, social tensions, and even sabotage of irrigation infrastructure. This creates a negative feedback loop: water scarcity accelerates land conversion, while the expansion of fish ponds intensifies competition and conflict over water resources.

Therefore, the sustainability of protected agricultural land in Muara Beliti depends heavily on equitable irrigation management, improving farmers' income through economically viable agricultural diversification, and ensuring an adequate supply of agricultural labor. The policy implications of this research emphasize the urgent need for integrated interventions, including investments in irrigation infrastructure, economic support mechanisms for farmers, and strengthening of local institutions to mediate water-related conflicts. Without these measures, the long-term protection of sustainable agricultural land will remain under serious threat from both economic pressures and socio-ecological conflicts.

REFERENCES

1. Akmal, F. A., & Mohammadi, Y. (2025). The nexus of agricultural land use change and food security: A comprehensive systematic review. *Land Use Policy*, *158*, 107717. https://doi.org/10.1016/j.landusepol.2025.107717
2. Alaerts, G. J. (2020). Adaptive policy implementation: Process and impact of Indonesia's national irrigation reform 1999–2018. *World Development*, *129*, 104880. https://doi.org/10.1016/j.worlddev.2020.104880
3. Anggalini, T. D., Retnandari, N. D., Yuliani, K., Keban, Y. T., & Mulyo, J. H. (2020). Sustainable food agriculture land protection policy for Gunungkidul, Yogyakarta, Indonesia: solution or dilemma? *IOP Conference Series: Earth and Environmental Science*, *423*(1), 012043. https://doi.org/10.1088/1755-1315/423/1/012043
4. Ansari, A., Pranesti, A., Telaumbanua, M., Alam, T., Taryono, Wulandari, R. A., Nugroho, B. D. A., & Supriyanta. (2023). Evaluating the effect of climate change on rice production in Indonesia using multimodelling approach. *Heliyon*, *9*(9), e19639. https://doi.org/10.1016/j.heliyon.2023.e19639
5. Appelt, J. L., Garcia Rojas, D. C., Verburg, P. H., & van Vliet, J. (2022). Socioeconomic outcomes of agricultural land use change in Southeast Asia. *Ambio*, *51*(5), 1094–1109. https://doi.org/10.1007/s13280-022-01712-4
6. Azadi, H., Keramati, P., Taheri, F., Rafiaani, P., Teklemariam, D., Gebrehiwot, K., Hosseininia, G., Van Passel, S., Lebailly, P., & Witlox, F. (2018). Agricultural land conversion: Reviewing drought impacts and coping strategies. *International Journal of Disaster Risk Reduction*, *31*, 184–195. https://doi.org/10.1016/j.ijdrr.2018.05.003
7. Batubara, B., Guntoro, Rachman, N. F., Herlily, & Adianto, J. (2024). Land Occupation, Re-occupation, and Housing Cooperative: Commune Formation by Jakarta's Urban Poor. *Agrarian South: Journal of Political Economy: A Triannual Journal of Agrarian South Network and CARES*, *13*(1), 89–109. https://doi.org/10.1177/22779760241226816
8. Bryła, M., Zdralewicz, I., Lejcuś, I., Kraj, K., Dumieński, G., Tokarczyk, T., & Walczykiewicz, T. (2025). Integrated Water Resources Management for Implementing Sustainable Energy Development—Challenges and Perspectives in Poland. *Sustainability*, *17*(3), 1169. https://doi.org/10.3390/su17031169
9. Christoforidou, M., Borghuis, G., Seijger, C., van Halsema, G. E., & Hellegers, P. (2023). Food security under water scarcity: a comparative analysis of Egypt and Jordan. *Food Security*, *15*(1), 171–185. https://doi.org/10.1007/s12571-022-01310-y
10. Chu, L., Nguyen, H.-T.-M., Kompas, T., Dang, K., & Bui, T. (2021). Rice land protection in a transitional economy: The case of Vietnam. *Heliyon*, *7*(4), e06754. https://doi.org/10.1016/j.heliyon.2021.e06754
11. Ferreira, A. F., Zimmermann, H., Santos, R., & Von Wehrden, H. (2018). A Social–Ecological Systems Framework as a Tool for Understanding the Effectiveness of Biosphere Reserve Management. *Sustainability*, *10*(10), 3608. https://doi.org/10.3390/su10103608

12. Gain, A. K., Giupponi, C., Renaud, F. G., & Vafeidis, A. T. (2020). Sustainability of complex social-ecological systems: methods, tools, and approaches. *Regional Environmental Change*, *20*(3), 102. https://doi.org/10.1007/s10113-020-01692-9
13. Garrett, R. D., Lambin, E. F., & Naylor, R. L. (2013). Land institutions and supply chain configurations as determinants of soybean planted area and yields in Brazil. *Land Use Policy*, *31*, 385–396. https://doi.org/10.1016/j.landusepol.2012.08.002
14. Haeffner, M., Lave, R., Linton, J., Mukherjee, J., Ndiritu, J., Pacheco-Vega, R., Rusca, M., & Zwarteveen, M. (2024). Editorial: Innovating a new knowledge base for water justice studies: hydrosocial, sociohydrology, and beyond. *Frontiers in Water*, *6*. https://doi.org/10.3389/frwa.2024.1389030
15. Hao, P., & Tang, S. (2023). Migration and consumption among poor rural households in China. *Habitat International*, *137*, 102832. https://doi.org/10.1016/j.habitatint.2023.102832
16. He, L., & Rosa, L. (2023). Solutions to agricultural green water scarcity under climate change. *PNAS Nexus*, *2*(4). https://doi.org/10.1093/pnasnexus/pgad117
17. Hensengerth, O. (2024). Inclusive governance of hydropower on shared rivers? Toward an international legal geography of the Lower Mekong basin. *Frontiers in Climate*, *6*. https://doi.org/10.3389/fclim.2024.1275049
18. Hoffmann, P., & Villamayor-Tomas, S. (2023). Irrigation modernization and the efficiency paradox: a meta-study through the lens of Networks of Action Situations. *Sustainability Science*, *18*(1), 181–199. https://doi.org/10.1007/s11625-022-01136-9
19. Hussain, I., & Hanjra, M. A. (2004). Irrigation and poverty alleviation: review of the empirical evidence. *Irrigation and Drainage*, *53*(1), 1–15. https://doi.org/10.1002/ird.114
20. Ingrao, C., Strippoli, R., Lagioia, G., & Huisingh, D. (2023). Water scarcity in agriculture: An overview of causes, impacts and approaches for reducing the risks. *Heliyon*, *9*(8), e18507. https://doi.org/10.1016/j.heliyon.2023.e18507
21. Jouf, C., & Lawson, L. A. (2022). European farmers' responses to higher commodity prices: Cropland expansion or forestlands preservation? *Ecological Economics*, *191*, 107243. https://doi.org/10.1016/j.ecolecon.2021.107243
22. Kurnia, A. A., Rustiadi, E., Fauzi, A., Pravitasari, A. E., Saizen, I., & Ženka, J. (2022). Understanding Industrial Land Development on Rural-Urban Land Transformation of Jakarta Megacity's Outer Suburb. *Land*, *11*(5), 670. https://doi.org/10.3390/land11050670
23. Lambin, E. F., & Meyfroidt, P. (2010). Land use transitions: Socio-ecological feedback versus socio-economic change. *Land Use Policy*, *27*(2), 108–118. https://doi.org/10.1016/j.landusepol.2009.09.003
24. Liao, L., Ma, E., Long, H., & Peng, X. (2022). Land Use Transition and Its Ecosystem Resilience Response in China during 1990–2020. *Land*, *12*(1), 141. https://doi.org/10.3390/land12010141
25. Liu, J., Wang, M., Yang, L., Rahman, S., & Sriboonchitta, S. (2020). Agricultural Productivity Growth and Its Determinants in South and Southeast Asian Countries. *Sustainability*, *12*(12), 4981. https://doi.org/10.3390/su12124981
26. Liu, Z., Wei, Y., Liao, R., & Liu, J. (2025). The Role of Agricultural Socialized Services in Mitigating Rural Labor Shortages: A Multi-Crop Analysis of Production Performance. *Agriculture*, *15*(11), 1151. https://doi.org/10.3390/agriculture15111151
27. Meinzen-Dick, R. (2014). Property rights and sustainable irrigation: A developing country perspective. *Agricultural Water Management*, *145*, 23–31. https://doi.org/10.1016/j.agwat.2014.03.017
28. Moghaddam, S. M., Azadi, H., Sklenička, P., & Janečková, K. (2025). Impacts of Land Tenure Security on the Conversion of Agricultural Land to Urban Use. *Land Degradation & Development*, *36*(8), 2517–2529. https://doi.org/10.1002/ldr.5535
29. Mupaso, N., Makombe, G., & Mugandani, R. (2023). Smallholder irrigation and poverty reduction in developing countries: a review. *Heliyon*, *9*(2), e13341. https://doi.org/10.1016/j.heliyon.2023.e13341
30. Norbu, N. P., Tateno, Y., & Bolesta, A. (2021). Structural transformation and production linkages in Asia-Pacific least developed countries: An input-output analysis. *Structural Change and Economic Dynamics*, *59*, 510–524. https://doi.org/10.1016/j.strueco.2021.09.009
31. Nouri, M., Homaee, M., Pereira, L. S., & Bybordi, M. (2023). Water management dilemma in the agricultural sector of Iran: A review focusing on water governance. *Agricultural Water Management*, *288*, 108480. https://doi.org/10.1016/j.agwat.2023.108480
32. Oktavia, D., Pratiwi, S. D., Kamaludin, N. N., Widiawaty, M. A., & Dede, Moh. (2024). Dynamics of Land use and Land cover in the Belitung Island, Indonesia. *Heliyon*, *10*(12), e33291. https://doi.org/10.1016/j.heliyon.2024.e33291
33. Ostrom, E. (1990). *Governing the Commons*. Cambridge University Press. https://doi.org/10.1017/CBO9780511807763
34. Palatnik, R. R., Raviv, O., Sirota, J., & Shechter, M. (2025). Water scarcity and food security in the mediterranean region: The role of alternative water sources and controlled-environment agriculture. *Water Resources and Economics*, *49*, 100256. https://doi.org/10.1016/j.wre.2025.100256
35. Prayitno, G., Dinanti, D., Hidayana, I. I., & Nugraha, A. T. (2021). Place attachment and agricultural land conversion for sustainable agriculture in Indonesia. *Heliyon*, *7*(7), e07546. https://doi.org/10.1016/j.heliyon.2021.e07546
36. Reich, C., & Musshoff, O. (2025). Oil palm smallholders and the road to certification: Insights from Indonesia. *Journal of Environmental Management*, *375*, 124303. https://doi.org/10.1016/j.jenvman.2025.124303

37. Ricks, J. I. (2017). Street-Level Bureaucrats and Irrigation Policy Reform in Southeast Asia. *Asian Politics & Policy*, *9*(2), 310–319. https://doi.org/10.1111/aspp.12319
38. Rigg, J., Salamanca, A., & Thompson, E. C. (2016). The puzzle of East and Southeast Asia's persistent smallholder. *Journal of Rural Studies*, *43*, 118–133. https://doi.org/10.1016/j.jrurstud.2015.11.003
39. Rosa, L., & He, L. (2025). Global multi-model projections of green water scarcity risks in rainfed agriculture under 1.5 °C and 3 °C warming. *Agricultural Water Management*, *314*, 109519. https://doi.org/10.1016/j.agwat.2025.109519
40. Sanchis-Ibor, C., García-Mollá, M., Torregrosa, T., Ortega-Reig, M., & Sevilla Jiménez, M. (2019). Water transfers between agricultural and urban users in the region of Valencia (Spain). A case of weak governance? *Water Security*, *7*, 100030. https://doi.org/10.1016/j.wasec.2019.100030
41. Soliman, A., Thiel, A., & Roggero, M. (2021). Institutional Performance of Collective Irrigation Systems: A Fuzzy Set Qualitative Comparative Analysis in the Nile Delta of Egypt. *Sustainability*, *13*(3), 1103. https://doi.org/10.3390/su13031103
42. Sutardi, Apriyana, Y., Rejekiningrum, P., Alifia, A. D., Ramadhani, F., Darwis, V., Setyowati, N., Setyono, D. E. D., Gunawan, Malik, A., Abdullah, S., Muslimin, Wibawa, W., Triastono, J., Yusuf, Arianti, F. D., & Fadwiwati, A. Y. (2022). The Transformation of Rice Crop Technology in Indonesia: Innovation and Sustainable Food Security. *Agronomy*, *13*(1), 1. https://doi.org/10.3390/agronomy13010001
43. van Aalderen, N., van Berkel, F., van der Roest, E., Meekel, N., & Segrave, A. J. (2024). Reimagining public water: an intergenerational exploration of paradigms for future system design. *Policy Studies*, 1–23. https://doi.org/10.1080/01442872.2024.2421530
44. Wahyuningrat, Rosyadi, S., Haryanto, T., & Setiansah, M. (2019). Formulation of protection policy for sustainable cropland agriculture. *IOP Conference Series: Earth and Environmental Science*, *250*, 012073. https://doi.org/10.1088/1755-1315/250/1/012073
45. Wang, J., Zhu, Y., Sun, T., Huang, J., Zhang, L., Guan, B., & Huang, Q. (2020). Forty years of irrigation development and reform in China. *Australian Journal of Agricultural and Resource Economics*, *64*(1), 126–149. https://doi.org/10.1111/1467-8489.12334
46. West, T. A. P., Caviglia-Harris, J. L., & Fearnside, P. M. (2025). Additionality in Theoretical von Thünenian Models of Deforestation and Conservation Payments. *Land*, *14*(2), 272. https://doi.org/10.3390/land14020272
47. Widyatmanti, W., & Umarhadi, D. A. (2022). Spatial modeling of soil security in agricultural land of Central Java, Indonesia: A preliminary study on capability, condition, and capital dimensions. *Soil Security*, *8*, 100070. https://doi.org/10.1016/j.soisec.2022.100070
48. Yong, M. L. (2022). Transboundary environmental publics and hydropower governance in the Mekong River Basin: A contested politics of place, scale and temporality. *Environmental Policy and Governance*, *32*(4), 292–304. https://doi.org/10.1002/eet.1973
49. Zhang, Y., & Xie, H. (2019). Welfare Effect Evaluation of Land-Lost Farmers' Households under Different Livelihood Asset allocation. *Land*, *8*(11), 176. https://doi.org/10.3390/land8110176
50. Zhang, Z., Ghazali, S., Miceikienė, A., Zejak, D., Choobchian, S., Pietrzykowski, M., & Azadi, H. (2023). Socio-economic impacts of agricultural land conversion: A meta-analysis. *Land Use Policy*, *132*, 106831. https://doi.org/10.1016/j.landusepol.2023.106831
51. Zou, B., Chen, Y., Mishra, A. K., & Hirsch, S. (2024). Agricultural mechanization and the performance of the local Chinese economy. *Food Policy*, *125*, 102648. https://doi.org/10.1016/j.foodpol.2024.102648