

Spatial and Temporal Factors Influencing Environmental Benefits on the Socioeconomic Changes of the Poor: A Case Study in Kuala Krai, Kelantan

Muhammad Rahim Bin Zaidi, Mohd Azmeer Abu Bakar

School of Humanities, Universiti Sains Malaysia, 11800 Minden Pulau Pinang

Email: azmeerm@usm.my

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Abstract

Rural poverty continues to pose major challenges in Malaysia, particularly in districts that are geographically isolated and vulnerable to climatic variability. Kuala Krai in Kelantan represents one of the poorest regions where households depend heavily on land, forests, and rivers for their livelihoods. This study investigates how spatial factors such as infrastructure accessibility, distance to markets, and adoption of technology together with temporal factors such as seasonal floods, droughts, and harvest cycles shape socioeconomic outcomes for poor households. A mixed-method approach was employed, combining surveys with 351 respondents and in-depth interviews with household heads. Principal component analysis revealed that access to infrastructure and markets significantly enhances income stability, while temporal shocks, especially floods, disrupt farming cycles, damage crops, and increase reliance on informal coping strategies. Findings highlight that environmental resources provide essential benefits but are undermined by the combined impact of spatial and temporal constraints, particularly in remote areas such as Dabong. The study concludes that poverty reduction strategies must integrate infrastructure development, climate risk management, and technological innovation to ensure the sustainable utilization of environmental resources as a pathway out of poverty.

Keywords: Spatial Factors, Temporal Factors, Environmental Benefits, Socioeconomic Change, Rural Poverty

Introduction

Poverty reduction in rural areas continues to be one of the central challenges for many developing countries, including Malaysia. Although national poverty rates have declined significantly over the past decades, regional and spatial disparities remain acute, with states such as Kelantan consistently recording higher poverty incidences than the national average (Department of Statistics Malaysia [DOSM], 2023). Within Kelantan, the district of Kuala Krai

stands out as one of the poorest, primarily due to its geographic isolation, limited infrastructure, and heavy dependence on natural resources such as land, forests, and rivers for livelihood (Musa, Jabil, & Suriani, 2014; Ibrahim, 2016). These environmental assets form the economic foundation of rural households but also expose them to spatial and temporal instabilities that perpetuate poverty.

The challenges of Kuala Krai are compounded by its vulnerability to seasonal and climatic shocks. The catastrophic *Bah Kuning* flood of 2014 displaced more than 45,000 residents and caused widespread damage to infrastructure, agricultural land, and livelihoods, leaving long-term socioeconomic repercussions (Ibrahim, 2016; Chan, Roy, & Lai, 2017). Such recurring floods, coupled with prolonged dry seasons, exemplify how temporal factors—especially climate variability—intersect with spatial isolation to deepen rural poverty. Flood-prone communities not only lose productive assets but also face disruptions to market access, income generation, and social stability.

Previous research on poverty-environment linkages has established that natural resources play a crucial role in sustaining rural livelihoods (Fonta, Ayuk, & Ichoku, 2015). However, scholars also caution that excessive dependence on these resources can entrap communities in cycles of poverty, especially when productivity is low and environmental conditions are volatile (Dhrifi, Jaziri, & Alnahdi, 2020). In Malaysia, studies have highlighted that infrastructure deficits, weak market connectivity, and limited technological adoption continue to hinder rural development (Abdul-Rahim et al., 2020; Nasir et al., 2021). Meanwhile, research on temporal dimensions shows that floods, droughts, and seasonal variations destabilize household income and food security, particularly among the poor (Shahid et al., 2020; Abdullah et al., 2022).

Despite these valuable insights, the majority of studies have examined spatial and temporal dimensions in isolation. The effects of poor infrastructure and market inaccessibility are often analyzed separately from the impacts of seasonality and climate shocks (Xu, Chen, & Liu, 2015; Leslie, Campbell, & Herr, 2015). This fragmented understanding overlooks how these two dimensions interact to shape the lived realities of poor households. As Berkes and Folke (1998) emphasize in their socio-ecological systems framework, livelihoods are not only determined by the availability of environmental resources but also by the spatial and temporal conditions governing access, resilience, and sustainability.

In this context, Kuala Krai provides an important case study to understand how environmental benefits are mediated by both space and time. Spatial constraints such as poor road networks, long distances to markets, and weak technological access intersect with temporal constraints such as floods, droughts, and seasonal income fluctuations to shape household welfare. Without recognizing this interaction, poverty alleviation efforts risk misdiagnosing the root causes of vulnerability. As the Department of Statistics Malaysia (2023) and the Ministry of Rural Development (2020) highlight, spatial inequality and environmental exposure remain the primary barriers to inclusive development in rural Malaysia.

Therefore, this study seeks to address the critical gap by analyzing how spatial factors (infrastructure accessibility, market distance, and technology adoption) and temporal factors

(seasonal floods, droughts, and harvest cycles) jointly influence the utilization of environmental benefits among poor households in Kuala Krai. By adopting an integrated spatial-temporal perspective, this research provides a more holistic understanding of rural poverty dynamics. The findings aim to contribute to policy design by emphasizing the importance of infrastructural investment, climate risk management, and technological innovation as key pillars for sustainable poverty reduction in environmentally vulnerable regions such as Kuala Krai, Kelantan.

Purpose of the Study

The primary purpose of this study is to analyze the role of spatial and temporal factors in shaping the utilization of environmental benefits by poor households in Kuala Krai, Kelantan. By integrating both dimensions, the study seeks to provide empirical evidence that can guide rural development strategies, emphasizing infrastructure improvement, climate risk management, and technological adoption as pathways to poverty alleviation.

Research Methods

This study employed a mixed-method approach combining quantitative surveys with qualitative interviews to capture a holistic view of how spatial and temporal factors shape the utilization of environmental benefits among poor households in Kuala Krai, Kelantan.

Study Area

Kuala Krai is a predominantly rural district located in the interior of Kelantan, Malaysia, covering an area of approximately 2,329 square kilometers (Department of Statistics Malaysia [DOSM], 2020). The district is characterized by hilly terrain, dense forest cover, and major river systems, particularly the Sungai Kelantan and its tributaries, which play a crucial role in agriculture and household livelihoods (Jamaludin, 2015).

Due to its geographic setting, Kuala Krai is especially vulnerable to seasonal flooding during the northeast monsoon. The catastrophic flood of December 2014, known locally as *Bah Kuning*, displaced more than 45,000 residents in Kuala Krai alone and caused long-term socioeconomic disruption (Ibrahim, 2016; Chan, Roy, & Lai, 2017). Seasonal floods not only damage infrastructure and crops but also undermine household income stability, making Kuala Krai one of the most environmentally vulnerable districts in Kelantan.

Administratively, Kuala Krai is divided into three main branches including Batu Mengkebang, Olak Jeram, and Dabong—comprising a total of 15 mukim (sub-districts) (Kuala Krai District Office, 2022). These mukim exhibit considerable spatial variations in terms of infrastructure, market connectivity, and exposure to environmental risks. For example, Batu Mengkebang has relatively better road networks and accessibility, while remote areas such as Dabong remain geographically isolated, with limited infrastructure and higher vulnerability to environmental hazards. This diversity across mukim provided the rationale for their inclusion in the study, ensuring that spatial differences in infrastructure access and exposure to floods were adequately represented.

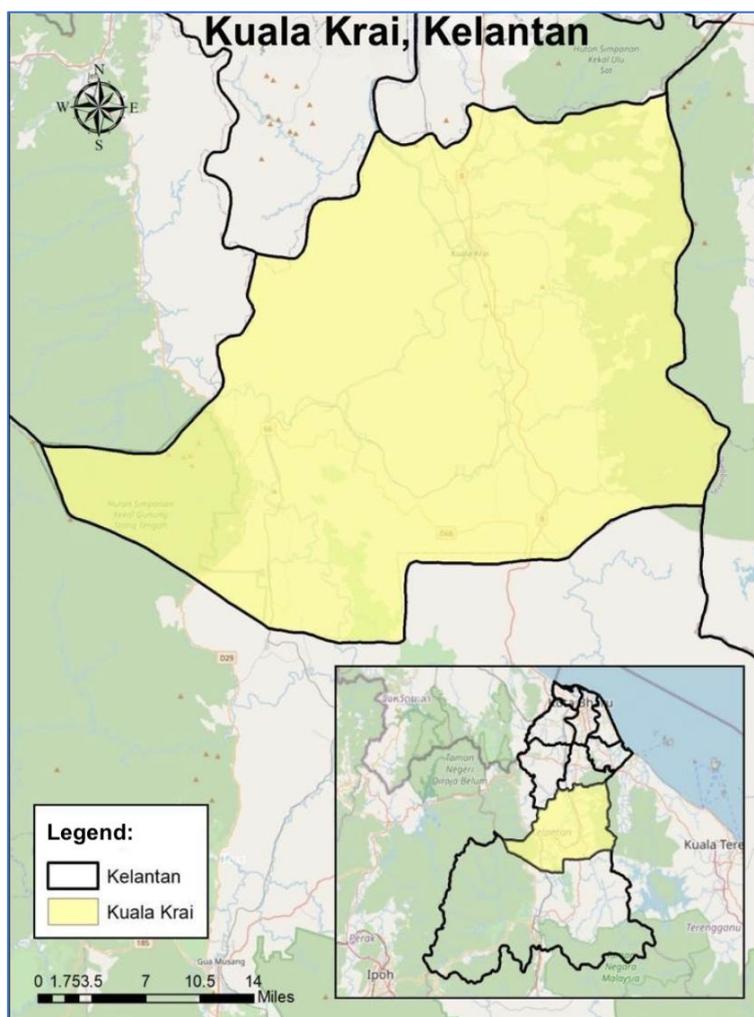


Figure 1. The Study Area

Table 1

Administrative Branches and Sub-Districts (Mukim) in Kuala Krai District, Kelantan

Administrative Branch	Number of Sub-Districts	List of Sub-Districts
Batu Mengkebang	8	Batu Mengkebang, Enggong, Kenor, Kuala Krai, Kuala Nal, Kuala Pahi, Mambong, Telekong
Olak Jeram	3	Gajah, Manek Urai, Manjor
Dabong	4	Kandek, Kuala Geris, Kuala Pergau, Kuala Stong
Total	15	—

Source: Field Survey, 2024

Sampling and Respondents

A stratified random sampling technique was employed to ensure that the survey sample accurately reflected the socioeconomic and spatial diversity of poor households in Kuala Krai. The sampling frame was derived from the national poverty database (e-Kasih), administered by the Prime Minister’s Department, which provides an official listing of households living below the national poverty line (Prime Minister’s Department, 2019). This

ensured that all selected respondents met the official poverty criteria established by the Malaysian government.

To determine the minimum number of household respondents required for the survey, Yamane's (1967) sample size estimation formula was applied, assuming a 95 percent confidence level and a 5 percent margin of error. The formula is expressed as follows:

$$n = \frac{N}{1+N(e)^2} \quad (\text{Equation 1})$$

where n = required sample size, N = total population of poor households, and e = margin of error (0.05).

According to data obtained from the Kuala Krai District Office and the e-Kasih database, the total number of poor households (N) across the three administrative branches—Batu Mengkebang, Olak Jeram, and Dabong was estimated at approximately 2,000 households. Substituting this value into Equation 1 gives:

$$n = \frac{2000}{1 + 2000 (0.05)^2} = 333.33$$

Thus, a minimum of 333 respondents was required to achieve representativeness. To enhance statistical robustness and account for potential non-response, the final sample size was increased to 351 household respondents. The sample was proportionally stratified according to the population distribution of poor households within each administrative branch. This approach ensured balanced representation across the fifteen mukim (sub-districts), which vary in infrastructure quality, market accessibility, and exposure to floods. Stratification was crucial for minimizing bias caused by spatial heterogeneity particularly between relatively well-connected areas such as Batu Mengkebang and remote regions like Dabong.

In addition to the quantitative survey, 20 household heads were selected for semi-structured qualitative interviews using purposive sampling. These interviews explored household experiences with environmental changes, flood-related challenges, and adaptive livelihood strategies, providing depth to the quantitative findings.

The use of a mixed-method research design allowed for both statistical generalization and contextual interpretation. Quantitative data captured measurable variations in spatial and temporal conditions, while qualitative insights enriched understanding of household perceptions and adaptive capacities. Such methodological triangulation strengthened the validity and reliability of the research (Etikan & Bala, 2017; Creswell & Plano Clark, 2018).

Data Collection

The data were collected using a structured questionnaire designed to capture multiple dimensions of household livelihoods and vulnerabilities. Respondents were asked about their access to environmental resources, including land, forests, and rivers, alongside spatial conditions such as infrastructure availability, market distance, and the use of agricultural technology. To capture the temporal dimension, the questionnaire included items on seasonality, flood events, and drought periods, and how these shaped household activities and income cycles.

Socioeconomic indicators were also measured, covering income levels, employment stability, food security, and coping strategies during periods of environmental and economic

stress. To complement the quantitative survey, qualitative interviews were conducted with 20 selected household heads. These interviews provided deeper insights into household perceptions of environmental change, the challenges of seasonal variations, and the adaptive strategies households employed to maintain livelihoods under uncertain conditions.

This mixed-method design strengthened the study by enabling both breadth and depth: the survey offered statistically generalizable findings, while the interviews provided contextual richness and captured the lived experiences of poor households in Kuala Krai (Creswell & Plano Clark, 2018). Mixed-method approaches are particularly effective in rural poverty research, where quantitative measures often miss subtle but significant socio-ecological dynamics (Johnson, Onwuegbuzie, & Turner, 2007).

Data Analysis

Survey data were analyzed using Principal Component Analysis (PCA) to identify the latent constructs underlying spatial and temporal dimensions of household vulnerability. Prior to extraction, the data were assessed for sampling adequacy and factorability. The Kaiser-Meyer-Olkin (KMO) measure was 0.72, exceeding the recommended threshold of 0.60 (Kaiser, 1974), while Bartlett's Test of Sphericity was highly significant ($\chi^2 = 1,045.23$; $p < 0.001$), confirming the appropriateness of the dataset for factor analysis.

The PCA extracted five dominant factors, which collectively explained 69.37% of the total variance. These factors captured household access to natural resources, infrastructure and transportation, seasonal and climatic shocks, dependence on agriculture/forestry, and access to technology and financial capital.

Following PCA, inferential statistics including *t*-tests and one-way ANOVA were applied to assess group differences across mukim, infrastructure levels, and exposure to seasonal shocks. This allowed for the identification of statistically significant variations in socioeconomic outcomes across different household groups.

Qualitative interview transcripts were subjected to thematic coding, focusing on household perceptions of environmental changes, flood impacts, and adaptation strategies. These themes were then triangulated with quantitative results, enhancing the validity and robustness of findings (Nowell et al., 2017).

Table 2

Principal Component Analysis of Spatial and Temporal Factors Affecting Environmental Benefits in Kuala Krai

Factor	Eigenvalue	Variance Explained (%)	Cumulative Variance (%)	Description
Factor 1	4.988	27.71	27.71	Access to land, forest, and river resources
Factor 2	2.968	16.49	44.20	Infrastructure and transportation (roads, markets)
Factor 3	1.837	10.21	54.40	Seasonal and climatic influences (floods, monsoon)
Factor 4	1.580	8.78	63.18	Economic dependence on agriculture/forest products
Factor 5	1.114	6.19	69.37	Access to technology and financial capital

Source: Field Survey, 2024

Findings

Demographic Profile of Respondents

The demographic profile of respondents provides important context for understanding the socioeconomic challenges faced by poor households in Kuala Krai. In terms of gender, the survey revealed a slightly higher proportion of male respondents (54.1%) compared to females (45.9%). This reflects the tendency for men to be recorded as household heads, although the significant presence of female respondents highlights the crucial role women also play in household livelihoods, particularly in subsistence farming and informal trading. Similar patterns have been reported in rural Kelantan, where women contribute significantly to household survival despite limited recognition in official records (Ariffin & Wahab, 2021).

Regarding age distribution, most respondents were in the economically active age groups: 31–40 years (26.8%) and 41–50 years (33.6%). Together, these groups accounted for over 60% of the sample, suggesting that most households were represented by individuals actively engaged in income-generating activities. However, a substantial proportion (21.9%) were above 50 years of age, reflecting the persistence of older household heads who may face additional barriers in adopting new technologies or diversifying livelihoods. Recent studies highlight that aging rural populations in Malaysia often remain dependent on traditional farming practices, making them vulnerable to climate-related risks (Kadir & Shamsudin, 2020).

Household income levels remain the most critical marker of vulnerability. Nearly half of the households (44.4%) reported monthly incomes below RM1,000, while another 36.5% earned between RM1,001 and RM2,000. Altogether, over 80% of respondents fell below RM2,000 monthly income, well under Malaysia's 2020 median household income of RM5,209

(DOSM, 2021). This demonstrates the persistence of absolute and relative poverty in Kuala Krai. Similar findings were reported by Ghazali et al. (2022), who showed that rural Kelantan continues to exhibit structural poverty due to dependence on low-return agricultural activities and limited access to alternative employment.

These demographic findings confirm that poor households in Kuala Krai are primarily low-income, resource-dependent, and composed of middle-aged household heads. Such characteristics compound their vulnerability to both spatial challenges (limited infrastructure, market isolation) and temporal shocks (seasonal floods and droughts).

Table 3

Demographic Profile of Respondents (Gender, Age, Income)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	190	54.1
	Female	161	45.9
Age Group	Below 30 years	62	17.7
	31–40 years	94	26.8
	41–50 years	118	33.6
	Above 50 years	77	21.9
Monthly Household Income	Less than RM1,000	156	44.4
	RM1,001 – RM2,000	128	36.5
	RM2,001 – RM3,000	47	13.4
	More than RM3,000	20	5.7

Source: Field Survey, 2024

Spatial Barriers to Environmental Benefits: Infrastructure, Market Access, and Technology Adoption

Survey results highlighted significant spatial inequalities across the three administrative branches of Kuala Krai. In Dabong, 64% of households reported difficulty accessing markets during the rainy season, compared to 46% in Olak Jeram and only 28% in Batu Mengkebang. Similarly, 52% of Dabong respondents experienced losses from perishable goods that could not be sold in time, compared to 37% in Olak Jeram and 19% in Batu Mengkebang.

Technology adoption also reflected this spatial divide. While 41% of households in Batu Mengkebang reported using modern farming technologies (fertilizers, small-scale machinery, mobile-based tools), only 12% in Dabong and 24% in Olak Jeram had access to such practices.

These results demonstrate that infrastructure, market access, and technology adoption are critical spatial factors shaping household vulnerability. Remote households in Dabong face systematic disadvantages, where weak road networks and geographic isolation exacerbate flood impacts and restrict access to markets. Perishable losses highlight the absence of storage facilities and efficient transportation, making environmental benefits unstable.

By contrast, Batu Mengkebang households benefit from better infrastructure and higher technology adoption, which improve their capacity to convert environmental resources into steady income. This supports findings by Abdul-Rahim et al. (2020), who showed that rural infrastructure is a key predictor of poverty reduction in Malaysia, and Salleh et al. (2022), who found that digital and agricultural technologies remain concentrated in better-connected regions. Nasir et al. (2021) further emphasized that transportation constraints in Malaysia's East Coast disproportionately affect small farmers, raising transaction costs and lowering competitiveness. Overall, spatial factors in Kuala Krai act as both enablers and barriers: households in well-connected areas can stabilize livelihoods, while those in remote *mukim* remain trapped in cycles of vulnerability.

Beyond household-level implications, these spatial barriers reflect wider structural inequalities in rural development. Poor connectivity and weak infrastructure in Dabong mirror challenges found in other rural districts across Southeast Asia, where physical isolation translates directly into economic marginalization. Rahman et al. (2021) emphasize that remoteness in hilly and flood-prone areas often results in limited access to markets, schools, and health services, reinforcing cycles of poverty. Similar findings were reported in Bangladesh and Indonesia, where weak transportation networks not only restricted farmers from reaching markets but also delayed recovery efforts during floods and disasters (Islam & Lim, 2022). In this way, Kuala Krai's case is part of a broader regional pattern in which geography and infrastructure jointly determine livelihood opportunities and poverty persistence.

Policy implications are also evident. The severe disadvantage faced by Dabong underscores the urgent need for targeted rural investment in physical infrastructure, storage facilities, and technology transfer. Malaysia's Rural Development Policy 2030 highlights infrastructure as a cornerstone for bridging rural-urban inequality and ensuring sustainable livelihood development (Ministry of Rural Development, 2020). Expanding agricultural extension services and subsidizing mobile-based farming tools could reduce farmers' reliance on traditional practices and enhance their competitiveness. Without such interventions, environmental resources in Kuala Krai will remain underutilized, while households in isolated areas continue to face systemic exclusion from the benefits of development.

Table 4

Spatial Inequalities in Infrastructure, Market Access, and Technology Use

Spatial Factor	Batu Mengkebang (%)	Olak Jeram (%)	Dabong (%)	Key Challenge Reported
Difficulty accessing markets in rainy season	28.0	46.0	64.0	Roads cut off during floods, high transport cost
Perishable goods lost before sale	19.0	37.0	52.0	Lack of storage, market delays
Adoption of modern farming technology	41.0	24.0	12.0	Limited capital, weak extension support

Source: Field Survey, 2024

Temporal Factors: Seasonal and Climatic Shocks Affecting Household Livelihoods

Temporal conditions in Kuala Krai exert a strong influence on household livelihoods, particularly through monsoon floods, seasonal agricultural cycles, and drought periods. Survey results indicated that 62% of respondents reported income losses exceeding 30% during the flood season, with Dabong households being the most severely affected. In addition, 47% of households relied on informal loans or temporary wage labor during floods, while 38% reported higher income during fruit harvest seasons, though only 12% considered this sustainable throughout the year.

The PCA analysis further confirmed this pattern. Factor 3 (seasonal and climatic influences) explained 10.21% of the total variance in household reliance on environmental resources, underlining the disruptive impact of floods and droughts. These findings reveal that temporal shocks intensify socioeconomic vulnerability in Kuala Krai. Floods during the northeast monsoon disrupt farming cycles, damage crops, and block transport routes, particularly in Dabong where spatial disadvantages compound temporal risks. While fruit harvest seasons temporarily increase incomes, their benefits are unstable and insufficient to offset losses from floods.

Qualitative interviews further illustrate the precarious situation:

“Every year when the flood comes, I stop farming and work in construction for two months. If not, there is no income at all.” (Male respondent, Olak Jeram, age 39)

This cyclical instability reflects patterns observed in other developing regions. Shahid et al. (2020) documented that seasonal floods in Malaysia’s East Coast states consistently disrupt agricultural productivity, while Ali & Noh (2021) found that reliance on seasonal income sources deepens vulnerability among poor households. Recent studies, such as Abdullah et al. (2022), emphasize that climate variability is now one of the leading drivers of rural poverty persistence in Malaysia, demanding integrated disaster preparedness and adaptive agricultural policies.

Overall, temporal factors in Kuala Krai act as destabilizing forces: floods amplify losses, droughts reduce yields, and seasonal income spikes are unsustainable. Unless supported by climate risk management and adaptive strategies, these temporal constraints will continue to undermine the socioeconomic stability of poor households.

The impacts of temporal shocks extend beyond immediate income losses and influence household coping strategies in the long term. For instance, reliance on informal loans during floods, as reported by nearly half of respondents, creates cycles of indebtedness that persist long after the floodwaters recede. Studies in rural Malaysia have shown that such credit dependence often leads to long-term financial strain, especially when households lack access to formal microfinance or insurance schemes (Othman & Yusof, 2022). Moreover, climate-induced disruptions have a compounding effect on education and health outcomes, as limited income during floods forces households to reduce expenditure on children’s schooling or medical care (Yunus, Aziz, & Hashim, 2021). This demonstrates that temporal shocks not only destabilize livelihoods but also undermine broader aspects of household resilience.

At the same time, seasonal advantages such as fruit harvests provide only temporary relief and often benefit a small proportion of households with access to suitable land or crops. For many respondents, the seasonality of income opportunities means that poverty remains cyclical rather than structural, with short-lived income gains followed by extended periods of hardship. This finding resonates with evidence from Thailand and Vietnam, where rural households relying on seasonal crops experience significant fluctuations in welfare indicators, making them highly vulnerable to climate variability (Nguyen et al., 2020). Without long-term interventions such as diversified farming systems, crop insurance, or community-based disaster risk reduction programs, households in Kuala Krai are likely to remain locked into unstable livelihood cycles dictated by climatic variability.

Table 5

Temporal Shocks and Household Livelihoods in Kuala Krai

Temporal Factor	Percentage of Respondents Affected (%)	Key Impacts Reported
Income loss during floods (>30%)	62.0	Crop destruction, inability to access markets
Reliance on informal loans during floods	47.0	Household debt, financial instability
Increased income during fruit harvest	38.0	Short-term gains, not sustained annually
Long-term sustainability of harvest income	12.0	Seasonal dependence, lack of stability

Source: Field Survey, 2024

Interaction of Spatial and Temporal Factors: Compounded Vulnerabilities

Survey data and PCA results show that spatial and temporal factors are not independent but mutually reinforcing drivers of household vulnerability. For example, Dabong households, already disadvantaged by weak road networks and limited technology adoption, reported the highest proportion of income loss during floods (68%), compared to Batu Mengkebang (34%). Additionally, 56% of Dabong households reported being cut off from markets for more than two weeks during the 2024 flood season, while only 18% of Batu Mengkebang households faced similar disruptions.

The PCA model also reflected this compounded vulnerability. While Factor 2 (infrastructure/transport) and Factor 3 (seasonality/climatic shocks) emerged independently, combined qualitative and quantitative evidence suggested a strong overlap: poor infrastructure magnified the socioeconomic impacts of floods and seasonal disruptions.

The evidence demonstrates that households in remote areas such as Dabong are not only disadvantaged spatially but also more severely exposed to temporal shocks. Poor roads and limited bridges prolong isolation during floods, causing higher income losses and food insecurity. Even when environmental resources such as fertile land or forests are abundant, their benefits remain inaccessible without reliable infrastructure.

Qualitative interviews captured the realities of this compounded marginalization. One respondent explained:

“When the flood blocks the road, we cannot sell our vegetables at all. Even if the crops survive, they rot before reaching the market.” (Male respondent, Dabong, age 47)

Another interviewee highlighted how spatial disadvantages increase the burden of temporal shocks:

“During the floods, we are cut off for weeks. Aid takes too long to arrive, and we have no savings. Life is harder here than in Batu Mengkebang.” (Female respondent, Dabong, age 42)

The compounded effects of spatial and temporal vulnerabilities also influence household decision-making regarding livelihood strategies. Many respondents in Dabong reported withdrawing from farming during flood seasons and seeking temporary wage labor in nearby towns. While this provides short-term income, it disrupts agricultural productivity and weakens long-term food security. Similar patterns were observed in Olak Jeram, where households combined informal trading with wage labor to compensate for agricultural losses. This suggests that spatial and temporal constraints not only reduce immediate welfare but also force households into unstable and unsustainable livelihood diversification (Rahman & Chamhuri, 2021).

Furthermore, the interaction of these factors has significant implications for intergenerational poverty. Interviews revealed that children in Dabong often miss school during floods due to inaccessibility, while households facing prolonged isolation reduce educational expenditure to prioritize basic food and survival. Research has shown that educational disruption during climatic shocks perpetuates cycles of poverty by limiting opportunities for upward mobility (Yunus et al., 2021). In Kuala Krai, these disruptions are intensified by spatial barriers, which prevent children from accessing alternative schooling or online education facilities during flood periods.

Finally, the compounded nature of spatial and temporal factors highlights the urgent need for integrated policy approaches. Addressing infrastructure alone will not be sufficient if climatic shocks continue to destabilize livelihoods, while climate adaptation strategies will remain ineffective if households remain physically isolated. Therefore, interventions must be multidimensional, focusing simultaneously on rural infrastructure development, disaster preparedness, and livelihood diversification. Without such integrated measures, communities like Dabong will remain locked in a cycle of compounded vulnerability where natural resource abundance fails to translate into real poverty alleviation (Salleh & Wahid, 2022).

These findings mirror regional studies. Shah & Mustapha (2019) observed that rural Kelantan communities experience “double marginalization” when geographic isolation overlaps with seasonal flooding. Similarly, Kaur et al. (2021) found that infrastructural deficits amplify climate risks in rural Malaysia, leading to prolonged poverty traps. Othman & Yusof (2022) further emphasized that poor households in Malaysia’s flood-prone districts are disproportionately affected due to weak coping capacity and poor access to technology.

In summary, the interaction of spatial and temporal factors compounds household vulnerability, particularly in Dabong. This section directly answers the research question by demonstrating that environmental benefits alone are insufficient to improve socioeconomic

outcomes when spatial barriers (infrastructure, market access, technology) and temporal shocks (floods, droughts, seasonality) overlap to perpetuate cycles of poverty in Kuala Krai.

Table 6

Compounded Impact of Spatial and Temporal Factors

Administrative Branch	% Income Loss During Floods	% Cut Off from Markets (>2 weeks)	Technology Adoption (%)	Key Combined Challenge
Batu Mengkebang	34.0	18.0	41.0	Short-term disruption, faster recovery due to infrastructure
Olak Jeram	51.0	32.0	24.0	Medium disruption, limited recovery
Dabong	68.0	56.0	12.0	Severe disruption, prolonged recovery, high vulnerability

Source: Field Survey, 2024

Conclusion

This study examined how spatial and temporal factors influence the environmental benefits and socioeconomic outcomes of poor households in Kuala Krai, Kelantan. The findings confirm that environmental resources such as land, forests, and rivers remain critical to rural livelihoods, yet their benefits are highly unstable due to compounded spatial and temporal constraints. In terms of spatial factors, households in Batu Mengkebang benefitted from better infrastructure and market accessibility, which enabled them to achieve greater income stability. Conversely, households in Dabong, characterized by poor road networks and geographic isolation, were significantly disadvantaged, highlighting how infrastructural deficits perpetuate poverty in remote areas. This aligns with earlier studies which emphasize that connectivity, infrastructure, and technology adoption are decisive factors in rural poverty reduction (Abdul-Rahim et al., 2020; Nasir et al., 2021).

Temporal factors also emerged as destabilizing forces, with seasonal floods, droughts, and harvest cycles exerting a strong influence on household well-being. Annual floods during the northeast monsoon disrupted farming cycles, destroyed crops, and cut off households from markets, leading to income losses exceeding 30% for a majority of respondents. While fruit harvest seasons temporarily improved earnings, these benefits were short-lived and insufficient to ensure long-term livelihood stability. Similar findings have been reported in studies across Malaysia's East Coast, where recurring floods and climate variability deepen the vulnerability of rural households (Shahid et al., 2020; Abdullah et al., 2022). These results demonstrate that temporal shocks intensify poverty by reducing household resilience and magnifying existing vulnerabilities.

Most critically, the study demonstrated that spatial and temporal factors are not independent but mutually reinforcing. In Dabong, poor infrastructure prolonged recovery from floods, making households more vulnerable compared to those in better-connected areas. This compounded disadvantage reflects a "double marginalization," where geographic isolation interacts with seasonal shocks to deepen poverty (Shah & Mustapha, 2019; Kaur et

al., 2021). Thus, environmental benefits alone cannot guarantee poverty alleviation unless spatial and temporal barriers are systematically addressed.

Based on these findings, several policy directions can be recommended. First, rural infrastructure development including roads, bridges, and storage facilities should be prioritized to reduce transaction costs and ensure access to markets, particularly during floods (Salleh et al., 2022). Second, community-based climate risk management, such as flood preparedness programs and climate-resilient agricultural practices, must be scaled up to enhance rural adaptive capacity (Ali & Noh, 2021). Third, targeted efforts are needed to expand access to modern agricultural technologies through subsidies, training, and mobile-based tools, especially in remote areas with low adoption rates. Finally, inclusive development policies should ensure that geographically isolated communities such as those in Dabong receive equitable support to overcome compounded vulnerabilities.

In conclusion, this study answers its central research questions by showing that spatial accessibility and infrastructure (RQ1), temporal variability and floods (RQ2), and their combined interaction (RQ3) jointly determine the sustainability of environmental benefits for poor households. Addressing these structural and climatic barriers through integrated infrastructure, technology, and climate adaptation strategies is therefore essential for transforming environmental resources into sustainable pathways out of poverty in rural Malaysia.

This study contributes to both theory and context by extending the socio-ecological systems framework (Berkes & Folke, 1998) to incorporate the combined effects of spatial and temporal dimensions in rural poverty analysis. Theoretically, it refines existing poverty environment models by demonstrating that environmental resources alone cannot improve welfare without supportive spatial and temporal conditions such as infrastructure, market connectivity, and climate stability. Through the integration of quantitative (PCA) and qualitative data, the study introduces a multidimensional analytical approach for examining how environmental benefits are mediated by physical access and climatic variability an area previously underexplored in the Malaysian context. Contextually, this research provides empirical evidence from Kuala Krai, one of Malaysia's most flood-prone and infrastructurally constrained districts, illustrating how geographic isolation and seasonal shocks interact to perpetuate poverty. The findings therefore advance current understanding of spatial-temporal interdependence in rural livelihoods and offer valuable guidance for designing adaptive, inclusive, and resilience-based rural development strategies in environmentally vulnerable regions.

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