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REVEALING THE ROLE OF LIVELIHOOD ASSETS IN SHAPING THE LIVELIHOOD DIVERSIFICATION OF COASTAL COMMUNITIES IN YOGYAKARTA, INDONESIA

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ABSTRACT

Coastal livelihoods depend on natural resources in areas where land meets the sea. Nevertheless, poverty rates in coastal communities remain relatively high. This study explored the impact of livelihood assets on livelihood diversification in three coastal communities of Yogyakarta. It surveyed 283 households in Trisik, Parangtritis, and Baron using questionnaire-based interviews. Households were categorised into four types: Farm, off-farm, non-farm wage, and non-farm non-wage. Livelihood assets were analysed using Principal Component Analysis (PCA) and Pentagon asset analysis. A multinomial logistic regression model was then used to investigate the relationship between livelihood assets and livelihood diversification. Results showed that the Trisik coastal community excelled in human and financial capital, while the Parangtritis community demonstrated stronger social capital. The main determinants of livelihood diversification were human, physical, and financial capital. The gender of the household head, education level, location, and income level significantly influenced livelihood diversification choices. Location-specific interventions are needed to strengthen livelihood assets and support sustainable livelihoods.

Introduction

A livelihood comprises individuals, their capacities, and their resources, including food, income, and assets (Chambers & Conway, 1992). According to Ellis (1998), the term "livelihood" encompasses a range of factors, such as income, social institutions (including kinship, family, community, gender, and property rights), and the necessary support structures to maintain living standards. The sustainability of livelihoods rests on five principal assets: Human, natural, social, physical, and financial capital (Department for International Development, 2001; Adger, 2006; Scoones, 2009; Morse & McNamara, 2013). A livelihood strategy is crucial for achieving sustainable development (Department for International Development, 2001; Biggs *et al*., 2015; Ismail *et al*., 2023). Nevertheless, research on the link between asset ownership and sustainable livelihood outcomes remains limited (Sibarani & Somboonsuke, 2024).

A key element of the livelihoods approach is poverty alleviation (Scoones, 1998; Department for International Development, 2001), which aligns with the Sustainable Development Goals (SDGs) mandate (United Nations, 2022). The Sustainable Livelihoods Approach (SLA) is a framework used to analyse and improve the lives of poor and marginalised communities.

This collaborative approach is based on the understanding that every individual possesses assets and competencies that can be enhanced to improve their living standards (Ismail *et al*., 2023). Some scholars argue that the SLA capital framework provides a more nuanced understanding of social interactions and their resulting benefits (Morse & McNamara, 2013).

Livelihood diversification is a core element of livelihood strategies, which are typically classified into intensification, extensification, diversification, and migration (Chambers & Conway, 1992; Scoones, 1998; Department for International Development, 2001; Morse & McNamara, 2013). Household livelihoods are inherently dynamic, shifting in response to multiple factors. These include short-term fluctuations such as shifts in crop prices, pest infestations, floods, and pandemics. Long-term transformations, such as structural economic changes and population ageing, also shape livelihoods. Climate change is an increasingly significant driver of livelihood change (Natarajan *et al*., 2022). Diversification views income diversity as an active social process in which households progressively engage in more complex portfolios of activities over time. In contrast, income diversity refers to the composition of household income at a single point in time (Ellis, 1998).

Poverty and the environment are interconnected phenomena, making ongoing discussions about poverty and environmental management practically inevitable (Gai *et al*., 2018). Integrated Coastal Management (ICM) is a conceptual framework that acknowledges the underlying circumstances perpetuating poverty among coastal communities. Consequently, coastal poverty persists, and sustainability remains difficult to achieve within the ICM approach. ICM offers a conceptual and practical bridge between the rhetoric of poverty alleviation and the practical challenges of achieving sustainable coastal livelihoods (Glavovic, 2006). Coastal areas are increasingly vulnerable to climate change (Nath *et al*., 2020), and development processes further influence the vulnerability of coastal communities (Ellis, 1998). This is exemplified by two coastal communities in Fiji, each affected differently by modernisation processes (Chambers & Conway, 1992; Becker, 2017). Therefore, coastal people adapt by developing livelihood strategies.

Indonesia is an archipelago comprising 12,000 inhabited islands, with a total of 17,504 islands and 95,181 km of coastline. Notably, approximately 65% of Indonesia's population resides in coastal areas (Nurzaman *et al*., 2020). The country is characterised by its vast geography, rich socio-cultural diversity (Siry, 2007; Sukardjo & Pratiwi, 2015), extensive marine biodiversity, and strong socio-cultural plurality (Baiquni, 2021). Coastal communities primarily depend on local natural resources for their livelihoods (Islam *et al*., 2016). In 2021, 212 Indonesian cities experienced extreme poverty, with 69.34% (147 cities) located in coastal areas (Kementerian Komunikasi dan Informatika Republik Indonesia, 2021). The province of Yogyakarta, with a coastline extending 133 kilometres, has a significantly higher poverty rate in its three coastal districts compared to inland districts (BPS DI Yogyakarta, 2022).

This study investigates the relationship between livelihood assets and strategies of coastal communities using multinomial logistic regression. Prior to this analysis, livelihood assets were measured using Principal Component Analysis (PCA) and Pentagon Asset Analysis. The sustainable livelihoods perspective provides an appropriate analytical lens to examine how livelihood assets can reduce poverty. A Pentagon Asset is a visual representation of individual livelihood assets (Department for International Development, 2001). Managing economic and environmental shocks and alleviating rural poverty in developing nations requires diversified livelihood strategies (Habib *et al*., 2023).

Despite a considerable body of research on the relationship between livelihood capitals and diversification (Hua *et al*., 2017; Habib *et al*., 2023), research on coastal regions remains scarce. Coastal areas exhibit different

typologies and characteristics, classified by their origin of formation. These typologies are broadly classified as primary and secondary coasts (Shepard, 1973). In Yogyakarta, coastal typologies include structurally shaped, wave erosion, marine deposition, land erosion, sub-aerial deposition, aeolian, and anthropogenic coasts (Marfai *et al*., 2013; Santosa, 2015; Suryani, 2020). The environment can significantly affect human activities, and vice versa (Dorrell & Henderson, 2018). Research on human-environment interrelationships across a range of geographical dimensions is increasingly important (Pallathadka & Pallathadka, 2021).

This study's focus on livelihood diversification across diverse coastal typologies is a distinctive contribution. However, local-level data availability in developing countries is severely limited. The present study uses primary data collected through questionnaires to examine coastal communities. Moreover, this research addresses a gap by examining the relationship between gender and livelihood diversification (Habib *et al*., 2023).

Materials and Methods

Study Area

Trisik, Parangtritis, and Baron are the three coastal areas in Yogyakarta Province that were purposefully chosen for this study (Figure 1). The geographic locations of the research areas are depicted in Table 1. These three coastal areas have been well-known recreational destinations since the 1990s. In addition to tourism, local community livelihoods also include agriculture and fisheries. However, the study sites are situated in rural settings across three districts with high poverty rates in Yogyakarta.

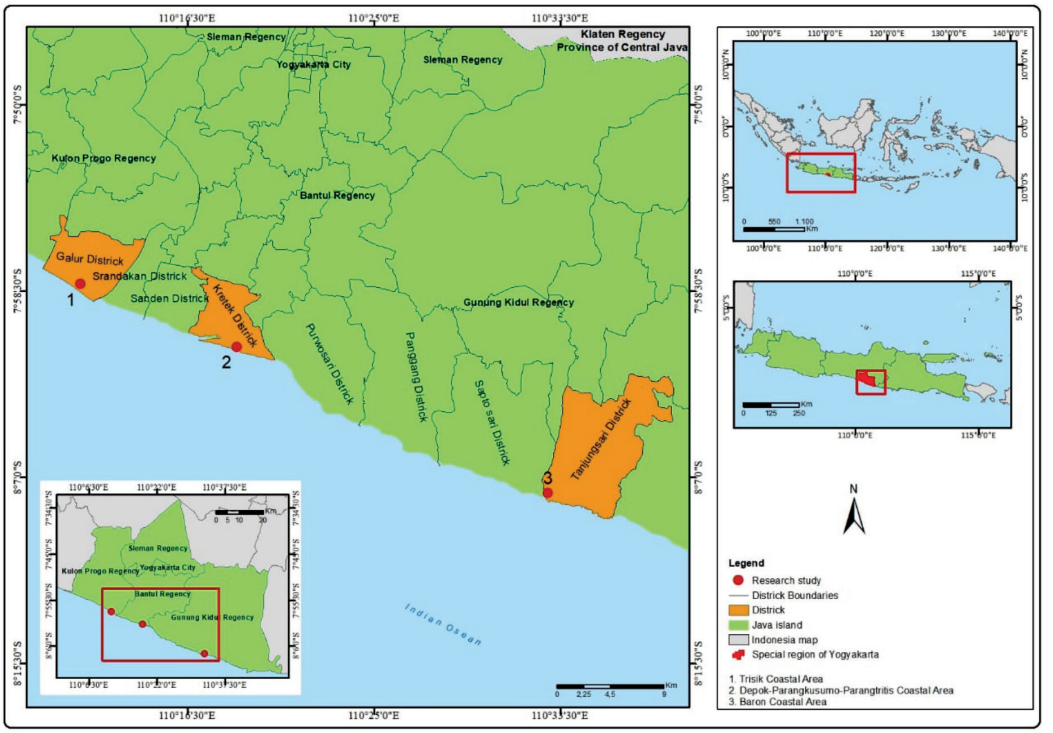

Figure 1: Map of the study area

Table 1: Geographic location, coverage, and coastline of research areas

Research Areas	Geographic Location	Hectares	Coastline (Km)
Trisik	110° 10' 44.769" - 110° 12' 23.890" E 7° 57' 37.608" - 7° 58' 55.461" S	466.95	2.60
Parangtritis	110° 17' 8.877" - 110° 20' 29.673" E 8° 1' 57.314" - 8° 0' 27.174" S	494.98	6.61
Baron	110° 32' 46.142" - 110° 33' 6.923" E 8° 7' 29.081" - 8° 7' 56.957" S	6.45	0.235

Data Collection

Table 2 shows the study population, consisting of coastal households that rely primarily on natural resources. The total population across the three study areas was 2,598 coastal households. Data were collected from 283 coastal households through a survey conducted between October 2023 and January 2024. The sample size was determined using the Slovin formula (Equation 1). The sample size (n) was calculated by dividing the population size (N) by 1 plus N multiplied by the square of the margin of error (e^2). This study employed a 10% margin of error to reduce time, cost, and effort. The Slovin formula is as follows:

$$n = \frac{N}{1 + Ne^2} \quad (1)$$

where n is the minimal sample size, N represents the population, and e is the margin of error (0.1).

In addition, 10% of the sample size was added to account for potential nonresponse or unreachable households. Stratified random sampling was used to determine the number of samples for each study site. This technique ensured that the selected samples were representative of the population. Every household had an equal chance of selection, as respondents in each category were chosen randomly (Babbie, 2013; Creswell, 2014). Figure 2 depicts the distribution map of respondents.

Primary data were gathered through a survey questionnaire. This study used a semi-structured questionnaire to capture respondents' information. A questionnaire is a specifically designed tool with multiple questions to elicit data for analysis (Babbie, 2013). Survey design provides a strategy to quantitatively describe trends, behaviours, or opinions within a population (Creswell, 2014).

Livelihood Assets Measurement

Livelihood assets, including human, social, physical, financial, and natural assets, were quantified, as they play a significant role in shaping households' selection of different livelihood strategies. To assess these assets, two processes were undertaken. The following steps outline the assessment process.

Table 2: Total population and sample of the study areas

Location	Occupation	Population (HH)	Sample (HH)
Trisik	farmer, fishermen, seller, aquaculture, tourism	280	81
Parangtritis	tourism, farmer, food seller, livestock, fishermen	1,495	104
Baron	tourism, seller, fishermen, lobster fishers	827	98
Total		**2,598**	**283**

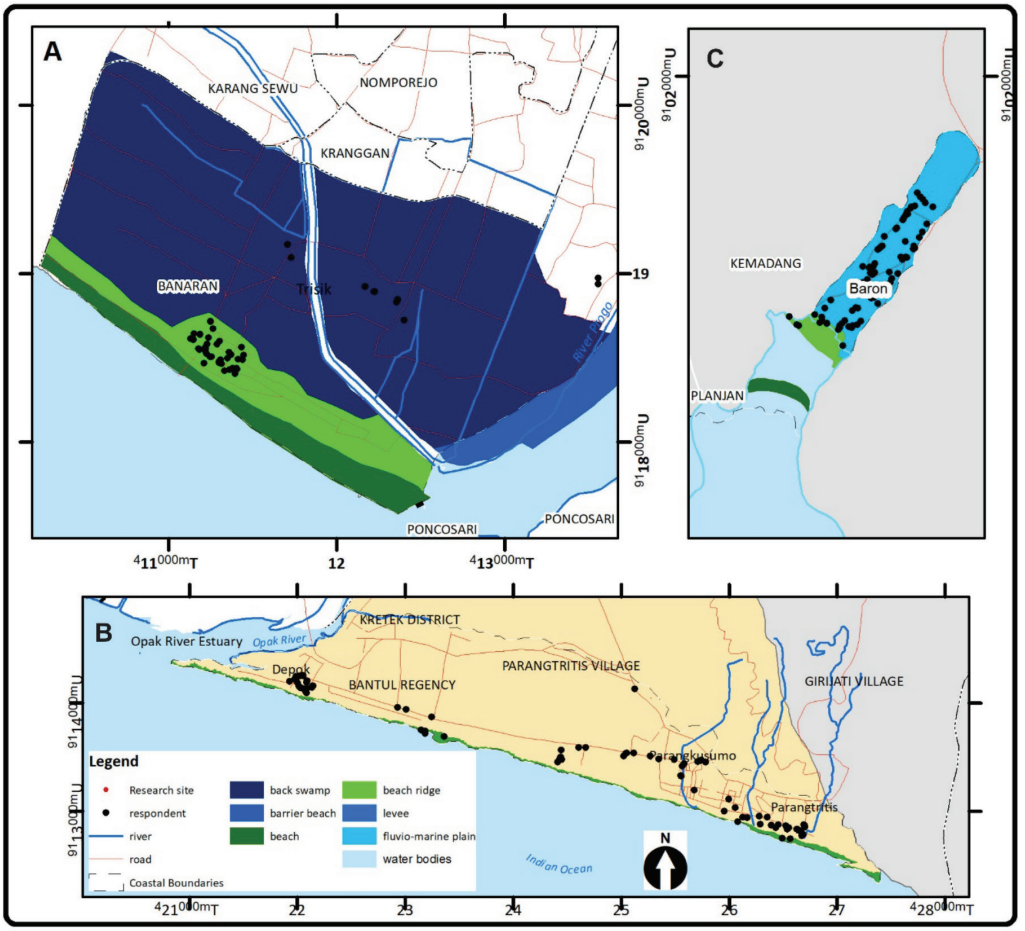

Figure 2: Map of the distribution of respondents in Trisik (A), Parangtritis (B), and Baron (C)

Step 1: Determining relevant proxy variables

The proxy variables for each asset were identified based on definitions, literature analysis, and the socio-economic characteristics of the study area. A total of 20 variables were considered to describe the characteristics of the five livelihood assets, as shown in Table 3.

Step 2: Principal Component Method

Factor analysis using the principal component approach was employed to estimate each livelihood asset independently from observable factors. The changing conditions of each livelihood asset may be independent or interrelated. By producing a single indicator, the Principal Component Analysis (PCA) technique effectively captures circumstances with significant fluctuations.

PCA is a reliable statistical method for reducing complex data sets to a manageable size by identifying the key components that account for the most significant data (DelSole & Tippett, 2022). It involves transforming the original variables into a new collection of principal components—a set of uncorrelated variables ranked by their contribution to overall variance (Soto-Quiros & Torokhti, 2021). PCA has been shown to rely more strongly on internal factors compared to the Analytical Hierarchy Process (AHP) and simple equal-weighting methods (Ghosh and Mistri, 2021). Unlike AHP, which

Table 3: Key research variables in livelihood asset analysis

Capitals	Variables	Source
Human capital	• Education: Proportion of household members with at least junior high school education • Skills: At least one household member possesses a skill • Training: At least one household member has received formal training • Disability: Presence of at least one household member with a disability • Health: Proportion of household members in good health • Labour: Proportion of household members engaged in work	Department for International Development, (2001); Hua *et al*., (2017); Gai *et al*., (2018); Xu *et al*., (2023); Sibarani and Somboonsuke, (2024); Pujiwati *et al*., (2024)
Natural capital	• Land: Extent of land use in coastal areas • Water: Access to water resources in coastal areas • Natural resources: Use of coastal natural resources	Department for International Development, (2001); Hua *et al*., (2017); Gai *et al*., (2018); Xu *et al*., (2023); Sibarani and Somboonsuke, (2024)
Social capital	• Networking: Proportion of household members engaged in networking or social media use • Organisation: Involvement in community-based social organisations • *Gotong royong**: Participation in mutual cooperation activities (*gotong royong)*	Department for International Development, (2001); Hua *et al*., (2017); Gai *et al*., (2018); Xu *et al*., (2023); Sibarani and Somboonsuke, (2024)
Physical capital	• Internet: Proportion of household members using the internet • Work tools: Household ownership of tools and facilities for work • Motorbikes: Household ownership of motorbikes and related facilities • Cars: Household ownership of cars and related facilities	Department for International Development, (2001); Hua *et al*., (2017); Gai *et al*., (2018); Xu *et al*., (2023)
Financial capital	• Savings: Proportion of household members with a savings account • Loans: Percentage of household members with access to credit or loan • Belongings: Total number of property types owned by households (gold, boats, motorboats, livestock, and land) • Health insurance: At least one household member with health insurance	Department for International Development, (2001); Hua *et al*., (2017); Gai *et al*., (2018); Xu *et al*., (2023); Sibarani and Somboonsuke, (2024)

**Gotong royong is collective activities in the community*

applies unequal weighting, PCA does not require expert judgment. Consequently, the PCA values depend solely on the inherent data patterns.

(a) Livelihood Diversification Measurement

To categorise households by livelihood diversification, we classified them into four groups (Table 4) based on Ellis's (1998) criteria. The four groups were: farm, off-farm, non-farm wage, and non-farm non-wage. A farm household is defined as one in which the head is engaged in business activities within the agricultural sector. Off-farm households are those employed in other sectors of the agricultural economy and receiving wages. In non-farm wage households, the head works in non-agricultural sectors and receives wages. In contrast, the head of a non-farm non-wage household is self-employed in a non-agricultural sector. In this study, the term "agricultural sector" encompasses a range of

activities, including agriculture, horticulture, plantations, fisheries, livestock, and forestry.

(b) Determinants of Livelihood Diversification

Multinomial logistic regression was employed to conduct discrete choice modelling on the chosen livelihood diversification in order to determine the factors influencing the strategy based on livelihood assets.

In response to the multinomial logistic regression model,

$$p_{ij} = \frac{\exp(x_i'\beta_j)}{\sum_{i=1}^{m}\exp(x_i'\beta_i)}, j = 1, \ldots, m, \quad (2)$$

where x_i' represents case-specific regressors, which are a vector of observed livelihood assets that influence livelihood strategies. This model guarantees that $0 < pij < 1$. For model identification, one of the categories β_i was set to zero, and the coefficients were subsequently interpreted relative to this base category (Cameron & Trivedi, 2009). Additionally, this study compared three coastal locations in Yogyakarta using a comparative case study approach. This analysis identified both the distinct characteristics of each area and their shared features (Corbetta, 2003).

Results and Discussion

Characteristics of The Respondent

The survey analysis utilised data from household heads. A "household head" was defined as the primary economic provider of the family. Table 4 displays the characteristics of the respondents. Female household heads accounted for less than 10% of the sample, while the majority (61.13%) were aged 40 years to 50 years. Nearly one-quarter of households were headed

Table 4: Characteristics of respondents

Description	Frequency	Percentage
Sex		
Male	256	90.46
Female	27	9.54
Age of respondents		
20-39	40	14.13
40-50	173	61.13
> 60	70	24.73
Education		
Primary school	102	36.04
Junior high school	80	28.27
High school	69	24.38
Higher education (university)	2	0.71
Did not complete primary school	30	10.60
Income (rupiah)		
< 500,000	8	2.83
500,000-1,000,000	60	21.2
1,000,000-1,500,000	71	25.09
1,500,000-2,000,000	49	17.31
2,000,000-2,500,000	33	11.66
2,500,000-3,000,000	17	6.01
> 3,000,000	45	15.9

by individuals over 60 years old. Educational attainment was relatively low, with over one-third of household heads having completed only primary education.

In Trisik and Baron, most respondents engaged in agricultural activities, representing 21.91% and 13.78% of the total sample, respectively. In Parangtritis, the majority of respondents worked in non-farm wage activities, accounting for 15.19% of the sample. Overall, 41.34% of households participated in agricultural activities. The survey results indicated that 60.07% of households earned IDR 1–3 million per capita, 24.03% earned below IDR 1 million, and 15.9% earned above IDR 3 million.

In summary, respondents were predominantly male and mostly aged between 40 and 60 years. Most had low educational attainment and reported per capita incomes below IDR 1.5 million.

Livelihood Assets

The survey revealed average livelihood capital scores of -0.89 for Trisik, 0.63 for Parangtritis, and -0.07 for Baron. Figure 3A shows that Trisik excelled in human capital (0.519) and financial capital (0.624), while Parangtritis stood out in social capital (0.574). Parangtritis demonstrates strong capacity in leveraging social capital due to its higher networking scores compared to the other two areas.

Networking is an important factor in strengthening social capital, as reflected in the proportion of household members who use social media. Social media play a significant role in expanding networks and facilitating communication, thereby supporting economic and social activities. Meanwhile, Baron's five capital elements remain relatively average compared with the other two areas. Figure 3B depicts the livelihood assets of each household category. The farm category showed the highest human and financial capital (0.308), while the off-farm category had the highest natural capital (0.139). Non-farm non-wage activities exhibited high social and physical capital (0.382 and 0.220, respectively). Conversely, non-farm wage activities displayed moderate performance across all five livelihood assets in comparison to the other household livelihood categories.

The primary distinction among the three coastal areas is that most Trisik residents are farmers, while most residents of Parangtritis and Baron engage in tourism. All three areas are also known for fisheries, with many restaurants offering diverse fish dishes. Additionally, all three areas host regular fish auctions. Fishermen utilise outboard motorboats of approximately five gross tonnes, operating at sea from morning until noon. Along the coast of Parangtritis and Trisik, some fishermen use shoreline nets to catch fish.

Parangtritis demonstrates the highest overall score in livelihood capital, attributable to its robust social capital, characterised by extensive networking. Trisik exhibits excellence in human and financial capital, while Baron maintains an average performance across the three capital categories. The livelihood disparities among these regions are shaped by Trisik's agricultural dominance and the tourism-oriented economies of Parangtritis and Baron, alongside their shared reliance on fishing.

Table 5: Household livelihood category

Coastal	Sample Households	Household Livelihood Category			
		Farm	Off-Farm	Non-Farm Wage	Non-Farm Non-Wage
Trisik	81	62	1	13	5
Parangtritis	104	16	10	43	35
Baron	98	39	17	20	22
Total	**283**	**117**	**28**	**76**	**62**

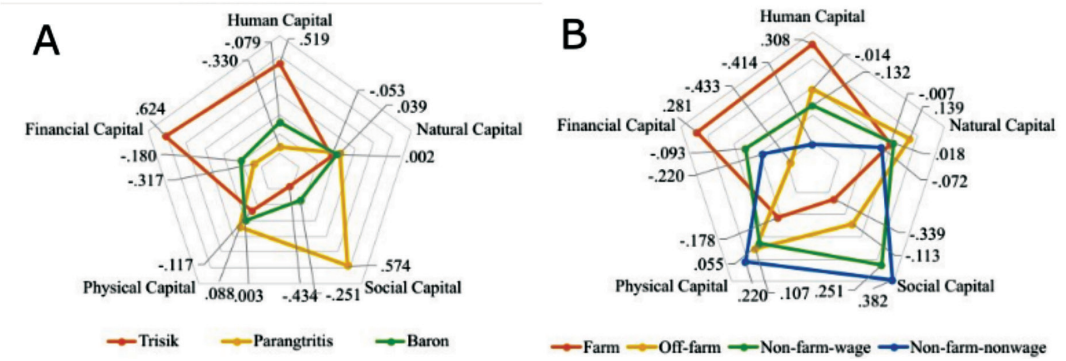

Figure 3: Pentagon assets of three coastal areas in Yogyakarta (A); Pentagon assets based on household livelihood category (B)

Human Capital

The Trisik coastal community excels in human capital compared to Baron and Parangtritis. This is due to Trisik's higher levels of education, skills, training, and health. It has a higher education level and fewer individuals with disabilities than Baron. The high level of human capital in Trisik is supported by strong skills, good health status, and other attributes, which remain comparable to those in the other two coastal areas. The majority of coastal communities are engaged in horticultural farming, receiving training from both government agencies and private companies related to agriculture.

All respondents reported possessing the requisite skills, and 70.37% had received agricultural training. This farming knowledge is rapidly disseminated to other farmers through their membership in agricultural groups. Additionally, the average health rating in Trisik is exceptionally high, at 93.948. The Trisik coastal area remains largely pristine and tranquil, free from crowding and pollution.

Baron and Parangtritis coastal communities also possess a range of competencies aligned with their respective business fields. However, training participation remains low in Baron (12.5%) and Parangtritis (13.27%). The relatively low mean health indicator (30.53) undermines the human capital of the Parangtritis community. This low level of health may be attributed to high housing density and a considerable influx of tourists. As a result, Parangtritis is particularly vulnerable to vehicle-related air pollution. Conversely, Baron records the lowest education level, at 16.51%, which contributes to its low human capital score.

Trisik's superiority in human capital stems from its higher education, skills, training participation, and health levels. In contrast, Baron and Parangtritis exhibit deficiencies in these areas due to lower training rates, poorer health in Parangtritis, and lower education levels in Baron.

Natural Capital

Natural capital includes land, water, and other natural resources. The natural capital analysis yielded scores of 0.039, 0.002, and -0.053 for Parangtritis, Baron, and Trisik, respectively. In all three areas, households utilise coastal land under a rent-free system. The Sultan of Yogyakarta owns Parangtritis and Baron, while the Pakualaman Palace owns Trisik. These coastal areas have been used by the local community for generations. Water-use issues in Trisik and Parangtritis were minimal (0.35%). Water is sourced from residents' wells for both daily use and to support their businesses. In Baron, water is sourced from a spring on Baron beach, which is also utilised by several surrounding villages.

In addition to water, coastal communities also utilise a number of other natural resources, including agriculture, fisheries, livestock, and recreational services. Trisik is characterised by a flat and extensive sandy terrain, bordered by a river estuary to the east and a lagoon to the west. Parangtritis is also a wide and flat stretch of sandy beach but exhibits distinctive characteristics, including central sandbanks, western estuaries, and an eastern boundary of steep karst cliffs. In contrast, Baron has a markedly different topography. Located in a karst mountain area, it resembles a bay enclosed by cliffs, with sandy pocket beaches. As can be observed in Table A1, all natural capital indicators were at or near 100%. Thus, the majority of coastal communities depend on coastal resources for their livelihoods.

Coastal communities in Parangtritis, Baron, and Trisik have a strong reliance on coastal resources for their livelihoods. However, their levels of reliance differ. Parangtritis demonstrates the highest dependence on natural capital, while Trisik exhibits the lowest, indicating differences in topography and resource utilisation despite comparable access to land, water, and natural assets.

Social Capital

Social capital in this study encompasses several indicators, including the use of social media for networking. Another indicator is the degree of involvement in political, social, religious, or communal organisations. Participation in collective community action, or *gotong royong* in Indonesia, is also included. The social capital of the Parangtritis coastal community is markedly higher than that of Trisik and Baron, with respective scores of 0.574, 0.251, and -0.434.

Parangtritis exhibits the highest average networking score (26.131) but the lowest rates of organisational participation and *gotong royong*. Participation levels in Trisik and Baron are notably high, with 95% of Baron residents and all Trisik residents engaging in organisational activities and mutual cooperation. Nevertheless, networking scores are lower: 24.83 in Baron and 18.954 in Trisik. This indicates that the high social capital score mainly reflects strong networking. In conclusion, Parangtritis records the highest social capital score, driven primarily by social media networking, while Trisik and Baron demonstrate stronger community participation but weaker networking.

Physical Capital

Physical capital was measured using internet utilisation as a proxy for telecommunications infrastructure and ownership of motorised vehicles used for transport and work. Parangtritis exhibits a physical capital score of 0.088, while Baron records 0.003. In contrast, Trisik exhibits the lowest physical capital score at -0.117.

Table A1 shows that mean internet use is highest in Parangtritis (72.618), followed by Baron (68.87) and Trisik (66.947). Ownership of work tools and transport (motorbikes, cars) is highest in Trisik, followed by Baron. Production equipment is diverse, including hoes, water pumps for agriculture, and fishing gear. Tourism-oriented facilities are also present, including jeep rentals. These results indicate that the internet strongly influences the construction of the physical capital score. This aligns with the view that networking is a crucial element of social capital. Today, the internet and social media are pivotal in daily life. In summary, Parangtritis ranks highest in physical capital, driven by higher internet use. Conversely, Trisik ranks lowest despite leading in vehicle and work-equipment ownership. This outcome reflects the high weight assigned to telecommunications infrastructure in the physical capital measure.

Financial Capital

Trisik's financial capital is notably higher than that of Baron and Parangtritis, with scores of 0.624, −0.180, and −0.317, respectively. In this study, financial capital includes health insurance, loans or credit, savings, and the variety of goods owned. The analysis shows that average savings in Trisik are significantly higher than in Parangtritis and Baron. Average savings in Trisik

are 59,925—about twice those in Parangtritis and three times those in Baron. Similarly, access to credit is highest in Trisik. Households utilise various credit facilities, including the People's Business Credit (*Kredit Usaha Rakyat*, or KUR), Rural Banks (*Bank Perkreditan Rakyat*, or BPR), pawnbrokers, leasing, Joint Business Groups (*Kelompok Usaha Bersama*, or KUBE), and Village-Owned Enterprises (*Badan Usaha Milik Desa*, or BUMDES).

Additionally, valuable assets, including gold, livestock, boats, motorboats, and land situated outside the coastal area, are highly concentrated in Trisik. Trisik households show higher asset ownership: 50.62% own two assets, compared with 37.76% in Baron, while 44.23% of Parangtritis households own only one asset. These three factors (savings, credit access, asset ownership) drive Trisik's high financial capital. Trisik is characterised by advanced horticultural practices, yielding substantial profits for farmers.

A comparative analysis of the economic indicators among the three coastal communities reveals that Trisik's community has considerably higher financial capital than those of Baron and Parangtritis. This higher financial capital reflects greater savings, wider credit access, and stronger asset ownership. Profitable horticultural activities further support these factors, strengthening financial resilience and economic vitality.

Relationship Between Livelihood Assets and Livelihood Diversification

Following the measurement of the livelihood asset index, an analysis was conducted to investigate the relationship between livelihood assets and factors influencing livelihood diversification. The multinomial logistic regression used farm households as the base livelihood category and Trisik as the reference location. Table 6 shows that human and financial capital are inversely related to the propensity of households to adopt the three livelihood categories relative to farm households (significance level 5%). Thus, the likelihood of households adopting off-farm, non-farm wage, and non-farm non-wage activities decreases as human and financial capital increase.

Physical capital, on the other hand, is positively associated: A one-unit increase in physical capital raises the odds of adopting off-farm activities by a factor of 2.5 (significant at 5%). Gender has a significant positive impact on non-farm strategies ($\alpha = 5\%$ for non-farm wage; and $\alpha = 1\%$ for non-farm non-wage). Female-headed households are 20.93 times more likely than male-headed households to choose non-farm wage livelihoods. Female-headed households are 175.33 times more likely than male-headed households to choose non-farm non-wage activities.

Education has a significant and positive effect on the choice of livelihood. As the level of education of the household head increases, so does the tendency to adopt a non-farm wage strategy. Household heads with a high school education are seven times more likely to adopt a non-farm non-wage livelihood ($\alpha = 5\%$) compared with those with lower education levels. Location also positively and significantly influences the adoption of alternative livelihood categories relative to Trisik, except in Baron. Income is strongly positively associated with households' inclination to pursue alternative livelihood categories. Compared to households earning below the minimum wage, those earning above it are more likely to adopt off-farm and non-farm non-wage strategies.

The adoption of off-farm or non-farm strategies is significantly influenced by several factors, including physical capital, female household headship, higher education, advantageous location, and income above the minimum wage. Together, these factors substantially increase the odds of adopting off-farm or non-farm strategies. However, higher human and financial capital has been shown to reduce this diversification. Gender exerts the strongest effect: Female-headed households are up to 175 times more likely to engage in non-farm non-wage work ($\alpha = 1\%$) compared with male-headed households.

Table 6: Multinomial logistic regression model analysis result (relative to farm)

Livelihood strategy	Off-farm		Non-farm-wage		Non-farm-nonwage	
	RRR	P > |z|	RRR	P > |z|	RRR	P > |z|
Livelihood Assets						
Human Capital	1.02337	0.967	0.34768	0.005***	0.383878	0.024**
Natural Capital	1.09224	0.737	0.96184	0.875	0.896381	0.671
Social Capital	0.88742	0.792	1.66808	0.132	1.762381	0.117
Physical Capital	2.53098	0.043**	1.55371	0.245	1.401787	0.412
Financial Capital	0.24251	0.002***	0.69740	0.245	0.483481	0.047**
Sex						
Male (reference) Female	0.00002	0.987	20.93748	0.021**	175.335700	0.000***
Education						
Early education (reference)						
Elementary	0.50409	0.478	4.24946	0.142	2.109983	0.428
Junior high school	1.00063	0.999	7.21937	0.047**	2.746347	0.291
High school	1.51648	0.697	20.35769	0.003***	7.099750	0.051*
Higher education/ university	0.00001	0.989	36.04127	0.044**	0.000055	0.989
Location						
Trisik (reference)						
Parangtritis	17.62145	0.019**	3.95035	0.020**	8.825165	0.006***
Baron	15.14117	0.019**	1.51443	0.440	3.556732	0.087*
Income Level						
Below regional minimum wage (reference)						
Above regional minimum wage	1.41637	0.028**	1.19024	0.148	1.326011	0.043**
Constant	0.00750	0.001**	0.03059	0.001***	0.012352	0.000***

Note: Significant levels at 1%, 5%, and 10% are denoted by ***, **, and * respectively

This research offers several distinct contributions, including advancing understanding of the relationship between livelihood assets and livelihood diversification in coastal areas. A further contribution is the examination of gender as a determinant of livelihood diversification, a factor that remains under-researched (Habib *et al*., 2023). The findings indicate that the various coastal regions differ in their capabilities to sustain livelihoods, as represented by the pentagon asset profiles. In the pentagon representation, the centre indicates zero asset access, whereas the outer perimeter indicates maximum asset access (Sibarani & Somboonsuke, 2024). Furthermore, this research compared the livelihood assets of coastal communities located in different districts. This study analysed the relationship between different forms of livelihood assets and the process of livelihood diversification. We refer to such

assets as sustainable livelihood capital: They help households attain sustainable livelihoods and influence fundamental livelihood strategy decisions (Guo *et al*., 2022).

The findings of this study highlight several key points, including the fact that each coastal area possesses distinctive livelihood capital advantages. Trisik is distinguished by strong human and financial capital, while Parangtritis demonstrates the highest social and physical capital. In contrast, Baron records the lowest scores, occupying middling-to-low positions across all five capitals (human, natural, social, physical, and financial capital). These findings support the assertion that households' geographical location is a significant external factor influencing the choice of livelihood strategies (Hoq *et al*., 2022). Additionally, changes in livelihoods alter the size, composition, and design of land use in rural settlements, which in turn drive land use change for residential purposes (Ma *et al*., 2018).

This study finds a negative correlation between human capital and livelihood diversification. Additionally, it also finds an inverse relationship between financial capital and livelihood diversification. These results contrast with Gai (2018), who found that high human capital is associated with increased productivity. Similarly, Yan (2010) found a strong correlation between human capital and livelihood diversification. Households with adequate labour are able to engage in a more diverse range of livelihood activities. Differences between this study and others may stem from training and skill improvements provided by the government and the private sector. These initiatives have enhanced the capacity of the farming community in the coastal area, enabling them to pursue more advanced agricultural businesses. Trisik, for instance, has become a prominent horticultural production area that supplies domestic markets. Furthermore, increased financial capital has prompted investment in farming productivity.

The capacity to save allows farmers to fund their farming activities without having to rely on external sources, such as bank loans or other forms of debt. This increases their financial security, as they are no longer dependent on external sources of capital. Livestock constitute a capital asset that can, in certain circumstances, be sold to generate cash flow (Sibarani & Somboonsuke, 2024). Access to financial resources enables residents to adopt economically viable livelihood options that require significant financial investments, such as purchasing motorbikes for transport services (Nath *et al*., 2020). This finding contrasts with Hua *et al*., (2017), who indicated that increased human and financial capital facilitate the pursuit of non-agricultural livelihood strategies.

The results of this study corroborate previous research, indicating that higher education facilitates the adoption of livelihood strategies with higher expected returns (Aazami & Shanazi, 2020; Albasri & Sammut, 2022; Hoq *et al*., 2022). Household education levels significantly influence livelihood strategies, enabling the exploitation of economic opportunities and the pursuit of more diverse options (Yan *et al*., 2010). In Indonesia, interest in agricultural professions declines as education levels rise. The likelihood of engaging in non-farm income-generating activities increases with higher education, including post-secondary education. Formal education has the potential to influence an individual's behaviour or creativity, which may subsequently lead to their involvement in more intensive and modern livelihood activities (Ellis, 1998; Department for International Development, 2001; Albasri & Sammut, 2022).

Physical capital provides the opportunity to engage in work as a farm labourer. This is facilitated by ownership of work tools and means of transport, as well as by the rapid exchange of information via the internet. It is notable that each household owns at least one motorbike, with some owning multiple motorbikes. Consequently, those seeking employment on a daily basis can readily access job-related information and travel to their place of work. Gender significantly influences

livelihood diversification. Field evidence shows that a significant proportion of women are engaged in economic activities in these three coastal areas. Most of these women are involved in trade activities, selling a range of products including food, souvenirs, and snacks, as well as retail items such as daily necessities.

Income levels support livelihood diversification. This is consistent with Dai *et al*., (2020), who found that higher income groups exhibit greater livelihood diversification. In this study, higher income enables households to develop larger businesses, particularly non-agricultural enterprises. Non-agricultural activities complement agriculture as the main livelihood. Parangtritis and Baron are among Yogyakarta's most visited tourist destinations. Data from the Yogyakarta Tourism Office show that from 2016 to 2020, the number of visitors exceeded one million tourists per year at each beach of Parangtritis and Baron. Hence, there are more non-agricultural business opportunities.

In relation to poverty alleviation, exploring livelihood strategies includes identifying alternative and increasingly actionable options to improve the livelihood prospects of the poor. Livelihood outcomes are the goals pursued by individuals through their chosen strategies and, in many cases, can be considered the opposite concept to that of poverty (Department for International Development, 2001). The ongoing debate around poverty is closely linked to the issue of environmental management, as poverty and the environment are two important phenomena that must be addressed together as one (Gai *et al*., 2018). Accordingly, we recommend tailoring poverty alleviation policies to the regional environmental context at the local level.

However, some issues remain. This study did not account for temporal variability. Natural and anthropogenic forces alter the biophysical characteristics of landscapes, producing temporal dynamics. It is recommended that future research examine the influence of temporal variation on the livelihoods of coastal communities exposed to a range of natural phenomena and development processes. The findings of this study have policy implications for sustainable coastal livelihoods. In particular, policies should increase access to livelihood assets tailored to specific regional contexts. Moreover, coastal management should prioritise women's empowerment. It is recommended to implement policies to enhance women's capabilities, particularly in terms of personal capacity, given that a significant proportion of women in coastal areas contribute to household income.

Conclusions

This study examined livelihood diversification in Yogyakarta's coastal communities using Pentagon asset analysis and multinomial logistic regression. Results showed that Trisik excelled in human and financial capital, while Parangtritis was stronger in social capital. Additionally, gender, income level, location, and education significantly influenced livelihood diversification choices. This study highlights that (i) each coastal area, with its different characteristics, has varying strengths across livelihood assets; and (ii) gender and per capita income significantly increase the likelihood of adopting alternative livelihood strategies. The findings emphasise the need for poverty alleviation policies tailored to local strengths, focusing on building livelihood assets through interventions such as capacity building, infrastructure development, and access to credit. The study contributes to the Sustainable Livelihoods Approach and supports Integrated Coastal Management by promoting inclusive, resilient, and sustainable coastal development.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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Appendix

Appendix 1: Livelihood assets analysis of 3 coastal areas in Yogyakarta

Variable		Location													
		Trisik			Parangtritis			Baron			Total				
		Mean	Count	%	Mean	Count	%	Mean	Count	%	Mean	Count	%		
Human Capital				**0.519**			**-0.330**			**-0.079**					
Education				36.040			31.076			16.506			27.451		
Skill	Yes				81	100%		68	65.38%		78	79.59%		227	80.21%
	No				0	0.00%		36	34.62%		20	20.41%		56	19.79%
Training	Yes				57	70.37%		13	12.50%		13	13.27%		83	29.33%
	No				24	29.63%		91	87.50%		85	86.73%		200	70.67%
Disability	Yes				5	6.17%		1	0.96%		2	2.04%		8	2.83%
	No				76	93.83%		103	99.04%		96	97.96%		275	97.17%
Labour				24.665			35.402			34.519			32.023		
Health				93.948			30.532			92.466			70.130		
Natural Capital				**-0.053**			**0.039**			**0.002**					
Land	Yes				81	100%		104	100.00%		98	100.00%			
Water	Yes, having little problems				0	0.00%		1	0.96%		0	0.00%		1	0.35%
	No problem at all				81	100%		103	99.04%		98	100.00%		282	99.65%
Natural resources	Yes				81	100%		100	96.15%		97	98.98%		278	98.23%
	No				0	0.00%		4	3.85%		1	1.02%		5	1.77%

Social Capital		**-0.434**			**0.574**			**-0.251**					
Networking		18.954			26.131			24.83			23.63		
Organisation	Yes		81	100%		64	61.54%		95	96.94%		240	84.81%
No		0	0.00%		40	38.46%		3	3.06%		43	15.19%	
Gotong royong	Yes		81	100%		61	58.65%		95	96.94%		237	83.75%
No		0	0.00%		43	41.35%		3	3.06%		46	16.25%	
Physical Capital		**-0.117**			**0.088**			**0.003**		0.00%			
Internet		66.947			72.618			68.87			69.70		
Work tools	Yes		81	100%		99	95.19%		95	96.94%		275	97.17%
No		0	0.00%		5	4.81%		3	3.06%		8	2.83%	
Motorbike	Yes		81	100%		97	93.27%		93	94.90%		271	95.76%
No		0	0.00%		7	6.73%		5	5.10%		12	4.24%	
Car	Yes		26	32.10%		12	11.54%		19	19.39%		57	20.14%
No		55	67.90%		92	88.46%		79	80.61%		226	79.86%	
Financial Capital		**0.624**			**-0.317**			**-0.180**		0.00%			
Savings		58.925			28.547			21.18			34.69		
Credits	Yes		45	55.56%		35	33.65%		9	9.18%		89	31.45%
No		36	44.44%		69	66.35%		89	90.82%		194	68.55%	
Belongings	0		2	2.47%		36	34.62%		7	7.14%		45	15.90%
1		29	35.80%		46	44.23%		30	30.61%		105	37.10%	
2													
3		41	50.62%		17	16.35%		37	37.76%		95	33.57%	
4													
5		9	11.11%		3	2.88%		21	21.43%		33	11.66%	
		0	0.00%		2	1.92%		2	2.04%		4	1.41%	
		0	0.00%		0	0.00%		1	1.02%		1	0.35%	
Health insurance	Yes		47	58.02%		68	65.38%		87	88.78%		202	71.38%
No		34	41.98%		36	34.62%		11	11.22%		81	28.62%	