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Evaluation of Mangrove Ecosystem Importance for Local Livelihoods in Different Landscapes: A Case Study of the Hau and Hoang Mai River Estuaries in Nghe An, North-Central Vietnam

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Abstract: Mangrove ecosystems play an important role in local livelihoods in coastal regions of tropical and subtropical countries. However, in recent years, urbanisation changed the income structure of residents near mangroves. Different landscapes provide different job opportunities; thus, analysis of regional landscape patterns is important for understanding income structures. In this study, surveys on the income structure and landscape patterns of the surrounding areas of three mangrove sites were conducted in the Hau and Hoang Mai River estuaries in Nghe An Province, North-Central Vietnam. The results reveal that both natural and socio-economic landscape components affected income structure. The major occupations in the study area were agriculture, including husbandry, sea fishing, and trading. Land morphology and river type were the major factors influencing the income from agriculture, while coastline morphology primarily affected income from sea fishing. Community-based trading was carried out in the study area; thus, the population inside each administrative unit was a significant factor increasing income, while the retail market size in an area had significant negative effects, potentially due to the increasing number of competitors. Our study aimed to evaluate mangrove ecosystem importance for local livelihoods in relation to landscape patterns, and the results contribute to urban planning based on the conservation and sustainable use of mangrove ecosystems.

Keywords: mangrove; ecosystem service; landscape; livelihood; income structure

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1. Introduction

Mangrove ecosystems provide socio-economic benefits, which can be classified into four functions: provisioning, supporting, regulating, and cultural [1]. Among these, provisioning of biota (e.g., fauna and flora) plays an important role in local livelihoods in coastal regions of tropical and subtropical countries [2–6]. Residents near large, rural mangrove forests were reported to be approximately 75–80% dependent on them [7,8]. However, this varies widely among residents; people living relatively far from mangroves are more dependent on offshore fishing [7], and those who possess suitable land for agriculture rely more on crop cultivation [8], resulting in lower dependency on mangrove forests. In addition, economic growth around mangrove forests and technological development changed occupations, especially near urban areas where residents shifted to other occupations, such as aquaculture [9–12] and external wage work [13]. Similarly, the relative economic value of mangrove ecosystems varies widely across regions.

The coastal region of Nghe An Province, North-Central Vietnam, includes some urban areas and mangrove patches in estuaries, rivers, and inland canals. According to local governments, residents near mangrove stands still make a living fishing in mangrove ecosystems, along with various other occupations. Since this region is developing rapidly (e.g., Decision 827/QD-TTg), urban planning based on the conservation and sustainable use of mangrove ecosystems is urgently needed. To successfully develop such plans, the income structures of mangrove-dependent areas and the influence of natural and socio-economic conditions should be clarified.

In Nghe An Province, mangrove patches are widely distributed from the fringes of estuaries to inland canals; thus, the land morphology and economic situation of the surrounding areas are heterogeneous, providing various occupational opportunities to residents. The landscape ecological approach, which is frequently used to understand landscape patterns, is applied for land use planning [14]. In terms of mangrove-related planning, this method is used in many cases [15–18] and could be appropriate for clarifying the relationship between natural and socio-economic landscape components and livelihoods.

We hypothesised that regional landscape patterns influenced job opportunities and the income structure of residents surrounding areas of mangrove ecosystems, and as a result, they affected mangrove ecosystem dependency. Thus, the landscape component was one of the indicators to evaluate mangrove ecosystem importance. The present study aims to elucidate (1) the fishery's catch in mangrove ecosystems and its productivity, (2) the total income, its sources, and its relationship to landscape components in the Hau and Hoang Mai river estuaries of the Nghe An coastal region, North-Central Vietnam, and (3), based on the results of (1) and (2), the ecological services mangrove ecosystems provide for local livelihoods.

2. Materials and Methods

2.1. Study Site

The study area was in the northern part of the Nghe An coastal region and included Hoang Mai town and Quynh Luu district. Herein, a town is characterised by a higher economic level than a district. It was located in the floodplain of the Hoang Mai and Hau rivers, which flow into Tonkin Bay, as well as the Mai Giang River, which flows from North to South, connecting the Hoang Mai and Hau rivers. A sandy beach extended parallel to the Mai Giang River, but rocky cliffs existed in the Hoang Mai and Hau River estuaries (Figure 1). The town of Hoang Mai consists of five urban wards (hereinafter simply referred to as wards) and five suburban communes (hereinafter simply referred to as communes) with a population of 115,295 as of 2019. In comparison, the Quynh Luu district includes one township and thirty-two communes with a population of 278,671 as of 2019 [19].

According to in situ observations, the dominant mangrove species in the study area were *Rhizophora stylosa* and *Avicennia maria*, scattering in the fringes, rivers, and inland canals. Additionally, *Aegiceras corniculatum* partially occurred in fluvial sand bars. Species were identified according to UNEP (2008) [20]. We selected each mangrove stand across the three above-mentioned rivers: *R. stylosa* stand in the inland canal connecting to the Hoang Mai River in the Quynh Di ward, Hoang Mai town, referred to as HM (19°14′36′′ N, 105°43′52′′ E); a mixture of *A. marina* and *A. corniulatum* stands in the Mai Giang River in the Quynh Bang commune, Quynh Luu district, termed MG (19°10′39′′ N, 105°42′30′′ E); *A. marina* stand in the estuary fringe in the Hau River in the Tien Thuy commune, Quynh Luu district, referred to as HA (19°07′05′′ N, 105°43′22′′ E) (Figure 1).

Based on the semi-structured interviews, user groups of the mangrove stands were not much different in their attributes, such as gender ratio, age distribution, education level, and family structure, thus, job selection was not strongly affected by the personal features. HM was the catch site of residents of Phu Loi 1 and 2, the Quynh Di (QD) ward and Village 2, the Quynh Loc (QL) commune. MG and HA were the catch sites of residents of Mai Giang 1 and 2, the Quynh Bang (QB) commune, Son Hai, the Tien Thuy (TT) commune.

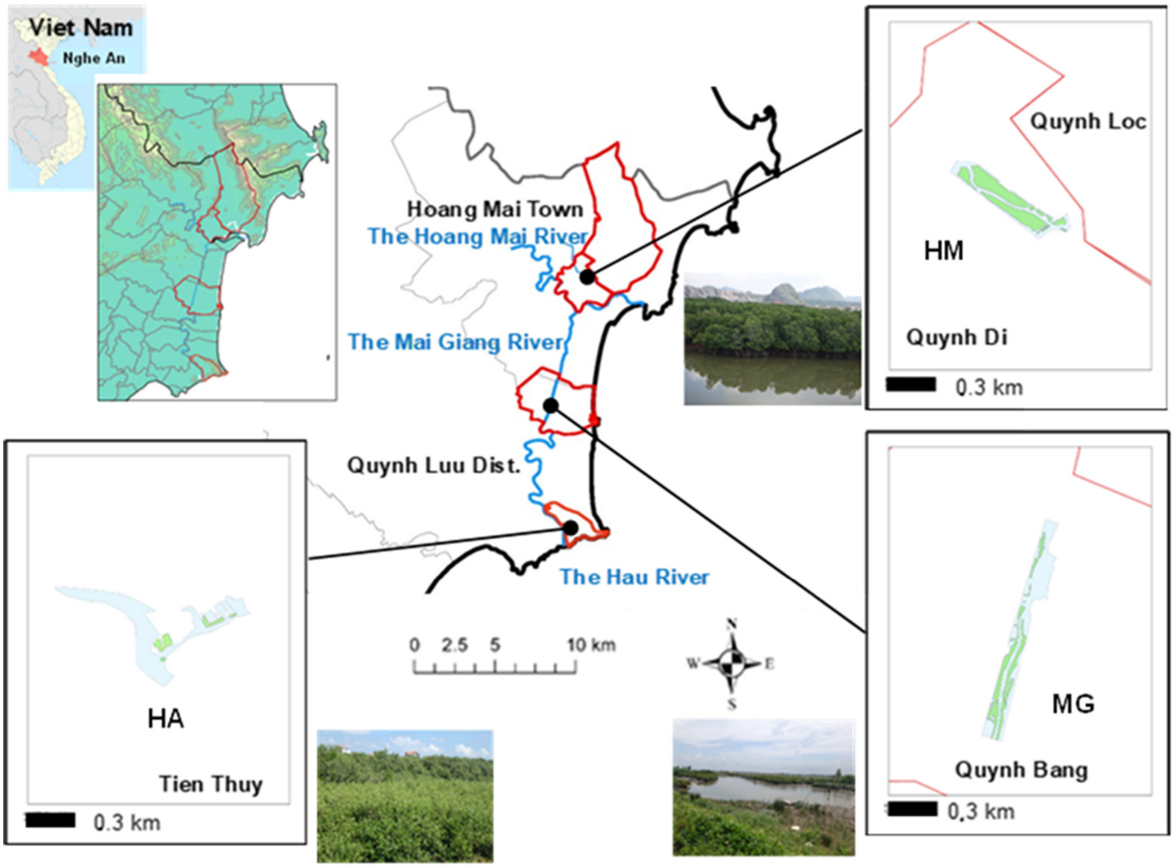

Figure 1. Study area and sites. Green shaded is a mangrove stand. Catch site areas of HM, MG, and HA are 17.8 ha, 27.7 ha, and 9.1 ha measured using Google Earth, respectively.

The region is influenced by the northeast monsoon and characterised by a mean annual temperature of 24.6 °C, with June being the warmest month (30.1 °C) and January the coldest (18.3 °C). Mean annual rainfall is 1753 mm per year, with a minimum mean precipitation in March (48 mm) and maximum mean precipitation in September (445 mm) [21].

2.2. Income, Mangrove Ecosystem Productivity and Catch

Semi-structured interviews of the heads of households living in QD, QL, QB, and TT were conducted by well-trained interviewers, subsequently, structured interviews with questionaries were carried out from 12 to 21 February 2020 and 20 to 25 June 2020. Respondents from 22 out of 22 households, 18 out of 18 households, 71 out of 85 households, and 30 out of 31 households of QD, QL, QB, and TT participated, respectively. The sample size was determined according to Yamane (1967) [22] using Equation (1), with an allowable error (e) of less than 0.05 for each user group.

$$n = N/\left(1 + Ne^2\right) \quad (1)$$

where n is the sample size, N is the total number of households, and e is allowable error (0.05).

The questionnaires included: (1) the mean household income from mangrove ecosystems per month (MIFME) in Vietnamese dong (VND) (rounded to less than five significant digits), (2) the species caught in mangroves, (3) the mean income from other sources per month (MIFOS) (rounded to the same significant digits as MIFME), and (4) their income sources, and (5) attributes of respondents, such as gender, age, education, and household size. Subsequently, we used the data on income and catch sites (Figure 1) to estimate the productivity of mangrove ecosystems.

Catch species were identified by referring to RIMF (2009) for bivalves [23], Rosenberg (2001), Viet and Sakuramoto (2013), and Samphan et al. (2016) for crustaceans [24–26], and Hau and Thuy (2014) for fish [27].

2.3. Landscape Components

Landscape features of the study areas were analysed using Geographical Information System (GIS) software (ArcGIS version 10.8.2, ESRI, Japan, Tokyo) using an overlay of a coastline and provincial borders (obtained from the United Nations Office for the Coordination of Humanitarian Affairs), river and ward/commune borders (obtained from Google Earth), and contour (obtained from the East West Management Institute) maps. Subsequently, location, land, river, and coastline were categorised into estuary or inland, lowland or hills, meandering or straight (including canals), and sandy beach or rocky cliff, respectively, to understand the natural landscape components of QD, QL, QB, and TT.

In terms of socio-economic components, information on the area, population, and location of retail markets of the four communes was obtained. The first two components were taken from the statistical yearbook of Nghe An, Vietnam [19], and the latter was obtained from interviews of local governments combined with in situ observations. Subsequently, the area of retail markets and their distances to the centre (defined as reaching from the ward/commune governmental office to the town/district governmental office) were measured using Google Earth.

2.4. Relationship between Income Structure and Landscape Components

After understanding the income structure of the mangrove stand user groups (i.e., their incomes from different sources) and selecting the major income sources, multiple regression analysis with natural/socio-economic landscape component variables was carried out to determine which landscape components affected the income structure. In the process of obtaining the equations, correlation matrixes among the natural landscape component variables were calculated to select explanatory variables to explain the response variables of the incomes.

3. Results

3.1. Income from Mangrove Ecosystems and Other Sources

The MIFME varied from VND 2,920,000 per month/HH (equivalent to USD 117 per month/HH) in QD to VND 7,2800,000 per month/HH (equivalent to USD 291 per month/HH) in QL, with that of QD being significantly lower than that of the other places ($p < 0.01$). The MIFOS showed a similar tendency, varying from VND 2,720,00 per month/HH (equivalent to USD 109 per month/HH) in QD to VND 7,420,000 per month/HH (equivalent to USD 297 per month/HH) in TT. The MIFOS of QL was not significantly lower than that of TT, but both were significantly higher than those of QB and QD ($p < 0.01$). Lastly, the MIFOS of QB was significantly higher than that of QD ($p < 0.01$). The dependence on mangrove ecosystems ranged from 47.3% in TT to 52.0% in QB (Table 1).

Table 1. Incomes from mangrove ecosystems and other sources. Alphabets next to SE indicate differences ($p < 0.01$). (ANOVA, Tukey–Kramer test). Figures after ± indicates standard error.

Site	MIFME	MIFOS	Mangrove Dependency	Exploiting Duration
	(VND per Month/HH)	(VND pre Month/HH)	(%)	
QD	2,920,000 ± 270,000	2,720,000 ± 270,000	51.8	Jun.–Sep.
QL	7,280,000 ± 120,000	7,310,000 ± 40,000	49.9	Around year
QB	6,720,000 ± 100,000	6,200,000 ± 130,000	52.0	Around year
TT	6,660,000 ± 60,000	7,420,000 ± 30,000	47.3	Around year

3.2. Productivity of Mangrove Ecosystems

The mean productivity of the mangrove ecosystems in the study area was USD 8520 per ha/year (Table 2). HA had the highest productivity with USD 10,476.8 per ha/year. In turn, HM showed seasonal variations in productivity owing to households in QD not fishing between October and May. Productivity of HM was USD 8263 per ha/year from June to September, and USD 7064 per ha/year during the remaining months, resulting from use of half of the catch sites. The annual productivity of the entire area of HM was USD 5109 per ha/year. The productivity of MG was close to that of HM between June and September, with USD 8273 per ha/year.

Table 2. Productivity of mangrove ecosystems. *: From Oct. to May, half of the HM was for the catch site for QL. **: Productivity through the year in HM. ***: Mean ± Standard Error, calculated when the HM productivity was evaluated by two seasons.

Study Site	User	Duration	Yield (VND/Year)	Area (ha)	Productivity (VND per ha/Year)
HM	QD, QL	Jun.–Sep.	3,677,640,000	17.8	206,568,000
	QL	Oct.–May	1,572,000,000	8.9 *	176,594,000
	QD, QL	All the year **	2,273,880,000	17.8	127,720,954 **
MG	QB	All the year	5,727,480,000	27.7	206,980,000
HA	TT	All the year	2,409,480,000	9.1	261,920,000
Mean					213,016,000 ± 17,786,000 ***

3.3. Longitudinal Distribution Patterns of Catch

Figure 2 shows a schematic of the longitudinal distribution patterns of fisheries' catch. Penaeid (*Metapenaeus ensis*) was the primary catch collected across the Hoang Mai and Hau River regions. Scallops (*Anadara subcrenatam*), clams (*Mactra* spp.) and green mussel (*Perna viridis*), and gudgeon (*Sillago sihama*) were caught in parts of the Hoang Mai River, the Hau River estuary, and between the Mai Giang and Hau River, respectively. Fiddler crabs (*Uca* sp.) were the primary catch of QD households, while others did not exploit it (Figure 3).

River					Hau Riv.	Mai Giang Riv.	Hoang Mai Riv.	
Location					Estuary	Inland	Inland	
River type					Inlet	River	Canal	
Mangroves					Fringe type *A. marina*	Riverine type *A. corniculatum, A. marina*	Riverine type *R, stylosa* with *A. marina*	
Taxa	Common Name: Vietnamese	Common Name: English	Family	Species	HA TT	MG QB	HM QL (Left side)	HM QD (Right side)
C	Tôm bạc đất	Greasyback shrimp	Penaeidae	*Metapenaeus ensis*	+++	++	+++	+
F	Cá đục	Gudgeon	Sillaginidae	*Sillago sihama*	++	++	-	-
B	Sò lông	Scallop	Arcidae	*Anadara subcrenatam*	-	-	+	++
B	Ngêu/Ngao	Clam	Mactridae	*Mactra* spp.	+	-	-	-
	Vẹm xanh	Green mussel	Mytilidae	*Perna viridis*	+	-	-	-
C	Cáy	Fiddler crab	Ocypodidae	*Uca* sp.	-	-	-	+++
F	Cá bống	Goby	Gobiidae	*Glossogobius* sp.	+++	-	+	*
C	Cua thịt, Cua giống	Meaty crab, Breed crab	Crab		+	-	+	*
F	Cá cơm	Commerson's acnhovy	Engraulidae	*Stolephorus commersonii*	-	++	-	*
F	Cá đối	Bully mullet	Mugillidae	*Mugil cephalus*	++	-	++	-
B	Hàu cửa sông	Oyster	Ostreidae	*Crassostrea rivularis*	+	+	-	-

C, F and B stand for crustacean, fish and bivalve

[single box]: Species exploited in certain areas. [double box]: Species widlely exploited from estuary to inland canal

Dependency ratio -: 0%, *: < 5%, +: < 50%, ++: < 95%, +++: 95% ≤

Figure 2. Longitudinal distribution patterns of catch.

Figure 3. The catch site for households of QD in HM (right side of the canal): (**a**,**b**) are *R. stylosa* with *A. marina* stands at low tide and high tide, respectively; (**c**,**d**) are residents collecting in the catch site; and (**e**) is fiddler crab (*Uca* sp.).

3.4. Income Structure

Figure 4 illustrates the percentage of households by income source. Agriculture, including husbandry and trading, was the main source of income in QD and QL, while sea fishing was the main source in QB and TT. Approximately 30% of households in QB engaged in agriculture, whereas almost all households (93%) in TT engaged in sea fishing. Additionally, wage work was a major income source in QD (18%), but not in other areas.

Figure 4. Income sources except for mangrove fishery and their portion.

3.5. Landscape Patterns

QD and QB were located in lowlands, their elevations were 4–23 m and 4–8 m, respectively. QL and TT were located in lowlands and hills; the former ranged from 4 to 214 m in elevation, while the latter sharply rose from 4 m to 83 m. Additionally, the types of rivers flowing in the study area differed. QD was developed around the Hoang Mai River estuary, containing meandering rivers and canals, while QL was located inland, thus possessing only canals. QB and TT both belonged to the Quynh Luu district, but the former was located in the middle reach of the Mai Giang River, whose water course is straight, while the latter was located in the lowest reaches of the Mai Giang River (i.e., located in the Hau River estuary). QD and QL did not possess a coastline, while QB and TT did (Figure 1; Table 3).

Table 3. Natural landscape components.

Site	Location	Land	River	Coastline
QD	Estuary	Lowland	Canal + Meandering	None
QL	Inland	Lowland –Hill	Canal	None
QB	Inland	Lowland	Straight	Sandy beach
TT	Estuary	Lowland –Hill	Meandering	Rocky cliff

Table 4 shows the socio-economic landscape components. QD and QL were relatively close to the town centre (2–4 km), while QB and TT were located more than 10 km from the centre (12–15 km). QL extended into the hills and QB was located in the plains, and their land area and population were greater than that of the others. The retail market size ranged from 5000 m^2 to 20,000 m^2 (from 0.5 m^2/person to 2.2 m^2/person).

Table 4. Socio-economic landscape components. *: Distance to the center of the districts.

Site	Area (km^2)	Population	Distance * (km)	Retail Market Size (m^2)	Retail Market Size (m^2/Person)
QD	6.44	6861	2	15,000	2.2
QL	23.07	11,630	4	10,000	0.9
QB	11.13	11,306	15	20,000	1.8
TT	3.67	9663	12	5000	0.5

3.6. Relationship between Income Structure and Landscape Components

The households in QL earned the most from agriculture, followed by those of QB, and the lowest agricultural income was drawn by those in QD ($p < 0.05$). TT was not included here because only one household was engaged in an agricultural occupation (Figure 5a). In terms of income from sea fishing, the households in TT earned the highest income, followed by those in QB, with the lowest sea fishing income being drawn by those in QD ($p < 0.01$). Households in QL did not engage in sea fishing (Figure 5b).

The income from agriculture, sea fishing, and trading (Figure 5a–c) was explained by Equations (2)–(4) which were derived from multiple regression analysis and whose coefficients of determination (R^2) were 0.5231 ($p < 0.001$), 0.7973 ($p < 0.001$), and 0.9770 ($p < 0.001$), respectively.

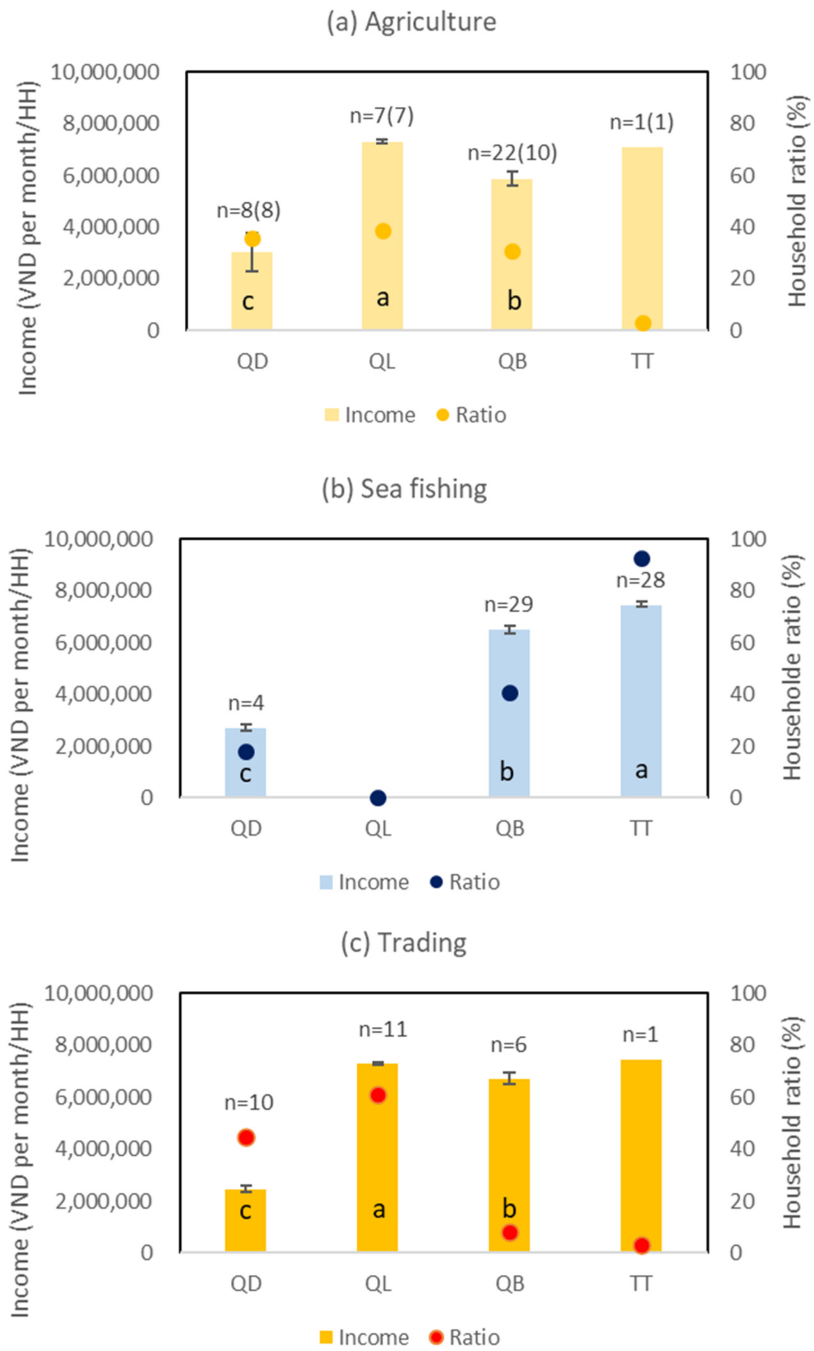

Figure 5. Incomes by sources: crop agriculture with husbandry, sea fishing, and trading. Alphabets in the bars indicate differences of incomes from (**a**) agriculture with husbandry, (**b**) sea fishing, and (**c**) trading, whose p values are < 0.05, < 0.01, and < 0.05, respectively (ANOVA, Tukey–Kramer test). Number in parenthesis in (**a**) means the number of households engaging in husbandry.

In terms of Equation (2), the variables hill and meandering river correlated with lowland and straight river/canal, respectively (both r is -1.000), thus, these variables were not selected. Since the variables inland and estuary correlated with sandy beach ($r = 1.000$ and $r = -1.000$, respectively), these were eliminated for Equation (3). The same procedures were followed for Equation (4) and its socio-economic landscape component variables (Table 4), resulting in elimination of the variables of area and market area per person, because of correlation with that of market size ($r = -0.827$ and $r = 0.758$, respectively).

$$IFA = -1,813,473^{**}\ lowland + 2,499,011^{**}\ straight\ river\ (canal) + 5,100,865^{**} \quad (2)$$

$$(R^2 = 0.5231, p < 0.001)$$

$$IFSF = 3,810,345^{**} sandy\ beach + 4,732,143^{**}\ rocky\ cliff + 2,700,000^{**} \quad (3)$$

$$(R^2 = 0.7973, p < 0.001)$$

$$IFT = 799^{**}\ population + 115,063^{**}\ distance - 159^{**}\ market\ size - 857,647 \quad (4)$$

$$(R^2 = 0.9770, p < 0.001)$$

where *IFA*, *IFSF*, and *IFT* represent income from agriculture and husbandry, sea fishing, and trading, respectively. The asterisks next to the figures indicate the significance of the partial regression coefficients, where * and ** are $p < 0.05$ and $p < 0.01$, respectively. R^2 is the coefficient of determination.

Equation (2) indicated that lowlands produced fewer crops, but that straight nearby water courses increased production (standard partial regression coefficient (ß) = −0.3891, $p < 0.01$; ß = 0.5591, $p < 0.01$, respectively). Equation (3) implied that rocky cliffs contributed more to the productivity of sea fishing than sandy beaches did (ß = 1.4834, $p < 0.01$; ß = 1.8383, $p < 0.01$, respectively). Equation (4) demonstrated that income from trading was strongly affected by the population in the respective ward or commune, which increased income from trading, whereas retail market size was a negative factor in reducing trading income (ß = 0.7796, $p < 0.01$; ß = −0.2916, $p < 0.01$, respectively).

4. Discussion

4.1. Mangrove Ecosystem Productivity and Catch

The mean mangrove productivity of the study area was USD 8520 per ha/year, which is less than the global average of USD 28,662 per ha/year [6]. However, it contributed to local household livelihoods, with approximately 50% of their income being derived from the mangrove ecosystems. Penaeid (*M. ensis*), a commercial species commonly found in mangrove forests in Vietnam [25], whose biomass is reported to be dependent on mangrove ecosystems [28] was widely collected between the Hoang Mai and Hau River and was the dominant catch for households across the study area, except for those of QD, which mainly exploited fiddler crabs (*Uca* sp.). Notably, in HM, fiddler crabs were caught for a limited time, decreasing its yearly production to USD 5109 per ha/year. This could be attributed to seasonal growth patterns that depend on the temperature regime [29]. Some bivalve played important roles for both mangrove ecosystems and the regional livelihoods [30]; scallops (*Anadara subcrenatam*), clams (*Mactra* spp.), and green mussels (*Perna viridis*) were marine species [31–33]; thus, they were exploited in/near the estuaries in the study area.

4.2. Income Structure and Its Relationship with Landscape Components

The income structure pattern in the study area was not homogenous. TT had a high percentage of households that engaged in sea fishing (93%). Similarly, sea fishing was the major income source in QB (41%), but agriculture and husbandry were also important, with 31% and 27% of households dependent on them, respectively. TT had a rocky coastline, which resulted in a 20% higher income from sea fishing compared to areas with sandy beaches, as revealed by the multiple regression analysis (ß = 1.8383, $p < 0.01$; ß = 1.4834, $p < 0.01$, respectively).

Agriculture and husbandry were the second major sources of income for QD, QL, and QB. Among the three, QL had the highest income, followed by QB and QD. Lowland was found to be unsuitable for agriculture and husbandry, thus reducing incomes. However, when the surrounding rivers flowed straight, including straight canals, it increased the total income from agriculture (ß = −0.3891; $p < 0.01$; ß = 0.5591; and $p < 0.01$, respectively).

Trading was the major income source for QL and QD, with 61% and 45% of households engaging in trading, respectively. According to residents, their trading was community-based, that is, transactions were performed inside their wards or communes; thus, their population was the major socio-economic factor increasing the income from trading, while distance to the centre increased it (ß = 0.7796; $p < 0.01$; ß = 0.2585; and $p < 0.01$ for QL and

QD, respectively). In contrast, retail market size acted as a negative factor ($ß = -0.2916$; $p < 0.01$), which could be due to an increase in competitors.

4.3. Ecological Perspective of Mangroves and Predictable Negative Impacts

The productivity of HA was the highest with USD 8520 per ha/year among the three study sites. However, it solely consisted of pioneer species, such as *A. marina* [34,35], which are frequently disturbed owing to their location at the fringes of the estuary. Thus, the productivity of HA could be fluctuated due to frequent disturbance by storms; households engaged in sea fishing were taking advantage of the rocky cliffs. The riversides were used as anchorages. Actually, the catch site was adjacent to the piers, it was located downstream of it, and in a result, sand and mud were accumulated to form the substratum for *A. marina* to grow. Increasing the number of ships for sea fishing, this place will be potentially dredged to change to the anchorage.

The productivity of HM was the lowest, but it played an important role in the livelihood of households in QD owing to a landscape unsuitable for both agriculture and sea fishing. It was located downstream of the low-height dam; thus, fluvial disturbances were reduced when it heavily rained, providing the stable habitat for *R. stylosa* to grow. HM consisted of *R. stylosa* and *A. marina*, and could be in the late succession stage and more stable than HA due to its location in an inland canal. Luong et al. (2015) [36] reported that the area of *Rhizophora* in the Can Gio biosphere in Vietnam continuously increased, whereas that of *Avicennia* decreased from 1996 to 2010 despite protection. Levees were constructed in both sides of the catch site, functioning to prevent flooding the surrounding area of crop fields; thus, there will be less of a possibility of the occurrence of negative impacts on the mangrove stands.

The mangrove stands at MG grew in a river frequently disturbed by floods; thus, the dominant species were pioneers of *A. marina* and *Aegiceras corniculatum* [35,37], yet their productivity was the second highest (USD 8273 per ha/year). The Mai Giang River, where MG existed, was under levee construction; actually, some mangroves were damaged. After completion of levee construction, fluvial condition might be changed, especially if it rains heavily, promoting regression of mangrove vegetation.

4.4. Evaluation of Mangroves

Based on the above information, the mangrove stand of HM was the most important to conserve, from both an ecological perspective and for local household livelihoods. Mangroves in the Mai Giang River grow unstably due to both natural and anthropogenic disturbances. This river flows parallel to the highway between large cities, such as Hanoi and Ho Chi Minh City and the sandy beach. There were crop fields and houses concentrated surrounding area. Thus, river modifications, such as levee construction should be required to guarantee the safety of life and property; however, careful riparian works are needed. The mangrove stands of HA remained even though surrounding fringes were used for anchorage. Their sustainable use and conservation were required.

5. Conclusions

This study provided evidence that landscape patterns of the study area had an effect on job opportunities and income structure of the residents around the mangrove ecosystems, and revealed that their livelihoods were significantly dependent on mangrove ecosystems. In addition, mangroves were evaluated in ecological aspects with predictable natural and anthropogenic impacts, and it was proposed what considerations are required for sustainable use of mangroves.

The methodology presented in this study could predict which occupations potentially provide higher incomes in the areas; thus, mangrove ecosystem importance can be evaluated through the consideration of local livelihoods in the future. The approach used in the present study can be generalised to mangrove forests near urban areas.

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