

# Sustainable livelihoods development by utilization of geomorphological resources in the Bai Tu Long Bay, Quang Ninh Province, Vietnam

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**Abstract** Located in the humid tropical zone and endowed with carbonate sedimentary formations, Vietnam has unique karst landscapes where caves, limestone, and dolines are common. If well managed, these are valuable geomorphological resources for a sustainable socio-economic development. Although publications on sustainable livelihoods associated with conserving biodiversity and local culture are plentiful, there is still a lack of studies linking livelihood quality with the conservation of geomorphological resources, in particular in karst areas. This study assesses the geomorphological resources in Vietnam's Bai Tu Long Bay and studies the relationship between livelihood and these resources. The current research area Bai Tu Long Bay is adjacent to the natural World Heritage site of Ha Long Bay in the Vietnamese part of the Gulf of Tonkin. Bai Tu Long is characterized by a karst landscape, which is at the same time similar but also different from Ha Long Bay. A field survey and interviews with 153 households allowed assessing people's perception of the value of the geomorphological resources and their importance for local income. The results show that Bai Tu Long Bay has abundant, diverse, and unique geomorphological resources, which are valuable for tourism development. However, the local people are unaware of these values likely because they have no direct benefit from them. Further a sustainable development strategy for Bai Tu Long Bay is recommended. The outcome is a proposal for tourism initiatives aiming at realizing more sustainability in the area.

**Keywords** Sustainable livelihoods · Karst · Geotourism · Vietnam

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## 1 Introduction

“Sustainable livelihood” term was introduced by Chambers and Conway (1991) as an integrating and over-arching concept. A *livelihood* is considered being *sustainable* when “it can cope with and recover from stress and shocks and maintain or enhance its capabilities and assets both now and the future, while not undermining the natural resource base” (Carney 1998; Scoones 1998; Chambers and Conway 1991).

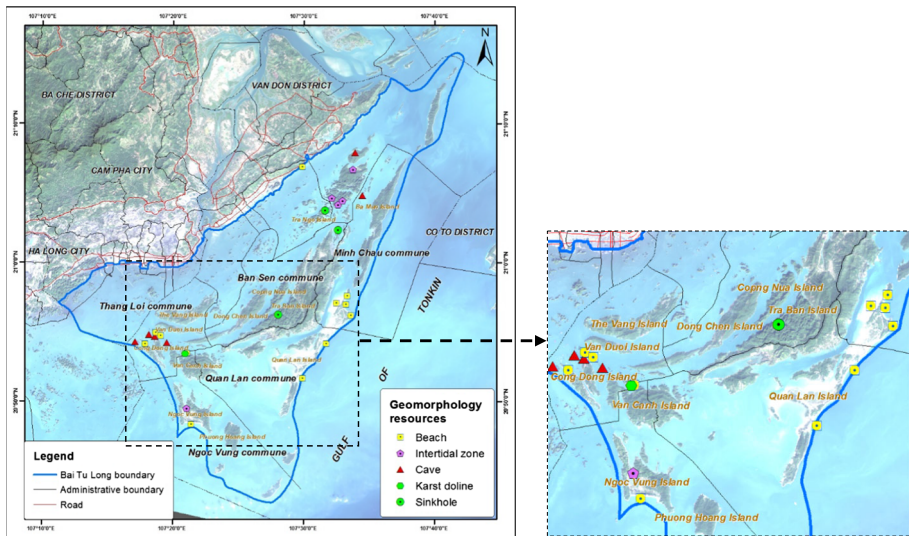
Research has focused on clarifying the concept, and on the livelihoods of local communities to reduce poverty and improve income and the living conditions (Krantz 2001; Montesquiou and Sheldon 2014). For example, Lamsal et al. (2015), Adhikari (2010), Ghimire (1994) and NEPAL (2002) targeted local communities in national parks resolving conflicts between conservation and benefit for locals while Tanner et al. (2015), SPWD (2013), and the International Centre for Integrated Mountain Development (2014) investigated the impacts of climate change on local communities and the adaptive measures. A number of studies addressed sustainable livelihoods in terms of relationships with the conservation of regional biodiversity values and local culture.

However, there is still a gap of studies linking livelihood and the conservation of geomorphological resources, especially in karst areas. There are some research focusing on evaluation of geomorphological resources for geotourism, a new type of tourism in a specific area in order to promote its geological and geomorphological heritage (Reynard 2008; Pralong 2006a, b). These research indicated that not all of these geomorphological resources are favorable for tourism development as well as conservation because they are not adapted to users with no specific knowledge of Earth sciences or not sufficiently visible in the landscape for people that are not trained in field observation (Reynard 2008). Thus, geomorphological resources need specific background research, both at the theoretical and application levels for better conservation and development.

Next to the World Heritage site of Ha Long Bay, also the bay of Bai Tu Long has a unique karst landscape, which is both similar and different from Ha Long Bay. The existing projects in the Bai Tu Long area “An evaluation of the Bai Tu Long Bay Biodiversity” (Frontier Vietnam 2004e), “Bai Tu Long Bay biodiversity awareness project” (Frontier Vietnam 2004a), “Bai Tu Long Bay National Park Biodiversity survey and conservation evaluation” (Frontier Vietnam 2004d) merely focus on biodiversity and tourism. Consequently, there is still a lack of research assessing the geomorphological value of the bay, addressing both natural resources and socio-economic aspects. This paper studies the perception of the geomorphology of Bai Tu Long in a context of the sustainable development of the local community. It focuses on assessing the geomorphology in a context of local ways of living and income. The conclusions offer strategic options for a more sustainable development of this area.

## 2 Study area

Bai Tu Long Bay is located North-East of Ha Long Bay, which is in the North-Western part of the Gulf of Tonkin. The area is part of the sea near Ha Long and Cam Pha cities. Administratively the bay is part of the Van Don district in the Quang Ninh province. Bai Tu Long Bay comprises hundreds of islands in both big and small sizes. The 20 larger islands, among which Tra Ban, Quan Lan and Ngoc Vung, occupy most of the bay’s surface (Fig. 1). They belong to two types: limestone islands and schist islands. The area is



**Fig. 1** Study area

part of the wider continental shelf formed from tectonic movements during the Caledonian and Hercynian orogenies, causing a strong faulting and folding. Now, the landscape has become a seascape due to rising sea levels since the early Holocene epoch c. 7000 years ago, which has left much of the lowlands underwater, resulted in a dramatic aesthetic of karst cliffs rising sharply out of the water (Frontier Vietnam 2004c). Unlike most of Ha Long Bay, however, significant parts of Bai Tu Long Bay are composed of non-limestone islands of sandstones and shale, some of which are very low-lying and still covered by the deposits of the sea level fluctuations of the past 7000 years (Frontier Vietnam 2004c; Sam and Binh 2001).

The climatic regime of Bai Tu Long Bay is heavily influenced by local factors of sea current and tide, and the strong westerly prevailing wind which in turn influences localized vegetation patterns. The average temperature is 22.8 °C (37.3 °Cmax/4.6 °C min); the average annual rainfall is 2400 mm, although outside the rainy season of May–October, the average falls to 200 mm. Humidity is high at 84% in the wet season, dropping to 70% in the winter months. Heavy rain accompanies storms between July and September, which also affects the salinity of the shallows (Frontier Vietnam 2004b).

There are virtually no over-ground water bodies within the main limestone area, as most precipitation percolates through the limestone and collects in or below the limestone bedrock in deep underground “wells,” forming a well-developed subterranean drainage system marked by seasonal fluctuations. On the non-limestone part of study area there are some non-seasonal streams (Frontier Vietnam 2004b).

The area is endowed with specific calcium dependent ecosystems and a rich biodiversity with typical ecosystems: mangrove ecosystem, coral reef ecosystem, ecosystem of tropical forests. The bay covers a total area of 15,783 hectares, including 6125 hectares of high islands, which is home to 1909 species of fauna and flora, forming a priceless treasure of the nation (Frontier Vietnam 2004e). In 2002, Bai Tu Long National Park was established with the area of 14 ha in order to preserve biodiversity in this region (Beharrell and Ryder 2004).

Bai Tu Long Bay hosts a population of about of 30,000 people whose livelihoods depend mainly on farming and fishing. On Bai Tu Long, there are many archaeological relics of Ha Long Culture (dating around 3000–2000 BC) and historical trails of the ancient Van Don commercial port (in Thirteenth century) (Nguyễn Văn Kim 2014).

### 3 Materials and methods

#### 3.1 Materials

This study uses the following data: (1) the statistics on the geomorphology, population, economics, career, employment, and number of tourists which were provided by the Statistics Office of Quang Ninh province (2015). These data were used to analyze the value of the geomorphological resources and as independent comparison material of the data provided by the interviews of the locals, (2) the cartographic map at 1:50,000 provided by the Department of Mapping, General Staff (2015) and a Landsat-OLI 8 image with a resolution of 30 m, less than 10% cloud cover, taken on 4/2015 (From USGS). These data allow determining the shape and the position of the islands in the study area, (3) the sociological survey data originate from 153 household interviews, which are based on the answers to a semi-structured questionnaire collecting information on: age, education, awareness of geomorphological resources, income and livelihood activity. These data allow analyzing the impacts of the geomorphological resources on the way of life of the households.

#### 3.2 Methods

##### 3.2.1 Assessing the geomorphological resources

Previously, the methods for assessing the geomorphosites focused mainly on the scientific quality of sites (Rivas et al. 1997; Bruschi and Cendrero 2005; Coratza and Giusti 2005; Serrano and Trueba 2005). They were used mainly within inventories of natural goods and environmental impact assessment (EIA) studies. Recently, the promotion of geoheritage has developed rapidly, due to the creation of geoparks and the development of geotourism. In this context, the assessment of geomorphosites needs to include also additional values (e.g., cultural, ecological) in the evaluation process (Emmanuel Reynard et al. 2007; Pralong 2005).

In this research, we combine the assessment of the central scientific value and several additional values for assessing the geomorphological resources of Bai Tu Long Bay because the importance of geomorphosites is not only related on their scientific value—that is their importance for knowledge of Earth history, but also on other characteristics and links with ecology, economy or culture (Panizza and Piacente 2014). The geomorphological resources in the study area include caves, limestone islands, dolines (i.e., “Ang” or “Tung” in Vietnamese), sandy beaches, and intertidal zones. Data on their numbers, size, location, and geomorphology offer an important basis to assess their value.

These values are determined by scientific, aesthetic, cultural–historical, and economic aspects (Pralong 2005; Emmanuel Reynard et al. 2007). In case the asset is economically used the income figures, conservation, and accessibility are taken into account on an equal

basis in a semi-quantitative assessment of the geomorphological resources. This is the basis for a proposal on regional development while preserving the traditional livelihood values.

Assessing the value of the geomorphological assets is based on the methodology developed by Pralong (Pralong 2005). This method allows one to know the tourist potential and the degree of exploitation of the geomorphological resources through the use of certain values (scientific, aesthetic, cultural–historical, and economic) which are given marks ranging between 0 and 1. Four criteria are considered: indicators, a rating score system, assessment and classification. The 18 indicators used in this study are listed in Table 1. Each indicator is semi-quantitatively assessed using a 5 levels score. Values ranging between 0 and 1 are allocated to each indicator. All indicators were measured and analyzed based on the available documents, the field survey data, and the results of the interviews. The final rating score was calculated according to the Simple Weighting Score Equation (Morgan 1999):

$$RS = W_S \cdot R_{i-n} + W_A \cdot R_{i-n} + W_C \cdot R_{i-n} + W_E \cdot R_{i-n}. \quad (1)$$

In which,  $RS$ : resource score  $W_S$ ,  $W_A$ ,  $W_C$ ,  $W_E$ : weighted score for scientific value, aesthetic value, cultural–historical value, and economic value  $R_{i-n}$ : rating score of indicator 1, 2, 3, ..., n

The study aims to recognize the total potential of the geomorphological resources in Bai Tu Long Bay, so we set the weighting scores of all values at 1. The evaluation score was then classified into 4 levels (A, B, C, D) with equal step ((maximum–minimum)/4), corresponding to very high, high, moderate and low value.

### 3.2.2 Field survey

The field survey allowed collecting data on the geomorphology of the terrain. This allows determining the relationships between the types of terrain, the current state of use, and the landscape. The nine islands are included in the survey. They are Tra Ban, Quan Lan, Ba Mun, Dong Chen, The Vang, Ngoc Vung, Cong Dong, Cong Tay and Van Canh islands (Fig. 1). The morphology of these islands is different from those in Ha Long Bay where mainly limestone islands are found. Also selected small, unique limestone islands were surveyed. The field survey was carried out simultaneously with the research on the geomorphology.

### 3.2.3 Interviews

The first challenge for this study was to decide on the area to cover, the selection of the interviewed households, and the number of households for representative sample support statistical. The sample size is usually over 50 (Parfitt 2005). Several studies have interviewed 20% of total households or 15–20 households per village (Mbaiwa 2011; Meyfroidt 2009; Hoang 2014) or interviews were undertaken until saturation, i.e., when the responses to the interview questions became relatively homogeneous (Truong et al. 2014). To evaluate the relationship between local livelihoods and geomorphological resources, a random sample of 153 households (21% of all households) were interviewed in 17 villages which are part of 4 communes in the Bai Tu Long Bay. This sample is representative for the households in the study area. The communes were selected for their variety in ecology and the different distances to the park headquarters, markets, other services, and factors influencing the livelihoods. The communes of Quan Lan and Minh Chau are located close

**Table 1** Rating score system for the geomorphological assets in Bai Tu Long Bay

Value	Indicator	Rating score system				
		0	0.25	0.5	0.75	1
Scientific	Paleo-geographic importance	–	Low	Medium	High	Very high
	Rare characteristic	>7	5–7	3–4	1–2	Unique
	Integrity	Destroyed	Heavy damaged	Medium damaged	Less Damage	Intact
	Ecological importance	–	Low	Medium	High	Very high
Aesthetic	View points	–	Poor	Medium	Good	Very good
	Area	–	Small	Medium	Large	Big
	Level of color contrast	Consistent	–	Light contrast	–	Sharp contrast
	Terrain morphology	Not impressive	–	Impressive	–	Very impressive
Cultural–historical	Relevance to culture—history	–	Low	Medium	High	Very high
	Relevance to history—archaeology	No monument, Archaeological site	Low	Medium	High	Very high
	Relevance to religion—faith	–	Low	Medium	High	Very high
	Cultural–historical events	Never	–	Sometimes	–	Annual
Economic	The accessibility of locations	Very difficult	Difficult	Average	Easy	Very easy
	Attraction	–	Local	Regional	National	International
	Natural risk	Uncontrollable	No control	Controlled 1 part	Good controlled	No risk
	Economic efficiency	–	Low	Medium	High	Very high
	Time for exploitation per year	0	1 season	2 seasons	3 seasons	4 seasons
Level of protection	Complete	Restrict	Average restrict	Non restrict	No protection	

to the tourist center but far from the district center (Cai Rong town), whereas the communes of Ban Sen and Thang Loi are further from the tourist center but closer to the district center with its markets and administration (Fig. 1). The interviews were carried out by 3 groups of 3 interviewers each (9 interviewers in total). The interviewers were trained

on surveying and interviewing techniques. Each interview was done in Vietnamese, and completion took approximately 1–1.5 h.

In each of the 17 villages, data on local livelihoods and resident's attitudes toward the geomorphological resources were collected during the summer of 2015. For the semi-structured interviews a standardized questionnaire (annex 1) was used to collect information on five capitals of livelihood: human, social, physical, natural, and financial as well as on livelihood strategies, outcomes and risks.

Reported income sources were assessed according to 5 categories: (1) off-farm income, (2) agricultural income (from crops and livestock), (3) marine income (from aquaculture and fisheries), and (4) forestry income. The total income is defined as the sum of the cash and subsistence incomes, using both reported and local market prices (Figs. 2, 3, 4 and 5).

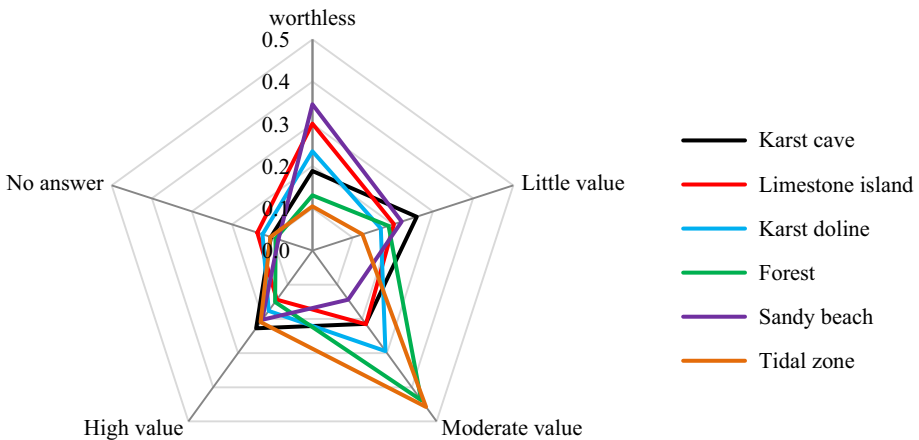
### 3.2.4 Clustering livelihoods

Four types of livelihoods are distinguished for these household surveys: (1) households mainly involved in aquaculture, (2) households mainly involved in off-farm activities, (3) households mainly involved in agriculture and (4) mixed households. The interviewed households were grouped in 4 classes using a k-means cluster analysis (XLSTAT software 2014) based on the following variables: off-farm income, agricultural income, income from marine resources and income from forest products. Then flux diagrams were drawn to show the major sources of income and the expenses for each household type (Fig. 6).

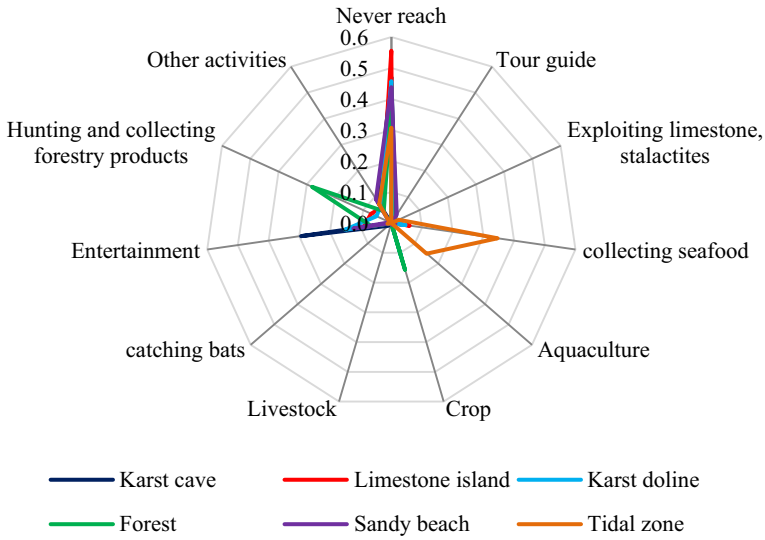
### 3.2.5 Indicators of the economic efficiency of livelihood activities

The net present value (NPV) and the benefit–cost rate (BCR) are often used as economic indicators of the efficiency of livelihood activities (Asian Development Bank 2011; Oxfam 2010; Chadburn et al. 2013).

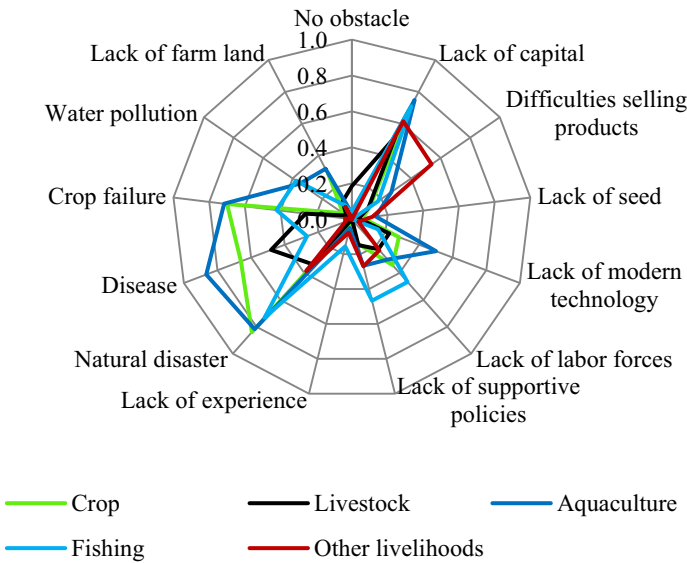
The NPV of a project or investment reflects the degree to which cash inflow, or revenue, equals or exceeds the amount of the investment capital for funding it. A higher NPV indicates that the project or investment is more profitable. At household level, the NPV is



**Fig. 2** Awareness of local people about the value of the geomorphological resources in Bai Tu Long



**Fig. 3** Local livelihood activities using the geomorphological resources in Bai Tu Long



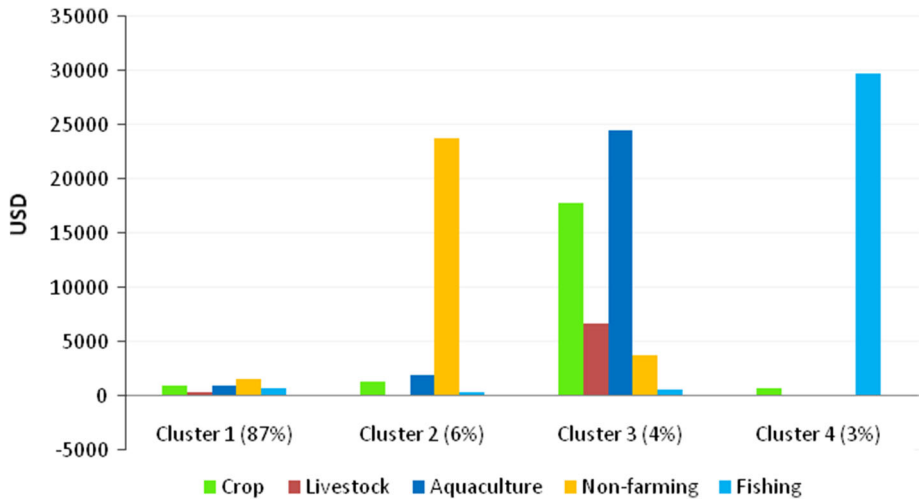
**Fig. 4** Obstacles in the livelihood activities of local people

calculated as the value of the household’s cash inflows minus the value of the household’s cash outflows.

A benefit–cost ratio (BCR) identifies the relationship between the costs and benefits of a proposed project. The higher BCR, the better investment. A general rule of thumb which applies is that if the benefit is higher than the cost, one deals with a good investment.

These relationships are expressed by the formulas (2) and (3) (Brent 2006):





**Fig. 5** Income by profession in the study area

$$NPV = \sum_{t=0}^n \frac{B_t - C_t}{(1+r)^t} \quad (2)$$

$$BCR = B/C = \frac{\sum_{t=0}^n [B_t/(1+r)^t]}{\sum_{t=0}^n [C_t/(1+r)^t]} \quad (3)$$

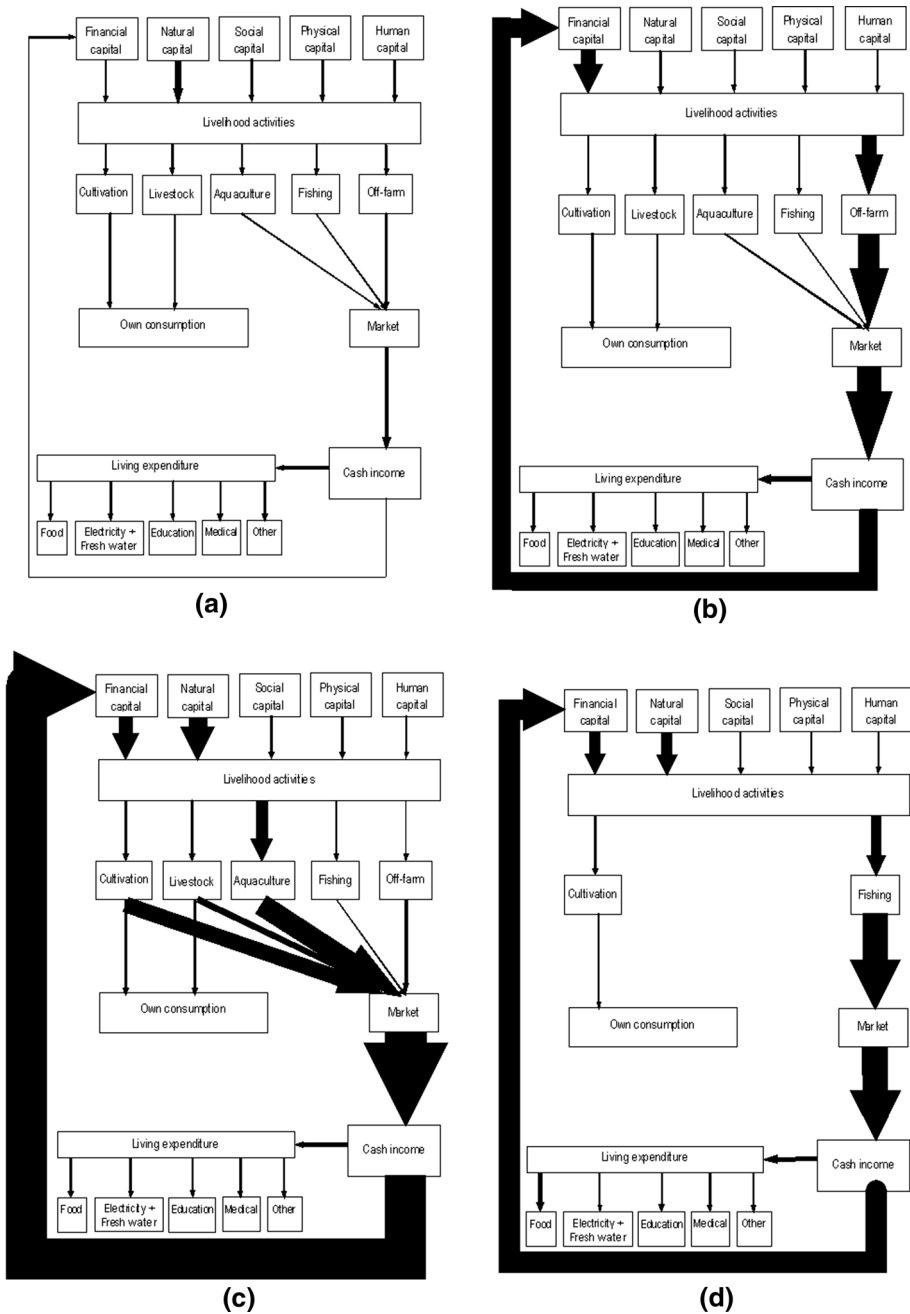
In which  $B_t$  is the revenue during period  $t$ ,  $C_t$  is the cost during period  $t$ ,  $r$  is the financial discount rate (take  $r = 2\%$  that is equivalent to the interest rate of current loans at the Commercial Bank for Foreign Trade of Vietnam (Vietcombank)),  $n$  is the number of crop cycles or livestock cycles.

## 4 Results and discussion

### 4.1 Valuating the geomorphological resources

#### 4.1.1 Valuating the geomorphological resources under the scientific point of view

Among the 46 geomorphological resource points (Table 2), two are classified as class A (Quan Lan island, Nha Tro cave), 5 resources are class B (Cong Dam cave, Dong Trong cave, Spoon doline, Cai Suoi doline, Tra Ban island), and the remaining ones are class C or D. Class A points cover the full range of scientific, aesthetic, cultural–historical, economic—social values. The class B assets lack of one or two of these values, impairing them from a class A classification, although they show unique values.



**Fig. 6** Models of livelihood typologies in the study area: **a** mixed, **b** service sector, **c** crop + aquaculture, **d** fishing. (The width of the *arrows* indicates the relative importance of the fluxes (in \$US) of five capitals of each livelihood type based on the household surveys. The unit of natural capital is the area of cultivated land, and the unit of human capital is the number of workers per household)

**Table 2** Geomorphological resource sites in Bai Tu Long Bay

No	Geomorphological resource types	Classification		Geomorphological resource point	Number of the location assessment
		By origin arising	By user characteristics		
1	Beach	Marine origin	Consumable resources	Quan Lan, Son Hao, Minh Chau, Long Beach, Robinson, Ngoc Vung, Tra Gioi, Cay Bang, Cat Oan, Va Gieng	10
2	Intertidal zone			Intertidal zone in Quan Lan commune, Minh Chau commune and Tra Ban island	03
3	Cave	Karst origin	Non-consumable resources	Nha Tro, Cai Lim, Thien Son, Dong Trong, Dau Giong, Ong But, Quan, Cai Suoi, Cong Dam	09
4	Sinkhole			Spoon, Tung Con, Cai Suoi, Sinkhole 1–11	14
5	Limestone island			Hon Xep, Hon Thien Nga	02
6	Land island	Denudation origin		Tra Ban, Quan Lan, Dong Chen, The Vang, Ngoc Vung, Cong Dong, Cong Tay, Van Canh	08
Total					46

*4.1.1.1 Scientific value* The scientific value of geomorphosites is important, because it allows us to evaluate the importance of the site for the knowledge of Earth science. This criterion has been applied for assessment of Natural Parks and Geological Conservation areas in Europe (Hose 1993; Pereira et al. 2007; Serrano and Gonzalez-Trueba 2005; Pralong 2006a, b).

The Bai Tu Long Bay entails a variety of geomorphological assets originating in the regional geology, its quaternary origin, marine geology, and karst geomorphology. In particular the latter one is most remarkable.

The Bai Tu Long Bay area and the adjacent islands near Ha Long Bay are parts of 340 million years old sedimentary carbonate formations of continental origin (Tran Duc Thanh et al. 2004). The karst includes thick limestone, which originated during a hot and humid climate period. The current appearance is the result of marine erosion processes. This culminated in patterns of mature karst in humid sub-tropical conditions with spire, towers, and caves. The karst development in Bai Tu Long Bay went through five stages: tectonic movements formed mountains, these were folded and lifted up, and the declining average sea levels, abrading, and solution of the limestone finally resulted in their nowadays appearance. These 5 stages can be illustrated pointing to the color and the components, the arrangement and composition of the rock layers and fossils, which have been preserved until now. All this is most clear in the Cong Dam and Dong Trong caves. They provide a precious and illustrative document of the long-term development of the local terrain.

**4.1.1.2 Aesthetic value** Assessing the aesthetic value is subjective and depends on the evaluator. Analytical indicators which can contribute to objectifying this process include the observation possibility, the area and the elevation of geomorphological features (related to the scale and the possibility appreciating the whole area), the original morphology, and the color contrast (visual perception) (Emmanuel Reynard et al. 2007). The aesthetic criterion has been applied for assessment of geomorphosites in China (JinFeng et al. 2014), in Morocco (Waele and Melis 2009), in Poland (Justyna Warowna et al. 2014).

Bai Tu Long offers unique landscapes with sandy beaches, dolines, limestone islands, and caves.

- Sandy beaches: the beaches in Bai Tu Long Bay (including Quan Lan, Minh Chau, Son Hao, Robinson, Long Beach) are 3-5 km long and show a slight slope, white sand, moderately waving clean and blue water. The famous beaches in Ha Long Bay (this of the Tuan Chau resort, Ti Top beach, Soi Sim beach, and Ba Trai Dao beach) are artificial and cover small areas. The bathing time for the tourists is limited by the tide; they lack clean water. In comparison with Ha Long Bay, the beaches of Bai Tu Long are larger, longer and have a good water quality—all prerequisites for better beach services, and building resorts (Tuấn and Hiên 2014).
- Doline karst: Locals in Bai Tu Long Bay, recognize two types of dolines: “Ang” is a karst lake, dotted with islands, while “Tung” is a bay with a narrow access. The Angs and Tungs in Bai Tu Long are impressive by the contrasting colors and features, projecting them against the blue sky, the height and the steepness of the cliffs, and the clean water. There are 14 dolines in Bai Tu Long Bay covering an area of about 200-500 m<sup>2</sup>. Most of them are found on the Tra Ban and Ba Mun islands. Spoon Ang, Cai Suoi Ang, and Tung Con Ang are the best known doline karsts.
- Limestone islands and caves: Bai Tu Long Bay hosts a mixture of more than 600 small and larger islands, which constitute part of its attractively. Especially, Hon Xep and Hon Thien Nga are limestone islands with the same horizontal or oblique-layered structure, specific morphology, reflecting on the waves and in the clouds. All together these limestone islands are beautiful natural sculptures with both attractive and alien shapes. Moreover each of the islands has a unique feature, with abundant caves (the Nha Tro and the Soi Nhu cave are the most known ones).

**4.1.1.3 Cultural–historical value** In some places, the cultural–historical value of geomorphosites is the most value of the destinations such as in Serra do Alvão (Portugal) (Pereira and Martins 2016; Bettencourt 2005), Trient Valley (Switzerland) (Reynard et al. 2009). The “cultural–historical value” criterion is the more heterogeneous one. Normally, there are 4 four independent sub-criteria related to cultural–historical value such as “religious importance,” “historical importance,” “artistic and literature importance” and “geohistorical importance” (Emmanuel Reynard et al. 2007). The experience has shown that geomorphosites have generally only one or two of the cultural sub-values. In the case of Bai Tu Long Bay, “historical importance” is most noticeable.

Bai Tu Long Bay contains archaeological sites of the Soi Nhu culture dating from 18,000 to 7000 years ago. By that time people lived on the limestone islands and sheltered in the caves. The representative archaeological sites are Me Cung, Thien Long, Tien Ong, and the Soi Nhu cave. The Soi Nhu collected shellfish and fruits, and lived from the hunt. Until today the islands provide habitat for the rare mountain snail (*Cyclophorus*), stream snail (*Melania*), and species of fresh water mollusks.

The location and the favorable geography (small basins, deep natural narrow passages, moderate winds and waves, safe conditions to anchor boats and ships) favor Bai Tu Long as a site to build a major seaport. Already in the XII century (1149), king Ly Anh Tong built the first international commercial port of Viet Nam (Van Don port) in the center of Bai Tu Long. This allowed not only trade between Vietnam and the other countries of South-East Asia, the Middle East, China and Japan, but also favored economic-political-cultural exchanges in this wider area during the Ly, Tran, and Le dynasties (Tù Thị Loan 2015).

Bai Tu Long Bay still conserves local culture which is most visible during the traditional festivals. In Quan Lan–Van Don the yearly festival is about the traditional way of living of fishermen, and reconstructs the 1288 naval battle of Truong Van Ho, on the Mang river. During this festival a variety of traditional games, performing arts and music (tug of war, swinging, singing “Tuong” “Cheo” and boat songs), are essential.

*4.1.1.4 Social-economic value* Many landforms belonging to karst topography may be considered as geomorphosites due to their natural and socio-economic value. Some of these geomorphosites will be objectives for tourism development; those landforms may generate a social-economic progress in this region, which nowadays is a deprived area such as in Romania (Laurențiu Artugyan 2014; Claudia Daniela Albă 2016), in Zanjan Mah-neshan (Iran) (Gholam Hassan Jafari et al. 2014). This section will point out that karstic geomorphosites in Bai Tu Long Bay may be a valuable resource.

- Interweaving islands with limestone features.

Noticeable in Bai Tu Long Bay is the harmonious interweaving of karst islands with larger non-limestone islands where most of the inhabitants live. This offers favorable conditions for tourism: sightseeing, ecotourism, bathing, and community tourism. This provides also opportunities differentiating tourism in Bai Tu Long from the sailing and sightseeing in Ha Long Bay. Tourism on the Quan Lan island is a recent development which dates only from 5 to 10 years ago. Nevertheless, the tourism activities are positively appreciated both by international and Vietnamese visitors. In particular, the wild beauty and the attractive sea and landscapes rank high on the tourist value scales. Bai Tu Long Bay became a first class destination for tourists travelling to Quang Ninh. As a result, the number of tourists in Bai Tu Long doubled during the period 2010–2014. This was facilitated by the marine transport facilities to the larger islands with private flotillas. They organize 20–30 trips a day of 30–90 min each from the mainland to the Bai Tu Long islands.

- Dry doline karst: While the immersed dolines have aesthetic and landscape value, the dry dolines offer farming opportunities. The layer of fertile terra rossa is 3–5 m thick, and can be used planting crops. The result of surveying the dry dolines on Tra Ban island—the largest island in the study area—shows that locals grow oranges which promotes them a significant income.
- Intertidal zones: The west coasts of the Bai Tu Long Bay islands are less affected by wave power. Sand deposition results in long and large intertidal zones. This favors the growth of mangroves where rare species as the *Sipunculus nudus*, a seafood species, survive. Harvesting this plant during 6 months of the year is the main source of income for a majority of the inhabitants of Quan Lan, and Ban Sen. The locals equally farm expensive seafood with a high monetary value as clams, shrimps, and snails in the intertidal zones.

Natural risks offer major obstacles for the use of resources. Almost every year, the rainy season (from June to October) has a significant effect on the beaches and the buildings along the coast. This causes major losses of seafood in the intertidal zones. Moreover, the farmed seafood is at risk of diseases. Currently, there are no effective measures in place to cope with these risks.

#### 4.1.2 Awareness of local people about the value of the geomorphological resources

As shown in Fig. 2, karst caves, limestone islands and sandy beaches are considered by the locals (50% of the respondents) as valueless. 30% of the respondents indicated that limestone islands and sandy beaches are not worth anything. 20% of the respondents believe that these resources have limited value. In contrast, the interviewees highly appreciate forests and tidal zones. For 70% of the respondents, tidal zones have a moderate to high value. For forests this number is 60 and 50% for dolines (Fig. 2).

Different opinions exist on the differential geomorphological value between Ha Long Bay and Bai Tu Long. Limestone islands and karst caves are the most valued resources of Ha Long Bay. They are the basic asset of the world heritage site. Even when the karst islands in Bai Tu Long are comparable to those of Ha Long Bay, the appreciation of local people in both locations differs significantly. From a scientific perspective, the geomorphological resources in Bai Tu Long are more diverse than the ones in Ha Long Bay. Dolines and vast islands only exist in Bai Tu Long and not in Ha Long. Doline is a typical geomorphological resource in Bai Tu Long, which is important for, but currently unused by tourism. In general, Bai Tu Long hosts rich geomorphological resources that are undervalued and economically under-used. Currently, local livelihoods hardly make use of these resources.

## 4.2 Local livelihoods and geomorphological resources

### 4.2.1 Livelihood activities related to the geomorphology

The results of the survey on local livelihood activities in Bai Tu Long area are shown in Fig. 3. The figure indicates that the local families hardly use the geomorphological assets. Limestone islands, caves and dolines are rarely visited by local people. 60% of the respondents never visit the limestone islands and 50% of respondents did not enter the caves or climb on the doline rocks. Forests and tidal zones matter more to the local households (60% of the respondents often go to the forests and another 60% indicated that their livelihood is tied to tidal zones). In the forest they mainly hunt and collect non-timber forest products. They also farm in the forest and go there for entertainment. Tidal zones are used for aquaculture of seafood and collecting food, e.g., sea worms (*Sipunculus nudus*). Few people use the caves as shelter or protection against the sun or the storms. Some households grow oranges near the dry dolines in the Ban Sen commune where the terra-rossa soil weathered from the limestone. These trees are at risk of cyclones and storms.

As mentioned in Sect. 4.1b, most of the geomorphological resources in the study area have limited value as assessed by local people except for forests and tidal zones. This shows that valuating the resources is closely related with the local habits of using the forests, and the tidal zones. Resources hardly influencing the local livelihoods such as limestone islands, karst caves, and sandy beaches are not or hardly valued.

**Table 3** Economic efficiency of major livelihood activities in Bai Tu Long

Livelihood income	Crop	Livestock	Aquaculture	Fishing	Service sector
NPV (\$US*)	3235	2135	3150	4510	3650
BCR	10	3	2.5	2	4.2

\* The monetary unit used during the interview is kVND. In May 2015, at the moment the fieldwork took place

1 \$US corresponded with ca. 20 kVND

#### 4.2.2 Economic efficiency of local livelihood activities

Table 3 shows the results of the economic efficiency analysis of the major livelihood activities in the study area.

Fishing realized the highest NPV (4510 \$US/year), followed by service activities (NPV = 3650 \$US/year). Farming activities and aquaculture have similar NPV values, respectively, 3150 and 3235 \$US/year. Livestock breeding shows the lowest NPV (with 2135 \$US/year) (Table 3).

The benefit–cost rate (BCR) of all the livelihood activities exceeds 1. This indicates that the local activities are profitable. Farming provides the highest BCR (BCR = 10), followed by income from service sector with a BCR = 4.2. Fishing shows the highest NPV but the lowest BCR (BCR = 2). In contrast, farming has a moderate NPV coupled with the highest BCR value. Fishing results in more revenue but also requires higher capital investment than agricultural activities.

Few lands are the main cause of the limited number of farmers on the limestone islands. Most people grow vegetables for their own consumption. The terrarossa soil in the Ban Sen commune where oranges are grown provides the exemption to the general rule. Oranges provide an economically most efficient income with a net profit value of NPV = 9350 \$US/year and a B/C = 15.9 (Table 4). However, only 8.5% of the households grow oranges, as the surface of the terrarossa soils is limited.

Breeding and raising livestock is not popular in the study area. The few buffalos have a low economic efficiency.

Aquaculture is the main economic activity in the study area. However, the economic efficiency of this activity is sub-optimal as shown both by the net profit value and benefit–cost rate. Fishing has a higher net profit value (4500 \$US/year) but a lower benefit–cost rate than aquaculture (Table 3).

Among the service sector, tourism has the highest economic efficiency (Table 4). Although tourism sector generates high income and geomorphological resources of Bai Tu Long Bay offer high potential for tourism development as mentioned above, only 1% of the interviewed households are involved in tourism. At the present, tourism is still a new livelihood typology in this area and has much potential for its development.

Distribution of goods (grocery) ranks second among the service activities. It shows a NPV = 3600 \$US/year and a B/C = 5. Grocery is popular in the study area, involving 17% of the interviewed households. Catering has a higher net profit value (4150 \$US/year) but a lower BCR (BCR = 1.3) than grocery (Table 4).

The survey shows that most households in Bai Tu Long derive their income from aquaculture, fishing, and farming. Tourism and services account for a small proportion of the local economy. The limited local economic value of tourism is disproportional to the

**Table 4** Economic efficiency of farming and service activities in the study area

Livelihood income	Farming					Service sector								
	Rice	Orange	Forestry	Vegetables	Buffalo	pig	Chicken	Tourism	Catering	Grocery	Builder	Hired labor	Motorbike taxi	Others
NPV (\$US/year)	485	9350	1400	750	565	2225	1171	6000	4150	3600	2300	1800	1225	3900
BCR	4.8	15.9	2.6	3.5	1.24	3	8.5	10	1.3	5	8	4	2	3.5
Percentage of involved household (%)	17	8.5	27.5	2	9	9	7.8	1	4	17	4.5	12	4	16

\* A household can be involved in more than one activity



existing natural, geological resources. Locals indicate that their geomorphological resources are well conserved. However, the survey revealed traces of harm. This might be a symptom of the local under-evaluation of these assets.

#### 4.2.3 Obstacles to the livelihood activities

The livelihood activities in the study area experience difficulties. A common one is the limited access to capital. 80% of interviewed seafood farmers report a lack of capital to invest in aquaculture. 70% of the fishermen and 50% of the cattle farmers indicate lacking capital to invest in their business. Moreover, each profession experiences specific obstacles. For farming and aquaculture, natural disasters, epidemics, and crop failure are most impacting. A few families pointed to a lack of farm land. Also the access to modern technology and water pollution are obstacles for aquaculture. Fishing is hampered by natural disasters, lack of labor forces, and supportive policies by the government. Livestock farmers struggle with disease (Fig. 4).

### 4.3 Assessment of sustainability of livelihoods in Bai Tu Long

#### 4.3.1 Livelihood typology

Results of the cluster analysis are shown in Fig. 5. According to their activities, the interviewed households can be grouped in 4 clusters.

*Cluster 1* consists of households deriving their income from mixed activities. The revenue originates from diverse sources such as crops, livestock, aquaculture, fishing and service sector (Fig. 5). The total income of these households is on average 4700 \$US/year. As a rule they do not have a core livelihood strategy. 87% of the interviewed households comply with this pattern. They mainly live in the Ban Sen and Thang Loi communes. The livelihood activities of this cluster 1 are modeled in Fig. 6a. The figure shows that these households mainly rely on vegetables they grow in their gardens. They sell few of aquaculture products and fish on the market, but this income is marginal. Revenues from these livelihood activities cover only daily living expenditures (food, fresh water, electricity, education and medicines). Investment capital to increase the production is negligible.

*Cluster 2* (Fig. 6b) consists of households deriving their main income from service activities such as tourism, grocery and catering. This type of livelihood accounts for a small proportion (6%) of the interviewed households. They mainly live in the Quan Lan and Minh Chau communes, which are “centers” of tourism. The average income of the households in this cluster totals 27,500\$US a year, which is much higher than the cluster 1 income. The households in cluster 2 have few farm lands which is hardly enough to sustain small-scale agriculture. They have possibilities investing in tourism, grocery, and/or catering, which proves profitable.

*Cluster 3* (Fig. 6c) consists of households of which main source of income is aquaculture, crops and fruits (oranges), and forestry. This reaches the highest average income (50,000 \$US/year). Of this aquaculture accounts for 24,450 \$US/year, and agriculture contributes 17,850 \$US/year. This group is small (4% of the interviewed households). They mainly live in the Ban Sen commune. These households own relatively large fields, allowing them to develop farming and aquaculture. Growing oranges increases the income while it demands a minimal investment; aquaculture on the contrary allows realizing a high income but requires relatively high investments. The terrarossa soil is suitable for the Ban Sen oranges, a local specialty.

*Cluster 4* (Fig. 6d) consists of fisherman households with a rather high average income of 30,450 \$US/year. With only 3% of the interviewed households, this is a small cluster. They live mainly in the Thang Loi commune. Fishing is profitable, but requires relatively high investments. Although households have plenty of land and surface water, they are not using it for agriculture and/or livestock. Their main income is based on wild catch fishing.

#### 4.3.2 Sustainability of the livelihood types

As discussed in the previous paragraphs, according to their main source of income Bai tu Long hosts four types of households:

1. Mixed livelihoods,
2. Service livelihoods,
3. Farming and aquaculture livelihoods,
4. Fishing livelihoods.

To assess the sustainability of these livelihood types, the following criteria are used: economic efficiency, rational use of natural resources, risks and trends of the livelihood strategies.

Type 1 is mainly based on self-sufficient farming and does not show a clear livelihood strategy. Therefore, it is not considered sustainable.

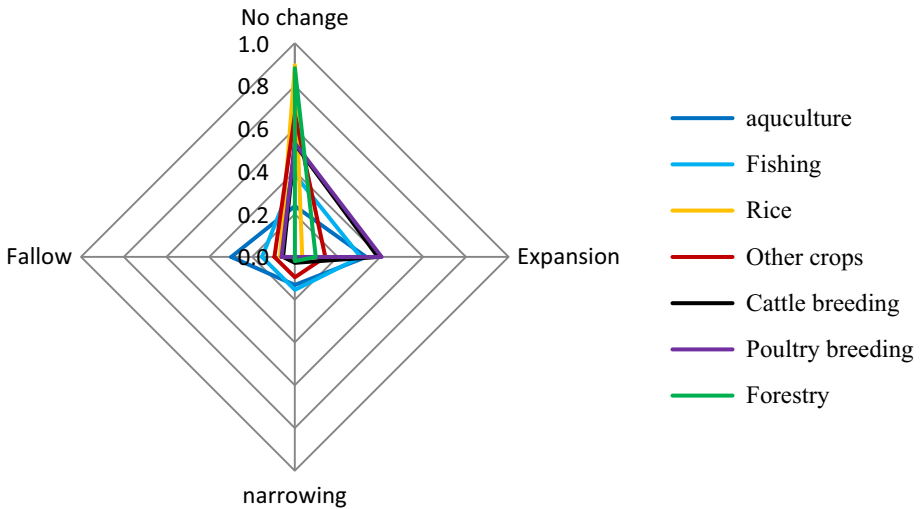
Type 2 is characterized by a relatively high economic efficiency. The households overcome the limitation of farming land and use the value of the geological resources to develop tourism. This is considered a long-term, sustainable livelihood strategy.

Type 3 shows the highest economic efficiency. Households use land and water to grow oranges and for aquaculture. However, they face a high risk. The oranges are prone to the effects of cyclones, storms, and floods destroying the trees. Also aquaculture faces production declines, disease, extreme weather conditions, and natural disasters (Fig. 4). Forestry is responsible for a limited part of the income, but the extensive approach has environmental benefits and low risks.

Type 4 provides a quite high economic efficiency and is mainly based on fishing. However, this activity is strongly influenced by weather conditions. Although these households own abundant areas of land, they do not use it for agriculture.

*Changing strategies* the interviews show that 23% of the households plan changing their income source(s) and 12% are considering this transition. The remaining 65% of households have no intention to change their income source(s). The most frequently cited alternative income sources in this context are grocery (23% of households planning to change their income sources), livestock (20%), aquaculture (17%) and tourism (17%).

*Changing scales* the interviews show that 30% of households intend to expand the scale of their aquaculture and fishing activities. Also 40% of the families intend to reduce or giving up aquaculture and/or fishing (Fig. 7). Aquaculture was introduced in Bai Tu Long only some 8 years ago. The activity shows two opposite trends: expanding and giving up. This reveals that aquaculture in Bai Tu Long does not provide a stable and sustainable income. Although some households manage to earn a (high) income from aquaculture, up to 20% lose money. In addition, aquaculture is a cause of water pollution. Local authorities should decide whether aquaculture is a core livelihood. The interviews also show that breeding cattle and poultry tends to expand in the study area; 40% of livestock households plan to expand the number of their animals (Fig. 7).



**Fig. 7** Changing scales of livelihoods: intention from 2005 to 2015

#### 4.4 Recommendations on the rational use of the geomorphological resources in the bay of Bai Tu Long

Sustainable livelihoods are in need of efficient and stable sources of income. This survey shows that although Bai Tu Long has unique and valuable geomorphological resources, and these resources have well been kept, the locals do not take advantage of these resources and even are hardly aware of their value. More than anywhere else, in Bai Tu Long, conservation should be considered as an integral part of development.

An economy primarily based on subsistence agriculture and non-renewable resources will not help the karst areas to escape from poverty (UNESCO and RIGMR 2005). All over in Bai Tu Long Bay, the most promising economic sector is tourism based on the conservation of the geomorphology and the biodiversity. The bay should be turned into a natural reserve or a national park, where community-based tourism should be promoted. The types of community-based tourism which can be developed in the study area are:

1. *Homestay* local people are offered a loan to renovate their houses to meet the hostel criteria for tourists (modern toilets, clean water, and modern equipment). Visitors experience the local life in these settings. In addition to capital investments, local people also need training to improving their service skills. This model has advantages: (1) Local people have an opportunity improve their income, skills and knowledge; (2) it makes optimal use of community resources as local people are empowered using and benefiting from their resources. However, this model also shows limitations: (1) Sufficient quality of housing and clean water is not for granted; (2) the service strongly depends on consciousness and the motivation of the local community, (3) conflicts in the community caused by inequities, in case these aspects are insufficiently managed.
2. *Farm tourism* this is similar to homestay, but differs in scale. Stays on a farm are as a rule longer than those in bed and breakfast settings. The visited farms are owned by a family, individual or organization. In the study area, the orange farms are most

- appropriate for this type of tourism. They have the required, under-used space in their farm, which can be turned in accommodation facilities. Tourists experience the daily activities on the farm. This model likely provides more jobs for local people, also to those not opening their farm or their house for tourists.
3. *Adventure tourism* Bai Tu Long offers abundant opportunities for adventure tourism. Adventure tourism models in Bai Tu Long might include exploring caves, hiking, and boat trips. The Nha Tro cave, e.g., is attractive and pristine. However, opening the pristine resources in the area necessitates at the same time a proper conservation management.
  4. *In addition, income from tourism associated activities* such as renting tourism equipment (motorbikes, bikes, floats, boats, etc.), accommodation, catering, and tour guides also bring income opportunities for local people. To achieve sustainable development, guidance on and monitoring of the environmental and social issues is needed. These opportunities also necessitate awareness, education, and training of the local households.

Along with tourism development, it is also necessary to develop traditional livelihoods. The new tourism activities are compatible with the existing ways of living. Moreover, tourism offers opportunities to promote local products replying to the demands of the tourists.

## 5 Conclusion

This study shows that Bai Tu Long has diverse and unique geomorphological resources. Located next to Ha Long Bay, a famous natural world heritage site, the bay of Bai Tu Long is characterized by a unique karst landscape, which is both similar and different from this in Ha Long Bay. These resources offer significant opportunities for community-based tourism.

The study results show that local people are not aware of the value of these assets yet because there is no direct benefit. Currently the traditional ways of living are aquaculture and fishing. The economic efficiency of these activities is limited and at risk of the effects of natural disasters, disease, and water pollution. At present only 1% of the households is involved in tourism. The sector offers, however, opportunities with a high economic efficiency and has the potential overcoming the limitations of agriculture in karst areas. It is driven by the local geomorphological resources.

The study results allow proposing a sustainable development strategy for the study area. This entails converting part of the subsistence farming and unsustainable fishery infrastructure to tourism which supports environmental protection and conservation of the geomorphological resources. Suitable tourism models for Bai Tu Long include homestay, farm tourism, and ecotourism. The traditional livelihoods should embrace opportunities supporting the tourism sector. The results of this study will be useful for local people as well as policy makers to realize the potential of Bai Tu Long Bay and choose the suitable livelihoods for sustainable development.

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