FARMERS' ADAPATION TO SEA-LEVEL RISE AND SALINITY INTRUSION: A CASE STUDY ON SEDGE GROWERS IN COASTAL VIETNAM

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ABSTRACT: Vietnam is one of the countries in the world that will be most negatively affected by the sea-level rise (SLR). The large agricultural population in the coastal areas of the country is already constrained by saltwater intrusion now, and will be more so by SLR in the future. In the coastal district of Nga Son, Thanh Hoa Province of Vietnam, the farmers had maintained their livelihood under the salinity constraint on salt-tolerant sedge (*Cyperus* spp.) plants sold for handicraft and mat-making. In recent years, however, their livelihood has been eroded by declines in productivity and quality of the sedge due to increased salinity intrusion and shortage of fresh water supply. The income from sedge was reduced to a greater extent in a group of communes that are closer to the Gulf of Tonkin than the other group of communes with less negative impacts. The farmers' responses to these changes showed similarity and differences between the two groups of communes. The seasonal peak of rainfall has become later and the sedge harvest had to be delayed. The farmers' capability to adapt to the hydrological and climatic changes thus depends on their local hydrological conditions mediated by their financial situation. These constraints could be ameliorated by financial and engineering supports at various institutional levels. Agronomic efforts could also ameliorate the problems via provision of better suited crops on an improved characterization of the local environmental conditions.

Keywords: Adaptive response; saltwater intrusion; freshwater shortage; Sedge; Vietnam

INTRODUCTION

The territory of Vietnam faces the Pacific Ocean with the 3,260 km of coastal line, 23% of the 84 million Vietnamese populations residing in only 12% of the total land area along the coastal line (General statistic office, 2008), and, hence, the impact of climate change via the sea-level rise (SLR) will be immense and direct. There are many studies on the consequences of SLR such as inundation, flooding, land erosion and saltwater intrusion (Dasgupta et al. 2009; Thanh et al. 2004; Wassmann et al. 2004). It is noteworthy that the above-mentioned studies have paid attentions mostly to the physical damages due to SLR, and that they have not addressed the questions on the behavior of the local people in response to the climate changes, such as "How the local farmers perceive the climate change?" and "How they adapt themselves to the changes in local climate and other stressors?". Addressing these questions is critical in understanding peoples' vulnerability to the climate change and appraising their capabilities to cope with the impacts (Ensor and Berger 2009; Paavola 2008).

The objectives of the study are to determine the adaptive responses of farmers to on-going environmental changes, and to locate the determinants of the farmers' adaptive responses. We studied the farmers in a coastal district near the Red River Delta in northern Vietnam. This district is the country's largest producer of sedge (*Cyperus malaccensis* Lam. and a few related species), which grows in brackish wetland and have been used for making handicrafts and mats. It is hoped that our findings will eventually help the process of adaptation at various scales from the farmers' decision to policy-making in response to the climate change, particularly to the rise in the sea level, freshwater shortage, and saltwater intrusion.

MATERIALS AND METHODS

Study site

The study site is Nga Son district (19°56'N, 105°54'E), Thanh Hoa province. This is the largest and the most famous area for the sedge production in Vietnam, about 135 km to the southeast of Hanoi, the capital of Vietnam.

In order to extend the land area, to protect the fields, and to increase agricultural production, they have built four dykes in the years 1960, 1972, 1982 and 1996 respectively. Dyke 4 is the newest and closest dyke to the Gulf of Tonkin, whereas Dyke 1 is the oldest and farthest from the sea and closest to the residential area (Fig. 1).

The farmers grow sedge in six communes, which are divided into two groups in this study (Fig. 1). Group 1 includes the communes of Nga Lien, Nga Thanh, and Nga Thai that are located inside Dyke 1, the farthest dyke from the Gulf of Tonkin (about 7 km). The elevation in these communes ranges approximately between 0 and 0.3 m above the mean sea level (a.s.l.). Group 2 involves Nga Tan, Nga Tien, and Nga Thuy communes that are located outside Dyke 1 and are closer to the sea (by about 4 km) than those in Group 1. The elevation ranges approximately from 0.3 to 0.5 m a.s.l.

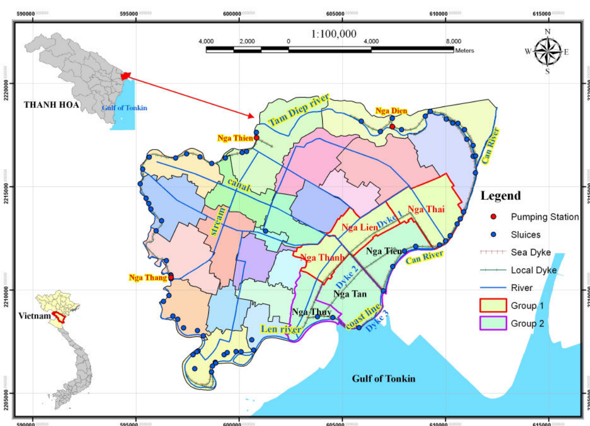

Figure 1 Map of the study site

The two groups have substantially different agronomic features (Table 1). In Group 1 communes, the farmers have access to irrigation water supply, and, hence, they perform double cropping in sedge production.

Some farmers grow rice as well. In Group 2 communes, in contrast, most farmers grow sedge on rain water and harvest the sedge once a year only with little rice being grown (Table 1).

Table 1 Characteristics of the two target groups of communes in Nga Son as of year 2007

Description (unit)	Group 1	Group 2
Total population (person)	22,212	19,470
Total labor population (person)	7,772	7,060
Number of households (HHs)	4,776	4,587
Number of Poor households (HHs)	918	1,598
Total land area (ha)	1,445	2,739
Agricultural land area (ha)	1,053	1,474
Total sedge area (ha)	660	814
(Sedge area for double crops, ha)	(642)	(302)
Rice paddy area (ha)	120	0.5
Aquaculture area (ha)	58.5	245
(Freshwater aquaculture area, ha)	(48.5)	(9)
(Brackish aquaculture area, ha)	(10)	(236)

Source: Nga Son district people's committee, 2008.

Sedge is widely grown in coastal and estuarine areas. Once the sedge seedlings are transplanted in the field, they can be harvested for about 5-7 yeas. There are usual two cropping seasons a year, the first is from February to July, and the second one from July to October, i.e. double cropping. The plants are then left unmanaged until the next spring. In some areas without irrigation water, they harvest the sedge only once, i.e. single cropping (Fig. 2).

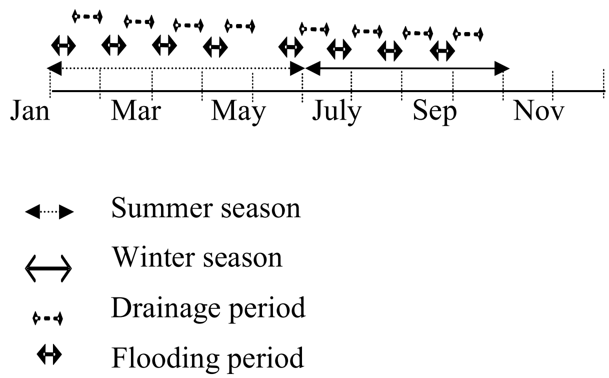

Figure 2 Schematic of the cropping calendar and water management for sedge production in Nga Son district, Thanh Hoa Province, Vietnam

After being harvested, sedge plants are immediately divided into 4 classes for different uses. The class 1 sedge is longer than 1.65 m, and is collected by foreign and domestic traders. The class 2 sedge is shorter than class 1 being in range from 1.2 to 1.65 m, and is collected by local factories and private companies. The plants are used to make mats, carpets, and handicraft products that are exported to foreign markets.

The third class sedge being in the range from 1.0 to 1.2 m is selected by domestic traders and producers who own shops in tourist places. Sedge of this class is used as raw material for making handicraft products and mats for domestic markets. The fourth class is for the shortest sedge that are used to two purposes. The first is to make ropes to be sold to China, and the other is to make handicraft products for the local markets. The price is highest in the class 1 sedge, and lowest in the class 4 sedge with those in other classes being priced in between.

Research methodologies

The exploratory and descriptive methods were used in this study. Primary data were collected by participatory approach including discussions with key informants, focus group discussion, and field observations. We interviewed 96 (Group 1) and 104 (Group 2) households (HHs). Family size, number of members at labor age, age and education of the head of HHs were quite similar between the two groups.

Secondary information on salinity and agricultural production was collected at the Statistics Office and the Department of Agriculture of this district.

The primary as well as secondary data were subjected to statistical analyses with JMP software (SAS Institute, Cary, USA).

RESULTS AND DISCUSSIONS

Trends in climate in Nga Son district, Thanh Hoa province, Vietnam

Observations over the past centuries have revealed some interesting trends in Nga Son district. Annual average temperature has increased by about 0.35°C over the past 50 years. The annual average of minimum temperature has increased by approximately 1°C over the past 50 years (p<0.001). This trend is similar with the average temperature in the coolest month (January) and hottest month (June). Annual precipitation has decreased by approximately 325 mm in the past 50 years. Recently, saltwater has penetrated further into several rivers bounding Nga Son with the salinity in the range of about 0.2-16 g/l during the dry season (Nga Son DPC 2008). The shortage of freshwater and salinity intrusion are so intertwined. Salinity had not been an issue of concern until November 2006, when they started to measure it due to rising concern over the salinity in irrigation water. Salty water has penetrated further in the inland. At the Nga Thang pumping station, which is located in the Len River and far about 15 km from the sea, the salinity in 2010 was higher than in 2009, it reached to 16 ppb in January 2010.

Farmers' perception of climatic and hydrological changes in relation to the sedge production.

The farmers ascribed the decline in sedge productivity for climatic and other environmental changes and for the market fluctuation. Among the interviewed farmers, about 79% (Group 2) and 29% (Group 1) have blamed the salinity as the primary cause of the decrease in sedge productivity.

Some farmers also complained about the shortage of freshwater supply. Since Group 1 communes are at lower elevations, and located in the middle of the irrigation system, irrigation water runs into the sedge fields by gravity. Group 2 communes are, by comparison, located at slightly higher elevations and at the end of the irrigation system, therefore, the freshwater is in short supply for irrigation. In addition, Group 2 communes are encircled by Hoat and Can Rivers that are connected to the Gulf of Tonkin and contain high salinity.

Recently, saltwater has penetrated further into several rivers bounding Nga Son with the salinity in the range of about 0.5-9.5 mg/l during the dry season (Nga Son District Reports, 2008).

Some farmers complained that, in the past, the heavy rainfall had happened at the beginning of September, whereas, in recent years, it occurs in late September, which has forced them to delay the harvest.

Table 3 Chemical analysis of the soil and water samples in Nga Son

Sample	Parameters (unit)	Location	
		Group 1	Group 2
Soil	EC (S/m)	0.139	0.204
	Dissolved solid (g/kg)	0.42	0.61
	Cl^- (mol/kg)	0.007	0.008
	$SO4^{2-}$ (mol/kg)	0.002	0.001
Water	EC (S/cm)	0.356	1.255
	Dissolved solid (g/kg)	2.136	7.528
	Cl^- (mol/kg)	0.032	0.107
	$SO4^{2-}$ (mol/kg)	0.003	0.008

The farmers' perception of freshwater shortage and salinity as the largest difficulties for Group 2 was supported by our own analysis of water and soil samples (Table 3). In Group 2 communes, 42% (2002) or 46% (2007) of the households harvested sedge only once a year, whereas, in Group 1, all the households had harvested sedge twice a year.

The harvested area was less in Group 2 than Group 1 (p<0.01), and has declined from 2002 to 2007 in either group (p<0.0001). The interaction between year and group was not significant (p=0.176). The productivity on annual basis showed a similar pattern with Group 2 having smaller harvested area (p<0.0001) and lower productivity (p<0.0001). The highly significant interaction between year and group (p<0.0001) indicates that Group 2 exhibited a greater decline in productivity from 2002 to 2007 than Group 1.

Table 4 Sedge area and productivity per household for the two groups in 2002 and 2007

Group	Year	Harvested area (m^2)	Productivity (kg/ha)
Group 1	2002	4,738 ^{A}	8,162 ^{A}
	2007	3,560 ^{BC}	6,322 ^{B}
Group 2	2002	3,727 ^{B}	6,427 ^{B}
	2007	2,911 ^{C}	3,112 ^{C}

Farmers household as influenced by the changes in sedge production and sales

Comparison within each length class shows that, for all but class 4, the price of the products was significantly lower in Group 2 than Group 1 (p<0.0001) (Table 5). The price declined from 2002 to 2007 across the groups (p<0.0001) to a significantly greater extent in Group 2 than Group 1 for most classes (Table 5).

Table 5 Comparison of sedge price between 2002 and 2007 by length classes

Group	Year	Mean price of sedge (VND*/kg)			
		Class 1	Class 2	Class 3	Class 4
Group 1	2002	5,272 ^{A}	3,331 ^{A}	2,018 ^{A}	1,431 ^{A}
	2007	4,991 ^{AB}	2,996 ^{B}	1,823 ^{B}	1,206 ^{AB}
Group 2	2002	4,844 ^{B}	3,046 ^{AB}	1,879 ^{AB}	968 ^{B}
	2007	3,807 ^{C}	1,939 ^{C}	1,268 ^{C}	999 ^{AB}

*VND (Vietnamese Dong) is the Vietnamese currency (1 U.S. Dollars = c. 18,000 VND as of Nov. 2009).

In 2002, the largest fraction of the harvested sedge was sold to factories and private companies. But 52% (Group 1) and 65% (Group 2) of the households who sold their products to this type of buyers in 2002 stopped doing so in 2007. The largest fraction now goes to handicraft and rope making followed by domestic traders.

It is noteworthy that, in 2007, the fraction of households for all the buyers but foreign traders was less in Group 2 than Group 1 (Table 6).

Table 6 Percentage of households selling products to different buyers

Buyers	Year	Fraction of households (%)		*p*-values
		Group 1	Group 2	
Foreign traders	2002	4.2	1.9	0.430
	2007	0.0	0.0	-
Factories and private companies	2002	87.5	74.0	0.020
	2007	36.5	9.6	< 0.0001
Domestic traders	2002	69.8	69.2	1.000
	2007	81.3	60.6	0.002
Handicrafts and rope making	2002	44.8	52.9	0.261
	2007	87.5	74.0	0.020

Comparison of annual income between the groups showed lower income of the households in Group 2 than those in Group 1 (Table 7) due evidently to the lower income from sedge sales. This is consistent with the lower sedge productivity (Table 4) and lower price per unit weight (Table 5) in Group 2 than Group 1. There was no significant difference between the groups in the non-sedge income (Table 7), whose actual sources, nevertheless, differed between the groups (Table 8). More households in Group 1 earned money ($\geq 10^6$ VND) from private business and aquaculture than those in Group 2, whereas the opposite was true for the income from rope-making (Table 8).

The income from non-agricultural jobs and animal husbandry are similar in the two groups. Non-agricultural jobs have become popular while productivity of sedge has declined. Men usually go outside of commune to work at construction sites in big cities. Women do lighter jobs such as house helper in big cities or coffee pickers in the highlands of Vietnam.

Table 7 Major income sources for the households as of 2007

Income sources	Median annual income (1000 VND)		*p*-value
	Group 1	Group 2	
Sales of sedge as raw material	8,320	4,000	< 0.0001
Other income sources	1,900	3,000	0.308
Total income	11,850	7,460	< 0.0001

Table 8 Sources of the other income for the households as of 2007

Income sources	Households (%) with the income $\geq 10^6$ VND from the source		*p*-value
	Group 1	Group 2	
Livestock rearing	26.0	25.0	0.873
Non agricultural jobs	13.5	16.3	0.693
Private business	20.8	7.7	0.008
Aquaculture	9.4	1.9	0.028
Rope and handicraft making	11.5	40.4	< 0.0001

Farmers' reactions to the changes in sedge production, environmental and climatic change

The responses of farmers to the current difficulties of decreasing productivity and quality of sedge included the change of cropping calendar, development of animal husbandry or aquaculture, setting up private businesses, finding non-agricultural jobs, switching from sedge to rice, and growing fruits and vegetables. The two groups showed similarity and difference in the order of preference and frequency in the choice of reactions (Table 9).

About a half of the interviewees in the both groups has changed cropping calendar. Some respondents explained that the end of rainy season has recently become later, and that they had to delay the harvest by 10-15 days to avoid the rains at the harvesting time. In response to the late rains, they have also developed a post-harvest technique. Some households have pooled capital to buy a drying machine. They can use it for their own demands and for rent. Other households who could not afford a drier could hire a machine from private companies. These responses have presumably made the farmers more robust against the risk of changing rainfall distribution.

Table 9 Reactions of farmers in the two groups to the changes in sedge productivity and quality

Adaptive responses	Households (%) who adopted the response		*p*-value
	Group 1	Group 2	
Change crop calendar	53.1	40.4	0.089
Develop animal husbandry	52.1	47.1	0.571
Find non-agricultural jobs	34.3	32.7	0.881
Develop aquaculture	22.9	4.8	0.0003
Set up private businesses	18.8	6.7	0.017
Switch from sedge to rice	9.4	3.8	0.153
Grow fruits and vegetables	8.3	7.7	1.000

Developing animal husbandry was equally popular among the farmers in either group as a response to the decreased productivity and quality of sedge. Finding non-agricultural jobs followed the two most popular choices in either group (Table 9).

In Group 1, more than 20% of the interviewed households have started aquaculture. They can get higher income from aquaculture than from sedge or rice cultivation, but they are required for larger spending in digging ponds and buying seedlings. Only 5% of the interviewees in Group 2 have developed aquaculture, whereas the aquaculture area in Group 2 communes is larger than that in Group 1. The main constraint mentioned during the interviews by those in Group 2 against aquaculture was the shortage of the initial capital.

The two groups also differed in the option for setting up private businesses. Since 2002, only 7% of the interviewed households in Group 2 have chosen this option, while they have recognized the much higher income than other jobs. In Group 1, about 19% of interviewees have started their own business.

DISCUSSIONS

In the coastal area of Nga Son district, Thanh Hoa province of Vietnam, farmers cannot grow food crops because of the high salinity, and have specialized in the sedge production. The income from one ha of sedge used to be about 3-5 times that of rice, and, hence, the farmers had no problems with the dependence of their households on income from sedge sales. The situation has changed, however, by the declines in sedge productivity and price (Tables 4, 5, 6) due to the increased salinity intrusion and declining fresh water supply particularly in the communes closer to the coast.

In response to the declined sedge income, the farmers have changed the cropping calendar and diversified the income sources to include livestock and non-agricultural jobs (Table 9). Diversification of income sources is a popular adaptive response that has been adopted since late 19th century (Bradshaw et al. 2004; McGuire and Sperling 2008; Mortimore and Adams 2001; Thomas et al. 2007). The moderate requirement for the initial capital allowed them to start raising pigs, chickens and ducks, which explains the popularity of this option (Table 9).

The change in cropping calendar was a response to the change in rainfall pattern around the harvesting time. The farmers currently harvest the sedge during the first half of October by about a half-month later than in the past. The introduction of drying machines has ameliorated the climatic constraint in exchange for the initial and running costs of the machine. The capital requirement plays an important role in adaptation to the climatic change in this respect also.

Besides the major responses mentioned above, some farmers have taken the adaptive measures of starting aquaculture or private businesses at different prevalence between the two groups of communes (Table 9), which is reflected in the sources of other income than sedge sales as of 2007 (Table 8). More households got income from aquaculture and private businesses in Group 1 than those in Group 2, whereas the opposite was true for the income from rope-making. The development of aquaculture and private businesses could potentially bring a higher income than the rope-making, and the interviewees have recognized the gap between the different income sources. They mentioned, however, that they cannot afford the initial capital to develop the higher income sources. The adaptive capacity thus depends at least partly on the capital availability. The farmers' ability to adapt to changed circumstances and to adopt different livelihood strategies should also be limited by the lack of access to new knowledge and opportunities for acquiring new skills in addition to the capital constraint (Adger et al. 2009; Burton and Lim 2005; Eakin et al. 2006; Ensor and Berger 2009; Mertz et al. 2009).

Farmers' adaptive strategies as listed above will be more successful with the involvement of relevant organizations at various institutional levels (Adger 2006; Yang et al. 2007). Since the vulnerable farmers are those who lack money and knowledge, they need external support to gain access to value-added agricultural and non-agricultural livelihood in their communities (Acosta-Michlik et al. 2008). The district and provincial governments in our study region have established action plans to help local people in coping with the hydrological and climatic changes through financial, technological and socio-economic means. The main activities are to change the land use, upgrade the infrastructures, and select the sedge varieties with higher salinity tolerance.

Against the clear trend of SLR in Vietnam, planning for adaptation must be started immediately (Dasgupta et al. 2009; Thanh et al. 2004). The adaptation would be made efficiently when it is based on the understandings of the on-going responses by the farmers and the local institutions to the changing climate and hydrology as we have attempted in this study.

CONCLUSIONS

The adaptive responses at the farm level in Nga Son include changes in the cropping systems and diversification of income sources. Some of the adaptation measures such as changes in cropping calendar and animal husbandry require capitals ranging from little to modest amount, and have indeed been adopted widely. Some other measures, e.g. starting aquaculture or private businesses, require larger investments than the capacity of many households in the study region. The financial capability is more limited in the households that have been affected more by the adverse hydrological changes. Agronomic options for the adaptation are also more limited for those who are constrained more by the local environmental changes.

The determinants of the adaptive capability at farm-level should be considered when designing external supports by relevant organizations at the higher levels. The sedge productivity could be increased by investments in agronomic research and engineering projects via selection of better-suited sedge species or varieties in combination with the improved salinity control and fresh water supply. The decline of sedge price could be ameliorated by stimulating the market via the development of trade villages and improved quality associated with expanded variety of the products. Diversification of income sources should be facilitated by financial and technical supports for those who embark on aquaculture, private businesses and other jobs of high capital requirements.

The local indigenous knowledge, experience, resilience and coping capacity to current climate variability could be utilized to give efficient supports to local communities with different vulnerability and to enhance their adaptive capacity to future climatic and environmental changes (Yamin et. al. 2005; Aalst et. al. 2007). Adaptation assessment and policy making in the next generation should entail more bottom-up approaches rather than the traditional ones from top-down (Huq and Khan 2006). In doing so, the policies will be better able to help the vulnerable communities adapt to the adverse environmental changes taking advantages of indigenous knowledge and local experiences.

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