ISSN 2012-4635

Discovering New Roads to Development

Climate Change Adaptation, Mitigation, and Resilience

SEAMEO SEARCA

Southeast Asian Regional Center for Graduate Study and Research in Agriculture

Science and education for agriculture and development

Discovering New Roads to Development

Climate Change Adaptation, Mitigation, and Resilience

Southeast Asian Regional Center for Graduate Study and Research in Agriculture

The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) is one of the 21 regional centers of excellence of the Southeast Asian Ministers of Education Organization (SEAMEO). Founded on 27 November 1966, SEARCA is mandated to strengthen institutional capacities in agricultural and rural development in Southeast Asia through graduate scholarship, research and development, and knowledge management. It serves the 11 SEAMEO member countries, namely, Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Timor Leste, and Vietnam. SEARCA is hosted by the Government of the Philippines on the campus of the University of the Philippines Los Baños (UPLB) in Laguna, Philippines. It is supported by donations from SEAMEO member and associate member states, other governments, and various international donor agencies.

Discovering New Roads to Development: Climate Change Adaptation, Mitigation, and Resilience
Published by SEARCA, Los Baños, Laguna, Philippines
Printed in the Republic of the Philippines
First Printing 2017

Cover photo credits: Aung Kway Tun, Chi Busque, Hikmah Sultan, Hoang Long Ly, and Herry Tjiang

ISSN 2012-4635

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Foreword

SEARCA is pleased to share with you the fourth in a series of this publication titled *Discovering New Roads: Climate Change Adaptation, Mitigation, and Resilience.*

The Center began publishing this series in 2009 to provide information on issues and concerns affecting agricultural and rural development (ARD) in the 11 countries of Southeast Asia. Previous editions focused on environmental resource management, lowland agricultural technologies, and coastal ecosystems technologies.

For this particular volume, due attention is given to climate change adaptation, mitigation, and resiliency because of its negative effects on the agricultural sector. Under SEARCA's Tenth Five-Year Plan focused on Inclusive and Sustainable Agricultural and Rural Development (ISARD), climate change is flagged as a priority concern as it hinders the sector's ability to provide food for a growing population that continues to struggle with poverty and hunger.

With an understanding that climate change is either won or lost at the grassroots level, this edition highlights some of the most promising studies and in-country initiatives, mainly of SEARCA graduate scholarship alumni, that address the adverse effects of climate change in their local communities. In publishing these studies, our goal is to provide researchers, development practitioners, and policy and decision-makers with useful reference material on current climate change actions and best practices which may be replicated or up-scaled in other communities of Southeast Asia similarly affected by this natural phenomenon.

Finally, we thank and congratulate the authors as well as reviewers who provided expert guidance and support for making this publication possible. SEARCA will continue to harvest and transform these research works into useful publications that contribute to the promotion of ARD in the region.

GIL C. SAGUIGUIT, JR.
Director

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Vulnerability Assessment of Rice Farming Provinces to Climate Change in the Red River Delta in Vietnam

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ABSTRACT

The Red River Delta is the second largest rice-producing region of Vietnam, contributing 16 percent of the country's rice production. However, changes in climate are projected to cause adverse impacts on the rice production of provinces within the delta. This study sought to assess the vulnerability of rice farming provinces in the Red River Delta to provide information for decision-makers to design an appropriate adaptation and mitigation plan. Since 1980, the temperature in summer in the Red River Delta has increased by 0.56ºC while the winter temperature has decreased by 3.2ºC. The trend of temperature change in winter is also faster than in summer. The result of the vulnerability index show that Hanoi is most vulnerable to climate change. Moreover, the coastal provinces are more vulnerable than provinces located farther inland. Among the indicators, rural density has significant positive correlation to vulnerability. This may indicate that the crowded population in the Red River Delta can exacerbate farmers' exposure to climate change. The results of the simulation model of paddy yield under different scenarios showed changes in the paddy yield in the Red River Delta. Specifically, the yield of spring paddy was projected to increase by 18 percent while the winter paddy would decrease by four percent in 2050.

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INTRODUCTION

The Red River Delta, located at the northern part of Vietnam, is a flat plain that was formed by the Red River and Thái Bình River. The total area of the region is 15,000 kilometers^2 (km^2) with a population of 19 million (General Statistics Office 2011). The Red River Delta includes nine provinces and two central level cities; Hanoi, which is the capital of Vietnam, is included in the region (Figure 1.1).

Figure 1.1. The Red River Delta

Source: Kim et al. (2013)

According to the medium emission scenario, at the end of the 21st century, the average temperature can increase up to 2.5ºC and annual rainfall will increase by seven percent in the Red River Delta (MONRE 2012). These predicted changes will impact on agriculture, especially in paddy-producing provinces.

This study was conducted at the provincial level to assess the vulnerability of rice farming provinces to climate change in the Red River Delta. Specifically, it aimed to:

1. Describe and analyze the trend of climate and the socio-economic profile of the rice-farming provinces in the Red River Delta;
2. Determine the vulnerability level of rice-farming provinces in the Red River Delta;
3. Identify the factors that affect the vulnerability of rice-farming provinces in the Red River Delta; and
4. Determine and analyze changes in paddy productivity under different temperature and rainfall scenarios.

METHODOLOGY

In this study, the definition of vulnerability by the Intergovernmental Panel on Climate Change (IPCC) was applied. IPPC defined vulnerability as a function of exposure, sensitivity, and adaptive capacity (IPCC 2001). In order to construct the vulnerability index of 11 rice-farming provinces in the Red River Delta, a quantitative assessment of vulnerability was conducted by building an index based on several indicators that represent the vulnerability of the region (Padmaja and Banerjee 2009). Other studies that used quantitative assessments of vulnerability were those of Luers et al. (2003) and Nelson (2010).

The construction of the vulnerability index is a process that includes four steps: identification of indicators, arrangement of data, normalization of indicators, and construction of vulnerability level.

From the IPCC definition of vulnerability, the indicators were also classified into three determinants of vulnerability—exposure, sensitivity, and adaptive capacity (Table 1.1). Indicators for the exposure of the system included predicted changes in rainfall, temperature, and sea level from the selected base year (Padmaja and Banerjee 2009). This study applied the predicted values from the medium emission scenario in 2050 projected by MONRE (2012) since exposure is related to climate stress on the system in the long-term. The larger the value of the changes, the more pressure is placed on the system so that the vulnerability is also larger. The sea level rise in the study was assumed to be purely facilitated by climate change as the overextraction of groundwater in the region can lead to the sink of the ground surface. Extreme climate indicators included high rainfall, low rainfall, high temperature, and low temperature. The values of these indicators were computed from the differences between the maximum and the minimum values of the mean rainfall and temperature. A higher difference meant more changes in climate variability and more risks in the region. Topographic elevation was another indicator considered under exposure. Region with large low-lying areas such as the Red River Delta, is extremely vulnerable to sea level rise (Koh 2011).

For sensitivity, several indicators were identified, namely, paddy land, rural population density, and rate of rainfed paddy. The higher the proportion of paddy land in the province, the greater the sensitivity of that province's rice production to climate change, which implies a positive relationship. Rural population density is an indicator of vulnerability because when more people are exposed; vulnerability is also high. Adger et al. (2004) also showed the positive relationship between density and vulnerability, where population density is high, vulnerability will be exacerbated due to settlements in hazard-prone areas. The rate of rainfed rice is the ratio of rainfed rice area over irrigated rice areas in the province. A higher rate means a larger proportion of rainfed rice compared to irrigated rice. It also implies that rice farming in the province is more vulnerable to climate change since rainfed rice is dependent on natural rainfall.

Table 1.1. Indicators to assess the vulnerability of rice farming provinces

Determinant, Indicator	Description	Correlation
Exposure		
Change in rainfall	Predicted changes in climate variables from the selected base year (1980)	Positive
Change in temperature		Positive
Change in sea level		Positive
High rainfall extreme	Amount of differences of minimum and maximum rainfall and temperature to the mean value	Positive
Low rainfall extreme		Positive
High temperature extreme		Positive
Low temperature extreme		Positive
Topographic elevation	Average topographic elevation of the province	Negative
Sensitivity		
Paddy land	Percentage of paddy land in total area	Positive
Rural population density	Percentage of rural population per km^2	Positive
Rate of rain-fed paddy	Ratio of rain-fed paddy area over irrigated paddy area	Positive
Adaptive capacity		
Farm organization	Number of agricultural organizations in the province	Negative
Literacy rate	Proportion of people who are able to read and write	Negative
Rice output	Output from rice production	Negative
Share of rice income	Percentage of rice production in the region's Gross Domestic Product (GDP)	Positive
Number of agricultural employees	Number of employees who are engaged in agriculture	Positive
Percentage of poverty	Percentage of people below poverty line	Positive

Sources: Adger 1999; Glwadys Aymone Gbetibouo and Ringler 2009; Koh 2010; Nelson 2010; Padmaja and Banerjee 2009; Wongbusarakum and Loper 2011

Adaptive capacity, on the other hand, was determined through a number of factors: farm organization, literacy rate, rice output, share of rice income, number of agricultural employees, and percentage of poverty. According to Gbetibouo and Ringler (2009), farm organization is a representation for social capital—the more farm organizations there are in the region, the more cohesive and organized the system becomes. Increasing literacy rate can reduce vulnerability because it increases people's awareness and capacity to cope, mitigate, and adapt to the impacts of climate change. Adger et al. (2004) showed that literacy rate has negative correlation with outcomes of climate disasters. Financial capital is represented through rice output and share of rice income into the region's gross domestic product (GDP). Regions that have higher output will have higher income and ability to prepare and cope with climate change. However, regions that have high share of rice income will be dependent on rice production, have less economic diversification, and become more vulnerable to climate change.

The dependence on agriculture and its relationship to climate vulnerability were also examined in the vulnerability assessment of Brooks, Adger, and Kelly (2005). The number of agricultural employees and percentage of people living under the poverty line are also indicators of the adaptive capacity of the region since regions with high percentage of agricultural workers or high percentage of people living under the poverty line will have less capacity to cope with climate change (Adger et al. 2004). This study used the United Nation's Development Programme's (UNDP) Human Development Index (UNDP 2006) method to normalize the indicators because the data were in different units and scales. The normalizing process required identifying the functional relationship between the indicators and the vulnerability (Table 1.1).

For the positive relationship, the equation for normalization was:

$$x_{ij} = \frac{X_{ij} - Min_i\{X_{ij}\}}{Max_i\{X_{ij}\} - Min_i\{X_{ij}\}}$$

For the negative relationship, the equation for normalization was:

$$x_{ij} = \frac{Max_i\{X_{ij}\} - X_{ij}}{Max_i\{X_{ij}\} - Min_i\{X_{ij}\}}$$

After being normalized, a principal components analysis (PCA) was conducted to obtain the weights for the indicators since different indicators would have different effects on vulnerability. PCA is widely applied in scientific research, especially in vulnerability assessment invarious fields (Abson, Dougill, and Stringer 2012; Hoque et al. 2012; Hughes et al. 2012; Johnson et al. 2012; Li et al. 2006; Sietz, Lüdeke, and Walther 2011).

After the weights were identified, the vulnerability index was constructed by applying the formula by Filmer and Pritchett (2001):

$$v_i = \sum_{i=1} \frac{\left[b_i\left(a_{ij} - x_i\right)\right]}{s_i}$$

Where:

v = vulnerability index;
b = weight;
a = indicator value;
x = mean indicator value; and
s = standard deviation of the indicators.

This study applied the AquaCrop Model to assess rice yield reduction in different years in the different scenarios for temperature and rainfall. AquaCrop is a model developed by the Food and Agriculture Organization (FAO) to simulate crop yield's responses to water. It is applicable to a wide range of users, including yield prediction under climate change scenarios. The model contains several components: soil; water balance; crop's characteristics, development, growth, and yield; atmosphere which includes thermal regime, rainfall, evaporative demand, and carbon dioxide (CO_2) concentration; and irrigation and fertilization practices.

Rice productivity was estimated for each of the rice seasons in the Red River Delta. The impact of climate change was then included in the model by changing the rainfall and temperature data. The baseline scenario was the rice productivity under observed temperature and rainfall. This predicted temperature and rainfall of 2030 and 2050 under different climate change scenarios for Vietnam were then integrated in the model to analyze the change in productivity. The CO_2 concentrations under low, medium, and high emission scenarios were also incorporated. Due to limitations, other data input except temperature, rainfall, and CO_2 concentration were not changed.

The selected study sites included nine provinces and two central level cities in the Red River Delta. Secondary data used in the study were collected from various government agencies.

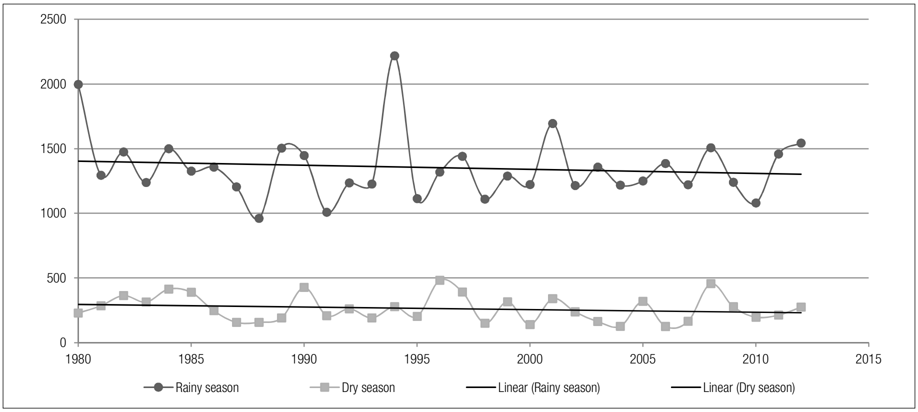
Some limitations in this study should be noted. First, the data for sea level rise was assumed to be solely facilitated by climate change. Other possible factors, such as regional tectonics, overextraction of groundwater, and other similar processes that lead to the sinking of the ground surface, were not considered. Moreover, in the simulation model for paddy yield, disease factors, impacts of salinity, and sea level rise were not taken into account. Besides, except temperature, rainfall, and CO_2 concentration, other data input such as soil characteristics or farming practices do not change much over time although these factors in reality do affect the crop yield. Lastly, although there are many varieties of paddy being used in different seasons and provinces, the study assumed that the characteristics of the varieties are not different and only estimated the yield of one rice variety in irrigated paddies for each delta.

RESULTS AND DISCUSSION

Changing Climate Trends in Red River Delta

Since 1980, there has been a significant decrease in the annual rainfall amount in the Red River Delta (Figure 1.2). At an average of 19 percent over 30 years. This trend was similar in all provinces of the region. The highest decreases were 34 percent and 28 percent in Ha Nam and Vinh Phuc provinces, respectively, while the lowest decrease was one percent over 30 years in Hai Phong (Vietnam Agricultural Science Institute 2006).

Figure 1.2. Trends in rainfall in the Red River Delta during dry and rainy seasons

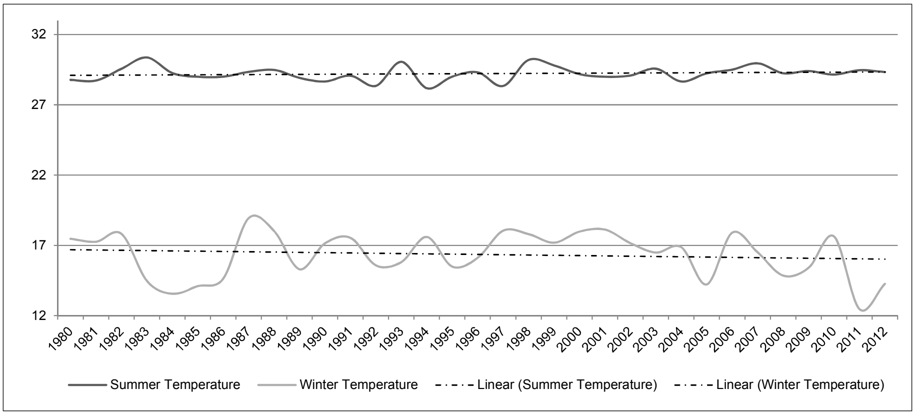


Source: Department of Environment and Natural Resources (2011); Vietnam Agricultural Science Institute (2006)

There were slight or no significant changes in the rainfall amount during the dry season, but rainfall was decreasing in the rainy season. The average decrease in the rainy season was 23 percent over 30 years. The most rainfall recorded was in 1994 while the least was in 2004 (MONRE 2012).

Since 1980, the average temperature in the Red River Delta has increased by 0.2ºC (Figure 1.3). In 2012, the province that had the highest average temperature was Hung Yen (24.73ºC) while the province with the lowest was Quang Ninh (22.6ºC). In general, the average temperature of all provinces tended to increase over 30 years. The trends in center provinces were more pronounced than coastal provinces of the region. Since 1980, the temperature during summer in the Red River Delta has increased by 0.56ºC while the winter temperature has decreased by 3.2ºC. The rate of change in winter was also faster than in summer.

Figure 1.3. Trends of temperature in summer and winter in Red River Delta



Source: Department of Environment and Natural Resources (2011); Vietnam Agricultural Science Institute (2006)

Socio-demographic Profile of the Red River Delta

The Red River Delta's population in 2011 was 19 million people, equivalent to 22.6 percent of Vietnam's total population, with a rural population of 13 million. Hanoi Province has the highest population in the region. This is also the most crowded place with over 2000 people per km^2 (Department of Agriculture and Rural Development 2012), which can be attributed to its role as the capital and economic center of the country attracting job-seekers from surrounding areas.

In 2011, the GDP of the Red River Delta was VND 710,306,603 (Department of Finance 2012). The economy in the Red River Delta mostly focused on industry and services development. Specifically, agriculture, forestry, and fishery sectors only contributed 12 percent in the delta's GDP while manufacturing contributed the most with 32 percent (Department of Finance 2012).

Since 2006, the number of employees engaging in agriculture in the Red River Delta has decreased by 27 percent. The dependence of rural households on income from agriculture, forestry, and fishery decreased from 53.45 percent to 36.78 percent, while income from industry and services increased by more than six percent (Department of Agriculture and Rural Development 2012).

The planted area for paddy production in the Red River Delta in 2011 was 1.2 million hectares (ha) and has since increased significantly from 1980. However, a reduction since 2000 can be explained by the shift in government policy from agriculture to industry and services development. There are only two paddy seasons in the delta: spring season and winter season. The low production of paddy in this area could be attributed to the differences in climate, geography, and land use practices. When categorizing the paddy land use of households, the delta showed much more fragmentations since

64.84 percent of households owned paddy land under 0.2 ha and 33.19 percent owned paddy land from 0.2 to under 0.5 ha (Department of Agriculture and Rural Development 2012).

In total, the paddy production in 2011 was 6.9 million tons. Although Nam Dinh had the largest planted area, Hanoi had the highest paddy production in the delta. This is because Hanoi has occupied Ha Tay Province, which is one of the highest paddy producers in the region, into its administrative boundaries since 2008. Therefore, the paddy production in Hanoi has been boosted significantly despite its being an industry- and services-oriented province.

Constructing the Vulnerability Index of Rice-Farming Provinces in the Red River Delta

From the PCA results based on the Kaiser criterion, the first five components had eigenvalues greater than 1. The first principal component explained 32.8 percent of the variation, the second explained 20.1 percent, the third principal component explained 15.1 percent of the difference, the fourth explained 11.5 percent, and the fifth principal component explained 7.1 percent.

In order to compute for the vulnerability index, eigenvectors were calculated then the first principal component (PC1) was chosen to represent the weights of indicators. The associated statistics of the data were determined afterwards (Table 1.2). The weights of indicators of exposure showed that change in sea level (–0.107), low rainfall extreme (–0.053), and high temperature extremes (–0.146) have negative weights in the vulnerability index. Moreover, the values of the weights of exposure indicators overall were lower than sensitivity (paddy land 0.301; rural density 0.394; and rainfed rice –0.337) and adaptive capacity indicators (farm organizations –0.308; literacy rate –0.338; rice output –0.339; share of rice income 0.108; number of agricultural employees 0.301; and poverty rate –0.071).

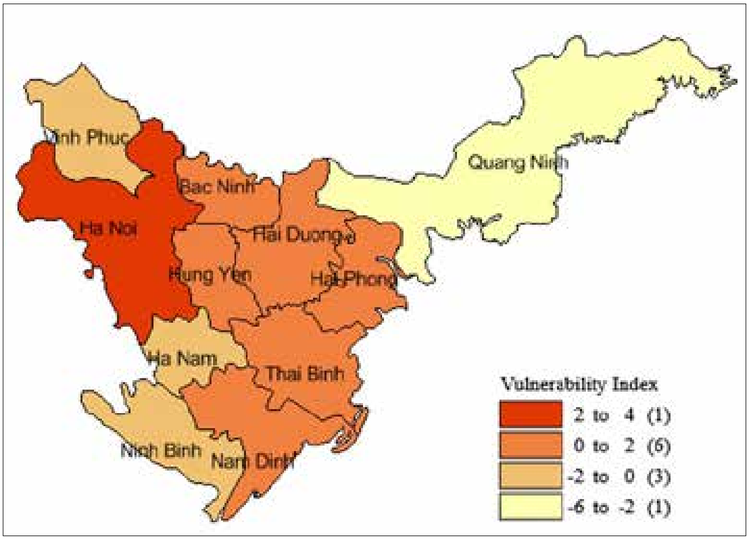
The vulnerability to climate change of each of the provinces within the Red River Delta was also determined by applying the formula of Filmer and Pritchett (2001). Rice farming in Quang Ninh had the lowest vulnerability because it is an industrial province, and paddy production and agriculture in this province are limited with low share of paddy land, low paddy production, and low dependence on agriculture in terms of GDP (Figure 1.4). Ha Nam, Vinh Phuc, and Ninh Binh were the three provinces identified as having low medium vulnerabilities (ranging from –2 to 0). These provinces were not vulnerable to projected sea level rise, had low dependence on rice income, and had low extremely high and low temperature values. On the other hand, Thái Bình, Hai Phong, Nam Dinh, Bac Ninh, Hai Duong, and Hung Yen have medium vulnerabilities (ranging from 0 to 2). Most of these provinces are located in coastal zones making them more susceptible to sea level rise; Thái Bình, Hai Duong, and Hai Phong had high values of extreme rainfall while Bac Ninh and Hung Yen had high rural population densities.

Hanoi had the highest vulnerability because of the highest value of high rainfall and low temperature extremes. It is also the most crowded province in the delta.

Table 1.2. Weights and associated statistics of indicators in the Red River Delta

Indicator	Mean	Standard Deviation	Weight: PC1
Rainfall change	0.610	0.282	0.025
Temperature change	0.455	0.522	0.265
Sea level change	0.364	0.505	−0.107
High rainfall extreme	0.668	0.335	0.085
Low rainfall extreme	0.321	0.319	−0.053
High temperature extreme	0.635	0.259	−0.146
Low temperature extreme	0.239	0.360	0.194
Elevation	0.722	0.341	0.240
Paddy land	0.676	0.287	0.301
Rural density	0.659	0.286	0.394
Rainfed rice	0.289	0.296	−0.337
Farm organizations	0.697	0.280	−0.308
Literacy rate	0.284	0.262	−0.338
Rice output	0.583	0.326	−0.339
Share of rice income	0.374	0.329	0.108
Agricultural employees	0.282	0.295	0.301
Poverty	0.597	0.346	−0.071

Figure 1.4. Vulnerability map of rice farming provinces in the Red River Delta



After constructing the vulnerability index of the Red River Delta, the study used regression analysis to analyze the relationships and the effects between vulnerability index and indicators. Simple linear regression model was estimated in which the dependent variable was vulnerability index and the independent variables were the indicators (Table 1.3).

Table 1.3. Regression analysis between vulnerability indices and indicators

Indicator	Correlation Coefficient	Probability
Rainfall change	0.058	0.865
Temperature change	0.627	0.039
Sea level change	–0.253	0.454
High rainfall extreme	0.208	0.540
Low rainfall extreme	–0.122	0.720
High temperature extreme	–0.335	0.313
Low temperature extreme	0.459	0.156
Elevation	0.571	0.067
Paddy land	0.711	0.014
Rural density	0.929	0.000
Rainfed rice	–0.801	0.003
Farm organizations	–0.727	0.011
Literacy rate	–0.804	0.003
Rice gross output	–0.797	0.003
Share of rice income	0.256	0.447
Agricultural employees	0.704	0.016
Poverty	–0.168	0.621

In terms of exposure, change in rainfall had the weakest positive relationship (0.058) to vulnerability while change in temperature had a strong positive relationship (0.627). Change in sea level indicators in the Red River Delta showed negative correlation to vulnerability (–0.253). These mean that the provinces are more exposed to predicted climatic changes. Temperature in particular, is predicted to constantly increase in the region so that it will create impacts on rice production.

The rural population density in the Red River Delta had the highest positive coefficient (0.929). This may be attributed to the crowded population in the delta, which contributed to the exposure of rice farmers. From this estimation, land use planning should be integrated in climate change mitigation plans in terms of settlement distribution by avoiding farmer concentration in hazard-prone areas.

The rate of rainfed rice and poverty rate showed negative correlation to vulnerability, which is an unexpected result. The relationship of sensitivity and adaptive capacity indicators also had higher coefficient than exposure indicators.

Estimating the Changes in Paddy Productivity under Different Climate Scenarios

From the baseline in 1980 and projected climate scenarios from MONRE (2012), climate conditions in 2030 and 2050 were computed for the low, medium, and high emission scenarios. The climate change scenarios for Vietnam were developed based on greenhouse gas (GHG) emission scenarios developed by IPCC (2000) which are: low emission scenario (B1), medium emission scenario (B2, A1B), and high emission scenario (A2, A1F).

In the Red River Delta, the trends of rainfall in the climate change scenarios were decreases from March to May (spring) and increases in the remaining months (summer, autumn, and winter); the increase of rainfall in autumn (June to August) was higher than those in summer and in winter (Table 1.4). Temperature tended to increase during all months.

There were two seasons of paddy production in the Red River Delta—spring season which starts from the end of October or the beginning of November and winter season which starts from the end of May.

In the delta, the estimated productivity of paddy under observed climate conditions in 2011 were 65.50 quintals/ha in the spring season and 55.28 quintals/ha in the winter season (Table 1.5). There were increases in productivity in the spring season (up to 18%) in climate conditions under the three scenarios; however, productivity during the winter season would decrease by about four percent.

The impacts of changes in temperature and rainfall could be seen clearly in the spring paddy. Under current climate conditions, the low temperature in the spring season (from December to May) caused stress on biomass production (13%), which reduced potential paddy production (Table 1.6). Moreover, the low rainfall from December to March also caused water stress on stomatal closure (16%). Under the three climatic scenarios, the minimum temperatures were increased so that stresses on biomass production are reduced in 2030 and 2050. Therefore, the paddy yield have better conditions to reach potential production. Moreover, the increasing trend of rainfall from December to February also reduced water stress from 16 percent in 2011 to 14 percent in 2050. These two factors contributed to the increases in paddy productivity in the spring season. In the winter season, due to the high temperature and large amount of rainfall, there was no temperature and water stress in both observed and projected climate conditions.

Table 1.4. Projected rainfall amount (mm) in the Red River Delta under different climate scenarios

Month	1980	Low Emission		Medium Emission		High Emission	
		2030	2050	2030	2050	2030	2050
January	5.3	5.3	5.4	5.3	5.4	5.3	5.4
February	31.1	31.4	31.7	31.5	31.8	31.5	31.8
March	35.9	35.7	35.5	35.7	35.4	35.6	35.4
April	106.5	105.8	105.2	105.7	105.1	105.6	104.9
May	124.1	123.2	122.5	123.1	122.4	123.0	122.3
June	324.5	334.2	341.7	334.8	343.1	335.8	344.0
July	436.9	450.4	460.8	451.2	462.7	452.6	464.0
August	448.4	462.0	472.5	462.8	474.5	464.2	475.7
September	422.6	427.5	431.2	427.8	432.0	428.2	432.3
October	204.4	206.8	208.7	207.0	209.0	207.2	209.3
November	6.9	6.9	7.0	6.9	7.0	6.9	7.0
December	33.6	33.9	34.1	33.9	34.1	33.9	34.1

Source: Department of Environment and Natural Resources (2011); Vietnam Agricultural Science Institute (2006)

Table 1.5. Estimated paddy productivity (quintal/ha) in the Red River Delta under different scenarios

Scenario	Year	Spring Paddy		Winter Paddy	
		Productivity	Change (%)	Productivity	Change (%)
	2011	65.50		55.28	
Low	2030	75.71	16.73	52.88	–4.34
	2050	76.60	18.09	52.88	–4.34
Medium	2030	75.67	16.67	52.88	–4.34
	2050	76.74	18.31	52.88	–4.34
High	2030	75.87	16.98	52.88	–4.34
	2050	76.87	18.50	52.88	–4.34

Table 1.6. Water and temperature stresses of paddy in the Red River Delta under different scenarios

Scenario	Year	Spring Paddy		Winter Paddy	
		Biomass (%)	Stomatal Closure (%)	Biomass (%)	Stomatal Closure (%)
	2011	13	16	0	0
Low	2030	3	15	0	0
	2050	2	14	0	0
Medium	2030	3	15	0	0
	2050	2	14	0	0
High	2030	3	15	0	0
	2050	2	14	0	0

CONCLUSION

From 1980 to 2011, annual rainfall decreased by 19 percent in the Red River Delta. In terms of temperature, the average temperature of summer in the region is increasing while winter's average temperature is decreasing.

Due to economic development policy, from 2006 to 2011, the dependence of income from agriculture, forestry, and fishery of rural households decreased from 53.45 percent to 36.78 percent while income from industry and services increased more than six percent. In the Red River Delta, 64.84 percent of households own paddy land under 0.2 ha and 33.19 percent own paddy land from 0.2 to under 0.5 ha.

In the Red River Delta, rice farming in Quang Ninh Province had lowest vulnerability. Ha Nam, Vinh Phuc, and Ninh Binh were the three provinces that had low medium vulnerability while Thái Bình, Hai Phong, Nam Dinh, Bac Ninh, Hai Duong, Hung Yen had medium vulnerabilities to climate change. Most of these provinces are located in coastal zones which make them more subjected to sea level rise. Hanoi had the highest vulnerability. In the principal component analysis, the first five components were significant and explained 86.60 percent of the variation.

Among the indicators, vulnerability of the Red River Delta will be exacerbated if future changes in temperature of the delta become larger and rural population density worsen. The problem of population density should be recognized and precautions should be taken and integrated into land use planning.

The results for the simulation model of paddy yield under different scenarios showed changes in the paddy yield in the Red River Delta. Specifically, the yield of spring paddy increased by 18 percent while there was a four percent decrease in winter paddy yield by 2050. The increased in paddy yield can be explained by a transformation from colder to warmer temperatures, which is more favorable for the growth of paddy.

RECOMMENDATION

The results of the study can be used as baseline information for policymakers in designing a climate change adaptation and mitigation plan for agriculture and paddy farming communities. The policies should first focus on provinces located at the coastal areas because these are the provinces (Nam Dinh, Thái Bình, and Hai Phong) that have high vulnerability level. The problem of congested population in the Red River Delta should also be prioritized. Vulnerability can also be reduced by enhancing the adaptive capacity of provinces through encouraging farmers to diversify their income sources and livelihoods and through subsidizing and supporting the poor communities.

Secondly, initial climate change mitigation actions such as preventing concentrated populations in hazard-prone areas can be done. Furthermore, the government's economic development that focuses on the industry and service sections will help reduce pressure on agriculture and lead to labor movement from agriculture to other production sectors.

Thirdly, in order to enhance and protect paddy production from the impacts of climate change, spring paddy season should be given more focus since paddy is more sensitive to changes in temperature and rainfall within these months. Although there were increases in spring paddy yield, the winter paddy yields were decreased. However, these reduction can be compensated by taking advantage of the favorable conditions in the spring season; enhancing production in this season does not only ensure agriculture production but also contributes to the food security issue in the winter paddy season when yields are reduced. Lastly, further research on the development of climate resilient varieties must be considered in planning climate change adaptation and mitigation for agriculture and paddy farming communities.

LITERATURE CITED

Abson, D. J., A. J. Dougill, and L. C. Stringer. 2012. "Using Principal Component Analysis for Information-rich Socio-ecological Vulnerability Mapping in Southern Africa." *Applied Geography* 35 (1–2): 515–524. doi:10.1016/j.apgeog.2012.08.004.

Adger, W. N. 1999. "Social Vulnerability to Climate Change and Extremes in Coastal Vietnam." *World Development* 27 (2): 249–269. doi:10.1016/S0305-750X(98)00136-3.

Adger, W. N., N. Brooks, G. Bentham, M. Agnew, and S. Eriksen. 2004. "New Indicators of Vulnerability and Adaptive Capacity." Technical Report. Norwich, England: Tyndall Centre for Climate Change Research.

Brooks, N., W. N. Adger, and P. M. Kelly. 2005. "The Determinants of Vulnerability and Adaptive Capacity at the National Level and the Implications for Adaptation." *Global Environmental Change* 15 (2): 151–163. doi:10.1016/j.gloenvcha.2004.12.006.

Department of Agriculture and Rural Development. 2012. *Statistical Data of Agriculture Forestry and Fishery of Mekong River Delta and Red River Delta in 2011*. Hanoi, Vietnam: Statistical Publishing House.

Department of Environment and Natural Resources. 2012. *Statistical Data of Land and Climate of Mekong River Delta and Red River Delta 2011*. Hanoi, Vietnam: Statistical Publishing House.

Filmer, D., and L. H. Pritchett. 2001. "Estimating Wealth Effects Without Expenditure Data—Or Tears: An Application to Educational Enrollments in States of India." *Demography* 38 (1): 115–132.

Department of Finance. 2012. *Statistical Data of National Accounts in Mekong River Delta and Red River Delta in 2011*. Hanoi, Vietnam: Statistical Publishing House.

General Statistics Office of Vietnam. 2011. *Statistical Yearbook of Vietnam 2011*. Hanoi, Vietnam: Statistical Publishing House.

Gbetibouo, G. A., and C. Ringler. 2009. "Mapping South African Farming Sector Vulnerability to Climate Change and Variability (A Subnational Assessment)". *International Food Policy Research Institute Discussion Paper* 00885. Washington, DC: International Food Policy Research Institute.

Hoque, Y. M., S. Tripathi, M. M. Hantush, and R. S. Govindaraju. 2012. "Watershed Reliability, Resilience and Vulnerability Analysis Under Uncertainty Using Water Quality Data." *Journal of Environmental Management* 109: 101–112. doi: 10.1016/j.jenvman.2012.05.010.

Hughes, S., A. Yau, L. Max, N. Petrovic, F. Davenport, M. Marshall, T. R. McClanahan, E. H. Allison, and J. E. Cinner. 2012. "A Framework to Assess National Level Vulnerability from the Perspective of Food Security: The Case of Coral Reef Fisheries." *Environmental Science & Policy* 23: 95–108. doi:10.1016/j.envsci.2012.07.012.

Intergovernmental Panel on Climate Change. 2000. *Emissions Scenarios*. Special Report. Cambridge, United Kingdom: Intergovernmental Panel on Climate Change.

———. 2001. *Climate Change 2001: Impacts, Adaptation and Vulnerability*. Third Assessment Report. Cambridge, United Kingdom: Intergovernmental Panel on Climate Change.

Johnson, D. P., A. Stanforth, V. Lulla, and G. Luber. 2012. "Developing an Applied Extreme Heat Vulnerability Index Utilizing Socioeconomic and Environmental Data." *Applied Geography* 35 (1–2): 23–31. doi:10.1016/j.apgeog.2012.04.006.

Kim, D. P., C. Saegerman, C. Douny, T. V. Dinh, B. H. Xuan, B. D. Vu, N. P. Hong, and M.-L. Scippo. 2013. "First Survey on the Use of Antibiotics in Pig and Poultry Production in the Red River Delta Region of Vietnam." *Food and Public Health* 3 (5): 247–256. doi:10.5923/j.fph.20130305.03.

Koh, J. 2011. "Local Vulnerability Assessment of Climate Change and Its Implications: The Case of Gyeonggi-Do, Korea." In *Resilient Cities: Cities and Adaptation to Climate Change*, edited by Konrad Otto-Zimmermann, 411–427. Proceedings of the Global Forum 2010, Local Governments for Sustainability, Bonn, Germany, May 28-31, 2010. doi:10.1007/978-94-007-0785-6.

Li, A., A. Wang, S. Liang, and W. Zhou. 2006. "Eco-Environmental Vulnerability Evaluation in Mountainous Region Using Remote Sensing and GIS: A Case Study in the Upper Reaches of Minjiang River, China." *Ecological Modelling* 192: 175–187. doi:10.1016/j.ecolmodel.2005.07.005.

Luers, A. L., D. B. Lobell, L. S. Sklar, C. L. Addams, and P. A. Matson. 2003. "A Method for Quantifying Vulnerability, Applied to the Agricultural System of the Yaqui Valley, Mexico." *Global Environmental Change* 13 (4): 255–267. doi:10.1016/S0959-3780(03)00054-2.

Ministry of Natural Resources and Environment. 2012. "Climate Change, Sea Level Rise Scenarios for Vietnam." Climate Change Scenarios. Hanoi, Vietnam: Ministry of Natural Resources and Environment.

Nelson, G. 2010. "Assessing the Vulnerability of Agriculture to Climate Change in Sub-Saharan Africa." Washington DC: International Food Policy Research Institute.

Padmaja, R., and R. Banerjee. 2009. "Quantitative Assessment of Vulnerability to Climate Change: Computation of Vulnerability Indices." Training on Agro-Climatic Analysis and Use of Qualitative Tools for Data Collection.Bangkok, Thailand, 2–3 Oct 2009.

Sietz, D., M. K. B. Lüdeke, and C. Walther. 2011. "Categorisation of Typical Vulnerability Patterns in Global Drylands." *Global Environmental Change* 21 (2): 431–440. doi:10.1016/j.gloenvcha.2010.11.005.

Wongbusarakum, S., and C. Loper. 2011. *Indicators to Assess Community Level Social Vulnerability to Climate Change: An Addendum to SocMon and SEM-Pasifika Regional Socioeconomic Monitoring Guidelines*. Washington DC: The Global Socioeconomic Monitoring Initiative for Coastal Management.

United Nations Development Programme. 2006. *Human Development Report 2006*. New York: United Nations Development Programme.

Vietnam Agricultural Science Institute. 2006. *Statistical Data of Climate of Vietnam from 1970 to 2005.* Hanoi, Vietnam: Statistical Publishing House.

2 Hotspots' Occurrence Classification Based on Physical, Socio-economic, and Peatlands Data

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ABSTRACT

A hotspot is one indicator of fire events that serves as early warning in forest fire management. Classifying the hotspots based on characteristics of areas where they took place can help users to anticipate their occurrences in the future. In this chapter, data mining algorithms (decision tree and Naïve Bayesian) were applied to classify hotspot occurrences in Riau Province, Indonesia, based on physical, socio-economic, as well as peatland data that influence fire events. Results of the experiment on the forest fire dataset revealed that the C4.5 decision tree model gave the highest accuracy of 69.44 percent. The model classified and predicted majority of hotspot occurrences in areas with the following characteristics: non-logging concession, covered by Saprists peat with moderate (100–200 centimeter [cm]) depth, and within bare lands and plantations. Furthermore, a high density of hotspots occurred in areas where distances from hotspots to the nearest road, river, and city center were less than or equal to 15 kilometers (km), 5 km, and 20 km, respectively. Moreover, hotspots were found in less populated areas (population of 0–4000) and in areas where the number of schools is less than or equal to five. In future studies, association rule mining using the Apriori algorithm will be applied to discover co-occurrences of hotspot and influencing factors for forest and land fires including physical, socio-economic, and peatlands data.

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INTRODUCTION

Riau Province in Indonesia is experiencing a fast rate of deforestation. During the last 25 years, Riau has lost more than four million hectares (ha) of forest cover (65%), in which forest cover decreased from 78 percent in 1982 to 27 percent in 2007 (Uryu et al. 2008). Riau province was covered by about 4,043,602 ha of peatlands in 2002 that spread in 12 districts (Wahyunto et al. 2005). The study by Uryu et al. (2008) found that the majority of the deforestation in Riau has occurred on peat soil.

Forest fires and peatland fires are one of the major causes of deforestation in Riau. More than 72,000 active fires (hotspots) were recorded in Riau by the National Oceanic and Atmospheric Administration's (NOAA) Advanced Very High Resolution Radiometer (AVHRR) and Moderate Resolution Imaging Spectroradiometer (MODIS) satellite sensors in the period of 1997 to 2007 (Uryu et al. 2008). The total emission in Riau was estimated to be about 3.66 gigatons (Gt) carbon dioxide (CO_2) between 1990 and 2007, which resulted from deforestation, forest degradation and decomposition, and burning of peat (Uryu et al. 2008).

Forest fires have detrimental effects on various aspects of life such as on the natural environment and on the economic and health conditions of people. Moreover, the effects of peatland fires are dangerous because these not only produce CO_2 emissions but also smoke haze problems. The smoke from peatland fires influences city traffic, sea transportation and flights, human health, and other economic losses (Herawati, Santoso, and Forner 2006).

Hotspots (active fires) represent spatial distribution of fire indicators that are important to study as a fire prevention activity, so that the damage due to forest fires can be minimized. Several methods such as logistic regression have been applied to predict hotspots occurrence. In addition, nowadays, data mining techniques have been successfully used to develop predictive models for hotspots occurrence.

This study created classification models for hotspots occurrence in Riau Province Indonesia using the classification algorithms in data mining, namely the decision tree and the Naïve Bayesian. Several influencing factors for forest fires were considered to classify hotspots' occurrence. These factors include land cover, roads, rivers, city centers, industrial timber plantation (ITP), logging concession, peatland, and socio-economic data (inhabitants' population, inhabitants' income source, and number of schools).

METHODOLOGY

Area of Study

The study area was Riau Province, Sumatera Island in Indonesia (Figure 2.1). The total area of Riau Province is approximately 8,915,016 ha or 89,150 kilometers^2 (km^2) consisting of both land and water areas. It is situated between 01°05'00" south latitude and 02°25'00" north latitude (Pemerintah Provinsi Riau 2011). The province is bounded by the Malaka Strait and the province of North Sumatera to the north, the province of Jambi and West Sumatera to the south, the Riau Islands and Malaka Strait to the east, and the province of West Sumatera and North Sumatera to the west (Pemerintah Provinsi Riau 2011).

Spatial and Non-Spatial Data

Two categories of data were utilized in this study, i.e. spatial and non-spatial data. Non-spatial data were the socio-economic data for villages in Riau Province represented in the DBF (Database file) format. These included the inhabitants' population, inhabitants' income source, and number of elementary, junior high, and senior high schools, which were collected from Statistics Indonesia (Badan Pusat Statistik, Indonesia). Spatial data, on the other hand, comprised the physical data, peatland data, and hotspots 2008 (Table 2.1). The datum WGS84 was assigned as the spatial reference system of all the spatial data in this study.

Data Pre-processing

Classification algorithms in data mining require datasets that contain some predictor attributes and one target attribute. These attributes characterize objects in the dataset. In the forest fire dataset, there were two types of objects, i.e. the target objects and the explanatory objects. Target objects were true and false alarm data. True alarm

Figure 2.1. Study area

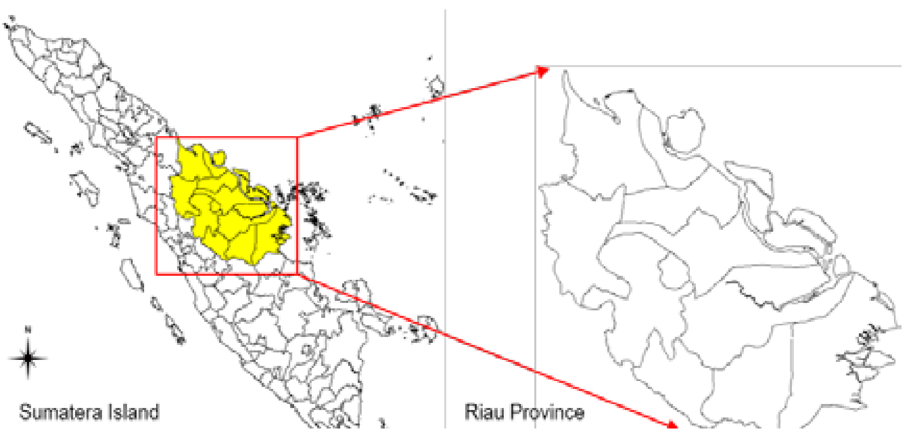
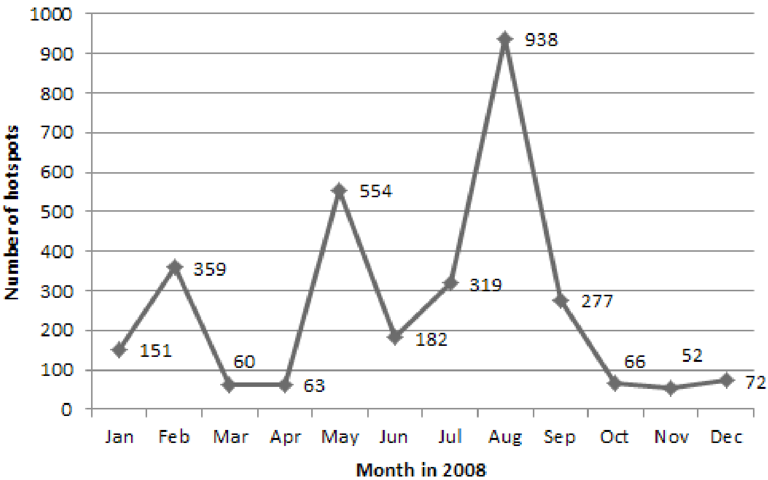


Table 2.1. Spatial data

Data	Source
Spread and coordinates of hotspots 2008	Ministry of Environment, Indonesia
Physical data: land cover, road, river, city center	National Land Agency (BPN) Riau Province, Indonesia
Administrative border for village, subdistrict, district, and province	Statistics-Indonesia (BPS-Indonesia)
Peatland depth and peatland types	Wetland Indonesia

Figure 2.2. Hotspots' distribution in Riau in 2008



data were 3,092 hotspots that spread in Riau Province in 2008 (Figure 2.2). The highest number of hotspots recorded in 2008 was 938 which occurred in August. This decreased from September to December when the rainy season began.

False alarm data are non-hotspot points which were randomly generated and were located within the area at least 1 km away from any true alarm data (Figure 2.3). As many as 3,300 random points were generated as false alarm data. These points were merged with hotspots 2008 to create the target layer (Figure 2.4).

Explanatory objects are physical, socio-economic data that may influence fire events in the study area. In the spatial database, explanatory objects and the target objects were organized in layers. Several pre-processing steps were conducted to relate explanatory layers to the target layer in order to create a dataset for hotspots' occurrence classification. All steps were performed using open source tools, namely: Quantum GIS 1.0.2 for spatial data analysis and visualization, PostgreSQL 8.4 as the spatial database management system, and PostGIS 1.4 for spatial data analysis. The

Figure 2.3. False alarm data being randomly generated outside buffers of true alarm data

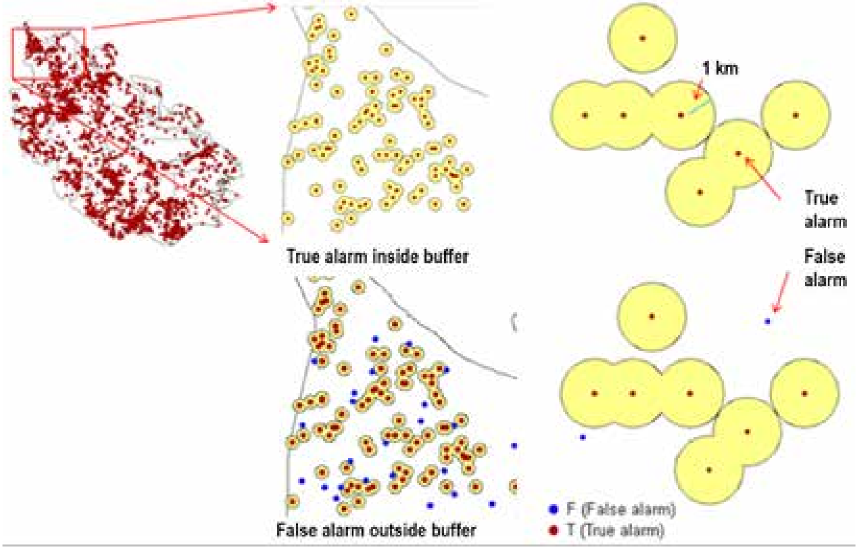
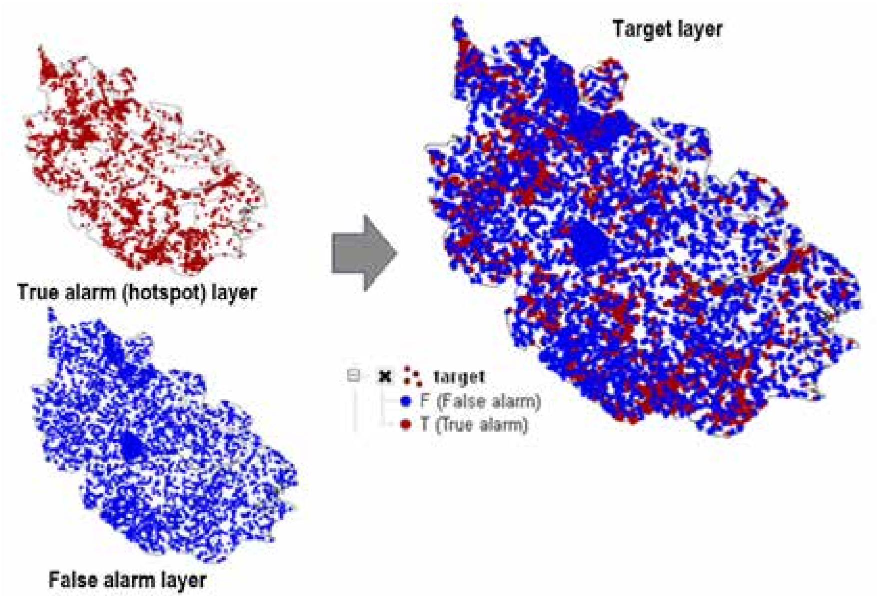


Figure 2.4. True alarm data are merged with false alarm data



distance between two objects was calculated in the decimal degree because all maps were referenced using WGS84. The decimal degree units were then converted to meters to prepare the final datasets. The pre-processing steps on explanatory layers are described as follows:

Physical Data

Distance target objects to nearest road, river, and city center

Relations between target objects and explanatory objects were determined by calculating distance of target objects to the nearest road, river, and city center. To accomplish this task, the PostGIS operation *ST_Distance* was applied. This operation computes distance from each target to all rivers, road networks, and city centers. The minimum value as distance from a target to the nearest road, river, and city center was then identified.

Land cover

There are 13 types of land cover: plantation (31.19% of the whole study area), dryland forest (19.20%), unirrigated agricultural field (9.08%), shrubs (8.97%), natural forest (8.90%), mix garden (8.80%), paddy field (4.38%), bare land (3.32%), swamp (2.44%), mangrove (1.67%), settlement (1.39%), water body (0.63%), and embankment (0.02%). Types of land cover for areas where target objects are located were determined. For this purpose, the topological operation *ST_Within* in PostGIS was applied to identify target objects inside an area and its type of land cover. There were 29 target objects located in more than one polygon of land cover (Figure 2.5) wherein smaller polygons were inside larger polygons. Only target objects in smaller polygons were considered for further processes. Some objects in the target layer were overlaid with the land cover layer (Figure 2.6).

Logging concession and industrial timber plantation

The logging concession layer and the industrial timber plantation (ITP) layer did not cover the whole study area, i.e. Rokan Hilir. Therefore, in order to relate target objects with polygons for logging concession and ITP, it had to be determined whether objects were in these polygons or not. The topological operation *ST_Within* in PostGIS was applied to determine target objects inside the logging concession layer and the ITP layer. Some objects in the target layer were overlaid with the logging concession layer and the ITP layer (Figure 2.7).

Peatland

Peatland types and peatland depth are two important characteristics of peatland used in this study. About 40,191 km^2 of the study area were covered by peatland. Several peatland types are Saprists/Hemists(60/40),Very deep (29.25% of the whole peatlands),

Figure 2.5. A target object (yellow point) located in two polygons (with red border)

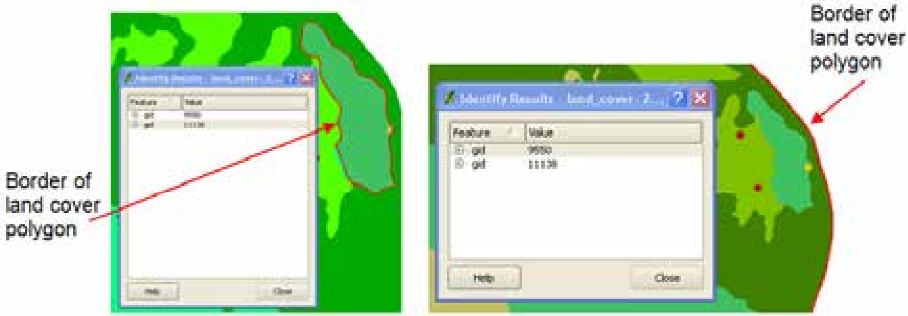


Figure 2.6. Objects in the target layer overlaid with the land cover layer

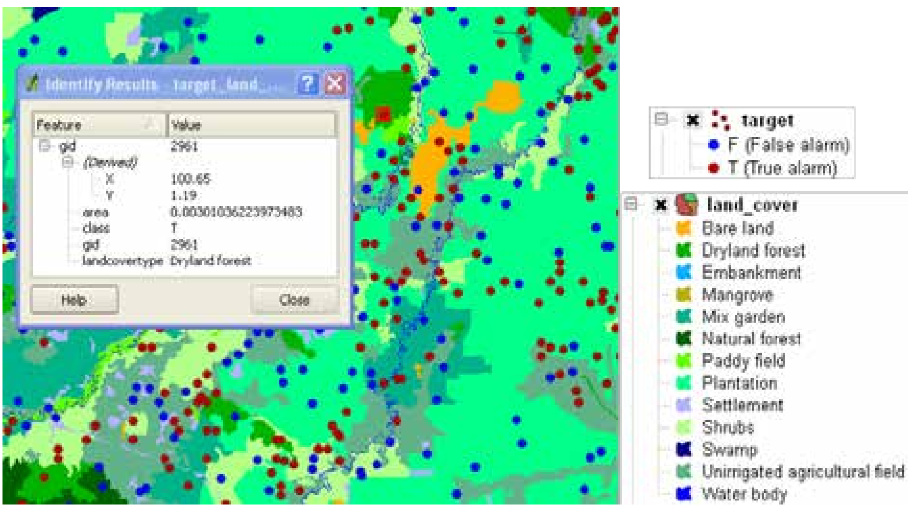
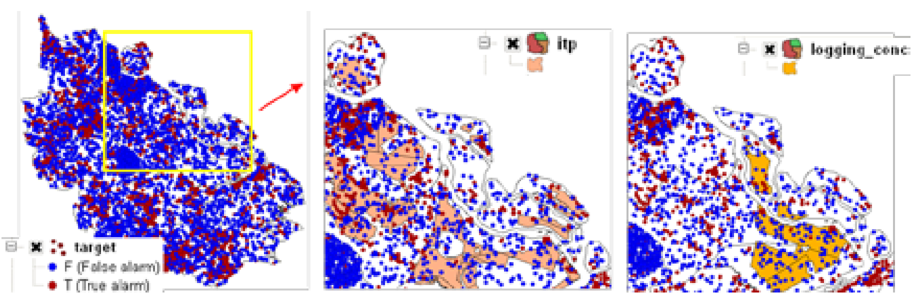


Figure 2.7. The target layer overlaid with the ITP layer and the logging concession layer



Hemists/Saprists(60/40), Moderate (27.02%), Hemists/Saprists(60/40), Very deep (20.60%), Saprists/Hemists(60/40), Deep (10.58%), and other types (11.98%). The label in peatland type for example "Hemists/Saprists(60/40), Moderate" is described as follows: Hemists and Saprists are peatland types; the values 60 and 40 mean that the area is covered by 60 percent Hemists and 40 percent Saprists, respectively. Moderate is a category of peatland depth. In addition, peatland depth is divided into five categories, namely: D0 (Very shallow/Very thin: < 50 centimeters [cm]) (2.12%), D1 (Shallow/Thin: 50–100 cm) (14.21%), D2 (Moderate: 100–200 cm) (23.15%), D3 (Deep/Thick: 200–400 cm) (20.54%), and D4 (Very Deep/Very thick: > 400 cm) (39.99%). The peatland types layer, peatland depth layer, and some target objects were overlaid with these two layers as well (Figures 2.8 and 2.9). The topological operation *ST_Within* in PostGIS was applied to select target objects inside peatlands.

Socio-economic data

Socio-economic data were extracted from the village potential survey which is conducted by Statistics Indonesia every four years. This study used socio-economic data from the village potential survey 2008 represented in the DBF format. The data include population, inhabitants' income sources, number of elementary schools, number of junior high schools, and number of senior high schools. The digital maps (the shapefile format) for socio-economic data were created using the village border map.

Three steps were performed in socio-economic data pre-processing: (1) matching identifiers for districts, subdistricts and villages in the DBF format to those in the village border map, (2) handling null values for some villages, and (3) modifying categorical values for income source. These steps are described as follows:

Identifier matching

The digital map for village border was for the year 2007, while the socio-economic data were selected from village potential data for the year 2008. There were 23 villages in the socio-economic data with identifiers different from those in the village border

Figure 2.8. Peatland types overlaid with the target layer

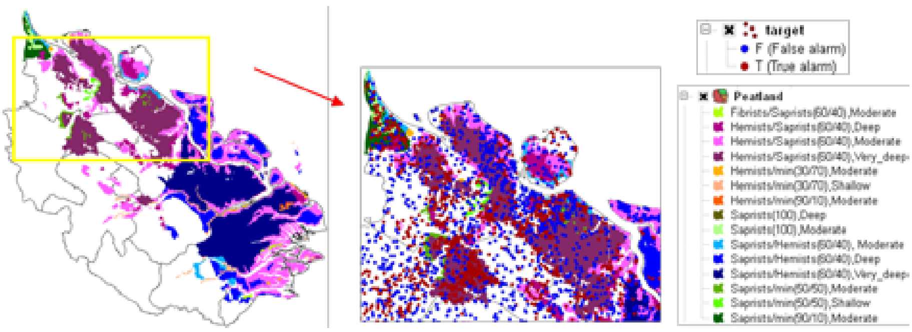
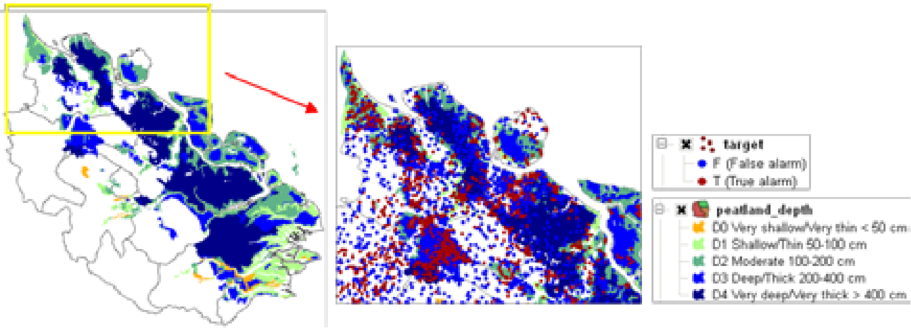


Figure 2.9. Peatland depth overlaid with the target layer



map. To overcome this inconsistency, identifiers in the map based on information from Statistics Indonesia were replaced so that the data from two different years can be related.

Handling null values

There were three villages with no data; two of these villages were located in the forest. Therefore, the value 0 for the attributes *population*, *income source*, *number of elementary, junior high,* and *senior high schools* in the forest areas was assigned because it was assumed that there were no people living in the forest. Bagan Punak Pesisir (Gid=1383), a non-forest village, had no data for all socio-economic attributes. GID is a unique identifier for every row of the table in PostGIS. New values were assigned to this village based on its neighbors. The topological operation *ST_Touches* in PostGIS was applied to find all neighbors that met Village Bagan Punak Pesisir.

Moreover, data on the types of income source were taken from values of neighbor polygons. All these polygons had agriculture as the income source (Figure 2.10). Therefore, the income source *agriculture* was assigned to the Village Bagan Punak Pesisir (Gid=1383). The population and number of schools were replaced by values of the nearest villages that had the same area. Three villages near the Village Bagan Punak Pesisir with the area of 38.513 km^2 have been identified, namely: Sungai Sialang, Sungai Sialang Hulu, and Bantayan Hilir (Figure 2.11).

Modifying categorical values for income source

Based on the village potential survey data in 2008 by Statistics Indonesia, income source labels include: agriculture; mining; manufacture; large/small scale trading, restaurant; transportation, warehousing, communication; services; and gas, electricity, banking, and the like. Most of the villages in the Riau Province had agriculture as income source (Figure 2.12). The purpose of income source modification was to identify the type of land cover for all villages that have *agriculture* as income source.

Figure 2.10. Three neighbor polygons of the Village Bagan Punak Sesisir

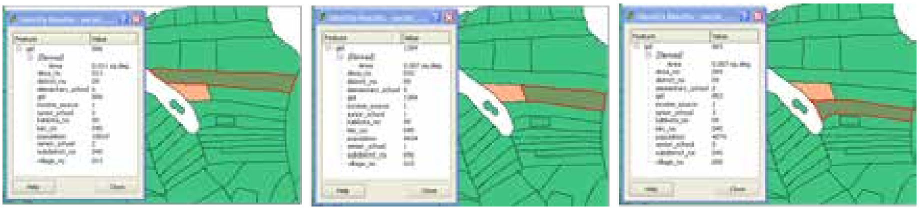
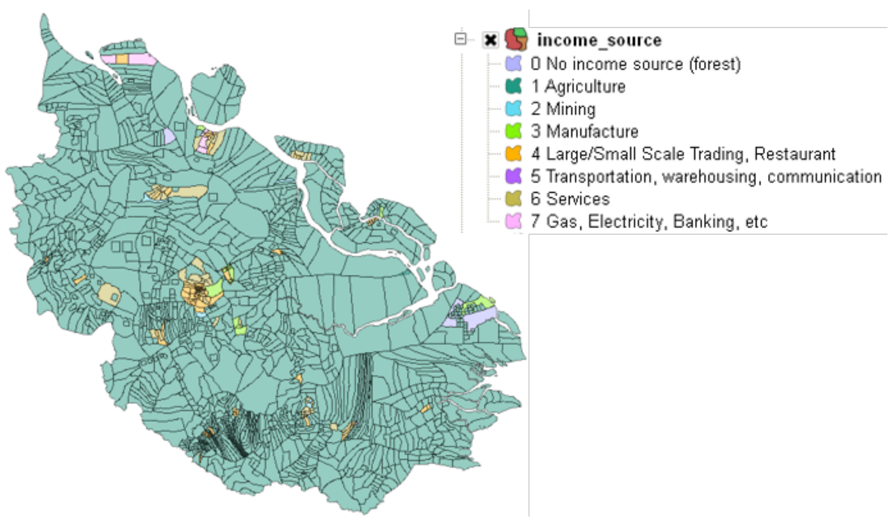


Figure 2.11. Three villages near Bagan Punak Pesisir with an area of 38.513 km^2

Figure 2.12. Income source layer



The land cover layer was then overlaid with the village border layer (Figure 2.13). In the figure, colorful polygons represent land cover types and black lines represent borders of villages. One village may be covered by more than one land cover type. A type of land cover that has the largest area was selected to modify the values for the attribute *income source*. Furthermore, the selected type was combined with the income source *agriculture* to create a new value for *income source*. The topological operation *ST_Intersection* in PostGIS was applied to define all intersection areas between the land cover layer and the income source layer.

A village (yellow area) located in an area wherein swamp constituted majority of the land cover type was illustrated (Figure 2.14). The value of income source for this village was renamed to *agriculture (swamp*) indicating that the area with the inhabitants' income source is agriculture and most of the area is covered by swamp.

Figure 2.13. The land cover layer overlaid with the village border layer

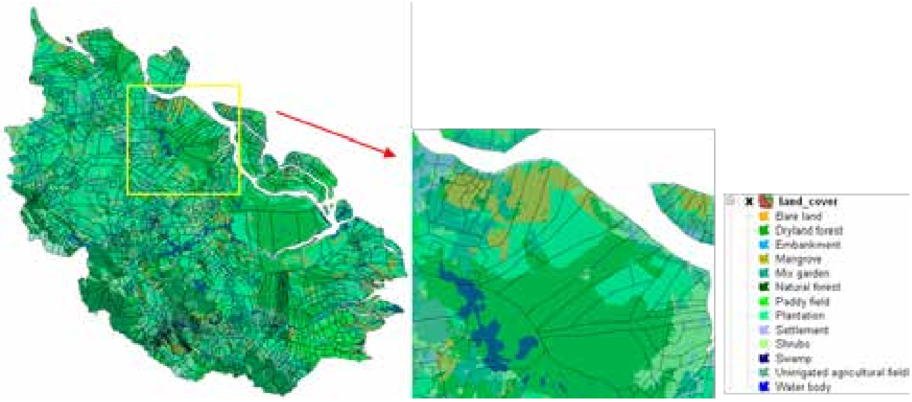
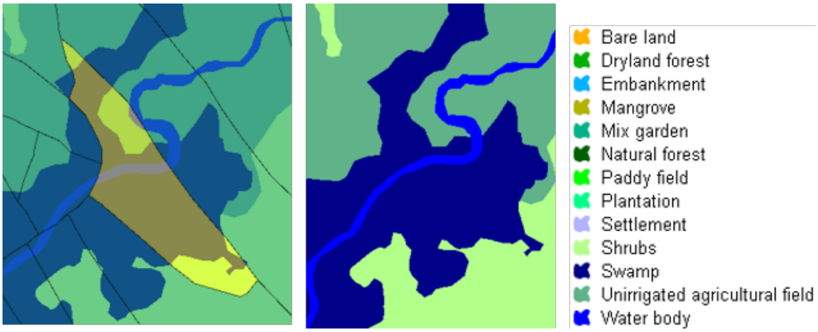


Figure 2.14. A village with Gid of 63 (yellow area) located in swamp



Creating a Dataset for Classification Task

All explanatory layers were related to the target layer using spatial operations including *ST_Within* and *ST_Distance*. The results are several new layers that are associated to an explanatory layer and the target layer. Moreover, these new layers were integrated by matching identifiers of objects in the target layer and those in explanatory layers. This operation produced another new layer. The new layer contains some non-spatial attributes and a spatial attribute. The spatial attribute stores the geometry type of spatial objects. In the DBMS PostgreSQL, the_geom denotes this spatial attribute. The spatial attribute was removed because only non-spatial attributes are used as the input for the classification algorithms. Furthermore, duplicate objects were deleted from the non-spatial dataset. The dataset, after removing the duplicate objects, contained 2,693 objects (1,373 objects that have the class True and 1,320 objects that have the class False). Table 2.2 lists the fields/attributes in the dataset.

Two decision tree algorithms available in the data mining toolkit Weka 3.6.2: J48 module as Java implementation of C4.5 algorithm and SimpleCart were applied. For comparison, the algorithm NaïveBayes was also run to develop classifiers on datasets. Furthermore, 10-folds cross validation was used to determine the accuracy of the classifiers. The accuracy of classifiers for forest fire data in the study area was also determined (Table 2.3).

Classification Algorithms

A classification task in data mining extracts models from a dataset. These models describe data classes or predict future data trends (Han and Kamber 2006). In this task, the dataset was divided into two sets, namely training set and testing set. The training set was used in the learning phase in which a classification algorithm was applied to create a classification model (a classifier). The testing set was utilized to assess the accuracy of the classification model. The training set consisted of data tuples and their associated class labels. A tuple is represented by an n-dimensional attribute vector which describes n measurements made on the tuple from n attributes (Han and Kamber 2006).

In addition to n attributes, the class label attribute determines a predefined class of each tuple in the dataset. The class label attribute is discrete-valued and unordered (Han and Kamber 2006). In this study, the class label attribute was hotspots occurrence that consisted of the true class (hotspot) and the false class (non-hotspot). Other attributes were factors influencing fire events.

The decision tree is one of the widely used methods in classification. A decision tree is a model expressing classification rules. This structure has three types of nodes, i.e. a root node, internal nodes, and leaf or terminal nodes. The labels of root node and internal nodes are attribute test conditions which separate tuples in the dataset. Moreover, the label of a leaf node is a class label. The C4.5 algorithm is the successor

Table 2.2. Fields in the data set

Field	Description
Physical data	
min_dist_to_road	Distance from target data to nearest road in km
min_dist_to_river	Distance from target data to nearest river in km
min_dist_to_city	Distance from target data to nearest city center in km
landcovertype	Land cover type for the area where target data are located
in_logging_conc	Logging concession in the area where target data are located
in_itp	Industrial Timber Plantation in the area where target data are located
peatland_type	Peatland type
peatland_depth	Peatland depth
Socio-economic data	
population	Number of population in the village where target data are located
income_source	Types of inhabitant's income source in the village where target data are located
school	Number of schools in the village where target data are located (sum of number of elementary schools, junior high schools, and senior high schools)
Target	
target	Target attribute containing true and false alarm (true alarm data –hotspot in 2008 for all areas in Riau Province, false alarm data – randomly generated outside 1 km buffer for true alarm data)

Table 2.3. Accuracy of classifiers

Algorithm	Accuracy (%)	Size of Tree
J48	69.43	Number of Leaves: 441 Size of the Tree: 609
SimpleCart	67.40	Number of Leaf Nodes: 150 Size of the Tree: 299
NaiveBayes	60.79	-

of ID3 that learns decision tree classifiers. The C4.5 algorithm uses information gain to select optimal splitting attributes and applies the post-pruning method to simplify the tree. There are three main tasks in the C4.5 algorithm: (1) generate the tree using the ID3 algorithm, (2) convert the tree to a set of if-then rules, and (3) prune each rule by removing preconditions if the accuracy of the rule increases without it (Marsland 2009). In addition to decision tree algorithms, Naïve Bayesian Classifier can be used to develop classification models. This method learns conditional probability of each attribute A_i given the class label C from training data (Friedman et al. 1997). Classification is then performed by applying the Bayes rule to compute the probability of C given the particular instance of A_1, …, A_n, and then predicting the class with the highest posterior probability (Friedman et al. 1997).

RESULTS AND DISCUSSION

Building Classifier

The C4.5 decision tree generated by the J48 module had the highest accuracy of 69.43 percent compared to SimpleCart and NaiveBayes (Table 2.3). However, SimpleCart gave a simpler tree with a size of 299, while that of the C4.5 decision tree was 609. The size of a tree refers to the number of nodes in the tree including the root, internal nodes, and leaf nodes.

The C4.5 decision tree generates as many as 441 classification rules. Some of the rules are as follows:

Rule 1: IF in_logging_conc = no AND landcovertype = Plantation AND population ≤ 4,174 AND income_source = Agriculture (Plantation) AND Peatland type = Hemists/Saprists (60/40), Very_deep AND min_dist_to_road ≤ 5.2161km AND min_dist_to_city > 4.9347 km THEN Hotspot Occurrence = T (87.0/16.0)

Rule 2: IF in_logging_conc = yes AND min_dist_to_road > 5.212 km AND land cover type = Dryland_forest THEN Hotspot Occurrence = F (140.0/13.0)

Rule 3: IF in_logging_conc = no AND land cover type = Shrubs THEN Hotspot Occurrence = T (111.0/27.0)

Rule 4: IF in_logging_conc = no AND land cover type = Unirrigated_agricultural_field AND income_source = Agriculture (Plantation) THEN Hotspot Occurrence = T (48.0/15.0)

Rule 5: IF in_logging_conc = no AND land cover type = Dryland_forest AND 9.2098 km < min_dist_to_road ≤ 45.9107 km AND depth = D4 (Very deep/Very thick > 400 cm) AND population > 1,078 AND min_dist_to_city > 5.4983 km AND in_itp = no AND school ≤ 3 AND income_source = Agriculture (Dryland forest) THEN Hotspot Occurrence = F (49.0/4.0)

Rule 6: IF in_logging_conc = no AND land cover type = Paddy_field AND min_dist_to_road > 29.4092 km THEN Hotspot Occurrence = T (29.0)

Rule 7: IF in_logging_conc = yes AND min_dist_to_road ≤ 5.212 km THEN Hotspot Occurrence = T (23.0/8.0)

The numbers in parentheses on each rule represent the number of examples associated with the rule whereas the number of misclassified examples is given after a slash. Rule 1 states that as many as 87 hotspots occurred in the area which had the following characteristics:

- No logging concession in the area
- Number of population was 4,174
- Inhabitants' income source was *agriculture* wherein most of the areas were covered by plantation

These hotspots were located in the area covered by peatland with depth that was greater than 400 cm (very deep). The peatland was composed of 60 percent Hemists and 40 percent Saprists.

The distance of hotspots to the nearest road was equal or less than 5.22 km, whereas the distance to the nearest city center was greater than 4.93 km.

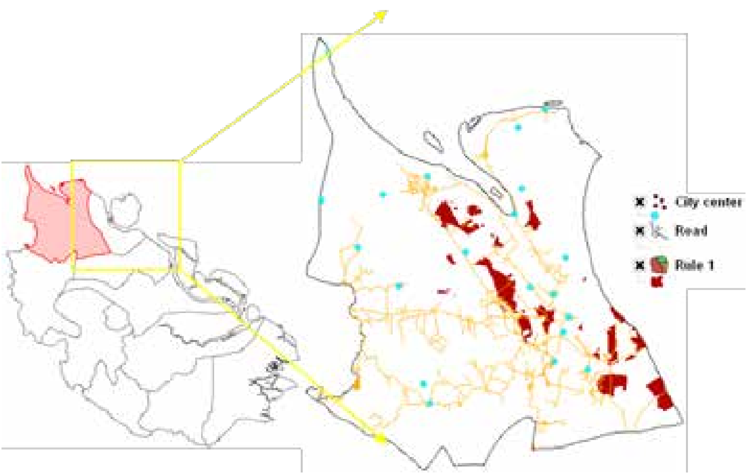
An area in District Rokan Hilir agreed with Rule 1 as generated from the dataset (Figure 2.15).

Hotspots' Classification Using the C4.5 Decision Tree

The C4.5 decision tree classifies hotspots occurrence based on the explanatory (predictor) attributes. Furthermore, this model can be used to predict hotspots' occurrence in a new area according to the characteristics of the area. The number of actual and predicted hotspots grouped by peatland type, peatland depth, land cover types, industrial timber plantation, and logging concession were determined.

The C4.5 decision tree predicted as many as 467 hotspots in Hemists/ Saprists(60/40),Very_deep, with the density of hotspots (number of hotspots per unit area of 1 km^2) at 0.056. Moreover, hotspots most likely occurred in areas covered by Saprists with depth of Moderate (100–200 cm) (Table 2.4). The density of actual

Figure 2.15. Area that agrees with Rule 1



hotspots in Saprists(100),Moderate and Saprists/min(90/10),Moderate were 0.098 and 0.085, respectively, whereas the density of predicted hotspots in these two peatland types were 0.102 and 0.109, respectively. Moreover, there were no predicted hotspots in fibrists. These results agree with those of the study in Pelalawan District in Riau Province that was conducted by Saharjo (2003) in Adinugroho et al. (2005). This study showed that fire had damaged sapric peat with thickness of 15.44–23.87 cm and hemic peat with thickness of 6.00–12.60 cm. Furthermore, it found that none of the fibric peat appeared to have been burnt in Pelalawan.

In terms of peatland depth, there were 484 hotspots that occurred in the peatlands with depth of 200–400 cm (Table 2.5). The C4.5 decision tree predicted 538 hotspots taking place in these peatlands with density of hotspots at 0.065. On the other hand, only 17 hotspots were identified for depths at less than 50 cm.

According to Pyne, Andrews, and Laven (1996), fire requires three factors, i.e. appropriate fuel, adequate oxygen, and enough heat. Land cover types such as plantation and forests, provide fuel for fire ignition. The Riau Province is largely covered by plantation with an area of 28,188.69 km^2 (about 31.19% of Riau) (Table 2.5). Moreover, for this land cover type, 651 hotspots were found and 659 hotspots were predicted (Table 2.6). The results further showed that the fire density for bare land had the highest susceptibility, while the fire density for natural forest and mangrove exhibited low susceptibility.

Fires may also be found in logging concessions and industrial timber plantations. According to Stolle and Lambin (2003), logging concessions were not very much affected by fires, and only had small, scattered fires caused by accidents or created to improve access to forests. During dry season, fire occurrences increased. Large-scale burning was much more likely to take place in areas allocated to plantations (Stolle and Lambin 2003). In these areas, fire is used to clear land before planting. Moreover, poor logging practices resulted in large amounts of waste wood left in the forest that highly increased fire hazard (Schweithelm and Glover 1999).

About 21 percent (18,687 km^2) of the study area was covered by ITPs with 394 (29%) hotspots in 2008 (Table 2.7). The C4.5 decision tree estimated 371 hotspots taking place in ITP with the density of predicted hotspots at 0.020. On the other hand, only 6,368.5 km^2 or about seven percent constituted logging concession areas in Riau. The hotspots density for non-logging concession area indicates the highest susceptibility with the number of predicted hotspots in this area at 1,380 (Table 2.8).

Roads, rivers, and city centers are determinant factors for human presence and activities. Human activities that influence the occurrence and potentially increase the risk of fires include road development, resettlement (Santoso 2006), and rivers (Almeida 1994). Roads represent areas of higher fire risk because of the influence of human activities (Almeida 1994). In addition, roads are potential routes for hiking or camping areas that may initiate fires (Chuvieco and Congalton 1989). According to Almeida (1994), the consideration of the proximity to rivers is also important because of its influence in humidity and vegetation type.

Table 2.4. Number of actual and predicted hotspots grouped by peatland type

Peatland Type	Area (km^2)	Actual Hotspots 2008	Actual Hotspots/km^2	Predicted Hotspots	Predicted Hotspots/ km^2
Fibrists/Saprists(60/40),Moderate	106.62	1	0.009	0	0
Hemists/min(30/70),Moderate	179.10	3	0.017	4	0.022
Hemists/min(30/70),Shallow	591.00	20	0.034	25	0.042
Hemists/min(90/10),Moderate	82.47	1	0.012	0	0
Hemists/Saprists(60/40),Deep	1,871.58	95	0.051	110	0.059
Hemists/Saprists(60/40),Moderate	10,859.24	225	0.021	183	0.017
Hemists/Saprists(60/40), Very_deep	8,277.85	452	0.055	467	0.056
Saprists(100),Deep	14.58	0	0	0	0
Saprists(100),Moderate	264.98	26	0.098	27	0.102
Saprists/Hemists(60/40),Moderate	813.73	48	0.059	53	0.065
Saprists/Hemists(60/40),Deep	4,254.13	167	0.039	186	0.044
Saprists/Hemists(60/40), Very_deep	11,756.90	251	0.021	244	0.021
Saprists/min(50/50),Moderate	318.75	23	0.072	30	0.094
Saprists/min(50/50),Shallow	168.35	7	0.042	8	0.048
Saprists/min(90/10),Moderate	632.69	54	0.085	69	0.109

Table 2.5. Number of actual and predicted hotspots grouped by peatland depth

Peatland Depth	Area (km^2)	Actual Hotspots 2008	Actual Hotspots/ km^2	Predicted Hotspots	Predicted Hotspots/ km^2
D0 (Very shallow/Very thin: < 50 cm)	851.80	17	0.020	20	0.023
D1 (Shallow/Thin: 50–100 cm)	5,710.18	136	0.024	137	0.024
D2 (Moderate: 100–200 cm)	9,303.14	332	0.036	341	0.037
D3 (Deep/Thick: 200–400 cm)	8,255.98	484	0.059	538	0.065
D4 (Very Deep/Very thick: > 400 cm)	16,070.87	404	0.025	370	0.023

Table 2.6. Number of actual and predicted hotspots grouped by land cover type

Land Cover Type	Area (km²)	Actual Hotspots 2008	Actual Hotspots/ km²	Predicted Hotspots	Predicted Hotspots/ km²
Plantation	28,188.69	651	0.023	659	0.023
Dryland forest	17,357.01	230	0.013	197	0.011
Unirrigated agricultural field	8,211.45	90	0.011	98	0.012
Shrubs	8,110.30	91	0.011	115	0.014
Natural forest	8,045.22	15	0.002	16	0.002
Mix garden	7,957.06	65	0.008	69	0.009
Paddy field	3,962.57	67	0.017	61	0.015
Bare land	3,005.07	127	0.042	158	0.053
Swamp	2,206.56	33	0.015	30	0.014
Mangrove	1,509.46	2	0.001	1	0.001
Settlement	1,254.84	2	0.002	2	0.002
Water body	565.55	0	0	0	0
Embankment	14.15	0	0	0	0

Table 2.7. Number of actual and predicted hotspots grouped by presence or absence of industrial timber plantation

Industrial Timber Plantation	Area (km²)	Actual Hotspots 2008	Actual Hotspots/ km²	Predicted Hotspots	Predicted Hotspots/ km²
Present	18,687.01	394	0.021	371	0.020
Absent	70,644.75	979	0.014	1035	0.015

Table 2.8. Number of actual and predicted hotspots grouped by presence or absence of logging concession

Logging	Area (km²)	Actual Hotspots 2008	Actual Hotspots/ km²	Predicted Hotspots	Predicted Hotspots/ km²
Present	6,368.50	40	0.006	26	0.004
Absent	82,963.26	1333	0.016	1380	0.017

The number of actual and predicted hotspots grouped by distance to nearest road (km), distance to nearest river (km), and distance to nearest city center (km) were also determined. The findings showed that the number of actual and predicted hotspots declined as the distance of hotspots to the nearest road increased (Figure 2.16). Most of the hotspots appeared in the locations where distance of the location to nearest road was less than or equal to 15 km.

Hotspots' distribution based on the distance to nearest river gave the same trend as those based on the distance to nearest road (Figure 2.17). Less hotspots occurred in areas farther from the nearest river. The actual and predicted hotspots were concentrated in locations where their distance to the nearest river was less than or equal to 5 km. Classification of actual and predicted hotspots based on the distance to nearest city center presented a slightly different pattern compared to classification based on roads and rivers (Figure 2.18). Actual and predicted hotspots were mostly found in locations where their distance to the nearest city centers was less than or equal to 20 km. Fewer hotspots were found in locations which were 35 km or more away from city centers.

Socio-economic factors, i.e. population and number of schools, were also considered in this study. It was found that hotspots mostly occurred in less populated areas (villages) (Figure 2.19). A high number of hotspots were found in the villages with populations ranging from 0 to 4000. Furthermore, about 1,500 hotspots occurred in the villages where the number of schools is less than or equal to five (Figure 2.20).

CONCLUSION

This study applied decision tree algorithms and the Naïve Bayesian algorithm on a forest fire dataset for the Riau Province, Indonesia. The dataset was consisted of physical, socio-economic, and peatlands factors that influence hotspots' occurrence. Several pre-processing steps using spatial operations were conducted to integrate spatial data and to prepare a task relevant dataset for the algorithms.

Experiments on the forest fire dataset showed that the best classification model was the C4.5 decision tree with an accuracy of 69.44 percent. Based on the model, hotspots were most likely to occur in non-logging concession areas and those locations covered by Saprists peat with depth of Moderate (100–200 cm). In addition, most actual and predicted hotspots took place in bare lands and plantations, which could provide fuel for fire ignition. Most hotspots were also found not far from roads and rivers where people have easy access to plantation and bare land. Furthermore, a high number of hotspots were predicted to occur in locations near roads, rivers, and city centers. Distance of hotspot locations to the nearest road was less than or equal to 15 km, distance to the nearest river was less than or equal to 5 km, and distance to the nearest city center was less than or equal to 20 km. Hotspots also took place in less populated areas (populations ranging from 0 to 4,000) and where the number of schools was less than or equal to five.

Figure 2.16. Number of actual and predicted hotspots grouped by distance to nearest road (km)

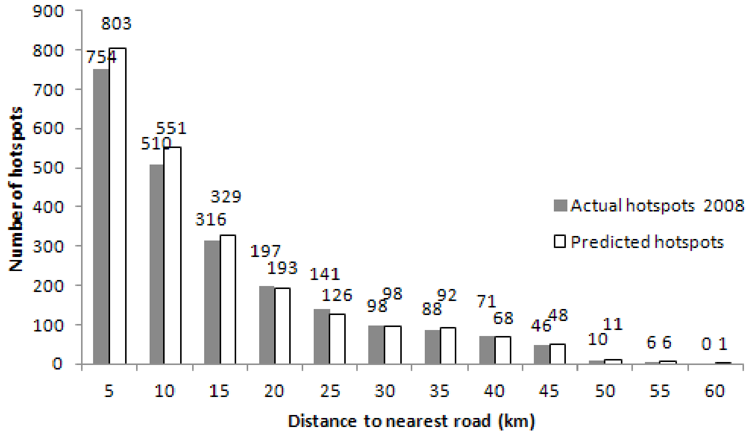


Figure 2.17. Number of actual and predicted hotspots grouped by distance to nearest river (km)

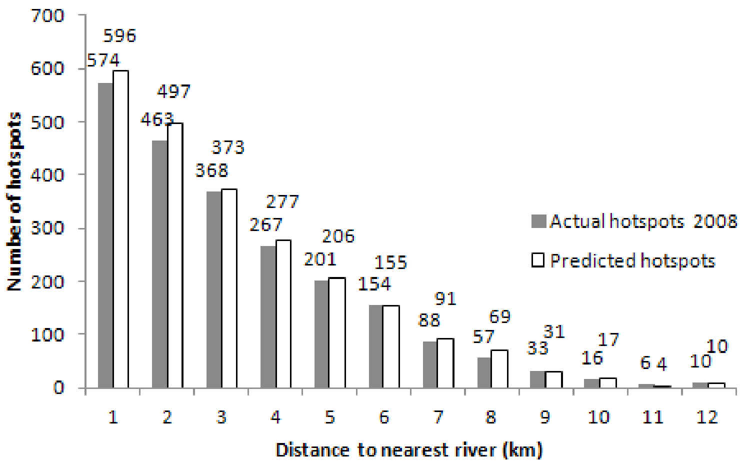


Figure 2.18. Number of actual and predicted hotspots grouped by distance to nearest city center (km)

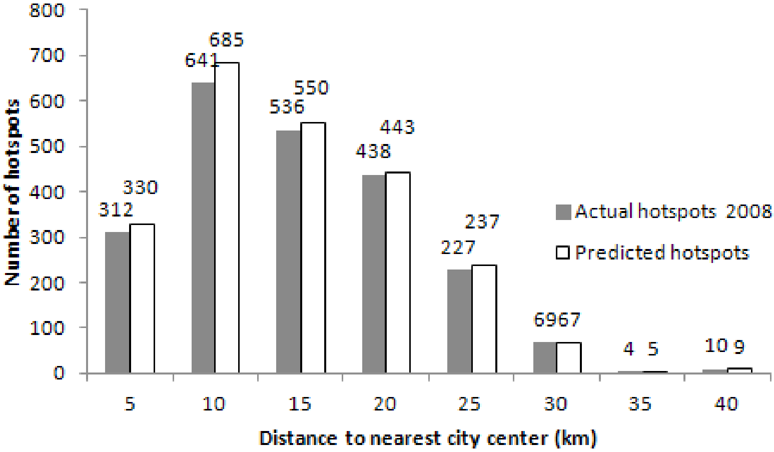


Figure 2.19. Number of actual and predicted hotspots grouped by population

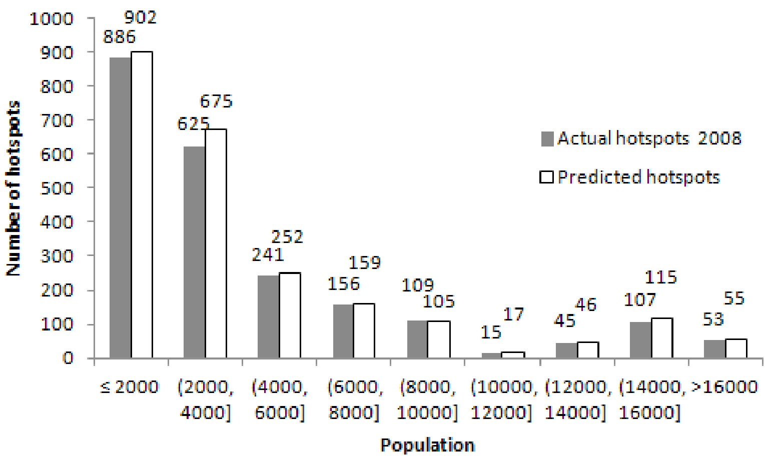
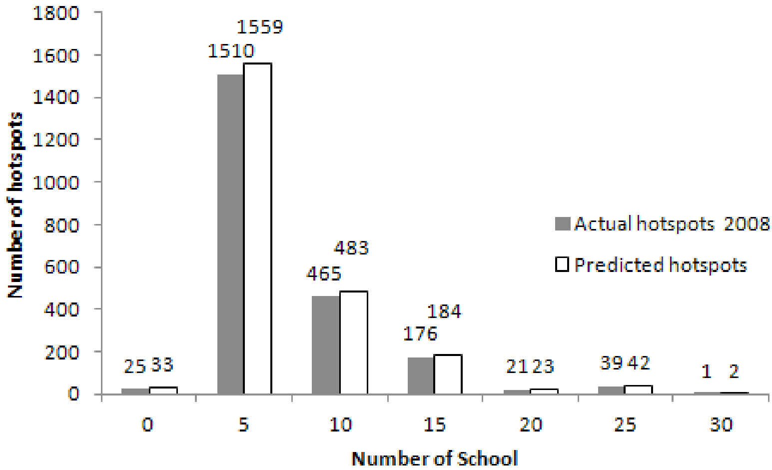


Figure 2.20. Number of actual and predicted hotspots grouped by number of schools



RECOMMENDATIONS

Further analysis of the hotspots' occurrence will focus on the association between the results of hotspots' occurrence classification and influencing factors for forest and land fires including physical, socio-economic, and peatlands data. The approach that will be applied is association rule mining using the Apriori algorithm to discover co-occurrences of hotspot and influencing factor for forest and land fires.

LITERATURE CITED

Adinugroho, W. C., I. N. N. Suryadiputra, B. H. Saharjo, and L. Siboro. 2005. *Manual for the Control of Fire in Peatlands and Peatland Forest.* Bogor, Indonesia: Wetlands International–Indonesia Programme.

Almeida, Rui. 1994. "Forest Fire Risk Areas and Definition of Prevention Priority Planning Actions Using GIS." In *EGIS/MARI '94 Conference Proceedings*, Paris, France, March 29–April 1, 1994, 1700–1706.

Chuvieco, E., and R. G. Congalton. 1989. "Application of Remote Sensing and Geographic Information System to Forest Fire Hazard Mapping." *Remote Sensing of Environment* 29 (2): 147–159. doi:10.1016/0034-4257(89)90023-0.

Friedman, N., D. Geiger, and M. Goldszmidt. 1997. "Bayesian Network Classifiers." *Machine Learning* 29: 131–163.

Schweithelm, J., and D. Glover . 1999. "Causes and Impacts of the Fires." In *Indonesia's Fires and Haze: The Cost of Catastrophe*, edited by David Glover and Timothy Jessup, 1–13. Singapore: Institute of Southeast Asian Studies and International Development Research Centre.

Han, J., and M. Kamber. 2006. *Data Mining: Concepts and Techniques*. 2nd ed. Massachusetts, United States: Morgan Kauffman Publishers.

Herawati, H., H. Santoso, and C. Forner. 2006. *Forest Fires and Climate Change in Indonesia, Background Document for the Southeast Asia Kick-off Meeting of the Project Tropical Forests and Climate Change Adaptation ("TroFCCA")*. Technical report, Tropical Forests and Climate Change Adaptation (TroFCCA).

Marsland, S. 2009. *Machine Learning: An Algorithmic Perspective.* Florida, United States: Chapman & Hall/CRC.

Pyne, S. J., P. L. Andrews, and R. D. Laven. 1996. *Introduction to Wildland Fire.* 2nd ed. New York, New York: John Wiley and Sons, Inc.

Riau, P. P. 2011. *Keadaan Geografis*. Accessed 27 July 2012 (date accessed). http://www.riau.go.id/index.php?/ind/Geo. (in Bahasa).

Santoso, H. 2006. "Adaptation to Recurrence Forest Fires and Their Risks Under the Influence of Climate Change and Climate Variability." 16th Asia Pacific Seminar on Climate Change. Jakarta, Indonesia: Center for International Forest Research.

Stolle, F., and E. F. Lambin. 2003. "Interprovincial and Interannual Differences in the Causes of Land-Use Fires in Sumatra, Indonesia." *Environmental Conservation* 30 (4): 375–387. doi:10.1017/S0376892903000390.

Uryu, Y., C. Mott, N. Foead, K. Yulianto, A. Budiman, Setiabudi, F. Takakai, Nursamsu, Suharto, E. Purastuti, N. Fadhli, C. M. B. Hutajulu, J. Jainicke, R. Hatano, F. Seigert, and M. Stüwe. 2008. "Deforestation, Forest Degradation, Biodiversity Loss and CO2 Emissions in Riau, Sumatra, Indonesia." Technical Report. Jakarta, Indonesia: World Wildlife Fund-Indonesia.

Wahyunto, S. Ri., Suparto, and H. Subagjo. 2005. *Sebaran Gambut dan Kandungan Karbon di Sumatera dan Kalimantan.* Bogor, Indonesia: Wetlands International - Indonesia Programme and Wildlife Habitat Canada. (in Bahasa).

3 Community Organizing for Flood Risk Reduction in Xieng Ngeun District, Luang Prabang Province, Lao PDR

Bounxou Xayxana[1] and Josefina T. Dizon[2]

ABSTRACT

Pakvaed and Xieng Ngeun are villages in Xieng Ngeun District in Luang Prabang Province of Lao PDR that were vastly devastated by the 8 August 2012 disaster flooding. These areas are highly vulnerable to flooding due to degraded forests and their proximity to the Nam Khan River that confluences with the Mekong River. Support agencies that serve as community organizers are available to assist these villages in times of such calamities through community organizing. This study assessed the community organizers for flood disaster risk reduction in Xieng Ngeun District, Luang Prabang Province, Lao PDR. Specifically, it aimed to: (1) discuss community organizing toward flood risk reduction in the affected communities, (2) analyze community organizing done for flood disaster risk reduction and management (FDRRM) in the affected communities, and (3) develop a community organizing framework for FDRRM for Lao PDR.

Based on the nine steps in community organizing, the support agencies acting as community organizers did not involve the local people in problem identification and analysis. Furthermore, these agencies implemented programs or activities on flood disaster risk reduction and management that they brought with them, which reflected a top-down process.

The study proposed a community organizing framework toward FDRRM for Lao PDR. It adopted a community-based approach that is peculiar in the political and socio-cultural context of Lao PDR and acknowledged the need for guidelines, resources, and facilitators.

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INTRODUCTION

Lao PDR, located in the Mekong Region, is characterized as having southeast monsoon-influenced tropical climate that causes significant rainfall and high humidity. The average annual rainfall is recorded at about 1,300 to 3,000 millimeters (mm). The country is mostly (80%) mountainous; thus, it is geographically safeguarded during storms. The remaining part (20%), however, is flat floodplains along the Mekong River (National Adaptation Programme of Action to Climate Change 2009) where disaster flooding has repeatedly occurred in the past. Flooding happens more frequently, the floods destroy farmland, livestock, food resources, environment; and cause health problems such as malaria, diarrhea, and cholera (Musah and Akai 2013; Mwape 2009). These floods have had severe adverse effects on livelihoods, especially those of the poorest and most vulnerable groups.

Xieng Ngeun District, Luang Prabang Province, Lao PDR is depicted as dominantly yellow in the SPOT (*Satellite Pour l'Observation de la Terre*, French for Satellite for observation of Earth) image of the country's forest and land cover inventory. This represents areas of "unstocked forests" or those that were densely forested in the past but have "very low crown density" at present because of logging, shifting cultivation, and other disturbances (Swiss National Centre of Competence in Research North-South, Department of Statistics, and Lao National Mekong Committee Secretariat 2008, 8). Similarly, according to the United Nations Educational, Scientific, and Cultural Organization (UNESCO 2004, 66) "already 70 percent of the province's forests have been lost, mainly to slash and burn agriculture." This forest degradation due to swidden farming or shifting cultivation, then, makes the area more vulnerable to flooding.

In addition, the Nam Khan River confluences with the Mekong River, allowing water to accumulate and outpour in these areas that become a catchment during wet season. River flooding is frequent from August to November during the rainy and southwest monsoon periods. In 2008, the Asian Disaster Preparedness Center (ADPC) reported that serious floods along the Mekong River and its tributaries "take place during the monsoon season and have the greatest macroeconomic impact on the country and affect a greater number of people, as the areas affected are primary locations of economic activity and are inhabited by 63 percent of the country's population" (ADPC 2008, 10). It was also reported that flash floods have occurred in the upper reaches of the Mekong tributaries and the effects were destructive, but brief and localized, and that there is a trend toward more frequent flash floods caused by severe deforestation in the hilly areas of northern Laos (ADPC 2008). The study site, Xieng Ngeun District of Luang Prabang Province, is in this area.

With this, the Government of Lao PDR (GoL) issued the Prime Minister's Decree No. 158 in 1999, creating the national, provincial, and district disaster management committees (DMCs). The National Disaster Management Committee (NDMC) Decree No. 097 series of 2000 identified the various sectors that compose the NDMC, designated their roles and responsibilities, and recognized the importance of disaster risk and vulnerability reduction in sustainable development (Asian Disaster Preparedness Center 2008). Thereafter, the GoL endorsed in 2003 the Disaster Management Strategy and Plan 2020 and Action Plan 2010, No. 1139/LSW.03, which aimed to lessen the negative impacts of natural disasters and to reduce disaster risks of communities. It adopted the Sustainable Development Mechanism (National Disaster Management Office or NDMO 2000 as cited by Sounnalath 2006, 4).

In the study villages of Xieng Ngeun and Pakvaed in Xieng Ngeun District, support agencies are available to assist people on matters of disaster flooding. These groups are called community organizers and they are composed of line ministries/agencies, non-government organizations (NGOs), and disaster coordinating councils. The line ministries/agencies that have significant roles in disaster risk reduction mechanisms are present and have satellite offices at the village and district levels. The NGOs that provide flood assistance services to Xieng Ngeun and Pakvaed villages are World Vision Lao, Save the Children International, Norwegian Church Aid, and Swiss Red Cross (even though they do not have offices in the area). The village, district, and provincial DMCs are present and functioning in the study area.

It is in light of these issues that this study was conducted to assess community organizing for flood risk reduction in Xieng Ngeun District, Luang Prabang Province, Lao PDR.

METHODOLOGY

The study was conducted in the villages of Pakvaed and Xieng Ngeun in Xieng Ngeun District, Luang Prabang Province, Lao PDR. These villages were chosen based on their proximity to the Nam Khan River that make them highly vulnerable to flooding and their being vastly devastated by the 8 August 2012 disaster flooding (Luang Prabang PAFO 2012).

The data collection methods used were: (1) household interview using a structured questionnaire, (2) key informant interview (KII) using guide questions to substantiate the data from the survey, (3) focus group discussions (FGDs) that are centered on community organizing based on the nine steps in community organizing formulated by Hollnsteiner (1979), Patron (1987), and Apuan (1988) as cited by Dizon (2012), and (4) desk review of relevant secondary documents.

The study used simple random sampling to determine the survey respondents. The sample population of 90 households from the two villages was determined using Slovin's formula (Sevilla et al. 1993). Individual surveys were then conducted from May to June 2013. The KIIs were participated in by five key informants from Xieng Ngeun district who were all employed as staff, were between 25 and 59 years old, and married. They were dominantly male, college degree holders, and residents of Xieng Ngeun District and Lao by ethnicity. One female and seven male adults composed the

FGD participants. Three of them were residents of either Xieng Ngeun or Pakvaed village and five were non-residents. These were the village head, the deputy village head, the respective heads and officers of the Rural Development Office, Labor and Social Welfare Office, and Office of Agriculture and Forestry and Extension of Xieng Ngeun District, a staff member of World Vision Project, and the head of the Northern Agriculture and Forestry Training and Extension Center.

RESULTS AND DISCUSSION

Community Organizing Process in the Affected Communities

Data from the individual survey revealed that most of the steps in community organizing were conducted except for two aspects in Step 1 (entry into the community) and all five aspects in Step 4 (problem identification and analysis) (Figure 3.1). The two aspects in Step 1 were adapting to the lifestyle of the community and choosing the appropriate family to live with while in the community; while the five aspects in Step 4 were identifying political and socio-cultural issues, investigating past efforts to solve flooding, analyzing origins of flooding problems, identifying factors that affect flooding, and undertaking consequence analysis and problem prioritization.

The respondents specifically identified the village head, the deputy head, the respective heads and officers of the Rural Development Office, Labor and Social Welfare Office, and Office of Agriculture and Forestry and Extension of Xieng Ngeun District as the community organizers.

Several development projects have been implemented in the villages of Pakvaed and Xieng Ngeun to address flood-related problems and concerns. The survey respondents described the implementation of these projects through the community organizing approach by identifying the activities conducted by the organizers. They pointed out that at the beginning of each project, the community organizers coordinated first with the district authorities and the village heads. The purpose of the project and corresponding activities to be conducted were then presented and discussed for transparency.

Integration with the villagers was accomplished through familiarization with the village and its inhabitants, establishment of rapport, and participation in various community activities, such as feasts and celebrations. The social and political structures were investigated through observation and interviews with leaders and key people in the community. The respondents believed that the community organizers were weak in identifying and analyzing the actual needs of the community and its inhabitants. Nonetheless, the respondents recognized that solutions to problems and plans of action were being identified.

Figure 3.1. Community organizing steps for Lao PDR

Step 1 - Entry into the community Introducing themselves Lifestyle adaptation
Step 2 - Integration with the people Getting to know the place and its people Establishing rapport Participating in various activities
Step 3 - Social investigation Acquiring information Analyzing political and socio-cultural characteristics of the communities
Step 4 - Problem identification and analysis Analyzing origins of flooding problems Identifying factors that affect flooding Undertaking consequence analysis and problem prioritization
Step 5 - Planning and strategizing Identifying solutions Setting plan of actions
Step 6 - Core group formation Organizing the core group Identifying contacts and potential leaders Conducting trainings in leadership and organizing
Step 7 - Organizing development and mobilization Setting up formal organization structure Mobilizing community effort
Step 8 - Evaluation and reflection Reviewing course of action Conducting discussion on lessons learned
Step 9 - Turn-over and phase-out

Table 3.1. Comparison of the survey and FGD results on community organizing activities performed in the Pakvaed and Xieng Ngeun Villages to address flooding

Activity	Performed	
	As Perceived by Respondents	As Perceived by FGD Participants
Step 1 – Entry into the community		
Introduced themselves	✓	✓
Lifestyle adaptation	×	✓
Chose appropriate place	×	×
Step 2 – Integration with the people		
Got to know the place and its people	✓	✓
Established rapport	✓	✓
Participated in various activities	✓	✓
Step 3 – Social investigation		
Acquired information	✓	✓
Analyzed political and socio-cultural characteristics of the communities	✓	✓
Step 4 – Problem identification and analysis		
Identified political and socio-cultural issues	×	×
Investigated past efforts to solve flooding	×	×
Analyzed origins of flooding problems	×	×
Identified factors that affect flooding	×	×
Undertook consequence analysis and problem prioritization	×	×
Step 5 – Planning and strategizing		
Identified solutions	✓	✓
Set plan of actions	✓	✓
Step 6 – Core group formation		
Organized core group	✓	✓
Identified contacts and potential leaders	✓	✓
Conducted trainings in leadership and organizing	✓	✓
Step 7 – Organization development and mobilization		
Set-up formal organization structure	✓	✓
Mobilized community effort	✓	✓
Step 8 – Evaluation and reflection		
Reviewed course of action	✓	✓
Conducted discussion on lessons learned	✓	✓
Step 9 – Turn-over and phase-out	✓	✓

A core group that acted in the forefront was organized and leaders were appointed. The officers and members of the organized group were trained in order to capacitate them for the group's intended purpose. Once skilled, the officers of the organized group were identified. Development organizers guided and closely monitored the group as they performed their activities. Courses of action and lessons learned within the duration of the project were discussed during meetings. The project was formally turned over to the people's organization at the end of each activity.

Based on the FGD results, it was also found that most of the community organizing steps were not conducted. The participants also stated that all five aspects of Step 4 (problem identification and analysis) were not conducted. However, the answers of the survey respondents and of the FGD participants to the first step were contradictory to each other. While the former declared that the community organizers did not adapt to the lifestyle of the community, the latter claimed that they did (Table 3.1).

The FGD was participated in by the community organizers from various agencies and NGOs involved in disaster risk reduction and management (DRRM) in the area. It was conducted on 7 June 2013 at the Northern Agriculture and Forestry Extension Training Center, Xieng Ngeun District. During the event, exchanges centered on the pre-drafted guide questions and were ordered according to the nine steps of community organizing. During the exchanges, most (four or more out of eight) concurred with the responses while the remaining participants' silence was taken as agreement.

As reflected in the succeeding discussion of what transpired in the FGD, the results showed that most of the steps were achieved by the community organizers when conducting activities related to flood disaster risk reduction and management (FDRRM), except for one activity in Step 1 (entry into the community), which was adapting to the lifestyle of the community and all the activities under Step 4 (problem identification and analysis).This means that they did not identify political and socio-cultural issues, investigate past efforts to solve flooding, analyze origins of flooding problems, identify factors that affect flooding, nor undertake consequence analysis and problem prioritization. It can be concluded that they implement programs or activities that they bring with them—a distinction of top-down process.

Community Organizing Steps for FDRRM

Step 1: Entry into the community

This initial phase of community organizing involved the community organizers' introduction of themselves (their project, its objectives, and the nature of their stay in the community) to the local officials and to the community and how they would adapt to the lifestyle in the community—how they would choose an appropriate place or family to stay with.

The FGD participants stated that the very first step the community organizers conducted was a site visit. This included an area inspection, a courtesy call with the village head and other village officials, coordination with related government agencies, and meeting with the community members, individually or in groups, to introduce themselves and to discuss the project's nature, scope, objectives, and activities to be conducted.

It is noteworthy that they considered their appearance so that they were viewed as approachable. The FGD participants stated that the villagers were generally very observant of the community organizers.

Five of the FGD participants who were employees in the various offices in the district, were non-residents of the two villages under study. Thus, they needed to be accommodated in the area when they went there. However, they were not allowed to choose which family to stay with. Rather, it was the community committee (spearheaded by the village head) that chose and made arrangements for their accommodation. Their preferences were not considered by the committee. This is standard practice in Lao PDR, under similar situations. The village head led and decided with which family the visitors or community organizers would be lodged.

To be fully adapted to the lifestyle of the community, the FGD participants stated that they had to eat whatever was served to them, participate in community activities, and be cordial to everyone in the village.

In the case of the District Officer of the Labor and Social Welfare Office, this entry into the community phase was achieved by, foremost, having a courtesy call with the village committee, and subsequently, by coordinating with a representative from the Women's Union and Youth Committee to assess the value of the damage of flood.

Step 2: Integration with the people

The second phase involved getting to know the culture, economy, leadership, history, and lifestyle of the people; establishing rapport (mutual trust and cooperation); and participating in the economic activities, household work, group discussions, and social functions of the community. The participants achieved these through solidarity with the people, by studying their culture and by respecting their ways of living. For example, when invited to eat or drink, it was prudent not to touch the food or drink to merely taste it when in the end it would be disliked. Another example was to not attempt to wash used dishes after being invited to eat in a household. It is their custom not to wash the dishes after eating or cooking. Going against these would be offensive to the villagers. It was important to be aware of their customs and lifestyle before the actual immersion in the community.

The community elders were the most practical choice for resource persons regarding the community's culture and history. In fact, their wisdom and knowledge were highly regarded even by the village committee.

Step 3: Social investigation

According to the FGD participants, this succeeding phase was also conducted by the community organizers by acquiring information and analyzing the political and socio-cultural structure of the community in order to identify issues around which to organize the people. Specifically, they achieved this by communicating with the people face-to-face. In doing so, they exhibited essential characteristics that they needed to project—the three S—sincerity, solidarity, and simplicity.

The people should sense honesty in the message being delivered to them. Looking at them straight in the eye and explaining to them in their language were vital because most of them did not believe immediately. They usually tested or "experimented" first by speaking with their relatives and family members and by sharing with them whatever service or goods were shared with them by the community organizers. Thereafter, they would listen to and believe whatever their relatives or family members told them. This, then, would be told to other members of the community who usually believed and considered what they were told. They had considerably close family ties that, at times, program implementation was affected. Group or collective viewpoints and decisions were highly valued and adhered to. Thus, elucidation in a sincere and not-so-fast yet not-so-slow manner was a necessity for community development workers in the area.

Solidarity with their daily activities was also established. This way, the community organizers got to know the villagers better. For instance, individual and group meetings had to be conducted during off-farm periods, particularly early in the morning or in the evening when they were not in the fields. The villagers did not cooperate when they were not involved in the meetings. Thus, proper scheduling of meetings paved the way to improved coordination and to a better-established solidarity with them.

Moreover, language used in dealing with them had to be simple. Since most in the community had only attained primary education, the manner of speaking and the type of language used was suited to that level. As much as possible, new concepts were described comprehensively using the Lao language.

Step 4: Problem identification and analysis

During the FGD, there were no answers in all activities related to the step on problem identification and analysis. They only expressed suggestions regarding the conduct of this step. They stated that they acknowledged the existence of socio-cultural and political issues in the community that hinder the success of development projects. They also noted that they needed to determine the specific needs of the community. Moreover, they pointed out that they had to provide assistance to the people and that there should have been "strong governance" in the community.

The participants did not answer how they conducted problem identification and analysis. Rather, they pointed out what the problems were in relation to this step. They identified the main problem as the lack of awareness about mitigation of flood disasters and the continuing slash-and-burn cultivation that exacerbated deforestation.

One participant expressed his aspiration for a warning system in the community, which emanated from his experience during the flood on 8 August 2012 when the waters rose at midnight as the people in the village were sleeping. He said that information could have been delivered faster if there was a warning system in the community.

Step 5: Planning and strategizing

As community organizers, they identified the solutions for flooding by first determining the existing resources, guidelines, related laws, and established strategies (those based on the experiences of the previous community organizers as documented in literature). They spoke with the elders in the community also because these people were very rich in experiences that allowed them to develop wisdom and skills in facing flood disasters. The elders were well versed with the physical structure and characteristics of the area and they knew exactly where surging waters would come from and which specific areas were safe for evacuation. Furthermore, they also knew the cycle of flooding. They stated that disastrous flooding occurred every 40 years. According to the FGD participants, the wisdom of the elders should also be considered in flood disaster planning and strategizing.

Action planning was done by local government units in the village, district, provincial, regional, and national levels.

Step 6: Core group formation

Organizing a core group to address flooding problems was conducted through local government units in trainings conducted yearly. In the village, the disaster coordinating committee is consisted of five to six trained members who collaborated with the district and province level committees. The contacts and potential leaders were usually identified with the assistance of the village committee spearheaded by the village head.

Step 7: Organization development and mobilization

A formal organizational structure was already established in the community, and it was the village committee composed of the village head and his council and staff. Thus, when going to these communities, there was no need to organize a formal structure. In addition, the committee members were already organized and assigned to specific concerns such as socio-economic, security, disaster, socio-cultural, among others. This is in accordance with one of the community organizing principles, which states that the community organizers should build on what the community has.

Step 8: Evaluation and reflection

Through the conduct of meetings and home visitations for data gathering, the FGD participants and the community members reviewed the course of action that had been undertaken and lessons learned in solving the flooding problems in the community. During those meetings, the community members addressed complaints and issues on insufficient humanitarian effort and unequal distribution of relief goods and services.

Step 9: Turnover and phase-out

In transferring the community organizing roles and responsibilities to the community, the FGD participants declared that they made a report on the current status of the project—what was already accomplished and what still needed to be done. Thereafter, they handed the program over to the local authority, which would then turn it over to the community. Follow-ups were conducted by government staff from related sectors.

Toward a Community Organizing Framework for FDRRM

The participants stated that, in general, the community organizing steps were applied when they conducted activities or projects related to FDRRM in the two villages studied. They failed to remember, however, that one activity in Step 1 and all activities in Step 4 were not carried out. As a last note, they all affirmed and emphasized that competence in the local dialect was vital in the community organizing process.

Notably, the result of the FGD was almost exactly similar to that of the household survey in terms of not conducting all aspects of Step 4 and one aspect of Step 1—not being able to choose a host family to live with. The only difference was with the community organizers' ability to adapt to the lifestyle of the community. The survey respondents asserted that the community organizers did not conduct this aspect while the FGD participants (who are also community organizers in the area) stated the opposite. The FGD participants even described how they adapted by citing instances and situations such as wearing particular clothing, eating with the community, and speaking with them using their own dialect.

As an outcome of the study, a community organizing activity geared towards FDRRM was proposed. The proposed community organizing was still based on the nine steps in community organizing formulated by Hollnsteiner (1979), Patron (1987), and Apuan (1988) as cited by Dizon (2012), but was modified based on the socio-political situation of the country. All the nine steps were included but some aspects were omitted since these could not be implemented in a socialist state like Lao PDR and on people who strictly adhered to their culture of trusting and giving high regard to authority.

Under Step 1, choosing an appropriate place or host family to live with was omitted. This was not applicable in the country because, as mentioned, it was always the village head or the village committee members who did this. Although Step 4 was not conducted by the community organizers (comprised of political and institutional agents) in the past, particularly in the context of the 8 August 2012 disaster flooding, it was still recommended because the problem identification and analysis step was deemed necessary. Among the five activities under this step, only three were proposed to be applied. The first two, identifying political and socio-cultural issues and investigating past efforts to solve flooding, were omitted.

Based on the findings of the study, the following modified steps were identified:

The proposed community organizing steps for FDRRM for Lao PDR were to be implemented by the political and institutional agents. In the district level, with the leadership of the District Disaster Management Committee (DDMC), they would form as a group and distribute tasks (Figure 3.2).

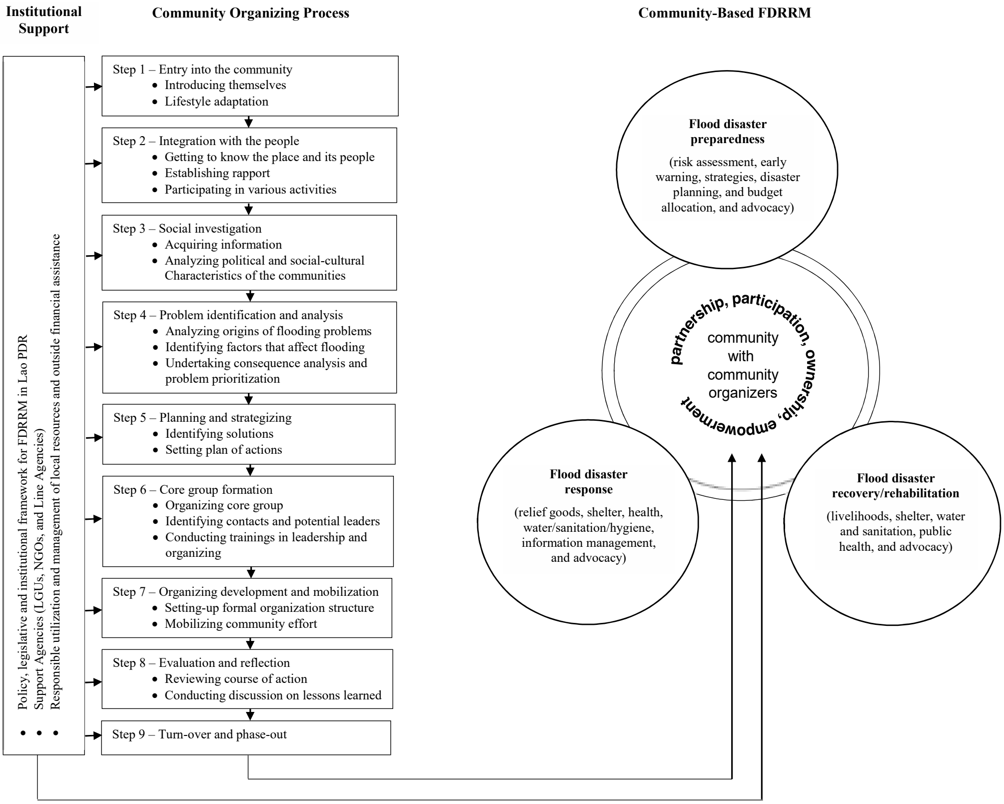
The local people participated in the community organizing process. However, after the ninth step (turn-over and phase out), the level of participation of the local people increased while they were still assisted by the support agencies such as the Agriculture and Forestry District Offices, World Vision, and the Northern Agriculture and Forestry Training and Extension Center that applied technical- and scientifically-based approaches and continued to adopt applicable steps from the nine steps in community organizing.

Three components supported and guided the community organizing process that was geared towards FDRRM. These were labeled in the diagram as “institutional support” (Figure 3.2). The first component is the policy, legislative, and institutional frameworks. For FDRRM to be feasible and successful in Lao PDR, it had to be endorsed by the government through its local government units (LGUs) or line agencies and it had to be in line with the programs of the government so that it would be considered “legal”. In Vietnam, it was not possible for the people to act apart from the government. The second component was responsible utilization and management of local resources and outside financial assistance. Finally, the third component was the support agencies or community organizers composed of the LGUs, NGOs, and line agencies that conducted the nine steps in community organizing at the outset and afterwards assisted the community whenever necessary especially on technical and scientific matters related to FDRRM.

In the diagram, this box of institutional support is pointed in every step in community organizing to mean that the laws, support agencies, and resources are present and assisting constantly. It is also pointed towards the FDRRM, the offshoot of community organizing, to mean that these three components are likewise necessary.

After having been organized through the implementation of the community organizing process, the people acted upon the problems and issues related to FDRRM by themselves. These were then brought up to the highest level of socio-political structure of society when necessary and appropriate. After the community organizing process,

Figure 3.2. Proposed community organizing framework for FDRRM



FDRRM moved forward from being community organizer-driven to being community driven. The villagers were empowered especially in decision-making and program implementation. They were listened to and were not treated as passive recipients but partners of development, active participants, empowered decision-makers, and “owning” implementers.

The proposed framework adapted a pragmatic and long-term approach. It was neither activity nor project-centered but employed a holistic approach that exhibited the cycle of flood disaster preparedness (risk assessment, early warning strategies, disaster planning and budget allocation, and advocacy), flood disaster response (relief goods, shelter, health, water/sanitation/hygiene, information management, and advocacy), and flood disaster recovery/rehabilitation (livelihoods, shelter, water and sanitation, public health, and advocacy).

CONCLUSIONS AND RECOMMENDATIONS

The findings show that the LGUs, NGOs, and line agencies conduct most of the schemes in flood disaster preparedness and mitigation, response, and recovery/rehabilitation phases of FDRRM. Those not conducted are the five schemes under preparedness and mitigation (carrying out disaster preparedness exercises/simulation; building up and/or strengthening local disaster preparedness capabilities and local rescue services; improving local infrastructures by preparing emergency evacuation area/building in times of flooding; participatory drafting of emergency plans; and advocacy/awareness-raising on flood risk reduction/trainings on disaster management), one scheme under flood disaster response (minimizing number of days of disrupted classes), and advocacy/awareness-raising on flood risk reduction/trainings under preparedness and mitigation and recovery/rehabilitation phases.

The proposed framework adapts the old tenets of community organizing but omits some sub-steps that are deemed not applicable to the Lao PDR context. The framework begins with the community organizers conducting the nine steps with the community. After those steps are conducted, the community takes the center while exercising partnership, participation, empowerment, and ownership of the FDRRM. Still, the organizers are there but only as a support. Together, they work on flood disaster preparedness, response, and rehabilitation/recovery cyclically. The community organizing towards FDRRM is supported by legislative and institutional frameworks for FDRRM in Lao PDR; responsible utilization and management of local resources and outside financial assistance; and support agencies or community organizers.

As the community organizers did not involve the local people in problem identification and analysis, it can be concluded that they implemented programs or activities that they brought with them—a distinction of the top-down process.

The proposed framework for community organizing for FDRRM is therefore a community-based approach that is particular to the political and socio-cultural context of Lao PDR and that acknowledges the need for guidelines, resources, and leaders from both outside and in the local community.

On the basis of the major findings and conclusions of the study, the following recommendations are advanced:

As the results of the study revealed that the villagers from Xieng Ngeun and Pakvaed were inadequately aware of FDRRM and ill-prepared for flood disasters, the village heads and the Village Disaster Protection Units should promote and support information dissemination, meetings, and trainings conducted by support agencies. As flood disasters usually occur during the southwest monsoon season from August to September, activities on FDRRM especially awareness-raising and disaster preparedness trainings should be conducted yearly during the months prior to the flooding season. The village heads should lead and facilitate in fostering public-private partnership in the village level for FDRRM activities. The villagers must make themselves available when their participation is called upon by the LGUs, NGOs, and line agencies that conduct activities on FDRRM. They should also volunteer to wherever they recognize themselves as fit such as being core group members, working committee members, and the like.

The Government of Lao PDR, with the National Disaster Management Office facilitating, should integrate DRRM into official national, regional, and local development plans and budgets. All ministries, with the Office of the Prime Minister leading and facilitating, should strengthen their coordination and networking among them, especially on DRRM matters. Roles, mechanisms, communication channeling, funding, resource mobilization, and implementation processes in DRRM should be clarified. The officials and staff of line agencies and LGUs, being found to be inadequate in knowledge and skills related to FDRRM have to undergo skills trainings, attend seminars, and participate in exposure visits. The Department of Budget should allocate adequate funds for such programs.

The Ministry of Education must make DRRM a national priority by integrating it in the school curriculum and by actually reflecting it in textbooks. The Department of Teacher Training of the Ministry of Education, in partnership with the Department of Climate Change and Disaster Management of the Ministry of Natural Resources and Environment (MONRE), should conduct teacher trainings on DRRM as part of the teachers' ongoing formation. The Department of Non-formal Education of the Ministry of Education should integrate disaster risk reduction into its educational materials.

The Ministry of Public Works and Transport, through its strict implementation of rules on building facilities and physical infrastructure, should ensure that schools, clinics, hospitals, water facilities, electricity facilities, communication lifelines, roads and bridges, and other important structures have appropriate designs and are disaster-resilient.

The Ministry of Health should conduct first aid trainings in the villages as preparation for flood disaster response. The women should be given priority in these trainings since they take care of the health of the family. The Ministry should be constantly ready in terms of medical supplies and medical professionals in times of disease outbreaks and epidemics brought about by catastrophic flooding.

The Ministry of Agriculture and Forestry (MAF) and MONRE should work together to promote reforestation, especially since Xieng Ngeun District has vast unstocked forests. Being responsible for the collection and interpretation of climatic and hydrological data, MONRE should ensure that early warning information is effectively and speedily disseminated in the village and household levels.

For future researchers, studies on best practices and case studies of FDRRM in Lao PDR should be conducted. For linguists and language teachers in Lao PDR, indigenous terms related to disaster and DRRM should be gathered, translated into Lao ethnic languages, and disseminated to the local people and support agencies. The corpus of indigenous terms related to disaster and DRRM can aid the concerned ministries and departments and other development workers in effectively delivering the message to the people in the grassroots level so that they will fully understand and will be led to safety and resilience during disasters.

LITERATURE CITED

Asian Disaster Preparedness Center. 2008. *Impacts of Disasters on the Education Sector in Lao PDR.* Bangkok, Thailand: Asian Disaster Preparedness Center.

Dizon, J. T. 2012. "Theoretical Concepts and Practice of Community Organizing." *The Journal of Public Affairs and Development* 1 (1): 89–121.

Luang Prabang PAFO. 2012. Luang Prabang Provincial Agriculture and Forestry Office, Lao People's Democratic Republic.

Musah, B. A. N, and C. Y. Akai.2013. *Effects of Flood Disasters on Livelihood Coping Mechanism in Tolon/ Kumbumgu District of Northern Region of Ghana.* Ministry of Food and Agriculture, Ghana.

Mwape, Y. P. 2009. "An Impact of Floods on the Socio-economic Livelihoods of People: A Case Study of Sikaunzwe Community in Kazungula District of Zambia." Mini Dissertation Submitted in Partial Fulfillment of the Requirements For the Master Degree in Disaster Risk Management. University of the Free State, Faculty of Natural and Agricultural Sciences, Disaster Risk Management Training and Education Center for Africa (DiMTEC).

National Adaptation Programme of Action to Climate Change. 2009. A background paper prepared by the Ministry of Housing, Transport and Environment for the Maldives Partnership Forum (MPF) to be held in Maldives, 23–24 March 2009.

Senkhamlue, S. 2013. Third Year Student in Northern Agriculture and Forestry College, Lao PDR.

Sevilla, C. G., J. A. Ochave, T. G. Punsalan, B. P. Regala, and G. G. Uriarte. 1993. *Research Methods*. Rev. ed. Quezon City, Philippines: Rex Printing Company Inc.

Sounnalath, P. 2006. "Disaster Risk Reduction and Management in Lao PDR." A paper presented during the ADRC Meeting 2006, 15–17 March, Seoul, Republic of Korea. Retrieved on January 20, 2014 from www.adrc.asia/acdr/2006seoul/documents/006b_country_presen/LaoPDR.pdf

Swiss National Centre of Competence in Research North-South, Department of Statistics, and the Lao National Mekong Committee Secretariat. 2008. Administrative divisions. In *Socio-economic Atlas and Poverty Maps.* Lao PDR: NCCR North-South, DOS, and LNMCS.

United Nations Educational Scientific and Cultural Organization. 2004. *Tourism and Heritage Site Management in the World Heritage Town of Luang Prabang, Lao PDR.* Bangkok, Thailand: United Nations Educational Scientific and Cultural Organization Bangkok. Accessed January 22, 2014 from http://www2.unescobkk.org/elib/publications/IMPACT_LuangPrabang/impact.pdf

Xieng Ngeun District of Environment Office. 2012. LuangPrabang Province, Lao PDR.

Appendix A

The River Khan in Pakvaed Village on a normal-weather day (top) and during the 8 August 2012 flooding (bottom)

Source: Senkhamlue (2013); Xieng Ngeun District of Environment Office (2012)

Appendix B

Inundated house (top) and part of Highway No. 13 (bottom) during the 8 August 2012 flooding

Source: Xieng Ngeun District of Environment Office (2012)

4

Carbon Sequestration in Faraon and Adtuyon Soils under Different Cropping and Tillage Systems in Zamboanga Peninsula

Eriberto D. Salang[1] and Reynaldo A. Comia[2]

ABSTRACT

This study focused on tillage and cropping systems' effects on sequestered soil organic carbon (SOC) in Faraon and Adtuyon soils of Zamboanga Peninsula. The tillage systems studied were no tillage, conservation tillage, and conventional tillage. The cropping systems, on the other hand, were classified as annual cropping system (corn, corn-legume, vegetables, and rootcrops), cover crop and forage cropping system (calopogonium cover crop and pastures), and perennial cropping system (banana and fruit crops).

Results showed that sequestered SOC was higher in no tillage and in conservation tillage than in conventional tillage at Faraon soil. However, only no tillage had significantly greater SOC among tillage systems in Adtuyon soil. Likewise, SOC was higher in soils under cover crop, forage, and perennial cropping systems.

In general, tillage systems significantly affected the sequestered SOC. No tillage had conserved the carbon stock in soils, while conservation tillage maintained the level of soil carbon. However, conventional tillage system reduced the carbon stock.

Carbon sequestered through no tillage farming, conservation tillage, covercrop, forage, and perennial cropping systems appeared to have great potential for carbon trading to mitigate climate change.

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INTRODUCTION

One of the primary concerns of humanity today is climate change brought by the continual increase of carbon levels in the atmosphere, a change attributed to anthropogenic activities. Greenhouse gas emissions from soil depend on land use, cropping systems, and tillage methods (Reincosky et al. 2002). So far, no soil management strategy combined with a specific soil type and cropping system has been identified to sequester more soil carbon in order to help mitigate the carbon releases into the atmosphere. Approaches in mitigating global warming have been considered in agriculture on soil management (Jones 2006) since soil organic carbon plays a major role in the carbon cycle, which largely contributes to the greenhouse effect (Lal et al.1998).

Carbon can be sequestered on farmland in the form of soil organic carbon, litter and above ground biomass, and in trees. Any increase in the carbon stored on a farm is regarded as sequestered. However, the soil carbon pool is highly reactive and dynamic (Lal 2002). Cultivation of soils or conversion of natural to agricultural ecosystem leads to depletion of the soil carbon pool with accelerated emission of greenhouse gases into the atmosphere which eventually cause global warming.

Land use and management practices have a significant impact on greenhouse gases in the atmosphere, both through emitting and by removing it from the atmosphere via carbon sequestration. Ways to mitigate climate change include conservation of existing carbon stock, expansion of carbon stock, substitution of products for fossil fuel-based products, and conservation farming (Lasco et al. 2004).

The general objective of this study was to investigate the potentials of tillage systems and cropping (vegetation) types on carbon sequestration in Faraon and Adtuyon soils. The study also evaluated the relationship between sequestered carbon levels and different cropping and tillage systems used. It was conducted in Zamboanga Peninsula where long term-tillage systems were practiced in coconut-based systems from April 2009 to December 2009.

METHODOLOGY

The study was conducted where long-term no tillage, conventional tillage, and conservation tillage were practiced in coconut-based fallow systems. Paired fields of no-tillage and tillage farming, classified further as conventional and conservation tillage under different types of cropping/vegetation were used. Locating the series was based on the secondary data produced by the Bureau of Soils and Water Management (2004). The selected municipalities that contain the soil types within the three provinces of Zamboanga Peninsula (Zamboanga del Sur, Zamboanga Sibugay, and Zamboanga del Norte) were then identified.

Three types of sampling procedures were used for the final collection of the soil samples to fit for spatial statistics. These were cluster sampling, purposive sampling, and stratified random sampling. In cluster sampling, five model farm-barangays in each municipality that practiced different long-term farming systems in upland areas were selected on the basis of recommendation by the Municipal Agriculture Officer. Purposive sampling was done upon seeing the area based on the purpose of the study. Sample sites were often collected as “typical” of a district or particular mapping unit (Webster and Oliver 1990) where there are at least ten composite samples per barangay. Stratified random sampling was done following the technical specification in soil carbon accounting (McKenzie et al. 2000).

Intact soil cores, using metal sleeves with 5 centimeters (cm) inner diameter by 5 cm long, were manually collected in triplicate from each study area from depths of 0–10 cm, 10–20 cm, and 20–30 cm. Composite soil samples of approximately 200 grams (g) were also obtained from the same area of each sampling location. The soil organic carbon (SOC) was analyzed through the Walkley-Black method as it was suitable in the routine analysis of Philippine soils (Alvarez 1968). Soil inorganic carbon was analyzed using carbon dioxide (CO_2) evolution. The sequestered CO_2 equivalent was calculated using the following equation:

$$W = 3.67\ [(C)\ (D_B \times d_s \times 10{,}000 m^2)]$$

Where:

W = sequestered CO_2 equivalent, expressed in ton ha^{-1}

C = soil organic carbon

D_B = soil bulk density

d_s = depth of soil sampling (30 cm) as recommended by Intergovernmental Panel on Climate Change (1997);

3.67 = carbon equivalent in CO_2

The uppermost 30 cm depth was the actual depth of soil sample collections as this portion was always affected by human activity. Data collected from the soil site include bulk density and pH to help evaluate carbon sequestration and carbon loss. Other data such as latitude and longitude coordinates, slope of the land, identification of common minerals, terms in farming system, previous and current plants cultivated, and landscape position were also recorded.

Descriptive statistics, inferential statistics, and spatial statistics were used in this study. The mean, maximum, minimum, standard deviation, skewness of data distribution, and coefficient of variation were calculated. Moreover, field comparison using Cochran t-test was used to test the difference among groups (tillage systems and cropping systems in terms of carbon of soils). Spatial statistics was used to estimate spatial dependence and distribution of the properties analyzed.

RESULTS AND DISCUSSION

Description of the Area

Faraon soils are derived from the weathering of coralline limestone. They usually occur on the undulating and rolling areas. In eroded areas, soft-angular limestone are exposed on the surface. Faraon soils are black (10YR 2/1) and usually clay in texture having pH ranging from 7.2 to 7.8. This soil series is found in the municipalities of Manucan, Olutanga, Mabuhay, and Zamboanga City (Figure 4.1). Faraon series are found both in lowland and upland areas, lying usually from undulating and rolling areas with relief of convex creep.

The Adtuyon series covers 12 municipalities of Zamboanga Peninsula. The soils of this series are developed from weathered rocks that originated from volcanic lava (*lahars*) chiefly composed of andesite and basalts. It is characterized by light brown (7.5YR 4/4), brown to dark brown (7.5YR 4/2 to 3/2), clay to clay loam surface soil with granular to sub-angular structure, and a pH of 5.0 to 5.4. This soil series is found in plateaus and on a strongly rolling relief, mostly in seepage slope. The external drainage is good to excessive, and the internal drainage is fair to good. Some soils of the municipalities of Katipunan, Polanco, Dipolog, Sibutul, Piñan, Libertad, Rizal, Mutia, Sergio Osmeña, Mahayag, Tungawan, and Liargao have Adtuyon soil series (Figure 4.2).

Description of Tillage Systems Used in the Study

No tillage system

No tillage system is practiced in Zamboanga Peninsula, in a way that the land is cleared of weeds cut close to the ground using locally fabricated *bolos* called "*lampisa*" and "*hilamon*". Lampisa is used to clear the area by scraping the soil surface to cut grasses. It is also used for weeding. Hilamon is another kind of bolo that has a flat and wide edged-bottom-blade used to cut grasses by thrusting it into the soil surface. It is also used for planting the seeds and/or seedling materials by making a small hole about 5 cm deep and 5 cm wide, placing the planting materials on it, and covering it with fine soil.

Usually, no tillage is done in sloping lands where farm implements are difficult to use. It also becomes an option in situations when farmers lack capital for crop production. The residues are left at the surface and allowed to decompose as the crops grow in the fields.

Conservation tillage system

Conservation tillage is done by plowing and harrowing once, using a carabao to draw the farm implements, returning the residues on the field for decomposition. Clearing is done by plowing, allowing grasses and other vegetative residues to rot for one to two weeks before harrowing. Harrowing is done using a locally fabricated rectangular

Figure 4.1. Locations of Faraon soils in Zamboanga Peninsula

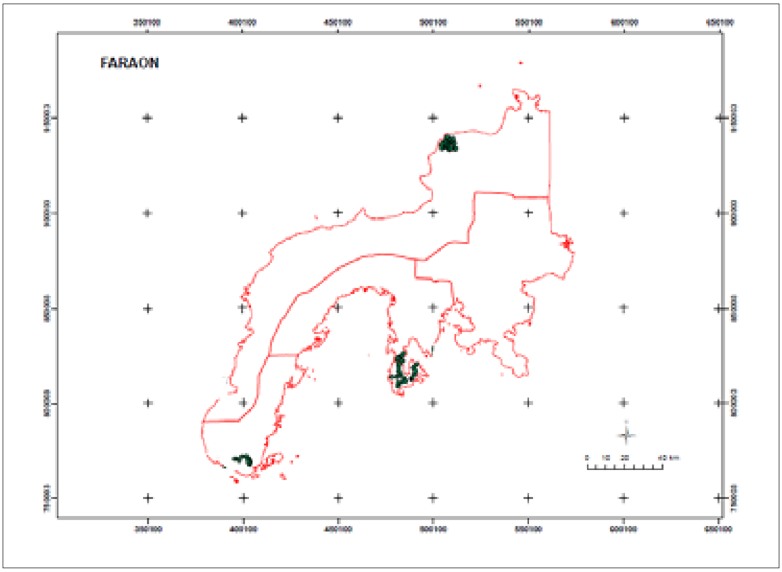
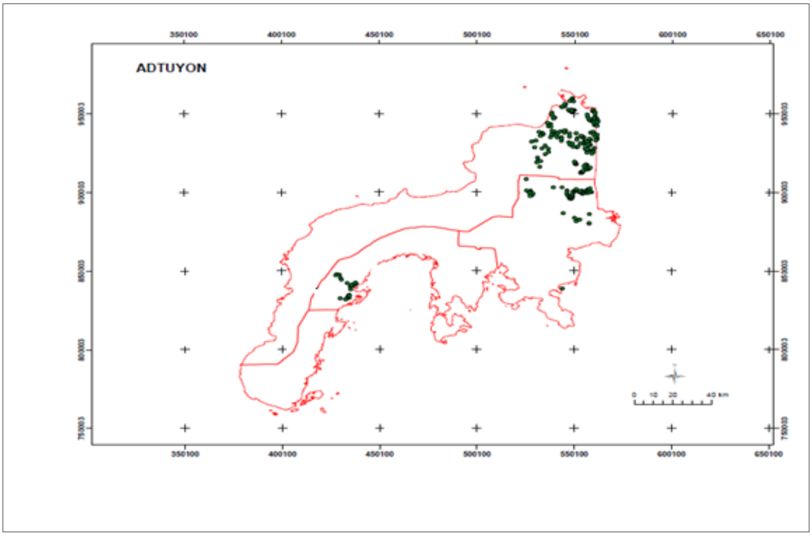


Figure 4.2. Locations of Adtuyon soils in Zamboanga Peninsula



spiked-tooth harrow. During harrowing, farm residues are returned to the field by lifting the harrow periodically to remove the weeds that are stacked on the spikes, rather than dragging the residues to the side of the farm.

Conventional tillage system

Conventional tillage is done by plowing and harrowing twice. This is similar to conservation tillage but the main difference, other than the number of soil surface disturbances, lies in the harrowing. During harrowing, farm residues are dragged to the sides of the farm leaving the field clear from any debris and without stubble incorporation. The piles of residues at the sides of the farms are sometimes burned or just allowed to decompose.

Selected Soil Properties in Two Soil Series

Soil carbon and soil properties

Table 4.1 shows the mean soil pH, bulk density, organic carbon content, and the sequestered CO_2 equivalent as influenced by soil series. On the average, Adtuyon soils were strongly acidic (pH 5.31), and had 2.3 percent more pore spaces, 42 percent greater soil organic carbon, and 37 percent higher sequestered CO_2 equivalent than Faraon soils. The high concentration of sequestered carbon in Adtuyon soils is due to the high organic matter at 30 cm depth, usually at various stages of decomposition, from humus to partially decomposed residues. Its accumulation in soils was probably brought by conservation of existing stock, and the increase in carbon stock.

The conservation of existing carbon stock could be attributed to the increased bonding between organic carbon compound and clay minerals having a low pH in Adtuyon soils. Varadachari et al. (1997) investigated the effects of the pH variation on the complexation of humic substances by dried clay-humus systems. They found that a decrease of pH up to 2.0 favored the increased bonding of fulvic acid. They added that more numerous negative charges on fulvic acid and more hydrophilic character were apparently responsible for the complexation. The exchangeable cation-fulvic acid link is strongest in illite. Physical forces of bonding appeared to be dominant in kaolinite complexes, less so with illite, and almost negligible on montmorillonite. It was deduced from chemical bonding concepts that interaction of the acidic group of humus with exchangeable cations is mainly electrostatic. The dominant clay minerals in Adtuyon are kaolinitic as characterized by non-expanding lattices. To some local residents on the site, the clay soil is used in making clay pots, jars, and bricks.

On the other hand, Faraon soils are calcareous soils that have calcium carbonate ($CaCO_3$) in abundance, and have pH greater than 7. Calcareous soils tend to be low in organic matter and available nitrogen. High pH or excessive application of lime can accelerate the decomposition process of humus; however, the low pH in acid Adtuyon soils can inhibit the activities of the bacteria. As pH is raised, bacteria populations grow and a relative increase in decomposition occurs (Alexander 1976), that would lead to release more CO_2 from soil organic matter.

Nayak et al. (2007) pointed out that in soil conditions wherein hydrogen ion activity is high (low pH), humus becomes saturated with absorbed hydrogen ions and is called humic acid. Humic acids have the ability to react with mineral particles in the soil liberating base ions such as potassium, magnesium, and calcium. As more and more

Table 4.1. Sequestered carbon and soil properties of Adtuyon and Faraon series

Soil Series	Soil Parameters			
	Soil pH	BD ($Mg\ m^{3-1}$)	SOC (%)	Sequestered CO_2 ($Mg\ ha^{-1}$)
Adtuyon	5.31	1.13	3.14	390
Faraon	7.18	1.16	1.92	246
cv (%)	15.34*	2.40ns	28.74*	28.12*

Note: * means significant at 5% level; ns: not significant

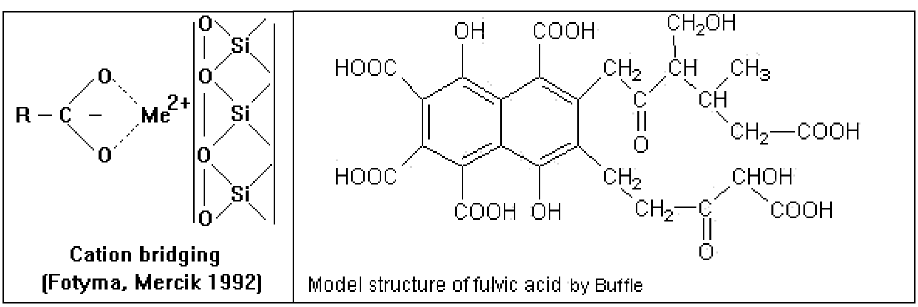
bases are released and are absorbed to the humic colloid, replacing hydrogen (H^+), humic acid is chemically changed to humate. Humates are organic colloids that are saturated with base cations. They added that soil with a near neutral pH would contain a high level of humates, whereas the same soil with a low pH would be filled with humic acids.

The finding that sequestered carbon was high in Adtuyon than in Faraon soils suggested that the bonding of fulvic acids (Figure 4.3b), the fraction of humic substances that is soluble in water under all pH conditions, to the polyvalent cations of soil clays such as iron (Fe^{3+}) and aluminum (Al^{3+}) were greater than calcium (Ca^{2+}). The divalent Ca^{2+} ion does not form strong coordination complexes with organic molecules. In contrast, Fe^{3+} and Al^{3+} form strong coordination complexes with organic compounds. The polyvalent cations act as a bridge between two charged sites (Figure 4.3a).

Moreover, the environmental conditions for microbial decomposition is not ideal in Adtuyon soils since the soils are strongly acidic. Although both soils are clayey, Adtuyon clay can also assist in more stabilization of humus.

It could also be possible that the difference of the two soils in terms of sequestered soil carbon is due to the method used in determining SOC. During the extraction of humic substances, only fulvic acids were extracted by Walkley-Black method and not the humic acids (the fraction of humic substances that are not soluble in water under acidic conditions (pH < 2), but soluble at higher pH values) and humates (the fraction of humic substances that are not soluble in water at any pH value and in alkali). On Walkley-

Figure 4.3. (a) Cation bridging and (b) model structure of fulvic acid



Cation bridging (Fotyma, Mercik 1992)

Model structure of fulvic acid by Buffle

Source: Fotyma (1992); Buffle (1999)

Black method, organic matter is oxidized by potassium dichromate in the presence of sulfuric acid (H_2SO_4). Thus, it is very likely that the humic subtances were not totally extracted.

Tillage System Effects on Sequestered Soil Organic Carbon

SOC and sequestered CO_2 equivalent were significantly higher under no tillage and conservation tillage than in conventional tillage (Table 4.2) in Faraon soils, while only no tillage was significantly different from the other two tillage systems in Adtuyon soils. In general, conventional tillage decreased the SOC levels in soils as this tillage favored the decay of any organic material trapped in soils. This eventually leads to the release of carbon in soils as carbon is dynamic once environmental conditions are favorable.

No tillage increased or conserved the carbon stock in both soils. Tillage favors diffusion of gases from the atmosphere to soil, thereby favoring oxidation of organic materials by biochemical processes. According to Brown et al. (1992), tillage and compaction can alter soil-pore geometry. Its pore size and geometry have important effects on soil-water retention and hydraulic conductivity. Tillage with more soil disturbance may reduce spatial variability of the bulk densities. Aggregates store and protect additional organic carbon until the aggregates break down.

Many soil conditions appear to improve after a few years under zero tillage with an accumulation of organic matter in the surface horizons, thus increasing the amount of soil carbon. Compared with conventional tillage, reduced or no tillage attained higher bulk densities and with a reduction in the wider pores. Tillage has favorable effects on the rate decomposition of organic materials by allowing the favorable movement of air and water in soil.

Table 4.2. Effects of tillage systems on carbon of soils

Tillage Systems	SOC (%)	Sequestered CO_2 Equivalent
Faraon		
No Tillage	2.01[a]	256[a]
Conservation Tillage	2.04[a]	261[a]
Conventional Tillage	1.75[b]	227[b]
cv (%)	13.30	14.60
Adtuyon		
No Tillage	3.14[a]	393[a]
Conservation Tillage	3.10[b]	382[b]
Conventional Tillage	3.09[b]	383[b]
cv (%)	18.84	18.12

Note: Column means with the same letter are not significantly different at 5% probability using t-test.

The finding that SOC was high in no tillage means that more sequestered carbon are conserved since there are no disturbances in the soil structure and pore arrangement, and the residues are left at the surface and allowed to decompose as the crops are grown in the fields. However, in tilled soil particularly from conventional tillage, the sequestered carbon in soil is low due to the removal of crop residues and more disturbances of soil structures and soil pore arrangement. Tillage tends to hasten the loss of organic stabilizers. Aeration from plowing is probably the most significant factor in the depletion of SOC levels of cultivated topsoil.

Notwithstanding, in conservation tillage system, the increase in carbon stock in soil is brought about by the depth and intensity of residue incorporation and less disturbance of soil matrix that lead to low oxidation of soil organic matter. Cropping with plow tillage significantly reduced soil organic matter content and total pore space (Laws and Evans 1994).

Effects of Cropping Systems on Soil Organic Carbon

SOC under cover crop, forage, and perennial cropping systems were significantly higher than those of soils under annual cropping systems (Table 4.3). The high sequestration of SOC in cover crop, forage, and perennial cropping systems was due to the increase of carbon stock that contributed to continuous supply of raw material for humus accumulation. In addition, no tillage in these types of cropping systems led to conservation of the existing SOC. The resistance to decay and the non-disturbance of soils were the factors that contributed to the preservation and increase of the carbon stock.

In the components of organic residues, some forms of carbohydrates such as sugars and starches will decompose faster than some other carbohydrates such as cellulose and hemicelluloses. Fats, waxes, and lignin are more resistant to decay than carbohydrates.

Although many of these components exist in humus, the degree to which they exist in the organic residues plays a role in the quantitative accumulation of SOC. Materials that contain a high percentage of easily decomposed component are, for the most part, assimilated back into the living mass. Materials that contain a large percentage of lignin, cellulose, or other biologically resistant components have less to offer plants in the way of recyclable nutrients but contribute significantly to the formation of SOC.

Different plants inherently have different ratios of the organic components but variances also appear in the same plants at different stages of their life. Green leaves from deciduous trees, for example, have a very different analysis of their components than their dry. At the young succulent stage, organic matter from this source would not contribute very much substance for accumulation of SOC but would benefit the immediate needs of microorganisms and plants more. Whereas, near the end of its life, the plants would add little to the nutrient needs of plants and soil life but provide more raw materials needed in the formation of humus.

Table 4.3. Effects of cropping systems on carbon of soils

Cropping System	SOC (%)		Sequestered CO_2 Equivalent (Mg ha^{-1})	
	Adtuyon	Faraon	Adtuyon	Faraon
Annual Cropping System				
Corn	3.00[b]	1.88[b]	352[b]	241[b]
Corn-Legume	3.12[b]	1.90[b]	368[b]	244[b]
Vegetables	3.00[b]	1.86[b]	371[b]	249[b]
Rootcrops	2.98[b]	1.85[b]	361[b]	243[b]
Cover Crop and Forage Cropping System				
Cover crop (Calopogonium)	3.29[a]	2.59[a]	394[a]	328[a]
Pastures	3.26[a]	2.28[a]	398[a]	326[a]
Perennial Cropping System				
Banana	3.27[a]	2.58[a]	389[a]	325[a]
Fruit crops	3.13[b]	1.85[b]	387[a]	321[a]

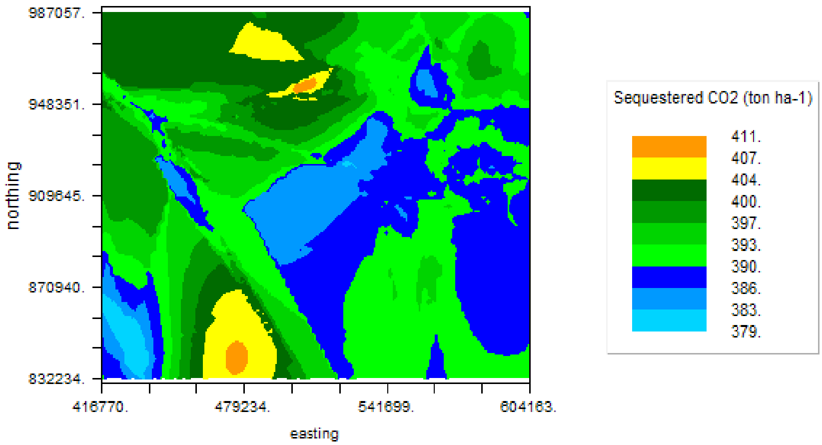
The change in SOC is influenced by the quantity of organic matter, depth and intensity of organic matter incorporation, and the efficiency of tillage management (Carter and Mele 1992).

Spatial Sequestered Soil Organic Carbon

The interpolation of all points in Adtuyon soils can be seen in a map (Figure 4.4) that exhibits the pattern where most of the measured parameters were shown. The map presents different tones (quality of a given color that differs slightly from another) in sequestered carbon indicating more heterogeneous discrete patches.

The result suggests that the sequestered SOC is more likely to have similar levels in nearby locations from the points where actual soil samples were collected. It shows that interrelation between entities increases with proximity in site; thus soil carbon at proximal locations appears to be correlated positively. Whatever are the effects on one location are similar to nearby locations (Goodchild 1987).

Figure 4.4. Spatial variability map of sequestered carbon in Adtuyon soils



CONCLUSION AND RECOMMENDATIONS

The vulnerability of soil to loss of sequestered carbon depends on the cropping and tillage systems used. As a consequence, no tillage and conservation tillage systems are being promoted as alternatives to conventional tillage for conserving sequestered SOC. It is generally viewed that switching from conventional tillage to no tillage or conservation farming would restore the SOC pool that has been lost, thereby, offsetting emissions by fossil fuel-combustion and alleviating concern of the projected global climate change.

Further research is needed to clarify the impact of no tillage on SOC sequestration for the entire soil profile. Furthermore, more researches on the methodologies to value soil carbon for trading purposes are necessary. Agricultural practices that use less fertilizer and restore soil carbon also need to be looked into.

An increase in the stock of the sequestered carbon stored in pools represents a net removal of carbon from the atmosphere. Prevention of land degradation, enhancement of carbon sequestration, and biodiversity conservation through land use changes, cropping systems with no or less soil disturbances, and no tillage or conservation tillage can be promoted to increase soil carbon sequestration. Any increase in the stored carbon in farmlands is regarded as sequestered carbon. Under a carbon trading scheme, this sequestered carbon can be sold as carbon credits. The farmer should be rewarded for building carbon levels in the soil. Carbon sequestration trading must

LITERATURE CITED

Alexander, M. 1976. *Introduction to Soil Microbiology*. 2nd ed. New York: John Wiley and Sons.

Alvarez, E. I. 1968. "Carbon-Nitrogen Ratio of Some Philippine Soils." Undergraduate Thesis, University of the Philippines Los Baños.

Brown, H. J., R. M. Cruse, D. C. Erbach, and S. W. Melvin. 1992. "Tractive Device Effects on Soil Physical Properties." *Soil and Tillage Research* 22 (1–2): 41–53. doi:10.1016/0167-1987(92)90021-3.

Buffle, J. A. E. 1977. "Les Substances Humiques et leurs Interactions avec les Ions Mineraux." In *Conference Proceedings de la Commission d'Hydrologie Appliquee de A.G.H.T.M.*, L'Universite de Paris-Sud, Orsay, France, January 1977, 3–10. (in French).

Bureau of Soils and Water Management. 2004. *Land Resource Evaluation Projects in the Province of Zamboanga Peninsula*. Quezon City, Metro Manila: Department of Agriculture.

Carter, M. R., and P. M. Mele. 1992. "Changes in Microbial Biomass and Structural Stabililty at the Surface of a Duplex Soil Under Direct Drilling and Stubble Retention in North-eastern Victoria." *Australian Journal of Soil Research* 30 (4): 493–503. doi:10.1071/SR9920493.

Food and Agriculture Organization (FAO) of the United Nations. 1998. "World Reference Base for Soil Resources 1998." Rome: Food and Agriculture Organization of the United Nations.

Fotyma, M., and S. Mercik. 1992. *Agricultural Chemistry.* Warszawa, Poland: Wydawnictwo Naukowe PWN.

Goodchild, M. F. 1987. "A Spatial Analytical Perspective on Geographical Information Systems." *International Journal of Geographical Information Systems* 1 (4): 327–334. doi:10.1080/02693798708927820.

Jones, Christine E. 2006. "Balancing the Greenhouse Equation, Part IV–Potential for High Returns from more Soil Carbon." *Australian Farm Journal* 4: 55–58.

Kimble, J. M., L. R. Everett, R. F. Follett, and R. Lal. 2002. "Carbon Sequestration and the Integration of Science, Farming, and Policy." In *Agriculture Practices and Policies for Carbon Sequestration in Soil*, edited by Rattan Lal, John M. Kimble, and Ronald F. Follett, 3–10. Boca Raton, Florida: CRC Press.

Lal, R., J.M. Kimble, R.F. Follett, and C.V. Cole. 1998. *The Potential of U.S. Cropland to Sequester Carbon and Mitigate the Greenhouse Effect.* Chelsea, Mich.: Ann Arbor Press.

Lal, R. 2002 "Soil Carbon Dynamics inCropland and Rangeland." *Environmental pollution* 116, no. 3: 353–362.

Lasco, R. D., F. B. Pulhin, J. M. Roshetko, and M. R. N. Banaticla. 2004. LULUCF Climate Change Mitigation Projects in the Philippines. Los Baños, Laguna: College of Forestry and Natural Resources, University of the Philippines Los Baños.

Laws, W. D., and D. D. Evans. 1949. "The Effects of Long-time Cultivation on Some Physical and Chemical Properties of Rendzina Soil." *Soil Science Society of America Journal* 14: 15–19.

Mckenzie, N., P. Ryan, P. Fogarty, and J. Wood. 2000. "Sampling, Measurement and Analytical Protocols for Carbon Estimation in Soil, Litter, and Coarse Woody Debris." Technical Report No. 14. Parkes, ACT: Australian Greenhouse Office.

Nayak, D. R., J. B. Yeluripati, A. Datta, and T. K. Adhya. 2007. "Methane Oxidation in an Intensively Cropped Tropical Rice Field Soil under Long-term Application of Organic and Mineral Fertilizers." *Journal Environmental Quality* 36 (6): 1577–1584. doi:10.2134/jeq2006.0501.

Reiscosky, D.C. 2002. "Long Term Effect of Moldboard Plowing on Tillage-induced CO2 Loss." In *Agricultural Practices andPolicies for Carbon Sequestration in Soil*, edited by Rattan Lal, John M. Kimble, and Ronald F. Follett, 87–98. Boca Raton, Florida: CRC Press.

Varadachari, C., T. Chattopadhyay, and K. Ghosh. 1997. "Complexation of Humic Substances with Oxides of Iron and Aluminum." *Soil Science* 162 (1): 28–34. doi:10.1097/00010694-199701000-00005.

Webster, R., and M. A. Oliver. 2001. *Geostatistics for Environmental Scientists.* New York: John Wiley and Sons.

5

Mitigating the Impacts of Climate Change through Spiked Pepper (*Piper aduncum L.*) in Southern Mindanao

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ABSTRACT

This study explored the possibility of harnessing the potentials of spiked pepper (*Piper aduncum*) for climate change mitigation and adaptation. With Upper Buayan Watershed in Sarangani Province as study area, the study aimed to: (1) map old and young spiked pepper stand within the entire watershed, (2) assess carbon stocks of old and young spiked pepper stand within the entire watershed, (3) evaluate carbon stocks at different pools of spiked pepper stand within different classes, (4) determine the relationship among the carbon pools of spiked pepper stand, and (5) categorize spiked pepper's carbon stock according to different stand classes.

Sixty sample plots were randomly selected from the study area. Pre-stratification was conducted with age as the defining factor, while post-stratification was done to classify samples based on slope class and stand type. Data on the following were collected: upper storey carbon biomass, understorey biomass, forest litter carbon (necromass), root biomass, and soil organic carbon (SOC). The t-test was used to determine the significance of differences on carbon deposits among different carbon pools while the Pearson's Correlation was used to identify the association among different carbon pools.

The results revealed that the total area with spiked pepper stand was 1,992.84 hectares (ha), 657.68 ha of which have old stands and 1,335.16 ha with young stands. The surveyed area had a mean carbon of 110.15 Mg ha^{-1}. Under the old-

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age spiked pepper stand at the upper storey, carbon density (23.41 Mg C ha^{-1}) was considered as an indicator of the species' potential to sequester carbon in the future.

Comparing carbon density within slope classes, those of the upper storey and understorey were significantly different at p=.007 and p=.040, respectively. When comparing within age class for the upper storey, understorey, and root biomass, carbon density of old stand was significantly higher (p=.007), (p=.040) and (p=.005) than young stand. For the comparison for type of stand, only upper storey and root biomass were significantly different at (p=.033) and (p=.21). Among the carbon pools, only A, B, and C horizons of soil were found to have a strong relationship.

With the presence of spiked pepper, grasses were eliminated and fire was prevented. The microclimate would eventually improve, hence, the area can be subjected to sustainable watershed management strategies.

INTRODUCTION

The terrains in the southern and western portions of Mindanao as well as some parts of the Visayas were used to be covered with small trees that have been growing abundantly. These trees were eventually cleared in favor of species planted for reforestation, agroforestry, rattan plantation, and assisted natural regeneration. The tree seemed to grow well even by the roadsides and in marginal hilly lands dominated by hard and difficult-to-eradicate weeds such as the cogon grass (*Imperata cylindrica*) and the hagonoy shrub (*Chromolaena odorata*). Locally called *boyo-boyo*, this tree species is commonly referred to in the literature as spiked pepper (*Piper aduncum*) (Figure 5.1 and Figure 5.2).

Spiked pepper (*Piper aduncum*) is a small tree belonging to the family *Piperaceae* which is considered an economically important species in the Pacific. Occasionally reaching a height of seven to 10 meters (m), its leaves are alternate, it has spiky flowers and fruits, and its seeds are very small. *P. aduncum* is native to tropical America such as Mexico and Bolivia. According to Hartemink (2006), *P. aduncum* was first described scientifically in 1753 by Linnaeus. The genus name Piper is derived from the Greek word peperi, which means pepper (Wagner, Herbst, and Sohmer 1999).

Spiked pepper was introduced in the Philippines, particularly in western Mindanao, through bird migration (FPRDI 1994 as cited by Ramilo and Natividad 2000). An ocular survey conducted in most parts of Mindanao revealed that spiked pepper exists in the provinces of Zamboanga del Sur, Zamboanga del Norte, Basilan, eastern part of Misamis Occidental, southern portion of Lanao del Norte, Maguindanao, South Cotabato, Davao del Norte, Davao del Sur, Davao Oriental, and the southern areas of Surigao del Sur and Agusan del Sur (Ramilo et al. 1998). It is also found in the grassland areas in Bukidnon and Leyte (Nasayao and Fabella 1997).

The spiked pepper tree was turning into an invasive species as it appeared to grow easily and take over as dominant vegetation in rocky sites, as well as former cogon and hagonoy sites in Sarangani Province, Mindanao. Thus, the study attempted to address the question: "Is the spiked pepper good or bad for our environment?"

Some trees (such as the *balete*) that were initially considered as weed and with no commercial value turned out to have beneficial uses. Given this, several questions have been raised in relation to the growth of spiked pepper: Are there other uses and potentials of this tree species aside from helping eradicate *hagonoy* and cogon? Can it help in the global pursuit for climate change mitigation and adaptation?

Thus, this study aimed to:

1. Map the old and young spiked pepper stand within the entire watershed;
2. Assess carbon stocks of old and young spiked pepper stand within the entire watershed;
3. Evaluate carbon stocks at different pools of spiked pepper stand within different classes;
4. Determine the relationship among the carbon pools of spiked pepper stand; and
5. Categorize spiked pepper's carbon stock according to different stand classes.

Currently, there has been no attempt to study the carbon stock and sequestration potentials of spiked pepper. The results of this study may serve as a guide in the development of an integrated watershed-based forest land use plan. Furthermore, sound management options for spiked pepper will give farmers a chance to help the government protect the forest from further degradation, rehabilitate the degraded watershed, and mitigate the effects of climate change.

This study is an early attempt to conduct a watershed-based land-use allocation model on spiked pepper-dominated areas.

Figure 5.1. Large area of mountain slope covered by spiked pepper in South Cotabato, Mindanao, Philippines

Figure 5.2. Naturally grown spiked pepper looking like a tree plantation in Tampakan, South Cotabato, Mindanao, Philippines

METHODOLOGY

Selection of the Study Area

The study was conducted in the Upper Buayan Watershed that forms part of the landscape of Sarangani Province near its border with South Cotabato (Figure 5.3). It is a fraction of the Buayan River Basin that consists of four watersheds, namely: (1) Maribulan River Watershed, (2) Big Mainit River Watershed, (3) Domolok River Watershed, and (4) Buayan River (Department of Environment and Natural Resources [DENR] 12-3 2007). The area has been annually visited by fire in previous years, making the landscape dominated by grassland.

Data were gathered between July 2010 and January 2011 or within a period of seven months.

Geographic location

The study area lies within the geographical coordinates of 06°21'43" to 06°27'09" longitude and 125°04'29" to 125°09'03" latitude.

On the Sarangani Province side, the watershed area embraces Barangays Datal Batong, Barrio Blaan, and Datal Bila of the Municipality of Malungon; while on the South Cotabato side, it embraces a portion of Barangay Miasong of the Municipality of Tupi and Barangay Tablu of the Municipality of Tampakan. Called Upper Buayan Watershed, the area is part of Buayan Watershed, which is a component of the Buayan River Basin (Figure 5.4).

Area description

The study site has a total area of 4,845.47 hectares (ha), while the whole watershed of the Buayan River Basin is 11,826.18 ha.

Site Selection

Selection of the site for carbon stock assessment and floral diversity study was done during the walkthrough and ocular survey. Initial site identification was based on the thematic mapping from secondary data of various reliable sources such as Provincial Environment of Local Provincial Environment and Natural Resources of Sarangani, DENR Regional, Provincial and Community Environment and Natural Resources Office (CENRO). Subsequently, during the field validation, ground truthing and actual mapping of spiked pepper in the area were conducted. The selection of sample plot and data gathering activities were simultaneously conducted. The following considerations were used to determine the sample plots: (1) completely colonized by spiked pepper, (2) undisturbed long before the observation, (3) accessible, and (4) no peace-and-order risks.

Figure 5.3. Location map of the provinces of Region 12 showing the study area

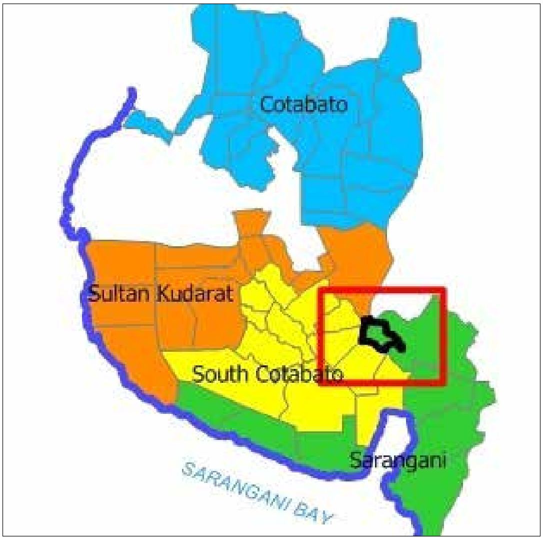
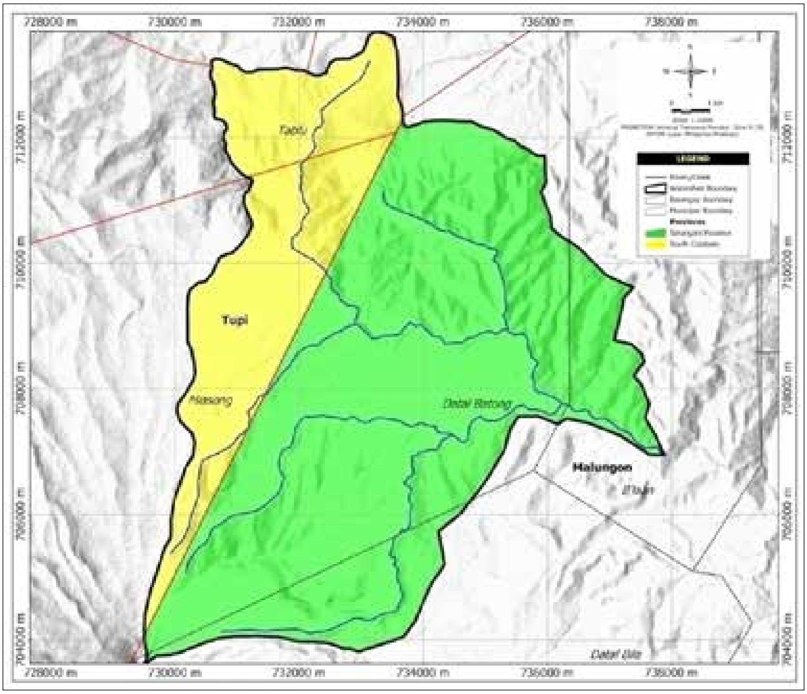


Figure 5.4. Administrative map of Upper Buayan Watershed



Sampling Procedure

Samples of 60 plots having a dimension of 10 × 10 m (100 m^2) were randomly selected from the study area. Pre-stratification was conducted and plot selection was done based on age class (young or old) (Table 5.1).

Post-stratification was conducted after the survey, using remarks and attributes of each sample plot. The attributes considered were slope classes (undulating or steep slopes) and stand type (intact or coppice), classifications of which were based on biophysical criteria (Table 5.1).

The strata were characterized and evaluated in terms of stocking, basal area, volume, bulk density (A, B, and C layers), soil fertility, and biomass.

Age classes were further stratified into slope classes and extent of vegetation type. These information would help predict spiked pepper stand based on biophysical characteristics.

Table 5.1. Criteria for sampling determination based on age class and slope and type of stand

	Criteria
Age Class	
Young	Height ≤5 m, most diameter <5 cm
Old	Height >5 m, almost all diameter at breast height >5 cm
Slope Class	
Undulating	0%–18% slope
Steep slopes	More than 18% slope
Type of stand	
Intact	Majority of the trees were not subjected to harvesting
Coppice	Subjected to utilization, sprout

Upper storey carbon biomass

The upper storey carbon biomass was determined from the 60 sampling plots. All spiked pepper trees with at least two centimeters (cm) in diameter were considered in the biomass study. Diameter at breast height (DBH) of trunks and approximate height of trees were gathered using a diameter tape and calibrated pole. All of the trunks whether grown singly or in clump were measured.

The species-specific allometric equation developed by Tandug and Ramilo (2000) for spiked pepper was used. The biomass (kilogram/trunk) was calculated for each tree using diameter and total height as predictor variables for above-ground biomass. Thus, the equation derived was:

$$\textit{Regression model } W = b_1 D^2 H \text{ (Equation 1)}$$

Where:

W = Oven dry weight (kg/tree)

b_1 = Regression coefficient (0.0137)

D = Diameter at breast height (cm)

H = Total height (m)

The carbon density values were derived by multiplying the computed biomass (Mg C ha^{-1}) using allometric equation with the carbon content default value of 0.45 based on the overall estimate of carbon content of biomass of trees as proposed by the Intergovernmental Panel on Climate Change or IPCC (1996).

Understorey biomass

To determine the understorey biomass, three subplots measuring 1 m × 1 m (Lasco et al. 2005) were randomly laid out within 10 m × 10 m inside the spiked pepper stand. All individual trees having below 2 cm DBH and other woody vegetation found within the subplot were harvested. Thereafter, 300 grams (g) fresh weight of grasses and herbs and other minor vegetation were separated for oven-drying after air-drying. The oven-dried weights of the original biomass samples were obtained through ratio and proportion of the total weight of the sample and sample for oven-drying. The carbon density (Mg C ha^{-1}) for each quadrat was derived by multiplying 0.45 percent IPCC default value for carbon content. This method was also applied on necromass and root biomass.

Forest litter carbon (Necromass)

Litter was collected from the three randomly laid out 0.5 m × 0.5 m subplots within the plot (10 m × 10 m). Collected litter samples from the three subplots were gathered, after which about 300 g of litter were reserved for air-drying and oven-drying. Samples were placed inside the oven with a temperature of ±102°C for at least 48 hours or until the weight of the sample became constant (Lasco et al. 2005).

Root biomass

The mathematical model of Cairns et al. (1997, adopted by Lasco, Sales, and Banaticla 2004) was used to estimate the root biomass based on above-ground biomass (AGB):

$$\textit{Root Biomass (Mg/ha)} = e\,[-1.0587 + 0.8836 * \ln(AGB)] \text{ (Equation 2)}$$

Where:

e = represents the exponential function

ln = refers to natural logarithms

AGB = above-ground biomass

Soil organic carbon

Within each sample plot for understorey biomass, soil samples were taken at various depths (0 cm–10 cm, 11 cm–20 cm, and 21 cm–30 cm) of the soil pits following the ASB Lecture Manual 4B (ICRAF 2001). Samples of soil bulk density were taken using the soil core or improvised metal canister (5 cm diameter and 5 cm height) as tool. Samples for organic carbon content were collected at the same spot where bulk density was taken. Samples were taken to the Central Mindanao University (CMU), Department of Soils Laboratory for chemical analysis using the Walkley-Black Method. To get the carbon content, organic matter was multiplied by 58 percent (Young 1997, as reported by McConkey et al. 1999). Carbon density storage was computed using the following formula (Lasco, Sales, and Banaticla 2005):

$$\text{Bulk density (grams/cubic centimeter [g/cc])} = \frac{\text{Oven-dried weight of soil}}{\text{Volume of canister}} \qquad \text{(Equation 3)}$$

Computation for soil organic carbon (SOC) per hectare:

$$\textit{Volume of one hectare} = 100\ \text{m} \times 100\ \text{m} \times 0.60\ \text{m} \quad \text{(Equation 4)}$$

$$\textit{Weight of soil sample (Mg)} = \text{Bulk density} \times \text{volume} \quad \text{(Equation 5)}$$

$$\textit{Carbon density (Mg/ha)} = \text{weight of soil} \times \text{SOC} \quad \text{(Equation 6)}$$

Statistical analysis

For comparison of means between different classes, t-test was used to determine the significance of differences on carbon deposits among different carbon pools. For determining the association among different carbon pools, Pearson's Correlation was used.

RESULTS AND DISCUSSION

Mapping and Ground Validation of Spiked Pepper Stand

Based on the results, spiked pepper has a total land area of almost 2,000 ha (Table 5.2). This was complemented by data from the vegetative map (Figure 5.5) taken from the Philippine Environment Governance Project (EcoGOV) in 2004, which shows that grassland and brushland have been replaced with and dominated by spiked pepper.

The total land area covered by spiked pepper was further classified into old and young stand (Figure 5.6). The old stand covered 657.68 ha (33%) while the young stand spanned 1,335.16 ha or equivalent to 67 percent (Table 5.2).

Figure 5.5. Vegetative map of Upper Buayan Watershed

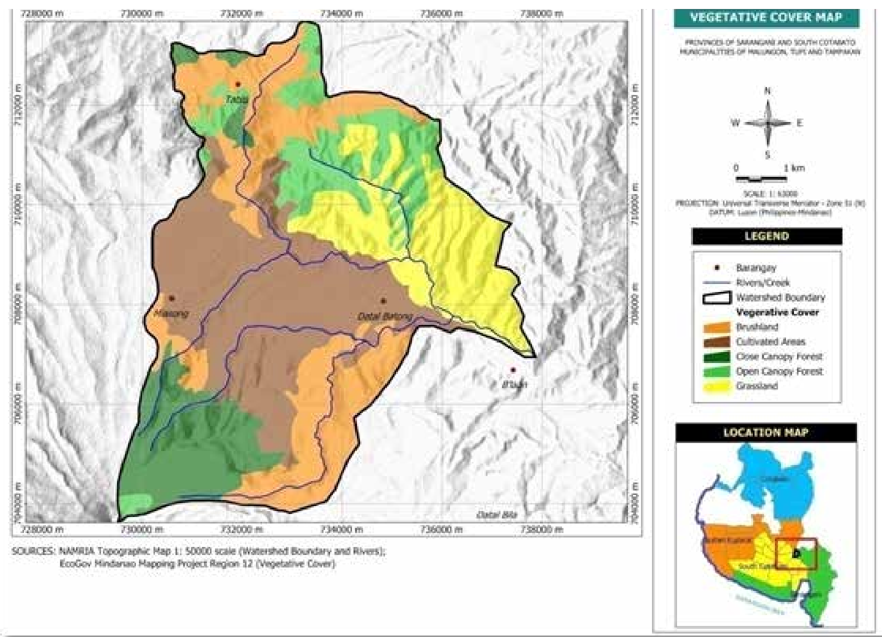


Table 5.2. Distribution of land area in different vegetative covers and land area of spiked pepper stand according to age class within the study site

	Area (ha)	Percentage
Type		
Old Growth	1,916.87	39.56
Cultivated	938.06	19.36
Spiked pepper	1,992.84	41.08
Total	**4,845.45**	**100.00**
Age Class		
Old	657.68	33.00
Young	1,335.16	67.00
Total	**1,992.84**	**100.00**

Carbon Stock Assessment and Evaluation

Distribution of carbon pool

The amount of carbon stock in terms of percentage of above-ground, necromasss, and below-ground (root and soil) biomass and carbon density based on the total computed values from the sampled area were determined (Table 5.3). Based on the overall weighted mean, about 19.06 percent of biomass was contained in upper storey, 0.32 percent for understorey, 1.98 percent for litter, and 3.11 percent for root biomass. The percentage of carbon deposited in the soil was found to be 23.71 percent, 25.35 percent, and 26.46 percent for horizons A, B, and C, respectively. The surveyed area had a mean carbon of 110.15 Mg ha^{-1}.

The above-ground biomass is composed of two strata: the upper storey and understorey vegetations. The upper storey stratum is composed mainly of spiked pepper trees while the understorey stratum consists of various species of shrubs, herbs, ferns, and vines.

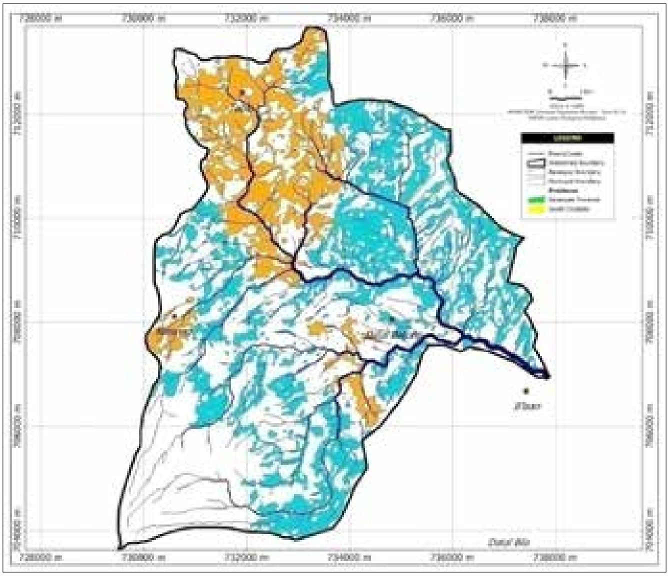
A large proportion of the total above-ground biomass accumulated in the upper storey biomass was 89.24 percent. This finding is consistent with the study of Lasco et al. (2000, as cited by Lasco and Pulhin 2006) which found that the above-ground biomass in the mossy forest in Pagbilao, Quezon and in the Mt. Makiling Forest Reserve were 90 percent and 82 percent, respectively. Similar results on spiked pepper biomass were seen in the studies cited by Lasco et al. (2000, as cited by Lasco and Pulhin 2006) for different types of forest and plantation, particularly the following: 85 percent from tree plantation in Nueva Vizcaya (Lasco et al. 2000, as cited by Lasco and Pulhin 2006); 82 percent from the dipterocarp and mahogany in the Mt. Makiling Forest Reserve, Laguna (Racelis 2000, as cited by Lasco and Pulhin 2006); and 89 percent from the secondary forest in Isabela (Pulhin 2003, as cited by Lasco and Pulhin 2006).

Meanwhile, understorey and necromass exhibited a litter percentage on the total above-ground biomass which were found to be 1.14 percent and 9.27 percent, respectively. Consequently, root biomass shared 3.11 percent, constituting the entire carbon density,

Table 5.3. Summary of carbon density (Mg C ha^{-1}) under different carbon pools of spiked pepper

	Upper Storey	Under-storey	Litter	Total AGB	Root Biomass	SOC			Total SOC	Grand Total
						A	B	C		
Old	23.41	0.36	2.05	**25.82**	3.84	26.27	28.36	30.45	**85.08**	**114.74**
Young	11.33	0.31	2.70	**14.35**	2.03	24.97	26.35	24.08	**75.40**	**91.78**
Mean	20.99	0.35	2.18	**23.52**	3.48	26.14	27.95	29.18	**83.27**	**110.15**
%	19.06	0.32	1.98	**21.32**	3.11	23.71	25.35	26.46	**75.51**	**100.00**

Figure 5.6. Age classification map of spiked pepper



which was highly comparable to 5- and 6-year-old mahogany plantations in Leyte (Sales, Lasco, and Banaticla 2005).

The amount of carbon stock in terms of percentage of above-ground and below-ground (root and soil) biomass and carbon density based on the total computed values from the study site were also derived (Table 5.3). More than 19 percent of the carbon density was tied up in the above-ground biomass, 3.11 percent contained in the root biomass, and 76 percent was deposited in the soil. Schnitzer's (1991) finding that soil is the second major global natural carbon pool corroborates this.

A large percentage (75.51%) of the total carbon density was found in the soil, consistent with the findings of similar studies. Results of previous researches conducted in the Philippines revealed that more than 50 percent of the total carbon are stored in the soil. Lasco, Arnuevo, and Guillermo (1999) found that 59 percent of the total carbon stored in the secondary forests in Leyte were contained in the soil, while in the study at East Timor conducted by Lasco and Cardinoza (2006), it could reach up to 96 percent. Differences in values were due to the history of land use and extent of disturbances in the soil (Sales 1998, as cited by Sales et al. 2004). Another reason identified was the depth of soil sampled. As the soil goes deeper, the mass of soil becomes higher.

Aside from the biomass, soil is also a significant sink and source of carbon (Bouwman 1989, as cited in Lugo and Brown 1993; ENFOR 2007). It has the longest residence time among the organic carbon pools in the forest (Lugo and Brown 1993). The soil component can also contain as much carbon as vegetation (Watson et al. 2000).

This finding on spiked pepper has implications on soil conservation and management since there was no tillage done inside the spiked pepper stand whose stored carbon was measured. It will protect this important carbon pool from erosion and at the same time, provide a favorable climate for microorganisms thereby preserving the fertility of the soil. However, many studies revealed that in tropical soils, carbon storage decreases as the stand matures because carbon is tied up in the biomass.

Lugo and Brown (1993) mentioned that the capacity of the soil to store SOC is dependent on a number of factors: (1) mean annual precipitation, (2) degree of forest disturbance, and (3) extent of land use change.

It is to be noted that a high percentage OM content coupled with low bulk densities are the reasons for the huge carbon density in the soil horizons. Lower bulk density indicates a higher OM content in the soil (Brady 1974, as cited by Sales et al. 2005). The results indicated that the age class (old and young) was not related to its soil carbon density. Similar findings were gathered in the site wherein carbon change of the soil sampled below a depth of 30 cm had no significant relationship with stand age (Polgiase et al. 2000, as cited by Sales et al. 2005).

Furthermore, the age class C values under different carbon pools were determined (Table 5.3). The old-age value showed the potential of spiked pepper stands under favorable site conditions within the study site. The upper storey biomass could reach between 11.33 Mg C ha^{-1} and 23.41 Mg C ha^{-1}. It has a wide and varying biomass density. This finding supports the study of Rogers and Hartemink (2000) in Papua New Guinea which found that two-year-old spiked pepper can grow up to 4.5 m high and can accumulate 48 Mg dry matter (DM) ha^{-1} y^{-1} in the first year and 40 Mg DM ha^{-1} y^{-1} in the second year when 76 percent of the biomass was consisted of the main stems. Its highest growth rate could reach up to 134 kg DM ha^{-1} day^{-1} when it is 17 months old. The difference is due to the site condition where the latter was grown, i.e. in prime agricultural soil as part of agroforestry systems. Another reason is that, this could be due to age, slope, parent material, aspect of the area, type of soil, history of land use, and extent of destruction as a result of utilization and clearing for agriculture. However, Lugo and Brown (1993, as cited by Lasco and Pulhin 2006) stressed that higher biomass values are often associated with less human or natural disturbance.

Under the old spiked pepper stand age, carbon density was considered as an indicator of the species' potential to sequester carbon in the future. It is comparable to and even higher than some of the reforestation species measured in the study of Lasco et al. (2005) in Pantabangan-Caranglan watershed. These species were eucalyptus (12.33), Ipil-ipil (18.98 Mg C ha^{-1}), mixed species (19.97 Mg C ha^{-1}), and gmelina (24.49 Mg C ha^{-1}). This finding is also consistent with the results of some reforestation species according to Sales et al. (2005) in Leyte. These species consist of mahogany 5 years old (15.24 Mg C ha^{-1}), mahogany 6 years old (28.27 Mg C ha^{-1}), and gmelina 4 years old (26.91 Mg C ha^{-1}). Buante (1997) also found a tree plantation in Leyte that attained an average of 25.4 Mg C ha^{-1} for mangium 4 years old and 28.6 Mg C ha^{-1} for acacia 4 years old.

The remarkable carbon density of spiked pepper could be attributed to its number of trunks per hectare. The carbon stocks in horizon A of the soil ranged from 22.31 Mg C ha^{-1} to 26.47 Mg C ha^{-1}. In the same manner, horizon B and horizon C ranged from 25.17 Mg C ha^{-1} to 28.23 Mg C ha^{-1}, and 22.74 Mg C ha^{-1} to 29.74 Mg C ha^{-1}, respectively.

In 2010, it stored an amount of 30,523.65 Mg C in the entire watershed. Meanwhile in 2015, the spiked pepper's ability to absorb carbon from the atmosphere totaled 46,652.39 Mg C in the study area by the year 2015 (Table 5.4).

Table 5.4. Total carbon stored in the upper storey of the entire watershed dominated by spiked pepper, by age class

Age Class	Area (ha)	Carbon Density (Mg ha^{-1})	2010 Carbon Stocks (Mg C)	2015 Carbon Stocks (Mg C)
Upper storey				
Old	657.68	23.41	15,396.29	15,396.29
Young	1,335.16	11.33	15,127.36	31,256.10
Total	**1,992.84**		**30,523.65**	**46,652.39**
Entire watershed				
Old	657.68	114.74	75,462.20	75,462.20
Young	1,335.16	91.78	122,540.98	153,196.26
Total	**1,992.84**		**198,003.19**	**228,658.46**

Including soil carbon and root carbon, total carbon density (Table 5.4) among the carbon pools is higher in the old stand (114.74 Mg C ha^{-1}) compared to the young stand (91.78 Mg C ha^{-1}). The total carbon stock in 2010 was 198,003.19 Mg ha^{-1}. In 2015, it stored a total of 228,658.46 carbon stocks. It is assumed that the young stand will mature in six years. The price of carbon was based on the suggestion by the United Nations report (2007) as cited by Aginci (2007) which is USD 20 Mg^{-1}.

Evaluation of Different Stand Classes

Slope class

In terms of carbon density for upper storey, undulating stand had a mean of 23.91 Mg C ha^{-1} (standard deviation [SD], 17.13 Mg C ha^{-1}), which was higher than the steep stand's value of 10.42 Mg C ha^{-1} (SD, 6.13 Mg C ha^{-1}) (Table 5.5). Consequently, for understorey biomass, undulating stand had a higher mean (0.41 Mg C ha^{-1}; SD, 0.24 Mg C ha^{-1}) compared to the steep slope (0.21 Mg C ha^{-1}; SD, 0.36 Mg C ha^{-1}). These differences were significant at p=.007 and p=.040, respectively (Appendix A). The total mean for undulating stand was 114.60 Mg C ha^{-1} (SD, 63.36 Mg C ha^{-1}), while it was 93.34 Mg C ha^{-1} (SD, 42.59 Mg C ha^{-1}) for the steep slope stand.

Age class

Old-age spiked pepper stored higher carbon at 113.26 Mg C ha^{-1} compared to those with young age (81.30 Mg C ha^{-1}) (Table 5.5). The older stand structure has more carbon stock than young ones due to the metabolic processes of trees. Upper storey carbon density of spiked pepper had 2.28 Mg C ha^{-1} (SD, 1.40 Mg C ha^{-1}) which was significantly higher (p=.007) (Appendix B) compared to young stand with mean carbon of 1.96 Mg C ha^{-1} (SD, 1.54 Mg C ha^{-1}).

Similar findings were observed with understorey biomass in which the old stand's mean of 0.38 Mg C ha^{-1} (SD, 0.28 Mg C ha^{-1}) was significantly higher at p=.040 than the young stand's 0.14 Mg C ha^{-1} (SD, 0.29 Mg C ha^{-1}). The root biomass of the old stand at 3.71 Mg C ha^{-1} (SD, 2.34 Mg C ha^{-1}) was also significantly higher at p=.005 than the young stand which was 1.42 Mg C ha^{-1} (SD, 0.90 Mg C ha^{-1}). As the stand structure got older, carbon stock increased as the tree biomass increased. This result was supported by Lasco and Pulhin's (2006) finding which found that one of the factors for carbon stocking capability of trees is their age.

The estimated total carbon density values obtained from this study is a little bit higher than the estimate reported by Lasco and Pulhin (2006) from various tree plantations of La Mesa watershed in Novaliches, Quezon City. Their estimate has a total carbon density that ranged between 40 Mg C ha^{-1} to 106 Mg C ha^{-1} with a mean of 66 Mg C ha^{-1}. Moreover, the same trend was also seen in the study on tree plantations in Mindanao by Lasco and Pulhin (2009) that reported 31.28 Mg C ha^{-1} of carbon in a four-year-old falcata (*Paraserianthes falcataria*) plantation.

This study also confirmed the agroforestry studies conducted by Lasco et al. (2001), wherein a cacao-based agroforestry farm with Gmelina trees in Mt. Makiling had carbon stocks of 113.4 Mg ha^{-1}, and Zamora (1999) on cacao-based agroforestry farm with Narra trees which had 84.3 Mg ha^{-1}.

Table 5.5. Mean and standard deviation of different carbon pools in the study area based on slope class, age class, type of stand

Carbon Pool	Slope	Mean (Mg C ha^{-1})	Standard Deviation (Mg C ha^{-1})
Slope			
Upper storey*	Steep	10.42	6.13
	Undulating	23.91	17.13
Understorey*	Steep	0.21	0.36
	Undulating	0.41	0.24
Necromass	Steep	2.64	2.02
	Undulating	2.06	1.04
Root biomass	Steep	1.89	0.99
	Undulating	3.92	2.41
Soil A	Steep	24.11	10.56
	Undulating	26.64	12.54
Soil B	Steep	27.62	11.36
	Undulating	27.93	14.16
Soil C	Steep	26.45	11.17
	Undulating	29.73	15.84
Total	**Steep**	**93.34**	**42.59**
	Undulating	**114.60**	**63.36**
Age class			
Upper storey*	Old	22.48	16.51
	Young	7.56	5.46
Understorey*	Old	0.38	0.28
	Young	0.14	0.29
Necromass	Old	2.28	1.40
	Young	1.96	1.54
Root biomass	Old	3.71	2.34
	Young	1.42	0.90
Soil A	Old	26.47	12.10
	Young	22.31	11.26
Soil B	Old	28.23	13.54
	Young	25.17	12.50
Soil C	Old	29.71	15.15
	Young	22.74	9.39
Total	**Old**	**113.26**	**61.32**
	Young	**81.30**	**41.34**
Type of stand			
Carbon pool	Stand	Mean (Mg C ha^{-1})	Standard Deviation (Mg C ha^{-1})
Upper storey*	Coppice	9.95	6.17
	Intact	23.47	16.94
Understorey*	Coppice	0.09	0.15
	Intact	0.44	0.28
Necromass	Coppice	2.97	2.02
	Intact	1.98	1.06

Table 5.5. *Continued*

Root biomass*	Coppice	1.81	0.99
	Intact	3.85	2.39
Soil A	Coppice	23.21	11.31
	Intact	26.78	12.19
Soil B	Coppice	25.88	11.52
	Intact	28.44	13.92
Soil C	Coppice	24.39	9.86
	Intact	30.18	15.70
Total	**Coppice**	**88.30**	**42.02**
	Intact	**115.14**	**62.48**

Note: * means significant at 5%

Table 5.6. Correlation among SOC at A, B, and C horizons

		Soil A	Soil B
	Pearson Correlation	1	0.928*
Soil A	Significant (2-tailed)		0.000
	N	47	47
	Pearson Correlation	0.928*	1
Soil B	Significant (2-tailed)	0.000	
	N	47	47
		Soil A	**Soil C**
	Pearson Correlation	1	0.905*
Soil A	Significant (2-tailed)		0.000
	N	47	47
	Pearson Correlation	0.905*	1
Soil C	Significant (2-tailed)	0.000	
	N	47	47
		Soil C	**Soil B**
	Pearson Correlation	1	0.938*
Soil C	Significant (2-tailed)		0.000
	N	47	47
	Pearson Correlation	0.938*	1
Soil B	Significant (2-tailed)	0.000	
	N	47	47

Note: * means correlation is significant at 0.01 level (2-tailed).

Type of stand

In terms of carbon biomass for type of stand, the intact stand had higher carbon biomass in all categories except for the necromass (Table 5.5). Only the upper storey and root biomass were significantly different at p=.033 and p=.21, respectively (Appendix C). The total carbon for intact stand was 115.14 Mg C ha^{-1} (SD, 62.48 Mg C ha^{-1}), while coppice had 88.30 Mg C ha^{-1} (SD, 42.02 Mg C ha^{-1}).

Relationship among different carbon pools

Among the different carbon pools evaluated for relationship, only SOC at A, B, and C horizons were found to have a significant difference at 0.01 level (Table 5.6). It also revealed very strong positive correlations. For A horizon and B horizon, r=0.928 (significant) while for A horizon and C horizon, r=0.905 (significant). In addition, a significant difference was seen for C horizon and B horizon (r=0.938). This implies that as A horizon increased, B and C horizons also increased. It is important to note that bulk density and percentage of organic matter also played a major role in the values obtained from SOC among the three soil horizons.

Categorization of Spiked Pepper Stand

Upper storey biomass carbon

Data for all sample plots reflecting the mean value on number of trunks, basal area, volume, biomass density, carbon content, and carbon density were taken for upper storey (Table 5.7). The minimum number of trees was 3,300 while the maximum number of trees was 61,400. Spiked pepper has one or more erect trunks per tree and this is enhanced by its ability to coppice as a result of harvesting.

Table 5.7. Mean values

Variable	Unit/M	Minimum	Maximum	Mean	Standard
Upper storey					
No of Trunks	pcs	3,300	61,400	8,540	9,500
Biomass	Mg ha^{-1}	6.21	190.48	47.65	36
Basal Area	m^2 ha^{-1}	6.34	6,214	131.26	798
Volume	m^3 ha^{-1}	8.21	873.60	211.39	167
Carbon Density	Mg ha^{-1}	2.80	85.72	20.99	16
Understorey					
Fresh Weight	kg ha^{-1}	0	500	423.91	345.32
Dry Matter	kg ha^{-1}	0	136.62	48.65	35.30
Biomass	Mg ha^{-1}	0	273.24	77.74	65.36
Carbon	Mg ha^{-1}	0	1.23	0.35	0.29
Necromass					
Fresh Weight	kg ha^{-1}	56.25	1,750	329.83	263.50
Dry Matter	kg ha^{-1}	26.35	395.94	125.76	66.70
Biomass	Mg ha^{-1}	12.44	353.86	124.04	78.25
Carbon Density	Mg ha^{-1}	0.22	6.37	2.23	1.41
Root Biomass					
Root Biomass	Mg ha^{-1}	32.26	663.78	186.04	51.84
Carbon Density	Mg ha^{-1}	0.60	12.35	3.48	2.33

The average stem or coppice per hectare was 8,540 (SD, 9,500) with an average of four per tree. The average number of hills per hectare was 2,135 hills with an equal spacing of 2.1 m × 2.1 m. The average spacing for old stand was 2.4 m × 2.4 m, while that for young stand was 1.6 m × 1.6 m. The former had 1,675 hills ha^{-1}, while the latter had 4,025 hills ha^{-1}. This finding was supported by the study of Rogers and Hartemink (2000) in Papua New Guinea. They noted that 90 percent of the tree seed bank at the fallow site was dominated by spiked pepper. Aggressive invasion and monospecific stands of spiked pepper are brought about by its dominance in the seed bank, fast growth, and high rates of biomass accumulation.

Basal area varied greatly ranging from 6.34 to 6,214 m^2 ha^{-1} with a mean value of 131.26 m^2 ha^{-1} (SD, 798 m^2 ha^{-1}). As for volume, the species had a volume per hectare which ranged from 8.21 m^3 ha^{-1} to 873.60 m^3 ha^{-1}. The huge difference was due to variations in the site quality, age, and physiographic characteristics of an area.

The number of trunks in the old stratum was 6,622 trunks per hectare, while it was 25,800 for the young stratum (Table 5.8). There were more trunks for the young stand because it had very dense, intact, and aggressive growth that it overgrew other minor vegetation. The number of trunks per hectare by age class had an inverse relationship with the carbon density values where the obtained data were 22.48 Mg ha^{-1} and 7.56 Mg ha^{-1} for the old and young stands, respectively. This is brought about by the diameter of the trunk being the predictor variable of the computation of the carbon density. Consequently, the number of trunks for the steep slope (13,947) was higher than the undulating stand (7,034), while the coppice stand (15,445) had more trunks compared to intact vegetation (6,990). For slope class, the steep slope had more trunks compared to undulating because the former usually has rocky and thin soil. Moreover, it was seen that the volumes of old, undulating, and intact stand were higher compared to other classes.

Understorey biomass

The minimum value was zero for biomass content for understorey because there were plots that had no other minor vegetation present (Table 5.7). Of the total 60 sample plots, seven sample plots were found to have no grasses.

An interesting finding is that in areas where spiked pepper reached the stage of final invasion, the understorey plants were eliminated, as manifested by the dead tissues of minor vegetation such as grasses and vines. The sample plots that were devoid of minor vegetation comprised about 12 percent of the total sample plots. These observations support the findings of the study conducted by Orapa (2001) that spiked pepper turn out to be a prospective aggressive invader in the grassland area.

Based on the age classes, the old stand had higher carbon density at 0.38 Mg ha^{-1} than the young stand (0.14 Mg ha^{-1}), while in terms of slope class, the ones on steep slope had higher carbon of 0.21 Mg ha^{-1} than those in undulating slopes (0.04 Mg ha-

^{1}) (Table 5.9). For the type of stand, it was noted that intact stands were denser than coppice stands with a value of 0.44 to 0.09 Mg ha^{-1}, or a difference of 0.35 Mg ha^{-1}. It is important to also note that the fresh weight figure was high because the samples had not been air-dried due to time constraint. The values were based on the results of the outright weighing done in the field.

Forest litter carbon (Necromass)

Floor litters are composed of dead parts of plant tissues at different stages of decomposition. The minimum value of carbon density was 0.22 Mg ha^{-1}, and it could reach up to 6.37 Mg ha^{-1} with a mean value of 2.23 Mg ha^{-1} (SD, 1.41 Mg ha^{-1}) (Table 5.7). The value for fresh weight was based on the collection of samples from the site, thus the high value. This pool had a minimum value of 0.22 Mg ha^{-1} and a maximum of 6.33 Mg ha^{-1}.

In terms of age class, the old stand had higher carbon value (2.27 Mg ha^{-1}) compared to the young stand (1.96 Mg ha^{-1}) (Table 5.9). At this stage, there are remnants of minor vegetation left on the ground. This is also the phase wherein the final colonization of grasslands takes place, which can be attributed to dead organic matter from minor vegetation. For old stand, the organic matter had been already decomposed and incorporated in the soil. Undulating stand had higher carbon than the steep slope stand with a value of 2.41 Mg ha^{-1} and 1.90 Mg ha^{-1}, respectively. For steep slope, coppice had a higher value of 2.64 Mg ha^{-1} compared to 2.06 of intact forest (Table 5.5).

For slope class, steep slope had a higher carbon density with a value of 2.63 Mg ha^{-1} compared to 2.06 Mg ha^{-1} of undulating slopes. For type of stand, coppice stand had a value of 2.96 Mg ha^{-1} which was bigger than intact stand's (1.98 Mg ha^{-1}).

An aspect to consider in evaluating necromass is that the bulk of plant tissues is comprised of varying levels of several major classes of organic compounds. This is affected by the size of molecules and cell wall thickness of cellulose, hemicelluloses, and lignin. Different compositions affect the degradation processes with the thicker and harder cell walls being degraded more slowly (Berg and McClaugherty 2008, as cited by Malayao 2010). The slower the litters are decayed, the longer the carbon is stored in the environment. In theory, during the process of degradation, chemical reaction takes place converting the carbon stocked in the material into another form. Some are leached into the soil and become organic carbon while others become methane which eventually escapes to the atmosphere.

Root biomass

Carbon density could go as low as 0.60 Mg ha^{-1} and could reach as high as 12.35 Mg ha^{-1}, but its average value was 3.48 Mg ha^{-1} (SD, 2.33 Mg ha^{-1}) (Table 5.7). The summary of each plot is presented in Appendix Table 13. The roots of spiked pepper are characterized as fibrous and diffused and the root system shallow.

Table 5.8. Upper storey mean values among different classes

Classes	No. of Trunks	Biomass (Mg ha^{-1})	Basal Area (m^2 ha^{-1})	Volume (m^3 ha^{-1})	Carbon Density (Mg ha^{-1})
Age class					
Old	6,622	49.9	28.17	283.35	22.48
Young	25,800	19.80	1,058.83	92.00	7.56
Slope class					
Steep slope	13,947	23.16	20.53	120.15	10.42
Undulating	7,034	53.14	161.85	304.06	23.91
Stand type					
Coppice	15,445	22.10	20.45	111.82	9.95
Intact	6,990	52.15	156.10	298.43	23.46

Table 5.9. Understorey mean values among different classes

Classes	Fresh Weight (ha^{-1})	Dry Matter Weight (g)	Total Biomass	Carbon Density (Mg ha^{-1})
Understorey				
Age class				
Old	549.29	50.56	97.97	0.38
Young	362.50	43.73	69.54	0.14
Slope class				
Steep slope	680.00	62.00	139.79	0.21
Undulating	399.21	41.50	63.39	0.04
Type of vegetation				
Coppice	211.54	27.14	47.08	0.09
Intact	620.93	57.97	108.65	0.44
Necromass				
Age class				
Old	307.30	126.54	113.87	2.27
Young	388.04	123.75	150.30	1.96
Slope class				
Steep slope	234.67	140.35	105.35	2.63
Undulating	380.81	117.94	134.05	2.06
Type of vegetation				
Coppice	467.79	108.23	146.46	2.96
Intact	270.05	133.35	114.32	1.98

Undulating stand root biomass obtained the highest carbon density value (3.92 Mg ha^{-1}) among the stand classes (Table 5.10). Moreover, the old stand (3.70 Mg ha^{-1}) had a higher carbon than the young stand (1.42 Mg ha^{-1}) while the intact stand (3.85 Mg ha^{-1}) had a greater carbon value than the coppice stand (1.81 Mg ha^{-1}).

Table 5.10. Root biomass mean values among different classes

Classes	Root Biomass (Mg ha^{-1})	Carbon Density (Mg ha^{-1})
Age class		
Old	198.25	3.70
Young	76.08	1.42
Slope class		
Steep slope	101.15	1.89
Undulating	209.41	3.92
Type of vegetation		
Coppice	97.33	1.81
Intact	205.95	3.85

Soil organic carbon

The bulk density for A horizon ranged from 0.75 to 1.53 g/cc, while for carbon density it ranged from 4.26 to 66.09 Mg ha^{-1} (Table 5.11). The former had an average of 0.98 g/cc (SD, 0.25 g/cc), while the latter had 25.94 Mg ha^{-1} (SD, 11.96 g/cc).

Table 5.11. Mean bulk and carbon densities under the A, B, and C horizons

Variable	Unit/M	Minimum	Maximum	Mean	Standard Deviation
A horizon					
Bulk density	g/cc	0.75	1.53	0.98	0.25
Carbon density	Mg ha^{-1}	4.26	66.09	25.94	11.96
B horizon					
Bulk density	g/cc	0.61	1.18	1.05	0.29
Carbon density	Mg ha^{-1}	5.00	74.54	27.84	13.33
C horizon					
Bulk density	g/cc	0.66	1.5	1.07	0.26
Carbon density	Mg ha^{-1}	3.51	88.35	28.82	14.65

On the other hand, B horizon had a minimum bulk density of 0.61 g/cc, while the maximum is 1.18 g/cc with an average of 1.05 g/cc (SD, 0.29 g/cc). The carbon density could reach as high as 74.54 Mg ha^{-1} and as low as 5 Mg ha^{-1}. Despite the big difference, its mean value was 27.84 Mg ha^{-1} (SD, 13.33 Mg ha^{-1}).

As for the C horizon, the minimum bulk density was 0.66 g/cc while the highest was 1.5 g/cc with a mean value of 1.07 g/cc (SD, 0.26 g/cc). The carbon density ranged from 3.51 Mg ha^{-1} to 88.35 Mg ha^{-1}, with an average of 28.82 Mg ha^{-1} (SD, 14.65 Mg ha^{-1}).

Similar figures were observed for the bulk densities across classes (1.00 g/cc), except for coppice stand which had a value of 0.90 g/cc. In terms of carbon density, intact stand slopes had the highest carbon value of 26.78 Mg ha^{-1}, followed by undulating and old age stands which had 26.64 Mg ha^{-1} and 26.47 Mg ha^{-1}, respectively. Most of the steep slope areas were undisturbed as compared to undulating (Table 5.12).

The highest value that reached the B horizon within 10–20 cm was intact stand at 28.44 Mg C ha^{-1}, while the lowest value was the young stand (25.17 Mg C ha^{-1}). In terms of mean value for the age category, the old age stand obtained 28.23 Mg C ha^{-1} compared to the young age stand at 25.17 Mg C ha^{-1}. Data from the undulating stand was slightly higher than that from steep slope with a value of 27.93 Mg C ha^{-1} compared to 27.62 Mg C ha^{-1}. Intact stands had a higher carbon value (28.44 Mg C ha^{-1}) than coppice stands (25.87 Mg C ha^{-1}). Bulk densities ranged from 1.01 g/cc to 1.06 g/cc with an average of 1.05 g/cc (Table 5.12).

The young-steep slope (Y, S) had the lowest bulk density across the classes in the C horizon (Table 5.12). But in terms of carbon density, old-coppice (O, C) obtained the highest value of 38.49 Mg C ha^{-1} .

Table 5.12. Mean values for bulk density and carbon density in the A, B, and C horizons under different age, slope, and stand classes

Classes	Bulk Density (g/cc)	Volume/ha	Weight of Soil (Mg/ha)	Carbon Density (Mg ha^{-1})
A horizon				
Age class				
Old	1.00	1,000	2,910.00	26.47
Young	1.00	1,000	3,018.00	23.30
Slope class				
Steep slope	1.00	1,000	3,005.90	24.11
Undulating	1.00	1,000	2,898.90	26.64

Table 5.12. *Continued*

Type of stand				
Coppice	.90	1,000	2,749.60	23.21
Intact	1.00	1,000	3,009.40	26.78
B horizon				
Age class				
Old	1.06	1,000	1,056	28.23
Young	1.05	1,000	1,053	25.17
Slope class				
Steep slope	1.13	1,000	1,126	27.62
Undulating	1.01	1,000	1,015	27.93
Type of vegetation				
Coppice	1.03	1,000	1,030	25.87
Intact	1.06	1,000	1,064	28.44
C horizon				
Age class				
Old	1.12	1,000	3,362.64	29.71
Young	0.96	1,000	2,878.25	22.74
Slope class				
Steep slope	1.20	1,000	3,598.77	26.45
Undulating	1.01	1,000	3,035.08	29.73
Type of stand				
Coppice	1.00	1,000	2,994.26	24.39
Intact	1.11	1,000	3,332.53	30.18

CONCLUSIONS

The results revealed that the total area with spiked pepper stand was 1,992.84 ha, 657.68 ha of which have old stands and 1,335.16 ha with young stands. Based on the overall weighted mean, about 19.06 percent of biomass was contained in the upper storey, 0.32 percent for understorey, 1.98 percent for litter, and 3.11 percent for root biomass. The percentage of carbon deposited in the soil was found to be 23.71 percent, 25.35 percent, and 26.46 percent for horizons A, B, and C, respectively. The surveyed area had a mean carbon of 110.15 Mg ha^{-1}.

Under the old spiked pepper stand age at the upper storey, carbon density (23.41 Mg C ha^{-1}) was considered as an indicator of the species' potential to sequester carbon in the future. This is comparable to and even higher than some of the reforestation species measured in studies of Buante (1997), Sales et al. (2005), and Lasco (2009). The remarkable carbon density of spiked pepper can be attributed to its number of trunks per hectare. As of 2010, it stored an amount of 30,523.65 Mg C in the entire watershed. In 2015, spiked pepper's ability to absorb carbon from the atmosphere totaled 46,652.39 Mg C in the study area.

Spiked pepper stand was further categorized in terms of number of trunks, biomass, basal area, volume, bulk density, soil fertility, and carbon density based on age class, slope class, and type of stand structure. Comparing carbon density within slope classes, those of the upper storey and understorey were significantly different at p=.007 and p=.040, respectively. When comparing within age class for the upper storey, understorey, and root biomass, carbon density of old stand was significantly higher (p=.007, p=.040, and p=.005) than young stand. For the comparison for type of stand, only upper storey and root biomass were significantly different at p=.033 and p=.21. Among the carbon pools, only A, B, C horizons of soil found to have a strong relationship.

The minimum number of trees was 3,300, while the maximum number of trees was 61,400. The fact is that spiked pepper has one or more erect trunks per tree and this is even enhanced by its ability to coppice as a result of harvesting.

The average stem or coppice per hectare is 8,540 with an average of four per tree.

Basal area varied greatly ranging from 6.21 to 6,214 m^2 ha^{-1} with a mean value of 131.26 m^2 ha^{-1}. As for volume, the species remarkably showed that the volume per hectare ranged from 8.21 m^3 ha^{-1} to 873.6 m^3 ha^{-1}.

As shown in Table 5.8, the average number of trunks in the old stratum is 6,622 trunks per hectare, while it is 25,800 for the young.

The number of trunks for the young stand was found to be higher in terms of age class. The young stand has very dense, intact, and aggressive growth that it has overgrown other minor vegetation.

The minimum value was zero for biomass content for understorey because there were plots that had no other minor vegetations present. Of the total 60 sample plots, seven sample plots were found to have no grasses.

An interesting finding is that in areas where spiked pepper reached the stage of final invasion, the understorey plants are eliminated, as manifested by the dead tissues of minor vegetation such as grasses and vines. The sample plots that are devoid of minor vegetation comprised about 12 percent of the total sample plots. These observations support the findings of the study conducted by Orapa (2001) that spiked pepper turn out to be a prospective aggressive invader in the grassland area.

Based on the age classes, the old stand had higher carbon at 0.38 Mg C ha^{-1} than the young (Table 5.9), while in terms of slope class, the ones on steep slope had higher carbon of 0.21 Mg C ha^{-1} than those in undulating slopes. For the type of stand, it was noted that intact stands are denser than coppice stands with a value of 0.21 to 0.04 Mg C ha-^{1} or a difference of 0.17 Mg C ha^{-1}.

The minimum value of carbon density was 0.22 Mg ha^{-1} and it could reach up to 6.37 Mg ha^{-1} with a mean value of 2.23 Mg ha^{-1}. The value for fresh weight was based on the collection of samples at the site–the reason for having high value. This pool had a minimum value of 0.22 Mg ha^{-1} and a maximum of 6.33 Mg ha^{-1}.

In terms of age class, Table 5.9 showed that the young stand had higher carbon value compared to old stand. Young age stand has higher carbon value (2.27 Mg C ha^{-1}) as compared to the old stand (2.1 Mg C ha^{-1}).

For slope class, steep slope has bigger carbon compared to undulating slopes which has a value of 2.63 Mg ha^{-1} compared to 2.06 Mg ha^{-1}. For type of stand, coppice stand has a value of 2.6 Mg C ha^{-1} which is bigger than intact stand (1.98 Mg C ha^{-1}). The mean value was 1.98 Mg C ha^{-1}.

Data reveals that carbon density could go as low as 0.6 Mg ha^{-1} and could reach as high as 12.35 Mg ha^{-1}. But its average value was 3.48 Mg ha^{-1}.

The undulating stand root biomass obtained the highest value (3.92 Mg ha^{-1}) among the stand classes. Old stand was greater than young stand while intact stand had greater value than undulating stand.

The bulk density for A horizon ranged from 0.75 to 1.53 g/cc, while for carbon density, it ranges from 4.26 to 66.09 Mg ha^{-1}. The former has an average of 0.98 g/cc while the latter has 25.94 Mg ha^{-1}. Soil B horizon had a minimum bulk density of 0.61 g/cc, while the maximum is 1.18 g/cc with an average of 1.05 g/cc. The carbon density could attain as high as 74.24 Mg ha^{-1} and as low as 5 Mg ha^{-1}. Despite the big difference, its mean value is 27.84 Mg ha^{-1}.

As for the Soil C horizon, the minimum bulk density of 0.66 01 g/cc is the lowest value of bulk density and the highest is 1.5 g/cc with mean value of 1.07 g/cc. The carbon density ranged from 3.51 Mg C ha^{-1} to 88.36 Mg C ha^{-1} and an average of 28.22 Mg ha^{-1}, respectively.

The bulk densities wherein the same values were observed (1.0 g/cc) except for coppice stand which has a meager difference, having a value of 0.9 g/cc. In terms of carbon density, intact stand slopes had the highest carbon value of 26.78 Mg ha^{-1}, followed by undulating and old age stands which had 26.64 Mg ha^{-1} and 26.47 Mg ha^{-1}.

The highest value that reached the B horizon within 10–20 cm was intact stand at 28.44 Mg C ha^{-1}, while the lowest value was the young stand (25.17 Mg C ha^{-1}). In terms of mean value for the age category, the old age stand obtained 28.23 Mg C ha^{-1} compared to the young age stand at 25.17 Mg C ha^{-1}. Data from the undulating stand was slightly higher than that from steep slope with a value of 27.93 Mg C ha^{-1} compared to 27.62 Mg C ha^{-1}. Intact stands had a higher carbon value (28.44 Mg C ha^{-1}) than coppice stands (25.87 Mg C ha^{-1}). Bulk densities ranged from 1.01 g/cc to 1.06 g/cc with an average of 1.05 g/cc.

LITERATURE CITED

Aginci, U. 2007. "Global Warming: How Much a Ton of Carbon Dioxide Will Cost?" Accessed March 10, 2010. http://ezinearticles.com/?Global-Warming---How-Much-a-Ton-of-Carbon-Dioxide-will-Cost?&id=573939.

Berg, B., and C. McClaugherty. 2008. *Plant Litter: Decomposition, Humus Formation, Carbon Sequestration*. 2nd ed. Berlin: Springer-Verlag.

Brickell, C., and J. D. Zuk. 1997. *The American Horticultural Society A-Z Encyclopedia of Garden Plants.* New York: DK Publishing, Inc.

Buante, C. R. 1997. "Biomass Production of *Acacia mangium Willd.*, *Gmelina arborea Roxb.*, and *Acacia auriculiformis A. Cunn. Ex Benth*. as fuelwood species in Leyte." In *Developments in Agroforestry Research,* edited by M. Cabangbang, F. Baradas, and A. Cabrera, 224–246. Los Baños, Laguna: Philippine Council for Agriculture, Forestry and Natural Resources Research and Development.

DENR (Department of Environment and Natural Resources) 12-3A. 2007. "Watershed Characterization of Buayan River Basin Watershed." Final Report. Alabel, Sarangani Province: DENR 12-3A.

Environmental Forestry (ENFOR). 2007. "Resource Inventory of Angat Watershed Reservation." Project Report. Los Baños, Laguna: Environmental Forestry Programme, College of Forestry and Natural Resources, University of the Philippines Los Baños.

Gann, G. D., and K. A. Bradley. 1999. "The Exotic Plants of Southern Florida." Accessed October 30, 2002. http://www.home.earthlink.net/~mark_phagan/sfexotics/sfehome.html.

Intergovernmental Panel For Climate Change. 1996. *Revised Guidelines for Greenhouse Gas Inventory, Land Use and Forestry Sector.* London: Intergovernmental Panel on Climate Change.

Lasco, R. D., M. T. Arnuevo, and I. Q. Guillermo. 1999. "Carbon Dioxide Absorption and Sequestration in the PNOC-Geothermal Reservation." Final Report. Los Baños, Laguna: Environmental Forestry Programme, College of Forestry and Natural Resources, University of the Philippines Los Baños.

Lasco, R. D., R. F. Sales, R. Estrella, S. R. Saplaco, A. S. Castillo, R. V. O. Cruz, F. B. Pulhin. 2001. Carbon Stock Assessment of Two Agroforestry Systems in a Tropical Forest Reserve in the Philippines. *The Philippine Agricultural Scientist* 84(4): 401–407.

Lasco, R. D., R. F. Sales, and M. R. N. Banaticla. 2004. "Carbon Storage and Sequestration Potential of Smallholder Tree Farms on Leyte Island, the Philippines." In *ACIAR Proceedings from the End-of-Project Workshop* 2005-01-01, Ormoc City, the Philippines, August 19–21, 2004, 129–141.

Lasco, R. D., F. B. Pulhin, R. V. O. Cruz, and S. S. N. Roy. 2005. "Carbon Budget of Terrestrial Ecosystems in Pantabangan-Caranglan Watershed." *AIACC Working Paper* No. 10. Accessed March 10, 2010. http://www.start.org/Projects/AIACC_Project/working_papers/Working%20Papers/AIACC_WP_No010.pdf

Lasco, R. D., and F. B. Pulhin. 2006. "Assessing the Role of Watershed Areas in Mitigating Climate Change in the Philippines: The Case of the La Mesa Watershed." *Journal of Environmental Science and Management* 9 (1): 19–29.

Lasco, R. D., and M. M. Cardinoza. 2007. "Baseline Carbon Stocks Assessment and Protection of Future Carbon Benefits of a Carbon Sequestration Project in East Timor." *Mitigation and Adaptation Strategies for Global Climate Change* 12 (2): 243–257. doi:10.1007/s11027-005-9011-8.

Lugo, A. E., and S. Brown. 1993. "Management of Tropical Soils as Sinks or Sources of Atmospheric Carbon." *Plant and Soil* 149: 27–41.

Malayao, S. L. "Comparative Evaluation of Biodiversity and Carbon Sequestration of Fruit Tree-Based Agroforestry Systems in CARAGA Region, Philippines." MS Thesis, University of the Philippines Los Baños, 2010.

McConkey, B., B. Liang, W. Lindwall, and G. Padbury. 1999. *The Soil Organic Carbon Story.* Agriculture and Agri-Food Canada, Semiarid Prairie Agricultural Research Centre, Swift Current, SK, S9H 3X2.

Nasayao, E. E., and M. R. Fabella. 1997. *Morphology, Distribution and Indigenous Uses of Spiked Pepper* (*Piper aduncum L*). Tacloban City: Ecosystems Research and Development Bureau, Department of Environment and Natural Resources Region VIII.

Orapa, W. 2001. "Impediments to Increasing Food Security in PNG: The Case of Exotic Weed Species." In *Food Security for Papua New Guinea*, edited by R. Michael Bourke, Matthew G. Allen, and J. G. Salisbury, 308–315. Proceedings of the Papua New Guinea Food and Nutrition 2000 Conference, Papua New Guinea University of Technology, Lae, June 26–30, 2000.

Ramilo, V. C., and T. D. Natividad. 2000. "Germination Test of Palo Verde." In *Development and Management Technologies for Palo Verde (Piper arborescens) Plantation in Western Mindanao.* Terminal Report. Pasonanca, Zamboanga City: ERDS, DENR-Region IX.

Rogers, H. M., and A. E. Hartemink. 2000. "Soil Seed Banks and Growth Rates of an Invasive Species, Piper aduncum, in the Lowlands of Papua New Guinea." *Journal of Tropical Ecology* 16 (2): 243–251.

Sales, R. F., R. D. Lasco, and M. R. N. Banaticla. 2005. "Carbon Storage and Sequestration Potential of Smallholder Tree Farms on Leyte Island, the Philippines." In *ACIAR Smallholder Forestry Project: Redevelopment of a Timber Industry Following Extensive Land Clearing*, edited by Steve Harrison, John Herbohn, Jung Ho Suh, Eduardo Mangaoang, and Jerry Vanclay, 129–141. Proceedings from the End-of-Project Workshop, Ormoc City, Philippines, August 19–21, 2004.

Schnitzer, M. 1991. "Soil Organic Matter: The Next 75 Years." *Soil Science* 151 (1): 41–58.

Tandug, L. M., and V. C. Ramilo. 2000. "Wood Biomass Estimation of Palo Verde (Piper arborescens)." In *Development and Management Technologies for Palo Verde (Piper arborescens) Plantation in Western Mindanao.* Terminal Report. Pasonanca, Zamboanga City: ERDS, DENR Region IX.

Wagner, W. L., D. R. Herbst, and S. H. Sohmer. 1999. *Manual of the Flowering Plants of Hawaii.* Rev. ed. Bishop Museum Special Publication 83. Honolulu, HI: University of Hawai'i Press.

Watson, R. T., I. R. Noble, B. Bolin, N. H. Ravindranath, D. J. Verado, and D. J. Dokken (Editors). 2000. *Land Use, Land Use Change, and Forestry.* Cambridge, UK: Cambridge University Press.

Wunderlin, R., and B. Hansen. 2002. "Atlas of Florida Vascular Plants." Accessed October 30, 2002. http://www.plantatlas.usf.edu/

Zamora, D.S. 1999. "Carbon Dioxide (CO2) Storage Potential of Multistorey Agroforestry Systems in Mt. Makiling." College, Laguna, Philippines, College of Forestry and Natural Resources, UPLB. (MS thesis)

Appendix A

Independent samples test for carbon density under slope class category

		Levene's Test for Equality of Variances		T-test for Equality of Means						
		F	Sig.	t	dF	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
NECROMAS	Equal variances assumed	9.894	.003	1.245	41	.220	.57849	.46483	-.36025	1.51723
	Equal variances not assumed			.978	14.842	.344	.57849	.59139	-.68319	1.84017
UPPERSTOREY	Equal variances assumed	2.278	.137	-2.777	58	.007	-13.49033	4.85854	-23.21575	-3.76491
	Equal variances not assumed			-4.464	54.034	.000	-13.49033	3.02184	-19.54867	-7.43198
LOWER	Equal variances assumed	1.388	.245	-2.120	41	.040	-.19879	.09378	-.38818	-.00941
	Equal variances not assumed			-1.823	16.994	.086	-.19879	.10906	-.42891	.03132
ROOTBIO	Equal variances assumed	1.977	.165	-2.948	58	.005	-2.02784	.68793	-3.40488	-.65080
	Equal variances not assumed			-4.551	49.388	.000	-2.02784	.44561	-2.92315	-1.13253
SOILA	Equal variances assumed	.006	.941	-.645	45	.522	-2.53100	3.92632	-10.00360	5.37702
	Equal variances not assumed			-.697	25.700	.492	-2.53100	3.63330	-10.00360	4.94161
SOILB	Equal variances assumed	.086	.771	-.069	45	.945	-.30380	4.39310	-9.15196	8.54436
	Equal variances not assumed			-.076	27.018	.940	-.30380	3.97887	-8.46752	7.85992
SOILC	Equal variances assumed	. 562	.457	-.681	45	.499	-3.27498	4.80662	-12.95600	6.40605
	Equal variances not assumed			-.795	30.908	. 433	-3.27498	4.12018	-11.67916	5.12920

Appendix B

Independent samples test for carbon density under age class category

		Levene's Test for Equality of Variances		T-test for Equality of Means						
		F	Sig.	t	dF	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
NECROMAS	Equal variances assumed	2.545	.116	2.375	58	.021	12.07667	5.08464	1.89866	22.25468
	Equal variances not assumed			3.973	51.539	.000	12.07667	3.03933	5.97650	18.17683
UPPERSTOREY	Equal variances assumed	.991	.325	.496	41	.622	.05003	.10084	-.15362	.25368
	Equal variances not assumed			.432	15.772	.672	.05003	.11585	-.19586	.29591
LOWER	Equal variances assumed	2.163	.149	-1.380	41	.175	-.65417	.47396	-1.61135	.30302
	Equal variances not assumed			-1.296	17.820	.212	-.65417	.50483	-1.71554	.40721
ROOTBIO	Equal variances assumed	2.254	.139	2.497	58	.015	1.80250	.72194	.35739	3.24761
	Equal variances not assumed			3.988	45.672	.000	1.80250	.45198	.89254	2.71246
SOILA	Equal variances assumed	.133	.717	.322	45	.749	1.30150	4.04174	-6.83898	9.44198
	Equal variances not assumed			.326	19.507	.748	1.30150	3.99496	-7.04536	9.64836
SOILB	Equal variances assumed	.101	.752	.447	45	.657	2.01131	4.49695	-7.04601	11.06862
	Equal variances not assumed			.459	20.005	.651	2.01131	4.38383	-7.13305	11.15567
SOILC	Equal variances assumed	.154	.697	1.309	45	.197	6.36690	4.86454	-3.43078	16.16459
	Equal variances not assumed			1.551	27.264	.132	6.36690	4.10517	-2.05238	14.78619

Appendix C

Independent samples test for carbon density under type of stand category

		Levene's Test for Equality of Variances		T-test for Equality of Means						
		F	Sig.	t	dF	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
NECROMAS	Equal variances assumed	11.306	.002	2.083	41	.044	.98727	.47398	.03004	1.94450
	Equal variances not assumed			1.549	11.930	.147	.98727	.63732	-.40222	2.37677
UPPERSTOREY	Equal variances assumed	1.946	.168	-2.594	58	.012	-13.52121	5.21185	-23.95385	-3.08856
	Equal variances not assumed			-4.429	45.376	.000	-13.52121	3.05267	-19.66819	-7.37422
LOWER	Equal variances assumed	2.342	.134	-4.010	41	.000	-.35335	.08812	-.53132	-.17538
	Equal variances not assumed			-5.333	33.233	.000	-.35335	.06625	-.48811	-.21859
ROOTBIO	Equal variances assumed	1.676	.201	-2.763	58	.008	-2.04020	.73829	-3.51804	-.56237
	Equal variances not assumed			-4.493	39.141	.000	-2.04020	.45404	-2.95849	-1.12192
SOILA	Equal variances assumed	.107	.745	-.862	45	.393	-3.56283	4.13322	-11.88757	4.76191
	Equal variances not assumed			-.897	17.710	.382	-3.56283	3.97009	-11.91349	4.78783
SOILB	Equal variances assumed	.065	.800	-.554	45	.582	-2.56480	4.62572	-11.88148	6.75188
	Equal variances not assumed			-.614	19.790	.546	-2.56480	4.17770	-11.28527	6.15567
SOILC	Equal variances assumed	.679	.414	-1.151	45	.256	-5.78869	5.03078	-15.92119	4.34382
	Equal variances not assumed			-1.462	26.889	.155	-5.78869	3.95951	-13.91451	2.33713

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Climate Change Adaptation and Resilience of Coastal Communities in the Red River Delta Biological Reserve, Vietnam

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ABSTRACT

This case study assessed the climate change adaptation and resilience of coastal communities in Giao Thien and Giao Xuan in GiaoThuy District, Vietnam. Methods used included a survey, key informant interview, and review of documents on the community profile. A total of 194 households served as respondents in the study. Descriptive and inferential statistics were employed, particularly the Pearson Product Moment Correlation in determining the relationship between climate change adaptation and resilience.

The results revealed that majority of the respondents were knowledgeable on climate change adaptation and have plans in addressing climate change. Preparing materials to shield houses, storing food, monitoring of weather bulletins, and, if needed, evacuating, were practices that respondents were accustomed to. Different types of capital were also analyzed to determine the communities' resilience to climate change. It was found that the coastal communities have low social, economic, human, physical, and natural capitals. Moreover, climate change adaptation and resilience had weak association. Thus, there is a need to unify and link different stakeholders to mitigate the effects of climate change.

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INTRODUCTION

Vietnam is one of the most vulnerable countries to climate change impacts (Dasgupta et al. 2007). It is ranked as the region's most hazard-prone areas because of the regular occurrence of floods, droughts, and typhoons (World Bank Group 2011). Recent research revealed that by 2050, sea level would rise up to 33 centimeters (cm) more and by 2100, it would rise by up to 1 meter (m).This scenario may lead to a reduction in the country's Gross Domestic Product (GDP) by about 10 percent (Dasgupta et al. 2007). This implies that the livelihood of the coastal communities would be highly affected by climate change. Thus, it is imperative to conduct an in-depth study in the Red River Delta, particularly on climate change adaptation and resilience due to the environmental, economic, and social importance of the area.

Climate change adaptation and resilience are development issues that should be taken into account in planning and developing programs and projects. Resilience refers to the patterns of positive adaptation reflecting the process of adaptation, capacity to adapt, or the outcome of successful adaptation, despite the presence of challenging or threatening circumstances (Masten, Best, and Garmezy 1990, as cited in Yates and Masten 2004). On the other hand, climate change adaptation pertains to the ability of ecological, social, or economic systems to adjust to climate change including climate variability and extremes (Easterling et al. 2007).

According to the Organization for Economic Co-operation and Development (OECD) (2010), there is a need to identify how coastal communities adapt to climate change to determine the productivity and sustainability of the systems in place and to assist in framework development. Lagos and Wirth (2009) indicated that many Least Developed Countries (LDCs) and small islands have a limited capacity to respond to the challenge of adaptation. In this regard, it is timely to document the resilience of the coastal communities to adapt to climate change to serve as models for countries that have limited capacity to do such.

One of the adaptation strategies to climate change is the strengthening of community capacity. In the context of climate change, community capacity is the ability of the communities to adapt to real and potential impacts. The common goal is to reduce the vulnerability of the community while increasing its resilience to the effects of climate change. Communities can increase their resilience to the adverse impacts as well as take advantage of opportunities that may result from climate change by preparing for the future in a locally meaningful and policy-relevant way (Mendis, Mills, and Yantz 2003).

Because of the vulnerability of the coastal communities to the effects of climate change, community development is highly needed. Community development, according to the Budapest Declaration (2004), is a way of strengthening civil society by prioritizing communities' actions and their perspectives in developing social, economic, and environmental policies. It seeks to empower the local communities, communities of interest or identity, and communities organizing specific themes or policy initiatives.

It also strengthens the capacity of people as active citizens through their community groups, organizations, and networks. Even the institutions and agencies are being capacitated to work in dialogue with citizens to shape and determine changes in their communities. Community development, therefore, plays a vital role in supporting active democratic life by promoting the autonomous voice of the disadvantaged and vulnerable communities.

Thus, documenting the coastal communities' resilience to climate change is valuable. This can serve as baseline information for the Vietnam government in conducting environmental planning, specifically in identifying appropriate projects/programs, formulating policies, and recommending strategies to make coastal communities resilient to climate change.

METHODOLOGY

The study utilized a case study approach using various methods such as survey among households in coastal communities, key informant interview with the Director of Xuan Thuy National Park, and review of documents particularly the profile of the study sites, which serve as baseline information in analyzing the study sites. The research was conducted in the biological reserve of the Red River Delta, particularly in GiaoThuy District under Nam Dinh Province located in the easternmost province of Nam Dinh adjacent to South and East China Sea.

Giao Thien and Giao Xuan communes in GiaoThuy District were chosen as study sites because they are the most adjacent to the sea, which make them bear all the direct effects of climate change. Moreover, their sources of income are agriculture and fishing.

The sample population size was computed using Slovin's formula at 10 percent margin of error. Out of the 5,721 households, 194 households served as the sample size. Simple random sampling was used in selecting household heads that would serve as respondents of the study. To ensure validity and reliability of the research instrument, it was pretested to households in other communes in the biological reserve. Questions focused on preparation activities and preventive measures to adapt to climate change. Descriptive statistics such as frequency distribution, percentages, means, and standard deviations were computed to describe the data. Pearson Product Moment Correlation was used to determine the relationship between climate change adaptation and resiliency. This is used to measure relationship between climate change adaptation and resilience of coastal communities. Value 0 to +/-0.20 means very weak linear association, +/-0.21 to +/-0.40 means weak linear association, +/-0.41 to +/-0.60 means moderate linear association, and +/-0.61 to +/-0.80 means strong linear association.

RESULTS AND DISCUSSION

Climate Change Adaptation

Knowledge on climate change adaptation

When the effects of both inherent and gained knowledge of the people in a community were studied and related to the ability of a community to adapt to climate change, results revealed that majority (63%) of the respondents considered themselves knowledgeable on how to adjust to climate change (Table 6.1). They acquired information through trainings and workshops (62%), media (20%) such as television, radio, and newspaper, and through self-learning and diffusion of folk experience (15%).

The knowledge obtained from trainings/workshops included methods and techniques on how to cultivate plants, raise livestock with strong resistance against diseases, and treat diseases (28%). Information gathered also included raising awareness on environmental protection through the use of organic matter and planting more trees (26%). Knowledge on climate change could be heightened by sharing and exchanging information on adaptation strategies adopted.

Table 6.1. Respondents' knowledge on climate change adaptation

Particulars	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Knowledge to adapt						
Yes	61	63	62	64	**123**	**63**
No	36	37	35	36	**71**	**37**
Total	**97**	**100**	**97**	**100**	**194**	**100**
How knowledge was obtained*	(n=61)		(n=62)		(n=123)	
Trainings/workshop	38	62	38	61	**76**	**62**
Television, newspaper, radio	15	25	9	15	**24**	**20**
Retransmission of local/folk experience and self-learning	6	10	12	19	18	15

Note: * means multiple responses

Kinds of knowledge on climate change adaptation

The respondents' knowledge on climate change is associated to land salinity (19%); irregular weather changes, hot temperature, and rise in sea level (15%); erratic weather changes, and temperature increases (13%) (Table 6.2).

Based on the study conducted by Concepcion et al. (2009) in Camarines Sur, Philippines, the farmers can no longer predict the dry and wet seasons also. Similarly, they observed rapid changes in weather patterns particularly from very hot weather to heavy rain showers. In Misamis Oriental, Philippines, the farmers are also having difficulty in predicting the wet and dry seasons. They observed that the typhoons started to arrive earlier from 2006 to 2009 and are becoming more frequent and stronger (Concepcion et al. 2009). This shows that climate change is not only evident in Vietnam, but is also being experienced in other countries.

Table 6.2. Respondents' knowledge on climate change

Particulars	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Knowledge	(n=95)		(n=96)		(n=191)	
Frequent storms and floods resulting to damage in agriculture	28	30	26	27	**54**	**28**
Saline land, erratic weather, increasing temperature resulting to more rain	17	18	19	20	**36**	**19**
Irregular weather changes, hot temperature, and sea level rise	20	21	8	8	**28**	**15**
Sea level rise, erratic weather changes, temperature increases	4	4	20	21	**24**	**12**
Environmental disruption alters the life of natural resources (rice, fish); Many pests in rice and livestock.	8	8	13	14	**21**	**11**
Global warming	11	12	8	8	**19**	**10**
Extreme weather conditions (summer is too hot, winter is too cold)	7	7	2	2	**9**	**5**
Total	**95**	**100**	**96**	**100**	**191**	**100**

Preparedness

The respondents had already experienced typhoons for several times. The activity of the majority (62%) prior to the occurrence of typhoon includes preparing materials such as bamboo, wooden pillars, and sandbags that can be used to shield their houses. Others shield their houses from strong winds by closing their windows (17%) while the rest intend to build concrete houses (12%) (Table 6.3).

The answers of the respondents are based on their experiences when a typhoon is coming (Table 6.4). Majority (76%) of the respondents cited that they prepare food particularly rice, dried fish, noodles and water. The data obtained only show that the priority of the respondents is food to eat since they are not aware of how long will the flood subside. By reserving food at home, they are assured that they will not get hungry even if they cannot go out of their respective houses to purchase food. On the other hand, others (12%) cited that they store water in containers and place them in a high area inside the house.

Table 6.3. Respondents' activities to secure their houses

Activities	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Prepare the materials (bamboo, wooden pillars, sandbags) to shield the house; clear the bushes and trees around house	59	61	62	64	121	62
Shield the house by closing the windows due to strong winds	9	9	23	24	32	17
Solidify/ concretize the houses	20	21	4	4	24	12
None	9	9	8	8	17	9
Total	**97**	**100**	**97**	**100**	**194**	**100**

Table 6.4. Respondents' preparatory activities before a typhoon

Activities	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Reserve food (noodles, rice, dried fish) and water	70	72	77	79	147	76
Reserve water in closed containers and store in a high area of the house	9	9	14	14	23	12
Prepare rice and floaters such as plastic containers and car tires	6	6	0	0	6	3
None	12	12	6	6	18	9
Total	**97**	**100**	**97**	**100**	**194**	**100**

Community practices

Whenever a storm threatens to hit the study sites, a number of respondents (25%) evacuate the elderly and children first and then collaborate with concerned organizations for assistance. Another 16 percent cited that before a typhoon, they prepare necessary materials, solidify the sea dikes, and mobilize the people and organizations involved in typhoon responses (Table 6.5).

In Vietnam, the goal of the natural disaster risk management program is to enhance the community's resilience against the impacts brought by natural hazards. The recent economic and human toll of natural disaster events in Vietnam served as an avenue to prioritize investment on this aspect when factoring in climate change (UNDP 2010).

In a study conducted by Peñalba (2008) in the five vulnerable municipalities in the provinces of Cavite, Pampanga, Batangas, and Isabela, it was found that households

Table 6.5. Household practices in response to an upcoming typhoon

Activities	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Prioritize evacuation of the elderly, children, and youth and collaborate with concerned organizations	28	29	20	21	**48**	**25**
Prepare the materials needed, solidify sea dikes, and mobilize the people and organizations involved in typhoon response	12	12	20	21	**32**	**17**
Conduct meeting of the Board of Administration; disseminate information to all villages; prepare food, and evacuate people	16	17	9	9	**25**	**13**
Go to government evacuation center, shield the house, coordinate sea embankment, and monitor typhoon movement	14	14	6	6	**20**	**10**
Protect the house, prepare food, and track the typhoon	6	6	14	14	**20**	**10**
Protect the house, prepare food, and evacuate	9	9	10	10	**19**	**10**
Regularly monitor sea dikes, help families reinforce their houses, and migrate to a safe place	8	8	4	4	**12**	**6**
Support disadvantaged families/ minorities, evacuate the elderly and young children, and protect the house	4	4	8	8	**12**	**8**
Provide information on storm losses prevention, arrange medical staff, and help each other	0	0	6	6	**6**	**3**
Total	**97**	**100**	**97**	**100**	**194**	**100**

employed temporary adaptive measures, such as placing their appliances and furniture on the second floor of their houses or on stilts when anticipating the occurrence of flood. In a related study conducted by Shen et al. (2011) in the Zhejiang Province of China, 52 percent of the households moved to a safer place whenever a typhoon came. On the other hand, 28 percent evacuated as recommended by their government. Majority of the households (67%) found these measures effective. Seventy-seven percent (77%) of the households purchased and stored food, drinking water, and other basic necessities. Most of the households opted to resort to this since it was a common practice in the community. On the other hand, 9 percent adhered to the habit because it was a routine taught by their ancestors or elders. Majority (70%) of the households found this strategy effective.

Information needs

Majority (75%) of the respondents would still like to gain more knowledge to prepare and adjust to climate change better (Table 6.6). Among the information that the respondents primarily wanted to obtain is the knowledge on how to adapt to climate change, particularly on how to prevent natural disasters from occurring and to reduce their impact on agricultural production (16%). This is followed by knowledge on new farming techniques and soil improvement measures (15%), effects of climate change to the environment (13%), and training on preventive methods to reduce damage to agricultural production and aquaculture (11%). Similarly, it could be noticed that the households' main concern is to gain information on topics related to their source of livelihood. This is due to the reason that emphasis on coastal livelihoods is expected to intensify with more sudden and increased climatic fluctuations (Thien 2008).

Almost a third of the respondents (31%) recognized the need to collect information concerning floods and typhoons and few (13%) monitored weather information through television. Based on the study conducted by Ligasan (2011) in Iloilo, Philippines, information and technology are used during disasters such as radio and television on the adverse effects of disasters. Data showed that the respondents were concerned with the occurrence of flood and drought since these could affect their primary source of income—agricultural production (Table 6.7).

To get information about typhoons, half of the respondents (50%) monitored the weather through the daily weather bulletin from the television. Furthermore, the respondents also listened to radio (18%) and got information from commune officers (18%). In the locality of the Red River Delta, most communes had loudspeakers. This radio system managed by the commune People's Committee emphasizes the role of information and communication in the community's social and cultural, as well as local production activities. It disseminates information such as weather news, seasonal calendar, and plant pest information, among others (Table 6.8).

Adaptation planning

Adaptation planning involves responding to the impacts of climate change, both proactively and reactively. It includes preventive measures to slow down the progression of climate change and also mitigation measures to reduce its effects. It is not a domain of a specific department or agency but requires cooperation and interrelationship among concerned institutions. The commendation of the climate change adaptation plan would find its way into other communities' planning documents such as emergency measures plan, energy strategy, transportation plan, strategic plan, community land use plan, economic development strategy, public work plan, and other significant community planning endeavors (Bowron and Davidson 2011).

Table 6.6. Other knowledge that households still want to learn with regard to climate change adaptation

Particulars	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Interested to Learn Additional Knowledge on Climate Change						
Yes	68	70	77	79	**145**	**75**
No	29	30	20	21	**49**	**25**
Total	**97**	**100**	**97**	**100**	**194**	**100**
Additional Knowledge to Learn	(n=68)		(n=77)		(n=145)	
Knowledge to be able to adapt to climate change: how to prevent natural disasters; reduce the impact on agricultural production	14	21	9	12	**23**	**16**
New farming techniques, soil improvement measures, reduce salinity, new varieties with high yield and resistant to climate change	17	25	5	6	**22**	**15**
Effects of climate change on the environment	11	16	8	10	**19**	**13**
Training on response and preventive methods to reduce damage to agricultural production and aquaculture	10	15	6	8	**16**	**11**
Reduce pest/diseases in plants and animals; livestock breed that can adapt to climate change	4	6	9	12	**13**	**9**
Waste treatment, methods to reduce salt water intrusion	2	3	9	12	**11**	**8**
Alternative livelihood	0	0	10	13	**10**	**7**
Conservation of marine resources; how to adapt to sea level rise	2	3	6	8	**8**	**5**
Mangrove protection	2	3	6	8	**8**	**6**
Protection of water sources by using water filters to remove toxins	0	0	6	8	**6**	**4**
Disaster prevention at the household level	4	6	1	1	**5**	**3**
Local policies on climate change and adaptation measures when storm comes	2	3	2	3	**4**	**3**
Total	**68**	**100**	**77**	**100**	**145**	**100**

Table 6.7. Information that needs to be collected in preparation for climate change

Information needed	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Status of flood and typhoon	37	38	23	24	**60**	**31**
Weather bulletin	0	0	26	27	**26**	**13**
Natural disasters and drought	10	10	10	10	**20**	**10**
Timely response measures for natural disasters	6	6	6	6	**12**	**6**
Types of plants and animals that are resistant to harsh climatic conditions	6	6	2	2	**8**	**4**
No information (no answer)	38	39	30	31	**68**	**35**
Total	**97**	**100**	**97**	**100**	**194**	**100**

Table 6.8. Communication activities during typhoon

Activities	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Monitor the weather through the daily weather bulletin	41	42	57	59	**98**	**50**
Listen to radio daily for update	19	20	16	16	**35**	**18**
Update information from TV and from commune officers	15	15	19	20	**34**	**18**
No answer	22	23	5	5	**27**	**14**
Total	**97**	**100**	**97**	**100**	**194**	**100**

Due to their high level of awareness on climate change, majority (84%) of the respondents had personal plans on how to adapt to climate change. The plans of the respondents varied, however, many (20%) of them intended to acquire equipment for mobilization and build solid and firm infrastructures and/or facilities (Table 6.9). Relevant to this is the study on vulnerability of households in Zhejiang, China by Shen et al. (2011), which revealed that it is necessary to build houses that are strong enough to withstand typhoons. Policies of the Vietnam government, however, focused on the assessments of all sectors and on hard adaptation measures such as building of sea dikes, reinforced infrastructure, and durable buildings (World Bank 2010).

Table 6.10 presents the plans as preventive measures in response to climate change. Results show that all respondents were planning to build dikes. On the other hand, majority were planning to enlarge the reservoir (67%); to upgrade the drainage system (59%) and to change the use of water (81%). Also, majority of the respondents have

Table 6.9. Respondents' preparation plans for the occurrence of climate change

Particulars	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
With Plans						
Yes	81	84	82	84	163	84
No	16	16	15	16	31	16
Total	**97**	**100**	**97**	**100**	**194**	**100**
Preparation Activities	(n=81)		(n=82)		(n=163)	
Prepare equipment for mobilization; Build solid and firm infrastructure and/or facilities	21	26	12	15	33	20
Prepare raw materials (bamboo, sandbags, net) to shield the house when the storm comes.	12	15	16	20	28	17
Prepare food, renovate houses, and prepare sandbags to prevent floodwaters	8	10	16	20	24	15
Shield the house and move to a safer place	12	15	11	13	23	14
Monitor information on television, radio, and newspapers regularly, and solidify house	12	15	9	11	21	13
Restructure crops (drought-resistant and pest-resistant crops)	2	2	6	7	8	5
Clear bushes, plant trees and mangroves	1	1	6	7	7	4
Permanent housing capacity and environmental protection	5	6	2	2	7	4
Shield the aquaculture area, and move to the evacuation area	4	5	2	2	6	4
Conduct environmental protection campaign against indiscriminate exploitation of natural resources, preparation of facilities	2	2	2	2	4	2
Prepare pumps and drainage in agricultural lands.	2	2	0	0	2	1
Total	**81**	**100**	**82**	**100**	**163**	**100**

plans to restore plans for flood (79%), conserve mangrove forest (94%), and improve forecasting and information (83%), and adapt insurance schemes against flood damage (64%).

Table 6.10. Planned preventive measures for climate change

Particulars	Giao Xuan (n=97)		Giao Thien (n=97)		Total (194)	
	F	%	F	%	F	%
Flood Protection Methods *						
Raise dikes	97	100	97	100	**194**	**100**
Enlarge reservoirs	63	65	70	72	**133**	**69**
Upgrade drainage systems	69	71	45	46	**114**	**59**
Natural Retention of Flood Water *						
Floodplain restoration	81	83	72	74	**153**	**79**
Change of water use	75	77	82	84	**157**	**81**
Maintain Mangrove Conservation						
Yes	95	98	87	90	**182**	**94**
No	2	2	10	10	**12**	**6**
Total	**97**	**100**	**97**	**100**	**194**	**100**
Improve Forecasting and Dissemination Information						
Yes	80	82	81	84	**161**	**83**
No	17	18	16	16	**33**	**17**
Total	**97**	**100**	**97**	**100**	**194**	**100**
Adaptation of Insurance Schemes Against Flood Damage						
Yes	65	67	59	61	**124**	**64**
No	32	33	38	39	**70**	**36**
Total	**97**	**100**	**97**	**100**	**194**	**100**

Note: * means multiple responses

Preparedness

In a case study conducted by Predo (2010) in Ormoc and Cabalian, Philippines, natural disasters affected the households' welfare and the natural resources from where they obtained their livelihood. This implies that it is important to identify the impacts of climate change on the livelihood of the households particularly among those who belong to the low socio-economic status.

In the study site, majority (73%) of the respondents had no plans of learning alternative livelihood aside from the one which they were engaged in (Table 6.11). Only 27 percent of the respondents had plans to have other source of income as preparation for climate change effects. In terms of alternative livelihood, opening a small-scale business was the most cited answer (11%), while other respondents noted that they would still look for other livelihood sources (10%).

Table 6.11. Livelihood plans intended for implementation in preparation for climate change

Alternative Livelihood	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Open a small-scale business	12	12	10	10	**22**	**11**
Look for other source of livelihood	10	10	10	10	**20**	**10**
Learn from training courses (Women's Union)	4	4	4	4	**8**	**4**
Seek other job and raise livestock	2	2	0	0	**2**	**1**
No plans	69	71	73	75	**142**	**73**
Total	**97**	**100**	**97**	**100**	**194**	**100**

Aside from having alternative sources of income, most of the respondents had plans to build infrastructures that can withstand the effects of climate change such as stronger typhoons. Many wanted to use steel to reinforce their houses (42%), solidify and repair their existing houses (28%), and build two-storey houses that could not be reached by floods (10%) (Table 6.12).

Some respondents (20%) prepared batteries, kerosene, and candles whenever they learned that a typhoon was coming. Thirty-seven respondents (19%) prepared batteries for lighting and listening to radio for news (Table 6.13). This adaptation strategy was further emphasized by the Buenos Aires program on the need for preventive measures, planning, preparedness, and management of disasters relating to climate change, as well as for contingency planning, particularly for droughts and floods, and extreme weather events (UNFCCC 2006).

Coastal Communities' Resilience to Climate Change

Social capital

Schneider (2002) describes social capital as social relationships and patterns of trust, which enable people to gain social networks. It is good to note that almost all of the respondents (94%) joined meetings/consultations with the local government (Table 6.14). The level of participation was high since majority (66%) regularly attended the meetings. Their participation ensured that people were informed, that discussions were being done, and that the activities of the government of Vietnam were being monitored relative to democracy.

Table 6.12. House improvement plans intended for implementation in preparation for climate change

Plans	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Use steel to reinforce the house	41	42	41	42	82	42
Solidy and repair the house	20	21	34	35	54	28
Build two-storey house to avoid floods	13	13	7	7	20	10
Build houses in regional clusters	2	2	4	4	6	3
Ensure the quality of the house to adapt to climate change	0	0	2	2	2	1
No plans	21	22	9	9	30	16
Total	**97**	**100**	**97**	**100**	**194**	**100**

Table 6.13. Use of fuel and light during typhoon

Use of Fuel and Lighting	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Use of batteries, kerosene, and candle for lighting	14	14	24	25	38	20
Fuel for cooking and lighting	24	15	13	13	37	19
For lighting and radio to track the news	19	20	18	19	37	19
For lighting and gas for cooking	7	7	24	25	31	16
For lighters, kerosene for lighting	7	7	4	4	11	6
Use of firewood/husk for cooking, oil lamps, and batteries for lighting	4	4	4	4	8	4
Use of batteries and kerosene for lighting	2	2	4	4	6	3
No answer	20	21	6	6	26	13
Total	**97**	**100**	**97**	**100**	**194**	**100**

Table 6.14. Meetings/consultation with local goverment

Participation in Meetings	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Yes	95	98	88	91	**183**	**94**
No	2	2	9	9	**11**	**6**
Total	**97**	**100**	**97**	**100**	**194**	**100**
Level of Participation	(n=95)		(n=88)		(n=183)	
Seldom	23	24	23	26	**46**	**25**
Very often	66	70	55	63	**121**	**66**
Always	6	6	10	11	**16**	**9**
Total	**95**	**100**	**88**	**100**	**183**	**100**

Majority of the respondents (70%) received help from the local government and other organizations. The kinds of help extended included food (46%), agricultural training (31%), cash aid (16%), and health security (11%) (Table 6.15). This only implies that a strong social network may allow greater access to resources and reduce the psychological stress caused by climatic disturbances; hence, this may strengthen adaptive capacity (Ospena and Heeks 2010). A strong social network was seen in the communes as almost all of the respondents (95%) were members of organizations. Among the 185 respondents, 64 percent of them were members of a farmers' association. With regard to the nature of their respective organizations, most of them (30%) helped each other by providing technical support and inputs in agricultural production.

Building and maintaining resilience require different actors with complementary capacities and skills. Through partnerships and drawing on diverse networks, communities, civil society, academic research institution, the government, and the private sector can strengthen the ability of vulnerable populations to improve people's well-being and capacity to adapt to change (Frankenberger et al. 2012).

It is evident in this study that social capital can ameliorate resilience. Ritchie and Gill (2010) also stressed that social capital enhances a community's ability to work toward collective goals, which is necessary for disaster recovery. It contributes to resilient recovery by enhancing sense of belonging and by strengthening bonds between individuals and groups. Bridging social capital affords connections needed to solicit and leverage external support. Social capital also facilitates access to other forms of capital essential to recovery such as human, financial, political, and cultural capital. However, World Bank (2010) reported that the Vietnam government does not give much attention to soft adaptation measures such as social capital and the role of collective action in building resilience.

Among the 194 respondents, only 155 had plans to coordinate with various agencies in preparing for disaster-related incidents due to climate change. Most of the respondents also wanted to coordinate with the Women's Union and the Youth Union

(23%) and with different organizations and the local government for storm prevention (21%).Meanwhile, other respondents had no plans at all regarding this matter (20%) as seen in Table 6.16.

Table 6.15. Help from local goverment and other organizations

Particulars	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Help from Institutions						
Yes	60	62	76	78	**136**	**70**
No	37	38	21	22	**58**	**30**
Total	**97**	**100**	**97**	**100**	**194**	**100**
Kind of Help Received*						
Food	42	43	48	50	**90**	**46**
Agricultural training	30	31	30	31	**60**	**31**
Cash aid	10	10	22	23	**32**	**16**
Health security	12	12	9	9	**21**	**11**
Subsidized input	4	4	10	10	**14**	**7**
Assistance in building a house/repair	5	5	6	6	**11**	**6**
Clean water	4	4	5	5	**9**	**5**
School tuition	6	6	2	2	**8**	**4**
Clothing and blankets	6	6	1	1	**7**	**4**
Finding a job	4	4	2	2	**6**	**3**
Consumable products	0	0	6	6	**6**	**3**

Note: * means multiple responses

Economic capital

Data gathered through the survey revealed that majority (72%) experienced an increase in their annual income since 2005. For some (18%), there was no change in their level of income (Table 6.17). Vietnamese farmers in general and the farmers in the Red River Delta prioritized rice production to ensure consumer demand and the sustainability of food for the family. Although they lived in coastal areas, the farmers' main income-generating activity was rice production even if other activities (i.e., aquaculture, fishing) could bring higher income.

Agriculture is highly affected by climate change. Thus, the respondents should imitate the adaptation measures of farmers in the Trieu Van commune such as: (1) planting different drought-tolerant crop varieties and local breeds; (2) applying an integrated production model, intercropping bean and sweet potato, rotational cultivation, and

Table 6.16. Coordination with agencies for implementation in preparation for climate change

Coordination Plans	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Coordinate with Women's Union and Youth Union for prevention	21	22	23	24	**44**	**23**
Coordinate with different organizations (e.g Women's Union, Youth Union) and local government for storm prevention	22	23	18	18	**40**	**21**
Close coordination with different concerned agencies	8	8	18	19	**26**	**13**
Coordinate with military for sea dike protection in the border	13	13	10	10	**23**	**12**
Coordinate with local Commune People's Committee to move people for safety when a storm comes	6	6	8	8	**14**	**7**
Prepare a team of youth to provide rapid reactions and timely response	6	6	2	2	**8**	**4**
No plan	21	22	18	19	**39**	**20**

Table 6.17. Variation in household income in the last seven years (2005–2011)

Household Income and Expenses	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Changes in Income						
Increase	69	71	70	72	**139**	**72**
Decrease	9	9	12	12	**21**	**11**
No change	19	20	15	16	**34**	**17**
Total	**97**	**100**	**97**	**100**	**194**	**100**
Changes in Expenses						
Increase	90	93	96	99	**186**	**96**
Decrease	2	2	0	0	**2**	**1**
No change	5	5	1	1	**6**	**3**
Total	**97**	**100**	**97**	**100**	**194**	**100**

diversifying crops; (3) adjusting the seasonal calendar; (4) practicing soil management measures; and (5) adjusting farm inputs including fertilizers and pesticides (Le 2011). It is good to note that most of the respondents (54%) had savings which could be accessed in time of disasters. These savings were kept in homes (35%), the Mutual Loan Club (32%), and the bank/commune fund or in the form of gold reserves (25%) (Table 6.18).

Table 6.18. Financial sources in the occurrence of natural disasters

Particulars	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Savings						
Yes	54	56	50	52	**104**	**54**
No	43	44	47	48	**90**	**46**
Total	**97**	**100**	**97**	**100**	**194**	**100**
Depository of Savings	(n=54)		(n=50)		(n=104)	
Kept at home	24	44	12	24	**36**	**35**
Mutual Loan Club	17	32	16	32	**33**	**32**
Bank, commune fund, gold reserves	10	18	16	32	**26**	**25**
Savings were borrowed by others	3	6	6	12	**9**	**8**
Total	**54**	**100**	**50**	**100**	**104**	**100**

The Mutual Loan Club ("Hui") is a convenient scheme for raising capital and saving money. In the past, when the Vietnamese banking system was still new and underdeveloped, the Mutual Loan Club was popular among the common people. Even after the development of banking, wherein the banks usually had many loan requirements and borrowing procedures were difficult, the Vietnamese people, specifically the famers continued to patronize the Mutual Loan Club. Other businessmen and wage-earners also subscribed to the Mutual Loan Club.

From the capital-raising mechanism of the Mutual Loan Club, many people had new business ventures, while others were able to address their financial problems immediately. Thus, the Vietnam government agreed to the existence of this scheme which later became part of the Civil Code 2006.

In a study conducted by the Intergovernmental Panel on Climate Change (2011) regarding the social impacts of storm, results revealed that taking odd jobs, consumption reduction, and acquiring multiple loans were the commonly adopted coping strategies. The findings of the IPCC corroborate with this study's results, particularly in borrowing money through loans in case their respective houses would be affected by disasters.

Human capital

Human capital is one of the factors affecting the resilience of a community to climate change. It could be further examined by looking into the health, skills, and knowledge that the people in a community have. This is consistent with the sectors and variables used in the Vulnerability-Resilience Indicators Model (VRIM) (Brenkert and Malone 2005).

In the study sites, it is good to note that many (62%) of the respondents are not sickly (Table 6.19). This is because the overall health quality in Vietnam is regarded as good based on the 77 years life expectancy estimates in 2010 (Huong et al. 2007).

Table 6.19. Present health condition of households

Health Condition	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Very healthy	6	6	4	4	**10**	**5**
Healthy	57	58	64	66	**121**	**62**
Not healthy	34	35	29	30	**63**	**33**
Total	**97**	**100**	**97**	**100**	**194**	**100**

As shown in Table 6.20, the trend in general results to an almost equal number of households who do (41%) and do not have (59%) regular yearly health check-up. However, in Giao Thien, a greater number of residents appear to participate less in annual check-up. This same result was noted in the condition of the health care centers. Based on the gathered data, majority of them (58%) perceived that their local health center is not fully capable of providing help to the local communities. This was due to the following reasons: lack of medical equipment and medicine (46%); and poor quality of health care because it did not meet the minimum requirements, and could only address mild and common diseases (30%). Based on 2001 data (Huong et al. 2007), this can be attributed to the budget allocation of the Vietnamese government which only uses 0.9% of its gross domestic product (GDP) for health care.

Others still found the health centers helpful due to recent medical equipment and medicines, good services of doctors and nurses (35%), and investment for upgrading the healthcare institutes, thus resulting to a better condition as compared in the past (23%). According to Respondek et al. (2010), Vietnam's healthcare sector has witnessed some dynamic changes during the last 20 years.

Table 6.20. Regular yearly health check-up and condition of local health center

Particulars	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Regular Yearly Check-up						
Yes	42	43	38	39	**80**	**41**
No	55	57	59	61	**114**	**59**
Total	**97**	**100**	**97**	**100**	**194**	**100**
Local Health Center Can Provide Adequate Health Care						
Yes	52	54	30	31	**82**	**42**
No	45	46	67	69	**112**	**58**
Total	**97**	**100**	**97**	**100**	**194**	**100**

From Table 6.21, it could be seen that there is almost an equal number of households who have and who do not have health insurance card. It is noticeable that in Giao Thien, although an equivalent number of households have health insurance, there were still relatively more people who do not undergo regular check-up. This may be attributed to the fact that the health insurance of the respondents was from the government. In 2008, the Vietnamese government enacted a policy distributing free health insurance cards to: (1) children under 6 years of age, (2) poor families, (3) family of wounded and deceased soldiers, and (4) members of an ethnic minority (Respondek et al. 2010). Furthermore, since the health insurance card came from the government, it only had limited coverage. The Vietnamese government only subsidized 20% of healthcare expenditures while 80% came from the individuals' own pocket (Library of Congress 2005).

Table 6.21. Health insurance acquisition

Response	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Yes	62	64	39	40	101	52
No	35	36	58	60	93	48
Total	**97**	**100**	**97**	**100**	**194**	**100**

In terms of skills that enabled the respondents to adapt to climate change, 45 percent of the respondents identified swimming skills as the most important skill that can help them adapt to climate change. Other skills included ability to make weather observations to predict storms as cited by 20 percent of the respondents (Table 6.22). Accordingly, the skills have been taught by their grandparents.

In terms of having access to information, findings showed that almost all of the respondents (91%) had access to information pertaining to climate change adaptation strategies (Table 6.23). The information came from television (82%), national radio stations (44%), and local radio stations (25%). The main information gathered from television and national radio stations were the weather forecasts, while local radio stations featured storm preparation awareness.

It was found that majority of the respondents (61%) did not undergo any training associated to climate change. Only 39 percent had the opportunity to attend these trainings; thus, they were the ones who were relatively knowledgeable on climate change.

Regarding the livelihood training for the respondents in the study sites, only few (3%) attended trainings on straw mushroom planting, knitting, and beekeeping conducted in 2008 by the Women's Association (Table 6.24).

Table 6.22. Respondents' climate change adaptation skills

Particulars	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Possess Skills to Adapt						
Yes	79	81	68	70	147	76
No	18	19	29	30	47	24
Total	**97**	**100**	**97**	**100**	**194**	**100**
Skills of the Respondents*						
Swimming	42	54	45	46	87	44.8
Weather observations in predicting storm	18	19	22	23	38	19.6
Ability to climb tree to avoid floods	15	16	19	20	34	17.5
Running	14	14	10	10	24	12.4
Saline soil improvement, crop rotation	12	12	12	12	24	12.4
How to avoid lightning	15	16	6	6	21	10.8
How to shield/ reconstruct/ consolidate the house before typhoon season	10	10	7	7	17	8.8
Rowing and making a raft	6	6	10	10	16	8.2

Note: * means multiple responses

Table 6.23. Access to information regarding climate change adaptation

Particulars	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Ability to Access Information						
Yes	90	93	87	90	177	91
No	7	7	10	10	17	9
Total	**97**	**100**	**97**	**100**	**194**	**100**
Access Channels/Media *						
Television	83	85.6	77	79.4	160	82
National Radio	43	44	42	43	85	44
Newspapers	30	31	18	19	48	25
Local Radio Station (Commune)	35	36	14	14	49	25
Internet	2	2	6	6	8	4
Handbook Documents	4	4	4	4	8	4

Note: * means multiple responses

Table 6.24. Attendance to livelihood trainings

Response	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Yes	0	0	5	5	5	3
No	97	100	92	95	189	97
Total	**97**	**100**	**97**	**100**	**194**	**100**

Physical capital

Results of the survey revealed that majority of the respondents (70%) had concrete houses and 22 percent had houses made of both concrete materials and wood. For the house type, most of the respondents' (50%) houses were tiled; 42 percent were one-storey while 7 percent were two-storey houses (Table 6.25).

Table 6.25. House type and materials used

Particulars	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Housing Materials						
Concrete	69	71	67	69	136	70
Combination of concrete and wood	20	21	23	24	43	22
Wood	6	6	7	7	13	7
Bamboo	2	2	0	0	2	1
Total	**97**	**100**	**97**	**100**	**194**	**100**
House Type						
Tiled house	46	47	52	54	98	51
One-storey	41	42	41	42	82	42
Two-storey	10	11	4	4	14	7
Total	**97**	**100**	**97**	**100**	**194**	**100**

Facilities were also available in the study sites. Majority of the respondents (66%) answered that there were available facilities where people could evacuate in the event of disasters caused by climate change. The kinds of facilities included school of communes (89), Office of the People's Committees of Commune (63), and place of worship (58). Others cited the presence of high buildings, used trucks, and Office of the Bank of Commune. With this, majority (71%) believed that there were enough facilities to accommodate the affected households (Table 6.26).

For the infrastructure plans in preparation for climate change, most of the respondents intend to renovate their houses (22%) and affirm the needs to improve sea dike, upgrade water supply and sewerage system (22%). On the other hand, other respondents plan to repair sea embankments to prevent sea water intrusion (16%), and to build public facilities (8%) (Table 6.27).

Table 6.26. Availability of evacuation facilities during disasters brought about by climate change

Facilities	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Awareness of facilities available for evacuation						
Yes	70	72	59	61	129	66
No	27	28	38	39	65	34
Total	**97**	**100**	**97**	**100**	**194**	**100**
Kind of Facilities *						
School of communes and others (inland)	51	53	38	39	89	46
Office of the People's Committees of commune and others (inland)	38	39	25	26	63	32
Place of Worship	19	20	39	40	58	30
High Buildings	18	19	10	10	28	14
Used trucks	11	11	13	13	24	12
Office of the bank of commune and others (inland)	3	3	0	0	3	2

Note: * means multiple responses

Table 6.27. Infrastructure plans intended for implementation in preparation for climate change

Plans	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Renovate the house	26	27	17	17	43	22
Improve sea dike, water supply, and sewerage	18	19	24	25	42	22
Repair sea embankments to avoid salt water intrusion	9	9	23	24	32	17
Build public facilities	8	8	8	8	16	8
Build infrastructure to avoid typhoon	0	0	6	6	6	3
Build fresh water tank	2	2	2	2	4	2
No answer	34	35	17	18	51	26
Total	**97**	**100**	**97**	**100**	**194**	**100**

Natural capital

Most of the residential lands of the respondents (20%) ranged from 0.60–1.09 *sao* (Table 6.28). On the other hand, most of the gardens (30%) ranged from 0.60–1.09 *sao*, while 17 percent measured 0.10–0.59 *sao*. A small percentage of the respondents (15%) did not have a home garden.

Table 6.28. Size of households' residential land (*sao*)

Area of Residential Land	Giao Xuan (n=97)		Giao Thien (n=97))		Total (n=194)	
	F	%	F	%	F	%
0.10–0.59	12	12	9	9	**21**	**11**
0.60–1.09	16	16	13	13	**29**	**15**
1.10–1.59	7	7	20	21	**27**	**14**
1.60–2.09	23	24	16	16	**39**	**20**
2.10–2.59	16	16	10	10	**26**	**13**
2.60–3.09	8	8	8	8	**16**	**8**
3.10–4.09	8	8	7	7	**15**	**8**
4.10–5.09	6	6	12	12	**18**	**9**
5.10–6.00	1	1	0	0	**1**	**1**
> 6.00	0	0	2	2	**2**	**1**
Total	**97**	**100**	**97**	**100**	**194**	**100**

Note: one sào = 360 m^2. This is the unit for land measure in Vietnam

The lack of gardens and ponds was due to the limited land area of the households. More than half of the respondents (52%) did not have ponds; only two (1%) had more than 6 *sao* of pond area. In scrutinizing the land area used for agriculture, most (26%) used 4.10–5.09 *sao*; 17 percent cited 1.60–2.09 *sao*; and 16 percent reported to 3.10–4.09 *sao* (Table 6.29). Results of the key informant interview with the Director of Xuan Thuy National Park revealed that a vast number of people did not experience changes in the use of agricultural lands since 2005.

Furthermore, most of the respondents agreed that there were many available coastal resources in their area. All respondents mentioned the presence of mangroves because of their crucial role in climate change mitigation (Table 6.30). Literature shows that in the context of climate change, mangroves have played a vital role in preventing coastal erosion and in protecting inland areas (Chi et al. 2015). Other resources included seafood and fish as indicated by 145 respondents (72%) and 62 percent cited sea grasses.

A close examination of the water resources revealed that almost half of the respondents believed that there was an abundant supply (44%).There were only 18 percent who observed a decrease in the amount of water resources provided for domestic use. Meanwhile, there were also some (38%) who claimed that the supply remained unchanged.

Ritchie and Gill (2010) indicated that natural capital is vital to human survival and fundamental to society. In the aftermath of a disaster, natural capital represents basic necessities that support human life, ranging from uncontaminated air to potable water to renewable resources. A community's relationship with its natural environment also influences ways in which it responds to disaster-related environmental degradation.

Table 6.29. Area of ponds owned by the households

Area/Change	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Pond Area (*sao*)						
0	51	53	50	52	**101**	**52**
0.10–0.59	30	31	20	21	**50**	**26**
0.60–1.09	14	14	21	22	**35**	**18**
1.10–1.59	0	0	0	0	**0**	**0**
1.60–2.00	2	2	2	2	**4**	**2**
>2.00	0	0	2	2	**2**	**1**
Total	**97**	**100**	**97**	**100**	**194**	**100**
Changes since 2005						
Increase	2	2	0	0	**2**	**1**
Decrease	5	5	2	2	**7**	**4**
No change	90	93	95	98	**185**	**95**
Total	**97**	**100**	**97**	**100**	**194**	**100**

Table 6.30. Existing coastal resources in the community*

Coastal Resources	Giao Xuan (n=97)		Giao Thien (n=97)		Total (n=194)	
	F	%	F	%	F	%
Mangroves	97	100	97	100	**194**	**100**
Sea foods	73	75	72	74	**145**	**75**
Sea grasses	41	42	80	82	**121**	**62**
Fishes	74	76	65	67	**139**	**72**
Corals	5	5	7	7	**12**	**62**
Clams	18	19	9	9	**27**	**14**
Crab	12	12	6	6	**18**	**9**
Prawn	16	16	31	32	**47**	**24**

Note: * means multiple responses

Relationship Between Resilience to Climate Change and Capacity to Adapt

Findings revealed that the coastal communities had high knowledge on climate change adaptation based from the obtained mean of 8.47 (SD=1.69). The knowledge of the communities pertains to information on the occurrence of storms, floods, sea level rise, and drought, which they derived from television programs and trainings. Meanwhile, the plan of coastal communities to learn to adapt to climate change had a mean of 8.61 (SD=1.32) which could be attributed to their knowledge on climate change.

Mean was low at 4.19 (SD=0.92) concerning the application of what they knew about climate change. This implies that, in general, the coastal communities were not practicing what they have learned about climate change. Also, there were similarities in terms of the coastal communities' practices based from the obtained standard deviation.

Table 6.31. Descriptive statistics for climate change adaptation

Commune	Particulars	Climate Change Adaptation		
		Knowledge	Plan	Practice
Giao Xuan	Mean	8.40	8.61	4.03
	Standard deviation	1.75	1.42	1.11
Giao Thien	Mean	8.55	8.62	4.35
	Standard deviation	1.62	1.22	0.65
Total	**Mean**	**8.47**	**8.61**	**4.19**
	Standard deviation	**1.69**	**1.32**	**0.92**

On the sources of capital, the coastal communities had low social, economic, human, physical, and natural capital based from the obtained means. The findings revealed that among the five capitals, social capital had the highest mean (4.53; SD=0.99). Moreover, there was only a very slight difference on the social capital means of Giao Xuan (4.60; SD=0.95) and Giao Thien (4.46; SD=1.03). On the other hand, physical capital obtained the lowest mean at 1.78 (SD=1.21).

Social capital refers to the linkages to various institutions and membership of the respondents in different organizations. Almost all of the respondents aside from being a member of the farmers' organization were also members of other organizations depending on their interest.

Physical capital refers to the presence of dikes and evacuation centers, and the structure of houses in the communities. Majority of the respondents had one-storey houses only; hence, they wanted to build a two-storey house to protect their belongings and their lives. These houses could threaten the resilience of communities. A similar finding was obtained in Danang City, wherein the physical dimension of resilience was threatened by fragile warning systems (Shaw et al. 2009).

Based from the respondents' perception, it was necessary to build more infrastructures, particularly dikes, to protect the coastal communities from the adverse effects of climate change. The existing dikes according to the respondents were no longer adequate and did not ensure safety of the coastal communities particularly when there was a strong typhoon which might lead to sea level rise.

There was also a perceived need to build evacuation centers because using schools as evacuation centers affected the students due to the noise of the evacuees. Hence, it was deemed necessary for the government to build structures that would serve as evacuation centers when disasters happened due to climate change.

Among the five capitals, natural capital showed the smallest deviation based from the value obtained which is 0.84, while the biggest deviation was observed on economic capital.

One of the natural capitals being referred to is the presence of mangrove forest which helps in climate change mitigation and avoid its adverse effects. The almost similar value obtained for standard deviation implies that both sites are fully aware on the value of the mangrove forests. Mangroves are known for protecting the shoreline during storm and tsunami events through frictional reduction of wave energy and by promoting sedimentary resilience to erosion through the root mat (Hiraishi 2008; Dahdouh-Guebas et al. 2005).

Since majority of the respondents were into agricultural production, their livelihoods were affected by typhoons, which disrupted their source of income. Coupled with this is the fact that they had limited savings. Thus, they opted to use their savings to buy the basic necessities, but there was no guarantee that their savings would be enough. Experience in other countries showed that the ability to cope with increasing climatic hazards relied mostly on the ability to diversify income sources. Hence, access to credit, insurance, and other financial services including non-cash loans is highly imperative. Building financial incentive systems into loans can lead to reduction in environmental impacts (MONRE and UNDP 2009).

Table 6.32. Descriptive statistics for resilience to climate change

Commune	Particulars	Resilience				
		Economic Capital	Human Capital	Physical Capital	Natural Capital	Social Capital
Giao Xuan	Mean	4.60	3.29	3.69	1.81	2.17
	Standard deviation	0.95	1.28	1.21	1.29	0.83
Giao Thien	Mean	4.46	3.02	3.58	1.74	1.88
	Standard deviation	1.03	1.68	1.31	1.13	0.82
Total	**Mean**	**4.53**	**3.15**	**3.63**	**1.78**	**2.02**
	Standard deviation	**0.99**	**1.50**	**1.26**	**1.21**	**0.84**

As shown in Table 6.33, results revealed that in general, there was a positive significant linear association between social capital and planning for household adaptation (r=0.260; p=0.01). The positive correlation had lower level of significance in both sites at p=0.05. This relationship indicates that with higher social capital, planning on climate change adaptation of the households is enhanced. However, the relationship was weak.

Furthermore, a weak negative correlation was seen between social capital and climate change adaptation practices of households (r=-0.162; p=0.05) considering both sites. This implies that an increase in social capital would result in a decrease in the climate change adaptation practices. There may be a need to further improve people's participation in community activities related to climate change adaptation. Meanwhile, a weak but positive correlation is observed in Giao Thien commune (r=0.322; p=0.01) which means that with higher social capital households' climate change adaptation practices will be enhanced. These practices were learned from their membership in organizations, linkages with various institutions, and passing of traditional knowledge from grandparents, as well as their own experiences.

Table 6.33. Relationship between climate change adaptation and resilience to climate change

Resilience	Climate Change Adaptation								
	Giao Xuan			Giao Thien			Total		
	K	Pl	Pr	K	Pl	Pr	K	Pl	Pr
Social Capital	.127	.316*	.097	–.133	.213*	–.322**	**–.006**	**.260****	**–.162***
Economic Capital	–.100	.024	–.055	–.024	–.035	.183	**–.068**	**–.004**	**.057**
Human Capital	.140	.172	.190	.103	.244*	.100	**.119**	**.208****	**.119**
Physical Capital	–.200	.170	.039	.072	.103	–.047	**–.231****	**.131**	**–.022**
Natural Capital	.326*	.025	–.153	–.042	.148	–.119	**.124**	**.089**	**–.154***

Notes: K = Knowledge on climate change adaptation, Pl: Planning of households on, climate change adaptation; Pr: Practices of households on climate change adaptation
** is significant at p = .01, * significant at p = .05

Overall, the result of the study indicated a weak but positive and highly significant correlation between human capital and planning on climate change adaptation (r=0.208; p=0.01). The same positive correlation was found to be significant but weak (r=0.244; p=0.05) in Giao Thien commune. These indicate that there is a linear relationship between human capital and planning of households in adapting to climate change. The weak association could be attributed to the limited knowledge and skills of the coastal communities on climate change adaptation.

Results of the correlation also revealed that there is a weak negative linear association between physical capital and knowledge on climate change adaptation (r=-0.231; p=0.01) in Giao Thien. This implies that the presence or availability of infrastructures like dikes makes the coastal communities feel safe and do not seek further knowledge about climate change.

The findings revealed that natural capital and knowledge on climate change adaptation also had a weak but positive linear association ($r=0.326$; $p=.05$) in Giao Xuan. The coastal communities were more aware of the importance of mangrove forests in mitigating the effects of climate change. This can be attributed to their belief that the mangrove forest is a good natural shield. However, in general, there was a weak negative correlation between natural capital and practices on climate change adaptation ($r=-0.154$; $p=0.05$).

Further, the statistical analysis also showed that there was no significant relationship between economic capital and knowledge, plans, and practice of climate change adaptation.

CONCLUSIONS

The coastal communities of Giao Xuan and Giao Thien had limited knowledge on climate change adaptation. Their knowledge were mainly from television programs and limited trainings. Information about adaptation strategies is critical, as climate change has a significant impact on agricultural production brought about by frequent storms, sea level rise, salt water intrusion, and floods. The low knowledge on climate change implies that the respondents were not practicing what they learned about climate change. To prepare for climate change, the most common plan of the households focused on house renovation which is not enough. It is also imperative to have sustainable means of livelihood.

The communities had limited capacities to adapt to climate change due to limited knowledge, skills, trainings, meager income, and few investments. Infrastructure in the communities was also insufficient to be able to cope with climate change. Moreover, natural resources decreased due to mining, destructive fishing, and pollution, which could further aggravate climate change. The mangrove forest resources have the capability to combat climate change, avoid saltwater intrusion, and limit the damage caused by natural disasters.

The coastal communities had low economic, human, physical, and natural capital, but high social capital.

In terms of the relationship among the variables on climate change adaptation and resiliency, social capital and planning for climate change adaptation for both communes, human capital and planning in Giao Thien, and natural capital and knowledge on climate change adaptation in Giao Xuan had positive significant linear associations. These findings imply that there may be a need to take a closer look on how these capitals can be improved in order to enhance the community's knowledge, planning and practices in climate change adaptation.

RECOMMENDATIONS

It is imperative to promote a close link among the farmers, scientists, enterprises, and the government to create favorable conditions on endorsing new plant varieties and animal breeds that are resistant to climate change. Consequently, this will lead to sustainable livelihood and will eventually result in resilience of the respondents to the effects of climate change.

Moreover, the government should invest in putting up early warning systems in coastal communities to protect properties and human lives. Budget allocation for infrastructure facilities like evacuation centers during typhoons and floods should also be prioritized. Food and clean water must be provided to the evacuees in these centers. To ensure health and safety, infrastructure for the water system should be available in the community. Decentralization in the management of mangrove resources and ecosystems is also needed to define the distinct functions of Xuan Thuy National Park and local authorities. This will prevent the overlap in the policies on conservation and management of the environment.

Coastal communities should be united to mitigate the effects of climate change through solid waste management, planting and protection of mangroves, and prohibition of destructive fishing activities.

LITERATURE CITED

Bowron, B., and G. Davidson. 2011. *Climate Change Adaptation Planning: A Handbook for Small Canadian Communities*. Accessed February 28, 2013. http://www.fcm.ca/Documents/tools/PCP/climate_change_adaptation_planning_handbook_for_small_canadian_communities_EN.pdf

Brenkert, A., and E. L. Malone. 2005. "Modeling Vulnerability and Resilience to Climate Change: A Case Study of India and Indian States." *Climatic Change* 72 (1): 57–102. doi:10.1007/s10584-005-5930-3.

Budapest Declaration. 2004. Fourth Ministerial Conference on Environment and Health, Budapest, Hungary.

Chi, V. K., N. T. T. Hang, D. T. B. Hoa, L. T. Van, Xuan, N. H. Shuan, T. T. Ha, and N. T. T. Trang. 2015. "Coastal Urban Climate Resilience Planning in Quy Nhon, Vietnam." *Asian Cities Climate Resilience Working Paper Series*. Vietnam: International Institute for Environment and Development.

Dasgupta, S., B. Laplante, C. Meisner, D. Wheeler, and J. Yan. 2007. "The Impact of Sea Level Rise on Developing Countries: A Comparative Analysis." *Climatic Change* 93 (3): 379–388. doi:10.1007/s10584-008-9499-5.

Daudouh-Guebas, F., L. P. Jayatissa, D. Di Nitto, J. O. Bosire, D. Lo Seen, and N. Koedam. 2005. "How Effective were Mangroves as a Defense against the Recent Tsunami?" *Current Biology* 15 (12): R443–R447. doi:10.1016/j.cub.2005.06.008.

Easterling, W., P. Aggarwal, P. Batima, K. Brander, L. Erda, M. Howden, A. Kirilenko, J. Morton, J.-F. Soussana, J. Schmidhuber, and F. Tubiello. 2007. “Food, Fibre and Forest Products.” In *Climate Change 2007: Impacts, Adaptation and Vulnerability*, edited by Martin L. Parry, Osvaldo F. Canziani, Jean P. Palutikof, Paul J. van der Linden, and Clair E. Hanson, 275–314. Cambridge, UK: Cambridge University Press.

Frankenberger, T., M. Langworthy, T. Spangler, and S. Nelson. 2012. *Enhancing Resilience to Food Security Shocks in Africa.* Arizona, United States: Tango International Inc.

Han, N. 2007. *Ha Nam Industrial Zone Management Board*. Phu Ly, Ha Nam Province.

Hiraishi, T. 2008. “Effectiveness of Coastal Forests in Mitigating Tsunami Hazards.” In *Proceedings of the Meeting and Workshop on Guidelines for the Rehabilitation of Mangroves and Other Coastal Forests Damaged by Tsunamis and Other Natural Hazards in the Asia-Pacific Region,* edited by Chan Hung Tuck and Jin Eong Ong, 65–73. Okinawa, Japan: International Tropical Timber Organization and International Society for Mangrove Ecosystems.

Huong, D. B., N. K. Phuong, S. Bales, J. Cheng, H. Lucas, and M. Segall. 2007. “Rural Health Care in Vietnam and China: Conflict Between Market Reforms and Social Need.” *International Journal of Health Services* 37 (3): 555–572. doi: 10.2190/H0L2-8004-6182-6826.

Intergovernmental Panel on Climate Change. 2011. *Renewable Energy Sources and Climate Change Mitigation: Summary for Policymakers and Technical Summary.* Cambridge Press, Cambridge, United Kingdom and New York, NY, USA. Accessed 30 January 2013.https://www.ipcc.ch/pdf/special-reports/srren/SRREN_FD_SPM_final.pdf

Lagos, R., and T. E. Wirth. 2009. *Facilitating an International Agreement on Climate Change: Adaptation to Climate Change.* Washington, DC: Global Leadership for Climate Action.

Le, T. H.P. “Climate Change and Farmers’ Adaptation. A Case Study of Mixed-farming Systems in the Coastal Area in Trieu Van Commune, Trieu Phong District, Quang Tri province.” MS Thesis, Hue University of Agriculture and Forestry, 2011.

Ligasan, S. R. P. “Factors Associated with the Effects of Flood Risks in Selected Rice Farming Communities in Pototan, Iloilo, Philippines.” Doctoral dissertation, University of the Philippines Los Baños, 2011.

Mendis, S., S. Mills, and J. Yantz. 2003. “Building Community Capacity to Adapt to Climate Change in Resource-Based Communities.” Accessed May 26, 2012. http://www.pamodelforest.sk.ca/pdfs/Building Community.pdf

Ministry of Natural Resources and Environment and United Nations Development Programme. 2009. Adaptive Strategies for Coastal Livelihoods Most at Risk to Climate Change Impacts in Central Vietnam. Hanoi, Vietnam: Vietnam Ministry of Natural Resources and Environment and the United Nations Development Programme.

OECD (Organization for Economic Cooperation and Development). 2010. *Integrating Climate Change Adaptation into Development Cooperation. A User Guide for Practitioners Working at the National Level*. Paris, France: Organization for Economic Cooperation and Development.

Ospena, A. V., and R. Heeks. 2010. *Linking ICTs and Climate Change Adaptation: A Conceptual Framework for e-Resilience and e-Adaptation.* Manchester, UK: Center for Development Informatics.

Peñalba, L. M. 2008. *Enhancing the Climate Change Adaptation Capacity of Local Government Units and Scientists in the Philippines.* Kobe, Japan: Asia-Pacific Network for Global Change Research.

Predo, C. 2010. *Adaptation of Community and Households to Climate-Related Disaster: The Case of Storm Surge and Flooding Experience in Ormoc and Cabalian Bay, Philippines.* Los Baños, Laguna: Economy and Environment Program for South-East Asia.

Ritchie, L. A., and D. A. Gill. 2010. "Considering Community Capitals in Disaster Recovery and Resilience." Accessed March 29, 2013. http://www.riskinstitute.org/peri/component/option,com_deeppockets/task,catContShow/cat,86/id,1086/Itemid,84/

Schneider, J. A. 2002. "Social Capital and Community Supports for Low Income Families: Examples from Pennsylvania and Wisconsin." *The Social Policy Journal* 1 (1): 35–55. doi:10.1300/j185v01n01_04

Shaw, R., B. Razafindrabe, P. Gulshan, Y. Takeuchi. 2009. "Climate Disaster Resilience: Focus on Coastal Urban Cities in Asia." *Asian Journal of Environment and Disaster Management* 1 (1): 1011–16. doi:10.3850/s179392402009000088.

Shen, Y., Z. Zhu, L. Li, Q. Lv, X. Wang, and Y. Wang. 2011. *Analysis of Household Vulnerability and Adaptation Behaviors to Typhoon Saomai, Zhejiang Province, China*. Singapore: Economy and Environment Program for South-East Asia.

UNDP (United Nations Development Programme). 2010. *Exploring an Integrated Approach to Disaster Risk Reduction and Climate Change Adaptation for Development Programming.* New York: United Nations Development Programme.

United Nations Framework Convention on Climate Change (UNFCCC). 2006. *Background paper – Impacts, Vulnerability, and Adaptation to Climate Change in Latin America.* UNFCCC Secretariat. Bonn, Germany.

World Bank. 2010. Economics of Adaptation to Climate Change Synthesis Report. Washington, D.C.: World Bank.

———. 2011. *Climate-Resilient Development in Vietnam: Strategic Directions for the World Bank.* Vietnam: Sustainable Development Department, Vietnam Country Office, and the World Bank.

———. 2011. *Climate Risk and Adaptation Country Profile.* Washington. Global facility for Disaster Reducation and Recovery. Accessed on March 29, 2013 at http://sdwebx.worldbank.org/climateportalb/doc/GFDRRCountryProfiles/wb_gfdrr_climate_change_country_profile_for_VNM.pdf

Yates, T. M., and A. S. Masten. 2004. "Fostering the Future: Resilience Theory and the Practice of Positive Psychology." In *Positive Psychology in Practice*, edited by P. Alex Linley and Stephen Joseph, 521–539. Hoboken, New Jersey: Wiley and Sons.

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ISSN 2012-4635

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