ASSESSMENT OF LAND COVER CHANGES AND THE CAUSES OF MANGROVE DEGRADATION IN PYINDAYE RESERVED FOREST, AYEYARWADY DELTA, MYANMAR TOWARD SUSTAINABLE MANGROVE MANAGEMENT TO MITIGATE THE CONSEQUENCES OF CLIMATE CHANGE

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SUMMARY

This study analyzed the land use changes during 2000 - 2019 by using multi-temporal landsat of unsupervised classification and the influencing factors on the key drivers of mangrove degradation especially fuel wood consumption and aquaculture areas expansion in the study area. This study employed both qualitative and quantitative methods including interviews with 118 participants through questionnaire surveys and focus group discussion. The results revealed both increase and decrease of different land cover change (LCC) from 2000 through 2019. Significant shifts from some classes to other was also observed. Drivers of the observed changes ranged from climatic factors such as natural disasters to socio-economic factors. Regression analysis results showed that the key drivers of mangrove degradation especially fuel wood consumption and aquaculture areas expansion have strongly and positively significant influenced on the mangrove degradation. Aquaculture was a cause of loss of mangrove areas in Ayeyarwady Delta including the study areas due to overexploitation to develop the commercial shrimp farms. Thus, mangrove degradation is one of the most important environmental problems that the government needs to address and set up the policy, rules and regulations in order to mitigate the consequences of Climate Change in this area.

Keywords: Aquaculture, Ayeyarwady Delta, fuel wood consumption, land cover change, mangrove degradation, mitigate.

1. INTRODUCTION

Mangroves are a major source on which large communities have been dependent for both subsistence and income generation long time ago. Mangrove plays an important in the life and livelihood of coastal regions (Spalding & Blasco, 1997). The main products of mangrove forest are timber, fuel wood, poles, thatching material, grass, honey, wax, industrial raw materials, and marine and fishery resources (Bandaranayake, 1998). The harvest and utilization of mangrove tree species for both domestic uses as well as commercial purpose has been practiced for several centuries.

Myanmar has total coast line about 2,000 km in length and continental shelve of nearly 270,000 km^2 (Sein, C C, 2015).There are three coastal regions in Myanmar, namely Rakhine, Ayeyarwady and Taninthari where mangrove common. Mangrove were found with the coverage of 7,850 km^2 (785,000 ha) of which 3,200 km^2 (320,000 ha) were designated as reserved forest in 1920s (Forest Department and ITTO, 2011). The Ayeyarwady delta covers an area of 33,670 km^2 (3,367,000 ha) having a large network of creeks, streams and rivers.

The mangrove forests in Ayeyarwady Delta are the largest but also the most affected by human actions (Aung . T, April, 2013). According to Ayeyarwady Coastal Region Conservation Association, "coastal land grabbing" has recently become more and more common (ICA, 2015). Therefore, further research is essential not only to assess causes of mangrove forest loss and degradation but also to clarify what are the key drivers of mangrove degradation in study area. Otherwise, there is a significant correlation

between people's income sources and sustainable ecosystem of mangrove.

In this study we analyze the land use changes during the period from 2000 to 2019 by using multi-temporal Land sat, identify the influencing factors on the key drives of mangrove degradation, and investigate how the mangrove forest conservation practices and policy are going there and their potential impacts for sustainable mangrove management to mitigate the consequences of Climate Change in the area.

2. RESEARCH METHODOLOGY

A Combination of satellite data (United States Geological survey) by using Land sat 5, 7 and 8 imageries from Pyindaye reserved forest was collected to analyze land use and land cover change in selected periods (from 2000 to 2019). Before the preprocessing and classification of satellite imagery, an extensive field survey was performed throughout the study areas using Global Positioning System (GPS) equipment. This survey was performed in order to obtain accurate location points for each land use included in the classification. The whole process is guided by ground observation and local knowledge. The land use map produced at year from 2000s to 2019 respectively at a scale of 1: 190,000 included six classes (Water body, cultivated land, shrub, forest, settlement and aquaculture) depending on the characteristics and objectives of the study site.

The semi structure questionnaires were used to interview 118 respondents who have direct impact to mangrove deforestation and degradation (48 respondents are aquaculture pond owners, 70 respondents are households and the rest are bamboo rack owners producing the dry shrimp) in two selected villages around Nauk Mi and Asha Phya villages to identify the fuel wood consumption by bamboo rack owners for dry shrimp commercial production and fuel wood consumption by households for multi-purposes. Focus group discussion with local stakeholders was conducted to obtain details and additional information related to land use changes and key drivers of mangrove deforestation and degradation in study areas.

GIS analysis was conducted to analyze land cover changes in Pyindaye reserved forest by using multi-temporal Land sat 5, 7 and 8 imagery for land use mapping from 2000s to 2019. The data collected from local stakeholders were analyzed using a descriptive statistics method and multiple regression method with the statistical software package SPSS version 23.

The multiple regression analysis was used in determining the factors that relate to fuel wood consumption of households and bamboo-rack owners in the study areas.

3. RESULT AND DISCUSSION

Change detection in land cover classes (LCC) between 2000-2010

Generally, over 10 years (2000-2010), the annual changes in areas coverage varied from one land cover class (LCC) to another with aquaculture area experiencing the most increases and forest undergoing the most decrease in area coverage as shown in Figure 1 and Table 1.

The forest areas in study area in 2010 has reduced (54.67%) compared to 2000 due to aquaculture area and cultivated land area expansion. Forest covers 22.32% of the state in 2010, down from 47.17% in 2000, forest cover areas reduced 20312 ha. The average annual loss rate of forest was 5.47%. Over 53 ha and 3310 ha of forest have been converted to aquaculture and cultivated land respectively. Over 14987 ha of forest have been degraded due to human actions and Cyclone Nagis in 2008 and then converted to shrub.

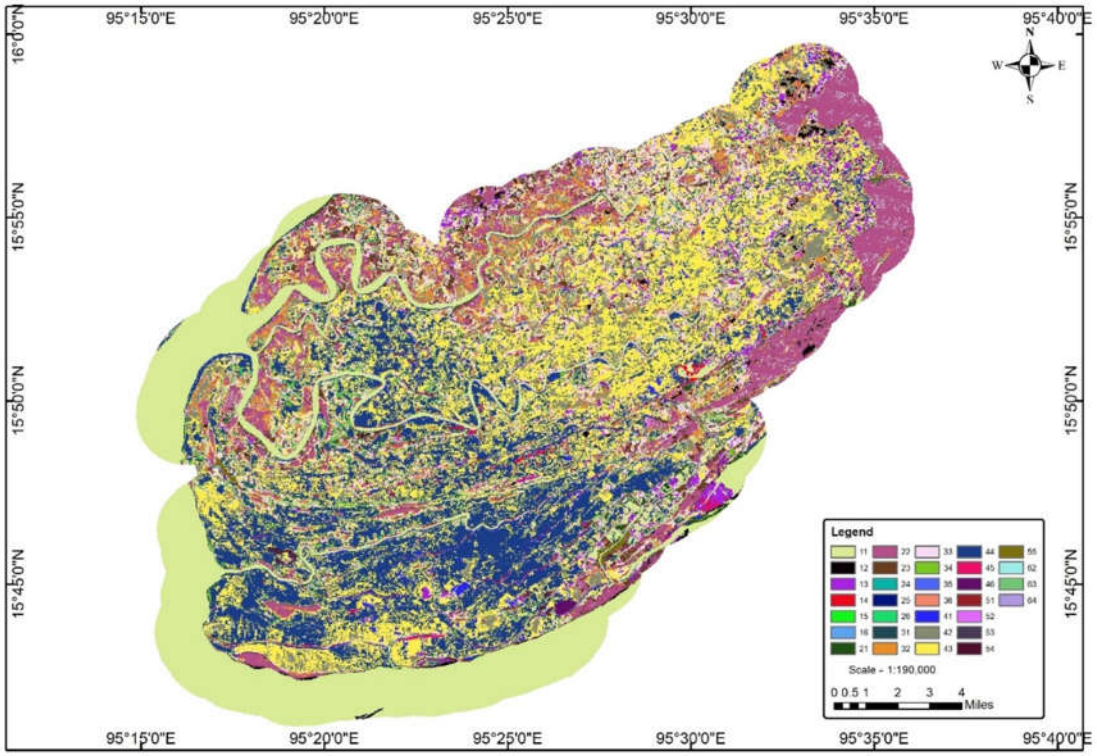

Figure 1. Land cover change detection between 2000-2010 in the study area

Table 1. Land cover changes by class between 2000-2010 and annual land cover changes (%)

Land cover classes	2000		2010		Land cover changes by class (ha)		Annual land cover changes (%)
	Area (ha)	% of area	Area (ha)	% of area	Area (ha)	Total land cover changes%	
Water Body	17123.4	21.74	15846.84	21.00	-1276.56	-7.46	-0.75
Cultivated Land	9996.84	12.69	13307.22	17.63	3310.38	33.11	3.31
Shrub	14155.47	17.97	29142.27	38.62	14986.80	105.87	10.59
Forest	37157.31	47.17	16845.12	22.32	-20312.19	-54.67	-5.47
Settlement Area	331.38	0.42	264.87	0.35	-66.51	-20.07	-2.01
Aquaculture	3.06	0.004	55.62	0.07	52.56	1717.65	171.76

Change detection in land cover classes (LCC) between 2010-2019

Generally, over 9 years (2010-2019), the annual changes in areas coverage varied from one LCC to another with cultivated land, forest, settlement area, aquaculture area experiencing the most increases and shrubs undergoing the most decrease in area coverage as shown in Table 2 and Figure 2.

The forest areas in study area in 2019 has increased again (20.94%) compared to 2010 due to reforestation and rehabilitation programs after striking the Cyclone Nagis in 2008. Forest covers 26.75% of the state in 2019, up from 22.32% in 2010. The average annual increase rate of forest was 2.33%. Over 7930 ha of shrub have been converted to forest due to reforestation program in this area. Cultivated land (4967.37 ha), settlement area (91.8 ha) and aquaculture (3.42 ha) has been increased over the years.

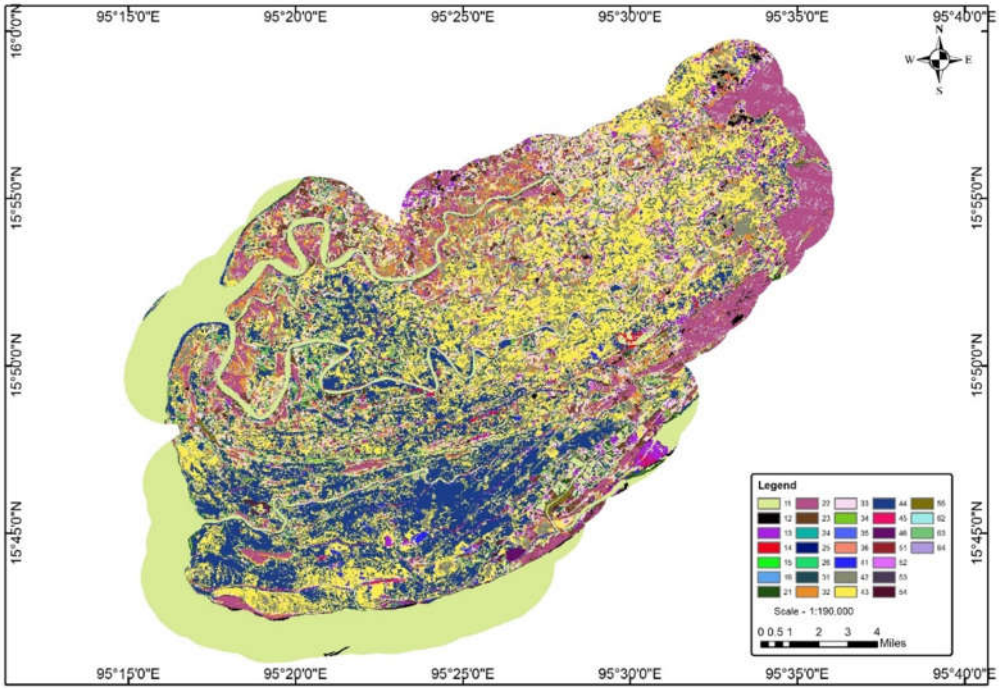

Figure 2. Land cover change detection between 2000-2010 in the study area

Table 2. Land cover changes by class between 2010-2019 and annual land cover changes (%)

Land cover classes	2010		2019		Land cover changes by class (ha)		Annual land cover changes (%)
	Area (ha)	% of area	Area (ha)	% of area	Area (ha)	Total land cover changes%	
Water Body	15846.84	21.00	15871.05	20.84	24.21	0.15	0.02
Cultivated Land	13307.22	17.63	18274.59	24.00	4967.37	37.33	4.15
Shrub	29142.27	38.62	21211.47	27.86	-7930.8	-27.21	-3.02
Forest	16845.12	22.32	20372.22	26.75	3527.1	20.94	2.33
Settlement Area	264.87	0.35	356.67	0.47	91.8	34.66	3.85
Aquaculture	55.62	0.07	59.04	0.08	3.42	6.15	0.68

Change detection in land cover classes (LCC) between 2000-2019

Generally, over 19 years (2000-2019), the annual changes in areas coverage varied from one land cover class to another with cultivated land, aquaculture area experiencing the most increases and forest undergoing the most decrease in area coverage as shown in table 3 and figure 3.

The forest areas in study area in 2019 has reduced (45.17%) compared to 2000 due to aquaculture area and cultivated land area expansion. Forest covers 26.75% of the state in 2019, down from 47.17% of the state in 2000, forest cover areas haven't been reached to forest areas in 2000 although forest areas have been increased again in 2008 later due to reforestation and rehabilitation programs. The average annual loss rate of forest was 2.38%. Over 55.98 ha and 8277.75 ha of forest have been converted to aquaculture and cultivated land over the years respectively.

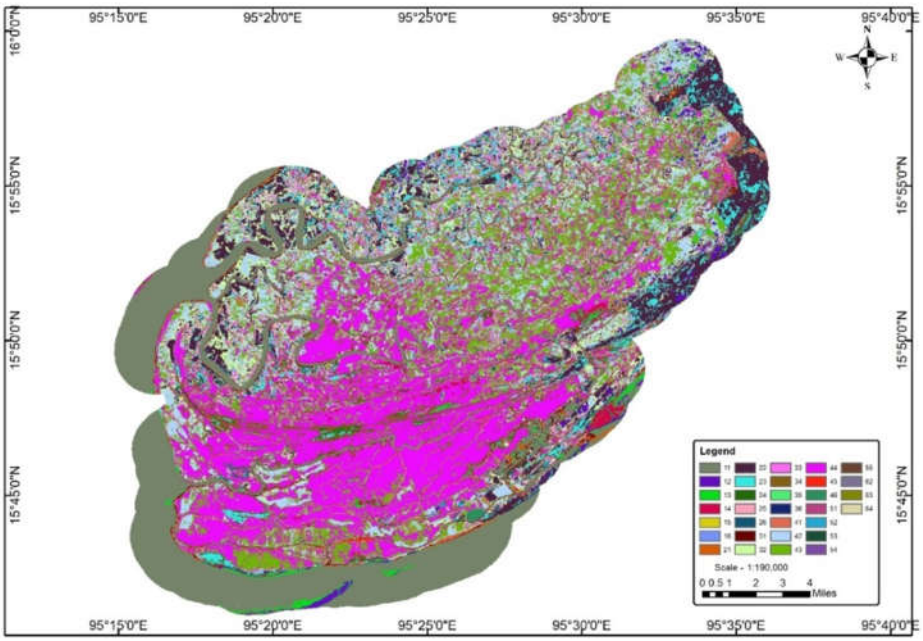

Figure 3. Land cover change detection between 2000-2019 in the study area

Table 3. Land cover changes by class between 2000-2019 and annual land cover changes (%)

Land cover classes	2000		2019		Land cover changes by class (ha)		Annual land cover changes (%)
	Area (ha)	% of area	Area (ha)	% of area	Area (ha)	Total land cover changes%	
Water Body	17123.4	21.739	15871.05	20.84	-1252.35	-7.31	-0.38
Cultivated Land	9996.84	12.692	18274.59	24.00	8277.75	82.80	4.36
Shrub	14155.47	17.971	21211.47	27.86	7056	49.85	2.62
Forest	37157.31	47.173	20372.22	26.75	-16785.09	-45.17	-2.38
Settlement Area	331.38	0.421	356.67	0.47	25.29	7.63	0.40
Aquaculture	3.06	0.004	59.04	0.08	55.98	1829.41	96.28

Influencing factors on the fuel wood consumption of households and bamboo-rack owners in the study areas

The results of the multiple regression analysis for households and bamboo-rack owners are presented in Table 4. The double logarithm gave the best fit and hence, was selected as the lead equation based on the number of significant variables, plausible magnitude of the regression coefficients, magnitude of the coefficient of determination (r2) and correctness of signs of the coefficients.

The result shows that four of the nine explanatory variables used in the model significantly affected the consumption of fuel wood by households while three of the nine explanatory variables used in the model significantly affected the consumption of fuel wood by bamboo-rack owners. According to the regression result, level of education and access to mangrove in next five years variables negatively influence the consumption of fuel wood by households while family size, level of education, source of fuel wood negatively influence the fuel wood consumption by bamboo-rack owners. In contrast, age, family size, source of fuel wood, mangrove timber collection changes in the past 5 year, economic situation of households within 5 years, type of

mangrove species and expenditure on fuel wood consumption variables positively influence the consumption of fuel wood by households but age, access to mangrove in next 5 years, mangrove timber collection changes in the past 5 years, type of mangrove species and expenditure on fuel wood positively influence the consumption of fuel wood by bamboo-rack owners.

The coefficient of access to mangrove in next 5 years was found to inversely effect on quantity of fuel wood consumption in the study areas at a probability level of 0.05. This implies that although household can able to access to mangrove in next 5 years, they might access to alternative fuel sources as well to substitute fuel wood for multiple purposes due to current local and international organizations development program for their livelihood development activities.

The positive coefficient of mangrove timber collection changes in the past 5 years and its significance at 5% implies that the more the changes of mangrove collection by households the higher the consumption of fuel wood. The coefficient of economic situation of households within five years is positive and statistically significant at 5%. This implies that household's economic situation gradually better off, their fuel wood consumption increases.

Expenditure on fuel wood consumption by households was found to positively affect the quantity of fuel of consumption at a probability level of 0.01. This implies that as expenditure on fuel wood consumption increases, quantity of fuel wood consumption increases. For every 1% increase in expenditure on fuel wood, quantity of fuel wood increases by 1.49%.

Table 4. Multiple regression estimates of socio-economic factors influencing fuel wood consumption in study areas

Variables	Households (n=35)		Bamboo-racks owners(n=35)	
	Coefficients	t-ratio	Coefficients	t-ratio
Constant	2.59	22.23***	7.151	21.613***
Age	0.001	0.159	0.005	1.047
Family size	0.006	0.016	-0.079	-2.491*
Level of education	-0.005	-0.509	-0.012	-0.604
Source of fuel wood	0.003	0.043	-0.014	-0.066
Access to mangrove in next 5 years	-0.141	-3.577**	0.000	0.003
Mangrove timber collection changes in the past 5 year	0.092	2.836**	0.039	0.290
Economic situation of households within 5 years	0.132	2.919**	0.282	2.228*
Type of mangrove species	0.051	1.406	0.032	0.343
Expenditure on fuel wood consumption	1.49	12.334***	2.69	6.804***
R^2	0.989		0.963	
Adjusted R^2	0.977		0.928	
F statistic	103.356***		30.717***	

** Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level*

Regarding the results of bamboo-rack owners, the coefficient of family size was found to inversely effect on quantity of fuel wood consumption in the study area at a probability level of 0.1. This implies that although the number of family members increases, it would not be affected on the quantity of fuel wood consumption because bamboo-rack owners used fuel wood mainly in dry shrimp commercial production activities.

The positive coefficient of the economic situation of bamboo-rack owners within the 5

years and its significance at 10% implies that the more increases in economic situation by bamboo-rack owners, the higher the consumption of fuel wood because they used a lot of fuel wood in their dry shrimp processing activities.

Expenditure on fuel wood consumption by bamboo-racks owners was found to positively affect the quantity of fuel of consumption at a probability level of 0.01. This implies that as expenditure on fuel wood consumption increases, quantity of fuel wood consumption increases. For every 1% increase in expenditure on fuel wood, quantity of fuel wood increases by 2.49%.

Influencing factors on the aquaculture areas expansion by pond owners in the study areas (n=48)

The results of the multiple regression analysis for pond owners are presented in table 5. The double logarithm gave the best fit and hence, was selected as the lead equation based on the number of significant variables, plausible magnitude of the regression coefficients, magnitude of the coefficient of determination (r2) and correctness of signs of the coefficients.

Table 5. Multiple regression estimates of socio-economic factors influencing aquaculture areas in the study areas

Variables	Pond owners (n=48)	
	Coefficients	t-ratio
Constant	-1.829	-1.111
Age(year)	-0.001	-0.108
Level of Education	0.364	2.491*
Access to Training	-0.574	-1.770*
Experience in aquaculture(year)	0.066	3.007**
Pond owner's difficulties	-1.025	-3.332**
Transportation cost(MMK)	0.001	2.115*
Gross income (MMK)	-2.47	-0.213
Total aquaculture productivity (Kg)	0.001	2.196*
R^2	0.847	
Adjusted R^2	0.718	
F statistic	12.395***	

** Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level*

The result shows that six of the eight explanatory variables used in the mode significantly affected the aquaculture areas by ponds owners. According to the regression result, level of education experience in aquaculture, transportation cost, total aquaculture productivity variables positively influence on the aquaculture areas expansions by pond owners while age, access to training, pond owner's difficulties and gross income variables negatively influence on the aquaculture areas expansions.

The coefficient of level of education was found to positively effect on aquaculture area expansion in the study area at a probability level of 0.1. This implies that the higher the pond owner education level, the more increase the aquaculture areas.

The negative coefficient of access to training and its significance at 10% implies that although the pond owners' access to training, aquaculture areas is not increased because they just received the information about how to manage the ponds and to increase the productivity.

The coefficient of experience in aquaculture of pond owners is positive and statistically significant at 5%. This implies that as experience in aquaculture increase, areas expansion increases. For every 1-year increase

in experience in aquaculture farm, area expansion by pond owners increases by 0.066%. However, the coefficient of pond owners face difficulties was found to negatively influence on the aquaculture area expansion at a probability level of 0.5.This implies that although they have a community forest certificate to access the mangrove for aquaculture area expansion, they have many strict regulations to get the license for aquaculture farm from department of fisheries.

Transportation cost for aqua-products trading was found to positively affect the aquaculture area expansion at a probability level of 0.1. This implies that although transportation cost increases, the aquaculture farm areas increase. For every 1% increase in transportation cost, aquaculture farm areas increase by 0.001%.

The positive coefficient of the gross income of aquaculture farm and its significance at 10% implies that the more increases in aquaculture areas, the higher the total aquaculture productivity. For every 1% increase in aquaculture productivity, aquaculture farm areas increase by 0.001%.

Research findings have indicated that mangrove loss in the coastal areas is often attributed to aquaculture (mainly shrimp) production, although a recent spatial assessment found that only 1.6 % of mangrove deforestation between 2000 and 2012 could be attributed to aquaculture in Myanmar (Richards & Friess, 2016). Similarly, another spatial analysis attributes most mangrove losses between 2000 and 2013 to agricultural expansion and large-scale deforestation (Webb et al, 2014). There is emerging interest in developing Myanmar's coastal aquaculture industry, particularly cultured shrimp for export (Fabrikant, 2013). Pond aquaculture represents major future potential for both small-scale and commercial income generation. The main cause of loss of mangrove areas in Ayeyarwady Delta including the study areas has been overexploitation and the development of shrimp farms. Because of its high economic return, shrimp farming has been promoted to boost national economies as a potential source of income for local communities and as a mean of poverty alleviation (Win Maung, 2014). However, this activity has caused loss of habitat and of ecosystem services provided by mangroves and may damage surrounding areas through pollution caused by the chemical products used (Maung, 2013).

4. CONCLUSION

The forest areas in study area in 2010 has reduced (54.67%) compared to 2000 due to aquaculture area and cultivated land area expansion. Forest covers 22.32% of the state in 2010, down from 47.17% in 2000, forest cover areas reduced 20312 ha. The average annual loss rate of forest was 5.47%. Over 53 ha and 3310 ha of forest have been converted to aquaculture and cultivated land respectively. Over 14987 ha of forest have been degraded due to human actions and Cyclone Nagis in 2008 and then converted to shrub.

Four of the nine explanatory variables used in the model significantly affected the consumption of fuel wood by households while three of the nine explanatory variables used in the model significantly affected the consumption of fuel wood by bamboo-rack owners.

Six of the eight explanatory variables used in the mode significantly affected the aquaculture areas by ponds owners. Level of education experience in aquaculture, transportation cost, total aquaculture productivity variables positively influence on the aquaculture areas expansions by pond owners while age, access to training, pond owner's difficulties and gross income variables negatively influence on the aquaculture areas expansions.

The depletion of forest resources and increasing demand for forest products especially of the rural people who depend on forests for livelihoods have widened the gap

between the demand and supply of forest products. Recent mangrove changes are due mainly to agricultural and shrimp farming expansion. The main causes of deforestation in the Ayeyarwady mangrove forests are due to socio-economic problem of the local communities.

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ĐÁNH GIÁ THAY ĐỔI ĐỘ CHE PHỦ VÀ NGUYÊN NHÂN SUY THOÁI RỪNG NGẬP MẶN TẠI KHU DỰ TRỮ PYINDAYE, ĐỒNG BẰNG AYEYARWADY, MYANMA ĐỂ HƯỚNG TỚI QUẢN LÝ RỪNG BỀN VỮNG NHẰM GIẢM THIỂU HẬU QUẢ CỦA BIẾN ĐỔI KHÍ HẬU

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TÓM TẮT

Nghiên cứu này phân tích sự thay đổi trong sử dụng đất trong giai đoạn 2000-2019 bằng cách sử dụng ảnh vệ tinh Landsat và các nhân tố ảnh hưởng tới suy thoái rừng ngập mặn, đặc biệt tiêu thụ gỗ củi và mở rộng diện tích nuôi thủy sản trong khu vực nghiên cứu. Nghiên cứu sử dụng cả hai phương pháp định tính và định lượng bao gồm phỏng vấn 118 người thông qua bộ câu hỏi khảo sát và thảo luận nhóm. Kết quả nghiên cứu cho thấy vừa có chiều hướng tăng lên và giảm đi trong sự thay đổi độ che phủ rừng ngập mặn giai đoạn 2000 đến 2019. Có sự thay đổi đáng kể giữa các loại rừng khác nhau. Nguyên nhân thay đổi do các yếu tố khí hậu như thảm họa tự nhiên cũng như các yếu tố kinh tế - xã hội. Kết quả phân tích tương quan chỉ ra rằng nguyên nhân suy thoái rừng ngập mặn, đặc biệt việc tiêu thụ gỗ củi và mở rộng diện tích nuôi thủy sản có mối quan hệ chặt chẽ và tương quan dương rõ rệt ảnh hưởng tới suy thoái rừng ngập mặn. Nuôi thủy sản là nguyên nhân gây mất rừng ngập mặn tại đồng bằng Ayeyarwady bao gồm khu vực nghiên cứu do việc khai thác quá mức rừng ngập mặn để phát triển các trang trại nuôi tôm thương mại. Suy thoái rừng ngập mặn là một trong những vấn đề môi trường quan trọng mà chính phủ cần chỉ ra và xây dựng chính sách, luật lệ và quy định nhằm giảm thiểu hậu quả của biến đổi khí hậu ở khu vực này.

Từ khóa: Đồng bằng Ayeyarwady, nuôi thủy sản, phát triển giảm thiểu, suy thoái rừng ngập mặn, thay đổi độ che phủ, tiêu thụ gỗ củi.

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