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“Natural Regeneration of Mangrove Vegetation on Farmlands in Wunbaik Reserved Mangrove Forest, Myanmar”

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Natural Regeneration of Mangrove Vegetation on Farmlands in Wunbaik Reserved Mangrove Forest, Myanmar

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Abstract

Mangrove forest covers the coast of Rakhine State, in north western part of Myanmar, and it provides various ecosystem services. This mangrove forest is decreasing rapidly after 1990s due to shrimp and rice farm encroachment and fuelwood collection. A farm is established inside a polder protected by hand-made embankment and the site is called "*kari*" in local language. On the other hand, the recolonization of mangrove is observed both in abandoned farms and farms in use. This study aims to clarify the current situation of the mangrove tree recolonization in the farms and discuss the relationship between the farm management and the recolonization. This study conducted in Wunbaik Reserved Mangrove Forest. Field survey was carried out in 10 sites, 3 sites on abandoned farms and 7 sites on farms in use. In each farm, two to ten plots of 5 x 5 m^2 or 10 x 10 m^2 size were set and altogether 45 plots were laid out. In each plot, all individual stems were recorded but herb and shrub species were excluded. Stem diameter at breast height (DBH) and total plant height were also measured. Within four years after the abandonment, the recolonization can establish the dense sapling stands in the *karis*. A total of 14 mangrove species and 2 mangrove associated species have been identified. Species composition was differed among 10 *karis*. *Avicennia officinalis* had the highest relative density in all growth-stages. Fruits of mangrove species carried by tidal flow is considered to be the main source of the recolonization. This successful fruit dispersal is available due to the extensive shrimp farming system in the farms. Natural regeneration of mangrove forest by these recolonizing fruits can be a feasible method for the restoration of the abandoned farmland.

Keywords: mangrove coverage, farmlands (*karis*), seedlings, saplings, trees

မြန်မာနိုင်ငံ၊ဝန်ဗိုက်ဒီရေတောကြိုးဝိုင်းအတွင်းရှိ ကာရီများ(ပုဇွန်ကန်နှင့်လယ်ယာမြေများ) အတွင်းသို့ ဝင်ရောက်လာသည့် ဒီရေတောမျိုးဆက်ပင်များအား လေ့လာခြင်း

စန်းစန်းဌေး၊ တောအုပ်ကြီး၊ သစ်တောဦးစီးဌာန

Dr. Mamoru Kanzaki (ပါမောက္ခ)

စာတမ်းအကျဉ်း

မြန်မာနိုင်ငံ၏ အနောက်မြောက်ဘက်တွင်ရှိသော ရခိုင်ကမ်းရိုးတန်း တစ်လျှောက်တွင် ဒီရေတောများ ဖုံးလွှမ်းလျက်ရှိပြီး ၎င်းတောများမှ အမျိုးမျိုးသော ဂေဟဗေဒ ဝန်ဆောင်မှုများကို ထောက်ပံ့ပေးနေပါသည်။သို့သော်လည်း ရခိုင်ပြည်နယ်ရှိ ဒီရေတောများသည် ၁၉၉၀ နှောင်းပိုင်း နောက်တွင် ပုဇွန်ကန်များ၊ စပါးခင်းများ ဝင်ရောက်ကျူးကျော်မှုနှင့် ထင်းများ ထုတ်ယူခြင်းတို့ကြောင့် လျှင်မြန်စွာကျဆင်းလျက်ရှိပါသည်။ ဒီရေတောအတွင်း၌ ကျူးကျော်၍ လယ်ယာမြေများ တူးဖော်ပြီး ထိုလယ်ယာမြေများကို လူတို့၏ လက်ဖြင့်ပြုလုပ်ထားသော မြေသားတမံများဖြင့် ကာကွယ်ထားကြပါသည်။ ထိုကဲ့သို့ မြေသားတမံများဖြင့် ကာကွယ်ထား သည့် လယ်ယာမြေများကို ရခိုင်ဒေသ အခေါ်အဝေါ်ဖြင့် **“ကာရီ”**ဟု ခေါ်ဆိုပါသည်။ အခြားတစ်ဖက်တွင်လည်း စွန့်ပစ်ထားသော ကာရီများနှင့် လက်ရှိအသုံးပြုနေဆဲ ကာရီများတွင် ဒီရေတောမျိုးစိတ်များ ပြန်လည်ဝင်ရောက်လာသည်ကို လေ့လာတွေ့ရှိပါသည်။ ဤစာတမ်းသည် ကာရီများအတွင်းသို့ ဝင်ရောက်လာသည့် ဒီရေတောမျိုးစိတ်များ၏ လက်ရှိအခြေအနေနှင့် ဒီရေတောမျိုးစိတ်များ ပြန်လည်ဝင်ရောက်လာခြင်း အကြောင်းတရားများနှင့် ဒေသခံပြည်သူတို့၏ ကာရီအုပ်ချုပ်သည့်စနစ်များကြား ဆက်နွယ်နေသည့် အကြောင်းအရာ များကို လေ့လာခြင်းဖြစ်ပါသည်။ ဤသုတေသနအား ဝန်ဗိုက် ဒီရေတော ကြိုးဝိုင်း အတွင်း တွင် ဆောင်ရွက်ခဲ့ပါသည်။ လက်တွေ့ ကွင်းဆင်းဆောင်ရွက်ခြင်းအား ကာရီ ၁၀ ခုတွင် ပြုလုပ်ခဲ့ပြီး ကာရီ ၃ ခုမှာ စွန့်ပစ်ထားသော ကာရီများဖြစ်၍ ကျန် ၇ ခုမှာ လက်ရှိ အသုံးပြုနေ သော ကာရီများဖြစ်ပါသည်။ ကာရီတစ်ခုတွင် အပင်ပေါက်ရောက်မှု အခြေအနေများအပေါ် မူတည်၍ ၅ မီတာ x ၅ မီတာ စတုရန်းကွက်များ နှင့် ၁၀ မီတာ x ၁၀ မီတာ စတုရန်းကွက်များ အသုံးပြု၍ နမူနာကွက် ၂ ကွက် မှ ၁၀ ကွက်အထိ ကောက်ယူခဲ့ပါသည်။

စုစုပေါင်း နမူနာကွက် ၄၅ ကွက် ကောက်ယူခဲ့ပါသည်။ နမူနာကွက်တစ်ခုစီတွင် အပင် ပေါက်မှစ၍ အပင်ကြီးများ အားလုံးကောက်ယူခဲ့ပါသည်။ အပင်ကြီးများ၏ ရင်စို့လုံးပတ်နှင့် အမြင့်များအားတိုင်းတာခဲ့ပြီး သစ်ပျော့ပင်များနှင့် ချုံပင်များ ကောက်ယူခြင်းအားချန်လှပ် ထားခဲ့ပါသည်။ ကာရီများစွန့်ပစ်ပြီး ၄နှစ် အကြာတွင် ဒီရေတောပင်များသည် ထူထဲစွာ ပေါက်ရောက်လာနိုင်ပြီး ပင်ပျိုများအဖြစ်ရှင်သန်ကြီးထွားလာနိုင်သည်ကိုတွေ့ရှိရပါသည်။ယခု ကောက်ယူခဲ့သော ကာရီ တစ်ခုစီတွင် ဒီရေတော ဖုံးလွှမ်းမှုသည် ၂၀ ရာခိုင်နှုန်းနှင့် အထက်ရှိသည်ကို လေ့လာ တွေ့ရှိခဲ့ပါသည်။ စုစုပေါင်း ဒီရေတောမျိုးစိတ် ၁၄ မျိုးနှင့် ဒီရေတော မိတ်ဖက်ပင် ၂ မျိုးကို လေ့လာ တွေ့ရှိခဲ့ရပါသည်။ ကာရီ ၁၀ ခု တွင် သစ်မျိုးပါဝင်မှု တူညီမှုမရှိသည်ကို တွေ့ရှိရပါသည်။ ကာရီများတွင် သမဲ့ကြီးပင်များကို အပင်ငယ်အဆင့်မှ အပင်ကြီး အဆင့်အထိ ပေါများ စွာတွေ့ရှိရပါသည်။ ဒီရေတောမျိုးဆက်ပင်များ ဝင်ရောက်လာနိုင်ရခြင်း၏ အဓိက အကြောင်း အရင်းမှာ ကာရီများအတွင်းသို့ ဒီရေနှင့်အတူ မျောပါလာသည့် ဒီရေတော အစေ့များကြောင့် ဖြစ်ပါသည်။ ထိုကဲ့သို့ ကာရီ အတွင်းသို့ အစေ့များ မျောပါလာခြင်းသည် ဒေသခံပြည်သူများ အသုံးပြုသည့် ပုစွန်မွေးမြူသည့် နည်းစနစ်ကြောင့် ဖြစ်ပါသည်။ ကာရီများအတွင်းသို့ အဓိကဝင်ရောက်လာသော ဒီရေတောမျိုးစိတ်များမှာကနဦး ဝင်ရောက်လာသော သစ်မျိုးများ ဖြစ်သည်ကို တွေ့ရှိရပါသည်။ ထိုကဲ့သို့ ဝင်ရောက်လာသော ဒီရေတောမျိုးဆက်ပင်များသည် စွန့်ပစ်ကာရီများတွင် သစ်တောများပြန်လည် ပေါက်ရောက်လာနိုင်သည့် အလွယ်ကူဆုံး နည်းလမ်းတစ်ခုဖြစ်ပါသည်။

Natural Regeneration of Mangrove Vegetation on Farmlands in Wunbaik Reserved Mangrove Forest, Myanmar

1. Introduction

Mangrove forests are threatened globally because of various anthropogenic activities and climate change. In a similar way, mangrove forest in Myanmar have disappeared at an unprecedented rate due to various anthropogenic factors. In addition, mangrove forest area in Rakhine State, a second hotspot in Myanmar after Thanintharyi Region, is also decreasing especially due to shrimp farming, paddy field and firewood production. One of the main causes is shrimp farming and it results in deforestation of mangrove because the traditional shrimp farming culture system is quite popular in Rakhine State (Arakan Mangrove). So, a huge area of mangrove forest was cut down to operate shrimp ponds. Moreover, Wunbaik Reserved Forest which is the only mangrove reserved forest in Rakhine State is also facing deforestation

The biodiversity of Wunbaik Reserved Mangrove Forest (WRMF) is also under constant flux due to natural disasters and anthropogenic factors. The areas of mangrove in WRMF were decreased especially during 1990-2014 due to farming practices (shrimp *kari* and rice *kari*) and illegal logging (Saw.,2017). After 2014, the conditions were getting better because the new Myanmar government pays greater attention for the conservation of forest. Besides, the government has been implementing Myanmar Rehabilitation and Restoration Programme (MRRP) to restore the degraded forest. Although there are positive changes of land use and land cover from 2014 to 2020 (Htay.S.S.,2020), deforestation still remains a concern in Wunbaik Reserved Mangrove Forest (WRMF) because of political instability. Thus, it is very difficult to handle to stop illegal logging and deforestation in such a volatile region. The status of natural regeneration should be studied not only for the restoration of degraded and deforested areas but also for sustainable forest management. In addition, it is very important to conserve mangrove forests or let the degraded areas regrow because a hectare of mangrove forest can buffer a lot more carbon than an equivalent area of tropical forest.

The present study aims to estimate the coverage of mangrove in the selected *karis* by using Remote Sensing and Geographic Information System (RS & GIS) techniques and set the following three objectives;

1. To quantitatively measure the recolonization of mangrove species into the farmlands
2. To clarify the relationship between the farm management and recolonization
3. To examine the recolonization of mangrove as the restoration methods of deforestation sites.

2. Materials and Methods

2.1 Study Area

This study was conducted in Wunbaik Reserved Mangrove Forest (WRMF). It is located between 19˚ 08' 10" & 19˚ 23' 40" North and 93˚ 54' 35" & 94˚ 02' 10" East in Yambye Township, Kyauk Phyu District, Rakhine State (Figure 1). It covers an area of approximately 22,919 hectares and it has been divided into eighty-four compartments for management purposes. This Reserved Forest was constituted by order No. 343 in February 15, 1931 by the British Government. The original objective of the Reserved Forest was to supply fuelwood to salt factories and inland steam vessels.

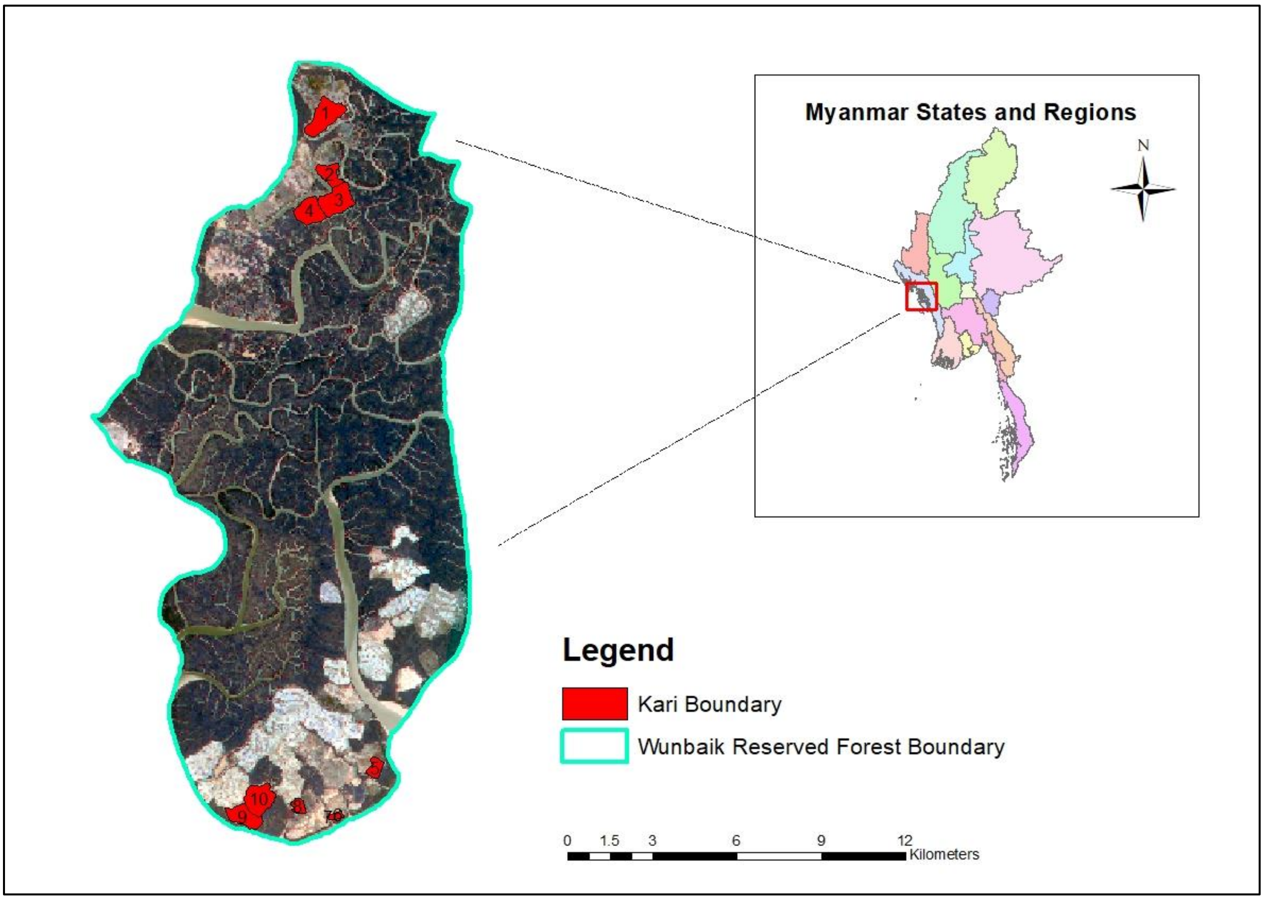

Figure 1. Location Map of Wunbaik Reserved Mangrove Forest and *karis* and their proximity to each other

2.2 Data Collection

The present study was carried out in Wunbaik Reserved Mangrove Forest (WRMF). Ten *karis* were selected to assess the coverage of mangrove by using RS&GIS techniques and to observe the population structure and status of mangrove regeneration colonizing naturally inside the *karis*. All study sites were decided based on the history of the *karis*, the conditions of mangrove regeneration and accessibility. Three abandoned *karis* and seven currently farmed *karis* were identified in this study.

Field experiment was conducted from November to December 2019. In each *kari*, two to ten plots of 5m x 5m plots and 10m x 10m plots were laid depending on the conditions of forest. Altogether 45 plots were collected.

Within each plot, trees (DBH ≥ 10 cm), saplings (> 1.5 m height with a DBH of < 10 cm) and seedings (sprouts to young plant up to 1.5 m height) were collected. Mangrove shrubs and herbs species like *Acanthus* species, *Acrostichum* species and *Sesuvium portulacastrum* were not considered in this study. Vegetation measurements, including tree height and DBH were noted for all trees and saplings. Species wise count data were collected for seedlings in each plot. Interview with *karis'* owners was also conducted during the field visit.

In addition, national forest inventory data (2017) provided by Forest Department was also applied to compare the vegetation structure of recolonized mangrove stand and natural forest stand.

2.3 Data Analysis

Estimation of Mangrove Coverage

In this study, estimation of mangrove coverage for each *kari* was done by using Remote Sensing and Geographic Information System (RS&GIS) techniques. The analyses also used very high resolution images (QuickBird and IKONOS) from 2019, available in the current version of Google Earth Pro. Very high spatial resolution images can be used as performant and mature tools in order to evaluate mangrove natural capacity of recovery or plantation growth performance (Proisy et al., 2018).

Qgis 3.4.9 was used for the pre-processing of satellite images. Pixel-based Land Use and Land Cover (LULC) classification performance has been tested by using ArcGIS Desktop 10.6 for mangrove cover estimation. Mangrove areas were discriminated from other surface types (water and bare soil) using a pixel-based algorithm for maximum livelihood supervised classification method. To determine the accuracy of each classification and class, thematic accuracy assessment was performed. For this purpose, a reference data set including ground truth data collection points and the points generated from google earth pro was created. These points were collected and selected over different *karis* representing different land use and land cover classes. Error matrix of each classification was created and total accuracy, user's accuracy and producer's accuracy values of each class were analyzed to evaluate classification accuracies. The accuracy assessment as kappa statistics for each *kari* were 0.97, 0.93, 0.94, 0.89, 0.83, 0.95, 0.96, 0.91, 0.95 and 1 respectively.

Vegetation Data

Vegetation data were entered into Microsoft Excel 2016 spreadsheets as the basic data format; they were thereafter transformed into other formats.

The total counts for the studied vegetation were analyzed by species, plots and diameter class. Tree density was calculated in this study to determine how closely trees are growing in a given area. The size-class distribution of the mangrove species was used to characterize population structures.

Ordination was also performed for data exploration and pattern analysis associated with mangrove vegetation composition by using R software. A similarity matrix was developed between samples and vegetation composition within each study site individually and as a comparison across all the *karis*, using collated data from each plot in the *karis.* The Bray-Curtis measure was used to construct the similarity matrix.

3. Results

3.1 Mangrove Coverage for Each *Kari*

Figure 2 illustrates the estimation of mangrove coverage for the selected *karis*. The areas, coverage of mangrove, overall accuracy and kappa coefficient of each *kari* were shown in table 1. According to calculations, the lowest mangrove coverage was 21% and the largest mangrove coverage was 50 %. But this study revealed that the coverage of mangrove is not related to the land use types such as abandoned *kari*, rice *kari* and shrimp *kari*.

Table 1. Area (Ha), Percentages of Mangrove Cover, Overall Accuracy and Kappa Coefficient of Each *Kari*

Kari Name	Area (Ha)	Mangrove Cover (%)	Others (%)	Overall Accuracy (%)	Kappa Coefficient (%)
Kari 1	104	33	67	99	97
Kari 2	49	24	76	96	93
Kari 3	97	32	68	97	94
Kari 4	75	31	69	95	89
Kari 5	29	39	61	92	83
Kari 6	7	43	57	98	95
Kari 7	5	49	51	98	96
Kari 8	21	50	50	96	91
Kari 9	68	21	79	98	95
Kari 10	89	41	59	100	100

*All the calculations were estimated by using Remote Sensing and Geographic Information System (RS & GIS).

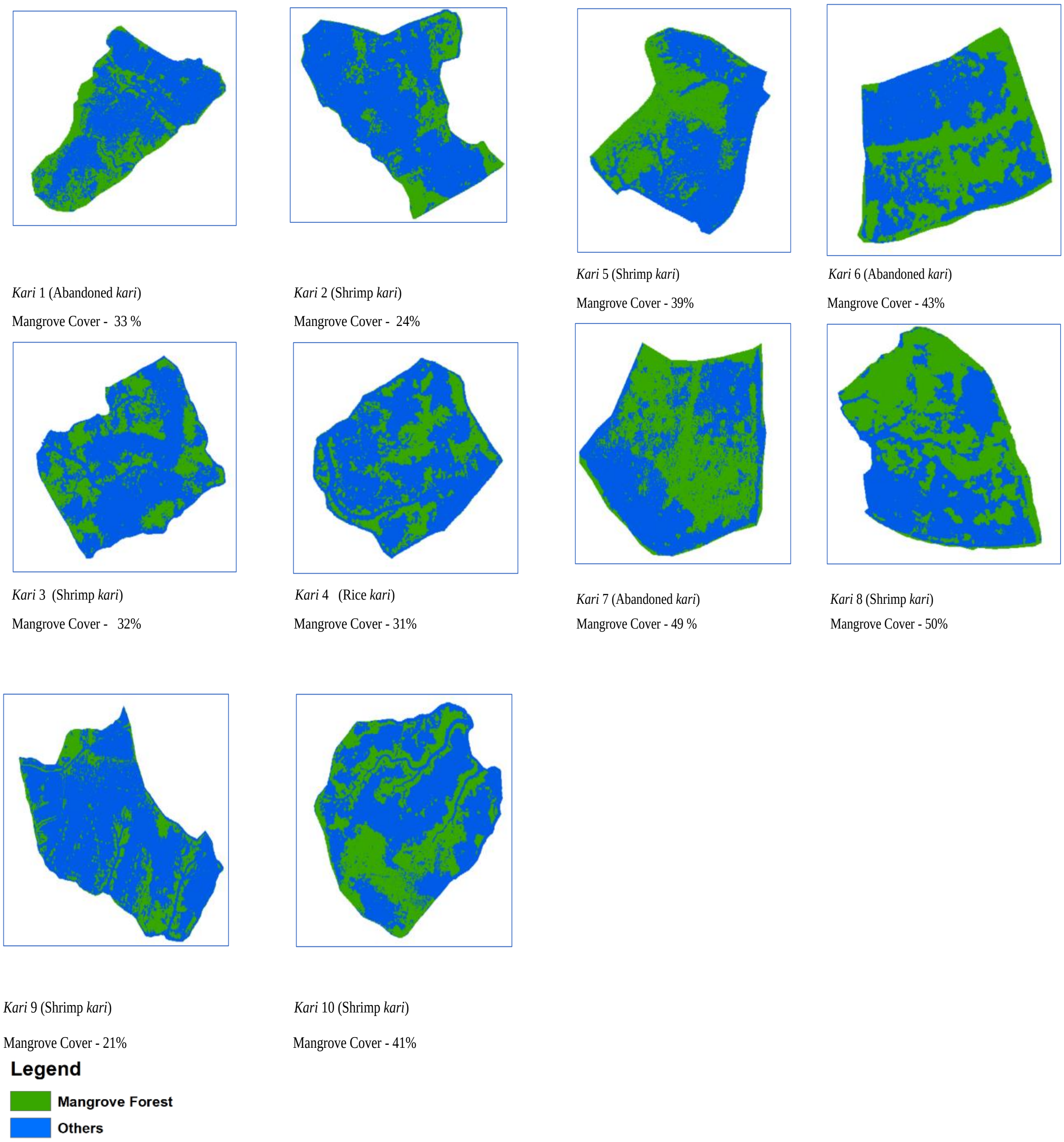

Figure 2. Coverage of Mangrove for all the selected *Karis*

3.2 Species Composition of Recolonized Mangrove Stand (*Karis*)

In this study, a total of 14 mangrove tree species belonging to six families were observed (Table 2). Among the six families, the highest species were occurred from *Rhizophoraceae* which accounted for 5 species, followed by *Avicenniaceae* (3 species), *Sterculiaceae* and *Sonneratiaceae* (2 species each). Furthermore, two mangroves associated species (*Dalbergia Spinosa* and *Derris trifoliata*) were recorded in this study.

The population census of the mangrove vegetation exhibited the greatest density value for *Avicennia officinalis* (mean density and the standard deviation was 34750 ± 24050 stems/ha). *Avicennia marina* possesses the second greatest density value which accounted for 30060±42245 stems/ha. *Avicennia* species was the dominant species in this study.

Among the study sites, the species composition is differed from one *kari* to another. The maximum number of species (13) was observed in *kari1* (abandoned shrimp pond *kari*), followed by *kari3* and *kari4* (Table 2). The tree species- *Avicennia officinalis, Avicennia marina*, *Ceriops decandra* and *Aegiceras corniculatum* were almost equally abundant among the *karis* while *Sonneratia griffithii*, *Rhizophora apiculata*, *Rhizophora mucronata* and *Heritirea fomes* were totally absent in some *karis*.

Table 2. Species Composition of Recolonized Mangrove Stand (*Karis*)

	Density for each *kari* (stems/ha)										mean density
	kari 1	*kari* 2	*kari* 3	*kari* 4	*kari* 5	*kari* 6	*kari* 7	*kari* 8	*kari* 9	*kari* 10	(stems/ha)
Avicennia officinalis	74100	37200	39000	28800	80400	9600	18800	9200	38800	11600	34750± 24050
Avicennia marina	0	1200	600	2400	51200	7200	26400	66400	7200	138000	30060± 42245
Ceriops decandra	4400	1200	51500	12800	400	2800	3200	3200	24800	1200	10550± 15391
Aegiceras corniculatum	26100	5200	32900	6400	1600	2800	0	2000	400	23200	10060± 11715
Aegialitis rotundifolia	300	0	29100	27200	0	4400	400	0	400	0	6180± 11066
Dalbergia spinosa	12300	400	3300	16400	0	400	3600	3200	400	0	4000± 5430
Sonneratia griffithii	1000	800	5800	0	0	0	0	0	0	0	760± 1718
Rhizophora apiculata	0	0	500	800	0	400	0	0	2400	0	410± 716
Bruguiera gymnorrhiza	100	0	800	2000	0	0	400	0	0	0	330± 610
Avicennia alba	500	0	0	0	1200	0	800	0	0	0	250± 413
Sonneratia apetala	1500	0	0	0	0	0	400	0	0	0	190± 453
Derris trifoliata	400	0	0	400	0	0	0	0	400	0	120± 183
Bruguiera cylindrica	100	0	300	800	0	0	0	0	0	0	120± 244
Heritiera littoralis	800	0	0	0	0	0	0	0	0	0	80± 240
Rhizophora mucronata	0	0	300	0	400	0	0	0	0	0	70± 142
Heritiera fomes	300	0	0	0	0	0	0	0	0	0	30± 90

NMDS ordination (Figure 3) shows data exploration and pattern analysis associated with mangrove vegetation composition. Three categories were classified in this analysis; abandoned shrimp *kari*, rice *kari* and shrimp *kari.*

According to NMDS ordination, variety of species composition occurred and it is difficult to explain by land use types. The species composition of abandoned *kari*s is diverse. *Heritiera fomes* and *Heritiera littoralis* were recorded on abandoned *kari* while these two species were totally absent in both rice *kari* and shrimp *karis*. In addition, no *Rhizophora* species were observed but largest numbers of *sonneratia apetala* were recorded on abandoned *kari*.

The species composition of rice *kari* is also diverse and the greatest number of *Bruguiera gymnorrhiza* belong to this *kari.*

In shrimp *karis*, diverse species composition was found and some plots were dominated by *Aegialitis routundifolia*, *Ceriops decandra*, *Sonneratia griffithii* while other plots were covered with greatest number of *Avicennia* species (*Avicennia officinalis*, *Avicennia marina* and *Avicennia alba*).

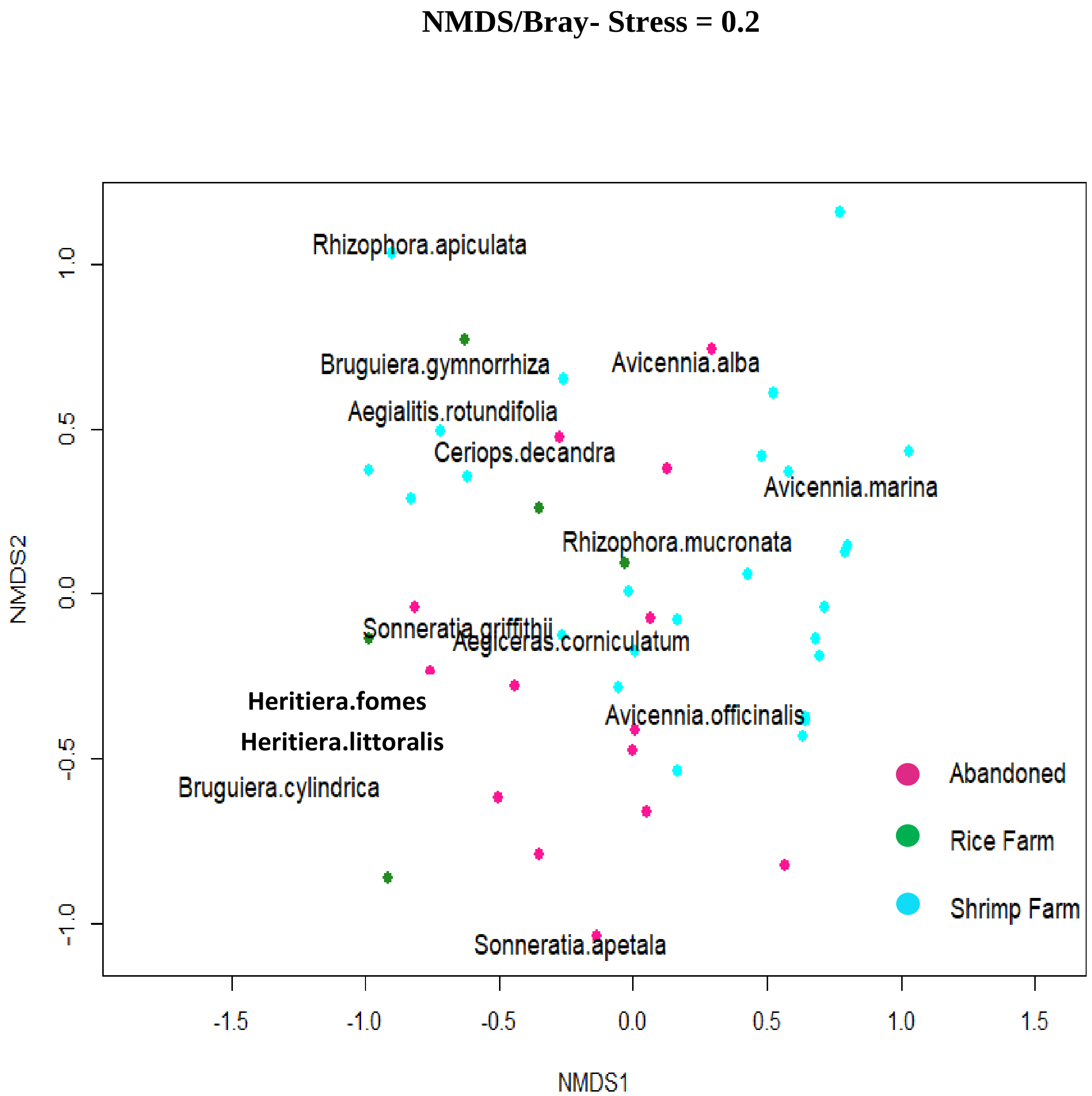

Figure 3. NMDS ordination of mangrove species based on the sum of densities of three size classes

3.3 Population Size Structure of Recolonized Mangrove Stand (*Karis)*

The population size structure of the *karis* (Table 3) illustrated smaller number of stems were observed at the tree layer and sapling layer but most of the stems were successfully growing at the seedling layer. *Avicennia officinalis* was the most dominant species at all layers, which were 64.6% at the tree layer, 43.4% at the sapling layer and 34.4 % at the seedling layer respectively. *Avicennia marina* followed the second dominant species at all layers. The largest number of *Sonneratia griffithii* and *Rhizophora apiculata* can be found at the tree stage and it can rarely be occurred at the sapling and seedling stages. *Avicennia* species exhibited the highest density among all the other species and some mangrove species were totally absent at the sapling and tree layers.

Table 3. Population Size Structure of Recolonized Mangrove Stand (*Karis*)

	Trees		Saplings		Seedlings	
Species	**Stems/ha**	**Relative Density(%)**	**Stems/ha**	**Relative Density(%)**	**Stems/ha**	**Relative Density(%)**
Avicennia officinalis	1020	64.6	2690	43.4	31040	34.4
Avicennia marina	130	8.2	2050	33.1	27880	30.9
Sonneratia griffithii	130	8.2	50	0.8	580	0.6
Rhizophora apiculata	90	5.7	30	0.5	290	0.3
Aegiceras corniculatum	50	3.2	340	5.5	9670	10.7
Dalbergia spinosa	40	2.5	20	0.3	3940	4.4
Avicennia alba	40	2.5	80	1.3	130	0.1
Ceriops decandra	30	1.9	750	12.1	9770	10.8
Rhizophora mucronata	30	1.9	0	0.0	40	0.0
Bruguiera gymnorrhiza	10	0.6	10	0.2	310	0.3
Sonneratia apetala	10	0.6	0	0.0	180	0.2
Aegialitis rotundifolia	0	0.0	90	1.5	6090	6.8
Derris trifoliata	0	0.0	0	0.0	120	0.1
Heritiera littoralis	0	0.0	0	0.0	80	0.1
Bruguiera cylindrica	0	0.0	90	1.5	30	0.0
Heritiera fomes	0	0.0	0	0.0	30	0.0
Grand Total	**1580**	**100**	**6200**	**100**	**90180**	**100**

According to DBH size distribution as shown in figure 4, most of stems belong to 1-4 cm diameter at breast height (DBH) category and the number of stems was decreasing as the DBH increases. Trees were rare in all the *karis* but few remnant trees (16-32 cm DBH and 64-80 cm DBH) were existed for a long time.

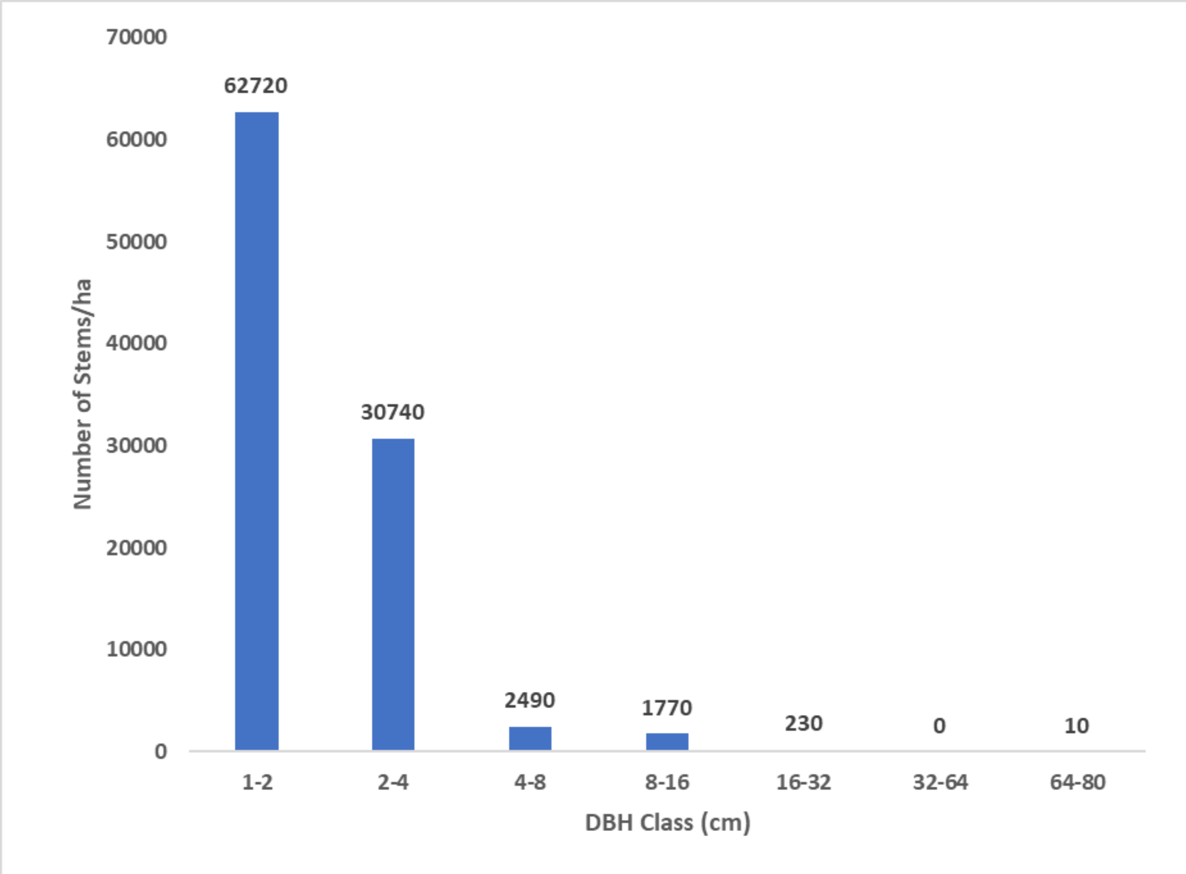

Figure 4. Frequency distribution of mangrove trees in recolonized mangrove stand (*karis*) based on their Diameter at Breast Height (DBH)

3.4 Population Structure of Natural Mangrove Stand in WRMF

In natural forest stand of Wunbaik Reserved Mangrove Forest (WRMF) as shown in table 4, tree layer is dominated by *Xylocarpus granatum*, *Rhizophora apiculata*, *Rhizophora mucronata* and *Avicennia officinalis.* The relative densities were 23.9 %, 15.3%, 13.7 % and 12.2 % respectively. *Bruguiera gymnorrhiza, Ceriops decandra* and *Rhizophora apiculata* were dominant species at the sapling layer and which stood at 43.6 %, 23.5 % and 21.8 % of relative density. On the other hand, *Ceriops decandra* (59.9 % relative density) and *Bruguiera gymnorrhiza* (14.1 %) were dominant species at the seedling layer.

Table 4. Population Structure of Natural Forest Stand in Wunbaik Reserved Mangrove Forest

Species	Trees		Saplings		Seedlings	
	Stems/ha	Relative Density (%)	Stems/ha	Relative Density (%)	Stems/ha	Relative Density (%)
Xylocarpus granatum	11	23.9	0	0.2	96	0.9
Rhizophora apiculata	7	15.3	26	21.8	627	5.6
Rhizophora mucronata	7	13.7	8	7.0	542	4.9
Avicennia officinalis	6	12.2	0	0.4	65	0.6
Avicennia alba	3	5.8	1	1.2	25	0.2
Sonneratia apetala	2	4.6	0	0.3	4	0.0
Ceriops decandra	2	4.4	28	23.5	6646	59.9
Heritiera fomes	2	4.4	1	1.0	60	0.5
Sonneratia griffithii	2	4.2	0	0.4	29	0.3
Bruguiera cylindrica	2	3.4	0	0.1	44	0.4
Bruguiera gymnorrhiza	1	2.8	52	43.6	1567	14.1
All other species	1	1.8	0	0.0	2	0.0
Aegiceras corniculatum	0	1.0	1	0.6	221	2.0
Sonneratia caseolaris	0	0.6	0	0.0	4	0.0
Xylocarpus moluccensis	0	0.6	0	0.0	13	0.1
Bruguiera parviflora	0	0.4	0	0.0	2	0.0
Sonneratia alba	0	0.4	0	0.0	0	0.0
Aegialitis rotundifolia	0	0.2	0	0.0	1094	9.9
Excoecaria agallocha	0	0.2	0	0.0	0	0.0
Ceriops tagal	0	0.0	0	0.0	62	0.6
Total	**48**	**100**	**120**	**100**	**11104**	**100**

Data Source: Forest Department

3.5 Comparison of Vegetation Structure between Recolonized Mangrove Stand and Natural Mangrove Stand

The vegetation structure of recolonized mangrove stand (*karis*) and natural mangrove stand of Wunbaik Reserved Mangrove Forest (WRMF) was different from each other. The current study was dominated by *Avicennia* species (*Avicennia officinalis* and *Avicennia marina*) at all layers; tree, sapling and seedling. *Sonneratia griffithii* was also abundant species at the tree stage of recolonized mangrove stand but it was rare at the sapling and seedling stages. These *Avicennia* species and *Sonneratia* species were mangrove swamp pioneer species. On the other hand, natural mangrove stand of WRMF is dominated by *Xylocarpus granatum, Rhizophora* species, *Avicennia officinalis, Ceriops decandra* and *Bruguiera gymnorrhiza.* Although abundant numbers of *Rhizophora* species were recorded in natural mangrove stand, it was rarely observed in the recolonized mangrove stand (*karis*).

4. Discussion

Mangrove Coverage in Each *Kari*

This study showed that mangrove recolonization was vigorous and more than 20% of land was covered by mangrove forest in all the sampled *karis*. Depending on the *karis*, mangrove stems are expanding inside, outside and over pond dykes. *Karis* with more than 20% mangrove cover are crucial not only for ecosystem of Wunbaik Reserved Mangrove Forest (WRMF) but also for the farmers while a number of countries (including Hong Kong, Thailand, Malaysia, Vietnam, Philippines, Kenya, Tanzania, Senegal and Jamaica) were pursuing a form of silvofisheries: Integrated Mangrove Forest Aquaculture Systems as part of a reforestation efforts (Fitzgerald, 2007).

There are so many factors that enable the recolonization of mangrove in the *karis*. The first one is farm management by the farmers. There is a relationship between recolonization of mangrove and farm management. The farmers practice traditional shrimp farming culture system so-called the "**Traditional Trap and Hold System**" and they collect both shrimps, fishes and mud crabs from their *karis*. This system is so sustainable and it is environmentally friendly aquaculture practices because of avoidance of chemicals and mechanical compounds, resulting in less waste generation. This traditional system also favors for the recruitment of natural regeneration because the propagules inflow with the high tide when the sluice gates are opened. In addition, muds and organic matters are also accompanied with the high tide which results in the recolonization of the mangrove swamp pioneer species like *Avicennia* and *Sonneratia* species.

Existing of remnant trees in the *karis* and natural forest stand next to the dykes also help for the recovery of natural mangrove vegetation. It is one of the factors for the recolonization of mangrove in the *karis*.

Another factor is breaching of the dykes. According to interview with local farmers, cyclones slam in this region very often and destroy the *karis* especially *karis'* earthen dykes. Normally, farmers repair the broken dykes by using their hands and they sometimes use the bulldozer. But using such kind of machine is very expensive. So, they cannot afford to use it. Sometimes, they cannot repair the embankment and abandon the *karis* at that time. Mostly, dykes of abandoned *karis* were broken. Usually, mangrove propagules arrived in the *karis* through the broken dykes.

Although some farmers welcome the mangrove recolonization, some farmers dislike the recolonization of mangrove in their *karis*. The farmers who dislike mangrove recolonization believe that when the mangrove leaves fall into the *karis*, it becomes rotten and gets terrible smell. The shrimp and crab don't like that smell. Furthermore, tannic acid from the leaves is potentially toxic to aquatic organisms. Thus, they usually cut down the mangrove trees that entered naturally in the *karis* when they have enough money. But they cannot control these mangrove stems because they need to hire labors for felling these trees. It is quite expensive and prices can vary depending on the size of *karis*. For example, they must pay 50,000 kyats (approximately 35 US$) for 120 ft x 120 ft (36m x 36m). Farmers normally let the mangrove trees to grow naturally because they cannot afford for the felling of mangrove trees. But it would seem that it does not impact the production of shrimps and crabs (field survey, 2019).

Farmers who welcome the natural recolonization of mangrove believe that the shrimps and crabs cannot live without mangrove trees especially in the summer season because mangrove trees can provide greater shelter to the shrimps, particularly during molting periods. Inoue et al, (1999, cited by Bosma et al., 2016) observed that leaves of *Avicennia* increased pond fertility and regulated pH during the rainy season. And according to (Binh et al., 1997), ponds with mangrove coverage of 30-50% of mangrove area had the highest economic return.

Species Composition of Recolonized Mangrove Stand (*Karis*)

A total of 14 mangrove tree species belonging to six families were recorded in the recolonized mangrove stand (*karis*). In addition, two mangrove associated species belonging to two families were also observed. The total number of species recorded in the present study does not include *Acanthus* species, *Acrostichum* species and *Sesuvium portulacastrum.* Some mangrove species belong to *Euphorbiaceae, Combretaceae, Arecaceae, Rubiaceae and Meliaceae* families were not observed totally in this study but the species that belong to those families can be occurred in natural mangrove stand of Wunbaik Reserved Mangrove Forest (WRMF). It seemed that the species belonging to those families might not thrive under the environmental conditions of *karis*.

Recolonized mangrove stand was dominated by *Avicennia* species and *Sonneratia* species and they are initial colonizing species in the *karis*. This result is also the same as (Lewis and Burbridge, 1999), *Avicennia marina* is the initial colonizing species during years 1-5 after dikes are breached on disused pond recolonization on the island of Bohol in the Phillines, followed by several species of *Rhizophora* and *Sonneratia* in the years 5-14. (Elwin et al., 2019) studied preservation and recovery of mangrove ecosystem carbon stock in abandoned shrimp ponds, Thailand. It was observed that *Avicennia* species was a dominant species present inside or around most of the abandoned ponds. The result of (Elwin et al., 2019) is also similar to this study. In addition, (Duncan et al., 2016) and (Matsui et al., 2012) show the same result, *Avicennia marina* was the dominant pioneer species. *A. marina* is often considered to play an important pioneering role in plant succession (Osborne and Berjak, 1997).

The results exhibited that *Avicennia officinalis* and *Avicennia marina* were dominant species. Pioneer *Avicennia* species colonized more than other mangrove tree species inside the *karis* because most of the plots were located in the shrimp ponds. Although the shrimp ponds are mostly covered with tidal water, this *Avicennia* species can thrive well because they can tolerate very high salinities. And these species grow better on low ground than on high ground. In addition, the muds and organic matters that accompanied with the tidal water created a more favourable environmental conditions for the pioneer *Avicennia* species and *Sonneratia* species.

Small number of *Rhizophora* species were observed in the *karis* because this species a slow-growing, much-branched, evergreen tree and natural regeneration always occur near mature trees. Only few mature trees of *Rhizophora* species were observed in the selected *karis* which result in low density of this species.

The species composition of recolonized mangrove stand is diverse and it is difficult to explain by the land use patterns according to non-metric multidimensional scaling (NMDS) method.

Abandoned shrimp *karis* have more diverse species than other *karis*. *Heritiera fomes* and *Heritiera littoralis* were occupied on abandoned *kari* but they were not observed in other land use types like rice *kari* and shrimp *kari*. The abandoned *kari* was located on high ground. Thus, such situation favours the occurrence of these species. On the contrary, *Rhizophora apiculata* and *Rhizophora mucronata* were not recorded on abandoned *kari* because these species grow in places where daily tidal inundation occurs. In addition, natural regeneration of these species usually occurs near the mature trees. It was not observed mother trees in this *kari* which causes lack of *Rhizophora apiculata* and *Rhizophora mucronata.*

The species composition of rice *kari* is also diverse and many mangrove regenerations were observed in this rice *kari*. This *kari* was shrimp *kari* in 2018. Thus, the recuperation of mangrove stems in this *kari* is related to the previous land use type. Most of the leftover stems were growing in this *kari* but they are fragmented.

The species composition in the shrimp *karis* is also diverse and some plots were dominated by *Aegialitis routundifolia*, *Ceriops decandra*, *Sonneratia griffithii* while other plots were dominated by greatest number of *Avicennia* species (*Avicennia officinalis*, *Avicennia marina* and *Avicennia alba*). Most of the shrimp *karis* were dominated by larger number of *Avicennia* species because this land use type favours to grow this species abundantly.

Population Size Structure of Recolonized Mangrove Stand (*Karis*)

The population size structure of the recolonized mangrove stand (*karis*) shows the number of seedlings (90180 stems/ha) is more than the number of saplings (6200 stems/ha) and trees (1580 stems/ha). This population structure is related to the land use types because the farmers operate the *karis* as shrimp *kari* and rice *kari* alternatively. When they use the *karis* as shrimp pond, they usually conserve the mangrove stems. But when they convert from shrimp *kari* to rice *kari*, they normally do the clear cutting of mangrove. The farmers convert rice *kari* to shrimp *kari* and vice versa when the production declines. Such kind of practices create the recuperation of larger number of seedlings in the *karis.* Thus, seedling population is greater than population of saplings and trees.

Most of the stems in the recolonized mangrove stand were fallen under 1-4 cm DBH category and the number of stems was decreasing when the diameter at breast height (DBH) increases. It means that the stems that possess 1-4 cm DBH were new regeneration and some trees which have large DBH were old remnant trees. In the recolonized mangrove stand (*karis),* old remnant trees can be occurred because the farmers sometimes left large trees due to difficulties of felling down and extracting their roots. Another reason is that they do not need to fell these trees along the creeks as the paddy cannot grow such kind of waterlogged areas. Thus, some remnant trees existed inside the *karis.* But existing such remnant trees are also helpful for the re-establishment of mangrove regenerations.

This study revealed the presence of uneven, age-mixed mangrove vegetation in the *karis*. Even in one *kari*, some parts of the *kari* were dominated by one-year-old mangrove tree and other parts were covered with four-year-old mangrove stems. The area covered with one-year-old mangrove stems was rice field in the previous year. Thus, size distribution of mangrove stems is strongly related to disturbance history and time since the last-stem replacement. Furthermore, different disturbance history produces different size distribution of stems.

Comparison of Vegetation Structure between Recolonized Mangrove Stand and Natural Mangrove Stand

The Food and Agriculture Organization (FAO) reported that the WRMF covers the 70 plant species; including 34 mangrove and 36 salt tolerant terrestrial plants. And according to National Forest Inventory (NFI) 2017, 21 mangrove species and 3 mangrove associated species were recorded in WRMF and it seemed that some mangrove species could not be identified. In recolonized mangrove stand, a total 14 mangrove species and 2 mangrove associated species were recorded.

The dominant species between recolonized mangrove stand and natural mangrove stand were not the same. Recolonized mangrove stand is dominated by larger number of *Avicennia officinalis* recruits, *Avicennia marina and Sonneratia griffithii* while natural mangrove stand is covered with *Xylocarpus granatum*, *Rhizophora* species and few recruits of *Avicennia officinalis*. In recolonized mangrove stand, main recolonizing species are mangrove swamp pioneer species (*Avicennia* species and *Sonneratia* species) but these species are not common in natural forest stand of Wunbaik Reserved Mangrove Forest (WRMF). *Rhizophora spp*., *Bruguiera spp*., and *Ceriops decandra* were few or absent in all the selected *karis.* There might be several factors why species composition is different between recolonized mangrove stand and natural stand. Different environmental conditions, ecology of species have impact on the recolonizing species because different mangrove taxa show different adaptation mechanism to cope with stressors such as salinity, tidal surges, waterlogged and anaerobic conditions. This study was designed to study the recolonization of mangrove vegetation in the *karis*. Thus, the environmental conditions are different from natural stand of Wunbaik Reserved Mangrove Forest (WRMF). Most of the *karis* in this study were operating as aquaculture ponds so that so much the areas were mostly covered with tidal water. Such conditions stimulate the recruitment of pioneer *Avicennia* species. In natural stand, *Avicennia* species (*Avicennia alba, Avicennia marina* and *Avicennia officinalis*) were not abundant species.

5. Conclusion and Recommendations

In this study, a total of 14 mangrove tree species belonging to six families were recorded from the recolonized mangrove stand (*karis*) and it was found that native vegetation has been allowed to regenerate naturally in the inactive *karis* and active *karis*. Moreover, the coverage of mangrove was more than 20% in each *kari* and it was observed that regrowth of mangrove vegetation was occurred within a short period of time; four years after abandonment.

The structural characteristics of the mangrove stems in the recolonized stand (*karis*) are strongly related to the previous land use history and different disturbance history produces different size distribution of stems. In addition, the abundance and distribution of the vegetation in the recolonized stand (*karis*) are also strongly controlled by disturbance history. Considering the overall structural data of the study sites, it could be concluded that the dominant species were different from natural forest stand of WRMF. Although both sites were secondary forest, the structures were not the same because of different environmental conditions.

This study emphasizes on natural regeneration of mangrove growing on disused *kari* and currently using *karis.* In this reserved forest, the land use pattern is always changing especially shrimp *karis* and rice *karis*. Although some *karis* were abandoned, it might change to other land uses in the future. So, the government should manage such abandoned *kari*s where mangrove vegetations were colonized naturally in order not to change to other land use types again because the farmers might come back to use this *kari* if there is no proper management. For the active *karis,* Forest Department (FD) should negotiate with the farmers to conserve these mangrove forest. In case of Vietnam, the government is implementing integrated mangrove aquaculture system and provides VDN 500,000 per hectare per year to plant and protect mangrove. Likewise, the government of Myanmar should negotiate with the farmers to conserve and protect the mangrove forest because local people participation is critical for the conservation of mangrove forest. Natural regeneration of mangrove forest by these recolonizing stems can be a feasible method for the restoration of the abandoned farmlands because the cost is relatively low and the recovery rate is so fast (Thant et al., 2012). The data provided in this study would be useful for the conservation of mangrove forest and for the reforestation and rehabilitation activities of Wunbaik Reserved Mangrove Forest (WRMF).

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