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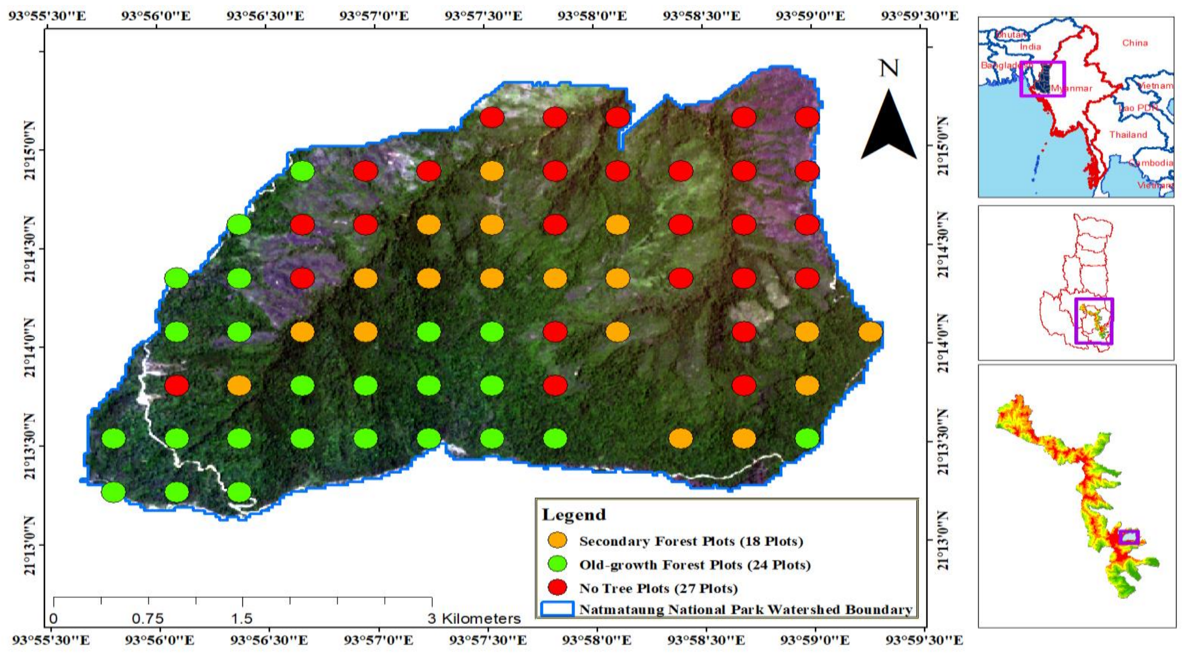
Forest Situation and Restoration Potential in Natmataung National Park Watershed, Kanpetlet Township, Chin State, Myanmar



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Abstract

Natma Taung National Park (NTNP)'s some virgin forest area is gradually transformed into other land use land cover types in terms of the major challenges of deforestation, forest degradation, and currently abandoned fallow lands. Therefore, NTNP needs the forest situation assessments including land use and land cover assessments for forest restoration potential. The research aimed to acquire information of the present forest situation of NTNP watershed and to assist the forest restoration potential. The total systematic 69 nested square plots (24 Old-growth Forest (OF)'s plots, 18 Secondary Forest (SF)'s plots and 27 plots with no tree of Scrub Land) with 500 m sampling distance were sampled for surveying of the tree species and family composition, forest stand structure, and estimated forest resources quantities in NTNP watershed area. In addition, land use land cover assessment was conducted for current land use land cover patterns in NTNP watershed area. This study found four main results; (1) current forest resources estimation with acceptable statistical proration of 1,814 ha of the study area, (2) compared results of OF and SF per plot level and per stem level in terms of tree species diversity indices and forest resources quantities and (3) updated maps in terms of main land use types and suitable area of restorability assessment, and (4) exploration appropriate forest restoration plans. All of the total values of forest resources quantities per stem level had significant differences with lower than 0.05 p values. The six main land-use types of NTNP watershed area were Dense Forest, Sparse Forest, Scrub Land, Bare Land with Low Grass, Bare Land with Fine-Grained Crystalline Rocks and Hard Schists, and Road. This research revealed that three main potential restoration plans of restorability. The ecological restoration should perform urgently with fast-growing-native pioneer tree species and climax species with high germination.

Keywords: Assisted Natural Regeneration, Deforestation, Natural Regeneration, Forest Degradation, Forest Restoration, Reforestation

မြန်မာနိုင်ငံ၊ ချင်းပြည်နယ်၊ ကန်ပက်လက်မြို့နယ်ရှိ နတ်မတောင် အမျိုးသားဥယျာဉ် ရေဝေရေလဲဒေသရှိ သစ်တောအခြေအနေနှင့် သစ်တောပြန်လည်တည်ထောင်နိုင်မည့် အလားအလာ

ရတနာဦး ၊ တောအုပ်ကြီး
သစ်တောဦးစီးဌာန

စာတမ်းအကျဉ်း

နတ်မတောင်အမျိုးသားဥယျာဉ်၏ အချို့သော မူလသစ်တောများသည် ရွှေ့ပြောင်းတောင်ယာစိုက်ပျိုးခြင်းကြောင့် သစ်တောပြုန်းတီးခြင်း၊ သစ်တောအတန်းအစားကျဆင်းခြင်း နှင့်စွန့်ပစ်တောင်ယာမြေများပေါ်များမှ စိန်ခေါ်များနှင့်အတူ အခြားသောမြေဖုံးလွှမ်းမှုပုံစံသို့ တဖြည်းဖြည်းပြောင်းလဲမှုများရှိလာခဲ့ပါသည်။ သို့ဖြစ်ပါ၍နတ်မတောင်အမျိုးသားဥယျာဉ် ၏ မူလနီးပါး / မူလသစ်တော ပြန်လည်တည်ထောင်နိုင်ရေး အလားအလာများ ဖော်ဆောင်နိုင်ရေးအတွက် လက်ရှိမြေဖုံးလွှမ်းမှုအား လေ့လာဆန်းစစ်ခြင်းအပါအဝင် လက်ရှိသစ်တောအခြေအနေများကိုပါ ဆန်းစစ်လေ့လာရန် လိုအပ်ပါသည်။ ဤသုတေသနတွင် နတ်မတောင်အမျိုးသားဉ ယျာဉ် ရေဝေရေလဲဒေသ၏ လက်ရှိသစ်တောများနှင့် ပတ်သက်သည့် သတင်းအချက်အလက်ရယူရန်နှင့် ၎င်းသတင်းအချက်အလက်များအား အသုံးချ၍ မူလနီးပါး/မူလသစ်တောပြန်လည်တည်ထောင်နိုင်ရေးအလားအလာဖော်ဆောင်ခြင်းအတွက် အထောက်အပံ့ပေးနိုင်ရန်တို့အတွက် ရည်ရွယ်၍ ဆန်းစစ်လေ့လာထားပါသည်။ နတ်မတောင် အမျိုးသားဉ ယျာဉ် ရေဝေရေလဲဒေသအတွင်း အကွာညီ Nested Sampling Design ဖြင့် သစ်တောနမူနာကွက် စုစုပေါင်း ၆၉ ကွက် (သက်ရင့်တောတွင် ၂၄ ကွက်၊ ပြန်ပေါက်တော တွင် ၁၈ ကွက်နှင့် ဖုန်းဆိုးတောတွင် ၂၇ ကွက်) တို့အားကောက်ယူခဲ့ပြီး သစ်ပင်မျိုးစိတ် ပါဝင်ပေါက်ရောက်ခြင်းအခြေအနေ (မျိုးစိတ်ကြွယ်ဝမှုနှင့် မျိုးစိတ်ကွဲပြားမှုညွှန်းကိန်းများ)၊ သစ်တောတည်ရှိမှု အနေအထားပုံစံ (Forest Stand Structure)၊ ခန့်မှန်းသစ်တောသယံဇာတအရင်းအမြစ်များ (သစ်တောပင်ထောင်အရေအတွက်၊ ရင်စို့ဖြတ်ပိုင်းဧရိယာ၊ မြေဆီလွှာအပေါ်ယံရှိ ဇီဝဒြပ်ထုနှင့် ကာဗွန်)တို့အား လေ့လာဆန်းစစ်ခဲ့ပါသည်။

ဤသုတေသန ၏ အဓိကရလဒ် (၄) ခုတို့မှာ (၁)၊ သစ်တောသယံဇာတစာရင်းကောက်ယူမှုမှတဆင့် နတ်မတောင်အမျိုးသားဥယျာဉ် ရေဝေရေလဲဒေသ၏ ခန့်မှန်းသစ်တော သယံဇာတ အရင်းအမြစ်ရလဒ်များ၊ (၂) သစ်တောသယံဇာတစာရင်း ကောက်ယူမှုမှတဆင့် သက်ရင့်တော နှင့် ပြန်ပေါက်တောတို့၏ သစ်ပင်မျိုးစိတ် ပါဝင်ပေါက်ရောက်ခြင်း အခြေအနေ (မျိုးစိတ်ကြွယ်ဝမှုနှင့် မျိုးစိတ်ကွဲပြားမှု ညွှန်းကိန်းများ) နှိုင်းယှဉ်မှုများနှင့်အကွက် တစ်ကွက်ချင်းအလိုက် သာမကပင်ထောင်တစ်ပင်ချင်းအလိုက် ခန့်မှန်းသစ်တောသယံဇာတ အရင်းအမြစ်များ၏ နှိုင်းယှဉ်မှုများ၊ (၃) မြေဖုံးလွှမ်းခြင်းဆန်းစစ်လေ့လာမှုမှတဆင့် လက်ရှိ မြေအသုံးချမှုပုံစံပြမြေပုံများ နှင့် မူလနီးပါး/ မူလသစ်တော ပြန်လည်တည်ထောင်နိုင်ရေး အလားအလာဖော်ဆောင်ခြင်းအတွက် သင့်တော်သည့် မြေဧရိယာပြ မြေပုံများနှင့် (၄) သစ်တောပြန်လည်တည်ထောင်ရေး လုပ်ငန်းစဉ်များအား ဖော်ထုတ်ခြင်း တို့ဖြစ်ကြပါသည်။ ပင်ထောင် တစ်ပင်ချင်းအလိုက် ခန့်မှန်းသစ်တောသယံဇာတ အရင်းအမြစ်များ၏ နှိုင်းယှဉ်မှုရလဒ်များအရ 0.05 P တန်ဖိုးထက်ငယ်၍ စာရင်းအင်းနည်းပညာ အရသိသာသည့် ခြားနားချက်များ ရှိကြပါသည်။သုတေသနဧရိယာ၏ အဓိက မြေအသုံးချမှု ပုံစံများမှာ ရွက်အုပ်ပိတ်တော၊ရွက်အုပ်ကြဲပါး သည့်တော၊ ဖုန်းဆိုးတော၊ သစ်ပင်ဖုံးလွှမ်းမှုမဲ့ မြက်တော၊ သစ်ပင်ဖုံး လွှမ်းမှုမဲ့ မြေတိုက်စား လွယ်သဲကျောက်များနှင့် လမ်းတို့ဖြစ်ကြပါသည်။ ဤသုတေသနမှတဆင့် မူလနီးပါး/မူလသစ်တော ပြန်လည်တည်ထောင်နိုင်ရေး အလားအလာများ ဖော်ဆောင် နိုင်ရေးအတွက် သင့်လျော်သည့် အဓိက နည်း ၃ နည်းအား တွေ့ရှိခဲ့ပါသည်။ အမြန်ပေါက်ရောက်နိုင်သော မူလဒေသသစ်မျိုးရင်းနှင့် သစ်ပင်ပေါက်နှုန်းမြင့်မားပြီး အများဆုံး ပေါက်ရောက်နေသောဒေသမျိုးရင်းများအား ဦးစားပေးရွေးချယ်စိုက်ပျိုးခြင်းဖြင့် ဂေဟစနစ် အခြေပြုမူလနီးပါး/မူလသစ်တော ပြန်လည်တည်ထောင်နိုင်ရေး သစ်တောပြုစုပျိုးထောင်ခြင်း နည်းလမ်းအား အမြန်ဆုံးနည်းလမ်းဖြင့် အကောင်အထည်ဖော် ဆောင်ရွက် သင့်ပါသည်။

Forest Situation and Restoration Potential in Natmataung National Park Watershed, Kanpetlet Township, Chin State, Myanmar

1. Introduction

In spite of the establishment and management for biodiversity conservation in all of protected areas of Myanmar in accordance with the legislative and regulatory framework of the Protection of the Wildlife and Protected Area Law by Forest Department (1994), the country is still facing with deforestation, forest degradation, and loss of habitats within and around of protected areas. Natmataung National Park (NTNP), the only one of Indo-Myanmar biodiversity hotspot of the eastern Himalayan mountain range is also undergoing the challenges of deforestation, forest degradation, and loss of habitats due to major threats namely collection of non-timber forest products, illegal hunting, encroached settlement, road expanding and upgrading, as well as shifting cultivation (Forest Department, 2018). Therefore, unstable land utilization and unsustainable shifting cultivation system with short-fallow period by local communities living under extreme poverty, inclusive of local major threats integrated with their forest dependence make the problems worse to park management in terms of currently abandoned fallow lands.

Regarding to forest restoration process at current abandoned fallow lands, forest ecological succession, recruitment, competition, mortality, and species turnover as well as current forest situation with indigenous species, whose community dynamics are mainly influenced (Yirdaw, Monge Monge, Austin, & Toure, 2019). In South East Asia of over last two decades, the investigation of the pattern of species diversity and biomass recovery in regrowth forests on former swidden land plays a major role of growing research interest (Suryanto et al., 2017). This understanding of ecological succession helps the fundamental approaches of the passive and active reclamation in the now burgeoning science and practice of ecological restoration (Clewell, Aronson, & Winterhalder, 2004; Jacobs et al., 2015; Walker & Del Moral, 2009). However, the current forest situation assessment should do for the forest restoration potential, which is the foundation of the passive and active reclamation approaches in the now burgeoning science and practice of ecological restoration. As swidden abandonment fallow lands widespread with deforestation and forest degradation throughout the NTNP, the results of this study can be applicable for the restoration potential assessment of currently abandoned fallow lands of degraded forest in a conservative and restorative point of the tropical biodiversity.

2. Objectives

The main four objectives of this study were:

i. To estimate the forest resources quantities including tree density, basal area, above-ground biomass (AGB) and carbon of the above ground biomass (AGC) through sampling with the fixed area method by conducting forest inventory

ii. To compare forest resource quantities per plot individual level and per stem individual level of Old-growth Forest (OF) and Secondary Forest (SF) and tree species richness and diversity indices per plot individual level of OF and SF by conducting forest inventory

iii. To identify the current main land use types and forest restoration potential suitable area by using Remote Sensing and Geographic Information System

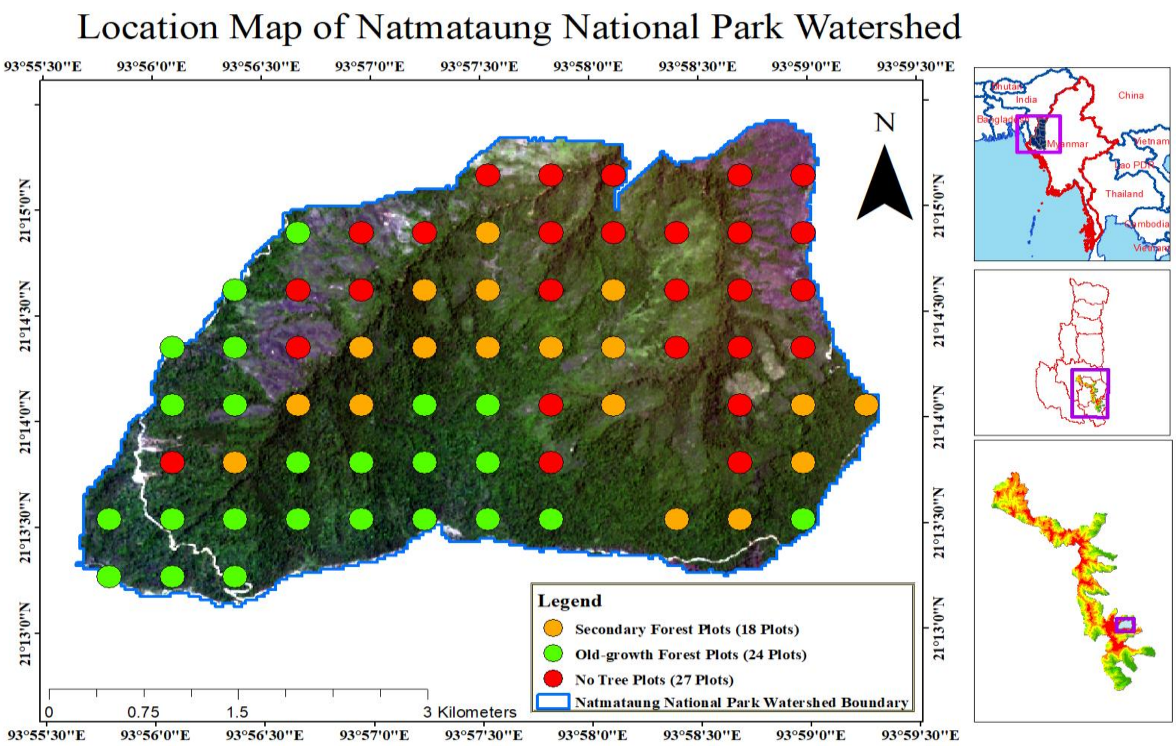
iv. To explore the appropriate forest restorability plans at forest restoration potential suitable area in accord with current forest situation assessments from conservation and restoration point of view

3. Materials and Methods

3.1 Study Area

The study area was conducted in the watershed area of NTNP at Kanpetlet Township, Chin State, western part of Myanmar. The study area location is North Latitude between 21° 15’ 10.73” N and 22° 13’ 24.25” N, East Longitude between 93° 57’ 25.10” E and 93° 57’ 22.21” E. The slope degree range is between 0.34° to 50.73° and the elevation range starts from 1,520 m to 2,979 m above sea level. The general forest type of study area, NTNP watershed area belongs to the semi-evergreen montane forest and specific forest type is Laurel forest in accord with the expression of Fujikawa et al. (2008). According to the statement of Forest Department (2018); Fujikawa et al. (2008), the general SF elevation border of whole NTNP is generally below 2,286 m (7,500 feet). In this study, the SF and OF categorization is fundamentally based on the SF elevation criteria (Forest Department, 2018; Fujikawa et al., 2008), minimal human disturbance, and field experience whereas the SF was above 1,990 m and below 2,380 m of lower elevation and the OF was above 2,380 m and below 3,000 m of higher elevation. According to the Department of Metrology and Hydrology from 2005 to 2019, Mindat Township, the total annual rainfall is 1,621.61 mm, the mean annual temperature is 21.72 °C and the mean aridity index is 47.78. The location map of study area in NTNP watershed is shown in Figure 1.

Figure 1 The location map of study area in NTNP watershed, Kanpetlet Township, Chin State, Myanmar



3.2 Data Collection for Forest Inventory

For forest inventory of the study, systematic sampling with nested plot design was applied to lay out the sample plots in this field study area. The total 69 square nested sample plots were conducted with 500 m sampling distance. Concerning the forest inventory of present research's tree stage, the collection of all measurable trees of ≥5 cm of diameter at breast height (DBH) and ≥ 1.3 m in height (H) was conducted in the largest plots of 20 m x 20 m (400 m^2 or 0.04 ha). The sapling status of this research was counted in smaller sub plots of 5 m x 5 m (25 m^2 or 0.0025 ha) with all measurable saplings of <5 cm of DBH and ≥1.3 m in H. The smallest sub plots of 1 m x 1 m (1 m^2 or 0.0001 ha) was conducted for the seedling counting of present research with all countable seedlings of H between ≥0.3 m and <1.3m were collected. The tree species of SF and OF were investigated in order to draw a species area curve comparison of the SF and OF in NTNP watershed area. Species identification was carried out with the assistance of Ms. Ling Shein Man, Local Plant Taxonomist, Range Officer of NTNP Office, Forest Department, Ministry of Natural Resources and Environmental Conservation of Myanmar. Her partial fulfillment books and journals of tree, small tree, and medicinal plant species identification are mainly concerned with the local specific region of whole NTNP area (D.-H. Kang, Ling, Kim, & Ong, 2017; D. Kang, Lee, Ong, Ling, & Kim, 2017; Lee, 2016; Ong et al., 2018a, 2018b).

3.3 Data Collection for Land Cover and Forest Restoration Potential Suitability Classification

The primary data of classified land cover map and forest restoration suitability map of this study were primarily based on also these accessible 69 plots and pre-identified unclear patterns of other study places in accordance with the preliminary ISODATA Unsupervised classification results. The preprocessed Sentinel-2A image of WGS 1984 Datum, the Universal Transverse Mercator (UTM) Map Projection at the 46 N UTM Zone was performed for the LULC classification and suitable area identifying in this study area. The preprocessed Sentinel-2A image with the production date of 15 December 2019, the final satellite image was downloaded from https://earthexplorer.usgs.gov/ using the Semi-Classification Plugin in 3.12.0 version of QGIS software in order to get the 10% less than cloud free and remove the noise of image of study area. The secondary data of topographic factor including slope and elevation with 30 m resolution were downloaded from https://earthexplorer.usgs.gov. NTNP watershed boundary was created with the assistance of the Soil and Water Assessment Tool (SWAT) in ArcGIS 10.5.

3.4 Methods and Data Analysis

3.4.1 Forest Resources Quantity Estimation

The collected data by spatial of Geo-informatics and forest inventory of this study were beneficially applied for the forest resources quantities estimation at the desired level of accuracy with affordable budget and time limitation for NTNP watershed. The sampled data by systematic sampling with nested plot design of forest inventory at NTNP watershed were applied to estimate the forest resources quantities for study site level based on the sampling with the fixed area method highlighted by Gregoire and Valentine (2007) and Myint et al.

(2017). In this study, the estimated forest resources quantities including tree density, basal area, AGB, and AGC of NTNP watershed at plot level and study site level were calculated based on the total 69 accessible plots with Microsoft Excel software.

The estimated of the mean and total AGB and AGC of the present study was derived by using the specific allometric AGB equation of Dry Evergreen Forest by Tsutsumi, Yoda, Sahunalu, Dhanmanonda, and Prachaiyo (1983). The weight of the AGB, W_{AGB} is derived by summing up of stem weight (W_s), branch weight (W_b), and leaves weight (W_l) of AGB density, whereas $W_s = 0.0509 \times DBH^2 \times H^{0.919}$, $W_b = 0.00893 \times DBH^2 \times H^{0.977}$ and $W_l = 0.0140 \times DBH^2 \times H^{0.669}$. The W_{AGB} is in kilograms, whereas DBH = diameter at breast height and H = height. The total AGB of plot level were calculated as the sum of all living trees on the plot in accord with this equation and the mean site-specific AGB quantities were calculated as the simple arithmetic average of generalized plot results. As outlined by IPCC (Goslee et al., 2015; In, 2006) , the carbon fraction was assumed to be 47% of the biomass and AGC of study area was also estimated by multiplying 0.47 and AGB.

From the field inventory data, the analyses of forest resources estimation at 95 % confidence interval is accomplished based on the sampling theory outlined for sampling with fixed area plots in sampling strategies for natural resources and environment by Gregoire and Valentine (2007). According to the results of total 69 fixed area plots, the independent estimator of total population ($\hat{T}_{y\pi s}$), the average unbiased estimator of total population ($\hat{T}_{y\pi rep}$), the average unbiased estimator of total population per unit area ($\hat{\lambda}_{y\pi,rep}$), the independent estimator of total population per unit area ($\hat{\lambda}_{y\pi s}$), and the important statistical parameters of 95 % confidence interval concerning Standard Deviation (SD), Variance (S^2y), Confident Interval (CI), Lower Limit (LL), Upper Limit (UL), Standard Error (SE), Margin of Error (MOER), Margin of Error Percent (MOER%), Standard Error Percent (SE%), Coefficient of Variation (CV), Coefficient of Variation (CV%) at plot level and study area level were computed.

Among the total 69 accessible sample plots, trees found only in 42 plots while any tree species did not find in 27 plots. Concerning with 42 tree plots, 24 plots are OF plots and 18 plots are SF. The calculations in terms of estimated forest resources quantities and their statistical values such as SE%, CV%, MOER%, SI% at 2.76 ha of plot level and 1,814 ha of study site level were principally based on 69 accessible plots.

In order to know the difference between two investigated stands based on 42 tree plots, the Two Independent Samples Unequal Variance test was applied in terms of forest resources quantities including tree density, DBH, basal area, AGB, and AGC per individual plot level (24 OF's plots and 18 SF's plots) and per individual stem level (394 OF's stems and 336 SF's stems).

3.4.2 Forest Tree Species Composition and Diversity

The surveyed vegetation data were also analyzed for the forest tree species composition, structural analysis, and species diversity indices (Narayan & Anshumali, 2015; Phillips, 1959). For assessing the ecological importance or significance of tree species, the species level important value index (IVI) and the family level important value index (FVI) values were calculated based on the 24 plots of OF and 18 plots of SF. In order to achieve both species level of IVI and FVI, Relative Abundance (RA), Relative Dominance (RDo), Relative Frequency (RF) of species level and family level were summed up (Cottam & Curtis, 1956). The species richness is the number of species in a community or in a region (Colwell, 2009). To provide quantitative estimates of species diversity of OF and SF, Simpson's index (1-D´) and Shannon-Wiener index (H´) and Evenness Index (J´) were used. For the coefficient of species similarity index for OF and SF, Sorensen's quantitative index (K_s) and the Lamprecht's modification index (K_d) were also applied which is accounting for the relative abundance of shared species was used to assess the degree of floristic similarity within and between the forest stands. To represent the sufficient sample size of the entire population, species-area curves of OF with 0.96 ha and SF with 0.72 ha were developed to determine the minimum representative area for each population. In order to know the two investigated stands' comparison results of species richness and tree species diversity indices including H´, 1-D´, and J´ per plot level of each stand based on 42 tree plots, the Two Independent Samples Unequal Variance test was also applied

3.4.3 Land Use Land Cover Classification

Regarding to the land cover classification methods, four main steps were conducted; first step; acquisition of preprocessed sentinel 2 A image with less than 10% free from Semi-Classification Plugin in QGIS, second step; band composting or band combination of the only selected 10 m resolution of Blue, Green, Red and Near-infrared bands, third step; image classification involving the ISODATA unsupervised classification image segmentation through generalization and supervised classification by field knowledge, fourth step; generating of land cover map of study area with accuracy checked results. The accuracy check of land cover classification map of study area with six main land uses was accomplished by the calculations of overall accuracy, producer's and user's accuracy through a standard method of Story and Congalton (1986). Moreover, the errors of omission percent (EO%), which was achieved based on the producer's accuracy percent PA% and the errors of commission percent (EC%), which was calculated based on the user's accuracy percent (UA%) were also conducted for accuracy assessment. For the research's Kappa Statistics or KHAT of overall Kappa accuracy assessment, the Kappa coefficient equation (K) is also conducted.

3.4.4 Forest Restoration Potential Suitable Area Classification

The suitability map for forest restoration potential area in terms of appropriate forest restoration plans for this study was revealed that four main steps; (1) selection of four main variables (slope in degree, distance to major road, distance to rural settlement, and elevation) whereas these 2 raster datasets variables of slope and elevation were projected from World Geodetic System (WGS) 1984 to Universal Transverse Mercator (UTM) 46 Zone and resampled from 30 m resolution to 10 m resolution, (2) assigning three reclassified credits of equal interval in accord with study area of NTNP watershed (highly suitable class, moderately suitable class, marginally suitable class), (3) combine with six land cover classes and four reclassified variables such as (i) slope in degree with 40% of weighted score, (ii) road distance with 30% of weighted score, (iii) settlement distance with 20% of weighted score, (iv) elevation with 10% of weighted score, and (4) generating of forest restoration potential area with three main suitable forest restoration plans such as (i) Natural

Regeneration (NR), (ii) Assisted Natural Regeneration (ANR) and (iii) Reforestation (RF). This research's overall suitability concept is mainly based on the (Kyaw, 2018), Kyaw et al. (2020), and Htoo et al. (2020). The equal interval method, which is the simplest method among land suitability studies, was conducted. The research's equal interval categorization is tended to represent the fair data distribution rates of present research's four main variables. Moreover, each category of four main variables was equally important.

The overall weighted decision matrix for each option was calculated based on categorized matrix in order to regenerate three main potential restoration area of each restoration plan through combine methodology in ArcGIS. Among the six main land use types, Bare Land with Fine-Grained Crystalline Rocks and Hard Schists, and Road are defined as constraint land use types because the area of Bare Land with Fine-Grained Crystalline Rocks and Hard Schists have the smallest probability of planting trees and road area cannot plant. Therefore, only four main land use types such as Dense Forest, Sparse Forest, Scrub Land, Bare Land with Low Grass were conducted for the combine stage with 4 main reclassified variables.

Out of the four parameters, the highest weightage was given to slope degree because slope ranges affect the tree planting of forest restoration whereas planting trees on 20°-35° slopes has good reinforcement effect while greater than 50° of slopes has less stability (Lan et al., 2020). Concerning to the equal interval of slope, the research' good slope range of planting trees was reasonably categorized. Regarding to the priorities of the accessibilities of road and settlement (second and third priority), the farthest proximity of road and settlement is more important than the elevation (fourth priority) to conduct the successful forest restoration. In addition, high elevation could be negligible because this study area is originally located in high altitude of mountain and/or hilly region. The challenge of accessibility of road should be done by the help of NTNP Office, regional Forest Department of Chin State, the local community and non-government organization.

4.Results

4.1 Estimation of Forest Resources Quantities

Although the preliminary MOER% of overall forest resources quantities estimation was prorated with 13.86%, the present MOER% results of present study failed to achieve this value due to the high CV% representing the heterogeneous forest type (ranging from 110% to 130%). However, the achieved results of SE% and MOER% of NTNP watershed are reliable because the acceptable MOER% can be assumed as 20% to 28% and the acceptable SE% can be also remarked as 12% to 16% (Myint et al.). The present results of SE% (ranging from 13% to 16%) and MOER% ranging from 26% to 31%) nearly similar to previous pilot study with 30 cluster plots at Siyin/Segyi Reserved Forest Pilot Study Area in Chin State (SE% ranging from 10% to 13% and MOER% ranging from 16% to 21%). Therefore, the SE% and MOER% of respective forest resources quantities can recognize as the reliable results. Concerning the total estimated forest resources values (tree density, basal area, AGB and AGC) of NTNP watershed per plot level and study area level, the detail values of forest resources quantity estimators and their usual statistics values of SE%, MOER%, and CV% are shown in Table 1.

Table 1. Total estimated forest resources quantities of NTNP Watershed per plot level and per study area

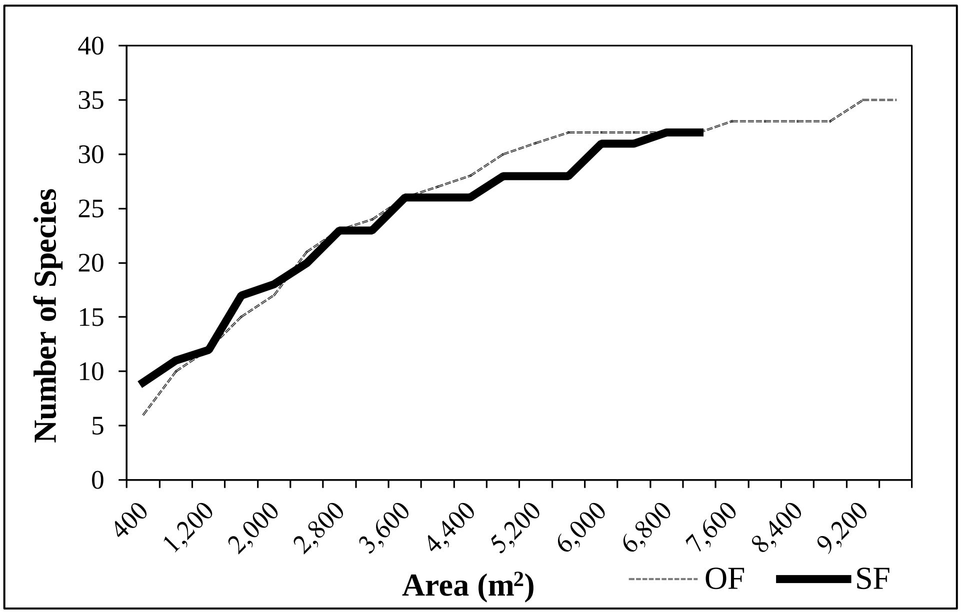
Forest Resources Parameters	Per Plot Level	Per Study Area Level	SE%	MOER%	CV%
Tree Density (n)	730.00	33,105,500.00	12.90	25.70	107.20
Basal Area (m^2)	55.63	2,524,305.56	14.60	29.02	121.80
AGB (tons)	615.64	27,919,274.00	15.60	31.20	130.80
AGC (tons)	289.35	13,122,022.50	15.60	31.20	130.80

4.2 Forest Tree Species Composition

4.2.1 Species Area Relationship

Regarding to the species area relationship of this study, the curve patterns of OF and SF in NTNP watershed were slightly similar (Figure 2). In accord with the species area curve comparison, 6 tree species of OF and 9 tree species of SF started to occupy at 400 m^2. The species curve of OF ended at 9,600 m^2 while that of SF ended at 7,200 m^2. From below Figure 2, the OF climbed gradually with over 30 tree species while SF went up slightly with fluctuations having under 30 tree species at 5600 m^2. After that, both of the forests were leveled off with the same number of 32 forest tree species at 7200 m^2. It can be concluded that the accessed per unit area of 0.72 ha for SF and 0.96 ha for OF represented the required minimum area. The minimum area acceptance of species area relationship assumed when the occurrence of new species remains below 10% with a 10% expansion in the sample area in accord with the highlights of (Cain, 1938) and Lamprecht (1989). Therefore, nearly 1 ha of each forest type of study area can be assumed as a representative area for species area relationship of both stands in this research.

Figure 2. Species area curve for SF and OF in NTNP Watershed



4.2.2 Tree species composition, richness and diversity

Among a total of 42 tree species (730 tree individuals, 24 families, 55.63 m^2) of the present study in NTNP watershed area, 35 tree species (394 tree individuals, 21 families, 36.47 m^2) were found at the OF and 32 species of (336 tree individuals, 20 families, 19.16 m^2) were found at the SF, respectively. Thus, species richness could be assumed as nearly similar for both stands of OF and SF.

In the present study, the overall dominant tree species including OF and SF found in the NTNP watershed area were *Lithocarpus xylocarpus*, *Neolitsea zeylanica*, *Schima wallichii*, and *Myrsine sacanden*, while species *Cephalotaxus mannii*, *Docynia indica*, *Mahonia nepalensis*, *Schima khasiana*, *Ficus semicordata*, *Lingustrum sp.*, and *Machilus robusta* were rarely found. In the OF, the dominant tree species were *Lithocarpus xylocarpus*, *Neolitsea zeylanica*, and *Osmanthus fragrans* and the rare species were *Docynia indica*, *Eriobotrya glabrescens*, *Mahonia nepalensis*, and *Schima khasiana*, respectively. The dominant tree species of SF were *Lithocarpus* xylocarpus, *Schima wallichii*, *Myrsine sacanden*, *Macropanax dispermus*, and *Neolitsea zeylanica*, while the SF's rare species were *Cephalotaxus* mannii, *Cinnamomum sp.*, *Elaeocarpus braceanus*, *Eriobotrya glabrescens*, *Ficus* semicordata, *Machilus robusta*, and *Osmanthus fragrans*.

The most nine important IVI and FVI of the OF and SF of NTNP watershed area (all stems with a DBH ≥ 5cm) are illustrated in Table 2 and 3. Regarding to the FVI level, the dominant families of OF were Fagaceae, Lauraceae, Primulaceae, and Oleaceae, while the dominant families of SF were Fagaceae, Theaceae, Lauraceae, and Primulaceae, respectively.

Table 2. The most nine important IVI of the OF and SF of NTNP watershed area (all stems with a DBH ≥ 5cm

Forest Type	Rank	Species Name	Absolute			IVI (%)
			Abundance (stems ha-^{1})	Dominance (m^2 ha^{-1})	Frequency (%)	
OF	1	*Lithocarpus xylocarpus*	91	17.83	13.64	85.62
	2	*Neolitsea zeylanica*	45	2.52	12.12	30.44
	3	*Quercus semecarpifolia*	14	3.72	6.06	19.80
	4	*Osmanthus fragrans*	24	1.61	5.30	15.81
	5	*Machilus dumicola*	17	2.02	5.30	15.16
	6	*Schima wallichii*	17	1.37	4.55	12.62
	7	*Machilus thunbergii*	10	1.59	4.55	11.45
	8	*Myrsine sacanden*	18	0.19	3.79	8.89
	9	*Prunus cerasoides*	13	0.78	3.03	8.47
	10	Others (26)	145	4.84	41.67	91.74
		Total (35)	394	36.47	100	300
SF	1	*Lithocarpus xylocarpus*	79	7.52	13.86	76.64
	2	*Schima wallichii*	37	2.16	11.88	34.18
	3	*Myrsine sacanden*	33	1.10	4.95	20.49
	4	*Alnus nepalensis*	19	1.52	4.95	18.56

5	*Neolitsea zeylanica*	21	0.78	7.92	18.27
6	*Engelhardia spicata*	17	0.86	7.92	17.45
7	*Macropanax dispermus*	22	0.59	6.93	16.55
8	*Schefflera hypoleucoides*	8	0.80	4.95	11.50
9	*Quercus semecarpifolia*	3	0.95	1.98	7.81
10	Others (23)	97	2.88	34.65	78.55
	Total (32)	336	19.16	100	300

Table 3 The most nine important FVI of the OF and SF of NTNP watershed area (all stems with a DBH ≥ 5cm

Forest Type	Rank	Family Name	Absolute			FVI (%)
			Abundance (stems ha^{-1})	Dominance ($m^2 ha^{-1}$)	Frequency (%)	
OF	1	Fagaceae	105	21.55	18.75	104.48
	2	Lauraceae	82	6.8	19.64	59.10
	3	Primulaceae	43	0.88	8.93	22.24
	4	Oleaceae	26	1.65	7.14	18.27
	5	Theaceae	18	1.4	6.25	14.65
	6	Rosaceae	15	0.81	5.36	11.37
	7	Symplocaceae	19	0.7	4.46	11.21
	8	Araliaceae	9	0.52	7.14	10.87
	9	Ericaceae	23	0.5	3.57	10.78
	10	Others (11)	54	1.67	18.75	37.03
		Total (20)	394	36.47	100	300
SF	1	Fagaceae	82	8.47	14.89	83.50
	2	Theaceae	37	2.16	12.77	35.07
	3	Lauraceae	37	1.31	13.83	31.68
	4	Primulaceae	46	1.41	8.51	29.54
	5	Araliaceae	30	1.39	10.64	26.81
	6	Betulaceae	19	1.52	5.32	18.93
	7	Juglandaceae	17	0.86	8.51	18.04
	8	Staphyleaceae	9	0.49	2.13	7.38
	9	Rosaceae	7	0.11	4.26	6.91
	10	Others (12)	52	1.44	19.15	42.15
		Total (21)	336	19.16	100	300

In this study, the species diversity indices of OF and SF were 2.96 and 2.83 (H´), 0.9064 and 0.9151 (1-D´) as well as 0.8176 and 0.8317 (J´). The results of the coefficient of floristic similarity indices according to K_s and K_d were 71.64 % and 93.64%, respectively based on the 24 common species. In this research, tree species of both stands were almost equally abundant as their J´ percentages were nearly close to 1 (Myat, 2016; Zin, 2017). The tree species richness, diversity indices, coefficient of similarity and their statistical T-test results per plot level of NTNP watershed is shown in Table 4. Regarding to their statistical differences of the values of species richness and diversity indices for plot individual level were tested by two tailed T-test of Two Independent Samples Unequal Variance at 95% CI. According to their statistical results of this research, the species richness and species diversity indices of two investigated stands did not have the significant differences with larger than 0.05 p value. The detailed results are shown in Table 4.

Table 4. Tree species richness, diversity indices, coefficient of similarity and their statistical test results per plot level of NTNP Watershed

Forest Type		Species Richness (n)	Diversity Indices			Coefficient of Similarity	
			1-D´	H´	J´	K_s	K_d
OF		35.00	0.9151	2.9570	0.8317	71.64%	93.64%
SF		32.00	0.9065	2.8338	0.8177		
T Test	T Value	2.0262	2.0211	2.0281	2.0227	-	-
	P Value	0.8828	0.8404	0.9126	0.3050		

4.3 Stand Structure

4.3.1 Forest Stand Structure Indicators

The three types; (1) stand diameter ($\bar{d}$), (2) stand height ($\bar{h}$), and (3) stand basal area of forest stand structure indicators including their SD of two forest types are given in Table 5. The stand diameters of OF than those of SF showed that the OF had larger diameter trees compared to SF because of the higher SD of OF' stand diameter. Concerning the stand basal area of two investigated stands, the stand basal area of OF was significantly larger than SF' basal area, although these two stands had nearly SD values. These stand basal area of two stands' results also highlighted that the presence of numerous larger diameter trees in the OF while most of the trees in SF with middle and small diameter trees. It can be clearly seen that human disturbances effect on the lower elevation in accord with the smaller DBH and basal area of current forest situation at SF sites. Therefore, the restoration silviculture based on applied forest ecology in terms of forest regeneration and carbon enhancement procedures at those sites of SF are importantly needed. For stand height comparison, the stand height of SF is larger than OF' stand height because some OF's trees' height at the upper region of mountain are not too high at this study area.

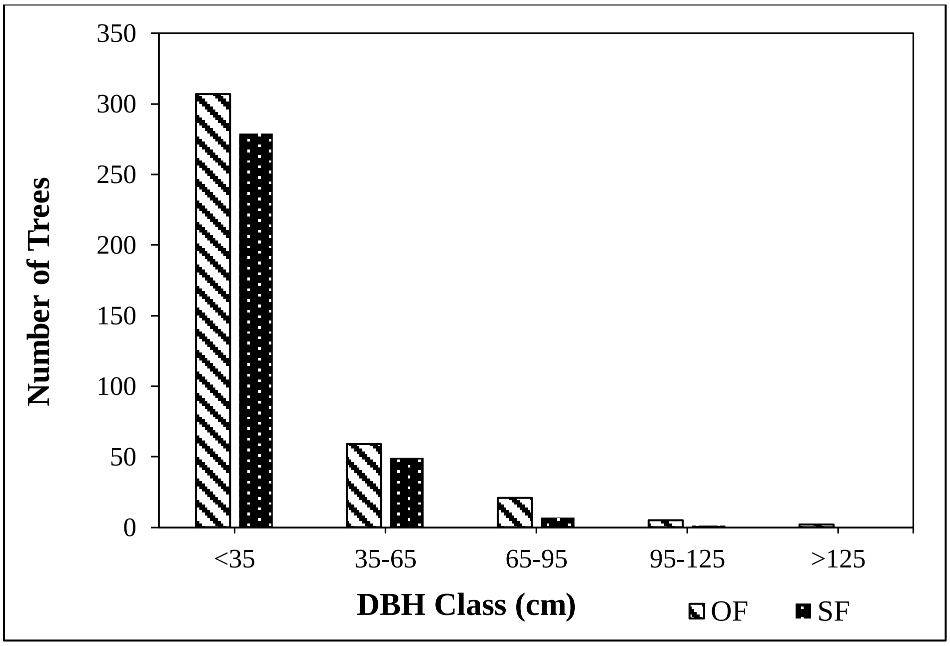
Table 5 Mean diameters of OF and SF of NTNP Watershed

Forest Type	Stand Diameter $\bar{d}$ (cm) ± SD	Stand Height $\bar{h}$ (m) ± SD	Stand Basal Area G (m^2) ± SD
OF	25.18 ± 23.38	10.16 ± 4.96	36.47 ± 0.2
SF	21.40 ± 16.40	10.95 ± 3.92	19.16 ± 0.1

4.3.1.1 Size Class Distribution

The tree density with <35 cm DBH of two investigated stands had highest tree densities of in accord with their respective 307 OF's tree individuals and 297 SF's tree individuals. The second highest tree densities at 35-65 cm of DBH class boundary was also nearly similar in both of these investigated stands. But the SF was significantly low for the last three of highest DBH size class boundaries especially at the size of >65 cm to <155 cm. A higher number of stems (21 stems) were counted in the OF as opposed to the SF (8 stems) at 65 cm to 95 cm, whereas the DBH distribution of SF was nearly a third of the stems of the OF. For another largest DBH classes such as 95 -125 cm and 125-155 cm, the SF had not occupied with higher DBH distribution due to the disturbance of shifting cultivation. The tree density comparison of diameter distributions of all stems with a DBH ≥5 cm of two forest types in NTNP watershed is shown in Figure 3.

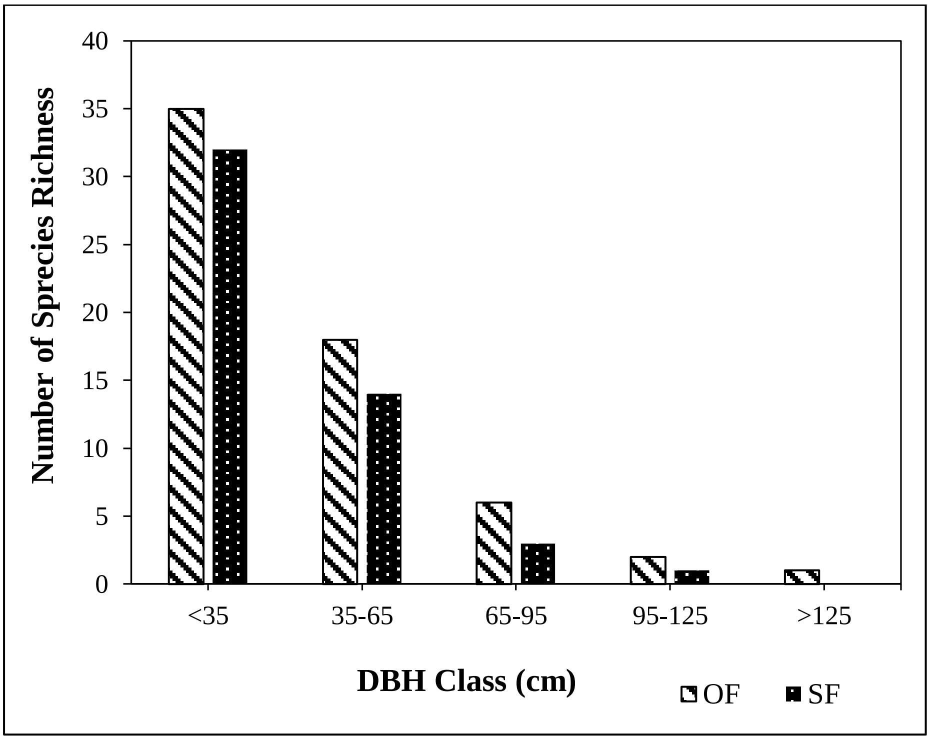
Figure 3 .Tree density comparison of diameter distributions of all stems with DBH ≥5 cm of two forest types in NTNP Watershed



In the smallest diameter class (≤35 cm DBH) of OF, all of the 100% of the 35 species richness found in all sample plots was present. Likewise, all of the 100% of 32 species of the SF had occupied at diameter size class of ≤35 cm DBH. For the DBH size class of 35 and 65 cm, 51.43% of species richness of OF and 43.75% of SF were occupied. For the record of the largest diameter class (≥65 cm to >125 cm DBH) of both investigated forests, a few species were occupied with small proportion.

Regarding to the dominant species richness, *Lithocarpus xylocarpus* had occupied all the coverage of size classes in both of low stands. *Neolitsea zeylanica*, *Osmanthus fragrans*, *Myrsine sacanden*, *Myrsine semiserrata*, *Schima wallichii*, *Rhododendron arboretum*, *Symplocos ramosissima*, and *Machilus dumicola* were the second most abundant species for OF. *Myrsine sacanden*, *Schima wallichii*, *Macropanax dispermus*, *Neolitsea zeylanica*, *Alnus nepalensis*, and *Engelhardia spicata* were the second most abundant species for SF. The species richness comparison of diameter distributions of all stems with DBH ≥5 cm of two forest types in NTNP watershed is shown in Figure 4.

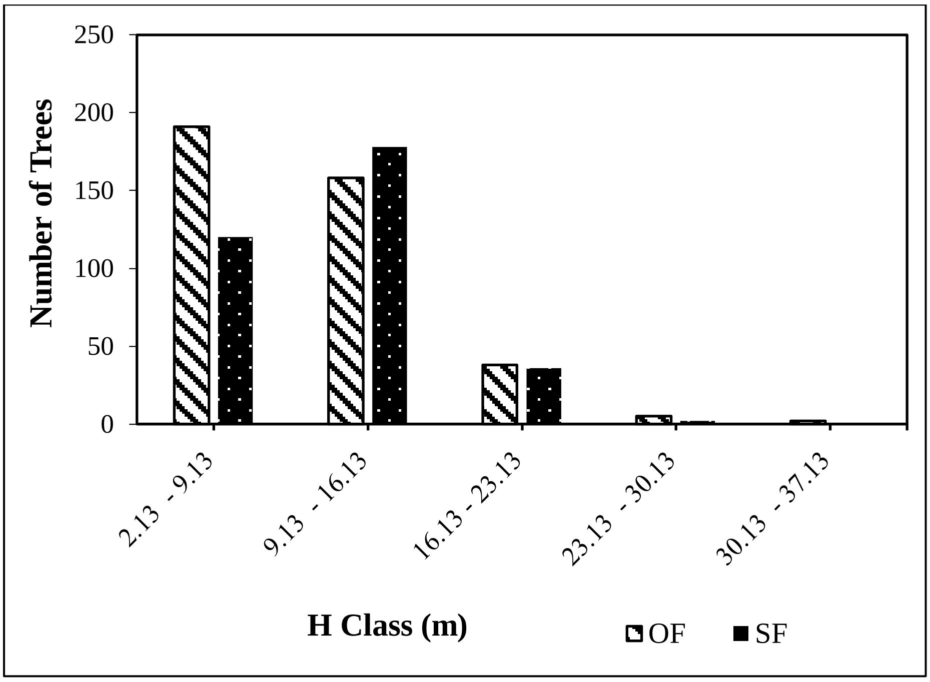
Figure 4. Species richness comparison of diameter distributions of all stems with DBH ≥5 cm of two forest types in NTNP Watershed



4.3.1.1 Height Class Distribution

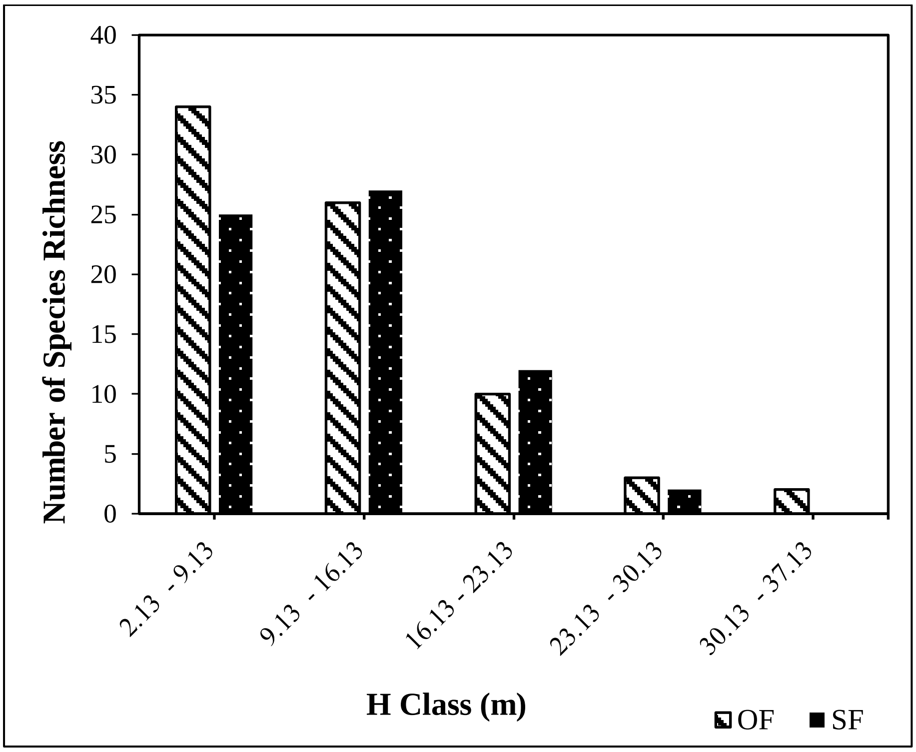
Regarding to the vertical structures of OF and SF, the height class distribution for tree density comparison also experienced with the dominance of small height trees in both forests under five main categorized height distribution classes. The small tree's contribution is more than 95% for the total tree density of two investigated forests at group (1) and (2) while the highest height class trees group (4) and (5) contributed less than near 2% of the total density of forest. The medium height class trees group (3) was composed only with more than 3% of total tree density. From the tree density based on height classes of this research, OF is mainly dominated by with balanced uneven aged stands including largest, medium and most of small height trees while SF is mainly composted with nearly uneven aged stands including most of medium and small height trees and few or less of large height trees. The OF's highest height class (>30 m tree height) was composed of only 2 tree individuals of the tree, while SF's one was not found >30 m tree height. The tree density comparison of height distributions of all stems with all stems with H ≥1.3 m of two forest types in NTNP watershed is shown in Figure 5.

Figure 5 .Tree density comparison of height distributions of all stems with H ≥1.3 m of two forest types in NTNP Watershed



In the smallest height class with the class boundary of 2.13 m -9.13 m, 97% with 32 species richness were found at OF sites while SF had only 78% with 25 species richness. For the second smallest height class (9.13 m -16.13 m), nearly three fourth of species richness were found at both stands (40.1% of OF and 52.97% of SF). For the third smallest height class boundary of 16.13 m -23.13 m, nearly three fourth of species richness were found in both forest types. For the second largest height class boundary of 23.13 m -30.13 m, near one third of OF's species richness and near one fourth of SF's species richness had occupied. For the largest height class boundary of 30.13 m -37.13 m, nearly one tenth of species richness were found at OF with 3 individuals or 8.57% of total species richness and 2 individuals or SF with 5.7% of total species richness. The largest height boundary class of 30.13 m -37.13 m, which is the only small proportion of 6% of total species richness, was found at OF sites. The species richness comparison of diameter distributions of all stems with H ≥1.3 m of two forest types in NTNP watershed is shown in Figure 6.

Figure 6 Tree density comparison of height distributions of all stems with H ≥1.3 m of two forest types in NTNP Watershed



4.3.2 Forest Resource Quantities Comparison of OF and SF

In this research, the two investigated stands' overall total values of forest stand structure parameters were 55.63 m^2 of total basal area (36.47 m^2 of OF and 19.16 m^2 of SF), 28.45 tons of mean AGB (17.27 tons of OF and 11.18 tons of SF), 13.37 tons of mean AGC (8.12 tons of OF and 5.25 tons of SF), 615.64 tons of total AGB (414.41 tons of OF and 201.23 tons of SF), 289.35 tons of total AGC (194.77 tons of OF and 94.58 tons of SF), 17,111.70 cm of total DBH (9,920.23 cm of OF and 7,191.47 cm of SF), 7,681.10 m of H (4,003.35 m of OF and 3,677.74 m of SF), and 730 stems of tree stems (394 stems of OF and 336 stems of SF), respectively. The OF's present total basal area is smaller than 0.7039 times than 51.81 m^2 of past total basal area (Myat, 2016) while SF's present total basal area is smaller than 0.9141 times of 20.96 m^2 of previous total basal area. These results showed that the present total basal areas of both stands were similar to total basal area of past research. The present OF's AGB amount is greater than other research with the AGB values reported by Yirdaw et al., 2019 at Napo (lower mixed deciduous forest) and Dong Na Tard (upper mixed deciduous forest and an upper dry evergreen forest) sites of the Vientiane prefecture and Savannakeht province of Laos. However, the SF's AGB data of this study is significantly greater than these both sites of SFs' AGB values.

The comparative forest stand structure of OF and SF can help the effective restoration silviculture of this research by transforming the structure and dynamics of degraded forest to nearly original forest. For comparable references for ABG in SF of present study and the other Laos' AGB study, the present OF's AGB result represents 1.42 times of the Napo's OF and 1.70 times of Dong Na Tard's OF while the SF's AGB result of this study is equal to the 19.44 times of the Napo's SF and 3.78 times of Dong Na Tard's SF, respectively. This comparison AGB results indicate that the remnant SF of NTNP watershed has many opportunities to do forest restoration potential. The total values of forest stand structure parameters per plot level and per stem level of NTNP watershed were tested by two tailed T test of Two Independent Samples Equal Variance at 95% CI. According to their statistical results per plot and per stem, all results of forest stand structure parameters per stem level of study area had apparent significant differences with lower than 0.05 p value while per plot level' results had no differences. The comparison of forest resource quantities and their statistical results per plot level and stem level of OF and SF in NTNP watershed are presented in Table 6.

Table 6. Comparison of forest resource quantities and their statistical results per plot level and stem level of OF and SF in NTNP Watershed

Forest Resource Parameters	OF		SF		The Two Independent Samples Unequal Variance T Test			
	Mean ± SD		Mean ± SD		Per Plot Level		Per Stem Level	
	Per Plot Level	Per Stem Level	Per Plot Level	Per Stem Level	T Value	P Value	T Value	P Value
Tree density (stems)	16.42 ± 9.41	-	18.67 ± 9.96	-	2.0281	0.4631	-	-
DBH (cm)	-	25.18 ± 23.38	-	21.4 ± 16.4	2.0227	0.1042	1.9639	0.0021
Basal Area (m^2)	1.52 ± 1.07	0.09 ± 0.2	1.06 ± 0.71	0.06 ± 0.1	2.0244	0.0782	1.9642	0.0051
AGB (tons)	17.27 ± 13.54	1.05 ± 2.89	11.18 ± 8.13	0.6 ± 1.26	2.0244	0.0782	1.9642	0.0051
AGC (tons)	8.12 ± 6.37	0.49 ± 1.36	5.25 ± 3.82	0.28 ± 0.59	0.2062	0.4189	1.9633	0.0109

4.3.3 Natural Regeneration

The total 77 sapling individuals (54 OF’s saplings and 23 SF’s saplings) were counted for the total area was 1,725 m^2 or 0.1725 ha (69 × 0.025 m^2). For seedling status, the only 12 seedlings were collected for the total coverage of 69 m^2 or 0.0069 ha (69 × 0.0001m^2). Regarding to the specific counting of seedlings, OF were 10 total seedlings and SF were 2 seedlings respectively. The sapling and seedling statuses of OF and SF in the NTNP watershed are illustrated in Table 7 and 8.

Table 7 Sapling status of OF and SF in the NTNP Watershed

Forest Type	Species Name	Family Name	Species Richness
OF	*Myrsine semiserrata*	Primulaceae	15
	Lithocarpus xylocarpus	Fagaceae	9
	Symplocos ramosissima	Symplocaceae	8
	Myrsine sacanden	Primulaceae	4
	Beilschmiedia globularia	Lauraceae	3
	Neolitsea zeylanica	Lauraceae	3
	Elaeocarpus braceanus	Elaeocarpaceae	2
	Eriobotrya glabrescens	Rosaceae	2
	Euonymus tingens	Celastraceae	1
	Macropanax dispermus	Araliaceae	1
	Myrsine sp.	Primulaceae	1
	Osmanthus fragrans	Oleaceae	1
	Prunus cerasoides	Rosaceae	1
	Rhododendron arboreum	Ericaceae	1
	Schima wallichii	Theaceae	1
	Total		54
Forest Type	Species Name	Family Name	Species Richness
SF	*Viburnum cylindricum*	Adoxaceae	1
	Lithocarpus xylocarpus	Fagaceae	6
	Celastrus paniculatus	Celastraceae	4
	Viburnum cylindricum	Adoxaceae	3
	Myrsine sacanden	Primulaceae	2
	Turpinia nepalensis	Staphyleaceae	2
	Macropanax dispermus	Araliaceae	1
	Neolitsea zeylanica	Lauraceae	1
	Prunus cerasoides	Rosaceae	1
	Sarcococca wallichii	Buxaceae	1
	Schima wallichii	Theaceae	1
	Symplocos ramosissima	Symplocaceae	1
	Total		23

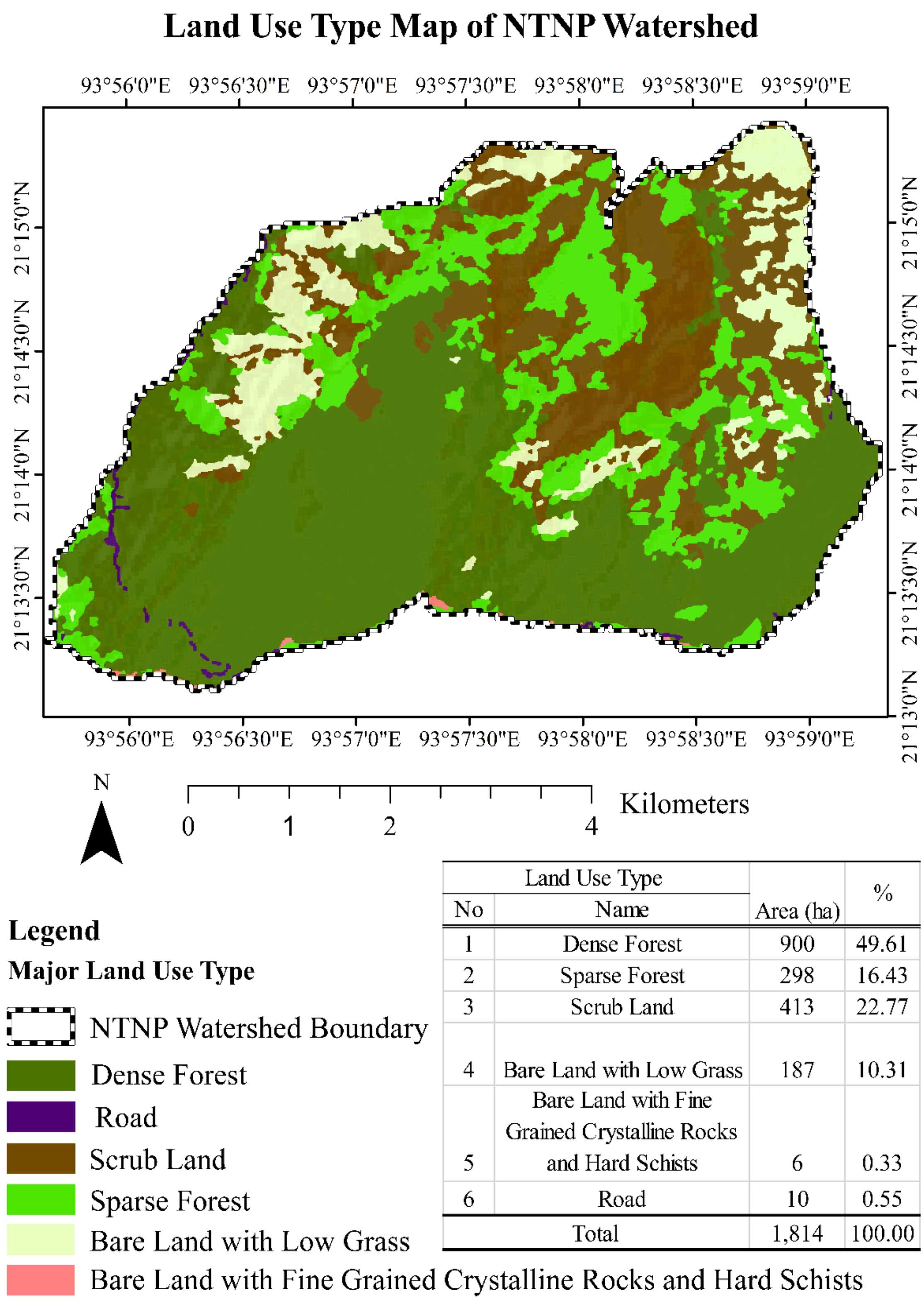
Table 8. Seedling status of OF and SF in the NTNP Watershed

Seedling				
No	Species Name	Family Name	OF	SF
1	*Lithocarpus xylocarpus*	Fagaceae	6	2
2	*Macropanax dispermus*	Araliaceae	4	0
	Total (12)		10	2

4.4 Land Use Land Cover Classification

Concerning to the LULC of study area, the total 1,814 ha of NTNP watershed is mainly constituted with six major land use types; (1) Dense Forest, (2) Sparse Forest, (3) Scrub Land, (4) Bare Land with Low Grass, (5) Bare Land with Fine-Grained Crystalline Rocks and Hard Schists, and (6) Road (Figure 7). The overall error matrix accuracy % is 89% while the overall Kappa cccuracy % is 86% (Table 9). For NTNP watershed, this updated land cover map can not only assist the forest restoration potential area suitability through the current forest status but also estimated areas of six main land uses. Consequently, the future forest carbon and/ or forest cover enhancement can proceed in accord with the estimated the current forest area extent in 2020 of this research.

Figure 7 Six major land use types of NTNP Watershed



Land Use Type		Area (ha)	%
No	Name		
1	Dense Forest	900	49.61
2	Sparse Forest	298	16.43
3	Scrub Land	413	22.77
4	Bare Land with Low Grass	187	10.31
5	Bare Land with Fine Grained Crystalline Rocks and Hard Schists	6	0.33
6	Road	10	0.55
	Total	1,814	100.00

Table 9 Overall error matrix accuracy % and overall Kappa accuracy %

LULC's Accuracy Assessment at NTNP Watershed									
Land Use Type No		**Reference Data**							Row Total
		1	2	3	4	5	6	7	
Classified Map Data	1	64	6						70
	2	1	61	8					70
	3		11	59					70
	4	1		2	32				35
	5		3			32			35
	6	1				1	33		35
	7							3	3
Column Total		67	81	69	32	33	33	3	318
PA%		96%	75%	86%	100%	94%	100%	100%	
EO%		4%	25%	14%	0%	6%	0%	0%	
UA%		91%	86%	84%	91%	91%	94%	100%	
EC%		9%	14%	16%	9%	9%	6%	0%	
Overall Error Matrix Accuracy%									89%
Overall Kappa Accuracy%									86%

4.5 Forest Restoration Potential Suitable Area Classification

In accord with the forest restoration potential suitability selection of NTNP watershed, three major restorability plans; (1) NR at Dense Forest, (2) ANR at Sparse Forest and (3) RF at Scrub Land and Bare Land with Low Grass were successfully accomplished. The constraint areas for forest restoration potential are Bare Land with Fine-Grained Crystalline Rocks and Hard Schists and Road. Regarding to the results of forest restoration potential suitability area, the overall restorability potential forest restoration area and three types of potential forest restoration suitability maps are illustrated in Figure 8, 9, 10 and 11 respectively.

The classification of restorability based on three main forest restoration plans (Table 10) and suitability classes of the study area in ha (Table 11) were performed for fulfillment of forest restoration potential assessment from this research.

Table 10. Classification of restorability based on three main forest restoration plans

No	Forest Restoration Potential Plan	Land Use Type		Restorability	Area (ha)	%
		No	Area (ha)			
1	NR	1	900	Passive Restoration	1198	65.96
2	ANR	2	298			
3	RF	3	413	Passive Restoration and/or Active Restoration	600	33.10
		4	187			
4	No Restoration Suitability	5	6	Constraint	16	0.94
		6	10			
	Total		1,814		1,814	100

Table 11 Suitability classes of the NTNP Watershed

Forest Restoration Potential Purpose	Area (ha)			
	Highly Suitable	Moderately Suitable	Marginally Suitable	Total
ANR	34	253	9	296
NR	106	764	29	899
RF	89	486	26	601
Constraints	18			18
Overall Total				1,814

Figure 8 Layout of forest restoration potential's suitable area of NTNP Watershed

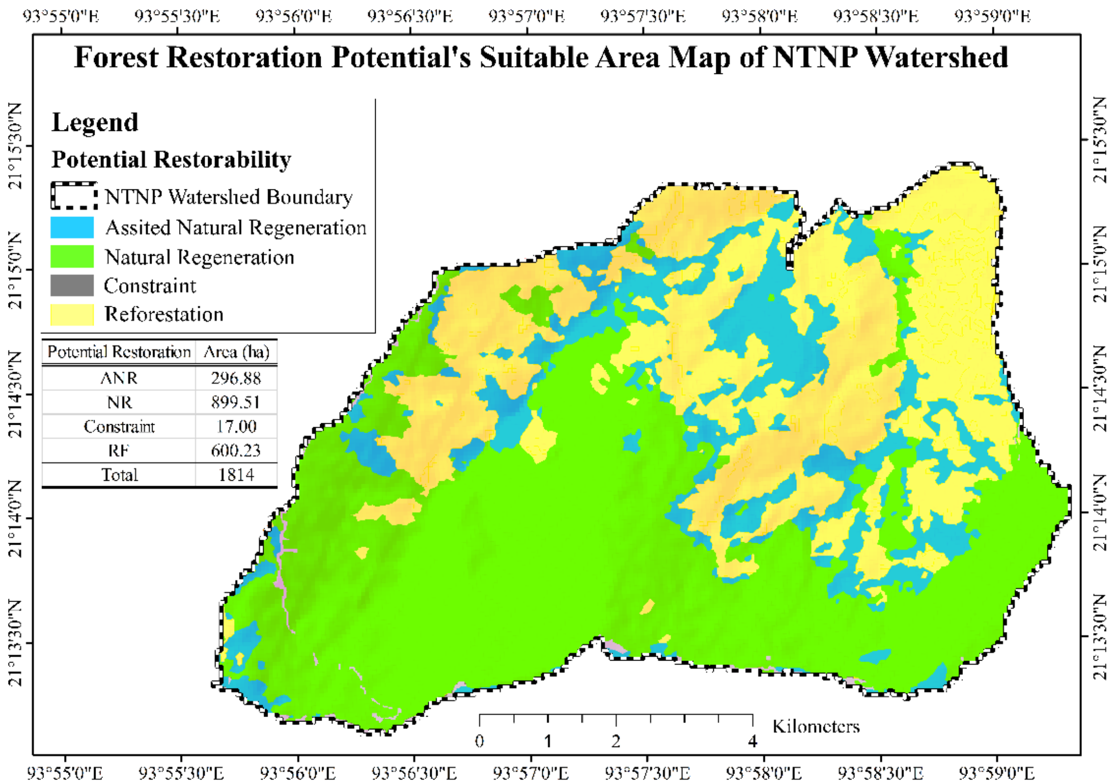


Figure 9. Layout of Potential NR's Suitable Area of NTNP Watershed

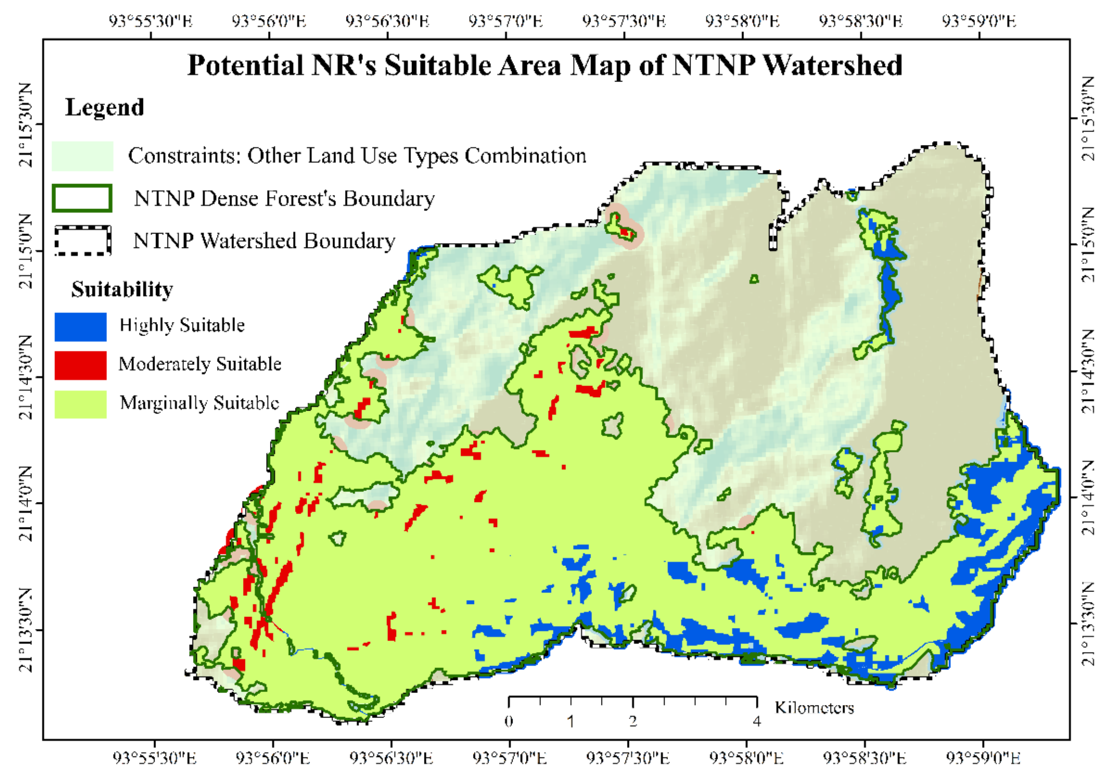


Figure 10 .Layout of Potential ANR's Suitable Area of NTNP Watershed

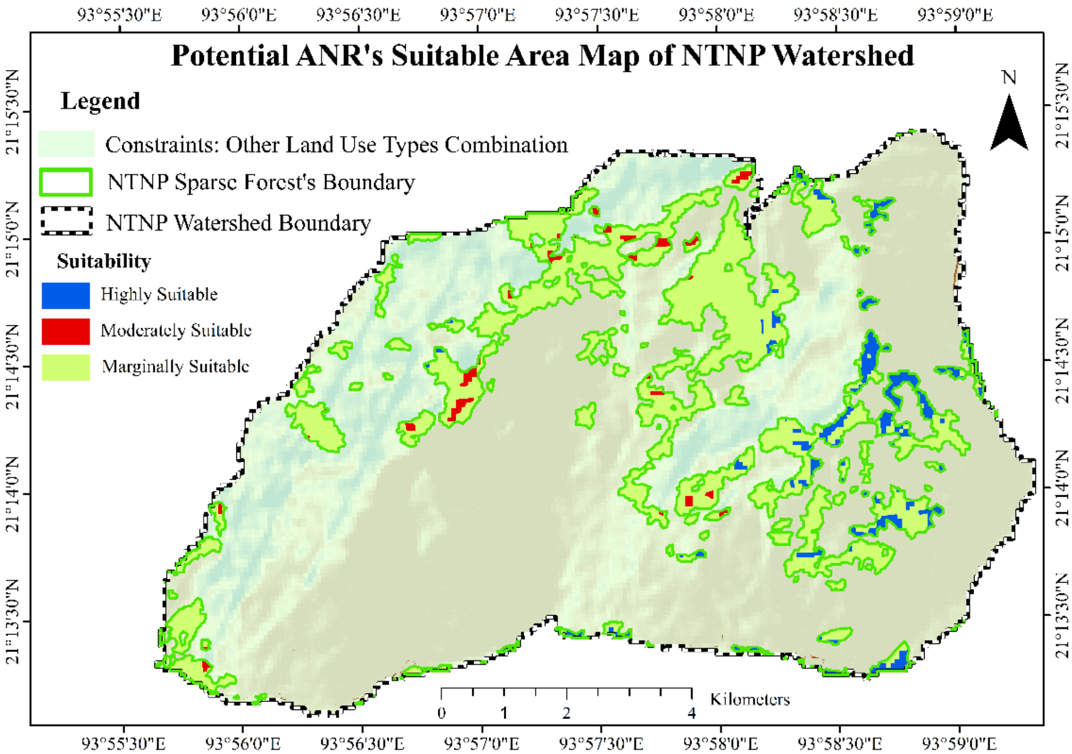
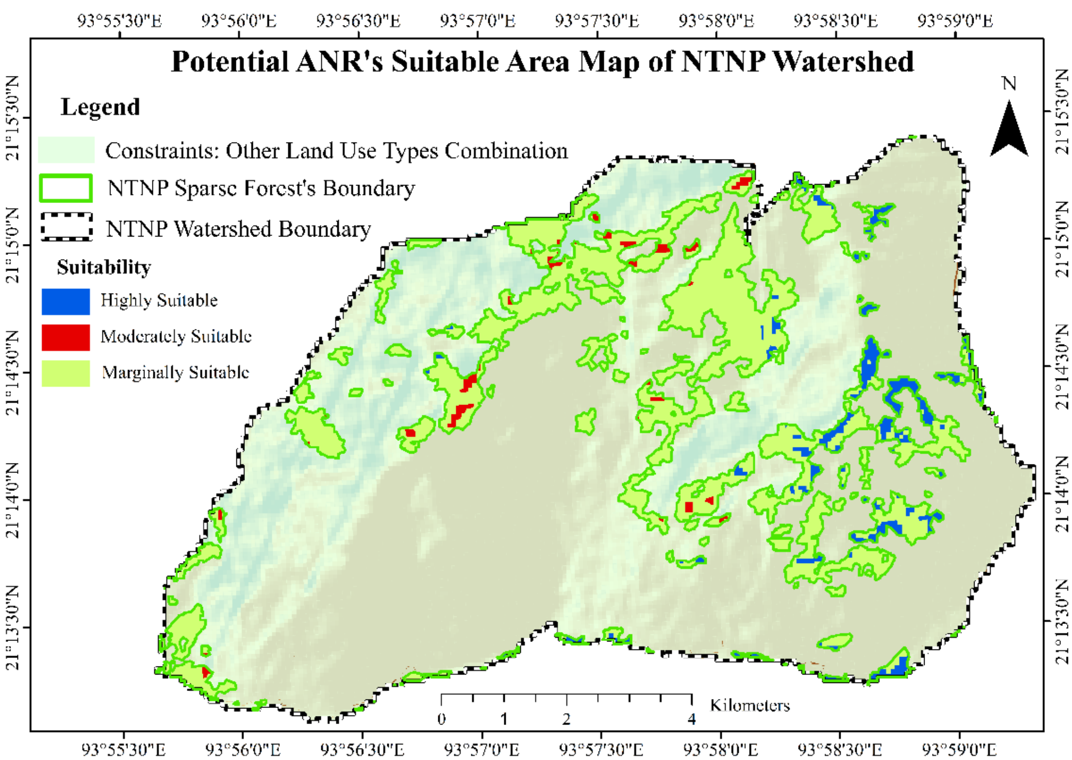


Figure 11 Layout of Potential RF's Suitable Area of NTNP Watershed



5. Discussion

Concerning the estimation of forest resources quantities, we concluded the achievement of the future desired 10% MOER% proration of similar land use patterns of study area requires at least 650 sample plots based on the highest result (130 CV%) of study area. For achieving 15% MOER% proration of similar land use types, at least 300 plots would be sampled. Based on this research' results also revealed that the systematic sampling of fixed area plots should nearly cover the overall target area of further forest inventories in order to give the more accurate and reasonable proration although the inaccessible plots can be negligible from a statistical view point. In addition, the accurate information with accessible plots is better than the inaccurate information or false information with all targeted plots. In this study, we analyzed that the systematic sampling design was hard for trees and other forest resources data collection in mountainous region of Chin state because of the abundance of cliff and steep slopes. The simple random sampling with independent distance should apply in these hill forests in order to get the easier forest inventory collection. Moreover, we analyzed the adequate required sample numbers and safeguard sampling design with representative sample size for target population played major important role for achievement of the most reliable results of MOER% and SE%. We also found that the selection of reasonable sampling design, cost, workforce and adequate local information for overall situations (slope, elevation, accessibility) of targeted area was the principal consideration before the forest inventory. From this research, these present estimated results of forest resources quantities (total tree density, DBH, basal area, AGB, and AGC) could beneficially apply the evidence for current forest situation as the baseline data for further researches, forest cover improvement, and forest carbon enhancement.

Regarding to the forest tree species composition, the variation of species composition between the two forest types were directly proportion with the variation in biogeography, habitat, and disturbance levels (Whitmore, 1984). Therefore, these all of accessed tree species of current forest situation results show differences in the ranking of the most important species between the two different forest types in the NTNP watershed obviously due to varying elevation and disturbance. The surveyed tree species results of the present study should principally apply for forest restoration based on applied forest ecology in terms of forest planting researches and Framework Species Method with native pioneer tree species as these species can perform well adaptation to local conditions of effective ecological restoration (Lu et al., 2017).

The common 23 species were *Alnus nepalensis*, *Beilschmiedia globularia*, *Cinnamomum sp.*, *Elaeocarpus braceanus*, *Engelhardia spicata*, *Eriobotrya glabrescens*, *Eurya sp.*, *Lithocarpus xylocarpus*, *Machilus dumicola*, *Macropanax dispermus*, *Myrsine sacanden*, *Myrsine semiserrata*, *Myrsine sp.*, *Neolitsea zeylanica*, *Osmanthus fragrans*, *Prunus cerasoides*, *Quercus semecarpifolia*, *Rhododendron arboreum*, *Schefflera hypoleucoides*, *Schefflera hypoleucoides*, *Schima wallichii*, *Symplocos ramosissima*, *Turpinia nepalensis, and Viburnum cylindricum*. These 23 common species among two investigated stands represented that nearly 66% of OF species richness similarity and nearly 72% of SF species richness similarity.

In this study, the pioneer native trees species of present study at NTNP watershed were *Alnus nepalensis, Quercus semecarpifolia, Lithocarpus xylocarpu, Rhododendron arboreum, Schima wallichii, Eurya sp., Symplocos racemosa and Symplocos ramosissima* (Ohsawa, Shakya, & Numata, 1986). Amongst these pioneer native tree species, *Alnus nepalensis* (early-successional forest status) and *Schima wallichii* (mid-successional forest status) were wind dispersed (Lu et al., 2017; Lu et al., 2016). According to the ranking of species performance standards based on the rates of seed germination, seedling survival and growth by Lu et al. (2017), the good species rating of NTNP watershed was *Alnus nepalensis* and marginal species ratings were *Schima wallichii* and *Myrsine semiserrata*, respectively. In summary, these 8 pioneer native tree species and highest IVI native species should apply the further restoration potential researches based on applied forest ecology.

The 15 common families for both of the investigated stands are Adoxaceae, Araliaceae, Betulaceae, Elaeocarpaceae, Ericaceae, Fagaceae, Juglandaceae, Lauraceae, Oleaceae, Pentaphylacaceae, Primulaceae, Rosaceae, Staphyleaceae, Symplocaceae, and Theaceae. The 3 different families for OF were Berberidaceae, Cornaceae and Sapindaceae and 4 different families for SF were Buxaceae, Euphorbiaceae, Moraceae and Taxaceae respectively. Therefore, these 15 common species among two investigated stands represented that nearly 75% of OF family richness similarity and nearly 71% of SF family richness similarity.

It can be seen that the family compositions of this research were not very different in family level from those of tropical moist evergreen forests in Thailand, Vietnam, and China. For example, the tropical moist evergreen forest in Kon Ha Nung in the Central Highlands of Vietnam was dominated by Magnoliaceae, Fagaceae, Myrtaceae, Euphorbiaceae, and Lauraceae (Van Cam, 2015) whereas Annonaceae, Euphorbiaceae, Lauraceae, Sapindaceae, and Ebenaceae were dominant in the Dry Evergreen Forest of Huai Kha Khaeng Wildlife Sanctuary in Western Thailand (Bunyavejchewin, 2001). Another example of similar dominant families for rainforests, Lauraceae and Sapindaceae were constituted in Xishuangbanna, Southwest China (Lü, Yin, & Tang, 2010) whereas the Upper Montane Forests at the summit of Mount Doi Inthanon, Thailand were dominated by Fagaceae, Lauraceae, Theaceae, and Myrtaceae (Khamyong, Lykke, Seramethakun, & Barfod, 2003).

Concerning the stand basal area of two investigated stands, the stand basal area of OF was significantly larger than SF' basal area, although these two stands had nearly SD values. These stand basal area of two stands' results also highlighted that the presence of numerous larger diameter trees in the OF while most of the trees in SF with middle and small diameter trees. It can be clearly seen that human disturbances effect on the lower elevation in accord with the smaller DBH and basal area of current forest situation at SF sites. Therefore, the restoration silviculture based on applied forest ecology in terms of forest regeneration and carbon enhancement procedures at those sites of SF are importantly needed. For stand height comparison, the stand height of SF is larger than OF' stand height because some OF's trees' height at the upper region of mountain are not too high at this study area.

Both of the two forest types of diameter distribution based on forest stand structure results are indicated a stable species with reverse J-shaped distributions. Although the investigated forests appeared to be in good condition, SF did not have the higher DBH distribution especially at the range of DBH greater that at 115 cm. The lack of larger stem sizes in the SF can be assumed that impacts of burning and clear cutting of shifting cultivation in the NTNP watershed area. According to the expression of a distinct feature of the OF and SF by Richards, Frankham, and Walsh (1996), occupied tree densities of OF had larger stems than those of the SF, despite similar site conditions. This information was relatively true for this study of OF and SF as the abundance of large stems is only found in the OF of NTNP watershed area. For largest diameter class groups of ≥ 65 cm to >125 cm DBH) of both investigated forests, small proportion of few species are found only in OF. Therefore, SF should be preserved from any disturbance in order to perform the transformation of OF.

The comparative forest stand structure of OF and SF can help the effective restoration silviculture of this research by transforming the structure and dynamics of degraded forest to nearly original forest. For comparable references for ABG in SF of present study and the other Laos' AGB study, the present OF's AGB result represents 1.42 times of the Napo's OF and 1.70 times of Dong Na Tard's OF while the SF's AGB result of this study is equal to the 19.44 times of the Napo's SF and 3.78 times of Dong Na Tard's SF, respectively. This comparison AGB results indicate that the remnant SF of NTNP watershed has many opportunities to do forest restoration potential. The total values of forest stand structure parameters per plot level and per stem level of NTNP watershed were tested by two tailed T test of Two Independent Samples Equal Variance at 95% CI. According to their statistical results per plot and per stem, all results of forest stand structure parameters per stem level of study area had apparent significant differences with lower than 0.05 p value while per plot level' results had no differences.

In accord with the silviculture theory of forest stand structure, the OF has few seedlings and saplings is the main reason of study area natural regeneration status (Oliver & Larson, 1996). Moreover, the study area of OF structure has many plots with the old-growth stages of forest stand development, some plots with understorey reinitiation stages, as well as the complex mixture of those two stages. Most of the SF's plots are composed of understorey reinitiation stages, stem exclusion stages and sometimes combined with patches of stand initiation stages. Some stand initiation stages at SF sites and even OF sites due to the clear cutting for growing of black pumpkins. According to the local knowledge from adjacent village of Hla Hlaung Pan and NTNP officers, the black pumpkin can grow only the medium elevation or even higher elevation of natural forests with excellent soil nutrients of NTNP. The economic market of black pumpkin and local disturbance are affected the forest degradation and changing natural forests to stand initiation stages of study area. Regarding to the present seedling status of study area, SF had few saplings and seedlings and some Scrub Land lands are dominated with woody climbers and heavy weed growth. The strong growth of weed species and woody climbers especially in the areas of abandoned shifting cultivation lands of study area can recognized as the main challenge for the growth of the seedlings and saplings. Therefore, the weeding process is also important for forest restoration in this study sites.

According to the land use land cover classes of the research, this updated land cover map can not only assist the forest restoration potential area suitability through the current forest status but also estimated areas of six main land uses through the current land cover information. Consequently, the future forest carbon and/ or forest cover enhancement could proceed with the estimated the current forest area extent in 2020 of this research.

In the case of Forest Restoration Potential Suitable Area Classification, the ANR with highly desirable native tree species by enrichment planting should perform in accord with the target native tree species selection rating by NTNP Office, Forest Department of Myanmar, local community of near NTNP watershed. For the degraded land use types of Bare Land with Low Grass and Scrub Land should implement with direct planting with fast-growing native species by Framework Species Method. When determining the forest restoration suitability site for forest restoration potential, the climatic and soil data did not used because the unique values of these raster datasets are same in accord with small area of NTNP watershed. Therefore, the exploration of designated forest restoration area is mainly based on the topographic parameters including slope and elevation variables, accessibility parameter of distance to road, and also the land cover map of NTNP watershed. The classification of restorability based on three main forest restoration plans (Table 14) and suitability classes of the study area in ha (Table 15) were performed for fulfilment of forest restoration potential assessment from this research. According to the output of forest restoration potential suitable classes, the marginal classes of this study can be hardly to perform the forest restoration implementation. Therefore, the forest restoration of study area should firstly implement at the high suitable sites. Secondly, the moderate suitable sites near the high suitable should also simultaneously perform in accord with the restorability. For the third step, the marginal suitable area can operate forest restorability in accord with the successful forest restoration of high and moderate suitable sites because this restorability process can create the natural regeneration automatically.

6. Conclusion

In this study, the forestation plan is critically important because of the huge mass of weeding which can interfere the natural regeneration growth and sapling survival. Activation of forest restoration by RF sites at the Scrub Land and Bare Land with Low Grass should be primarily performed the weeding procedure. Consequently, forest restoration silviculture with native tree species planting should be fundamentally based on the selection of high germinative percent and fast-growing pioneer native tree species. the Scrub Land and Bare Land with Low Grass are mainly suitable for RF because these areas need to transform the SF or even OF.

Concerning with the forest restoration implementation of study area, SF sites should upgrade to OF through the implementation of ANR methods at spare forest based on forest restoration methods in terms of ANR with EP, ANR without EP or ANR with Framework Species Method, respectively. Based on the field experience, ANR with EP should conduct near SF sites, ANR without EP should conduct at the boundaries between OF and SF sites, and ANR with

Framework Species Method should conduct at the boundaries between Scrub Land and Sparse Forest. ANR with Framework Species Method should implement with the 8 major pioneer native tree species by mixing with the top highest IVI tree species or 23 common tree species of study area. The Dense Forest of current forest situation should conserve and patrol for sustainable forest existence. For forest restorability of Dense Forest, NR is best suitable in accord with current forest situation from this research.

Although the average DBH and H of both investigated stands have the reverse J shaped curves in this research, the current forest extent and forest productivity should conserve by planting of pioneer native tree species and highest IVI species of this study especially at high and medium suitability areas of NTNP watershed. In regard with the forest carbon or forest cover area enhancement, the present study results such as the stand diameter, stand height, stand basal area, mean and total of AGB and AGC as well as the major land use types and suitable area of this present research can utilize as a benchmark for further implementation procedures of forest restoration potential and also forest restoration implementation in the future.

Regarding to activating of the forest restoration process, the studied AGB and AGC results can not only give the current forest biomass and carbon amount but also apply as the evidence for future implementation of potential of forest cover and or carbon enhancement. In addition, the results of similar species diversity of OF and SF highlighted clearly the current forest situation and other next procedures of forest restoration potential with selective native tree species selection.

As a recommendation in regard with present study, future planning of forest restoration silviculture process by ecological forest restoration with native tree species, further researches of fast-growing-native tree species with high germinative percent selection should principally require to implement the restorability. The seed ball forest restoration method with fast-growing pioneer native tree species for ecological forest restoration at higher region or marginal suitable area of this study area should perform by NTNP office as well as the local people. For the tree planting of seedlings or seeding, the future studies of species selection in terms of fast-growing native tree species, high germinative survival rate for forest restoration, comparison of growth rate for seed ball tests in terms of pioneer native species, climax native tree species and even the mixture of pioneer and climax native tree species for future forest restoration implementation. In this case, the forest restoration potential assessed results and current forest situation's information of this study can apply for forest restoration process and regaining of native climax forest types by replacing the degraded forest area and abandoned fallow lands. From this study, these research's fundamental facts can perform the transformation of abandoned fallow lands of degraded forests to SF and upgrading of SF with remnant trees to OF. The tree plantings of forest restoration of NTNP should conduct from the dry period of first April to end of July in accord with the climatic remark of NTNP's aridity index. Concerning the data results of this research, the concluded study results are shown in Table 12.

Table 12.Concluded study results

Data Category	Forest Resources Parameters	OF	SF	Total	T Test	
					Per Plot	Per Stem
Estimated Forest Resources Quantities	Tree Density (n)	394	336	730	×	-
	Sapling Density (n)	54	23	77		
	Seedling Density (n)	10	2	12		
	Total DBH (m)	99.2023	71.9147	171.117	×	√
	Mean DBH (m)	4.1334	3.9953			
	Total Basal Area (m^2)	36.47	19.16	55.63	×	√
	Mean Basal Area (m^2)	1.52	1.06	-		
	Total AGB (ton)	414.41	201.23	615.64	×	√
	Mean AGB (ton)	17.27	11.18	-		
	Total AGC (ton)	194.77	94.58	289.35	×	√
	Mean AGC (ton)	8.12	5.25	-		
Tree Species Composition and Diversity Indices	Species Richness (n)	35	32	42	×	-
	Family Richness (n)	20	21	24		
	1-D´	0.9151	0.9064		×	-
	H´	2.96	2.83		×	-
	J´	0.8317	0.8176		×	-
	K_s	0.7164				
	K_d	0.9364				

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