RELATIONSHIPS AND SPATIAL DISTRIBUTION OF SPECIES IN NORTH ZAMARI RESERVE FOREST, THAYARWADDY, MYANMAR

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SUMMARY

The study shows that dominant species of the old-growth forest is mainly *Lanea coromandelica, Terminalia crenulata, Stereospermum colais*, etc. The dominant species of the forest after 20 years of exploitation are usually *Berrya mollis, Lagerstroemia speciosa*… and the dominant species for the forest after 10 years of logging is *Vitex pubescens, Cratoxylum ligustrinum, Xylia xylocarpa*... The results of spatial relationship analysis between dominant species show that for the old-growth forest, the species tend to grow close together at a distance between 0 to 2.2 m, but with distance greater than 2.2 m, the species are repulsive. In contrast, the forest after 20 years and 10 years of logging, species are repulsive and attractive, respectively. In the old-growth forest, the spatial distribution of species is clustered for any distance from 0 to 3.5 m. In contrast, the spatial distribution for forests after 20 and 10 years of logging is clustered at any distance. A rate of good trees is old-growth forest is the highest. They are often in the top storey. And then, the forest after 20 and 10 years of exploitation are lower, respectively. On the contrary, the rate of the medium and bad trees is greatest in the forest after 10 years recorvery. And then gradually decrease in forest after 20 years restoration and old-growth forests.

Keywords: Dominant species, ecological species relation, Myanmar, North Zamari reserve, spatial distribution.

I. INTRODUCTION

Forest structure is a very important basis for understanding the past, present and determining future functions of forest ecosystems. Forest structure also has a great influence on the habitat of plant and animal species in forest ecosystems. Forest structure is also the basis for proposing silvicultural solutions and sustainable forest management solutions (Hung, B.M., 2016; Lamprecht, H., 1989).

Typically, the relationship between tree species is usually divided into three main groups: resistance, minor resistance and non-resistance. Understanding the relationship between natural forest species is essential for adjusting species compositions in plant communities, proposing silvicultural and decisive for selecting and coordinating species for mixed plantations. The species relationship of the natural forest is a result of many different factors and causes. That may be the result of competition for nutrients, light and living space among species. This may be the result of phytonites of neighbouring trees. In addition, the relationship is also influenced by shape and structre of branches and the trunk of forest species.

Spatial distribution of species on the ground plays a very important role in the analysis of forest structure. Spatial distribution of species is one of determinants for sampling design methods in forest inventory, timber supply capacity from forests, and treated silvicultural measures. Spatial distribution of forest trees is often influenced by many ecological processes. Thus, it will reflect a degree of competition between trees, density, size distribution, mortality rates, timber volume and carbon absorption capacity in stands (Li, L., et al., 2009).

The North Zamari Reserve Forest, is a roughly 75,000 - hectare zone of highly threatened moist upper mixed deciduous forests that contain numerous threatened and endangered species. However, there is currently limited research and analysis on relationships among species in this region. Especially, up to now there has never been any study analyzing the spatial distribution of species on the groud here.

Therefore, in order to solve these problems, the paper will: (1) Analyze the relationship between individual species based of individual frequencies; (2) Analyze the relationship between dominant species by distance and (3) Analyze and compare the spatial distribution patterns of forest trees on the ground between some natural forest states by using multivariate analyses to provide a solid basis for sustainable forest resource management in the study area.

II. RESEARCH METHODOLOGY

2.1. Study area and data collection method

Data were collected from 15 plots of natural forest at the North Zamari Reserve Forest, Thayarwaddy, Myanmar. Each plot has an area of 1000 m^2. The study established five plots for each forest type. Forest types include: old-growth forest, 20 years after logging and 10 years after logging.

The used sampling method was the stratified random method for selecting the plot positions. This is an appropriate method for surveying forest resources, because forest ecosystems are often not homogenous (Hung, B.M. and V.D. Hai, 2017).

In each plot, all trees with diameter greater than 6 cm are measured and their scientific names were identified. The species name is determined by the plant experts of the University of Myanmar. With unknown species in the field, samples were sent to a laboratory of the University of Myanmar for examination, analysis and identification. These data are used for analysis in this article.

2.2. Data analysis method

All data is analyzed by using R version 3.4.3. Specific contents are as follows.

2.2.1. Analysis of relations between species

2.2.1.1. Analysis of dominant species and differences in biodiversity between states

This analysis was conducted by correspondence analysis. Correspondence analysis was used two variables: species and plot variables. This analysis will find the relations between plot and species variable, based on occurrence frequencies of the species. From there, it can help scientists identify dominant species for each plot as well as classify plots with similar levels of biodiversity.

To do this analysis, following commands were conducted in R:

```
fit <- ca(data)
plot(fit)
```

2.2.1.2. Species relationship analysis

Hierarchical cluster analysis was used to analyze relationships among species. In principle, hierarchical cluster analysis will classify species that appear together and have the same number of individuals in a same group. To perform this analysis, the following commands were run in R:

```
clusters <- hclust(dist(data))
plot(clusters)
plot(clusters, hang = -2, cex =0.4)
```

In addition, principal component analysis (PCA) was also used to classify species into 3 groups: resistance, minor resistance and non-resistance. This is the basis for conducting additional planting, enhancing biodiversity for species depleted areas (Davies, A.M.C. and T. Fearn, 2017). The following statements were used to analyze PCA in R:

```
ir.pca <- prcomp(data,
           center = TRUE,
           scale. = TRUE)
biplot(ir.pca, scale = 0, col="black")
```

2.2.2. Spatial distribution patterns of species on the ground

2.2.2.1. Nearest-neighbor G function

In term of mathematics, Baddeley (2008)

showed that for the Poisson process, the nearest-neighbor distance distribution function is:

$$G_{pois}(r) = 1 - \exp(-\lambda \pi r^2) \qquad (1)$$

Where: λ = intensity and r is the distance.

G-test was applied and if the G(r) is greater than $G_{pois}(r)$, so the nearest-neighbor distances are shorter than for the Poisson process. Therefore, the distribution has a clustering pattern. In contrast, if G(r) is smaller than $G_{pois}(r)$, the distribution is regular (Baddeley. A., 2008).

2.2.2.2. The pair correlation function

The pair correlation function will calculate all distances between any two points. It will use the random pattern as a reference. After that, the relation between an observed frequency and frequency of random distribution will be generated. This function was used to analyze spatial distribution patterns of trees and relations between dominant species. Function is:

$$g(r) = \frac{K^{'}(r)}{2\pi r} \quad for \;\; r \geq 0 \qquad (2)$$

When r reaches infinity, then the limit of g(r) will be equal to 1, so in the Poisson process case, g(r) is 1. The distribution will be clustering if g(r) is greater than or equal to 1. On the contrary, the distribution has regular pattern, if g(r) is smaller than or equal to 1 (Baddeley. A., 2008).

2.2.2.3. The mark correlation function

The mark correlation function (kmm(r)) of a marked point process is a tool to measure the dependence between the marks of two points of the process a distance r. It includes summary statistics used for quantitatively marked patterns when the mark is quantitative. In this study, the mark is the tree diameter. In other words, the function will provide bases to understand how diameter classes will be distributed on the ground (Baddeley. A., E. Rubak and R. Turner, 2015).

III. RESULT AND DISCUSSION

3.1. Relationships between species in the forest

3.1.1. Dominant species and homologous biodiversity plot grouping

Dominant species and homologous biodiversity plot grouping results are summarized and indicated in the following diagram.

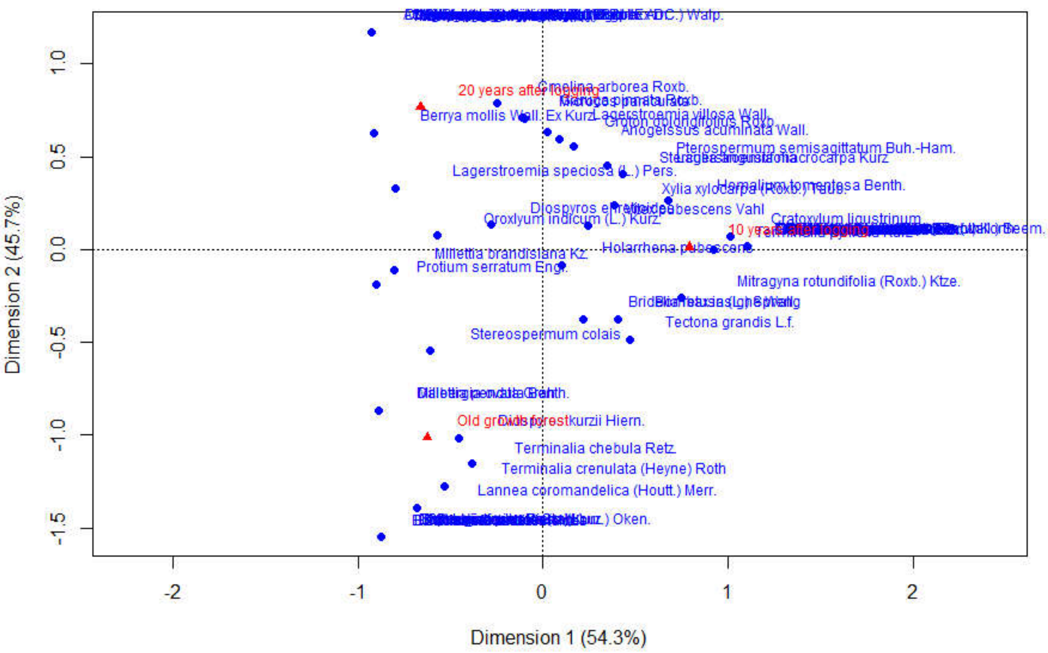


Figure 1. Dominant species and homologous biodiversity plot grouping results

Dominant species are plants species most commonly or conspicuously found in the forest. In the study, correspondence analysis (CA) was used. The reason is that CA is based on the relationship between species and forest type variables. Correspondence analysis can compare and classify species biodiversity between forest types. This analysis is based on the whole dataset of all plots, so the results reflect a more comprehensive ecosystem.

The above diagram shows that dominant species of the old-growth forest are *Lanea coromandelica, Terminalia crenulata, Stereospermum colais*, etc. The dominant species of the forest after 20 years of exploitation are usually *Berrya mollis, Lagerstroemia speciosa*… and the dominant species for the forest after 10 years of logging is *Vitex pubescens, Cratoxylum ligustrinum, Xylia xylocarpa*... Therefore, it is easy to see that species diversity varies considerably between forest types because the dominant species vary from type to type significantly. This proves that structure and climate conditions as well as the species relationships between forest types are markedly different and low levels of similarity. This is a result of many forest concessions and competition for light, nutrients, and growth inhibitors in soil among species.

3.1.2. Relationships among species

In this study, two multivariate analyses were performed to clarify the relationship between species in two studied forest states, cluster analysis and principal component analysis. The results are as follows. The results of the hierarchical cluster analysis are shown in the following digram.

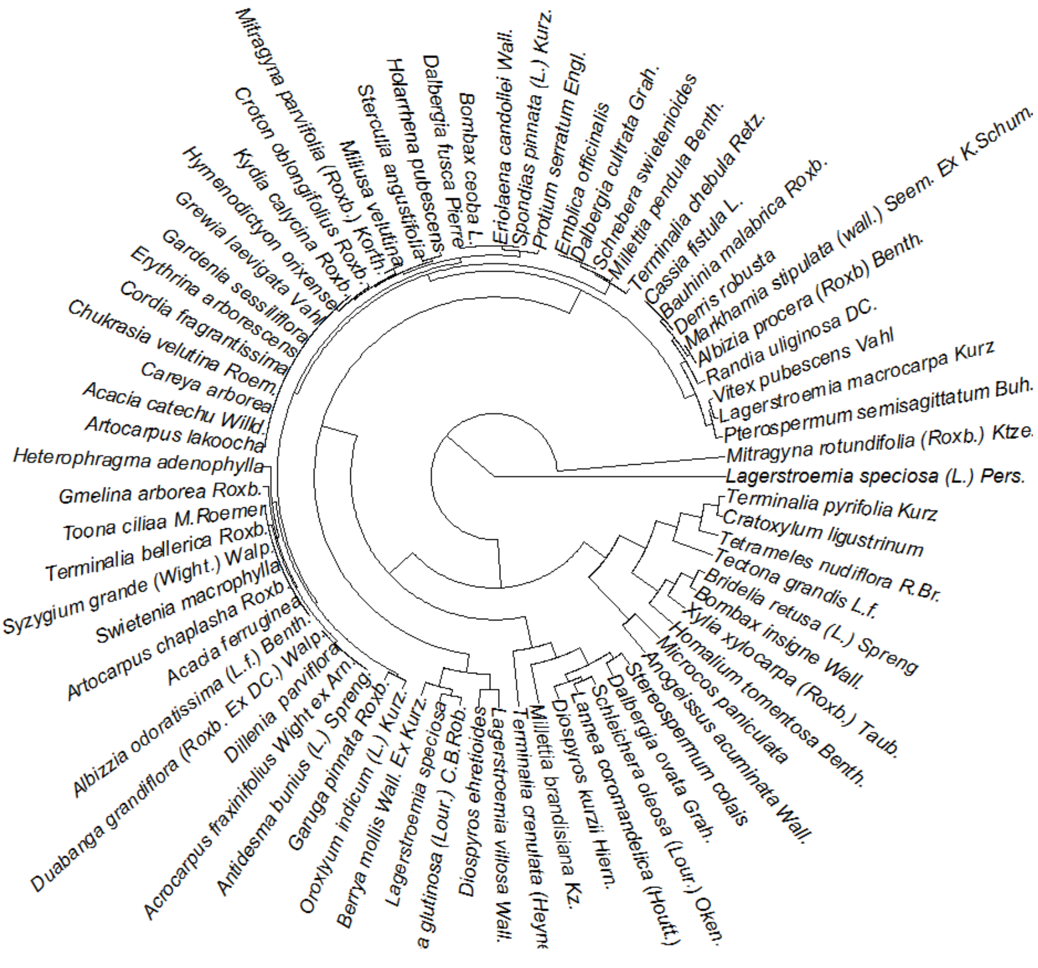


Figure 2. Species cluster analysis results

The relationship between species in natural forests is a very complex issue, requiring accurate quantitative analyses that fully reflect interactions between species as a basis for forest conservation and development and enhancing species biodiversity. Cluster analysis figure above shows that the species are grouped into sub-groups. Species in a same subgroup are non-antagonistic species. They support each other's development and often appear in the same stage. For example, *Stereospermum colais, Dalbergia ovate, Schleichera oleosa, Lannea coromandelica, Diospyros ehretioides* are a group that usually appears together. *Terminalia crenulata, Cratoxylum ligustrinum, Tetrameles nudiflora* are another group living together in the study area. Therefore, when rehabilitating forests for the purpose of enhancing species biodiversity, it is necessary to focus on species from different groups, which is a good basis for forest restoration and biodiversity enhancement.

Scores for main component 1 and 2 are calculated based on the number of individuals of each species for each stage and in a direction with least variances. The results are divided into four basic categories, both components are positive, both negative, positive component 1 and negative component 2, and vice versa. This is the basis for classifying species into three ecological groups. From scoring results in two main components for species, the ecological species groups are classified in the chart below.

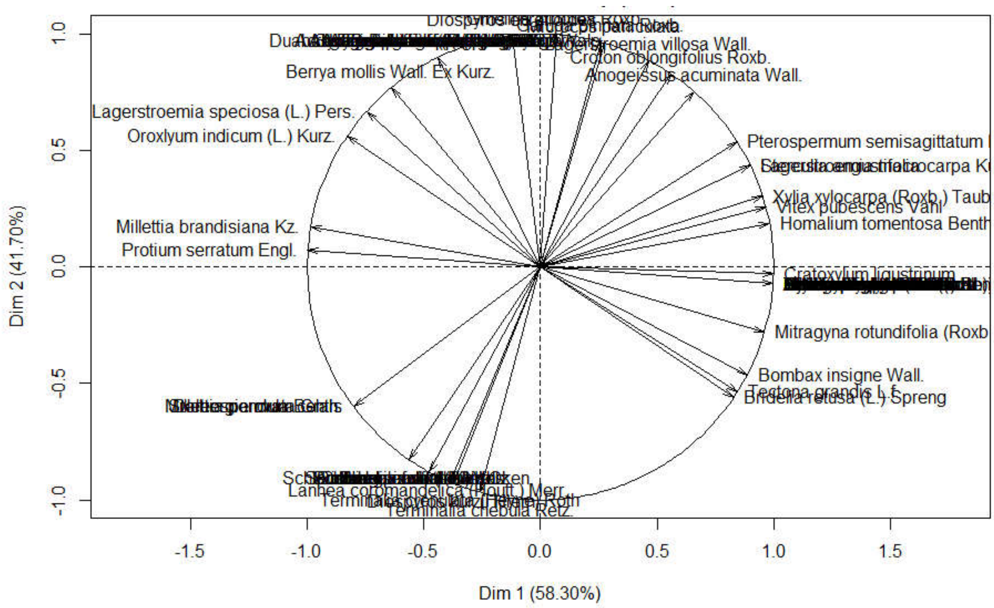


Figure 3. Grouping results: resistance, minor resistance and non-resistance

The results indicate that natural forest species are separated into groups: resistance, minor resistance and non-resistance. For example, *Berrya mollis, Lagerstroemia speciosa, Oroxlyum indicum* often live together and non-resistance. They are less resistant to *Pterospermum semisagittatum, Anogeissus acuminate, Lannea coromandelica, Terminalia crenulata*... However, they are very resistant to *Mitragyna rotundifolia, Bombax insigne, Tectona grandis*… Therefore, when planting plantations with natural species in the study area, resistant species should be avoided and focus should be on no-resistant or less resistant species. This is a physiological rule derived from plant communities. On the contrary, to enhance the biodiversity of a particular forest, it is necessary to focus on intercropping with different species, including resistance groups. That will help to diversify easily species in the area.

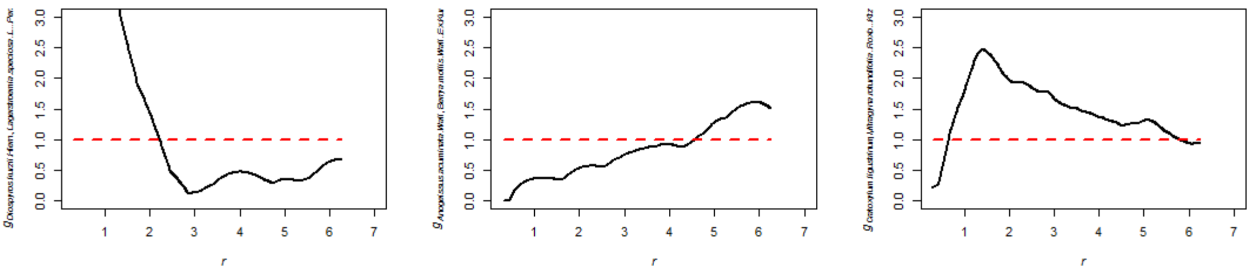
3.2. Spatial relationships between dominant species

Five species with the highest number of individuals in each forest state are listed in the table 1.

Table 1. Dominant species in forest types

Forest type	Species	Number of individuals
Old growth forest	Lagerstroemia speciosa (L.) Pers.	20
	Terminalia crenulata (Heyne) Roth	19
	Schleichera oleosa (Lour.) Oken.	11
	Diospyros kurzii Hiern.	10
	Millettia brandisiana Kz.	9
20 years after logging	Lagerstroemia speciosa (L.) Pers.	46
	Microcos paniculata	22
	Anogeissus acuminata Wall.	13
	Berrya mollis Wall. Ex Kurz.	12
	Lagerstroemia speciosa	12
10 years after logging	Mitragyna rotundifolia (Roxb.) Ktze.	41
	Tetrameles nudiflora R.Br.	25
	Cratoxylum ligustrinum	21
	Terminalia pyrifolia Kurz	20
	Tectona grandis L.f.	19

The table above shows that five dominant species are very different between forest stages. The different number of individuals among species is lowest in the old-growth forest, whereas, that is much higher in forest stages after logging. This proves that the old-growth forest has become more stable, while remaining forest stages are not really stable.



a. Old-growth **b. After 20 years of logging** **c. After 10 years of logging**

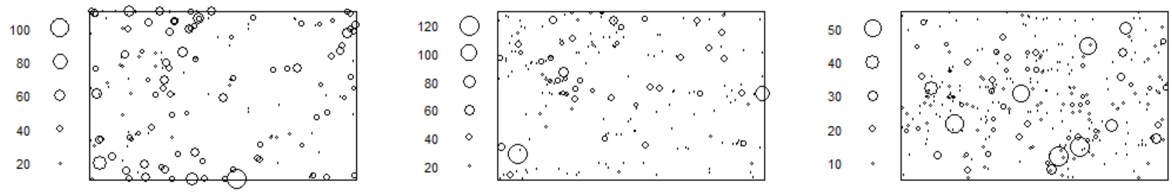
Figure 4. Relations for five most dominant species

The results of spatial relationship analysis between dominant species show that there is a great difference between the three stages. For the old-growth forest, the relationship between the species is quite complicated. The species tend to grow close together at a distance between 0 to 2.2 m, but with distance greater than 2.2 m, the species are repulsive. In contrast, the forest after 20 years of logging, species are repulsive almost all distances. Meanwhile, the relationship between these species of the forest after 10 years of logging is attactive. Dominant species tend to live close to each other.

3.3. Spatial distribution patterns of trees

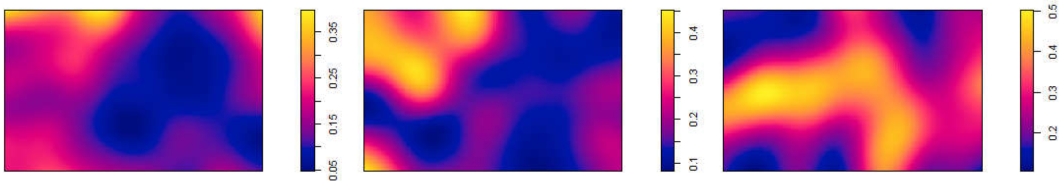
3.3.1. Density and tree positions

Location coordinates of trees in each forest stage are used for analysis. The distribution of trees by the diameter mark is shown in the figure 5.



a. Old-growth | b. After 20 years of logging | c. After 10 years of logging

Figure 5. Tree postions on the ground



a. Old-growth | b. After 20 years of logging | c. After 10 years of logging

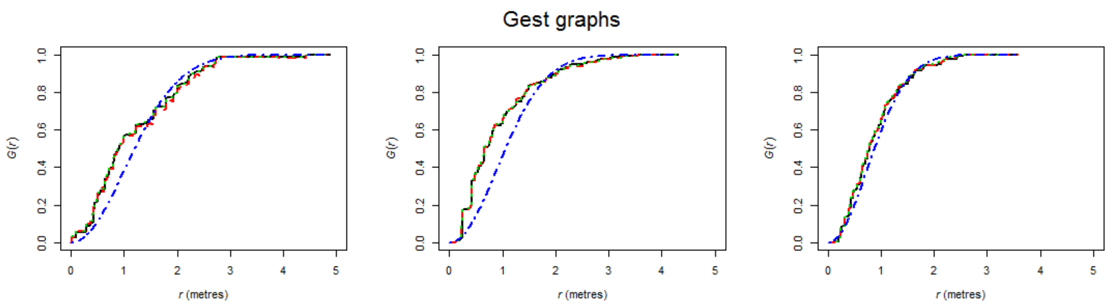
Figure 6. Density distribution

Figure 5 illustrates that tree density of the forest after 10 years of exploitation is greatest. Because this is a young stage, so it has many small and regenerating trees. Then, because of competition about light, nutrient, living space..., so the number of trees is decreased in old-growth forests and forests after 20 years of logging. A location with the highest density in the 10-year forests is at the plot center. In contrast, in old-growth forest and forests after 20 years of harvesting, forest trees concentrate mainly on the upper left corner of the plot (Figure 6).

3.3.2. Spatial distribution pattern testing

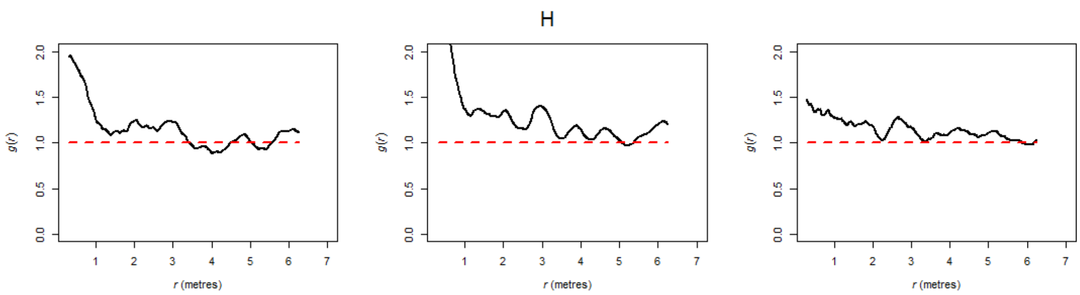
3.3.2.1. Nearest-neighbor G and pair correlation functions

The results of checking and analyzing spatial distribution of forest trees by distance using the nearest-neighbor (G) and the pair correlation function (pcf) are illustrated in the figure 7 and figure 8.



a. Old-growth | b. After 20 years of logging | c. After 10 years of logging

Figure 7. The nearest-neighbor G results



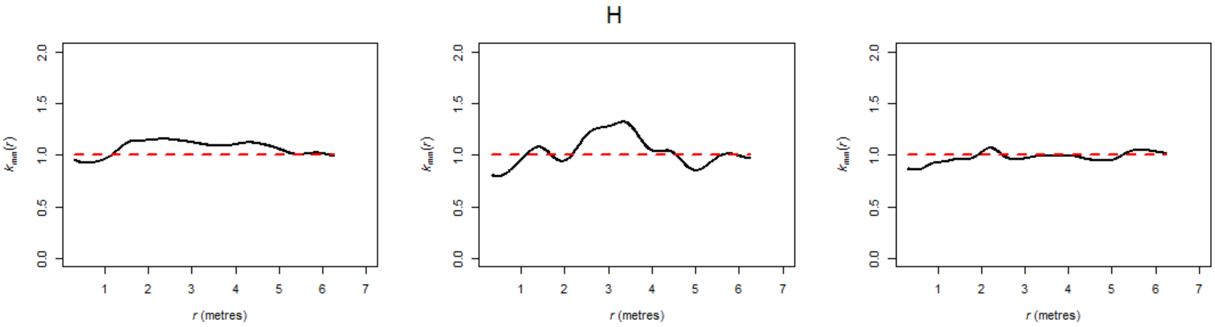
a. Old-growth | b. After 20 years of logging | c. After 10 years of logging

Figure 8. The pair correlation function results

The above results show that for the old-growth forest, the spatial distribution of species is clustered for any distance from 0 to 3.5 m. However, from a distance greater than 3.5 m, the distribution is random. That is very suitable for previous studies. Meanwhile, the spatial distribution for forests after 20 and 10 years of logging is clustered at any distance. The reason for that is that the forests after 10 and 20 years of logging are in the regenerating stages, not yet in the mature stage. As a consequence, forest trees, when they regenerated, tend to be closer to mother plants, or seed sources. At the same time, with low density, the living space for each tree is large enough, so the competition is not really significant in these forest stages. Therefore, the distribution type usually tends to be clustered. In contrast, for the old-growth stage, the forest is more stable, the density is higher. The number of large trees increases, so the competition between the species is fiercer. This has pushed individuals, which have same nutritional need, far apart. As a result, the spatial distribution of species tends to shift to random one (Fox, J.W., 2013).

3.3.2.2. Spatial distribution patters with the diameter mark

The forest tree diameter has a strong influence on a timber stock and total basal area of stands. In addition, if large trees, mother trees are distributed randomly or spreading on the whole region, it will be an excellent condition for forest restoration processes. The results of spatial distribution patterns with the diameter mark on the ground are shown in the figure 9.



a. Old-growth **b. After 20 years of logging** **c. After 10 years of logging**

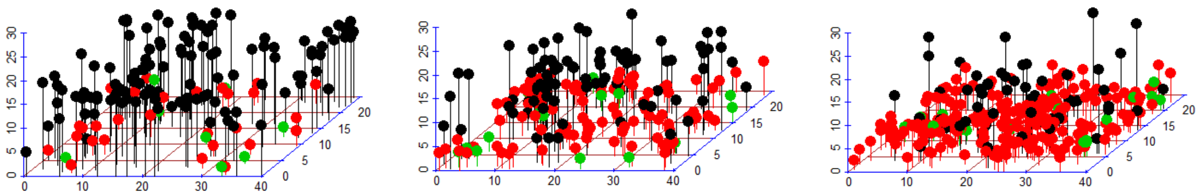
Figure 9. Spatial distribution patterns of trees with the mark

The above graphs show that, for the old-growth forests and the 10 - year forest, diameter classes tend to distribute randomly at any distance from 0 to 6.5 m. For the forest after 20 years of logging, diameter classes distribute randomly at distance: 0 - 2.2 and greater than 4 m. Only within the range of 2.2 to 4 m, diameter classes are randomly distributed in this stage. This may be a result of selective logging and a low density of this stage. This is also the result of competition between the forest trees and the seed dispersal process. After a period of time, seedlings with same diameter classes will be distributed more randomly on the ground.

3.3.2.3. Spatial distribution patterns of trees by quality

The chart below shows the distribution of forest trees by quality. The quality of forest trees is divided into good, medium and bad.

The results indicate that a rate of good trees is old-growth forest is the highest. And then, the forest after 20 and 10 years of exploitation are lower, respectively. Good quality trees are often in the top storey. This happens in all three forest types. In contrast, the rate of the medium and bad trees is greatest in the forest after 10 years recovery. And then gradually decrease in forest after 20 years restoration and old-growth forests. Poor trees often live under storeys in the forest canopy.



a. Old-growth b. 20 years after logging c. 10 years after logging

Figure 10. Spatial distribution of trees by quality: black is good, red is medium and green is bad trees

IV. CONCLUSION

The dominant species of the old-growth forest is mainly *Lanea coromandelica, Terminalia crenulata, Stereospermum colais*, etc. The dominant species of the forest after 20 years of exploitation are usually *Berrya mollis, Lagerstroemia speciosa*… and the dominant species for the forest after 10 years of logging is *Vitex pubescens, Cratoxylum ligustrinum, Xylia xylocarpa*... Therefore, the dominant species is distinctly different between studied forest types. Principal component analysis has separated the species into 3 groups: resistance, minor resistance and non-resistance. For example, *Berrya mollis, Lagerstroemia speciosa, Oroxlyum indicum* often live together and non-resistance. They are less resistant to *Pterospermum semisagittatum, Anogeissus acuminate, Lannea coromandelica, Terminalia crenulata*... However, they are very resistant to *Mitragyna rotundifolia, Bombax insigne, Tectona grandis*…

The results of spatial relationship analysis between dominant species show that there is a great difference between the three stages. For the old-growth forest, the species tend to grow close together at a distance between 0 to 2.2 m, but with distance greater than 2.2 m, the species are repulsive. In contrast, the forest after 20 years of logging, species are repulsive almost all distances. Meanwhile, the relationship between these species of the forest after 10 years of logging is attactive.

Analytical results show that for the old-growth forest, the spatial distribution of species is clustered for any distance from 0 to 3.5 m. However, from a distance greater than 3.5 m, the distribution is random. That is very suitable for previous studies. Meanwhile, the spatial distribution for forests after 20 and 10 years of logging is clustered at any distance. A rate of good trees is old-growth forest is the highest. And then, the forest after 20 and 10 years of exploitation are lower, respectively. In contrast, the rate of the medium and bad trees is greatest in the forest after 10 years recovery. And then gradually decrease in forest after 20 years restoration and old-growth forests.

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QUAN HỆ LOÀI VÀ PHÂN BỐ KHÔNG GIAN CÂY RỪNG TỰ NHIÊN TẠI KHU BẢO TỒN ZAMARI, THAYARWADDY, MYANMAR

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TÓM TẮT

Nghiên cứu đã cho thấy rằng, với rừng già, các loài ưu thế chủ yếu là *Lanea coromandelica, Terminalia crenulata, Stereospermum colais*... Loài ưu thế ở rừng sau 20 năm khai thác thường là *Berrya mollis, Lagerstroemia speciosa*… và loài ưu thế của rừng sau khai thác 10 năm là *Vitex pubescens, Cratoxylum ligustrinum, Xylia xylocarpa*... Kết quả phân tích mối quan hệ sinh thái giữa các loài ưu thế cho thấy rằng: Với rừng già thì các loài có xu hướng sống gần nhau, hỗ trợ cho nhau, đặc biệt trong khoảng cách từ 0 đến 2,2 m. Tuy nhiên, từ khoảng cách lớn hơn 2,2 m các loài thường đối kháng. Ngược lại, với rừng phục hồi sau 20 năm thì các loài ưu thế rất đối kháng. Trong khi đó rừng phục hồi sau 10 năm thì các loài ưu thế lại có xu hướng hỗ trợ nhau cùng phát triển. Với rừng già, phân bố không gian của các loài là phân bố cụm chỉ trong khoảng cách từ 0 đến 3,5 m. Ngược lại, phân bố không gian của các loài cây tại rừng phục hồi sau 10 và 20 năm là phân cụm ở mọi khoảng cách. Tỷ lệ cây có chất lượng tốt ở rừng già là cao nhất. Chúng thường nằm ở tầng trội của rừng. Tỷ lệ này thấp hơn ở rừng phục hồi sau 10 và 20 năm. Tỷ lệ cây trung bình và cây xấu thì lại lớn nhất ở rừng sau 10 năm khai thác. Sau đó tỷ lệ những cây này giảm dần ở rừng sau 20 năm khai thác và rừng già.

Từ khóa: Khu bảo tồn North Zamari, loài ưu thế, Myanmar, phân bố không gian, quan hệ loài.

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