Title: The Relative Growth rate and Carbon Storage among various tree species At Mae Sa Mai Restoring forest , Chiang Mai Thailand

Research team: Bhira Tayarangsee Pimchanok Srisukha Ekkawee champrasert Wichapat Sothorntweepong Panissara Wiratkasem
Project advisor: Mrs.Bannruck Tanjaphatkul Ms.Panithan Mankong
Scientist : Dr. Kwanphirom Naruangsri
School: Varee Chiang Mai School

Abstract

The current decline in forest areas has had a significant impact on biodiversity and the environment because forests are a hub of biodiversity and a crucial carbon sink. Recognizing this, many sectors are becoming more aware of the need to conserve existing forest areas and restore degraded forests. It is understood that forests are the key to effectively and sustainably addressing environmental issues.

Given the importance of forests mentioned above, the research team had the idea to study and compare the growth rates and carbon sequestration of seedlings and mature trees in the reforestation area of Ban Mae Sa Mai, Mae Rim District, Chiang Mai Province. This was done by analyzing data on height, diameter at breast height, and stem diameter at a height of 130 centimeters above ground level of the trees, along with weather data using Python programming to process data from the Terra satellite in the Google Earth Engine database.

The study found that different tree species have varying growth rates and carbon sequestration capacities depending on their physiological characteristics. These can be categorized into 3 groups: 1. Fast-growing plants with maximum carbon sequestration rates at 5 years old include *Erythrina Subumbrans*. 2. Trees that reach peak carbon sequestration between 6-20 years old include *Castanopsis calathiformis, Spondias axillaris, Alseodaphne andersonii*, and *Alseodaphne andersonii*.
3. Trees with maximum carbon sequestration when older than 20 years include *Alseodaphne andersonii, Ficus altissima, and Prunus cerasoides*.

Rainfall quantity is another important variable. Therefore, to restore forests to a fully functional ecosystem and efficient carbon dioxide sink, it is necessary not only to select tree species suitable for the area and climate but also to appropriately sequence the planting of seedlings in the area. This is another approach to develop forests into efficient carbon dioxide sinks.

Keywords: The rates of exponential growth, carbon sequestration, forest restoration, evergreen forests, and weather conditions.

Acknowledgment

The Relative Growth rate and Carbon Storage among various tree species at Mae Sa Mai Restoring forest , Chiang Mai Thailand has been successfully completed with great support from various agencies and individuals.

I would first like to thank Dr. Kwanphirom Naruangsri, the research officer from the Forest Restoration Research Unit (FORRU), for providing guidance on field surveys and knowledge of tree growth and carbon sequestration in the restoration forest area. the Forest Restoration Research Unit (FORRU) of Chiang Mai University and all staff members who provided knowledge about forest restoration, which has been the inspiration for this research study. Also, thanks for the data analysis of tree surveys from 1998 to 2020.

In addition, I would like to thank Varee Chiang Mai School for supporting various aspects, whether it be facilities or equipment, throughout the research period. Special thanks to Teacher Bannruck Tanjaphatkul and Teacher Panithan Mankong, the project advisors, for their constant and caring guidance. Finally, we could not have completed this research without support from our parents for their support in every aspect, both physically and mentally, as well as everyone else who has been involved but not mentioned here. The researchers express their gratitude at this moment.

Research Team

List of contents

List of Figure

Page

Introduction

Forest resources are one of the most important ecosystems in the world. Because it is the main source of biological diversity. Forests are also important in maintaining balance between nature and the ecosystem. In particular, it is a source of absorbing carbon dioxide and soil carbon sequestration. However, with the continuously increasing population and human lifestyles, consumption, which is more wasteful than in the past. Combined with the increasing problem of severe climate change, it has greatly affected forest areas around the world. It is predicted that by 2050, the world's forests and ecosystems will release more carbon dioxide than they can absorb and will continue to affect the appropriate temperature factors for the survival of plants and animals in the end.

It is expected that if global temperatures rise, some plants and animals will have to migrate or spread to cooler areas. They may be as far as hundreds of kilometres away or may migrate to higher ground 1–4 meters and lead to loss of biodiversity in some areas in the future (UNEP/GRID-Aredal,2008).

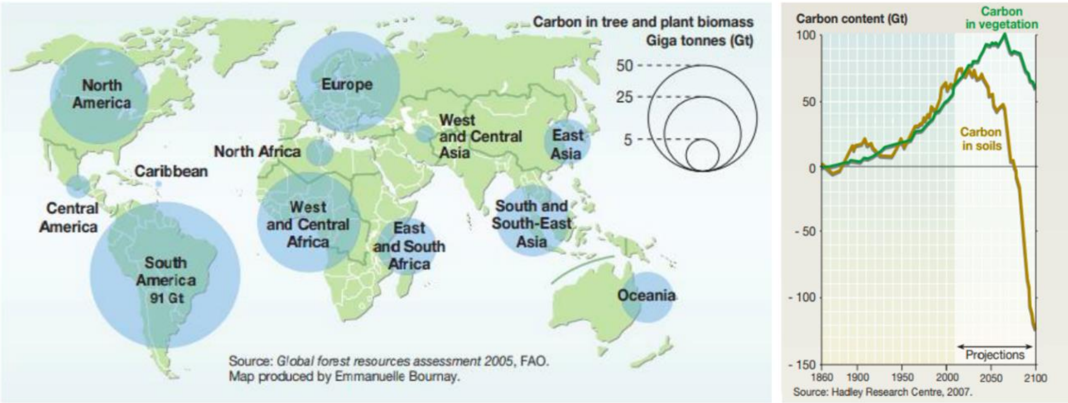


Figure 1 The amount of carbon stored in trees in each region of the world and future trends in carbon dioxide absorption in soil and trees. (UNEP/GRID-Aredal,2008)

Chiang Mai is an area in the northern part of Thailand that is surrounded by mountains. In the past, in 1961, the forest area used to be as high as 80 percent, but according to information as of 2019, it was found that the forest area had decreased to 69.59 percent (Chiang Mai Provincial Office, 2020) and it is expected that this decrease in forest area It is one factor that causes the average air temperature to increase from 26.2 degrees Celsius in 1997 to 27.7 degrees Celsius in 2017 and has a continuous impact on other problems. Whether there is a decrease in biodiversity in the area or a problem of unstable weather conditions due to an unbalanced airflow. The problem decreased agricultural production Including severe forest fires that lasted for many months. That in turn causes the loss of forest areas that may not be able to be restored in time with the rate of loss that has occurred. And it will make environmental problems in Chiang Mai even more critical.

From this wide-ranging impact. As a result, many government agencies, the private sector and people in the area are trying to create cooperation in both conserving existing forest areas and restoring degraded forests.   One of the organizations that is important in forest restoration is the Forest Restoration Research Unit of Chiang Mai University (FORRU-CMU).

FORRU-CMU was established to study research techniques. Methods for restoring forests and ecosystems to conserve biodiversity and the environment include studying the carbon storage ability of the reforestation plots. In the past year 2022, Varee Chiang Mai School participated in the Youth Forest Restorers project established by FORRU to disseminate the forest restoration process to youth. By learning from collecting seeds planting seedlings and bringing seedlings back into the reforestation plots, as well as monitoring the growth of seedlings from this activity. Researchers who are members of the project have found that different types of seedlings have different growth and survival rates. Therefore, we are interested in studying and comparing the growth rate of seedlings and the carbon storage capacity of different types of perennial trees. In the reforestation plots, it is expected that the results of this research will provide basic information for selecting suitable tree species for forest regeneration under current climate change. That will create an efficient source of carbon absorption in the future.

Figure 2 Varee Chiang Mai School learning about the forest restoration process of YFR project

Purposes of project

To study and compare the growth rate of seedlings and the carbon sequestration rate of each type of perennial plant

Research question

How do different types of perennial plants have different growth rates and carbon storage rates in each period?

Hypothesis

Different types of perennial plants have different seedling growth rates and carbon sequestration rates.

Benefits of research:

1. The results of the study can be used as information for selecting appropriate tree species for the reforestation plots, which will increase the efficiency of carbon storage in the reforestation plots in the future.
2. Raise awareness of the importance of forests in maintaining natural balance, which will lead to cooperation in solving environmental problems in communities.

The scope in research

Content

Comparative study of seedling growth rates and carbon storage of different types of perennial trees in the reforestation plots under climate change during 1998-2023.

Place

The reforestation plots at Ban Mae Sa Mai, Mae Rim District, Chiang Mai Province (coordinates 18.5127N , 98.5052E)

Time

December 2023 – February 2024

Literature Review

The role of forests in maintaining ecological balance

Forests are considered terrestrial ecosystems with higher biodiversity than other types of terrestrial ecosystems because they are important habitats. Moreover, forests are also an important source that provides benefits in many other ways, including

- Being an important part of the water, oxygen, carbon dioxide and nitrogen cycles in the ecosystem ,which brings balance to the system by circulating and changing minerals and substances in the ecosystem.
- Maintain soil stability both directly and indirectly whether it helps maintain the physical properties and characteristics of the soil ,as well as helping to preserve nutrients in the soil in which decaying leaves and plant remains will absorb water and reduce the rate of soil erosion.
- Taking part in adjusting the atmospheric conditions due to forests helps preserve moisture in the soil. The shade of the forest prevents the sun's heat from directly hitting the soil surface. In addition, in the forest area will be water vapor that results from the transpiration of plants. The air above the forest is therefore highly humid. Condenses into water droplets and creates many clouds.
- It Help reduce air pollution.
- It is a water source.
- It is a source of biodiversity resources.
- It helps alleviate the severity of storm winds.
- It is a source of relaxation.
- It is a source of carbon sink and stores carbon in various parts, including the trunk 62%, branches 11% and leaves 1% and underground parts such as roots, another 26%. When the tree dies, it will accumulate as organic matter. This causes carbon to be stored underground and is less likely to return to the carbon cycle in the atmosphere (Adis Isarangkun at Ayutthaya, 2022).

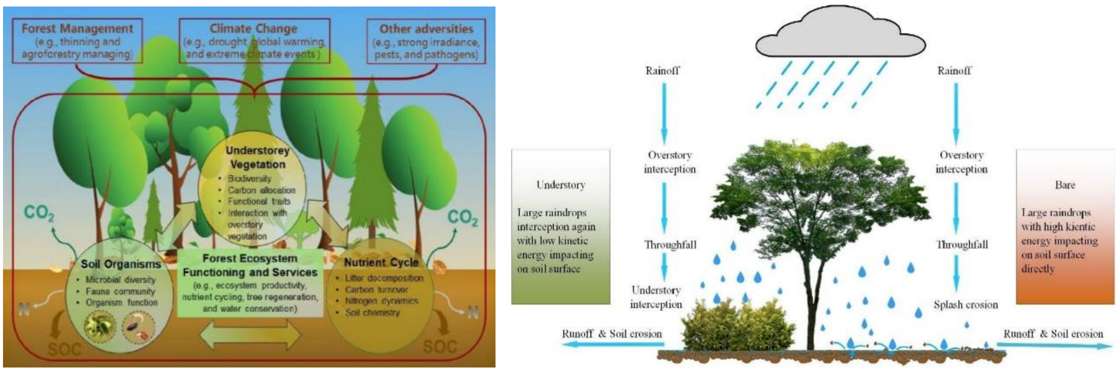


Figure 3. The role of forests in the ecosystem.
(Source: Maximum Academic Press,2023)

Carbon Sequestration

It is the process of pulling carbon from the atmosphere and storing it somewhere permanently or semi-permanently through the process of photosynthesis of plants. For example, perennial plants absorb carbon dioxide from the atmosphere and change it into various substances. That is used to grow and store approximately 50% of carbon in the form of wood. In addition, trees also cause carbon cycling in the forest through soil that helps store carbon in the form of tree roots. Rotting and decaying the leaves and wood will be decomposed by microorganisms in the soil and release carbon dioxide into the atmosphere for plants to absorb and use in photosynthesis.

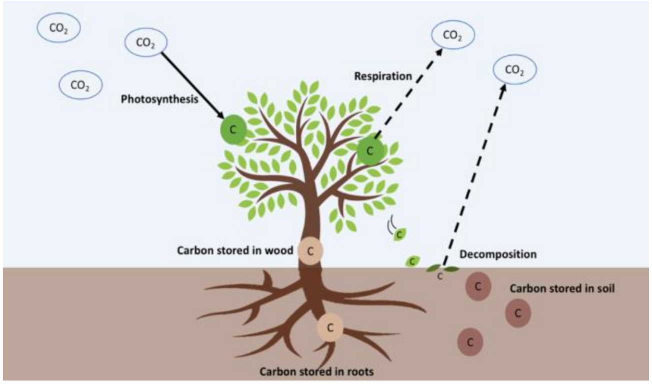


Figure 4. Carbon pools and carbon cycling in forests.
(Source: Murger,B.,2024)

In general, there are two principles for estimating tree carbon storage: direct biomass estimation; This can be done by cutting all the trees or plants that grow in the area we are interested in studying and then weighing them. and the so-called indirect estimation of biomass. “The Allometry Method " The main idea of this method is that the growth of the entire body of an organism is related to the growth of any one organ of the body. (Huxley,1972) For example, using head circumference to estimate brain weight of some animals. Or use trunk circumference and height to estimate the biomass of trees. However, we will find that each type of forest will have different rates of plant growth and carbon storage. Therefore, selecting the appropriate allometric equation for the forest characteristics is important to obtain accurate carbon sequestration values.

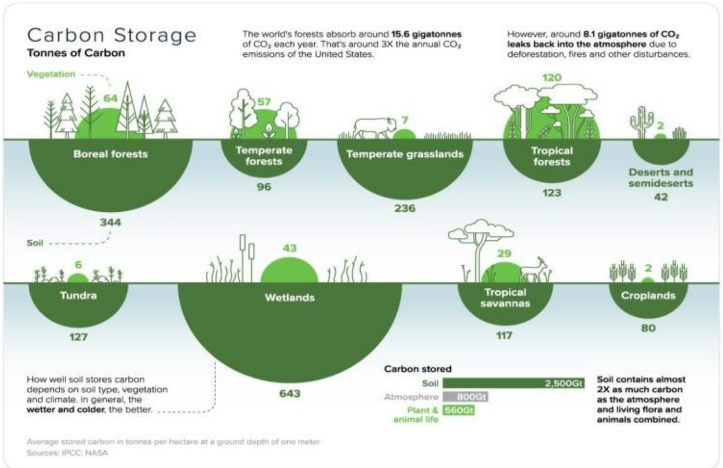


Figure 5. Carbon storage of each forest type. (Source: Neufeld,D. and Smith,M.,2024)

The amount of carbon storage is calculated from above ground biomass (ABG) using the allometry equation of Ogawa et al. (1965). Mixed forest type. (Environmental Research and Training Center Department of Environmental Quality Promotion, 2018)

$W_S = 0.0396\,(D^2H)^{0.9326}$ W_S = Stem biomass (kilogram)
$W_B = 0.003487\,(D^2H)^{1.0270}$ W_B = Branch biomass (kilogram)
$W_L = (28.0/W_{tc} + 0.025)^{-1}$ W_L = Leaf biomass (kilogram)
$GB = (W_S + W_B + W_L)$

The Intergovernmental Panel on Climate Change (IPCC, 2006) has determined that approximately 47 percent of tree biomass is carbon. Therefore, the assessment of trees' carbon storage is as follows.

$$C = GB \times 0.47$$

Where C is carbon storage.
GB is the above ground biomass of the tree.

Ban Mae Sa Mai Forest Restoration Plot

It is a forest restoration plot created through the cooperation of FORRU Forest Restoration Research Unit and the Hmong hill tribe community in Ban Mae Sa Mai, Mae Rim District, Chiang Mai Province, with a proactive forest restoration technique called "Framework species method" which is the restoration of the forest by planting trees that form the original ecosystem structure combined with accelerating the natural recovery of the area through various methods. To create a forest ecosystem that can continue to exist sustainably after just one planting. The properties of tree structures are as follows.

- High survival rate when planted in degraded forest areas.
- Grows fast.
- Has a thick, wide canopy that can block the sun well. Makes it impossible for weeds to grow.
- Flowers, bear fruit or provide resources that attract wildlife at a young age.
- Seeds can be grown in the nursery.
- The seedlings grow and can be planted in forest areas in no more than 1 year.

Figure 6. Developments in the Ban Mae Sa Mai rehabilitated forest area,
Mae Rim District, Chiang Mai Province,
Restoration using structural planting methods (Source: Elliott,S. et al,2018)

The results of forest restoration using those techniques found that the seedlings planted in the rehabilitated area are growing rapidly, helping to block light and prevent weed growth. This aids in creating a forest structure consisting of many layers of canopy, as well as assisting in restoring other systems in the area such as the nutrient cycle. These conditions make the area suitable for the germination and growth of the next generation of natural tree seedlings, along with attracting various types of animals, especially groups that help spread seeds from other areas. Ultimately, this helps restore the forest to its original state.(Elliott, S. et al, 2018)

Methods and Materials

Materials

1. Measuring tape (50 meters)
2. Tree height measuring stick
3. Clinometer
4. Densiometer
5. Google Earth engine
6. Excel program
7.python program

Methods

1. Select the study area; Ban Mae Sa Mai restoring forest, Mae Rim District, Chiang Mai Province. This is a forest restoration plot where seedlings have been planted since 1998 (18.5127N, 98.5052E)

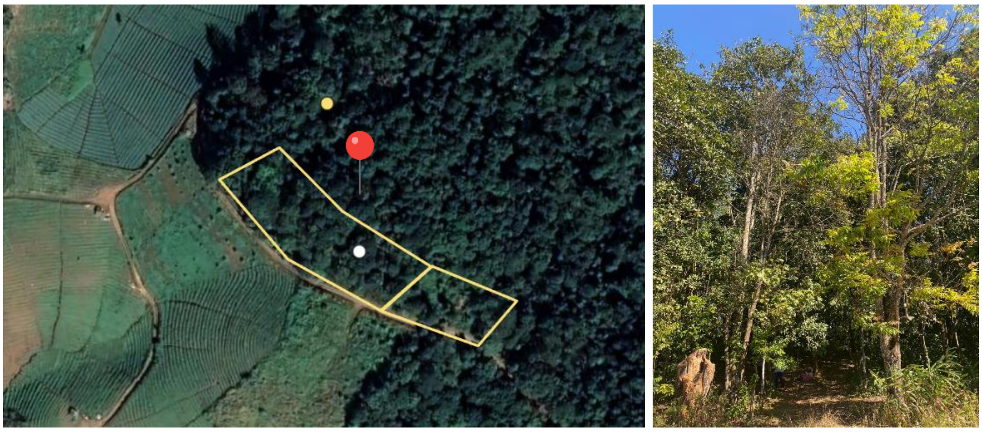


Figure 8 The Study area at Mae Sa Mai restoring forest.

2. Choose the species of trees from the FORRU database which have a survival rate over 75% for the first three years. There are a total of 12 species as follows;
   - *Castanopsis calathiformis* (Skan) Rehder & E.H. Wilson
   - *Spondias axillaris* Roxb.
   - *Bischofia javanica* Blume
   - *Alseodaphne andersonii* (King ex Hook.f.) Kosterm.
   - *Eugenia albiflor*a Duth. ex Kurz.
   - *Cinnamomum iners* (Reinw. ex Nees & T.Nees) Blume
   - *Heynea trijuga* Roxb. ex Sims
   - *Ficus altissima* Blume
   - *Phoebe lanceolate* (Wall. ex Nees) Nees
   - *Prunus cerasoides* Buch.-Ham. ex D.Don
   - *Nyssa javanica* (Blume) Wangerin
   - *Erythrina Subumbrans* (Hassk.) Merr.

3. Measure all tree species for data of year 2023, including height, diameter at breast height (DBH), canopy width and length.

Figure 9 Measuring of trees at the study area

4. Analyze the relative growth rate of root collar diameter (RGR-RCD) from the database of FORRU observe in 1998-2000 by the equation as follow; (Pimonrat Thiansawat et al., 2018)

$$RGR = \frac{\underline{Ln(RCD_2) - Ln(RCD_1)\ x\ 365\ x\ 100}}{(t2 - t1)}$$

RCD1 and RCD2 - The diameter of the tree's root neck in previous and current measurements.

T2-t1 - The measurement management period of the previous round and the current round (days).

5. Analyze the carbon storage rate of each tree species from the FORRU database in 2002-2020 and from the current collecting in 2023 by the equation as follows; (IPCC, 2006).

$$W_S = 0.0509\ (D^2H)^{0.919}$$
$$W_B = 0.00893\ (D^2H)^{0.977}$$
$$W_L = 0.0140\ (D^2H)^{0.669}$$
$$GB = W_S + W_B + W_L$$
$$C = GB\ x\ 0.47$$

W_S = Stem biomass (kilogram)
W_B = Branch biomass (kilogram)
W_L = Leaf biomass (kilogram)

6. Organize weather data including air temperature, air humidity and the amount of rainfall by writing commands from the python program and process through

the data of Terra satellite data in the Google Earth Engine database . Analyzed this weather data with growth rate of seedlings and carbon storage of tree species in each time period.

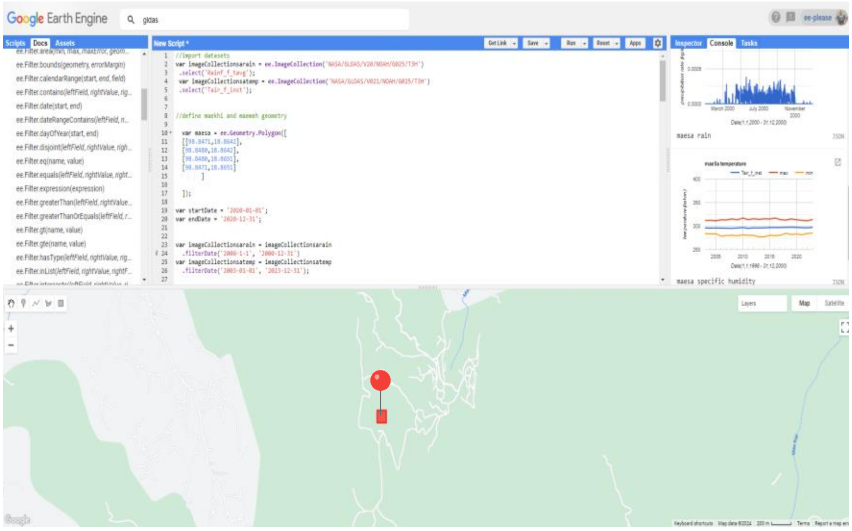


Figure 10 Organizing weather data in the Terra satellite database in Google Earth Engine using python program commands.

7. Compare seedling growth rates and carbon storage of each tree species.
8. Discussion and conclusion.

Results and discussion

The results of the analysis of tree data from the survey records database of the FORRU Forest Restoration Research Unit in 1998-2000 and from the field surveys in 2023, as well as weather data during the same period from the Terra satellite database in Google Earth Engine has the following analysis results:

1. **Relative Growth Rate of Root Collar Diameter**

It was found that each type of seedling has a different growth rate. As shown in the graph

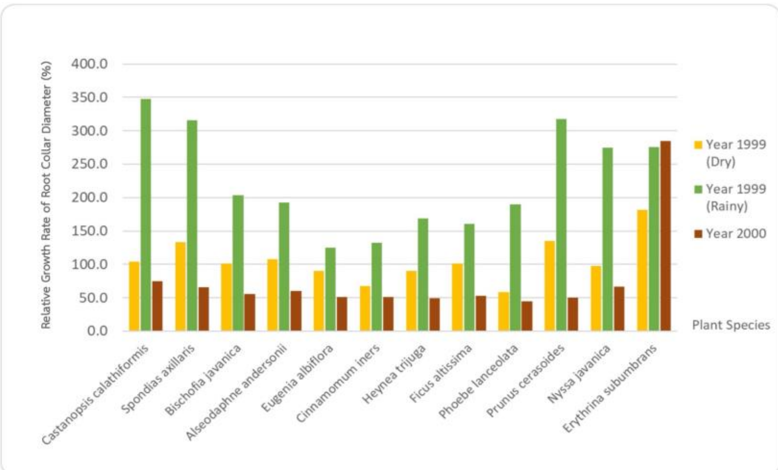


Figure 11.. Graph showing the relative growth rate of root collar diameter (RGR-RCD) from different seedling species

2. Carbon Storage

It was found that each type of perennial plant has a different carbon storage rate. Moreover, the same type of woody plant has different rates of carbon sequestration each year.

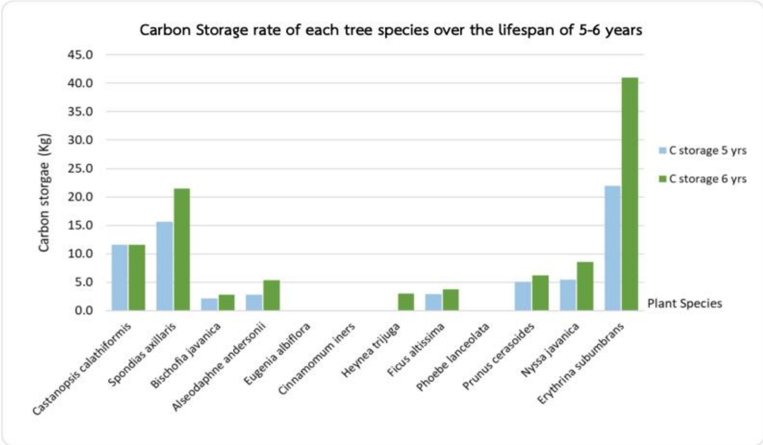


Figure 12: Graph showing the carbon sequestration rate of each type of tree over the lifespan of 5-6 years.

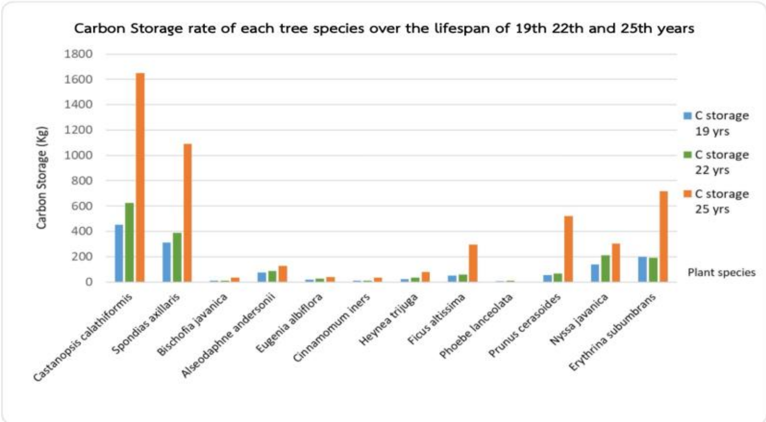


Figure 13: Graph showing the carbon sequestration rate of each type of tree during the lifespan of 19th 22th and 25th years.

3. Changes in weather conditions in the study area

We have studied the weather, including air temperature, air humidity, and rainfall. Additionally, we have categorized the monthly average data into three periods according to the growth stages of trees as follows:

Year 1998-2000 to analyze and compare the relative growth rates of root collar diameter.

Year 2001-2002 to analyze and compare carbon storage of trees in the 5th-6th year.

Year 2003-2023 to analyze and compare the carbon storage rate of mature trees.

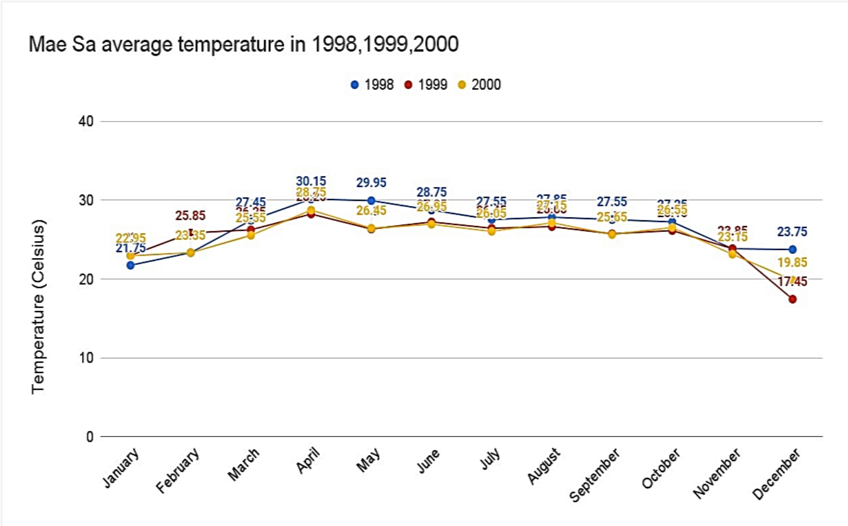


Figure 14 Graph showing monthly average air temperature data in 1998-2000

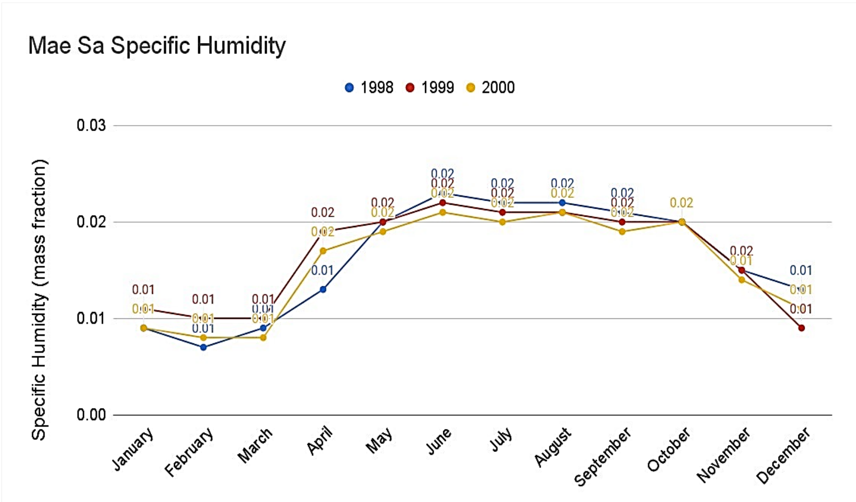
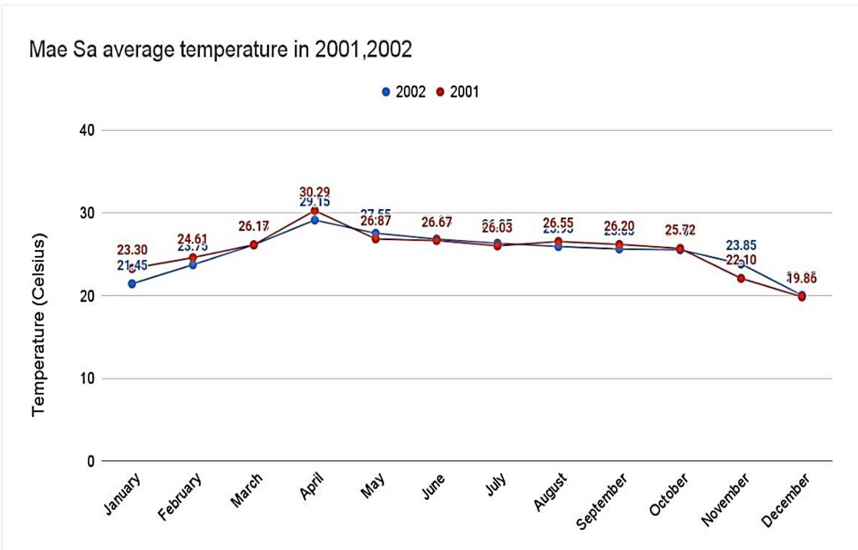


Figure 15 Graph showing monthly average air humidity data in 1998-2000 (1998-2000).



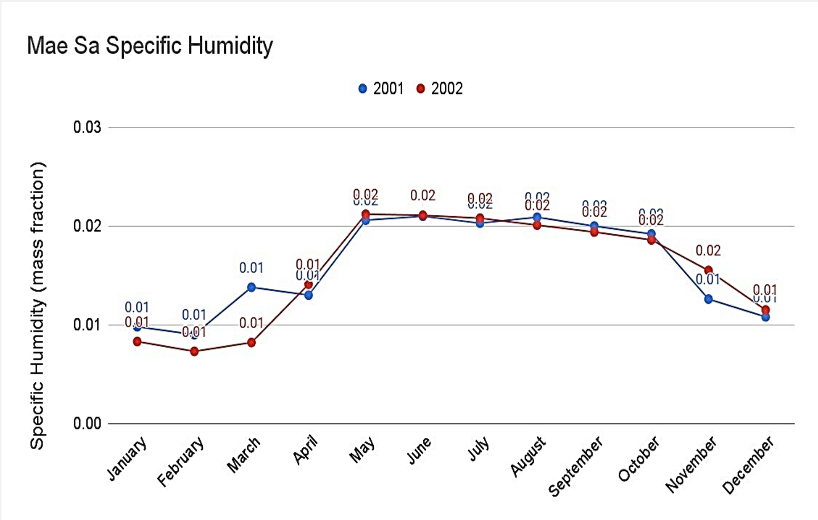


Figure 16 Graph showing monthly average temperature and air humidity data in 2001-2002.

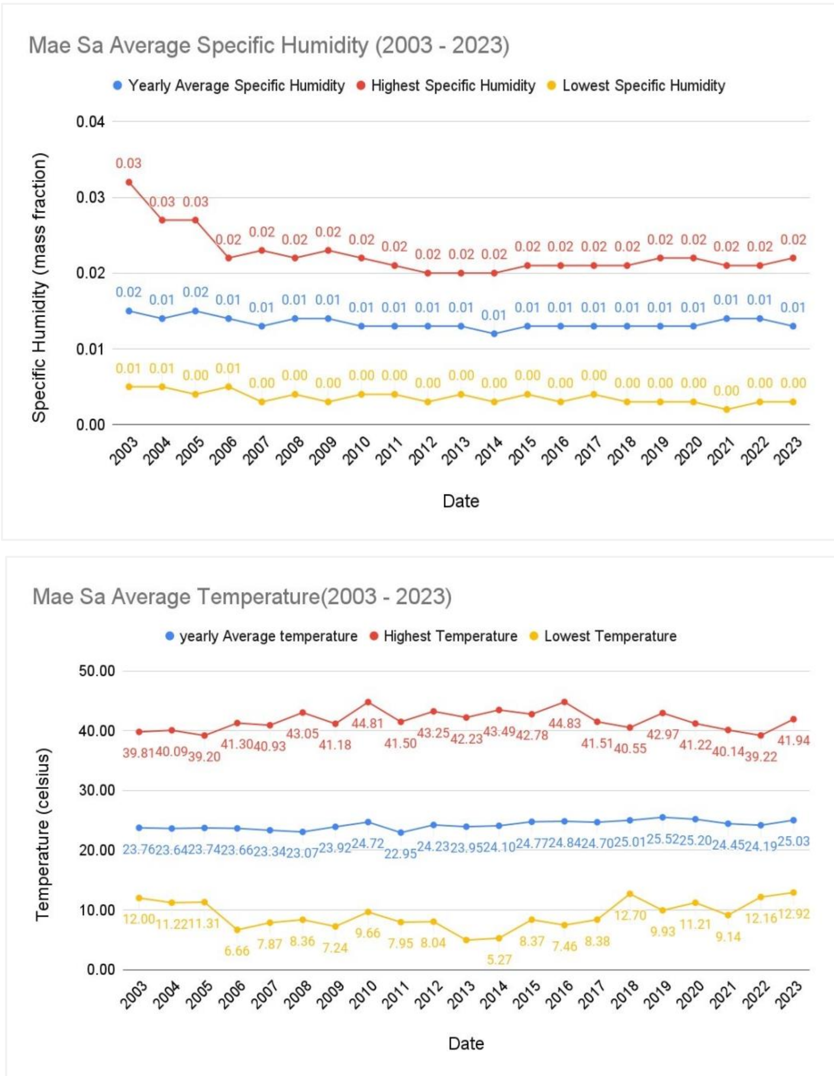


Figure 17 Graph showing average annual temperature and humidity data for the years 2003-2023 (years 2003-2023).

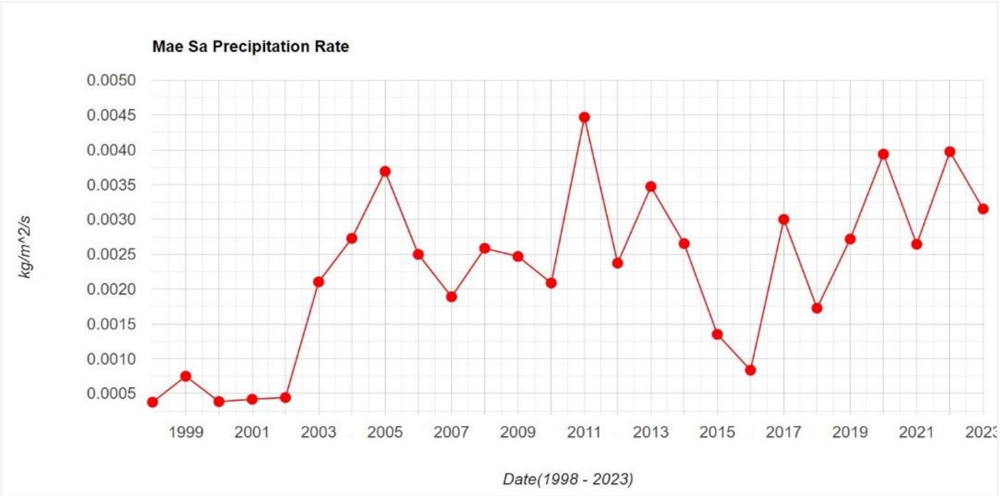


Figure 18 Graph showing average annual rainfall data in 1998-2023 (1998-2023).

Conclusion

From the results of data analysis, it was found that after the seedlings emerged from the seed, the percentage of surviving seedlings affects their growth and reduces carbon storage. Meanwhile, weather factors will have a greater effect on trees over time.This can be seen from the below graph showing the relationship between the relative growth rate in the root neck and the percentage of seedling survival. The seedlings with the highest growth rates were both types with higher survival rates, including *Castanopsis calathiformis* and *Spondias axillaris*, and those with lower survival rates, including *Prunus cerasoides* , *Nyssa javanica* and *Erythrina subumbrans* respectively.

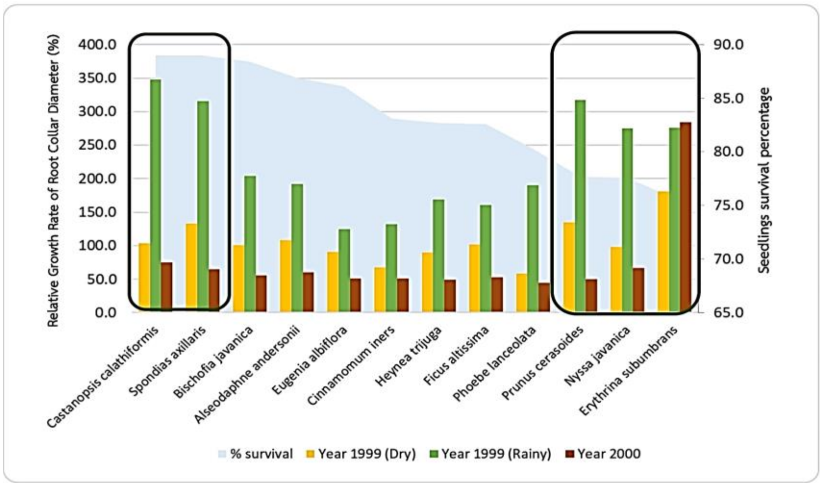
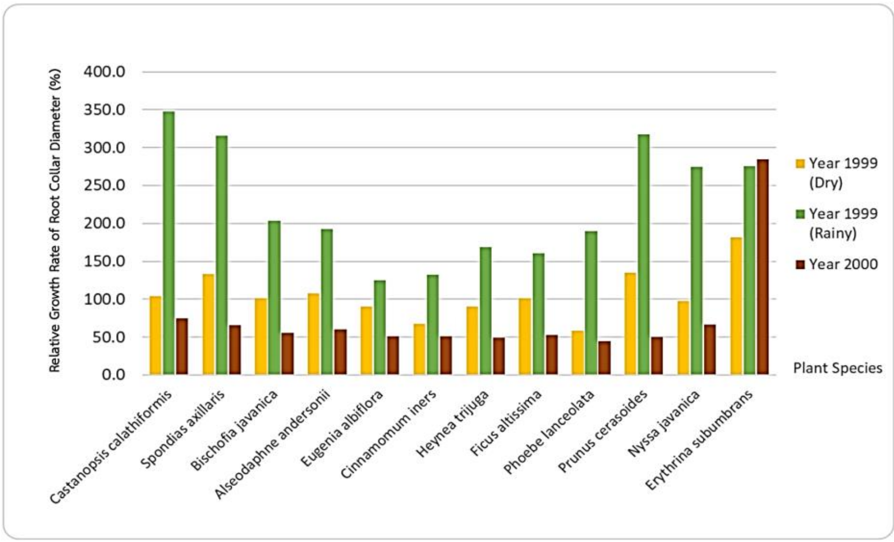
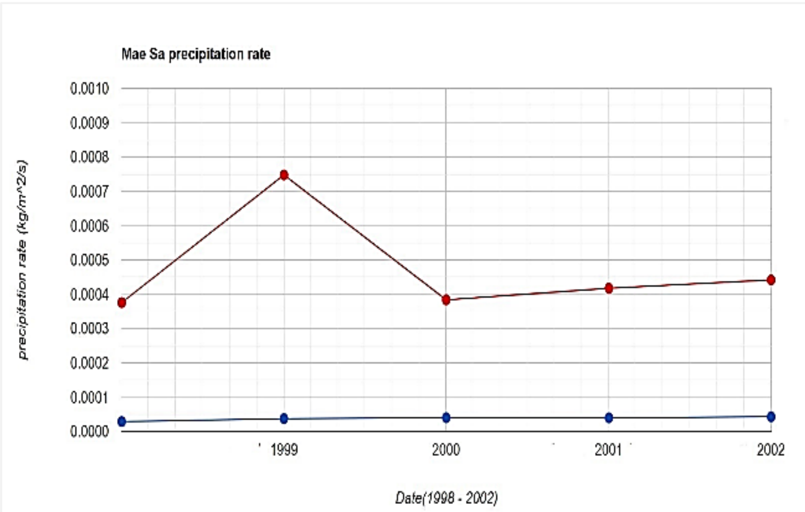
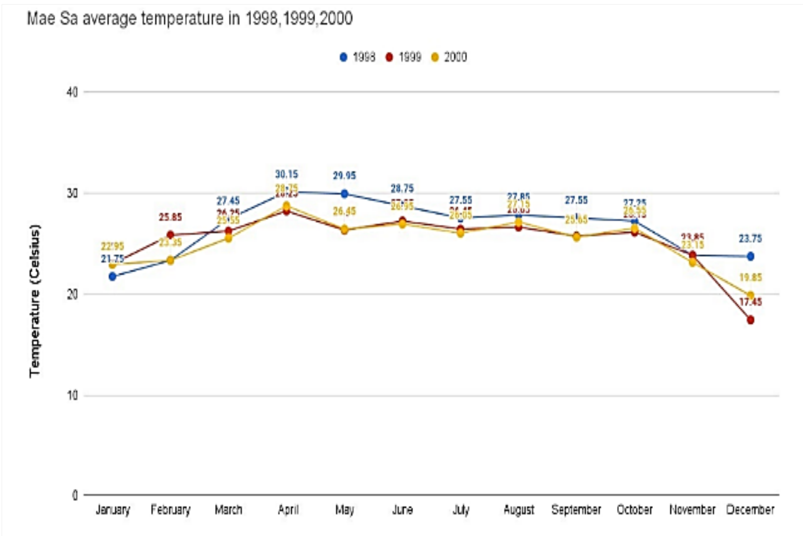


Figure 19. Graph comparing relative growth rates through the root neck and percentage of seedling survival (data as of the 4th year from the seedling planting date).

While the weather factors studied, including air temperature and humidity, were found to be related to the relative growth rates for all types of perennial plants, they initially showed relatively low growth rates from the initial measurement. This measurement was taken to record data after planting seedlings during the dry season (May 1999). The data differed from the relative growth rate measured the second time, which had greatly increased. This difference was observed because the data was recorded after the rainy season (November 1999). In 2000, the relative growth rates of almost all tree species dropped significantly which coincided with decreasing weather conditions in terms of rainfall and air humidity as well.







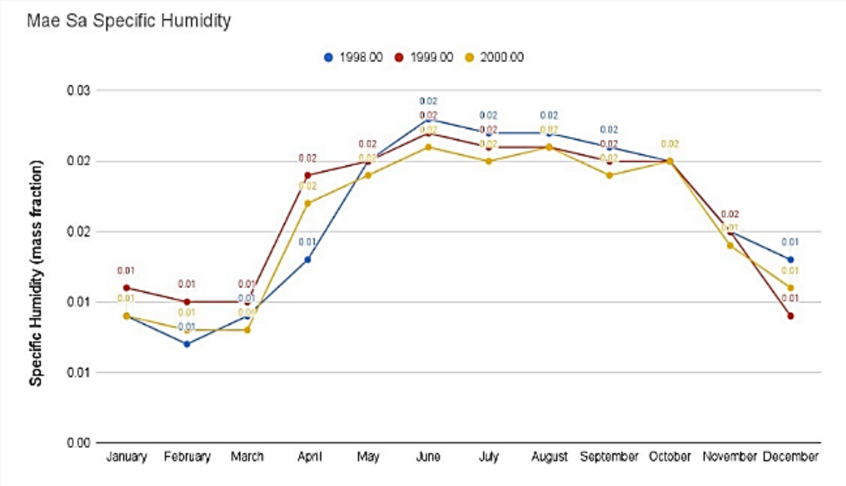


Figure 20: Graph showing relative growth rates in the root neck and analysis of climate data from 1998-2000.

After conducting a comparative analysis of the relative growth rates of average seedlings, it was determined that *Erythrina subumbran*s exhibited the highest relative growth rate among the perennial plants, followed by *Spondias axillaris* and *Nyssa javanica*, respectively.

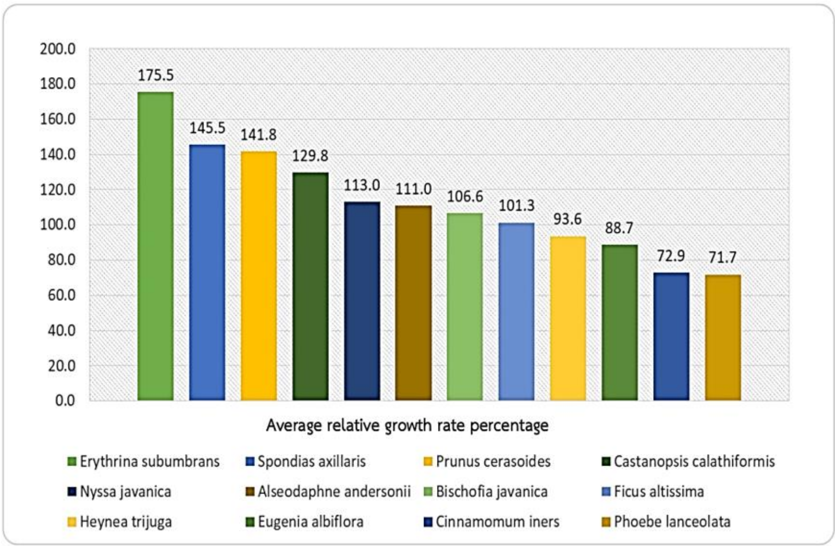


Figure 21: Graph showing the average relative root collar diameter growth rate of each type of seedling.

This is likely due to the fact that these perennial plants belong to a group of fast-growing species that germinate and thrive in areas with ample light. In the early stages of *Erythrina subumbrans* in the forest restoration plots, the spaces were mostly open, making them suitable for the growth of this particular group of plants.

As for the carbon sequestration rate, it was found that it was not correlated to the percentage of surviving trees as well. This can be seen from *Erythrina subumbrans* which had a survival rate at year 6 of only 13.2% but had the highest carbon storage rate which has the carbon sequestration value calculated from above-ground biomass of 41.0 kilograms.

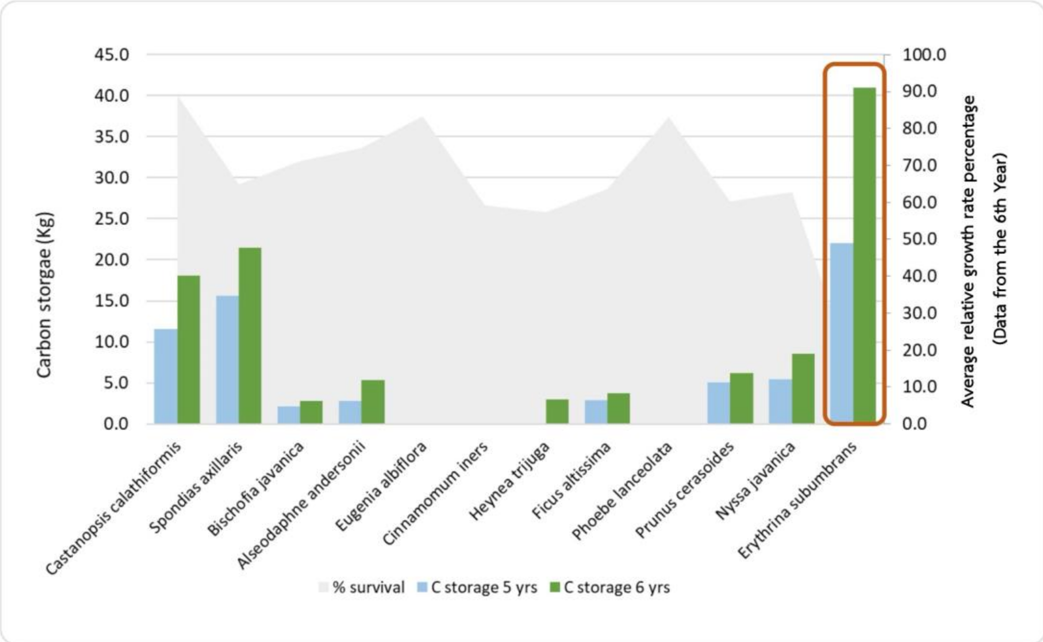
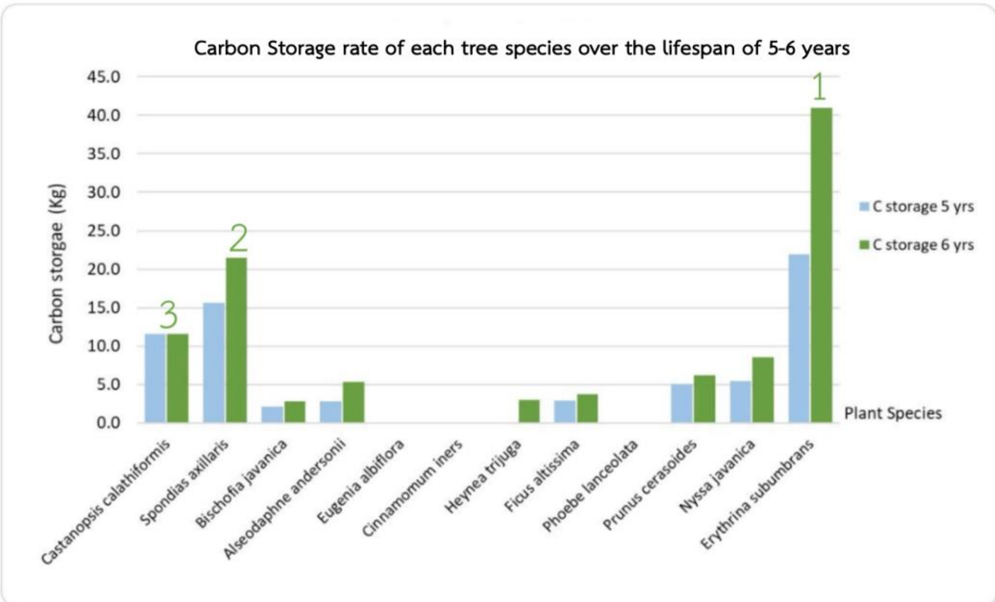


Figure 22. Graph showing the rate of carbon sequestration from above-ground biomass and percentage of survival of perennial plants. (data from the 6th year from the date of planting the seedlings).

We have considered the results of carbon storage from tree species and found that carbon storage at each life stage of trees, during the 5th-6th year, *Erythrina subumbrans* was the perennial tree with the highest carbon storage rate. This causes limitations of sunlight reaching the forest floor and may be a factor limiting the growth of light-demanding other tree species such as *Erythrina Subumbrans* and *Spondias axillaris* which have grown to maturity. It has tall trunks, creating a high dense canopy cover. This causes limitations of sunlight reaching the forest floor and may be a factor limiting the growth of light-demanding to other tree species such as *Erythrina Subumbrans*.



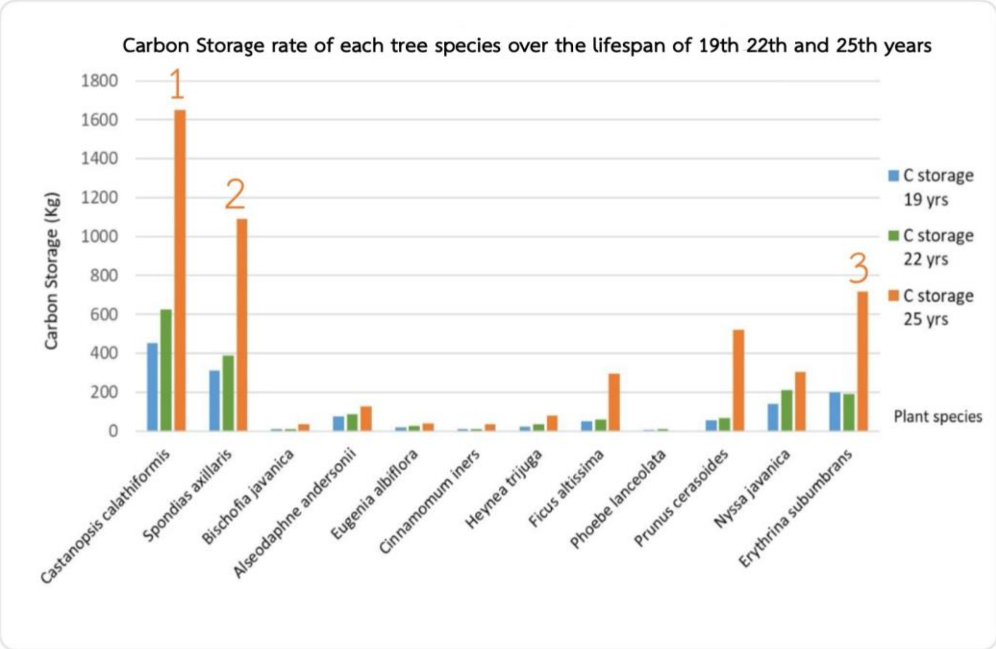


Figure 23 Graph showing the rate of carbon sequestration from above-ground biomass of perennial plants that changed during various periods
from the 5th to the 25th year.

We also conducted comparative analysis of the increased carbon storage of each successive year and found that almost all tree species have a low annual rate of carbon sequestration in their early years, which increases as they mature. However, as trees reach a certain age, their annual rate of carbon storage begins to decrease. Based on the results of this analysis, perennial plants can be classified into three general groups:

- A group of perennial plants that have the highest carbon storage at the age of 5 years is *Erythrina Subumbrans.*
- A group of perennial plants that store the most carbon during their lifespan of more than 5 years but not more than 20 years.
  - *Castanopsis calathiformis*
  - *Spondias axillaris*
  - *Alseodaphne andersonii*
  - *Nyssa javanica*
- A group of perennial plants with the highest carbon storage with a lifespan of more than 20 years.
  - *Bischofia javanica*
  - *Ficus altissima*
  - *Prunus cerasoides*

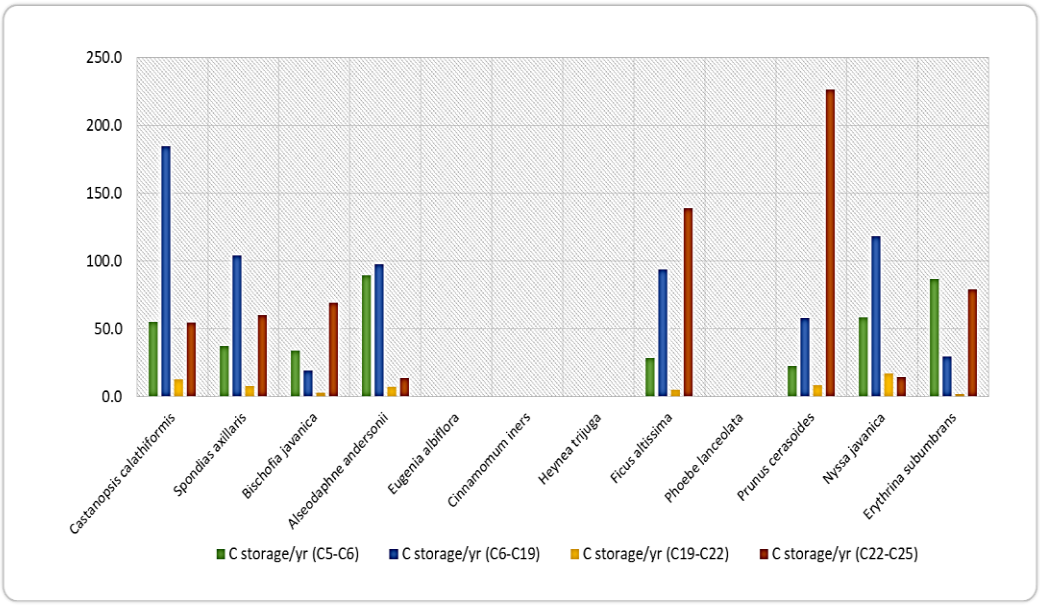


Figure 24 Graph showing the annual average increase in carbon storage rates of various tree species.

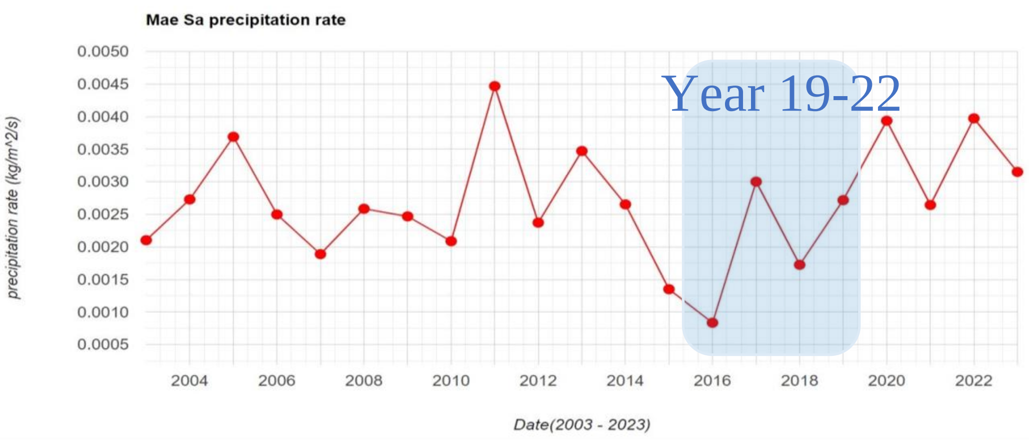


Figure 25 Graph showing the annual average of rainfall from 2004-2023

However, unfavorable weather conditions can also lead to a decrease in carbon sequestration rates. This can be observed from the average annual carbon sequestration of perennial trees in years 19-22, which decreased significantly. While aging may result in a decrease in the carbon sequestration rates of trees, lower rainfall during this period is likely an important factor causing the significant decrease in the carbon sequestration rates of trees. For some species, it was found that the biomass will remain low for several years. This can be seen from the graph of carbon sequestration rates of calendula and toadstool trees, which were low from 2016-2023 (C19-C23), as well as many other types of perennial plants that have low carbon sequestration values compared to prominent perennials such as *Eugenia albiflora*, *Cinnamomum iners*, *Heynea trijuga*, and *Phoebe lanceolata*. This may be due to poor drought resistance or possibly being disturbed by other tree species that grow faster.

From the experimental results and data analysis mentioned above, it can be concluded that each tree species has different growth rates and carbon storage. It depends on the physiology of each type of tree. The amount of rainfall is another important variable. Therefore, selecting the right type of tree that is suitable for the area is crucial. Additionally, favorable weather conditions will enable trees to have an efficient growth rate and carbon storage in the future, along with the proper sequencing of planting seedlings in the area.

For example, if the area is open and allows ample light to reach the forest floor, you can choose fast-growing plants that require sunlight and are drought-resistant. When the forest conditions begin to be fertile with more shade from the tree canopy. The first group of fast-growing tree species had a reduced rate of carbon storage. Therefore, you can add seedlings that thrive in lower sunlight, which have higher growth rates and carbon storage as they mature. Additionally, one should be cautious about introducing foreign trees into the area. While they may grow quickly and can store a lot of carbon, they could potentially impact the survival and growth of native plants. For example, in the Ban Mae Sa Mai rehabilitated forest area, *Castanopsis calathiformis*,
a native tree from Chiang Rai province, was brought to be planted in the area. With the physiology of trees with tall trunks and dense canopy, as well as in the food chain in the area, there are no consumers who eat *Castanopsis calathiformis* as food. The seeds and seedlings then spread and grow until they become prominent trees in the area and may result in a reduction in the number and ability of native trees to grow, eventually leading to disturbance of the biodiversity of the original area.

Figure 26 *Castanopsis calathiformis* and scattered seedlings are the dominant plants in the area.

Presentation clip

https://www.youtube.com/watch?v=NHZIzj-oPcs

Citations

A Febiriyanti, D H Pradana and A Putrika .(2021). Estimation of carbon stocks from tree stands vegetation in Universitas Indonesia's urban forest, Depok. **Journal of Physics: Conference Series.** January 1725 (2021).

Adisorn Isarangkun at Ayutthaya. (2016). **Reviving Forests with Forest Management Plans.** Bangkok: P.E.Leaf Wing Co., Ltd.

Atsadisit Hemmanmat. (2019). **Do You Know? How Much Forest Area Does Thailand Have Left?** December 2019, from https://www.salika.co/2021/03/16/thailand-forest-situation/.

Angkana Nakorn. (2019). **How Much Forest Have We Lost Compared to Forest Fires in the Northern Region?** December 2019, from https://urbancreature.co/greenindex-wildfire/.

Asamon Limasakul and colleagues. (2018). **Complete Research Report on the Development of Methods For Assessing Carbon Sequestration and Exchange Processes under the Carbon Assessment And Exchange Tool/Method Development Project**. Bangkok: Environmental Research and Training Center, Department of Environmental Quality Promotion, p. 27-34.

Biodiversity Division, Office of Natural Resources and Environmental Policy and Planning. (2011). **Biodiversity in Forests: The Wealth of Life**. Bangkok: Intergettech Promotion Technology Co., Ltd.

Elliott,S. et al. (2018). WHERE SCIENCE MEETS COMMUNITIES: DEVELOPING FOREST RESTORATION APPROACHES FOR NORTHERN THAILAND. **The Journal of the Natural History Society of Siam**, 63(1): p 11–26.

Jantawong, K.(2017). **Determination of aboveground carbon sequestion in restored forest by Framework species method.** PhD thesis, The Graduate School, Chiang Mai University.

Muhammad Zubair et al .(2022). Carbon Sequestration by Native Tree Species around the Industrial Areas of Southern Punjab, Pakistan. **Urban and Peri-Urban Forests Status, Ecosystem Services, and Future Perspectives**. September 11(9).

Ogawa, H., K. Yoda and T.Kira. (1965). A preliminary surway on the vegetation of Thailand. **Nature and life in SE Asia** 1: 21-157.

Panitanat Chananon. (2013). **Background Theory of Restoration**. Chiang Mai: Vitandesign Co., Ltd

Pimolrat Thiansawat et al . (2018). **The Influence of Weeds on Survival and Growth of Native Tree Seedlings during Forest Restoration in Northern Thailand. Journal of Science**, Khon Kaen University, Vol. 46, No. 4, p. 751-760.

P.J. Jithila and P.K. Prasadan.(2018). Carbon Storage and Sequestration by Trees - A Study in Western Ghats Wayanad Region. **Indian Journal of Ecology.** October 45(3).

UNEP / GRID-Arendal. .(2008). **Vital Forest Graphics-Stopping the Downswing?**. UNEP/GRID-Arendal, UNEP, FAO, UNFF.

Yuanyuan Wang, Xinzhu Dai, Xingling Chen et al. .(2024). Effects of urbanization and forest type on species composition and diversity, forest characteristics, biomass carbon sink, and their associations in Changchun, Northeast China: implications for urban carbon stock improvement. **Journal of Forestry Research.** January 35(1).

Appendix

Koh Mhoo Doi
Scientific name *Castanopsis calathiformis* (Skan) Rehder & E. H. Wilson
Family FAGACEAE

(Source:https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:358330-1)

Makok Ha Roo
Scientific name *Spondias axillaris* Roxb.

Therm
Scientific name *Bischofia javanica* Blume
Family Phyllanthaceae


(Source: https://assessment.ifas.ufl.edu/assessments/bischofia-javanica/ and https://www.picturethisai.com/wiki/Bischofia_javanica.html)

Toung Bai Chor
Scientific name *Alseodaphne andersonii* (King ex Hook.f.) Kosterm.
Family Lauraceae

(Source: https://www.picturethisai.com/wiki/Alseodaphne.html)

Ma Hah
Scientific name *Euenia albiflora* Duth. ex Kurz.
Family Myrtaceae

(Source: https://www.iucngisd.org/gisd/species.php?sc=983)

Aob Chury
Scientific name *Cinnamomum iners* (Reinw. ex Nees & T.Nees) Blume
Family Lauraceae


(Source: https://herbalramble.wordpress.com/2018/04/11/wild-cinnamon-cinnamomum-iners/)

Thar Suea Tung
Scientific name *Heynea trijug*a Roxb. ex Sims
Family Meliaceae


(Source: https://efloraofindia.com/2014/06/22/heynea-trijuga/)

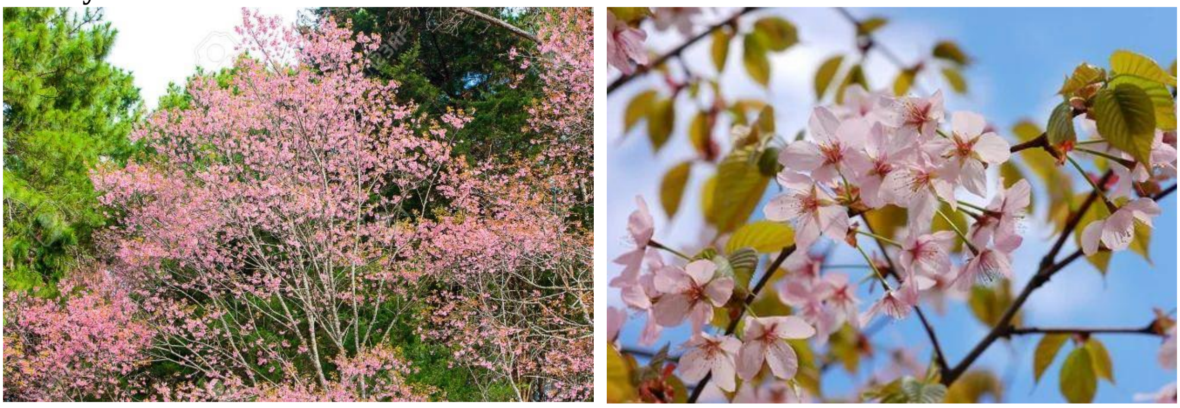
Grarng
Scientific name *Ficus altissima* Blume
Family Moraceae

(Source: https://www.picturethisai.com/th/care/Ficus_altissima.html)

Lae Book
Scientific name *Phoebe lanceolate* (Wall. ex Nees) Nees
Family Lauraceae

(Source: https://indiabiodiversity.org/observation/show/1800378)

Nang Pha Ya Suea Krong
Scientific name *Prunus cerasoides* Buch.-Ham. ex D.Don
Family Rosaceae



(Source: https://www.indiamart.com/proddetail/prunus-cerasoides-19038905112.html)

Kang Kak
Scientific name *Nyssa javanica* (Blume) Wangerin
Family NYSSACEAE

(Source: https://www.flickr.com/photos/helicongus/31740229028 and http://biotik.org/laos/species/n/nysja/nysja_03_en.html)

Thong lang pa
Scientific name *Erythrina subumbrans* (Hassk.) Merr.
Family Leguminosae

(Source: https://efloraofindia.com/2013/06/09/erythrina-subumbrans/)

GLOBE Data Entry (Biometry)

Latitude 18.5127, Longitude 98.5052, Elevation 1625m, SITE_ID: 338293
Observation Date: 5 February 2024

Dominant Vegetation Observation

Species	Tree no.	Height (m)	Circumference (cm)
Castanopsis calathiformis (Skan) Rehder & E.H. Wilson	#1	22.6	195
	#2	14.5	169
	#3	31.8	258
	#4	28	250
	#5	25.3	260
	#6	31.1	180
Spondias axillaris Roxb.	#1	18.7	148
	#2	22	277
	#3	24	215
	#4	21	173
	#5	21	200
	#6	29	201
Bischofia javanica Blume	#1	9	73
	#2	6.9	19.1
	#3	5	8.27
	#4	7	7.64
	#5	11	13.1
Alseodaphne andersonii (King ex Hook.f.) Kosterm.	#1	13	52
	#2	13.6	85
	#3	15	42.5
	#4	18	81
	#5	15	63
Cinnamomum iners (Reinw. ex Nees & T.Nees) Blume	#1	13	41
	#2	10	57
	#3	9	50
	#4	6	49
	#5	9.4	38
Heynea trijuga Roxb. ex Sims	#1	17	63
	#2	11	90
	#3	10	48
	#4	6	29
	#5	16	63
Ficus altissima Blume	#1	22	135
	#2	23	87
	#3	10	53
	#4	17	82
	#5	22	130
	#6	13.2	107

Species	**Tree no.**	**Height (m)**	**Circumference (cm)**
Prunus cerasoides Buch.-Ham. ex D.Don	#1	19.1	267
	#2	11	136
	#3	17	66
	#4	14	134
	#5	21	108
	#6	15	113

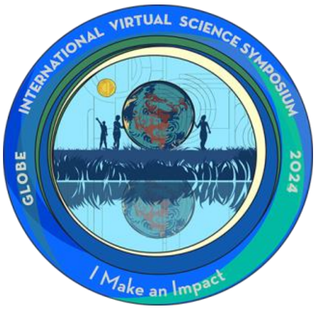
Due to some limitation with data entry system I has not been entry the data of dominant tree which observe at study site, Mae Sa Mai restoration forest. I has been sent an e-mail to GLOBE support team before to add scientific name of above tree species but sending e-mail is failed, so I add the data of tree species in this report instead.

Badges Descriptions

I AM A COLLABORATOR

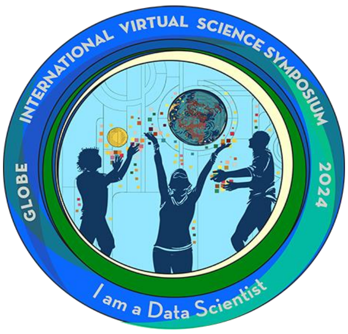
In the collecting data at the study site ,Ban Mae Sa Mai, we get the great collaboration with local people who stay and gain benefits from the forest and Dr.Kwanphirom. They are responsible for identify the location of each tree we choose to study in the plant plot because this forest is planted since 1998 and now it grows and becomes climax stage . Then each team member will measure and collect tree data according to task assignment as follows ;
Pimchanok and Bhira measure the canopy width and length Ekkawee measure DBH , Wichapat and Panissara measure tree height . Both of advisors record tree data. Furthermore the previous observe information of tree in study site during 1998-2020 which Dr.Kwanphirom gave us help us to prepare observing and collecting data before go to study site. With this great teamwork help us to finish task on time and get efficient data to analyze in the next step. After we get all data both from FORRU database and observing at study site the members will enter tree data and calculate RGR-CRD and carbon storage together through Google sheet. In the same time Ekkawee who has the talent in coding he responsible for organizing weather data from Google Earth Engine database through python.

I MAKE AN IMPACT



Our project get an inspiration from joining Youth Forest Restorers project with FORRU which and organization established to study the techniques for forest restoration and the ecosystem to conserve biodiversity. We learn and do many activities which built us an awareness of forest importance. We start the project of growth rates and carbon storage among various species of tree with hoping that our research will inspire other people in our Chiang Mai province and make an impact for heightened the local's awareness in conserving and restoring forests. Actually, we get an opportunity to present our project at "Celebrate activity" event which do by FORRU on 9 March 2024.

I AM A DATA SCIENTIST



In this project we analyze Relative Growth Rate of Root Collar Diameter and carbon storage from tree data including DBH and tree height during 1998-2020 from FORRU and our own observing in February 2024 for data year 2023. Furthermore, we organize weather information from data of TERRA satellite in Google Earth Engine and analyze this data with RGR-CRD and carbon storage to draw conclusions. However the data is discontinuous for many year due to limitation of staff team and COVID-19 pandemic we expect that in the next project we try to plan for continuous collecting data to draw more accurate conclusions.