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Study on the possibility of agroforestry intercropping system in aged forest plantations and stakeholder perspectives



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Abstract

Agroforestry practice involving the intercropping of crops with trees on the same unit of land is a win-win strategy to meet the need for wood products and food at the same time. Thus, this study was conducted to examine the possibility of planting elephant foot yam and tumeric between the tree rows of aged forest plantation. To access the yield of elephant foot yam (*Amorphophallus paeoniifolius*) and black ginger (*Kaempfera parviflora*), field experiments (25 m x 25 m) were conducted in Teak plantation (1988), Padauk plantation (1980) and bamboo plantation (2004) of Moe Swe Forest Research Station during 2021 to 2022. To access the performance of soil properties on the yield of crops, soil samples were collected from the top of 20 cm of each experimental plots and analyzed. To identify the stakeholders' perception of agroforestry intercropping system, we conducted structured interviews with 80 respondents including 40 households from Moe Swe village, 20 Staff Officers and 20 Assistant Directors of Forest Department. The results indicate that elephant foot yam can be profitably intercropped with aged forest plantations without any treatment whereas soil improvement would be necessry for tumeric. It was found that soil organic matter (SOM) increased significantly and the other nutrients slightly increased after one year planting. Crop yields were positively correlated with increasing levels of top SOM. Increased soil organic matter lead to increases in top SOM, resulting in increased crop yields. Likeart analysis shows that 53 % of respondents strongly agree intercropping system in aged forest plantations while 18 % agree, 11 % neither agree or disagree, 11 % disagree and 8 % strongly disgree. Challenges were mostly identified for the management and socio-economic categories.The study provides match-finding between perceived challenges and solutions identified by the stakeholders.

Keywords: agroforestry, aged forest plantations, experimental plots, soil organic matter, yield

သစ်တောသက်ကြီးစိုက်ခင်းများတွင် ရာသီသီးနှံများ ကြားညှပ်စိုက်ပျိုးခြင်းစနစ် နှင့် ၎င်းစနစ်အပေါ် ဆက်စပ်ပတ်သက်သူများ၏ သဘောထားအမြင်ကိုလေ့လာခြင်း

စာတမ်းအကျဉ်း

သီးနှံသစ်တောရောနှောစိုက်ပျိုးခြင်းသည် သစ်တောထွက်ပစ္စည်းနှင့် စားနပ်ရိက္ခာလိုအပ်ချက်ကို တစ်ချိန်တည်းတွင် ဖြည့်ဆည်းပေးနိုင်သော နည်းစနစ်တစ်ခုဖြစ်ပါသည်။ ယခုလေ့လာမှုမှာ သစ်တော သက်ကြီးစိုက်ခင်းများတွင် ဝဥနှင့် နနွင်းနက်ကြားညှပ်စိုက်ပျိုးနိုင်မှု ဖြစ်နိုင်ချေရှိ/မရှိအား စမ်းသပ်လေ့လာထားခြင်းဖြစ်ပါသည်။ ဝဥနှင့် နနွင်းနက်၏ အထွက်နှုန်းကိုလေ့လာရန်အတွက် မိုးစွေသစ်တောသုတေသနစခန်းရှိ ကျွန်းစိုက်ခင်း (၁၉၈၈)၊ ပိတောက်စိုက်ခင်း (၁၉၈၀)ခုနှစ်နှင့် ဝါးစိုက်ခင်း (၂၀၀၄) ခုနှစ်တို့တွင် ၂၀၁၂ ခုနှစ်မှ ၂၀၂၂ ခုနှစ်အထိ ၂၅ မီတာပတ်လည်စမ်းသပ်ကွက်များ တည်ထောင် စိုက်ပျိုးခဲ့ပါသည်။ ကြားညှပ်စိုက်ပျိုးသည့် သီးနှံများ၏အထွက်နှုန်းအပေါ်တွင် စိုက်ခင်း မြေဆီလွှာအရည်အသွေး၏ သက်ရောက်မှုကို သိရှိရန်အတွက် စမ်းသပ်ကွက် တစ်ခုချင်းစီ၏ အပေါ်ယံမြေဆီလွှာ၂၀ စင်တီမီတာမှ မြေနမူနာများကို ကောက်ယူလေ့လာခဲ့ပါသည်။ သက်ကြီးစိုက်ခင်းများတွင် ရာသီသီးနှံများကြားညှပ်စိုက်ပျိုးခြင်းအပေါ် ဆက်စပ် ပတ်သက်သူများ၏ သဘောထားအမြင်ကို သိရှိနိုင်ရန်အတွက် မိုးစွေကျေးရွာမှ အိမ်ထောင်စု (၄၀)ခု၊ သစ်တောဦးစီးဌာနမှ ဦးစီးအရာရှိ (၂၀)ဦးနှင့် လက်ထောက်ညွှန်ကြားရေးမှူး (၂၀)ဦး စုစုပေါင်း (၆၈) ဦးတို့အား တည်ဆောက်ထားသော မေးခွန်းများကို အသုံးပြု၍ မေးမြန်းခဲ့ပါသည်။ လေ့လာတွေ့ရှိချက်အရ သစ်တောသက်ကြီး စိုက်ခင်းများတွင် ဝဥကြားညှပ်စိုက်ပျိုးခြင်းဖြင့် အကျိုးအမြတ်ရရှိနိုင်ပြီး နနွင်းနက်စိုက်ပျိုးရန်အတွက် မြေဆီလွှာပြုပြင်ရန် လိုအပ်ကြောင်းတွေ့ရှိရပါသည်။ ရာသီသီးနှံများ ကြားညှပ်စိုက်ပျိုးပြီး တစ်နှစ်အကြာတွင် အပင်များအတွက် လိုအပ်သောအာဟာရများ၏ မြေဆီလွှာ အရည်အသွေးအနည်းငယ်သာ တိုးတက်မှုရှိသော်လည်း မြေဆွေးဓါတ်မှာ သိသိသာသာကောင်းမွန်လာပါသည်။ ရာသီသီးနှံများ၏ အထွက်နှုန်း မှာ အပေါ်ယံလွှာမြေဆွေးဓါတ်နှင့် ဆက်စပ်မှုရှိနေပြီး မြေဆွေးဓါတ်ကောင်းမွန်မှုသည် အပေါ်ယံမြေဆီလွှာကောင်းမွန်မှုကို ဖြစ်ပေါ်စေပါသည်။ Likeart scale ခွဲခြမ်းစိတ်ဖြာခြင်းအရ သက်ကြီးစိုက်ခင်းများတွင် ရာသီသီးနှံများ ကြားညှပ်စိုက်ပျိုးခြင်း စနစ်အား အလေးအနက်သဘောတူသည် (၄၅%)၊ သဘောတူသည် (၁၉%)၊ ကြားနေ (၁၄%)၊ သဘောမတူပါ (၁၃%) နှင့် ပြင်းပြင်းထန်ထန်ကန့်ကွက်သည် (၉%) ရှိကြောင်း တွေ့ရှိရပါသည်။ အဆိုပါစနစ်အတွက် စီမံအုပ်ချုပ်မှုနှင့် လူမှုစီးပွားရေးဆိုင်ရာ အဓိက စိန်ခေါ်မှုများကို ဖော်ထုတ်နိုင်ခဲ့ပါသည်။ စိန်ခေါ်မှုများကို ဖြေရှင်းနိုင်မည့် ဆက်စပ် ပတ်သက်သူများ၏ အမြင်များကိုလည်း လေ့လာတင်ပြထားပါသည်။

Study on the possibility of agroforestry intercropping system in aged forest plantations and stakeholder perspectives

1. Introduction

Plantation forests are increasing rapidly in the world in order to alleviate deforestation and degradation of natural forests, along with providing various goods and services (Corasa et al., 2018). The increasing demand is also related to mitigate greenhouse gas emissions. Each year, large areas of natural forests are cleared, degraded, and converted to other land uses and the global forest area has decreased with a rate of around 13 million ha per year during 2000 to 2010 (FAO, 2006, 2010). As a result, plantation forestry is developed to mitigate future wood shortage problems and produce a huge proportion of world industrial wood and other forest products.

Planted forests have a vital role in conserving natural forests, improving and restoring degraded lands, sequestering carbon dioxide and combating climate change. Since the 1960s, intensive forest plantations become increasingly ubiquitous in North America, South America, Oceania and parts of Asia. The total area of global forest plantations increased from 167.5 million ha in 1990 to 277.9 million ha in 2015, and the percentage increased from 4.1% to 7.0% over this period (Corasa et al., 2018).

While monoculture plantations have been the dominant type of plantation in practice and well recorded in research for its favorable timber production, easy management and climate change mitigation, some scholars argued that monoculture plantation may cause lower levels of biodiversity, soil erosion and degradation and lower assistance to pest and diseases. In the face of intensifying climate change and resource scarcity, there is a growing interest in mixed-species plantations. Agroforestry systems are also catching in the attention of scholars, foresters, smallholders and landowners (Corasa et al., 2018; Kusters et al., 2013). It also represents an important type of mixed-species system, where woody perennials (trees and shrubs) are grown in association with agricultural crops and pastures on the same land and at the same time.

The ASEAN guidelines for agroforestry development (2018) defines that "Agroforestry is the interaction of agriculture and trees, including the agricultural use of trees. This includes trees on farms and in agricultural landscapes, farming in forests and at forest margins, and tree-crop production. Interactions between trees and other components of agriculture such as livestock, fish and aquatic species is important at a range of scales: in fields (where trees and crops are grown together), on farms (where trees may provide fodder for livestock, fuel, food, shelter or income from products, including timber) and landscapes (where agricultural and forest land-uses combine in determining the provision of ecosystem services)'.

Several scholars such as Sanjeev et al., 2012; Diwakar et al., 2018; Wibawa et al., 2006; Roshetko et al., 2013 accessed the advantages of mixed-cropping by studying rubber-based agroforestry as alternative for rubber monoculture system in Indonesia; poplar-based and bamboo-based Agroforestry in India for livelihood and ecological security and contributions of agroforestry teak systems in Indonesia. They highlighted that agroforestry meets not only wood demand of the world but also food security of human population; enhance soil properties; produce commodities for both household consumption and market sale; encourage poverty reduction for the women who have no access on land reduce the weeding costs; increased participation of local communities in reforestation and create job opportunities.

To retard deforestation and to prevent the conversion of land use, Myanmar Forest Department has been carrying out three types of forest plantation system: state-owned forest plantations; community forest plantations and private owned forest plantations (Forestry in Myanmar, 2020). Large scale plantation forestry in Myanmar began in the early 1980s to fulfill the increasing demand for timber and to prevent the conversion of deteriorated forestland to agricultural land. The nature of ownership varies from government to the private sector who has large area of forest plantations and the local community. Till 2022 October, 948,436 ha of state-owned forest plantations and 273,251 ha of private-owned forest plantations had been established throughout the country (Plantation and Natural Forest Division, FD).

Myanmar Forest Department is being applied the Taungya system in establishing teak plantations. The Taungya System is a form of agroforestry system in which short-term crops are grown in the early years of the plantation of a woody perennial species to utilize the land, control weeds, reduce establishment costs, generate early income, and stimulate the development of the woody perennial species (Suzuki et al., 2009; Tin Min Maung & Yamamoto, 2010). Under Taungya system, shifting cultivators or local people who plant teak trees can cultivate intercrops between the rows of teak for 3 to 5 years after the tree plantations. After that, there is no more intercropping with cash crops until the trees reached harvesting age. To manage Taungya plantations successfully in the future, San Win (1998) stated two points: provision of adequate wage for forest workers and introduction of hight yield production technique for Taungya agricultural crops.

2. Objectives

We conduct this study with the following objectives:

- To examine the possibility of planting elephant foot yam and turmeric between the tree rows of aged forest plantation
- To access the soil properties after one year of intercropping
- To identify the perceptions of stakeholders on agroforestry intercropping system

3. Materials and Methods

3.1. Study Site and layout design

The experiments were conducted inside Teak plantation, Padauk plantation, ITTO Bamboo plantation at the Moe Swe research station of Forest Research Institute, which is located 16 miles from Nay Pyi Taw established in 1988, 1980 and 2004 respectively (Figure-1). The sample plots were laid out using randomized block design without treatments. The block size was 25 m square feet as shown in the figure 2. Site cleaning was done by clearing of all weeds and shrubs using manual labor. This was followed by preparing 30 rows in each plot for planting crops. Elephant foot yam (*Amorphophallus paeoniifolius*) tuber and black ginger rhizome (*Kaempfera parviflora*) were raised in the sample plots in the pits of 4 inches x 4 inches x 4 inches. The rhizome of black ginger is collected from Tuangkya village while elephant foot yam tuber is collected from Chin state via trader. The plant to plant distance was 1 feet for black ginger and 3 feet for elephant foot yam. The crops were planted in August 2021 (5 viss of elephant foot yam tuber and10 viss of black ginger were planted in each plots). Weeding and soil mulching was conducted once a year.

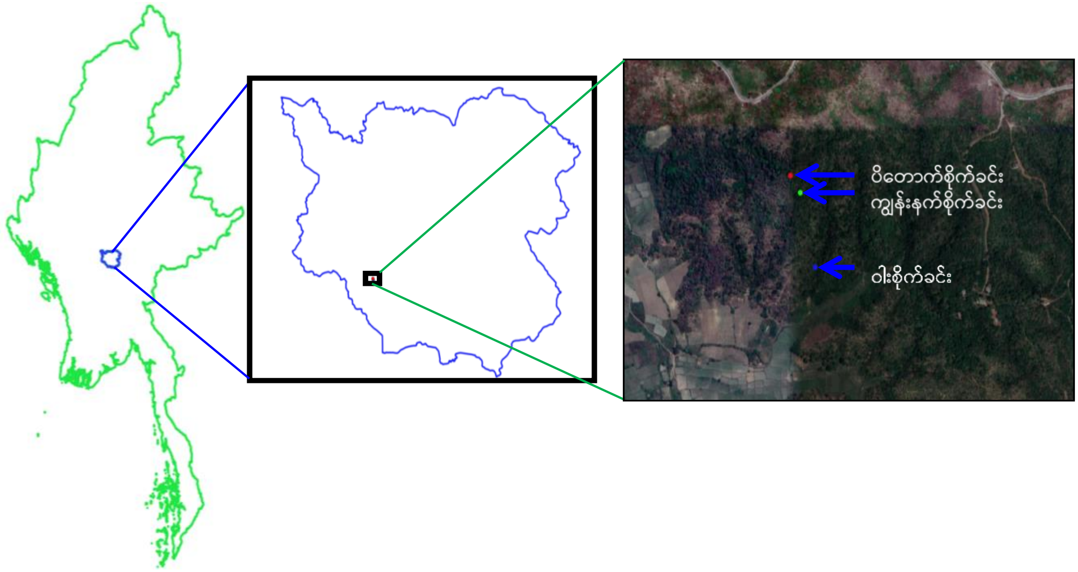

Figure1. Location map of the study areas in Moe Swe (Padauk Plantation, Teak Plantation and Bamboo Plantation)

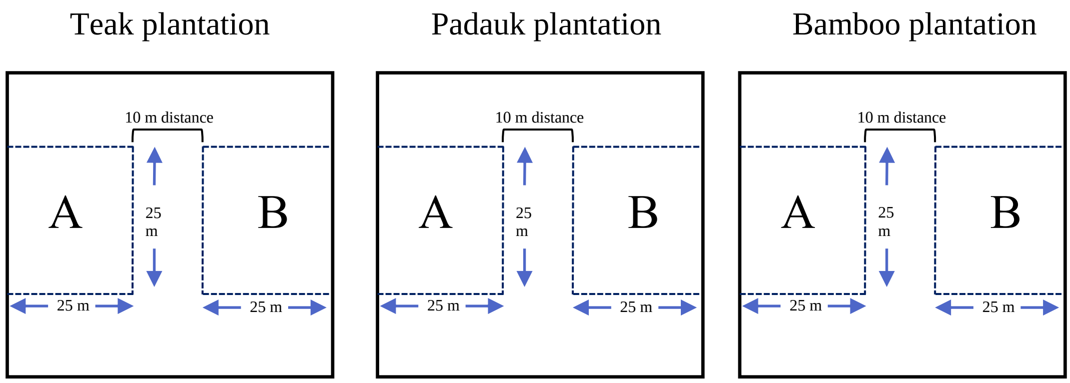

Figure 2. Experimental plots design

3.2. Data collection and analysis

To examine the possibility of planting elephant foot yam and turmeric between the tree rows of aged forest plantation, data were collected on growth (height), weight and length of harvested elephant foot yam tuber and black ginger rhizome. Soils were collected from the top 20 cm of each agro forestry plot and samples were air-dried and sieved to < 2 mm for soil analysis. Particle size distribution (Texture) was determined by the pipette method after dispersion with 0.4N sodium pyrophosphate. Soil pH was measured on 1:2.5 soils: water suspensions with glass electrode on a pH meter (1100). Total nitrogen was determined by using Kjeldahl method with digestion and distillation unit. Phosphorus can available by extraction with double acid by spectrophotometer DR/2000 wavelength 600nm. Extractable Ca and K were obtained by extracting soil with double acid with an atomic absorption spectrophotometer and Organic matter by the Loss of Ignition.

Stakeholders perceptions were derived from structured interview with 80 respondents consists of 40 households form Moe Swe village, 20 Staff Officers (SO) and 20 Assistant Directors (AD). Data such as demographic characteristics of households, prospects and challenges of intercropping in aged forest plantations and preferable crops were collected. Information obtained from the questionnaires was transmitted into a database for eventual analysis using Microsoft Excel 2010. Likert scale analysis was used to identify stakeholders' perceptions on agroforestry intercropping system. Perceived challenges and solutions are illustrated based on Rolo et al., (2020). The secondary sources of data were collected from journals, books, various publications through internet browsing.

4. Results and Discussions

4.1.Growth and yield of elephant foot yam and black ginger

At 1 year after planting, survival percentage of elephant foot yam and black ginger in each experimental plot were recorded (as shown in the Table 1). The survival percentage of elephant foot yam and black ginger is higher in Bamboo plantations as compared to Paduak and Teak plantations. This may be attributed to environmental parameters of plantations (e.g. soil conditions). Growth character in terms of height and leaves was also observed in July 2022 as shown in the Table 1. Harvesting was done during December to January.

Table1. Growth and yield of elephant foot yam and black ginger

Types of plantations	Survival Percentage (%)		Height (inches)		Yield (per acre)	
	Elephant foot yam	**Black ginger**	**Elephant foot yam**	**Black ginger**	**Elephant foot yam**	**Black ginger**
Teak	40	50	4-16 inches	2-4 inches	29 viss	13 viss
Paduak	60	70	8-25 inches	1-6 inches	47 viss	23 viss
Bamboo	70	75	10-28 inches	2-4 inches	50 viss	26 viss

It was found that the yield of elephant foot yam is highest in Bamboo plantations followed by Paduak and Teak plantations. However, the length and weight of tuber is the biggest in Paduak plantation (1 viss with 6 inches in length) followed by Bamboo (0.8 viss with 5.5 inches in length) and Teak plantation (0.5 viss with 3.5 inches in length). It may be related to nitrogen fixing species of Padauk which is required for post flowering and reproductive growth stage (Asafa and Akababi, 2018). According to literatures and phone conversation with local farmers, the yield is about 2 times that of the planted parent tuberous root. In this study, the yield of elephant foot yam is likely to get 2 times of planted tuber in Bamboo and Paduak plantations whereas the yield of black ginger is lower than planted rhizome although Black ginger demonstrated good growth. This may be attributed to environmental parameters of plantations (e.g. soil conditions). Further research is necessary to intercrop black ginger with treatments such as different age of plantations, planting method, source of rhizome and site preparation and shade conditions.

4.2.Relationship between soil properties and yield of intercrops

4.2.1. Soil Properties and Top SOM

Physio chemical properties of agroforestry plots are presented in Appendix. The soil texture in agroforestry plots are sandy-loam and Loamy-sand soil type condition. As shown in the following figures, Soil pH is moderately acidic reaction. The major nutrients such as Total Nitrogen and Available Phosphorus markedly low condition for the plant growth except available potassium. In addition, soil organic matter was also minimum status in all plots. It was found that soil organic matter increased significantly and the other nutrients slightly increased after one-year planting. Level of soil organic matter were 2.3% for P (Paduak) plots, 2.00% for T (Teak) and 4.00% for Bamboo (B) whereas the level of organic matter was 4.6 % for P plots, 3.8% for T and 5.8% for B after one year.

The highest topsoil organic matter was found in bamboo agroforestry plots with the average of 17.86 ton/ acre in elephant food yam and 29.01 ton/acre. The amount of top SOM in plots used to grow in padauk plot was the second followed by teak, with average top SOM values of 17, 19 ton/acre, 12 and 14 ton/acre respectively.

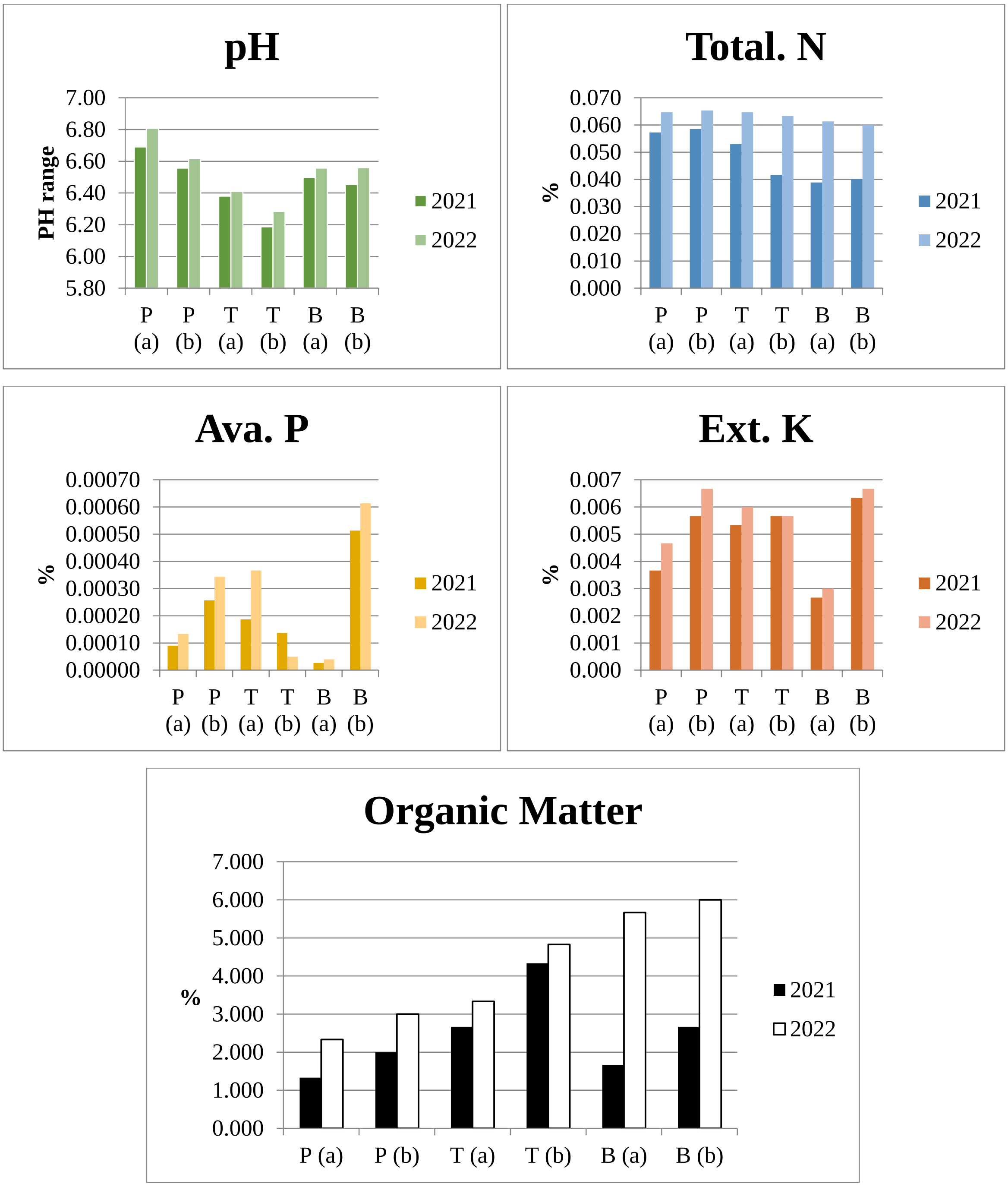

Figure 3. Physio chemical properties of agroforestry plots

4.2.2. Relationships between Top SOM and Crop Yields

As shown in Figure 4, crop yields were positively correlated with increasing levels of top SOM. Increased soil organic matter lead to increase in top SOM and that is resulting increase in crop yields. This might be due to high silica content in annual litter fall which absorb more carbon than any other species.

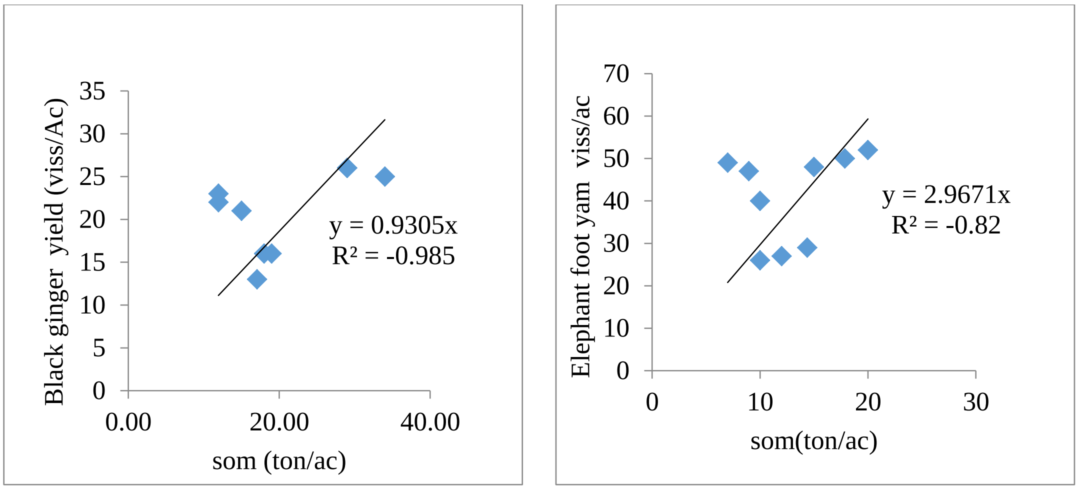

Figure 4. Relationships between Top SOM and Crop Yields

4.3.Stakeholders' perceptions of agroforestry intercropping system in aged forest plantations

4.3.1 Do you agree with agroforestry intercropping system in aged forest plantations?

Likert scale analysis was used to identify the stakeholders' perception of agroforestry in aged forest plantations using structure questionnaires. In the case of local communities of Moe Swe village, 63% of respondents strongly agree intercropping system in aged forest plantations while 10% agree, 8% neither agree nor disagree, 8% disagree and 13% strongly disagree. Within the Staff Officer of Forest Department, 25% of respondents strongly agree intercropping system in aged forest plantations while 30% agree, 5% neither agree nor disagree, 5% disagree and 15% strongly disagree. For Assistant Director, 60% of respondents strongly agree while 20% agree, 3% neither agree nor disagree, 3% disagree and 5% strongly disagree. As an overall, 53% of respondents strongly agree intercropping system in aged forest plantations while 18% agree, 11% neither agree nor disagree, 11% disagree and 8% strongly disagree. Based on the results, it can be concluded that stakeholders agreed on agroforestry intercropping system in aged forest plantations.

The Chi square analysis shows that there is a relationship between their experience and opinion. 93% of the experienced persons agree agroforestry in aged forest plantations while 64% of the experienced persons strongly agree, 67 of the inexperienced persons disagree and 67 % of the inexperienced persons agree or disagree agroforestry in aged forest plantations.

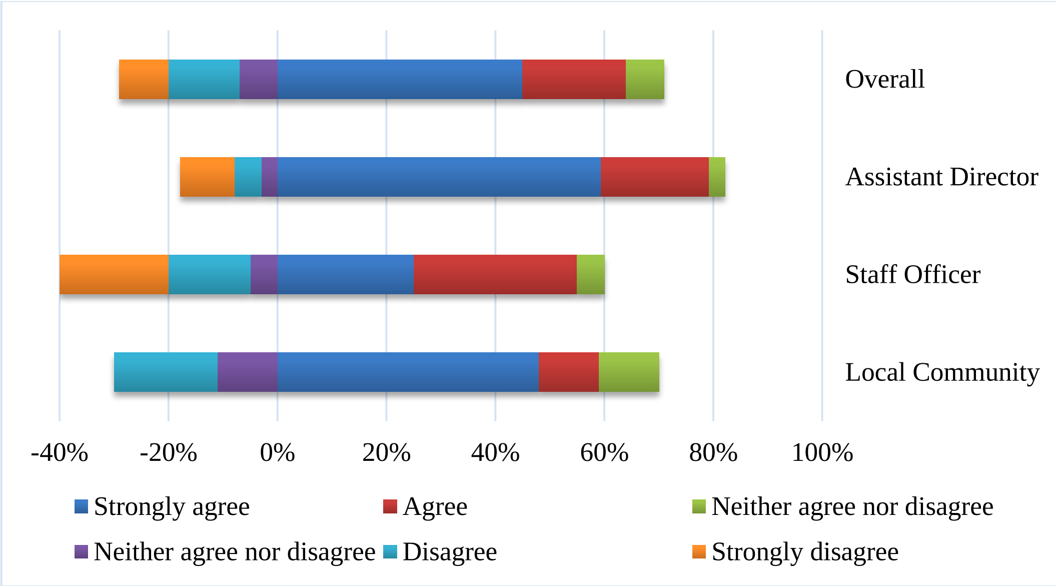

Figure 5. Stakeholders' perception of agroforestry intercropping system

4.3.2 What are the advantages and disadvantage of agroforestry intercropping system?

The advantages of agroforestry in aged forest plantations include increased income for rural family, protection of aged forest plantations, soil conservation, better relationship with local community and FD and others. Others include good program for land-less people, reduced illegal logging, food security and good soil decomposition. The disadvantages of agroforestry include illegal logging, conflicts with FD, fire and others. Figure (6) and (7) show the percentage respondents for each stakeholder group regarding advantages and disadvantages of agroforestry in aged forest plantations. Study revealed that FD staff as well as local community believed that income for rural family will be increased. Study found that illegal cutting would be negative attributes of this system although most of the respondents agree that the relationship with local community and FD would be better.

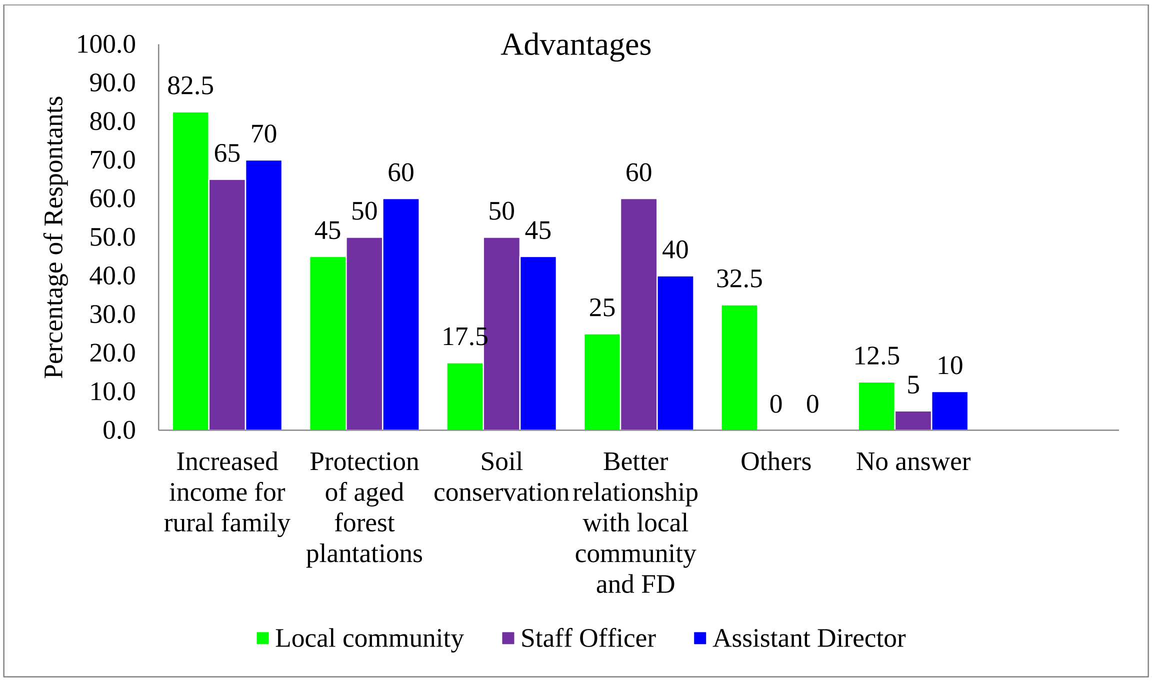

Figure 6. Stakeholders' perceptions on advantages of agroforestry intercropping system

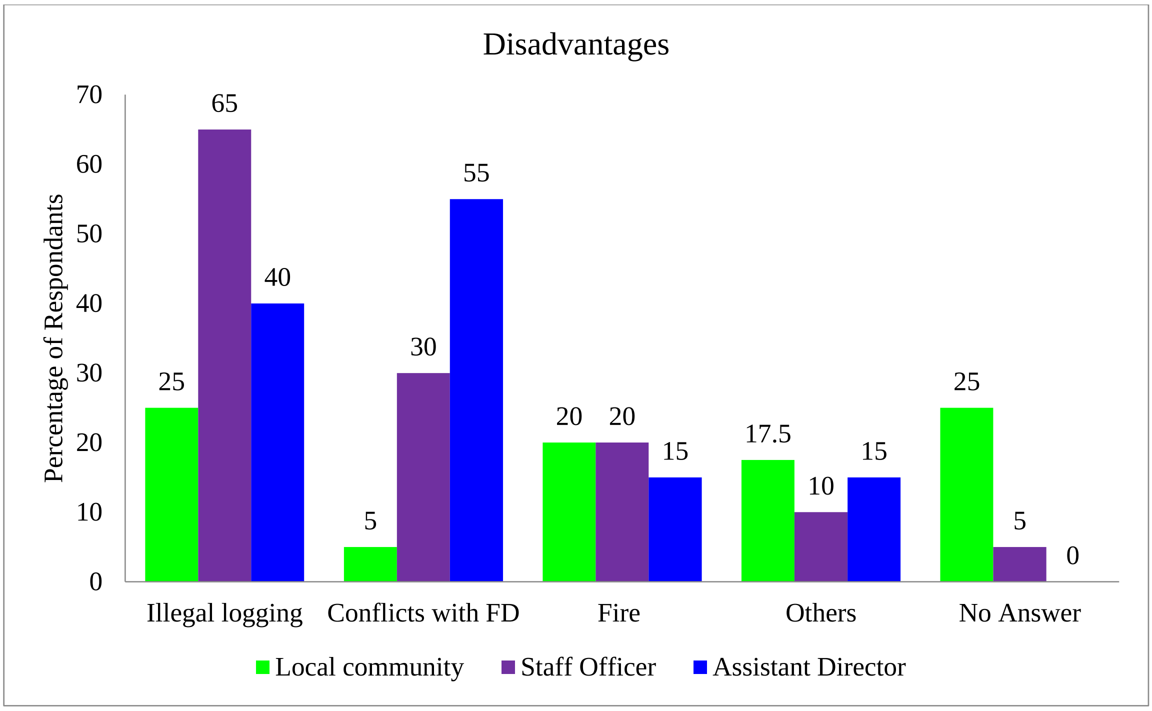

Figure 7. Stakeholders' perceptions on disadvantages agroforestry intercropping system

4.3.3 What are the perceived challenges and solutions?

Based on the interview with 80 respondents, eight main themes were identified in total: (i) Technical support, (ii) Investment, (iii) Land-use conflicts, (iv) Management conflicts, (v) Natural disasters, (vi) Profitability, (vii) Interest of communities and (viii) Extension. Seven challenges were related to management, eight to socio-economic issues, three to production and two to the environment as shown in figure (8) and table (2).

Under the management category, illegal cutting and land encroachment are common challenges. To address the illegal cutting, one common solution was the use of contract system with regulations. The need of extension and punishment according to the law were also identified by SO group while AD group identified the need of annual monitoring and ground check to address this. Informing FD staff and village head was identified by LC group. Land-use conflicts was mostly seen as a challenge by AD group as communities can assume their own land after long time of inter-cropping and changes of land use into agriculture or residence area. The identified strategies to address this included the use of contract system and mapping and the need of extension services. SO group pointed out the perceived management conflicts between FD staff and local communities while FD staffs are doing silvicultural operations in aged forest plantations so it is necessary to make them forest operations. LC also highlighted management conflicts between cultivators and illegal harvesters at the village.

Within the socio-economic category, decreased profitability of forest plantations by destroying planted trees was seen as a critical by two groups. Response from FD staff group highlighted regular check by FD staff, systematic species selection and the use of contract system to avoid misunderstanding. FPIC would be necessary to give message that FD gives only use-rights of the land. Pre-inventory should be done to record the number of existing planted trees before giving land-use rights. Meanwhile, there was a general perception of the need to consider communities' interest in terms of market, process of issuing permit/certificate for intercropping in aged forest plantations and area (space) for planting crops. Proposed solutions was setting up clear guidelines, rules and regulations before starting progarmme, allotment of forest plantations that had been finished thinning operations for the space and the need of extension services.

In terms of production-related challenges, all three groups highlighted the need of technical support in terms of species selection and cultivation technology. Local communities also highlighted the challenge of money (investment) for seeds and pre-planting and post-planting tasks in agriculture. Environmental challenges included climate factors and fire. The identified solution was not to allow throwing agro-waste in aged forest plantations.

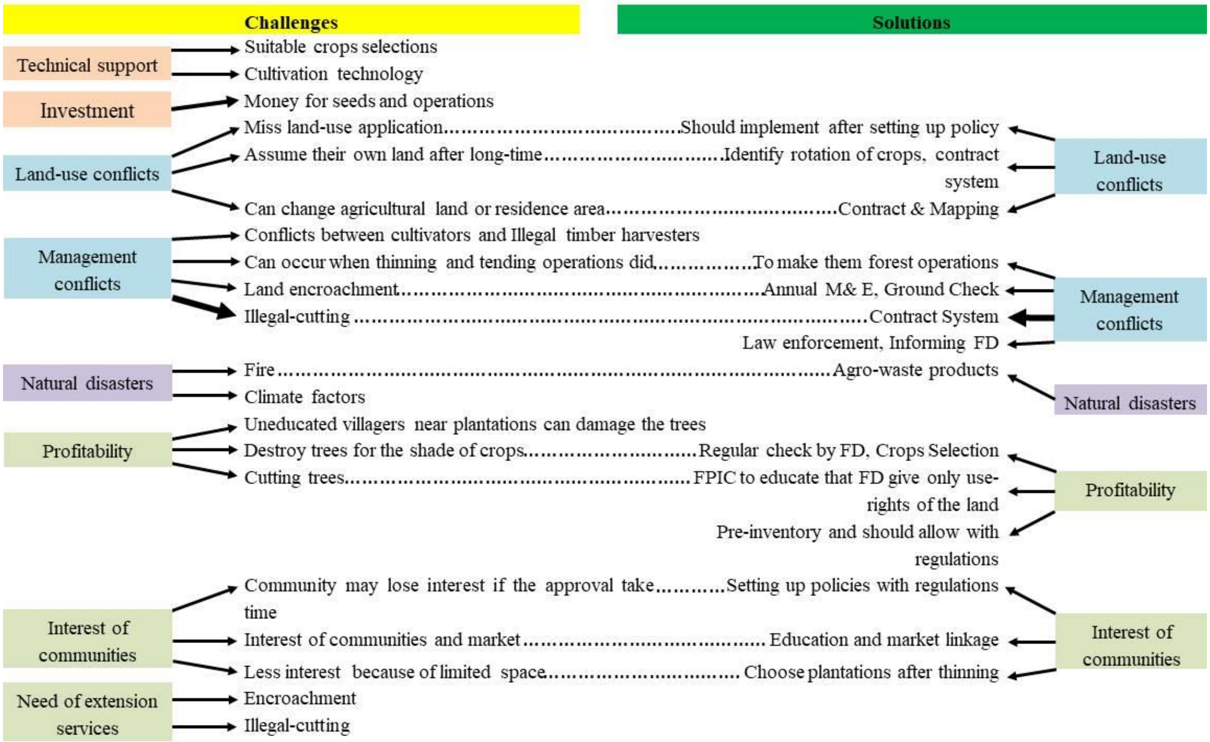

Figure 8. Match-finding between challenges and solutions identified by stakeholders

Table 2. Challenges prioritized by stakeholders and solutions

Categories	Themes	Challenges	Stakeholder Groups
Production	Technical support	Species selections	AD, SO, LC
		Cultivation technology	SO, LC
		Suitable crops selection	AD
	Investment	Money for seeds and operations	LC
Management	Land-use conflicts	Assume their own land after long-time of inter-cropping	SO
		Miss land-use application	SO
		Can change agricultural land or residence area	AD
	Management conflicts	Conflict between cultivators and Illegal timber harvesters	LC
		Conflict can occur when thinning and tending operations did	SO
		Land encroachment	AD, LC
		Illegal-cutting	AD, SO, LC

Categories	Themes	Challenges	Stakeholder Groups
Environment	Natural disasters	Fire	AD
		Climate factor	LC
Socio-economic	Profitability	Uneducated villagers near plantations can damage the trees	SO
		Destroy trees as community worry about shade for crops	AD
		Can damage trees for favorable conditions for crops	AD
	Interest of communities	Community may lose interest if the process for approval take time	AD
		Interest of communities and market	SO
		Less interest by communities because of limited space	AD
	Need of extension services	Encroachment	
		Illegal-cutting	

5. Conclusion

This study highlighted the possibility of intercropping in aged forest plantations through field experiments of elephant foot yam and black ginger in the selected plantations and stakeholder perspectives. Compared to the yield of elephant foot yam (50 viss per acre) and black ginger (26 viss per acre), intercropping elephant foot yam is more preferable than black ginger although black ginger had higher survival percentage. Further research would be necessary to intercrop black ginger with treatments such as different age of plantations, site preparation and shade conditions. It was found that soil organic matter (SOM) increased significantly and the other nutrients slightly increased after one-year planting. Crop yields were positively correlated with increasing levels of top SOM. Increased soil organic matter lead to increases in top SOM and that is resulting in increased crop yields.

According to the perceptions of stakeholders, 73% of LC group agree on the system of intercropping in aged forest plantations (63% strongly agree & 10% agree) while 55% of SO group agree on the system of intercropping in aged forest plantations (25% strongly agree & 30% agree); 80% of AD group agreed (60 % strongly agree & 20% agree). Therefore, it can be concluded that both of FD staff and local community support the intercropping in aged forest plantations. The positive correlation observed between the experience of agroforestry and perception on intercropping in aged forest plantations. Illegal cutting seems the main challenges by FD staff and they prefer the use of contract system to address this issue.

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8. Appendix

Mean (±S.D.) of Available nutrient properties in the 0-15 cm soil layer under agroforestry Plots

Agroforestry Plot	Depth(cm)	pH	Total N %	Ava. P %	Ext. K %	OM %	Particle size distribution (%)			Texture
							Sand	Silt	Clay	
2021 Year										
P (a)	0-15	6.8 ±0.15	0.057±0.01	0.000090±0.0001	0.004±0.001	1.33±0.58	78	15	4	Loamy Sand
P (b)	0-15	6.6±0.14	0.059±0.01	0.000257±0.0002	0.006±0.005	2.00±1.00	65	15	16	Sandy-Loam
T (a)	0-15	6.4±0.17	0.053±0.01	0.000187±0.0001	0.005±0.001	2.67±0.58	72	14	9	Sandy-Loam
T (b)	0-15	6.3±0.68	0.042±0.01	0.000137±0.0001	0.006±0.001	4.33±0.58	68	19	11	Sandy-Loam
B (a)	0-15	6.6±0.06	0.039±0.01	0.000027±0.0001	0.003±0.001	1.67±0.58	73	19	6	Loamy Sand
B (b)	0-15	6.6±0.23	0.040±0.01	0.000513±0.0003	0.006±0.002	2.67±0.01	65	15	16	Sandy-Loam
2022 Year										
P (a)	0-15	6.7±0.18	0.065±0.011	0.00013±0.0001	0.005±0.007	2.33±0.58	79	12	8	Loamy Sand
P (b)	0-15	6.6±0.19	0.065±0.016	0.00034±0.0001	0.007±0.006	3.00±1.00	67	15	16	Sandy-Loam
T (a)	0-15	6.4±0.17	0.065±0.012	0.00037±0.0002	0.006±0.002	3.33±1.15	71	16	13	Loamy Sand
T (b)	0-15	6.2±0.64	0.063±0.016	0.00005±0.0002	0.006±0.009	4.83±0.58	69	20	11	Sandy-Loam
B (a)	0-15	6.5±0.09	0.061±0.002	0.00004±0.0001	0.003±0.001	5.67±0.58	73	18	6	Loamy Sand
B (b)	0-15	6.5±0.17	0.060±0.009	0.00061±0.0003	0.007±0.002	6.00±0.01	68	21	7	Sandy-Loam