Contents

LIST OF TABLES

LSIT OF FIGURES

LIST OF ABBREVIATION

C	Carbon
Ca	Available Calcium
FAO	Food and Agricultural Organization
K	Extractable Potassium
L-O-I	Loss on ignition
Mg	Magnesium
OM	Organic Matter
P	Available Phosphorus
N	Total Nitrogen
S	Sulfur
SOM	Soil Organic Matter

စိုက်ခင်းတည်ထောင်ရာတွင် တောင်ယာခုတ် မီးရှို့ခြင်းနည်းလမ်းကြောင့် မြေဆီလွှာ၏ ဓါတုနှင့် ရုပ်ဂုဏ်သတ္တိများအပေါ် အကျိုးသက်ရောက်မှုများကို လေ့လာခြင်း

လှမျိုးအောင်၊ လက်ထောက်ညွှန်ကြားရေးမှူး
ဆွေဆွေထွန်း၊ လက်ထောက်သုတေသနအရာရှိ
ဖြူဖြူဆွေ၊ လက်ထောက်သုတေသနအရာရှိ

စာတမ်းအကျဉ်း

ဤစာတမ်းတွင် မြန်မာနိုင်ငံသစ်တောများပြန်လည်ပြုစုပျိုးထောင်ခြင်းစီမံကိန်းကို အထောက်အကူဖြစ်စေရန် အတွက် တောင်ယာခုတ်မီးရှို့ခြင်း နည်းလမ်းဖြင့် စိုက်ခင်းများတည်ထောင်ရာတွင် မြေဆီလွှာရှိ ရူပနှင့် ဓါတ်ဂုဏ်သတ္တိများ ထိခိုက်မှုကို လေ့လာဆန်းစစ်ခြင်းဖြစ်ပြီး ယခုသုတေသနကို နေပြည်တော်၊ ဥတ္တရသီရိခရိုင်၊ ဥတ္တရသီရိမြို့နယ်၊ ငလိုက်ကြိုးဝိုင်း၊ အကွက်အမှတ် (၂) တွင် ၂၀၁၇ ခုနှစ်၊ ဧပြီလ ၄ ရက်နေ့မှစတင်၍ (၂)နှစ်ခွဲကျော်ကြာ လေ့လာခဲ့ခြင်းဖြစ်ပါသည်။ ဤကဲ့သို့လေ့လာခဲ့ရာ တွင် တောင်ယာ မီးမရှို့ခင် ရှိသော မြေဆီလွှာများနှင့် တောင်ယာမီးရှို့ပြီးနောက် ရုပ်နှင့်ဓါတ်ဂုဏ်သတ္တိ များ ပြောင်းလဲသွားမှု၊ တစ်နှစ်ကြာပြီးအချိန်နှင့် နှစ်နှစ်ကြာပြီးအချိန် တို့တွင် ပြောင်းလဲမှု အခြေအနေ များကို နှိုင်းယှဉ်စစ်ဆေးခဲ့ခြင်းဖြစ်ပါသည်။ တွေ့ရှိချက်များအနေဖြင့် တောင်ယာမီးရှို့ ပြီးနောက် ချဉ်ငန်ဓါတ် (pH)၊ မီးစုန်းဓါတ်(P) နှင့် ပြာဓါတ်(K) တို့သည် တိုးပွားလာခဲ့ပြီး သစ်ရွက် ဆွေးဓါတ်(OM)၊ နိုက်ထရိုဂျင်ဓါတ် (N) နှင့် ကယ်လဆီယမ် ထုံးဓါတ် (Ca)တို့သည် လျော့နည်း သွားကြောင်း တွေ့ရှိရပါသည်။ သို့ရာတွင် မီးရှို့ပြီး (၁) နှစ်အကြာတွင် ပြန်လည် တိုင်းတာခဲ့ရာ ကယ်လ် ဆီယမ် (Ca)၊ နိုက်ထရိုဂျင်(N)နှင့် သစ်ဆွေးဓါတ်(OM) တို့သည် တဖြေဖြေးနှင့် ပြန်လည် တိုးပွားလာခဲ့ပြီး ချဉ်ငန်ဓါတ် (pH)၊ မီးစုန်းဓါတ်(P) နှင့် ပြာဓါတ်(K) တို့သည် ပြန်လည်ကျဆင်းလာ ကြောင်းတွေ့ရှိရ ပါသည်။ ထို့အပြင် (၂) နှစ်ကျော်အကြာတွင် ထပ်မံတိုင်းတာ စစ်ဆေး ခဲ့ရာ ကယ်လ်ဆီယမ် (Ca)၊ နိုက်ထရိုဂျင် နှင့် သစ်ဆွေးဓါတ်(OM) တို့သည် ထပ်မံ၍ တဖြေဖြေးနှင့် ပြန်လည် တိုးပွားလာခဲ့ပြီး ချဉ်ငန်ဓါတ် (pH)၊ မီးစုန်းဓါတ်(P) နှင့် ပြာဓါတ်(K) တို့သည် ပြန်လည်ကျဆင်းလာပြီး မီးမရှို့ခင် အချိန်က အခြေအနေ နီးပါးသို့ ပြန်လည်ရောက်ရှိလာကြောင်း တွေ့ရှိရပါသည်။ ထိုနည်းတူစွာ တောင်ယာမီးရှို့ပြီးနောက် ရုပ်ဂုဏ်သတ္တိများဖြစ်သည့် သဲ၊ နုန်းနှင့် ရွှံ့စေးပါဝင်မှုနှုန်း သိသာစွာ ကျဆင်းခဲ့ပြီးနောက် (၁) နှစ်(၂) ကျော်အကြာတွင် သဲ၊ နုန်းနှင့် ရွှံ့စေးပါဝင်မှုနှုန်းတို့သည် တဖြေဖြေးချင်း ပြန်လည်တိုးပွားလာခဲ့ သည်ကို တွေ့ရှိရပါသည်။ အချုပ်အားဖြင့်ဆိုသော် တောင်ယာမီးရှို့ပြီးနောက် မိုးရွာသွန်းမှုဖြင့် ကြုံတွေ့ရပါက လျှောစောက် ၃၀ ရာခိုင်နှုန်းအထက်တွင် စိုက်ပျိုးထားပါက အဖိုးတန်မြေဆီလွှာများ ရေတိုက် စားမှုကို ခံရခြင်းကြောင့် စိုက်ပျိုးခဲ့သော အပင်များအတွက် လုံလောက်သော အဟာရများ မရရှိနိုင်ခြင်း ကြောင့် ကြီးထွားမှု နည်းပါးနိုင်ပါကြောင်းနှင့် ဖြည့်စွက်ဓါတ်မြေဩဇာများကို အသုံးပြုသင့်ပါကြောင်း တွေ့ရှိရ ပါသည်။

Assessment on the Effects of Fire on Soil Properties in the Plantation Establishment area by using of Slash and Burn (Taungya) Method

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Abstract

This paper was to assess the effect of Taungya burning method on various properties of soil, which are important in the establishment of commercial plantation under the Myanmar Reforestation and Rehabilitation Program. This research was carried out in the compartment No. 2, Ngalaik Reserve Forest, Ottrathiri Township and District, Nay Pyi Taw since 4th April 2017.The purposes of this study were to find out changes of physical and chemical properties of soil due to the Taungya burning in order to estimate soil erosion rate in the Teak commercial plantation site. The analytical method for physical and chemical properties of soil by situation of before burning and after, 1 year and 2 year after burning method. This study found significantly increase soil pH (acidity), Available phosphorus (P) and potassium (K) in after burning while decreasing in organic matter (OM) and total Nitrogen (N), available calcium (Ca) after burning. However, Available Calcium (Ca), total Nitrogen (N) and Organic Matter (OM) were gradually increasing after Taungya burning, 1 year and 2 year burning which amount was not reaching normal (original) condition. Nevertheless, soil pH, available phosphorus (P), and extractable potassium (K) were gradually decreasing after 1 and 2 year burning compared to before burning condition.One year after Taungya burning, some chemical properties: organic matter, available P and K had growing nearly to their initial situation, however, pH (acidity) and total nitrogen (N) and available calcium (Ca) continued decreasing into fall compared to before burning condition. Moreover, two year after Taungya burning, several chemical components: organic matter, available total nitrogen and calcium gradually covered to normal condition (before burning) although pH (acidity), phosphorus and potassium were reducing slowly compared to 1 year after burning. This study indicated that effect of Taungya burning on forest soil is very complicated to compare changes between situation of before and after, 1 year and 2 year after burning. It significantly affects soil organic matter, pH (acidity), physical properties of soil such as sand, silt and clay percentages in soil texture.By and large, this observation clearly show that soil physical components were slightly changed by result of lower sand (%), higher silt (%) and higher clay (%) after Taungya burning. However, after one year and two year burning, sand 8 -11%, silt 5-10 % at 0-10 cm and 40-50 soil depth layer although clay percent were decreasing at all of soil layers (0- 90 cm) compared to after Taungya burning. Likewise, sand 3-4 %, silts 4-5 % at 0-10 cm to 40-50 soil depth although clay percent were dropping down at (40- 50 cm and 80-90 cm) after two year burning compared to 1 year after Taungya burning.In conclusion, these changes could cause soil erosion after high severity Taungya burning due to clear cutting that was significantly increasing erosion rates especially in over 30% sloping area with very sensitive changes of runoff and soil erosion.

Keywords: Taungya burning, Plantation, Soil properties changes, Described fire, Erosion

Assessment on the Effects of Fire on Soil Properties in the Plantation Establishment area through Slash and Burn (Taungya) Method

1. Introduction

According to the Global Forest Resource Assessment report about 42.92 % of total area of Myanmar is being covered by FAO in which Closed Forest contributes to 21.56% while Opened Forest accounts for 21.36%, of the country's total land area (FAO, 2015).

Forest plantation by Taungya has been established in many regions of Myanmar in 1856. The reforestation system by way of Taungya method was the rehabilitation to the natural forest or commercial plantation forests with the collaboration of forest department and Taungya farmers. In the every steps of plantation establishment, both concerned forest officer and Taungya cultivators were taken part in this method which was very profitable or symbiosis for them and can provide the national economy.

In Taungya cutting system, the small trees like herbs and shrubs, the underground-roots, creepers and climbers were clear cut first on the bed of plantation site. After that fire line of 4.5 meters width is prepared around the plantation site as fire protection operation. Taungya burning were carried out in the first or second week of April.

Depending on the weather condition, Taungya burning necessarily carried out within the month of April. Taungya burning severity increases fire intensity because of April which moth is a hottest season of Myanmar and also climate change. Moreover fuel load from debris on the plantation site also piling up increase intensity of fire again. Duration of Taungya burning is at least 30 minutes to two hour on the bed of plantation site. After Taungya burning, almost all the trees and bamboos are incinerated but the rhizome, stem and roots of larger trees are unburned and remained. After Taungya burning process, the unburned and remained debris is collected, piled up and burn again on that site. This operation is traditionally called the "Kyun-kwe" and completed in second week of May. In here, Taungya and Kyun-kwe burning is not wild fire and is really deliberated fire on the plantation site for land clearing process of commercial forest plantation since 1856.

Burning of cleared forest biomass, depending on its water content, can reach 800 1C near the soil surface, and these temperatures will be maintained for a longer period. If temperatures reach 400 1C, soil organic matter may be lost by combustion, resulting in decreases in soil organic C and N. Clay particles may fuse, altering the soil texture and its cation exchange capacity (CEC).

Windy conditions during the burn will increase such losses. In the Amazon, element transfer to the atmosphere due to ash particle transport and volatilization has been reported as up to 98% C, 98% N (these actually being inevitable losses), 33% P, 31% K, 24% Ca, and 43% Mg of the initial amounts in the fuel. Sulfur losses to the atmosphere were estimated between 69% and 76% of that in the original biomass (Hauser Stefan, & Norgrove Lindsey, 2013)

Fire is a dynamic process, predictable but uncertain, that varies over time and landscape space and it plays a dominant role in recycling organic matter (DeBano *et. al.*, 1998). Many human activities trigger forest fires directly or indirectly. Fires are often used to clear forests for plantation forest and agricultural lands, settlements and paths in Myanmar (Sein *et. al.*, 1999).

Fire is less applicable to clearing land with low volume of biomass such as grassland, low secondary vegetation or heavily logged-over forest. Burning is more economical for clearing high-volume forest because it is more difficult and time consuming to dispose of high volumes of piled wood mechanically.

Fire, as a necessary ecological process, determines the nature and characteristics of many ecosystems. Fire also impacts some ecosystems very negatively. Fire is a natural disturbance that occurs in most terrestrial ecosystems. It is also a tool that has been used by humans to manage a wide range of natural ecosystems worldwide. As such, it can produce a spectrum of effects on soils, water, riparian biota, and wetland components of ecosystems.

Plantation forest with clear cutting system in the mountain area is very sensitive with the changes of runoff and soil erosion. Forest plantation has opened up dramatically the canopy cover in the plantation establishment during clear cutting. The large open-forest area reduced forest interception and transpiration, increasing net rainfall reaching the forest floor and increasing soil moisture (Suryatmojo, H., & Widiyatno, Purnomo, S. 2009).

Clear felling leads to soil erosion and the leaching of nutrients. In high rainfall, the exposed topsoil is eroded, exposing the subsoil, as above. These enter watercourses where the excess phosphorous and nitrogen released by the disturbance can lead to eutrophication of the water bodies and mortalities of aquatic life including protected species. The nutrient and sediment rich run-off washes down over the open ground into the drainage channels (Hauser Stefan, & Norgrove Lindsey, 2013).

Clear cutting for Taungya system is among the main factors responsible for soil erosion. The removal of top-layer vegetation is required to convert forests into pastureland or crop land. This change in land use exacerbates risks of soil erosion as intense harvesting and overgrazing cause the soil to be more vulnerable to the erosive forces of rainfall and wind. De Ploey estimated in 1989 that areas covered with permanent vegetation are associated with soil erosion rates 100-1000 times lower than on unprotected fields (Thomas 2009).

Soil erosion continues to be a major threat in many regions of the world despite decades of focused scientific research and societal concern. Water erosion has been the most widely studied of the three types of erosion, and is arguably the one that affects the greatest land area.

Based on the severity and intensity of the fire, Taungya burn can impact water quality by heating the soil and killing soil organisms. Taungya burning of slash can increase erosion and sediment delivery to streams by eliminating protective cover and altering soil properties (Megahan 1980).

Knoepp and Swank (1993) found that clear cutting and burning increased stream water nitrate concentrations from less than 0.01 mg per L to a maximum of 0.075 mg per L. This small increase was associated with a slight increase in nitrogen transformations and little movement of inorganic nitrogen off the site (Knoepp and Swank 1993).

To fully evaluate the effects of fire on a soil, it is first necessary to quantitatively describe the soil during (Taungya burning) or prescribed burns. Such action often carried out during the April, resulted in the emission of large quantities of total suspended particles into the atmosphere and with excessive and prolonged burning, soil conditions impacted. During the process of soil heating, significant changes can occur in the physical and chemical properties that are relevant to the future productivity and sustainability of commercial Teak Plantation sites supporting its ecosystems.

In the past, for the establishment of commercial plantation, it was a common practice to burn remnants of trees after felling prior to land preparation. There are many reasons for the use of fire in land clearing activities, but probably the most important one is economics. There is still acceptance that fire is the cheapest, fastest, and most effective land clearing method with the added benefit of providing nutrients from ash residues.

The key nutrients within forest soils, mainly contained in its organic matter component (OM) are: nitrogen (N), available phosphorus (P), exchangeable potassium (K), exchangeable calcium (Ca) and exchangeable magnesium (Mg). Each nutrient reacts differently to fire, depending on its individual volatilization threshold (Wüthrich, C.; *et. al.,* 2002). The combustion of nutrients bound in vegetation and soil organic matter add inorganic forms of K, Ca, Mg, P and N to the soil (Miesel, J.R.*, et. al.,* 2012). Each nutrient has its own response to burning, e.g., early studies have found that concentrations of K, Ca and Mg ions can increase, whereas N and S often decrease (Hamman, S.T. *et. al.,* 2008). Fire intensity is directly linked to the temperature an object experiences during fire, which in turn impacts the type of nutrient and the amount volatilized. Fire acts as a rapid mineralizing agent (Bárcenas-Moreno, G. *et al.*, 2011).

This study is to provide a review of existing information on the changes of physical and chemical properties of soil between before and after burning, 1 year and 2 year after burning at the commercial plantation sites and in two year old (Taungya) slash and burn method with particular attention on the positive and negative soil impacts of fire use in land clearing activities in a same plantation site.

In order to make sure that change of chemical and physical properties of soil samples will be compared of soil condition not only before forest fire and after forest fire but also compare between burned and unburned plantation areas.

2. Objectives

1. To find change of physical and chemical properties of soil due to the slash burn in order to estimate soil erosion rate in commercial plantation site
2. To protect disadvantages of deliberate fire and its contextual causes and to gain practically successful outcomes and results from establishment of commercial forest plantations

3. Literature Review

In Myanmar, forest soils productivity is related to climatic factors and man’s indiscriminate cutting and burning. However, an important part is related to differences in chemical and physical properties, brought about by those agents active in soil formation. There are two basic types of forest fires: prescribed (controlled) fires and wildfires (Certini, G., 2005). Prescribed burning of naturally accumulated forest floor or slash following tree harvest is a standard practice to reduce fuel levels.

Because they consume soil organic matter (SOM), fires have detrimental impacts on soil physical properties, including increased bulk density (Neill, C.; Patterson, W.A., III; Crary, D.W., Jr., 2007) reduced soil porosity, and decreased water storage capacity (Scharenbroch, B.C.; Nix, B.; Jacobs, K.A.; Bowles, M.L., 2012).

Fires can decrease the total amount of nutrients on site through losses from volatilization, smoke, ash transport, leaching, and erosion (Arocena, J.M. & Opio, C., (2003). Soil pH has been found to increase because of the release of alkaline ions from production of potassium (K) and Na oxides, hydroxides, and carbonates in the ash [14] and also organic acid denaturation with heating (Scharenbroch, B.C. *et. al.*, 2012). The main reasons for increased nutrient availability are the generation of ashes and increased mineralization. Heating of SOM usually gives rise to ash with different properties, depending on fire severity, whereas increased pH values may increase nutrient availability (e.g., the availability of some micronutrients like Fe, Mn or Zn decreases with increasing pH). However, fires may also contribute to decreased nutrient availability in the longer term because nutrients released from organic matter and microbial biomass are likely to be removed from the ecosystem by leaching and runoff (Wüthrich, C. et al., (2002).

Soil properties can experience short-term, long-term, or permanent fire-induced changes, depending chiefly on type of property, severity and frequency of fires, and post-fire climatic conditions. During the process of soil heating, significant changes can occur in the physical and chemical properties that are relevant to the future productivity and sustainability of plantation sites supporting wild land ecosystems.

Soil physical properties such as soil pH, and texture (sand, silt, and clay) are those characteristics, processes, or reactions of a soil that are caused by physical forces that can be described by fire.

Soil chemical properties such as nitrogen, phosphorous and potassium (N, P, K) are basically known as primary plant nutrients because these components are consumed comparatively large quantities by plants, and are these essentials most regularly deficient in soils. Nitrogen (N) is primarily responsible for vegetative growth and is used by plants for lots of leaf growth and good green color. It is a component of chlorophyll and is required for several enzyme reactions. Phosphorus (P) is a major component in plant DNA and RNA and also critical in root development, crop maturity and seeds, fruit and flowers production. It's also used by plants to help fight disease. Potassium (K) increases water use efficiency and transforms sugars to starch in the grain-filling process and helps plants make strong stems and keep growing fast. It's important for a plant's ability to withstand extreme cold and hot temperatures, drought and pests.

Table 1. Soil nutrient, chemical symbol and their functions in plant

Nutrient category	**Element**	**Chemical Symbol**	**Function in plant**
Primary macronutrients	Nitrogen	N	Proteins, amino acids
	Phosphorus	P	Nucleic acids, ATP
	Potassium	K	Catalyst, ion transport
Secondary macronutrients	Calcium	Ca	Cell wall component
	Magnesium	Mg	Part of chlorophyll
	Sulfur	S	Amino acids

Source: Tin Tin Ohn & Sein Thet, 1982

Secondary macronutrients, namely, calcium, magnesium and sulfur are required in smaller quantities than other macronutrients nutrients and are less likely to be deficient for optimum plant growth as fertilizer or as soil amendments and are not so often deficient in soils because they are needed in very small quantities by trees and are not as likely to be deficient in soils (Tin Tin Ohn & Sein Thet, 1982).

In many cases, the impacts of slash- and-burn practices on soil properties are either negligible or short-lived and thus have little if any, impact on the overall ecosystem. In some cases however, the impact of the fire on soil conditions can be moderate or severe (Oluwole *et. al.,* 2008). The overall degree and longevity of the impact of fire on soil conditions is determined by numerous factors including fire severity, temperature, fire frequency, soil type and moisture, vegetation type, topography, season of burning, and pre- and post-fire weather conditions (Oluwole *et. al.,* 2008; Pantami *et al.,* 2010). Frequent and severe fire commonly results in degradation of soil (Anderson *et. al.,* 1981).

Forest fires usually decrease the total amount of nutrients present through some combination of oxidation, volatilization, ash transport, leaching, and erosion. There were slight negative changes in pH, organic matter, phosphorous and potassium whereas marked losses in nitrogen, calcium and magnesium were observed (Phyu Phyu Swe).

Slash-and-burn clearing of forest typically results in an increase in soil nutrient availability. Throughout the tropics, ash from consumed vegetation has been accepted as the primary nutrient source for this increase. In contrast, soil heating has been viewed as a secondarily and important mechanism of nutrient release. Through the use of multiple burn plots and intensive pre-burn and post-burn sampling of mineral soil, this study quantified changes in total N and P, K fractions, and Ca extractable in soil during the slash-and-burn conversion of a dry forest for commercial Teak Plantation sites.

Forest fires are usually reflected as biological agents of destruction and restoration. The most important effects of fire on soils is the loss of organic carbon and an increased risk of erosion in the next step, as well as a significant impact on the regeneration of previous species and on ecological conditions. Many soil physical and chemical properties change as a result of fires.

Fire affected the soil by drastic reduction of organic carbon, total nitrogen and available P_2O_5. It indicated that reduction of total nitrogen and available P_2O_5 levels and increased in available potassium levels in plantation sites compare to the unburned plantation sites are due to burning in Taungya method (Sein Thet & Tin Tin Ohn, 1982).

The impact of fire on site productivity is also related to intensity. While high intensity fires tend to decrease site productivity, low intensity fires can increase site productivity (Carter & Foster 2003).

The effect of fire on the erodability of a soil is also determined in large part by the soil texture. Sandy soils are highly erodible during heavy rains, even on slight slopes, once they have been uncovered by plowing or by burning. On level or gently sloping soils there is little to no damage from normal rains because the sands allow for the quick penetration of rain water into the soil (Smith, 1982). Clay soils, especially those compacted by cattle grazing are susceptible to superficial erosion after rains due to their reduced capacity for water infiltration and due to a greater amount of surface runoff. Agricultural burning on clay soils on slopes tends to cause soil erosion (Mobley *et al.*, 1973). The effect of water runoff on some types of clay soil on slopes is to produce gullies.

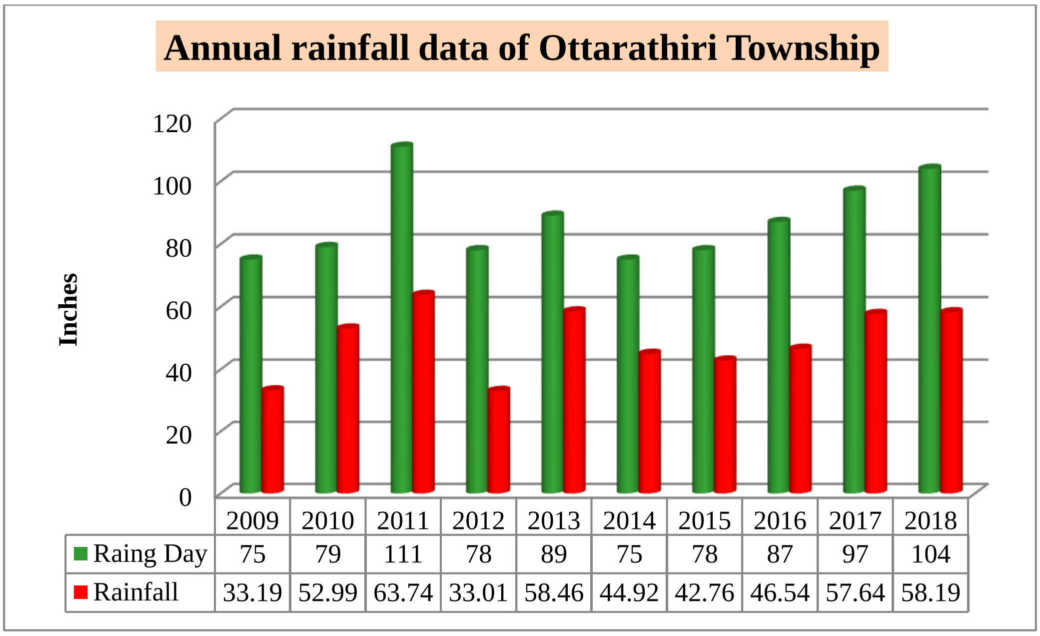
Numerous findings on the effects of fire on soil properties are available in the literature. The extent and duration of these effects depend firstly upon fire severity, which, in turn, is controlled by several environmental factors that affect the combustion process, such as amount, nature, and moisture of live and dead fuel, air temperature and humidity, wind speed, and topography of the site. Fire severity consists of two components: intensity and duration. Intensity is the rate at which a fire produces thermal energy. Although heat in moist soil is transported faster and penetrates deeper, latent heat of vaporization prevents soil temperature from exceeding 95C until water completely vaporizes (Campbell *et. al.*, 1994); the temperature then typically rises to 200–300C (Franklin *et. al.*, 1997).

Fire intensity will most likely determine post-fire soil nutrient dynamics. High intensity fires usually decrease nutrient pools more than low intensity fires and can have many other post-fire impacts that lower site productivity. Nutrient pools in the organic soil horizons are more likely to be impacted by fires than those in the mineral horizons.
Nutrients are abundant in superficial organic soil layers, and the amount of these layers consumed is proportional to fire intensity (Neary *et. al*,. 1999).

4. Materials and Methods

a. Study Area

This analysis had been conducted at the 150 acres of Teak Plantation in compartment of No. 2 of Ngalaik had been established in 2018 and its adjacent area compartment No. 17 of Ngalaik Reserve Forest, in which 200 acres of Teak plantation will be established by the Forest Department of Ottarathiri Township, Ottarathiri District, Naypyitaw in 2019.



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Raing Day	75	79	111	78	89	75	78	87	97	104
Rainfall	33.19	52.99	63.74	33.01	58.46	44.92	42.76	46.54	57.64	58.19

Figure.1: Annual rainfall pattern of Ottarathiri Township, Naypyitaw

The region of the study is characterized by steep hilly topography, is covered frequently with deciduous forest and bamboo which is mainly distributed over story vegetation with species of *Tectona grandis* (Teak), *Xylia xylocarpa* (Pyinkado), *Pterocarpus macrocarpus* (Padauk), *Shorea obtusa* (Thitya), *Shorea siamensis* (Ingyin) and *Dalbergia oliveri* (Tamalan) and meliaceae, Rubiaceae, Verbanaceae and Fabaceae species. The selected Teak plantation sites have been a degraded forest with Low Mixed Deciduous forest and *Bambusa polymorpha* (Kyathaung Wa), *Dendrocalamus brandisii* (Wabo wa), *Bambusa tulda* (Thike wa), *Dendrocalmus strictus* (Mhyin wa) *Dendrocalamus longisputhus* (Wa net) and Tin wa.

Study sites are mostly undulating, slopes for the site range from 0 to 30% and the highest elevation is about 153 meters (500 feet) above sea-level. Most of the rainfall occurs during the Monsoon onset of May to October with average annual rainfall ranges between 33.01 inches to 63.74 inches, and average mean daily temperature ranges between 29.2˚C – 33.2˚C (84.2˚F – 91.6˚ F).

b. Soil Sampling method

Soil samples were collected from two plantation sites in which soils at both sites are well-draining, alluvial deposits comprised of fine sandy loams of Ngalaik R. F, Ottarathiri District from Naypyitaw..

Soil samples were collected at compartment of No. 2 and No. 17 of Ngalaik Reserve Forest where 150 acres of Teak commercial plantation in No. 2 compartment had been established in the year 2018. Other 150 acres of Teak plantation has been establishing at the No. 2 compartment in the year of 2019. Forest vegetation was cut by knives and chainsaws in March 2017, allowed to dry in place for about 2 month, and then broadcast burning and pile burning from downslope to upslope were carried out as practiced by local farmers at the beside of Nay Pyi Taw to Kanbya road.

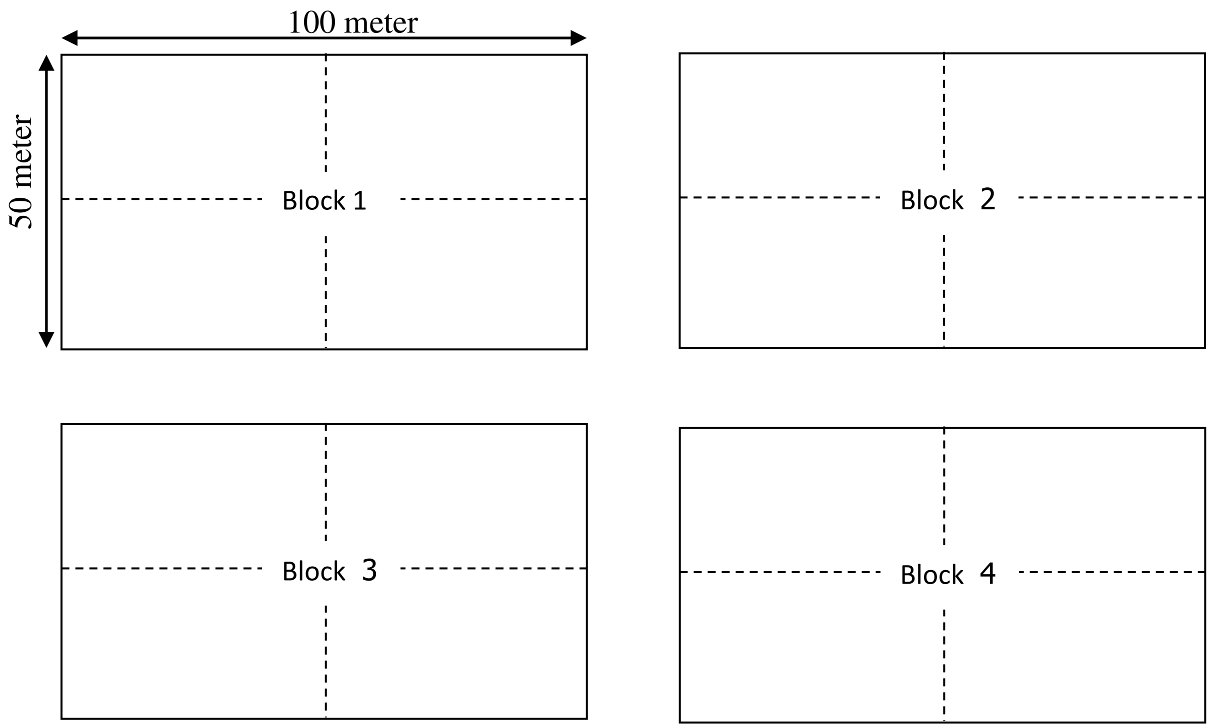
Soil samples from both of the areas were taken unburned in potential plantation sites and burned area in current Teak plantation sites as well as pre-burn (before) and post-burn (after) at current Teal plantation site of 2018 in April of the first year and once again in April of subsequent year. Pre-burn samples were collected during January of 2017 (before the wildfire); post-burn samples were collected during June of 2017 and (1 year after the burn).

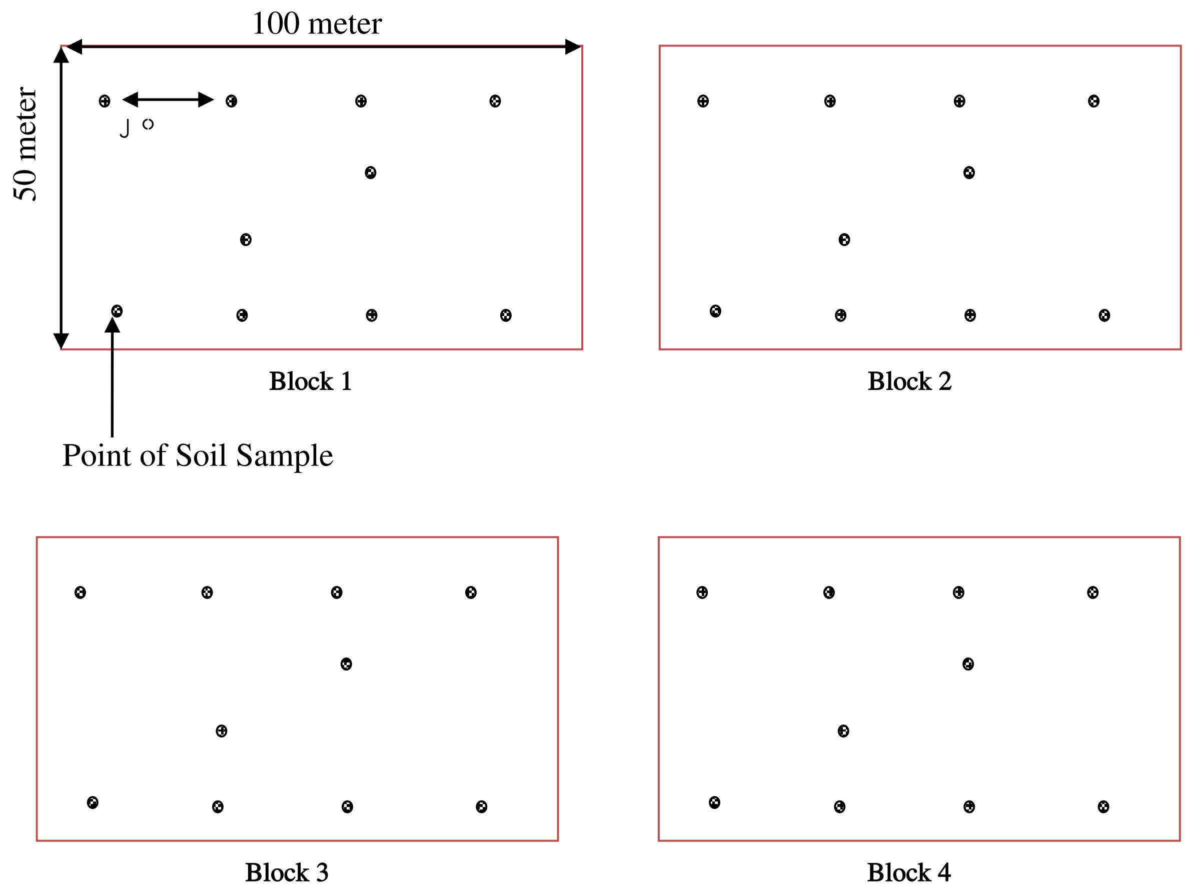
Pre- burn and post-burn mineral soil samples were taken immediately beneath the forest floor samples with ten systematic locations within each plot so that slope, topography, drainage, and soil parent material were comparable on burned-over and unburned areas.

There are 4 (100 m ×50 m) research plots were established in the fall of 2017 and total area cover 2 hectare (5 acres). In each block, remaining tree lists, GBH, height and natural regeneration of tree species were collected within burned and unburned plantation sites. Soil sample design is focus on zip zed design (25 meter). Then, the surface litters at the sampling blocks were removed and a depth of 0 to 10 cm, 40 to 50 cm and 80 to 90 cm dig were excavated by field staff. At least 10 to 15 samples from each sampling blocks were collected and placed into a plastic bags.

To identify dominant texture ranges from medium to heavy, soil was determined by hand, and color was determined by using a Munsell color chart.

Sampling Blocks for Tree List





c. Analytical Method

The analysis of the soil samples collected at the depth of 0-10 cm, 20-30cm, 40-50 cm, 60-70cm and 80-90 cm at all syudy site in the Ngalaik reserve was performed for the evaluation of soil fertility. Thus, soil samples were air-dried and crushed to pass through a 2 mm sieve. Due to the limited time and finance, organic matter as loss-on-ignition (L.O.I), soil pH (H2O), texture, total N%, available p% and extractable k% were analyzed.

Soil texture: particle size distribution was carried out by mechanical analysis by using the pipette method.

Soil Organic Matter (SOM): SOM was detected by using loss-on-ignition (L.O.I) method.

The principle of which method is simple: OM in a weighted quantity of soil is destroyed complete by heat, the sample reweighted and loss in weight represents the organic matter.

Total Nitrogen in soil: Total Nitrogen levels were settled by Kjedahl’s method by using Kjedahl digestion and distillation unit.

Available Phosphorus Content in Soil: Available Phosphorus levels were resolved with double-acid extracting solution and molybdenum blue complex method by using Spectrophotometer Hach 2000.

Extractable Potassium and Calcium Content in Soil: Potassium and Calcium was assessed with double-acid extracting solution by using GBC, Atomic Absorption Spectrophotometer.

d. Statistical Analyses

Then, the data were fed into the computer was performed using the SPSS software for data distribution normality. If not normal, data were logarithmically transformed. In order to determine the effects of each factor and their interaction between burned and unburned control areas, the multivariate analysis of variance test (ANOVA) was used and in order to compare the plots with different burning severity in the Teak plantation site.

5. Results and Discussion

During Taungya burning, chemical properties such as organic matter, pH, total nitrogen, available phosphorus, extractable potassium and calcium as well as physical properties of teak plantation site, such as sand, silt and clay percent of the soils under different permanent sample plots and localities are significant differently and achieving all physical and chemical properties are similarly promising for teak commercial plantation before Taungya burning.

5.1 (a) Effects of Taungya burning on soil acidity (pH)

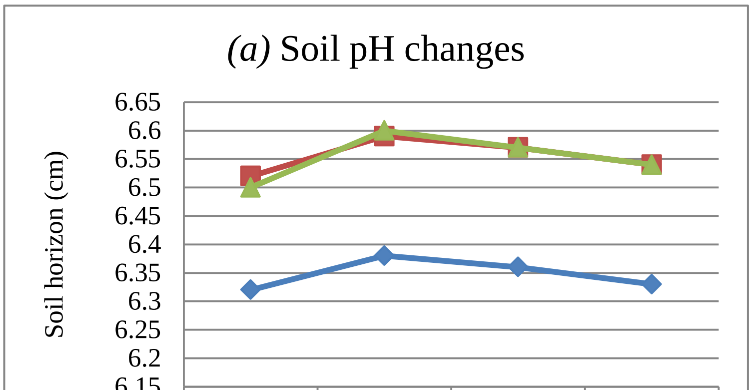
This study indicates that the amounts of soil pH significantly increase after Taungya burn because of logs, branches, twigs, debris and litter piling on the plantation site. Therefore, increased acidity can be one of the benefits of deliberated fire because the increase of soil response (pH), especially in acid soils, increases the ability to absorb essential nutrients.

Soil pH values determined immediately before, at 1 year after burning and 2 year after burning are shown in Table 1. On average, soil pH increased progressively with time from 6.40 ± 0.11 to 8.08 ±0.11 and 7.39 ± 0.18 (1 year after) and to 6.22± 0.20 (2 year after).

Nevertheless, soil fertility should increase with the pH reduction, considering that the pH value has changed from alkaline to neutral which is the optimum pH value for the majority of plants according to Ortega et al. (2012). In contrast, significant differences were found between initial and final (after 2 year period) soil pH, which decreased to about 7 % in one year and 11.7% in two years after the Taungya burning.

The pH of soil increased in the 80% of the Teak commercial plantation site after one year although changes of pH is not significantly after two year fire compared to measurements before burning. The pH decrease from the one-year post-burn soil may be related to losses of organic acids by heating. In this current study, the decrease in pH from the burned soil is an ephemeral phenomenon with a recovery time of two year.

Soil pH increased significantly one year after Taungya burning and then returned to the level of the before Taungya burned soil. This study shows that an increase in soil pH following forest burning and for the effect to last for one to several years and also described that soil pH significantly increased for two years after fires, and also found that soil pH was higher in logged burnout Teak plantation site for more than two years after combustion of downed logs compared with adjacent soil. The pH increase from the one year after burned soil relate to losses of organic acids by heating. In the present study, the increase in pH from the burned soil at the Teak plantation site is an ephemeral phenomenon with a recovery time of two and more than two year.



	Before	After Burning	After 1 Year	After 2 Year
0-10	6.32	6.38	6.36	6.33
40-50	6.52	6.59	6.57	6.54
80-90	6.5	6.6	6.57	6.54

Figure.2: Changes of pH (acidity) between before, 1 year and 2 years after burning.

Table.2: The results of the effects of fire on soil chemical properties.

Chemical/ Physical parameters	Burned area			
	Pre-Fire	Low Fire	Medium	High
(Acidity) pH	6.40	6.60	6.90	7.30
Total Nitrogen (N)	0.105	0.725	0.053	0.017
Available Phosphorus (P)	0.00052	0.00016	0.0009	0.0003
Extractable Potassium (K)	0.0027	0.0082	0.0088	0.0135
Extractable Calcium (Ca)	0.0549	0.1240	0.2120	0.3940
Soil Organic Matter (OM)	2.0	3.0	4.0	6.0
Texture (Sand)	65	60	70	80
Texture (Silt)	19	20	23	26
Texture (Clay)	16	17	19	22

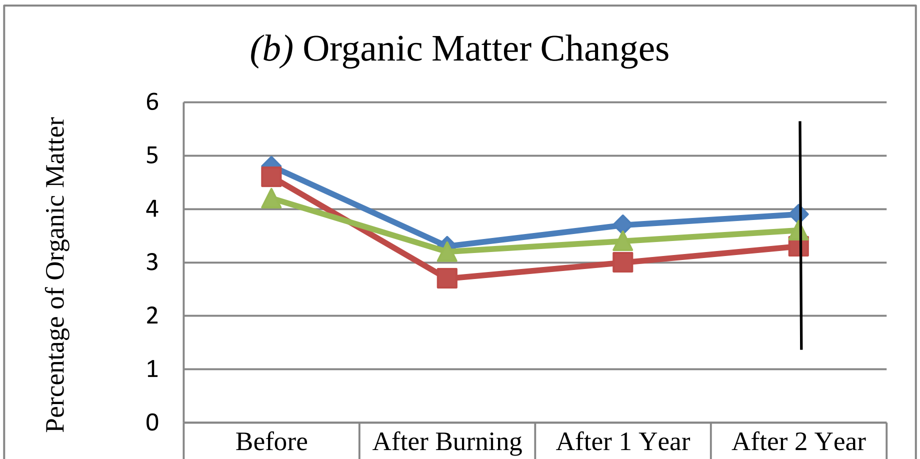
Table.3: Criteria and indicators for classifying the fire severity in the sampling area

Sr.	Fire severity	Indicators (in the next growing season after fire)
1.	Unburned (UB)	No confirmation of fire, Litter accumulation (depth & 15 cm), Soil surface covered by litter, debris and twigs.
2.	Low severity burn (LS)	No obvious sign of fire (only the scorched collar of burned grasses and annual plants), less than 2 % of the plantation site is severely burned, less than 15 % moderately burned, and the residue of the site burned at a low severity.
3.	Moderate severity burn (MS)	Obvious indication of fire, litter consumed, Soil surface bare or covered by ash, less than 10 % of the plantation site is severely burned, but more than 15 % is burned moderately, and the residue is burned at low severity.
4.	High severity burn (HS)	Obvious mark of fire, litter consumed, Soil surface bare or covered by ash, more than 10 % of the plantation site has spots that are burned at high severity, more than 80 % moderately or severely burned, and the residue is burned at a low severity.

(b) Organic Matter

Organic matter (OM) of soil, or humus, is approximately 50% carbon (C) by mass, holds significant provisions of nitrogen (N), phosphorus (P), and sulfur (S) and thus is an important store of small Teak tree nutrients in plantation site. OM also increases soil water holding capacity, stabilizes soil aggregates, and decreases the toxicity of aluminum to small trees (Stevenson 1994). Results of the study for organic matter (OM) content varied greatly among the plots (Figure 2). After Taungya burned OM% was lowered by a small amount (1.5% at 0-10 cm, 1.9% at 40-50 cm, and 1.0% at 80-90 cm depth respectively), though not significantly (Figure 4), whereas, after 1 year increased the amount of OM by 0.4% at 0-10 c, 0.3% at 40-50 cm and 0.2 % at 80-90 com depth respectively. After 2 year burned, OM increased by 0.2% at 0-10 cm, 0.3 % at 40-50 cm and 0.2 % at 80-90 cm depth again but that amount is not reach normal position. These results show that organic matter in Teak plantation site is not significantly affected by Taungya burning.

The recovery of soil organic matter in the burnt Teak plantation site starts with the natural reintroduction of vegetation and generally is fast, creates to the high net primary productivity of secondary vegetation successions.



	Before	After Burning	After 1 Year	After 2 Year
0-10	4.8	3.3	3.7	3.9
40-50	4.6	2.7	3	3.3
80-90	4.2	3.2	3.4	3.6

Figure 3. Changes of organic matter between before, after burning, 1 year and 2 year burned.

(c) Total Nitrogen

In this analysis of Taungya burning effects on Total Nitrogen, it was found that Total Nitrogen pool is not significantly decreased (Figure 4). After Taungya burned at plantation site, Total Nitorgen was lowered by a small amount (0.012 % at 0-10 cm, 0.012% at 40-50 cm, and 0.0083 % at 80-90 cm depth respectively, though not significantly (Figure 4), whereas, after 1 year increased the amount of Total Nitrogen by 0.0009% at 0-10 c, 0.0012% at 40-50 cm and 0.0004 % at 80-90 com depth respectively. After 2 year burned, Total Nitrogen increased by 0.014% at 0-10 cm, 0.021 % at 40-50 cm and 0.0028 % at 80-90 cm depth with low burning severity. The percentage also decreases with fire intensity. The effect of Taungya burning on total nitrogen is also variable.

Based on the results of this study, Taungya burning had a not significant effect on soil total nitrogen percentage. Total nitrogen is not significantly decrease after Taungya burning compared to before burning condition. After one year burning, total nitrogen gradually increase because of the new vegetation and annual rainfall in this plantation site, it is expected that topsoil had absorbing total nitrogen and this has increased the total nitrogen is in the soil.

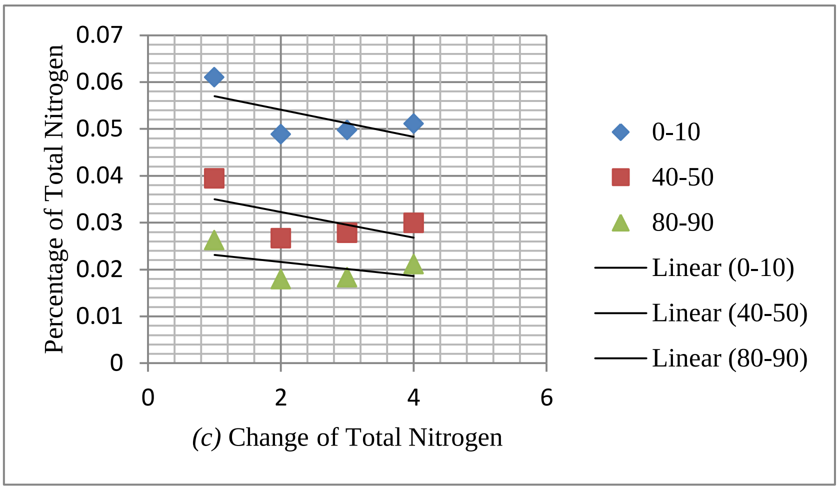


Figure 4: Changes of Total N between before, 1 year and 2 years after burning

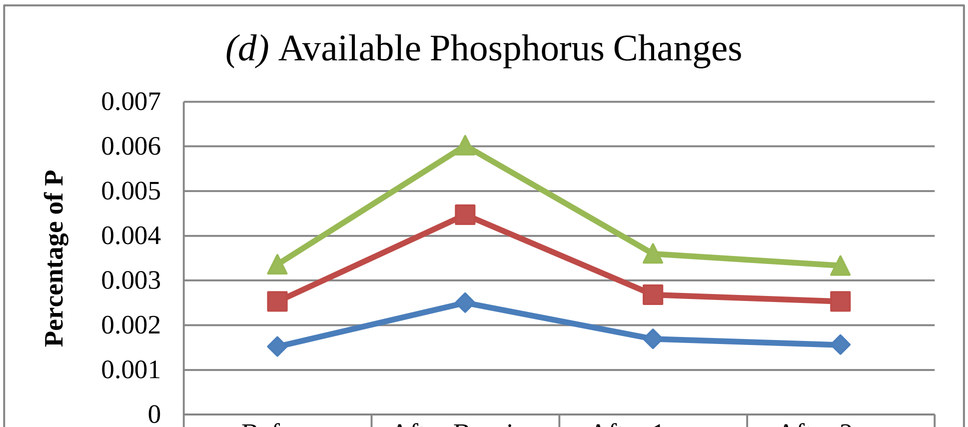
After the second year of the period of study, the total N is increase with small amount in the plots of plantation sites due to the annual rainfall and Taungya burning effect.

(d) Available Phosphorus

Available phosphorus (P) concentration significantly increased immediately after the Taungya burning, though there was significant difference in the available (P) amongst the soil after 1year burning and 2 year burning. However, four or five years after the Taungya burning, available (P) became not significantly lower in the Taunngya burned soils and then remained at this level. The decrease in soil available (P) was significant immediately after Taungya burning but significantly decreases after one and two year burning.

Extractable phosphorus showed different behavior. Extractable phosphorus increased in all 0-10 cm, 40-50 cm and 80-90 cm respectively in one year after the fire when compared to the reference situation (before Taungya Burning), showing a slight decrease twenty-four months after Taungya burning, yet with values always higher than the ones observed before the fire (Fig. 5).

In the surface layer (0–10 cm) the phosphorus contents are similar in all sampling dates, the other layers presenting not significant differences over time: the first two sampling dates (before and after burning) with lower values than the last two (after 1 year and 2 year burning).



	Before	After Burning	After 1 year	After 2 year
80-90	0.00083	0.00155	0.00092	0.0008
40-50	0.00101	0.00197	0.00099	0.00097
0-10	0.00152	0.0025	0.00169	0.00156

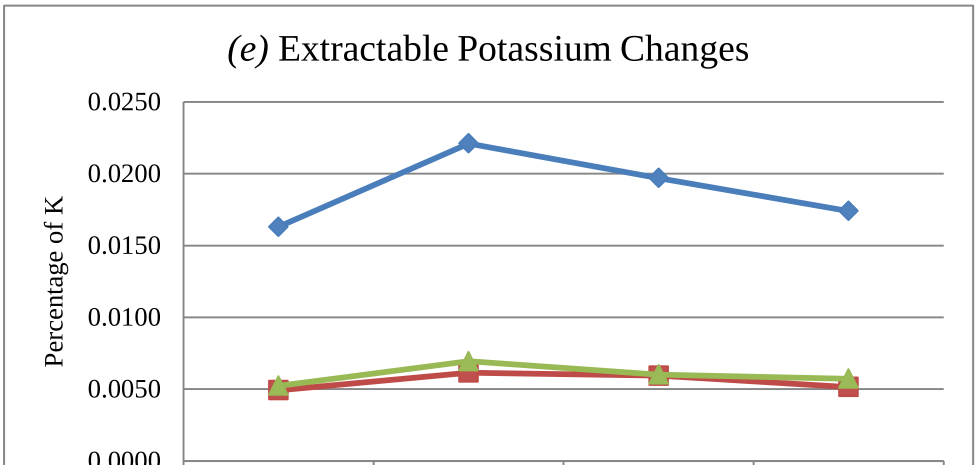
Figure 5. Changes of available P between before, 1 year and 2 years after burning

The main pool for (P) is in the soil (94%–98%) and not in the litter. Losses of (P) through burning may be more serious for Teak plantation site with low (P), because natural replacement of (P) from rainfall or mineral weathering is very low in the forests in Ngalaik Reserve Forest. Ottarathiri District, Nay Pyi Taw. This result estimate that available P recovers after 4 or 5 year after burning.

At the study site heavy rainfall occurred shortly (one month) after the Taungya burning, potentially contributing to greater P losses. The P concentration is typically low in the Ngalaik R.F. and is predominantly cycled through organic pools in the upper soil layers, which often limits tree growth. The study shows an enrichment of available P immediately and one year after Taungya burning, by inducing a change in soil pH toward neutrality.

(e) Extractable Potassium

Some nutrient dynamics are more sensitive to Taungya burning than others. The concentration of potassium and calcium ions in the soil can increase or be unaffected by fires whereas nitrogen often decrease (Hough 1981). The potassium levels in the soil decreased significantly for before burning at a significance of $p < 0.01$ (Figure 6.). The negative correlation has shown that higher intensity fires increase the amount of potassium present in the soil immediately after the Taungya burn. The increasing ratio is constant for after burning, 1 year and 2 year burning (Figure 5), dropping from 0.0221 % to 0.0197 and 0.0174%, respectively). Reference material accuracy was calculated at 85%, showing a high accuracy of the double-acid extracting solution by using GBC method. Therefore, the level of potassium in Teak plantation site can be significantly affected by fire of any intensity immediately after the fire event.

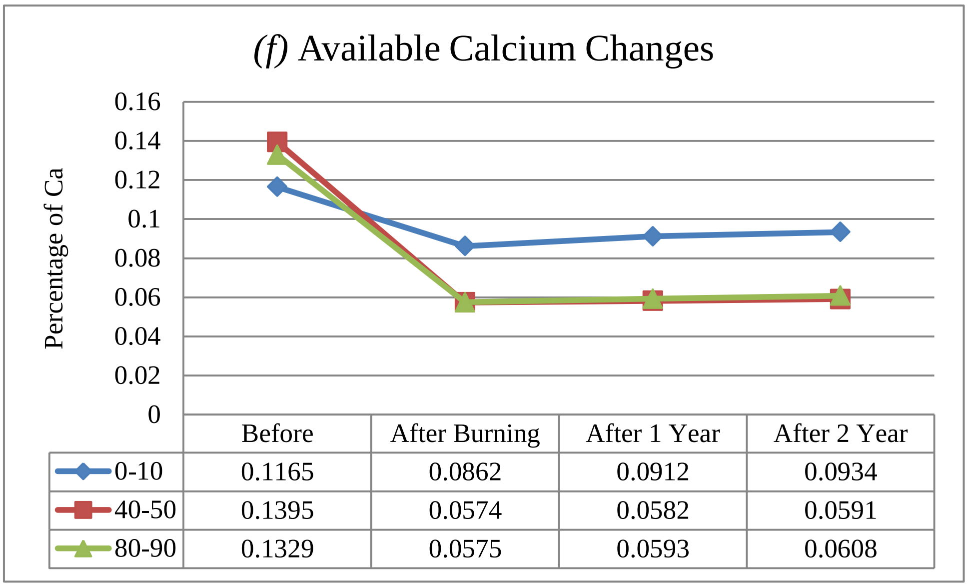


	Before	After Burning	After 1 Year	After 2 Year
0-10	0.0163	0.0221	0.0197	0.0174
40-50	0.00492	0.00615	0.00593	0.00514
80-90	0.00523	0.00694	0.00601	0.00572

Figure 6: Changes of extractable K between before, 1 year and 2 years after burning

(f) Available Calcium

The available Calcium levels in the soil decreased significantly for after burning at a significance of $p < 0.01$ (Figure 7.). The negative correlation has shown that higher intensity fires decrease the amount of Calcium present in the soil immediately after Taungya burn. The decreasing ratio is constant for after burning, 1 year and 2 year burning (Figure 6.), increasing from 0.0862 % to 0.0912 and 0.0934%, respectively. Therefore, the level of calcium in Teak plantation site can be significantly affected immediately by Taungya burning. Available calcium in soil decreases with fire intensity (Figure 6.), lower intensity Taungya burning result in more available calcium present. Trends for soil profile nutrients were almost identical to near-surface nutrients before treatment, and available calcium contents were higher on the burn plantation site at before.



	Before	After Burning	After 1 Year	After 2 Year
0-10	0.1165	0.0862	0.0912	0.0934
40-50	0.1395	0.0574	0.0582	0.0591
80-90	0.1329	0.0575	0.0593	0.0608

Figure 7: Changes of available Calcium between before, 1 year and 2 years after burning

5.2 Effects of Taungya burning on Soil Physical Properties

Taungya burning may alter several physical soil properties, such as soil structure, texture. The extent of fire effects on these soil physical properties depends on fire intensity, fire severity, and fire frequency. Low intensity fires do not cause enough soil heating to produce significant changes to soil physical properties (Carter and Foster 2003).

Soil physical components were slightly changed after fire, by which resulted in lower sand (%), higher silt (%) and higher clay (%) at the plots of the burned plantation site (Table 3.). Taungya burning has significant effect on soil texture in the studied locations. However, sand content increased in the burned plots at the 0-10 cm depth after Taunya burning which might be due to destruction of soil organic matters. These changes were not affected the coarse-textured structure of the soil (sandy loam).

High intensity fires can also change the physical characteristics of the soil making it more susceptible to nutrient loss through erosion (McColl an Grigal 1977). The impact of fire on site productivity is also related to intensity. While high intensity fires tend to decrease site productivity, low intensity fires can increase site productivity (Carter and Foster 2003).
Overall, present results show that soil physical properties considerably change after Taungya burning in the studied Teak plantation site, except a few variables. This study also shows that Taungya burning have limited effect on physical soil properties.

Table 4: Changes of Sand, Silk and Clay before, after, 1 year and 2 years after burning

Time Period	Soil depth	Sand (%)	Silt (%)	Clay (%)	Remark
Sand, Silk, Clay before burning	0 - 10	64	20	16	Sandy- Loam
	40 - 50	60	22	18	Sandy-Loam
	80- 90	60	21	19	Sandy-Loam
Sand, Silt, Clay after burning	0 - 10	31	37	32	Loam
	40 - 50	26	36	38	Clay-Loam
	80- 90	26	40	34	Loam
Sand, Silt, Clay 1 year after burning	0 - 10	39	32	29	Sandy-Loam
	40 - 50	37	30	33	Sandy-Clay-Loam
	80- 90	36	30	34	Sandy-Clay-Loam
Sand, Silt, Clay 2 year after burning	0 - 10	42	29	29	Sandy-Loam
	40 - 50	40	35	25	Sandy-Loam
	80- 90	40	34	26	Sandy-Loam

6. Conclusion

For the establishment of commercial Teak plantation, the need for burning depends very much on the amount of vegetation in the area to be cleared by slash (Taungya cutting). The need for using fire in the Teak plantation is easier and cheaper compared to initial land preparation for new establishment, because there will be less vegetation to be cleared.

Duration of Taungya burning is feasibly the component of fire severity that results not only on the surface but also below ground damage. In fact, Taungya burning at well fuel load compiling plantation sites transfer much heat down to more than few centimeters below the surface. After Taungya burning, soil temperatures can remain high for from a few minutes to several days.

In the final analysis, fire plays an important role in the management of ecosystems, not only in the Bago Yoma, but throughout the Myanmar. This study found evidence that the Taungya burning method has a significant impact on soil physical, chemical, and biological properties in the Teak plantation sites in the Ngalaik Forest Reserve, Ottarathiri Township, Ottarathiri District which is locating in Bago Yoma. Chemical changes in soil after forest Taungya burning are more important. Because changes in nutrient cycle and soil organic matter can change the productivity of ecosystem.

This study indicates that the amounts of soil pH significantly increase, although organic matter in Teak plantation site is significantly affected by Taungya burning, the recovery of soil Organic Matter (OM) in the burnt Teak plantation site starting with the naturally reintroduction of vegetation is fast, producing increased fertility.

Based on the results of this study, Total Nitrogen is not significantly decreased with changeable factors compared to before burning condition. The decrease is correlated with a higher volume of burned organic matter. However, total nitrogen gradually increase because of a rapid growth of the new vegetation coming out and a significant increase in plant storage of nitrogen in this plantation site, and it is expected that topsoil had absorbing total nitrogen and this has increased the total nitrogen is in the soil.

Available phosphorus (P) and potassium concentration significantly increased immediately after the Taungya burns, though there was significant difference in the available (P) amongst the soil after 1year burning and 2 year burning because of (P) can also be lost to the atmosphere by volatilization during the combustion. Moreover, natural replacement of (P) from rainfall or mineral weathering is very low in the Teak plantation site which amount recovers after 4 or 5 year after burning. Therefore, the level of available phosphorus (P), extractable Potassium (K) and Calcium (Ca) in Teak plantation site can be significantly affected by fire event.

The greatest change in soil physical properties occurs when smoldering fires burn for long periods. Soil physical components were slightly changed after fire, by which resulted in lower sand (%), higher silt (%) and higher clay (%) after Taungya burning, which depends on the temperature and the severity of the fire at the plots of the burned plantation site. Collectively, these changes could cause soil erosion problems after high severity fires.

When one year burning, sand and silt percent were improving from after burning to 1 year after burning increase in sand 8 -11%, silt 5-10 % at 0-10 cm and 40-50 soil depth although clay percent were decreasing at all of soil layers (0- 90 cm) compared to after Taungya burning.

Likewise, after two year burning, sand and silt percent were improved from 1 year to 2 year after burning increased with sand 3 -4 %, silt 4-5 % at 0-10 cm to 40-50 soil depth although clay percent were dropping down at (40- 50 cm and 80-90 cm) compared to 1 year after Taungya burning.

The effects of Taungya burn are chiefly a result of burn severity, which consists of peak temperatures and fire duration. Climate, vegetation and topographic conditions (especially in deep sloping area) of burnt area control resilience of the soil system; some fire-induced changes can even be permanent.

Clear cutting and using with Taungya burning system were found to increase erosion rates. Commercial Teak Plantation with clear cutting system at over 30% slope in the mountain area is very sensitive with the changes of runoff and soil erosion.

Overall, present results show that significantly increase soil pH (acidity), Available phosphorus (P) and potassium (K) while decreasing in organic matter (OM) and total nitrogen (N), available calcium (Ca) after burning. However, available Ca, total titrogen (N) and organic matter (OM) were gradually increasing after Taungya burning, 1 year and 2 year burning which amount was not reaching normal (original) condition. Nevertheless, soil pH, available phosphorus (P), and extractable potassium (K) were gradually decreasing after 1 and 2 year burning compared to before burning condition.

7. Recommendations

1. Once site selection is carried out, physical and chemical soil properties with remaining forest type and terrain should be observed before clear cutting.
2. Although fire can dramatically affect physical and chemical soil properties, cautious planning is necessary to assure the sustained long-term productivity of these ecosystems is not adversely affected by fire-related changes in soils.
3. Being Taungya burning can nitrogen losses, it is important to establish if there is compensatory stimulation of under story Nitrogen fixation by legume species within the plantation site.
4. Forest management practices should consider and attempt to minimize disturbance during each plantation establishing stage to control runoff response at the over 30% of slopes.
5. The following specific management measures should be applied as ways to reduce the magnitude of the effects of fire on water quality in the Forest Reserve area: (1) limit fire severity, (2) avoid burning on steep slopes, and (3) limit burning on sandy or water-repellent soils.
6. Low impact silvicultural systems must be used on fragile soils prone to erosion once establish Teak commercial plantation.
7. Wedge felling method must be used and appropriate forestry practices for areas prone to wind throw implemented rather than using of clear cutting method.
8. Mixed commercial tree species should be planted under the Myanmar Reforestation Restoration Program (MRRP) prone to wind throw and pure species (monoculture) must be refrained as much as possible.
9. Chemical compound fertilizer N: P: K - 16:16:16 should be fed to grow well for teak plants or trees once occurrence monsoon onset.
10. Residues from weeding operation should not be removed from plantation site in order to refill organic matters which is necessarily need for teak seedlings or trees.

In order to control soil losses from plantation site, small bush wood check dams should be constructed at all water channels and drainages by rain within plantation si

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