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Forest Research Institute
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<u>Study on Relationship between Soil Reaction (pH) and Nutrient Contents of Soils in Dry Zone Areas</u>

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အပူပိုင်းဒေသအတွင်းရှိ မြေများ၏ မြေဆီလွှာချဉ်ငံဓါတ်ပမာဏအပေါ်မူတည်၍ အာဟာရဓါတ်ပါဝင်မှု အခြေအနေကို ဆက်စပ်လေ့လာခြင်း

ဒေါ်သီတာဆွေ (သုတေသနလက်ထောက် – ၂၊ သစ်တောသုတေသနဌာန)
ဒေါ်တင်တင်ထွေး (သုတေသနလက်ထောက် – ၂၊ သစ်တောသုတေသနဌာန)

စာတမ်းအကျဉ်းချုပ်

အပူပိုင်းဒေသစိမ်းလန်းစိုပြည်ရေးအတွက် သစ်တောစိုက်ခင်းများ ထူထောင်ရာတွင် အပင်များ ရှင်သန်ကြီးထွားမှု ကောင်းမွန်စေရန် သစ်မျိုးအလိုက် ၄င်းတို့ကြိုက်နှစ်သက်သော မြေအမျိုးအစား မှန်ကန်စွာရွေးချယ်ရန် အရေးကြီးပါသည်။ စိုက်ခင်းမြေ၏ အခြေအနေကို အကဲဖြတ်ရာတွင် မြေချဉ်ငန်ဓါတ် (pH) သည် တိုင်းတာမှု အများဆုံးသော မြေဆီလွှာ၏ ဂုဏ်သတ္တိများထဲမှ ဂုဏ်သတ္တိတစ်မျိုး ဖြစ်ပါသည်။ pH တိုင်းတာခြင်း၏ အဓိက တန်ဖိုးမှာ မြေဆီလွှာချဉ်ငန်ဓါတ်ကို ဖေါ်ပြရုံသာမက အပင်စားသုံးနိုင်သော အာဟာရဓါတ်၊ ဆားဓါတ် ပါဝင်မှု စသည်ကဲ့သို့ ၄င်းနှင့် ဆက်စပ်နေသော ဂုဏ်သတ္တိများနှင့် ပတ်သက်သည့် သတင်း အချက်အလက်များကို ပေးနိုင်ပါသည်။ pH နှင့် အာဟာရဓါတ်တို့၏ဆက်စပ်မှုကို ရှာဖွေခြင်းအားဖြင့် pH တန်ဖိုးတစ်မျိုးတည်း တိုင်းတာရုံဖြင့် ၄င်းနှင့် ဆက်စပ်နေသော အာဟာရဓါတ်များ၏ အခြေအနေကို လွယ်ကူစွာခန့်မှန်းပေးနိုင်စေရန် နှင့် ဒေသတစ်ခုချင်း၏ မြေအမျိုးအစားအလိုက် ဂုဏ်သတ္တိများအား ကုန်ကျစရိတ် သက်သာစွာဖြင့် ခန့်မှန်းသိရှိနိုင်စေရန် ရည်ရွယ်၍ လေ့လာတင်ပြထားပါသည်။ လေ့လာတွေ့ရှိချက်အရ ဖော့စဖောရပ်စ်ဓါတ်အား အလွှာတိုင်းတွင် မြေချဉ်ငန်ဓါတ်နှင့် ဆက်စပ်မှုကို တွေ့ရှိနိုင်ပြီး ဆားဓါတ်များ ဖြစ်ကြသည့် ကယ်လ်ဆီယမ်ဓါတ်၊ မဂ္ဂနီဆီယမ်ဓါတ်နှင့် ဆိုဒီယမ်ဓါတ်တို့ကိုမူ အောက်အလွှာ (၈၀–၉၀ စင်တီမီတာ) တွင် မြေချဉ်ငန်ဓါတ်နှင့် ဆက်စပ်မှုအား တွေ့ရှိရပါသည်။ နိုက်ထရိုဂျင် အိုင်းယွန်းသည် အလွယ်တကူ ဆုံးရှုံးနိုင်သဖြင့် နိုက်ထရိုဂျင်ဓါတ်နှင့် မြေချဉ်ငန်ဓါတ်၏ ဆက်စပ်မှုကို မိုးရေချိန် နည်းပြီး အပူချိန်မြင့်သောဒေသ တို့တွင် မတွေ့ရှိနိုင်ပါ။ လေ့လာတွေ့ရှိချက်အရ ရီဂရက်ရှင်းညီမျှခြင်း (regression equations) များကို အသုံးပြု၍ ဒေသတစ်ခု၏ မြေဆီလွှာ အခြေအနေအား အကြမ်းအားဖြင့် ခန့်မှန်းသိရှိနိုင်ပါသည်။

Study on Relationship between Soil Reaction (pH) and Nutrient Contents of Soils in Dry Zone Areas

[1]Thida Swe,[2]Tin Tin Htwe

Abstract

As the population pressure is increased, the great demand of fuelwood and other needs for local people are also increased. Therefore, Dryzone greening afforestation programme has been launching in theses areas. Soil pH determination is one of the most commonly requested analyses undertaken for plantation establishment because of soil conditions tasks that can be made to diagnose the plant growth problems. The main value of pH measurement is that not only it shows a soil to be acid or alkaline but it gives the information about the associated soil properties such as nutrient availability, base status and so on. Soil pH influences the nutrient availability for plant growth. Based on the relationship between soil pH and nutrient contents in soils, we can establish a regression model between soil pH and other properties. Finding the relationship of pH and nutrients is one of the parameters which could be suggested for successful establishment of plantation in central dry zone of Myanmar. Measuring soil pH is rather time saving, least cost and can easily be measured, whereas measuring other chemical properties is complicated and the cost for analyzing is very expensive. The main objective of this study is to predict the existing nutrients status with regression equations easily by only measuring the soil pH value in Dry Zone Areas, for successful establishment of plantations.

Study on Relationship between Soil Reaction (pH) and Nutrient Contents of Soils in Dry Zone Areas

1. Introduction

As the population pressure is increased, the great demand of fuelwood and other needs for local people are also increased. Therefore, Dry Zone Greening afforestation programme has been launching in theses areas. Soil pH is one of the most commonly requested analyses undertaken for plantation establishment because determination of it is one of the most important tasks that can be made to diagnose the plant growth problems. The main value of pH measurement is that not only it shows a soil to be acid or alkaline but it gives the information about the associated soil properties such

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as nutrient availability, base status and so on. Based on the relationship between soil pH and nutrient contents in soils, it can be established a regression model between them from the soil sample analysis. By using this equation model it can be estimated the nutrient contents of an area over the soil pH for the effective plantation establishment. Measuring soil pH is rather time saving, least cost and can easily be measured with water while measuring other chemical properties is complicated and the cost for analyzing them is very expensive. Therefore, the objective of this study is to evaluate the nutrients status easily from the regression model obtained by measuring the pH value alone, for proper site selection in plantation establishment of dry zone.

2. Materials and Methods

2.1 Study Areas

Shwe Nat Taung Protected Public Forest in Thazi Township, Min Sone Taung Protected Public Forest in Nahtogyi Township and Dahatsi Protected Public Forest in Nyaung Oo Township are selected for this study. Each study area is stratified into three different classes according to their land-use conditions namely open land, plantation and remnant natural forest to get a wide a range of soil pH.

In the **fuel wood plantation** area of Thazi township, Eucalypt (*Eucalyptus camaldulensis*), Sha (*Acacia catechu*) and Bawzagaing (*Leucaena leucocephala*) were planted. The species planted for the fuelwood plantation in Nahtogyi and Nyaung Oo townships were Eucalypt (*Eucalyptus camaldulensis)*, Sha (*Acacia catechu*) and Tama *(Azadirachta indica).*

The species growing in **remnant natural forest** in Thazi Township are Kokko (*Albissia lebbek*), Nabe (*Lannea coromendelica*), Bonmeza (*Albizzia chinensis*), Magyi (*Tamarindus indica*) and Thanat (*Cordia dichotoma*). In the remnant natural forest of Nahotgyi township, Than (*Terminalis oliveri*), Dahat (*Tectona hamiltoniana*), Thanatka (*Kimonia acidicsima*) and Gandaya are growing. In the ravines, Thitya (*Shorea oblongifolia*), Ingyin (*Pentacme siamensis*), Kyetyo (*Vitex pubescens*), Pyinkado (*Xylia xylocarpa*) and Myin wa are also found. Than (*Terminalia oliveri*), Dahat (*Tectona hamiltoniana*), Haunkkyan, Nibase (*Chassalia chartacea*), Te (*Diospyros burmanica*), Zi (*Ziziphus jujuba*), Khan (*Carissa carandas*) and Naywe (*Flacourtia cataphracta*) are found in the remnant natural forest of Nyaung Oo township.

According to F. Bander (1983), the soil in study areas included in red brown soil of tropical dry savannas. The dry zone region has tropical savanna climate with a pronounced dry period between the monsoon rains. Rains generally start in mid-May and stop from July to mid-August and then resume intermittently between mid-August and September.

In Thazi and Nahtogyi Townships, the climate is characterized by a dry period from November to April with a mean monthly rainfall of less than 50 mm. However, Nyaung Oo site show a pronounced dry period of 8 months as shown in the following figures.

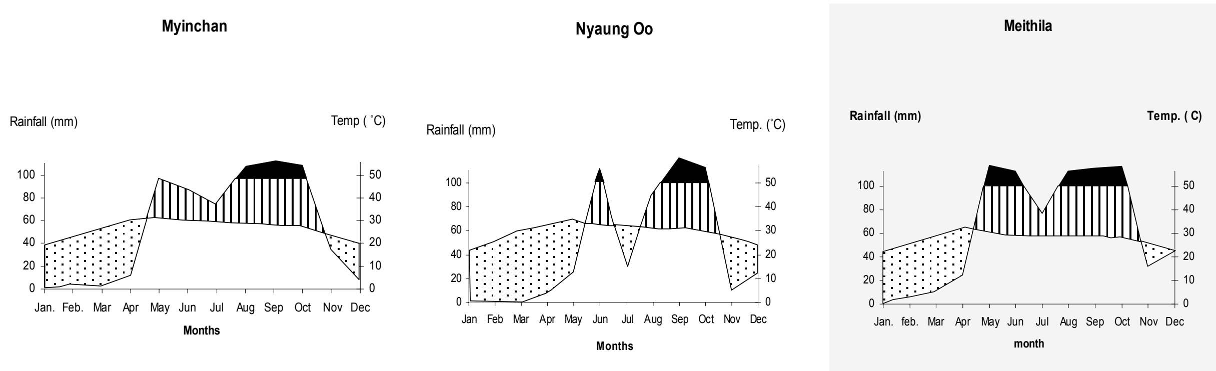


Figure (1). Climatograms of the study areas

2.2 Data Collection

Three plots for each study areas were selected by the Systematic Sampling Method for soil sample collection. In each plot, one soil profile (1m x 1m) and three points were selected and the procedures for allocating the points in each plot in all study areas are given below;

- From the center of the plot, forming a triangle set three points to the North, Southeast and Southwest directions, 25 m apart from the center of plot;
- After selecting the subplot in each sample site, soil pits were dug and the soil profile was dug in the center of the selected plot and the soil samples were collected.

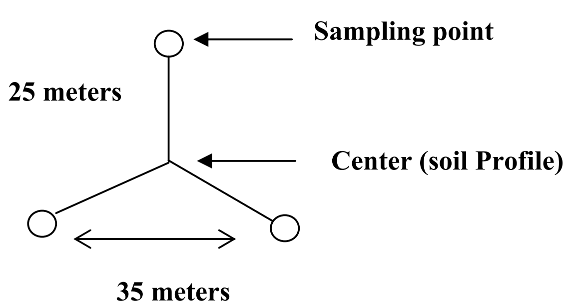


Fig (2) layout of the sample plot

Soil samples from each study site were collected at different depths (0-10 cm, 40-50 cm, 80-90 cm) by manually and the individual samples were collected in label-plastic bags. At the same time, soil profile was dug, classified the soil layers from which soil samples were collected.

2.3 Laboratory Analysis

The physical and chemical properties of soils were analysed at soil Lab, FRI and DAR (Department of Agricultural Research) in Yezin. Soil samples were air-dried and sieved through a 2mm sieve and the physical and chemical properties were analyzed. Particle size distribution was carried out by mechanical analysis. Organic matter was detected by using the weight loss ignition method. Soil reaction (pH) was determined by using corning pH meter equipped with cal mol glass electrode on distilled water suspension (1:2.5). Total nitrogen settled by micro khedival digestion and distillation units. Available phosphorus levels were resolved with double acid extraction solution and molybdenum blue complex method by using Hach DR/2000 spectrophotometer. Extractable potassium, calcium, magnesium, sodium, aluminum and iron were assessed with double acid extraction by using Atomic absorption spectrophotometer.

3. Results and Discussions

3.1 General Condition of Physical and Chemical Properties of soils in the Study Areas

Mean, maximum, minimum and standard deviation of selected physical and chemical properties for soils are listed in table (1).

Table (1). Statistical summarization of selected soil chemical and physical properties

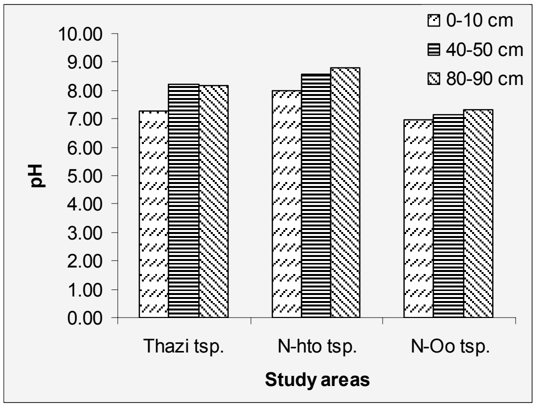
Statistic	pH	Ava. N	Ava. P	Ext. K	Ext. Ca	Na	Mg	Al	Fe	OM	Sand	Silt	Clay
		%				(me/100g)			(ppm)	%			
Thazi Township													
Mean	*7.89*	0.0581	0.00012	0.0009	0.135	0.5608	3.106	1.047	0.916	1.13	86	9	4
Sd	1.23	0.0257	0.00023	0.0008	0.065	0.6136	2.330	0.008	0.388	0.55	17	14	4
Max.	9.86	0.1560	0.00081	0.0028	0.204	2.0600	9.700	1.060	2.140	3.20	98	48	15
Min.	*4.47*	0.0319	0.00000	0.0002	0.008	0.1100	0.410	1.040	0.460	0.41	37	0	0
Nyaung Oo Township													
Mean	7.13	0.0498	0.00005	0.0021	0.123	0.1581	1.386	0.887	1.779	1.47	71	11	17
Sd	0.82	0.0169	0.00008	0.0010	0.079	0.0590	0.770	0.386	1.164	0.49	7	4	5
Max.	8.13	0.0986	0.00037	0.0052	0.233	0.2900	3.620	1.070	5.060	3.05	90	21	24
Min.	5.24	0.0260	0.00000	0.0009	0.028	0.0500	0.680	0.000	0.560	0.75	59	4	4
Nahtogyi Township													
Mean	8.48	0.0846	0.00035	0.0013	0.181	0.5127	2.745	1.056	3.262	1.85	15	66	18
Sd	0.92	0.0463	0.00138	0.0010	0.044	0.4480	1.260	0.023	4.431	1.09	7	12	8
Max.	10.64	0.2105	0.00725	0.0046	0.248	1.5400	4.930	1.150	15.40	4.10	28	88	35
Min.	7.08	0.0284	0.00000	0.0004	0.059	0.1200	0.350	1.040	0.400	0.39	1	38	4

The wide ranges of soil pH from acidic to slightly alkaline conditions are found in Nyaung Oo and Thazi Townships, whereas only alkaline soil was found in Nahtogyi Township. The types of soil in Thazi Township are sand and sandy loam in Nahtogyi Township throughout their various land-use types. In Nyaung Oo Township, sandy loam soil types are found in all land use areas with the exception of open land areas where sandy clay loam soils are dominated.

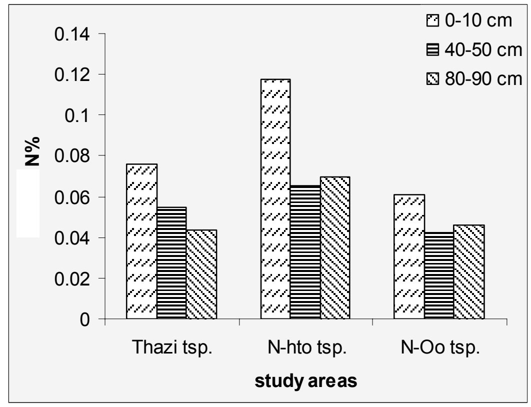
Nitrogen and potassium contents are very low to low level throughout the study areas. However, calcium and sodium contents are medium whereas magnesium levels were high in all study areas. Iron and aluminum contents are very low in these dry zone areas due to the hing concentration of soluble salts.

3.2. Chemical properties of soils in different depths of the study areas

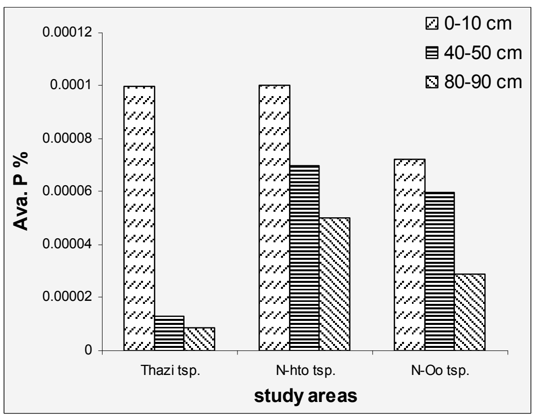
Selected soil chemical properties under the study areas at different depths are shown in these following figures.



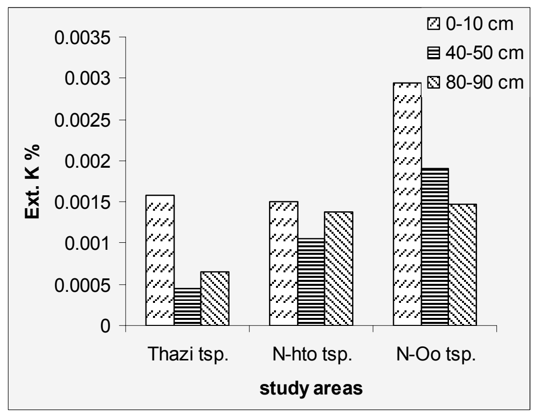
(a) pH contents



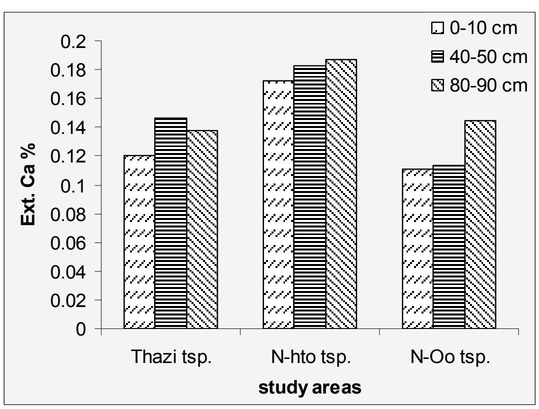
(b) Nitrogen contents



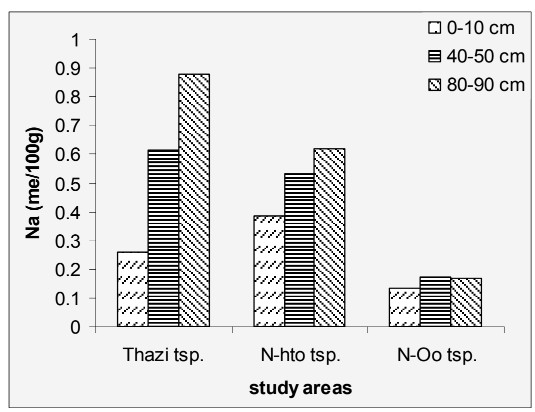
(c) Availble Phosphorous contents



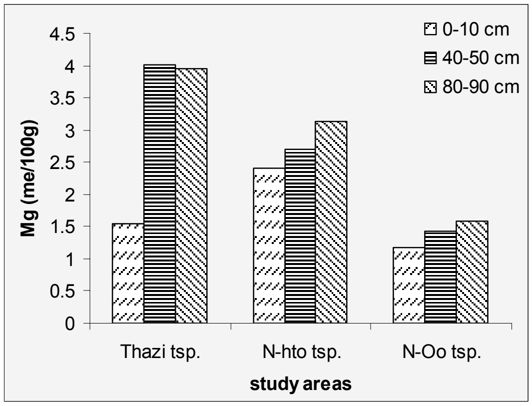
(d) Extractabel Potassium contents



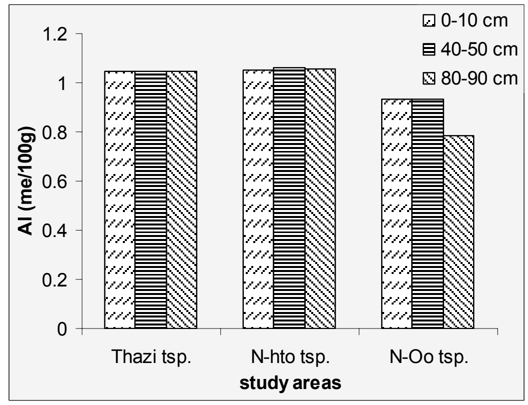
(e) Extractabel Calcium contents



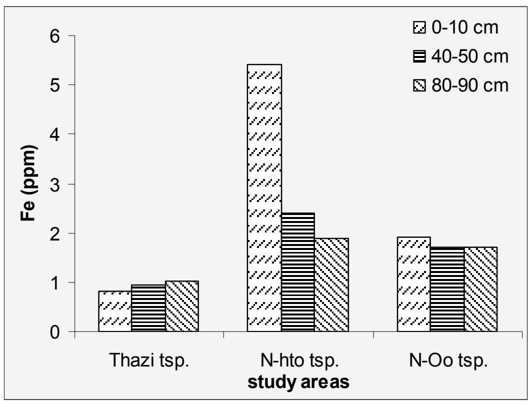
(f) Extractabel Sodium contents



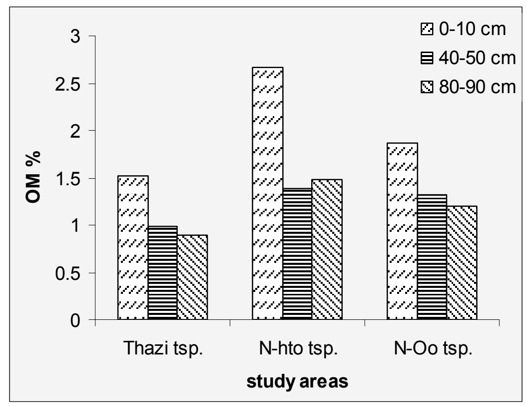
(g (g) Magnesium contents



(h (h) Aluminum contents



(i) Iron contents



(j) Organic matter contents

Figure (3) selected soil chemical properties observed at different depths in the study areas

As shown in the figure (3), the lowest pH levels are found in upper layers of the study areas and increase these pH values with increase in depths. This could be due to the accumulation of some soluble salts such as calcium, sodium and magnesium in the lower layers (see Fig. e, f & g). In contrast, primary nutrients (ie. nitrogen, phosphorous and potassium) are mostly found in surface layer and these contents are decreased with increasing depth. The aluminum (Al) contents, found in Thazi and Nahto Townships are no statistically different among their depths. In Nyaung Oo Township, relatively lower Al content is found and this content is slightly decreased in the lower layer. Iron (Fe) concentration is highest in upper layers in all study areas. The highest organic matter (OM) content is also found in the surface soils in all study areas.

3.3. Relation of soil pH to selected soil chemical properties

The type of model to use in deriving a regression equation depends upon the nature of the relationship between or among the variables concerned. When the relationship is linear, then the model should be appropriate for a straight line. When the relationship is non-linear, then the model should be based on the nature of the curve representing the relationship. Scatter diagrams and best-fit regression equation for pH and selected soil properties are presented in the following figures. In this study, depending on the soil characteristics and pH content of the study areas, most correlations between pH and nutrient status showed that the linear relation is weak. It could, however, actually be found nonlinear relationships between them as shown in the following figures.

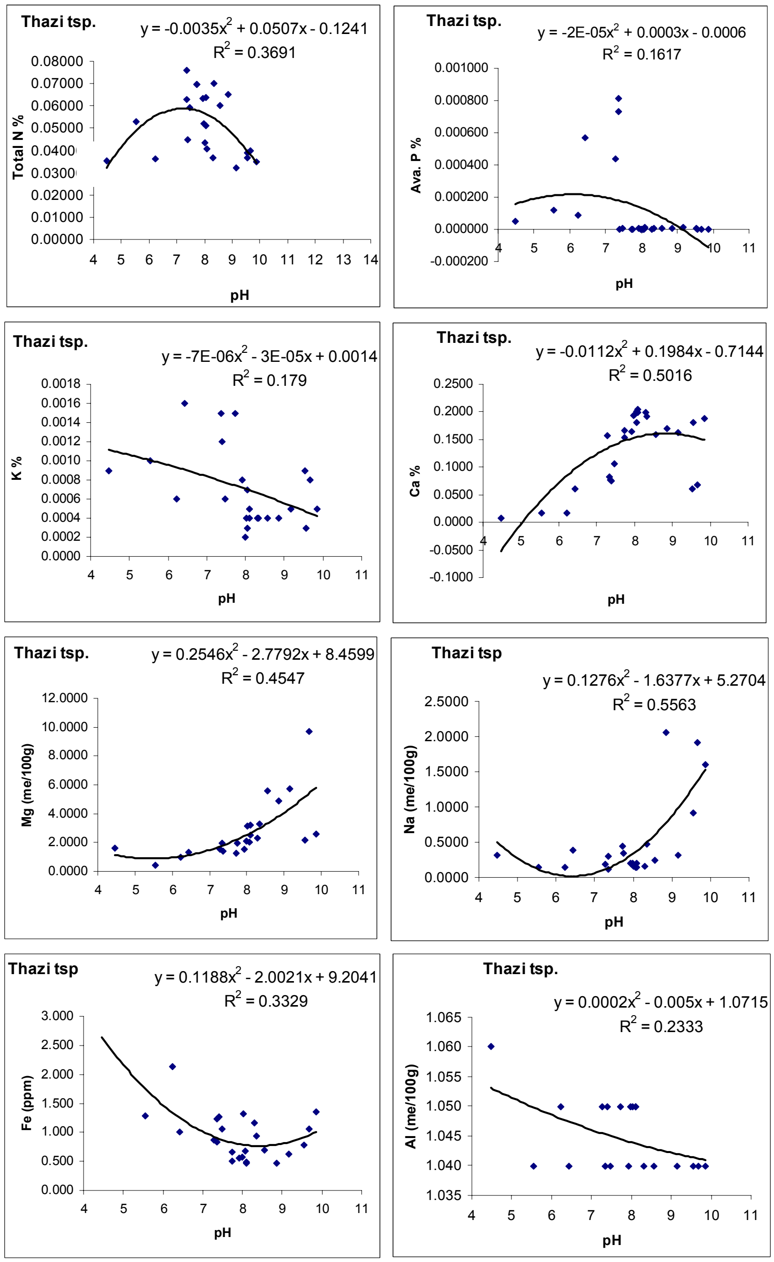


Figure (4). Regression relationships between pH and selected soil chemical properties in Thazi township

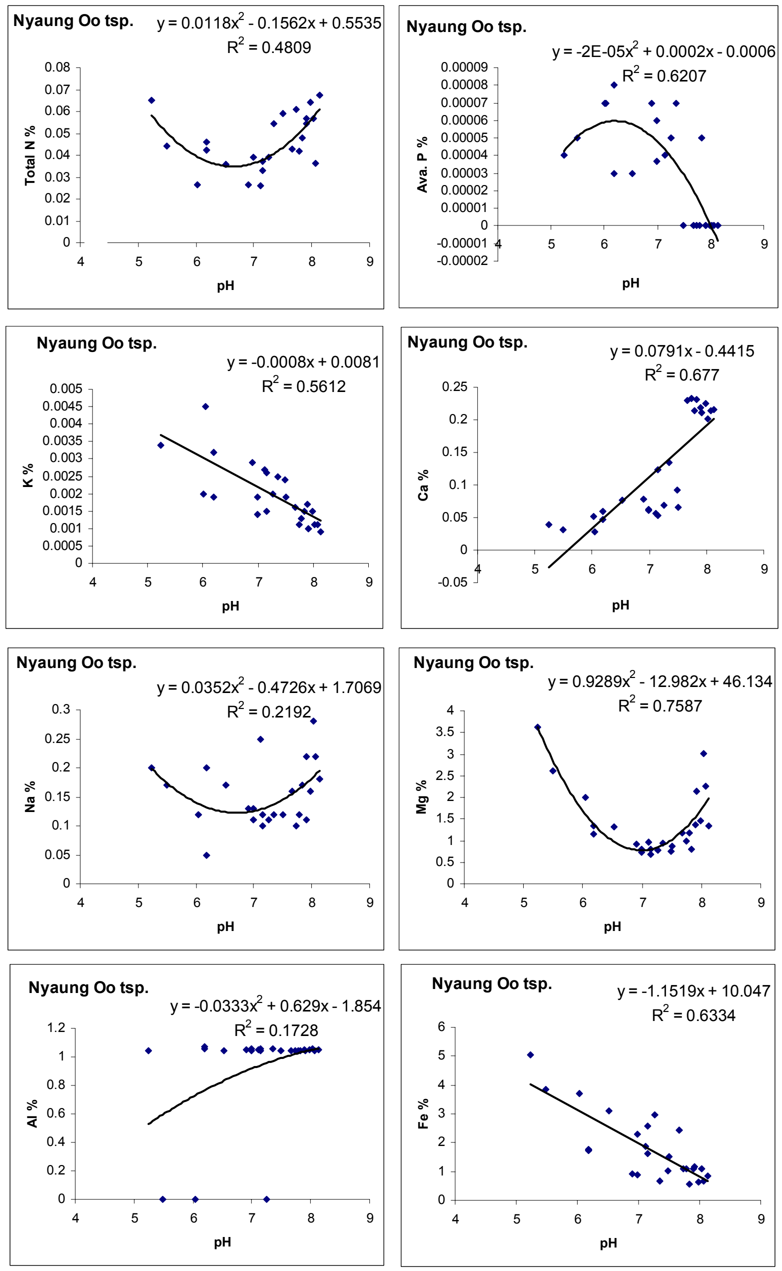


Figure (5). Regression relationships between pH and selected soil chemical properties in Nyaung Oo township

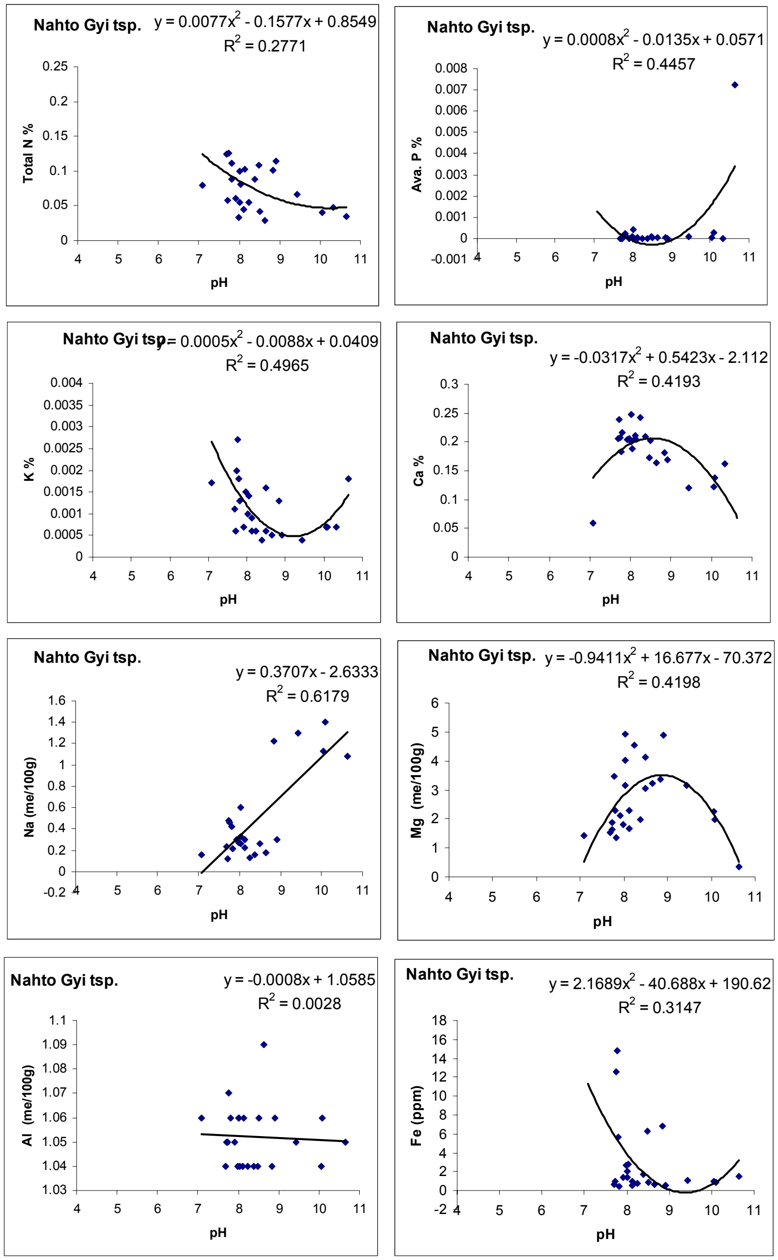


Figure (6). Regression relationships between pH and selected soil chemical properties in Nahto Gyi township

In Thazi Township, highly correlations are found among soil pH and Na, Ca, Mg, Fe and Na at 95% significant levels whereas there are little correlation among pH and P, K, Mg and Al (Fig 4). Generally, there are significant correlation among pH and selected soil properties except in Al and Na in Nyuang Oo Township at 95% to 99% significant levels (Fig. 5). In Nahto Township, little or no correlation is found between pH and Al and poor correlations are found in the relationships of soil pH and N and pH and Fe. The regressions of P, K, Ca, Mg and Na concentrations on soil pH are significant at the 0.05 and 0.01 level and the coefficient of determinations are 0.45, 0.50, 0.42, 0.42 and 0.62 respectively.

3.4. Relation of pH to soil chemical properties at selected layers

3.4.1 Relationship between pH and Nitrogen (N)

Nitrogen (N) in the NO_3^- form is very vulnerable to leaching. Nitrate is concentrated mainly in the surface soil where it is produced as an end-product of mineralization of organic N, or from fertilizers. Nitrate concentrations fluctuate markedly due to the interaction of temperature, pH, moisture, aeration and species effects on nitrification (Pritchett**,** 1979). The amount of mineralization of nitrogen from organic matter is greatest in the range from 6 to 8 and also nitrification is impaired beyond this range. However, nitrogen contents can poorly be estimated from the regression equation of pH relationship with N as the nitrogen can easily be lost by the processes such as leaching, volatilization, denitrification, etc., especially in the dry zone areas. Nitrogen availability can be increased if the vegetation recovered, possibly in association with soil faunal development.

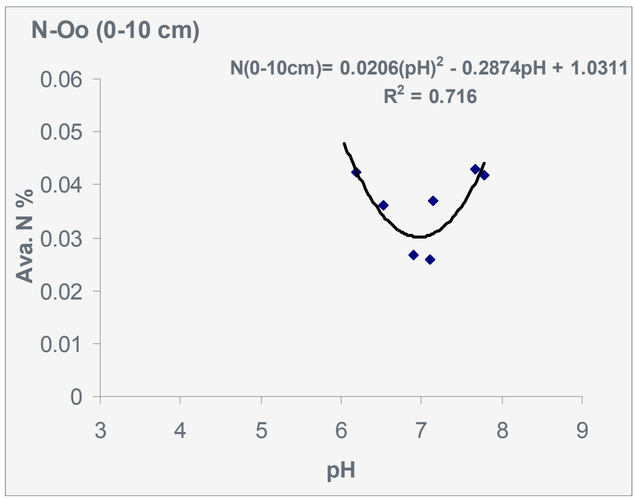


Figure (7). Regression relationships between Nitrogen and pH at the surface and lower layers of Nyaung Oo township

In Nyaung Oo Township, there are fair correlation (R^2 = 0.5) between soil pH and N in both subsoil and lower soil layers at 95% significant level whereas no relation is found in subsoil.

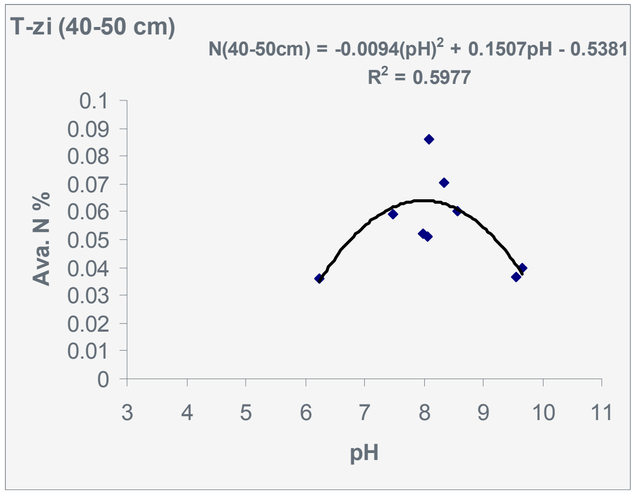


Figure (8). Regression relationship between Nitrogen and pH at the subsurface layer of Thazi township

In the subsurface layer (40-50 cm) of Thazi Township, correlation of soil pH with Nitrogen yielded the coefficient of determinations of 0.60 ($p = 0.01$). However, it could be said that no relationship was found in the surface and the lower layers (R^2 = 0.45 and 0.23).

There are little or no correlations between soil pH and N in the surface and subsurface layers of Nahto Township except in the lower layer where correlation coefficient is 0.61 at 99% significant level (Fig. 9).

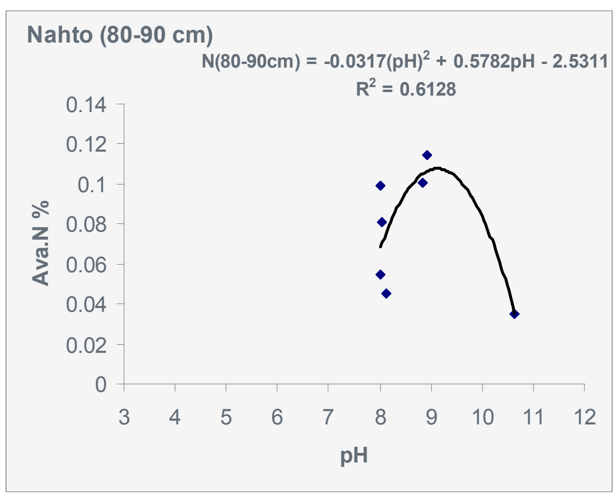
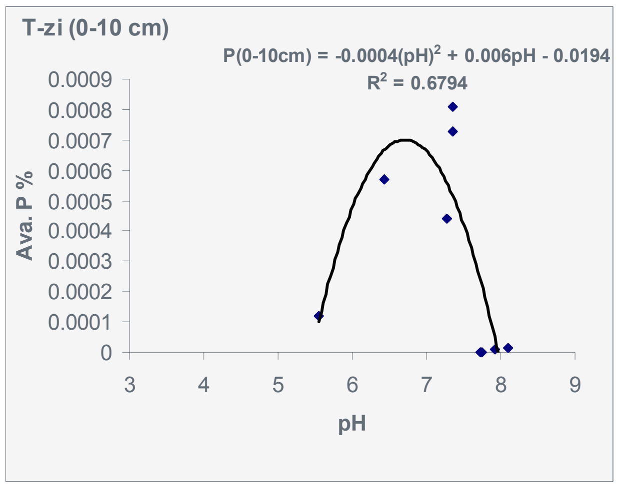


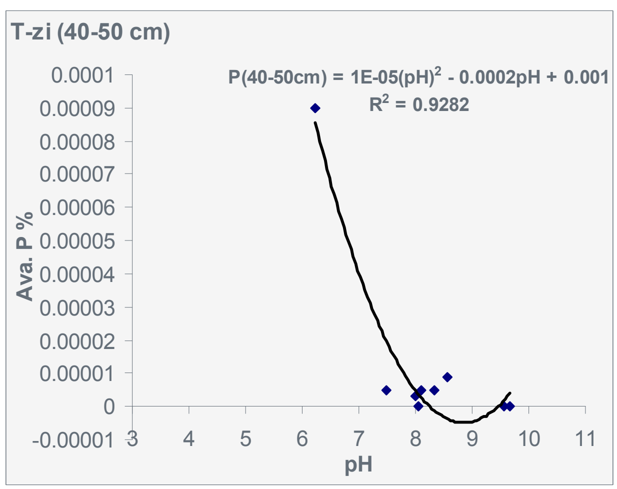
Figure (9). Regression relationship between Nitrogen and pH at the lower layer of Nahto township

Nitrification and nitrogen fixation take place vigorously in mineral soils only at pH values well above 5.5. However, mineralization, although curtailed, will still precede with considerable intensity at lower pH values because most fungi are able to affect these enzymic transfers at high acidities.

Nitrogen (N) content in soil is closely correlated to the amount of organic matter (OM) present in soil. As shown in the Fig (3. j), OM contents are mostly accumulated in the upper layers of all study areas and the same trend for N is also found. Nitrogen in the NO3- form is mainly concentrated in the surface soil where it is produced as and end-products of mineralization of organic N from OM. This could be the reason for this study why the relations of N on soil pH are mostly found in the upper layers. However, this form is very vulnerable to leaching and fluctuates markedly due to the interaction of temperature, moisture, aeration and species apart from pH.

3.4.2 Relationship between pH and phosphorous (P)





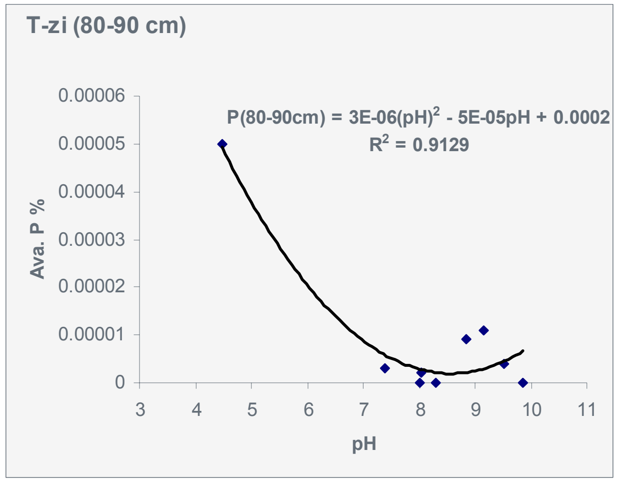


Figure (10). Regression relationships between Nitrogen and pH at all different layers of Thazi township

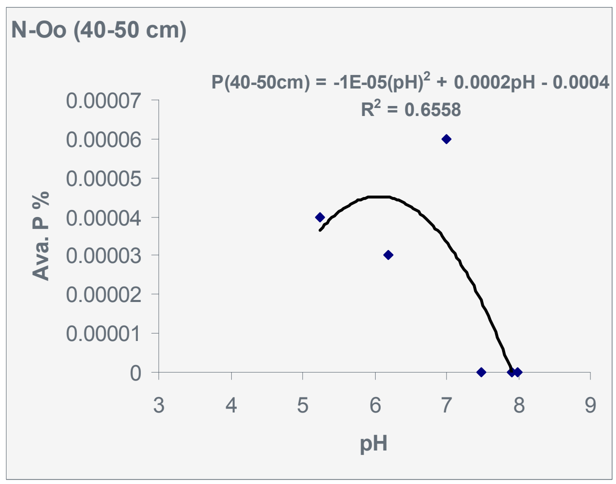


Figure (11). Regression relationship between Phosphorous and pH at the subsurface layer of Nyaung Oo township

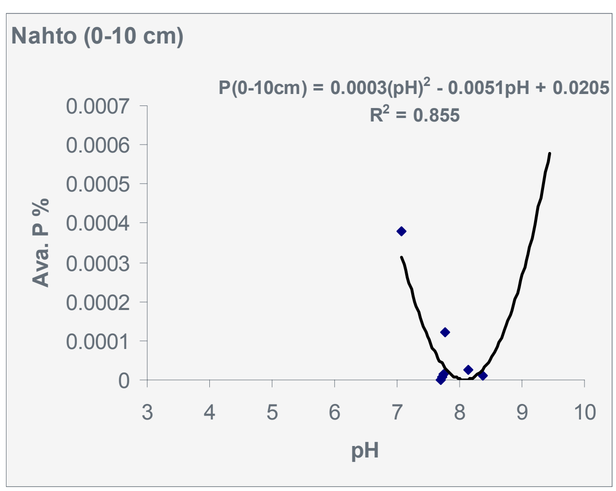
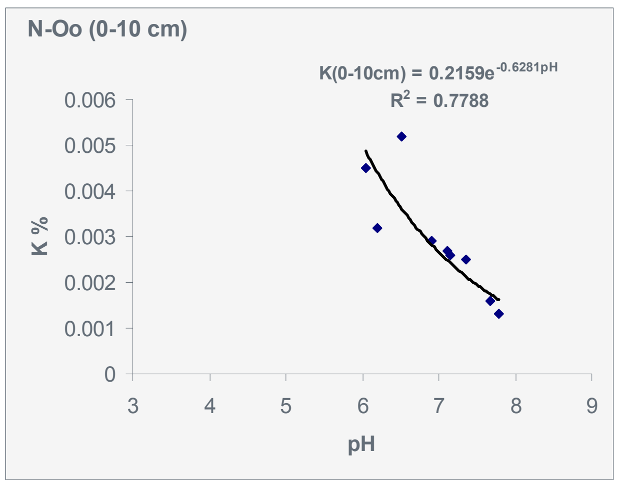


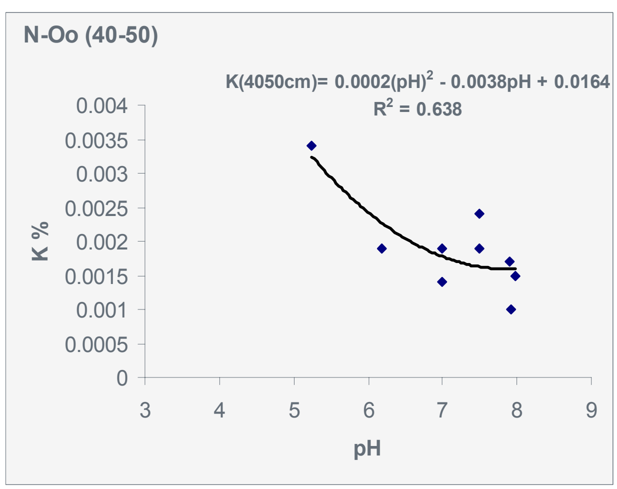
Figure (12). Regression relationship between Phosphorous and pH at the surface layer of Nahto township

As shown in figures, P solubility decreases with an increase in pH below about 7. And its solubility decreases as the pH rises above 7.5. However, in the lower layers in Thazi and Nahto Gyi Townships, this value again rises at the pH value of 8.5. This may be due to the fact that at the pH value of 8.5, where the effects of sodium and potassium ions are appreciable, phosphorous is again held with these ions in the soil in a more soluble condition. Above this pH range, their solubilities may be decreased and precipitated as phosphate ions. So, it can be said that P value can be estimated from the pH value of these ranges.

3.4.3 Relationship between pH and Potassium (K)

In alkaline soil, potassium (K) availability can either be decreased or increased. In this study, decreasing K contents are found with increasing soil pH and with increasing depth. This can be explained by increased potassium fixation in alkaline soils. So, correlations of K with pH are mostly found in the upper layers.





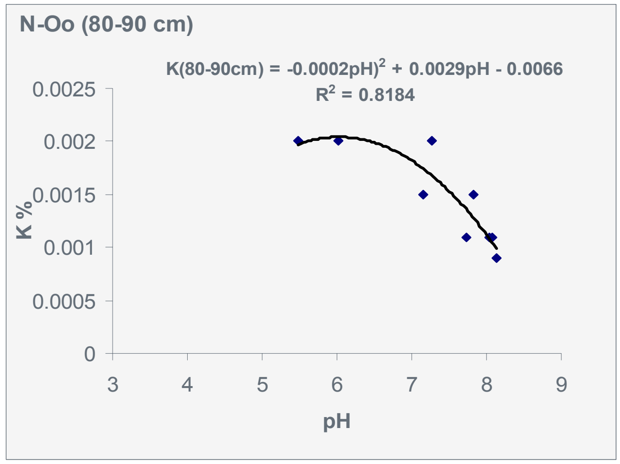


Figure (13). Regression relationships between Poatassium and pH at all different layers of Naung Oo township

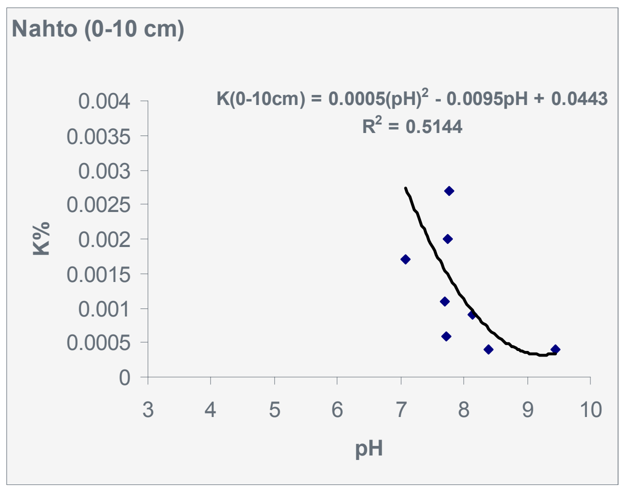
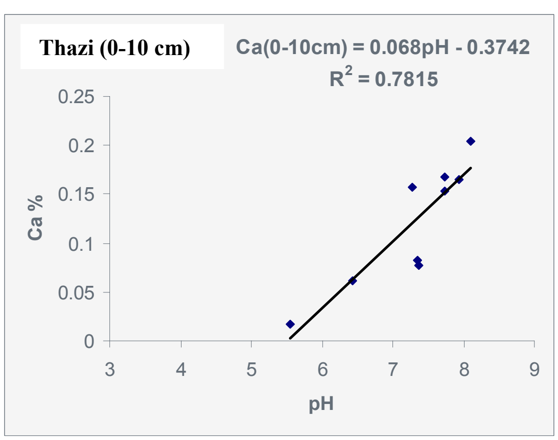
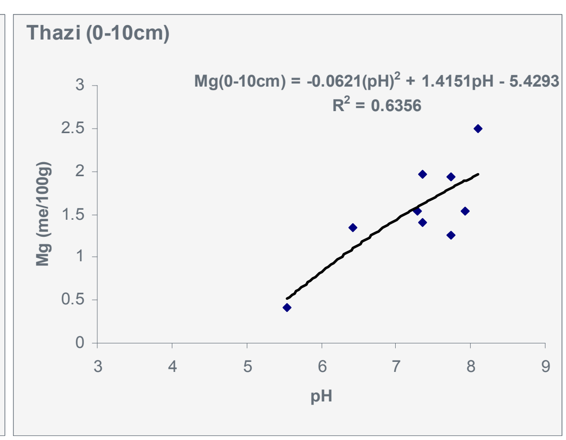


Figure (14). Regression relationship between Potassium and pH at the surface layer of Nahto township

3.4.4 Relationship between pH and Calcium (Ca) and Magnesium (Mg)





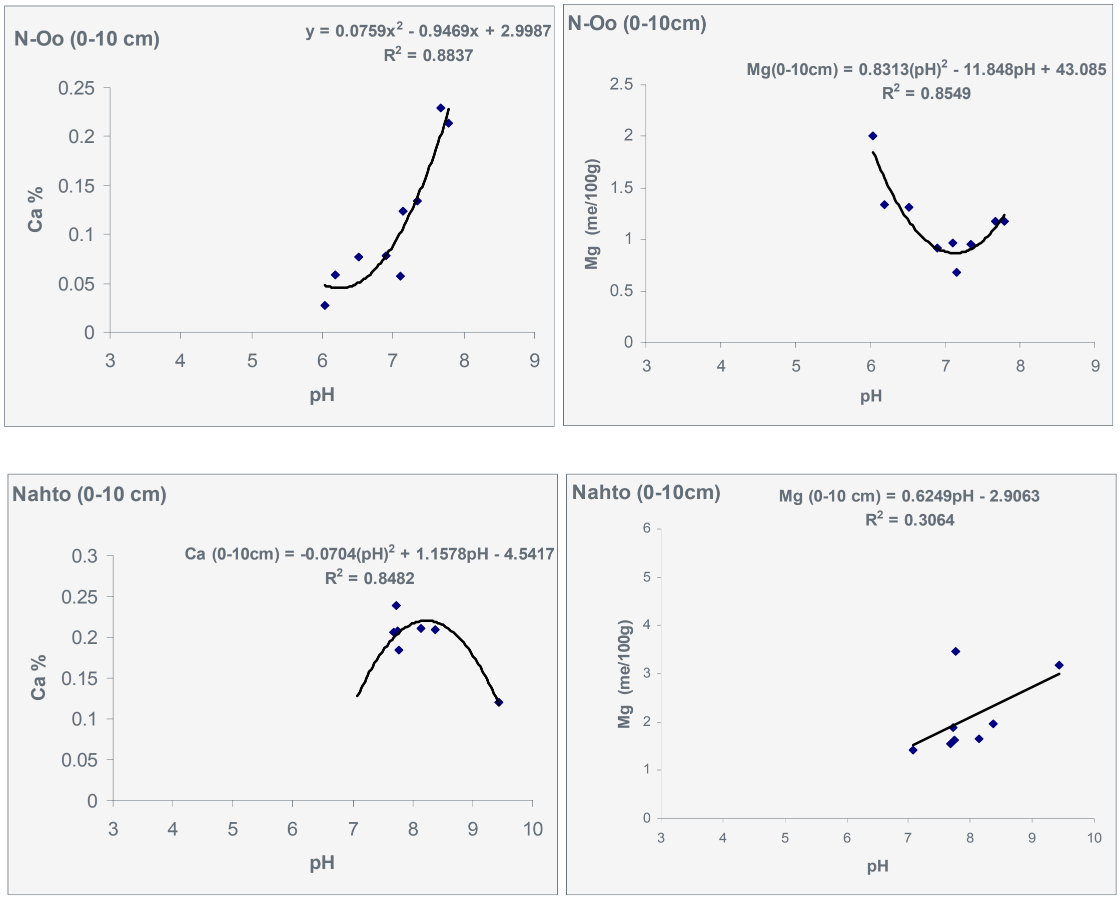
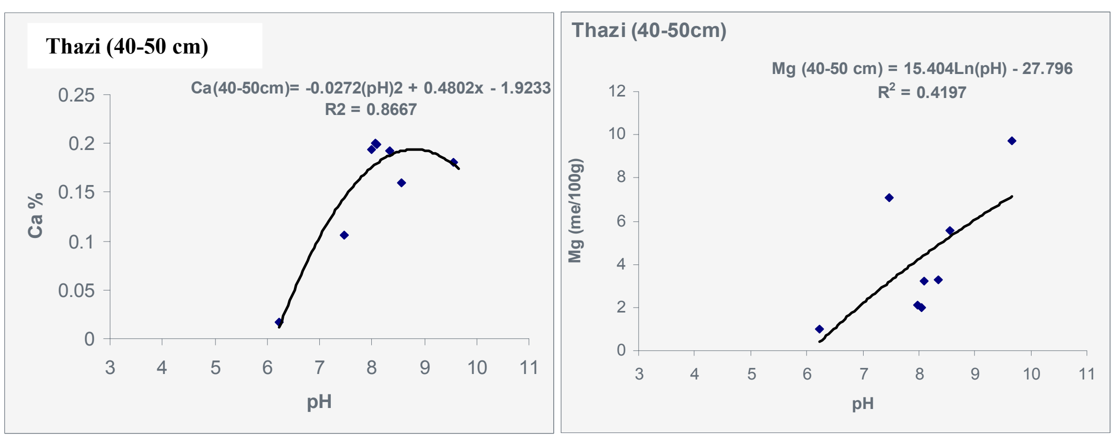


Figure (15). Regression relationships of pH with Calcium and Magnesium at the surface layers of the study areas



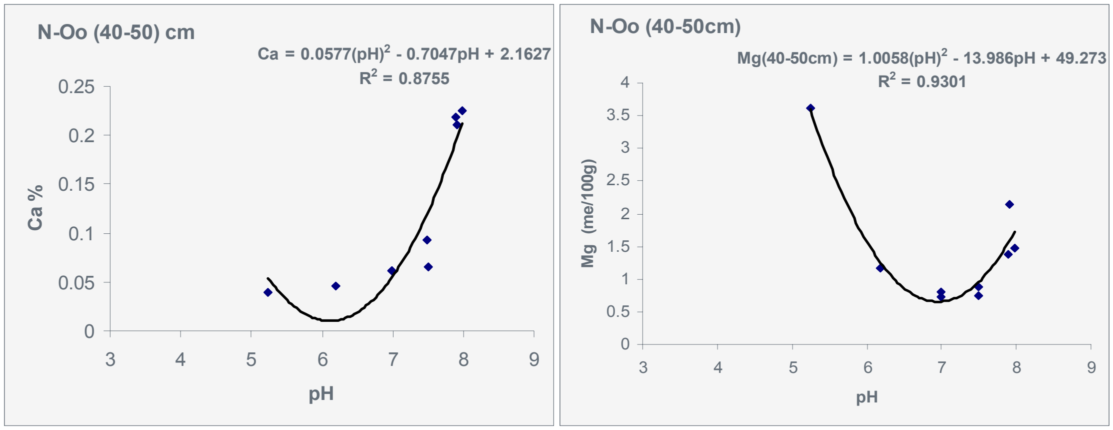
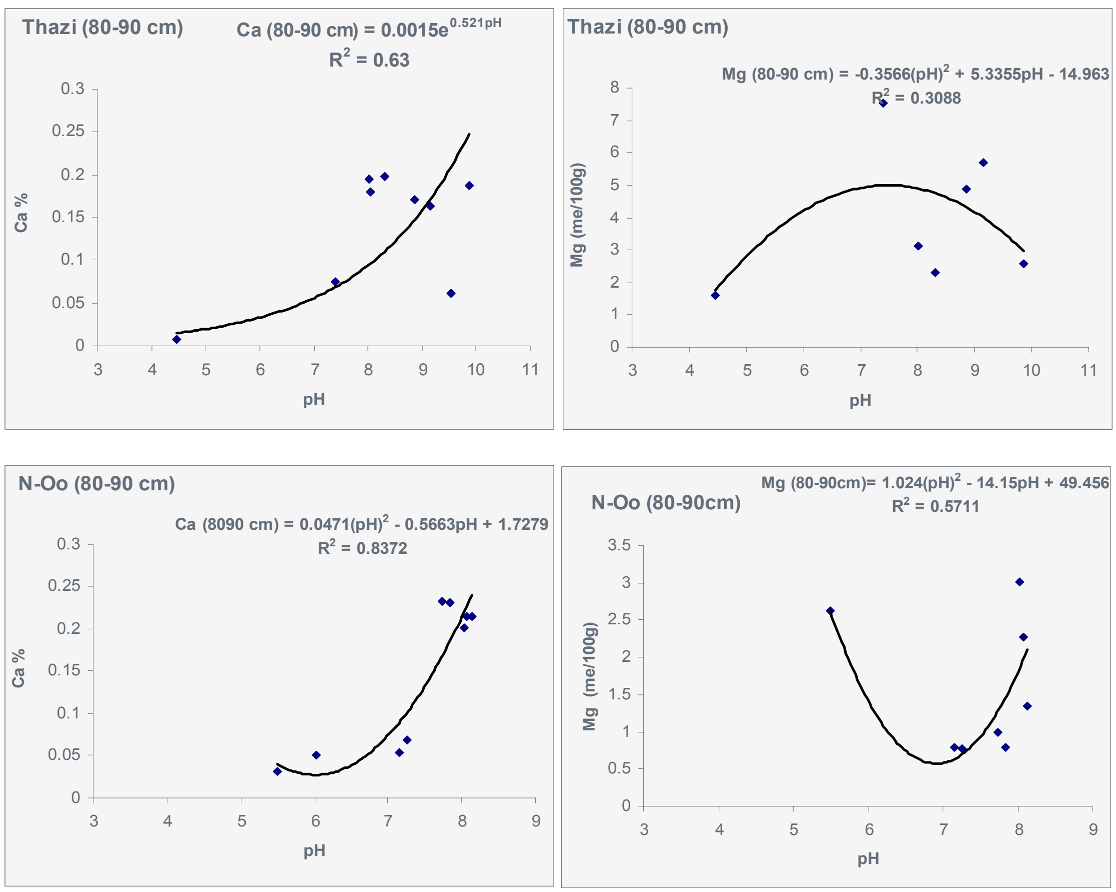


Figure (16). Regression relationships of pH with Calcium and Magnesium at the subsurface layers of Thazi and Nyaung Oo townships



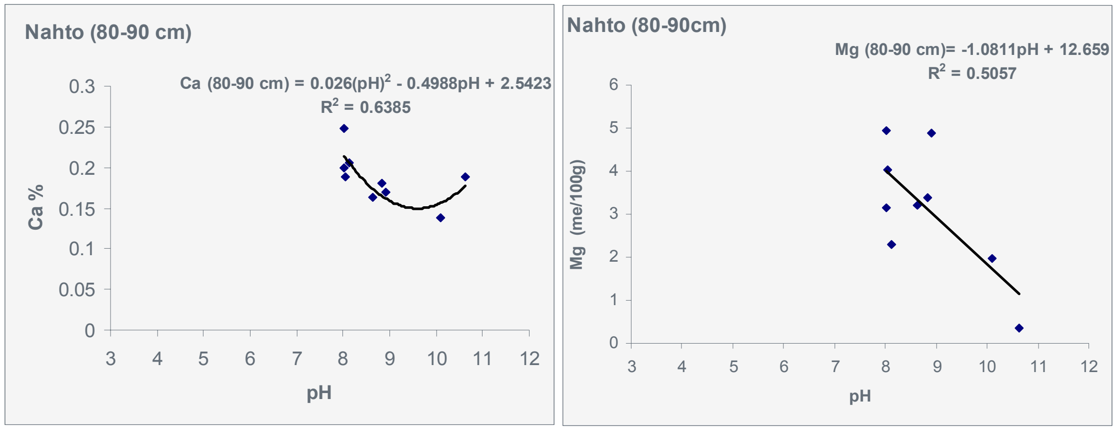


Figure (17). Regression relationships of pH with Calcium and Magnesium at the lower layers of the study areas

Calcium (Ca) and magnesium (Mg) are more soluble at higher pH values except under strongly alkaline conditions. It is only the logical that as the pH of a soil increases, the availability of Ca and Mg also increases, because it is generally through an increase in Ca and Mg that the pH is increased. If the pH is increased above 8.5 there is reduction in availability of these ions. This reduction is due to the fact that sodium and potassium replace Ca and Mg on the clay crystal, and then they are precipitation as carbonates. It can be said that the soils in these study areas are rich in Ca and Mg ions, but low in Na ions. So, relation of Na with pH cannot be found in this study.

3.4.5 Relationship between pH and Aluminum (Al) and Iron (Fe)

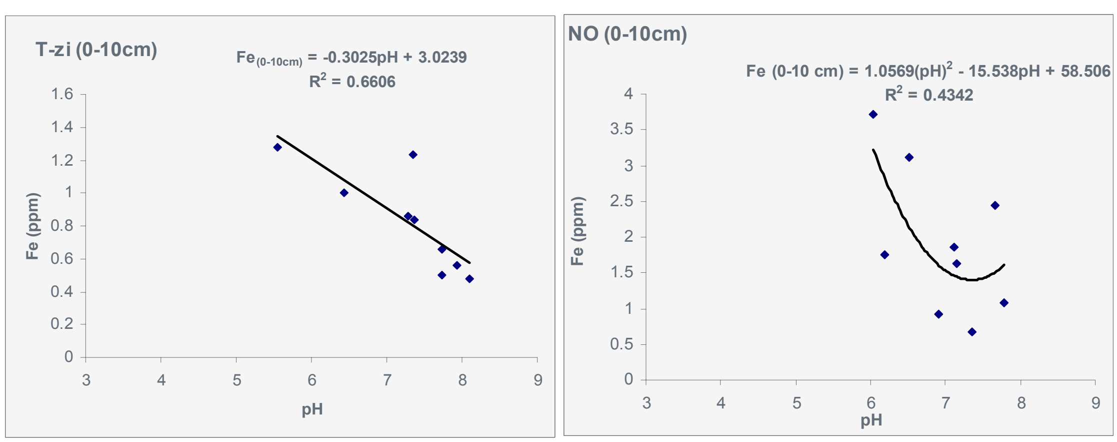


Figure (18). Regression relationships between pH and Iron at the surface layers of Thazi and Nyaung Oo townships

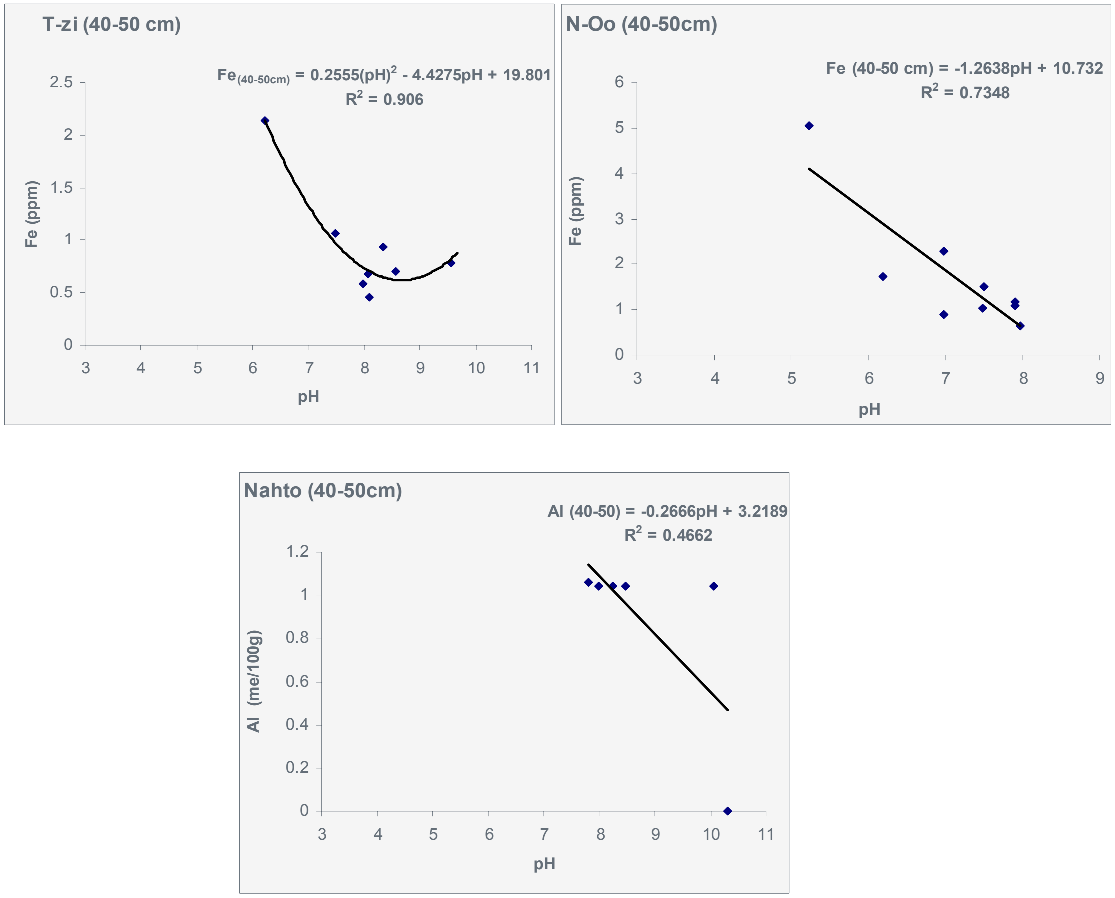
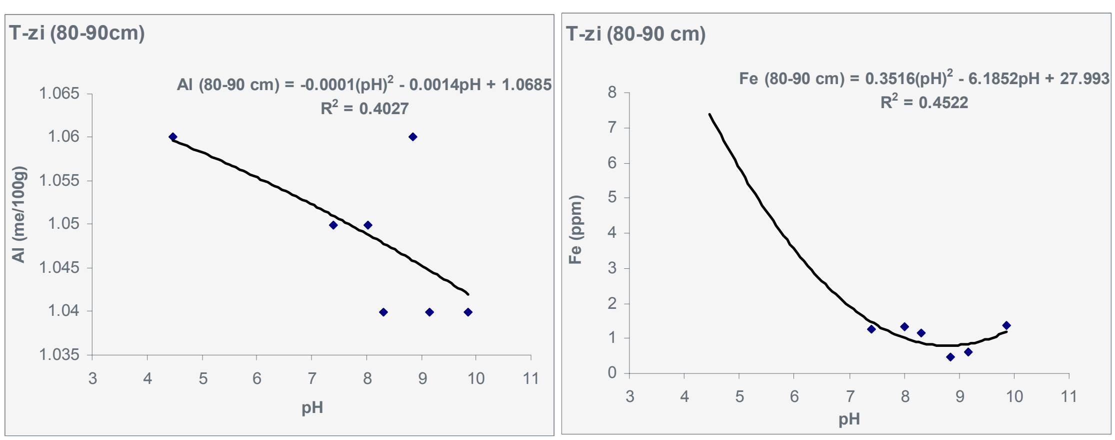


Figure (19). Regression relationships of pH with Aluminum and Iron at the subsurface layers of the study areas

T-zi (80-90 cm)



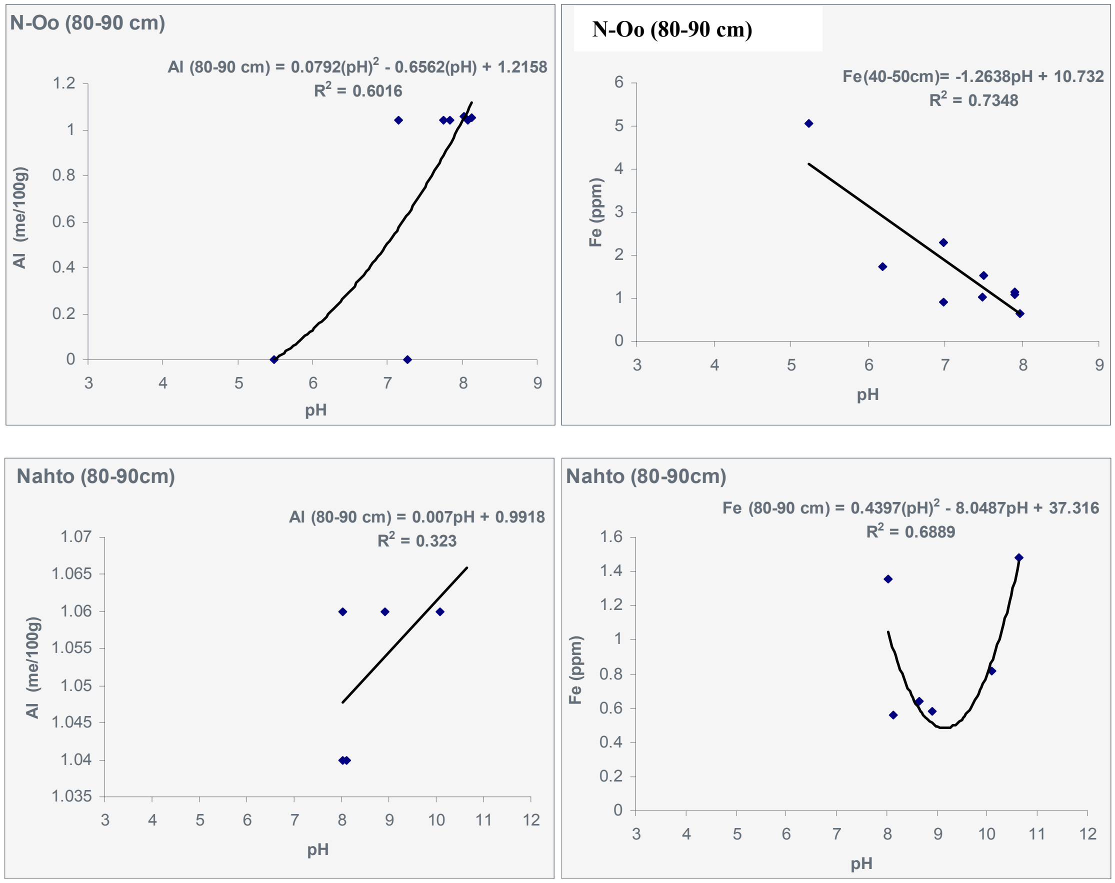


Figure (20). Regression relationships between Aluminum and pH at the lower layer of the study areas

When the pH of a mineral soil is low, appreciable amounts of Aluminum (Al) and Iron (Fe) constituents are soluble, so much that they may become extremely toxic to certain plants. However, as the pH is increased, precipitation takes place and the amounts of these ions in solution become less.

4. Recommendations and Conclusions

4.1. Recommendations

- In estimating the nutrient contents along with pH content of the area, it is more suited to use the regression equations for each depth.
- In estimating the N content over soil pH**,** climatic conditions such as temperature and rainfall, and other factors such as soil types, land use, etc. of the particular site should be evaluated.
- The areas like open or bare land with high temperature, low rainfall and sandy soils can have low soil organic matter and consequently low nitrogen contents. So, estimated amount of nitrogen contents in these areas cannot be deduced.
- However, low or high phosphorous values can be estimated from these pH regression equations.
- Potassium content can be estimated from the relationships of soil pH in the upper layers. For calcium, magnesium and sodium contents, relationships with pH can be found in the lower layers.
- The regression equations obtained from this study can only be used to estimate the nutrients content in soil. The exact value cannot be obtained. By estimating the nutrient contents in the study area, site conditions for plantation establishment can be selected.

4.2. Conclusions

Based on the results obtained from this study, it can be concluded as follows;

- Phosphorous (P) solubility decreases with a decrease in pH below 6.5 and decrease as the pH rises above 7.5. Therefore, the correlation of P availability and soil reaction can be found out within these pH values.
- Although the sequesoxides such as Aluminum (Al) and Iron (Fe) oxides are mostly accumulated in the upper layers of the study areas, negative relationships of these oxides on pH are observed in the lower layers of the pH range of mineral soil from 7 to 9.
- Sodium (Na) contents in soils of Nyaung Oo Township are lower than in soils of Thazi and Nahto Township. And these contents are not significant among their depths. That is why no relationship between pH and Na was observed in Nyaung Oo Township.
- In this study, the estimated values of Ca, Mg and Na can be obtained for the lower layers because these base ions are leached down and accumulated in the lower horizons. The pH range of 6.0 to 8.5 indicates saturation with bases, among which calcium is usually the most abundant.
- In contrast, the correlations of Potassium (K) with pH are mostly found in the upper layers in all study areas.

- Depending on the pH values observed in the particular site, the relation of pH and the nutrient contents in soil can be obtained negative or positive regression curves.

The pH of a soil indicates the availability of other nutrients. At approximately pH 6.5, all minerals are sufficiently soluble to satisfy plant needs, but with increasing deviation in either direction certain nutrients become less soluble.

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