# VARIATIONS OF CHEMICAL CHARACTERS AND IONIC CONTENT ALONG THE CATENA UNDER INTENSIVE VEGETABLE CULTIVATION IN UP COUNTRY WET ZONE

by

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**(00/AS/087)**

**Thesis submitted in partial fulfillment of the requirement for the degree of**

**Bachelor of Science**

**in**

**Natural Resources**

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**Buttala 91100**

**March 2004**

**DECLARATION**

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**ACKNOWLEDGEMENT**

First and foremost, I wish to express my deep and sincere gratitude to my external supervisor Dr. K.A. Nandasena, Senior Lecture, Department of Soil Science, Faculty of Agriculture, University of Peradeniya for his invaluable guidance, advice, continuous supervision, constant help and for all necessary arrangement provided for me to conduct my research project successfully.

Im also indebted to my internal supervisor Dr. Tilak Hewawasam, Senior Lecture, Department of Natural Resources, Faculty of Applied Science, Sabaragamuwa University of Sri Lanka, for his expert guidance, suggestions and advice given whenever necessary.

Im grateful to Prof. Mihinda Rupasinha and Dean of the Faculty for giving me this opportunity to carry out this research project at University of Peradeniya.

I like to extend my thanks to Mr. R.M.P. Rajakaruna and Miss. V. K. Ashesha Chamani (Research Assistant) for their enormous help given me to make this study a great success.

## ABSTRACT

Deterioration of soil quality and pollution of water bodies through the accumulation of nutrient elements and heavy metals due to the heavy application of chemical fertilizers and organic manure are the major concerns in the intensive vegetable cultivation system of upcountry Sri Lanka. Therefore, this research was conducted to study the variation of ionic contents (nutrient elements and heavy metals) and some soil chemical parameters along the soil catena.

Hulankapolla and katumanna provided a representative catena to represent Badulla and Nuwara eliya district respectively. Along the catena from prescribed distances surface soil samples were collected from 30 cm depth from both locations. There were five sampling locations along the catena and each location had three sampling points. Soil sampling was done monthly for the duration of three months period. Soil samples were analyzed for pH,EC,Cation Exchange Capacity[CEC], organic C,Total N, available P and S, exchangeable K,,Mn,Zn, and Cu.

The accumulation of plant nutrients and heavy metals is evident toward the bottom valley of the catena in both locations in the upcountry. Some soil chemical parameters such as EC were also increased in the bottom valley of the catena. This nutrients build up is associated with excessive application of fertilizer, for intensive vegetable cultivation. Continuous use of fertilizers and manure therefore may negatively affect to soil quality as well as to the water quality.

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# CHAPTER 1
# INTRODUCTION

## 1.1 Introduction

The up country wet zone of Sri Lanka refers to the region, which is above 1400m from mean sea level.(Wickramasinghe). The topography comprises of steeply dissected hills with rolling terrain. The mean air temperature ranges from $8C^0$ to $20C^0$, while average annual rainfall is more than 2500mm. Soils are mainly ultisols, with a pH range of 4.00 to 5.50. In general ,soils and environmental factors in the region are highly suitable for year around cultivation of high quality high priced vegetables. Farmers in the up country wet zone had grown potato and vegetable crops during the last two to three decades on an intensive manner. (Wickramasinghe, 2001)

Central highlands of Sri Lanka is famous for intensive cultivation of vegetables. About 60,000 ha of lands are under intensive cultivation. Cultivation on steep slopes, application of over-doses of fertilizer/manure and growing 3-4 crops a year even without a short fallow period are the common features in this unique cultivation system.

Main crops that are cultivated in this area include potato and vegetables. Beet, leek, carrot, cabbage, cauliflower which occupy a major part of the cropping sequence.

These crops are grown in the form of mono cropping or even in the form of mixe. cropping .Farm holdings are small, ranging from about 0.3 to 0.5 ha and ma maximum use of available land, farmers often cultivate more than 2 crops per year. Most farmers in this region use high quantities of chemical fertilizers and organic manure such as cattle and poultry manure.
Amount of fertilizers applied by farmers in the up country areas are much higher than quantity recommended by the department of agriculture.(Damashani kumaragamage, 1999)

The level of chemical fertilizers applied by farmers to potato and vegetable crops is almost 2 to 3 times the quantity recommended by the department of agriculture .In addition ,use of animal manure in potato and vegetable cultivation is also common in this region. Quantities added range from 10 to 15 t $ha^{-1}$ of poultry manure and from 20 to 30 t $ha^{-1}$ of cattle manure. (Damashani kumaragamage, 1999)

As a result, the accumulation of high amount of plant nutrients in the soil of this region is inevitable. (Damashani kumaragamage, 1999)

## 1.2 Problems

Because of the intensive vegetable cultivation, deterioration of soil quality and pollution of water bodies through the accumulation of nutrient elements and heavy metals could be observed. Some of the soil chemical parameters are also get effected due to the accumulation of nutrients.

## 1.3 Objectives

Therefore, the objective of the present research is to study the variation of ionic contents (nutrient elements and heavy metals) and some soil chemical parameters along the soil cateria.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Soil and plant growth

Soil is the world greatest natural resources which produce feed, fiber and oil to support human and animal population. Soil contains adequate amount of all essential elements readily available to plant .Soil must be in a good physical condition to support plants and contains the right amount of water and air for desirable root growth.

Some soils favor plant roots to grow deeply and to extend to a long distance laterally. These soils are ideal because the plants growing in them will be drought resistance and capable of absorbing water and nutrients from a large volume of soil. Plant roots may be restricted by compacted layers infertile horizons, excess soil moisture, stress or soluble salt in toxic quantities. Nutrients for desirable plant growth may be deficient because of bad soil physical chemical condition, cloddy surface of the soil, surface crusts or lack of soil aggregation, reduce exchange of oxygen, carbon dioxide, low water infiltration etc.(Donahue and Follet et.al,1976).

## 2.2 Fertilizers and crop yield

Vegetables differ from most perennial crops in that they have a short growing period of about 2 to 3 months and generate a very high quantity of biomass. In addition ,vegetable crops remove large quantities of plant nutrients. Furthermore, they are shallow-rooted and have to obtain their nutrient requirements from a small volume of soil. These conditions suggest that vegetables should receive a relatively large supply of plant nutrients in a short time from the soil or added fertilizer for adequate growth and subsequent satisfactory vegetable crop yields.

Due to the hilly nature and high rainfall in the upcountry areas of Sri Lanka, soils are rather poor in plant nutrient contents. Inherently, the soil fertility in ultisol which is the main soil group in this region is very low (Table2.1). (Damashani kumaragamage, 1999)

Table2.1 Some Chemical properties of uncultivated soils in the upcountry.

| **Property** | **Range** |
|---|---|
| pH[1:2.5 Soil: $H_2O$] | 4.0-5.5 |
| Total N[%] | 1.0-2.0 |
| Olsen's P[mg/ kg] | 2.0-10 |
| $NH_4OAc$ Extractable K [meq 100g] | 0.1-0.2 |
| Organic matter[%] | 1.0-2.0 |

Source- Damashani kumaragamage1999

2.2.1 Nitrogen

Introduction of high yielding vegetable varieties with an intensive system of cultivation on hilly lands have contributed to a large extent on the gradual depletion of N from the soil. Result of experiments conducted revealed that the application of N at the rate 100 kg $ha^{-1}$ significantly increased the yield of vegetables in this region. With the conclusion of a series of N response studies in the upcountry there was an opportunity to make available for upcountry vegetable farmers the appropriate N fertilizer recommendation for their vegetable crops. (Damashani kumaragamage, 1999)

2.2.2 Phosphorus

Phosphorus is the most limiting plant nutrient for vegetable yield in ultisols. A series of seasonal and long term experiments carried out in this region revealed that there is a positive response to added P even during the first season. This shows the importance of P fertilizer addition to crops grown in the ultisols. With regard to phosphorus ,it is important to note that the response to phosphorus by exotic vegetable is somewhat high. Vegetables grown in this region showed a good response to" high grade" P fertilizers such as TSP (Triple Super Phosphate) (Table 2). In addition, a number of experiments conducted on vegetable in the upcountry suggests that an application of phosphorus at 100kg per $ha^{-1}$ is needed[to obtain high potato and vegetable yields(Table2. 3). (Damashani kumaragamage, 1999)

Table2. 2 Effect of phosphorus (P) sources on crop yields.

| P Source | Crop yield[t /ha] | | | |
|---|---|---|---|---|
| | Potato | Cabbage | Pole bean | Tomato |
| TSP | 10.9 | 22.5 | 16.3 | 13.3 |
| HCRP | 8.7 | 10.4 | 13.1 | 7.7 |
| SERP | 8.9 | 6.8 | 12.5 | 5.5 |
| ERP | 7.8 | 2.2 | 10.7 | 5.3 |
| LSD[p=0.05] | 1.4 | 2.1 | 2.1 | 1.6 |
| CV[%] | 15.4 | 22.1 | 15.9 | 21.2 |

Source- Damashani kumaragamage1999

TSP-Triple super phosphate, HCRP-High citric acid soluble rock phosphate, SERP-Sectively mined Eppawala rock phosphate,ERP-Eppawala rock phosphate.

All treatments received N and K according to the DOA recommendation of 1990.

Table2. 3 Effect of different phosphorus (P) levels on crop yield

| **P level[kg/ ha]** | **Crop yield [t/ha]** | | | |
|---|---|---|---|---|
| | **Potato** | **Cabbage** | **Pole bean** | **Tomato** |
| 0 | 10.6 | 1.2 | 3.1 | 4.3 |
| 25 | 21.3 | 13.6 | 4.5 | 5.1 |
| 50 | 27.4 | 31.7 | 6.3 | 6.6 |
| 100 | 37.2 | 50.8 | 6.6 | 9.0 |
| LSD [P=0.05] | 4.2 | 7.2 | 1.2 | 1.3 |
| CV [%] | 14.1 | 24.1 | 18.4 | 17.4 |

Source- Damashani kumaragamage1999

All treatments received N and K according to the DOA recommendation of 1990

2.2.3 Potassium

Long term experiments have revealed that the application of potassium fertilizers does not have a major effect on the crop yield when compared to p fertilizers because of the high content of available K in ultisols .However ,an application of 100kg $K_2O$ ha is needed to maintain a reasonable soil K level and to obtain a high yeild of potato and vegetables (Table2. 4). (Damashani kumaragamage, 1999)

Table2. 4 Effect of different potassium (K) levels on crop yield

| K level | Crop yield [t/ha] | | | |
|---|---|---|---|---|
| [kg K2O ha] | Potato | Cabbage | Tomato | Pole bean |
| 0 | 22.5 | 65.2 | 34.5 | 14.8 |
| 25 | 23.8 | 71.9 | 37.7 | 18.5 |
| 50 | 26.4 | 69.3 | 34.7 | 18.0 |
| 100 | 23.7 | 77.8 | 34.0 | 19.2 |
| LSD[P=0.05] | NS | NS | NS | 1.4 |
| CV[%] | 12.6 | 10.3 | 15.5 | 6.4 |

Source- Damashani kumaragamage1999

NS –Not significant; All treatments received N and K according to the DOA recommendation of 1980.

2.2.4 Magnesium (Mg)

Studies conducted by Wijewardena and Amarasiri, (1993) and wijewardena ,(1996) on the ultisols of the upcountry have shown that application of Mg fertilizer increased the vegetable yield (Table 5). Results of the experiment showed that continuous cultivation of vegetable crops depletes exchangeable Mg. Hence, the application of at least 30kg Mg ha per crop would be necessary to maintain a reasonable level of Mg level in upcountry vegetable growing soils. These results suggest the necessity to include Mg in the fertilizer recommendation for vegetables in the upcountry region.

Table2. 5 Effect of different magnesium (Mg) levels on crop yield

| **Mg level** | **Crop yield [t/ha]** | | |
|---|---|---|---|
| **[Kg ha]** | **Cabbage** | **Tomato** | **Bush bean** |
| 0 | 41.5 | 67.8 | 6.4 |
| 15 | 44.0 | 73.1 | 7.5 |
| 30 | 47.6 | 69.6 | 7.0 |
| 60 | 43.3 | 74.8 | 7.9 |
| LSD[P=0.05] | NS | NS | NS |
| CV[%] | 22 | 18.4 | 13.3 |

All treatments received11, P and K according to the DOA recommendation of 1980.
Source- Damashani kumaragamage1999

2.2.5 Sulphur

An experiment conducted in the upcountry revealed that application of sulphur at the rate of 60 kg $ha^{-1}$ significantly increased the yield of cabbage . Results further showed that ammonium sulphate was more effective than gypsum as a source of sulphur. In addition , result of another long term experiment revealed that highest yield and sulphur content in the soil after each crop, was obtained in a treatment which received poultry manure. (Damashani kumaragamage, 1999)

2.2.6 Micronutrients

It is a well known fact that vegetables are high micronutrients feeders. .However in Sri Lanka, micronutrient requirements had not been considered when fertilizer recommendation were made for potato and vegetables.

2.2.7 Foliar fertilizer

Farmers in the upcountry use foliar fertilizers in addition to the soil applied fertilizers. There is an opinion among the farmers that the use of foliar fertilizer may increase crop yield substantialy. However, the results of a long term field experiment (Table 2.6)conducted showed that the application of foliar fertilizer is not necessary if poultry manure at the rate of 10 t $ha^{-1}$ is applied in combination with DOA recommended NPK chemical fertilizers.(Wickramasinghe, 2001)

Table2. 6 Effect of different foliar fertilizers on crops yields

| Treatment | Crop yield [t/ ha] | | | |
|---|---|---|---|---|
| | Tomato | Cabbage | Polo bean | Potato |
| No fertilizer | 8.1 | 2.3 | 4.5 | 2.7 |
| NPK | 34.7 | 32.3 | 13.9 | 5.2 |
| PM | 45.7 | 41.0 | 17.2 | 6.4 |
| PM +NPK | 52.6 | 63.7 | 21.9 | 9.9 |
| F.F. | 12.0 | 2.4 | 6.6 | 2.9 |
| F.F +NPK | 32.3 | 36.3 | 15.7 | 6.6 |
| F.F +PM | 45.4 | 48.2 | 18.5 | 7.0 |
| F.F+PM+NPK | 37.7 | 62.9 | 16.6 | 9.2 |
| LSD[P=0.05] | 8.6 | 10.7 | 4.5 | 2.2 |
| CV[%] | 14.7 | 16.8 | 18.0 | 20.3 |

Source-Wickramasinghe2001

NPK –Recommended by the DOA in 1990,PM –poultry manure 10t/ha.

F.F –Foliar fertilizer(Maxi crop)

2.2.8 Organic Fertilizers

Agriculture in the upcountry is dominated by vegetable and potato cultivation, for which high level of organic manure is used. An experiment conducted in two different sites indicates that both cattle and poultry manure application at the rate of 10t $ha^{-1}$ increased tomato yield over the control .However, poultry manure application gave higher tomato yields than cattle manure application (Table2. 8). Similarly a series of long term experiments conducted with potato and vegetables showed that poultry manure is a better source of organic manure when compared to compost or cattle manure (Table2. 8 and Table2. 9).Thus poultry manure appears to be a viable option for potato and vegetable production in the upcountry where the soils are very acidic with poor fertility .Increase of soil pH due to the application of poultry manure is one of the most important additional advantage in poultry manure use under potato and vegetable cultivation .(Wickramasinghe, 2001)

Table2.7 Effect of different organic manure sources and chemical fertilizers on crops yields.

| Treatment | Crops yield[t/ha] | | | | | | |
|---|---|---|---|---|---|---|---|
| | Cabbage | Tomato | Garlic | Polo bean | Potato | Cabbage | Tomato |
| Control | 13.9 | 10.2 | 33.8 | 3.3 | 6.7 | 10.4 | 2.2 |
| CF | 52.7 | 18.7 | 48.8 | 10.4 | 14.0 | 55.5 | 7.2 |
| CM | 9.3 | 9.7 | 42.5 | 4.7 | 11.0 | 32.4 | 5.1 |
| CP | 22.2 | 11.7 | 52.5 | 6.3 | 13.0 | 33.0 | 6.9 |
| PM | 68.2 | 25.4 | 85.0 | 10.2 | 14.2 | 58.0 | 18.7 |
| PM +CM | - | - | 16.5 | 27 .5 | 4.5 | 13 .7 | 34.9 |
| CM +CP | - | - | - | - | - | 55.5 | 9.3 |
| CP+CF | - | - | - | - | - | 57.9 | 8.4 |
| PM +CF | - | - | - | - | - | 88.1 | 24.6 |

Source-Wickramasinghe2001

CF-Recommended rates of NPK chemical fertilizers, CM-Cattle manure, CP-Compost 10t/ha,PM-Poulrty manure 10t/ha ,PM+CM –Poultry manure 5t/ha +Cattle manure 5t/ha

Table2.8 Effect of animal manure and chemical fertilizes on crop yield.

| **Treatment** | **Crops yield[t/ha]** | | | |
|---|---|---|---|---|
| | **Polo bean** | **Tomato** | **Cabbage** | **Potato** |
| Control | 5.0 | 3.8 | 4.1 | 6.0 |
| PM | 8.9 | 51.5 | 78.5 | 10.0 |
| CM | 6.5 | 17.0 | 36.6 | 6.2 |
| CF | 6.9 | 26.7 | 69.6 | 8.0 |
| PM +CF | 11.8 | 57.9 | 104.0 | 12.6 |
| CM+CF | 9.4 | 40.7 | 68.0 | 10.4 |

Source-Wickramasinghe2001

CF-Recommended rates of NPK chemical fertilizers, CM-Cattle manure, PM-Poultry manure 10t/ha ,PM+CM –Poultry manure 5t/ha +Cattle manure 5t/ha.CM- Cattle manure.

## 2.3 Soil erosion and intensive vegetable cultivation.

Soil erosion by water is a natural phenomenon. It is an important process for soil formation and landscape development .However the process is accelerated by activities of human beings .Accelerated soil erosion by water is a serious problem on agriculture land in several region of Sri Lanka (Nayakekorala, 1996) . Soil erosion is very acute in the hill country where most of the critical water sheds are located (Table 2.9).

Table 2.9 Soil erosion of Sri Lanka

| District | Percentage extent % |
|---|---|
| Colombo | 2.3 |
| Gampha | 2.4 |
| Kilinochchi | 8.0 |
| Kalutara | 11.1 |
| Mulativu | 14.6 |
| Mannar | 17.1 |
| Kegalla | 17.3 |
| Galle | 20.6 |
| Jaffna | 22.7 |
| Matara | 24.4 |
| Kurunagala | 26.5 |
| Vavuniya | 28.2 |
| Puttalama | 28.6 |
| Polonnaruwa | 28.7 |
| Batticoa | 30.9 |
| Matale | 38.1 |
| Ampara | 38.9 |
| Kandy | 39.7 |
| Anuradhapura | 41.0 |
| Rathanapura | 42.0 |
| Monaragala | 42.5 |
| Hambantota | 42.5 |
| Badulla | 54.8 |
| Trincomalee | 55.0 |
| Nuwara eliya | 58.0 |

Source-Nayakekorala 1996

The impacts of soil erosion can be classified as on site and off site .The on site effects include a decline in soil fertility and a reduction in soil depth .Floods and land slide are also indirect effects of soil erosion. Off site effects of soil erosion include damage to road ways ,choking drainage systems with silt and consequent flooding, siltation of reservoirs ,sedimentation of farmlands and rivers etc. The offsite impacts have grater economic and social implication. Since the major irrigation systems as well as hydropower systems are fed by the reservoirs, the economic costs of siltation and sedimentation can be very high (Bandara and Somasiri,1991).

## 2.4. Drinking water quality and intensive vegetable cultivation in upcountry

Deterioration of water in relation to quantity and quality would also be considered under the land degradation. The quality of ground as well as surface waters is affected in many parts of the country due to the agricultural and industrial activities. Ground and surface waters of upcountry areas and Kalpitiya area badly affected due to heavy use of chemicals in agriculture.

A significant change of nitrogen and sulphur in water bodies in the upcountry was observed in an experiment conducted on water quality parameters in Blackpool area from November 1995 to October 1996. It showed that NO3-N levels exceeded the WHO recommended level of 10mg/l for potable water durings some periods on Yala season. The presence of high level of NO3-N in the stream water is due to the usage of high amounts of fertilizers and inproper fertilizer management and poor agronomic practices of the farmers of blackpool area which represents the typical farming community in upcountry( Table 2.10).(Nandasena and Jayarathna 1993).

Table 2.10 Stream water quality parameters at Black pool from Nov 1995 to Oct 1996.

| Water quality parameter | Range of values |
|---|---|
| pH | 6.0 -7.84 |
| EC (mmhos/cm) | 0.04 – 0.18 |
| $NO_3$- N (mg/l) | 0.16 – 63.80 |
| $NH_4$- N (mg/l) | 0.01 – 1.68 |
| $SO_4$- S (mg/l) | 0.45 – 10.60 |

This study clearly shows the impact of heavy fertilization on the eutropication of water bodies in the upcountry of Sri Lanka. Therefore, precautions should be taken when the water is used for drinking purpose.

## 2.5 Fertilizer and soil quality

Few studies hane been carried out on the soil quality in relations to the accumulations of plant nutrients and other elements including heavy metals due to applications of fertilizers and organic manure in up country. Few studies campaired the effects of fertilizers and organic manure usage in intensively cultivated crop land with virgin lands in Nuwara eliya district.

A study conducted on fractionations of Zn and Cu in differently managed upcountry ultisols revealed that the total Zn contents in surface layer of cultivated soils was relatively high compared to the soil which was fallowed more than five years (Nandasena and Jayaratnne, 1993).

## 2.6 Important of chemical parameters

### 2.6.1 Soil reaction (pH)

The degree of acidity or alkalinity is customarily expressed as a Ph value, which is a measure of the relative concentration of hydrogen $[H^+]$ and hydroxyl $(OH^-)$ ions in solution . By definition, soil pH is the negative logarithm of H ion concentration. Soil pH gives an indication about soil fertility, such as nutrient availability and dynamics of soil. The soil pH has a decided influence on the availability of the all the micronutrients except chlorine. Under very acid condition, Molybdenum is rendered unavailable, at high pH, all the micronutrients are unfavorably affected. Over liming or a soil with naturally high pH is associated with the deficiencies of Fe,Mn,Zn,Cu and even B. Such conditions occur in the calcareous soils in arid regions. A pH of 6.5 was being considered as a good average level for most plants, based on the use of natural soils.(Brady,1990).

### 2.6.2 Electrical conductivity (EC)

EC is the parameter to measure the ionic concentration of a solution. Generally EC is used to measure ionic concentration in soil solution. The operating principle is that the greater the concentrations of fertilizers or salt, the greater will be the conductance, which indicates, the osmotic concentration of the soil solution. However, electrical conductivity only measures the electrolytes that are in solution,

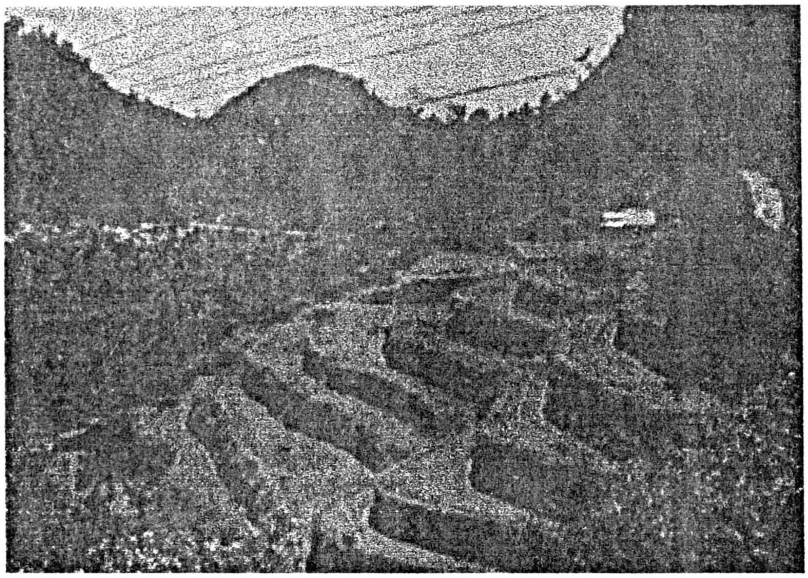
### 2.6.3. Catoin Exchange Capacity (CEC)

Cation exchange capacity is the amount of exchangeable cations per unit weight of dry soil. Cation exchange capacity of a soils important in the cationic nutrients such as $K^{++}$,$NH_4^+$,$Ca^{++}$and $Mg^{++}$,and therefore is considered as a major factor related to soil fertility. This is considered as one of the important soil chemical properties, which help to regulate the supply of certain nutrient to the plant. Cation exchange capacity is normally associated with the clay particles and humus colloids in a mineral soil. (Bunt,1988).

# CHAPTER 3
# MATERIALS AND METHODS

## 3.1 Study areas

Two micro catchments namely Hulankapolla and Katumanna in up counrty wet zone of Sri Lanka was selected as study sites to represent Badulla and N'Eliya districts respectively (Plate 3.1).



3.1.1 Katumanna site

Situated periphery by N' Eliya town along N'Eliya Welimada main road

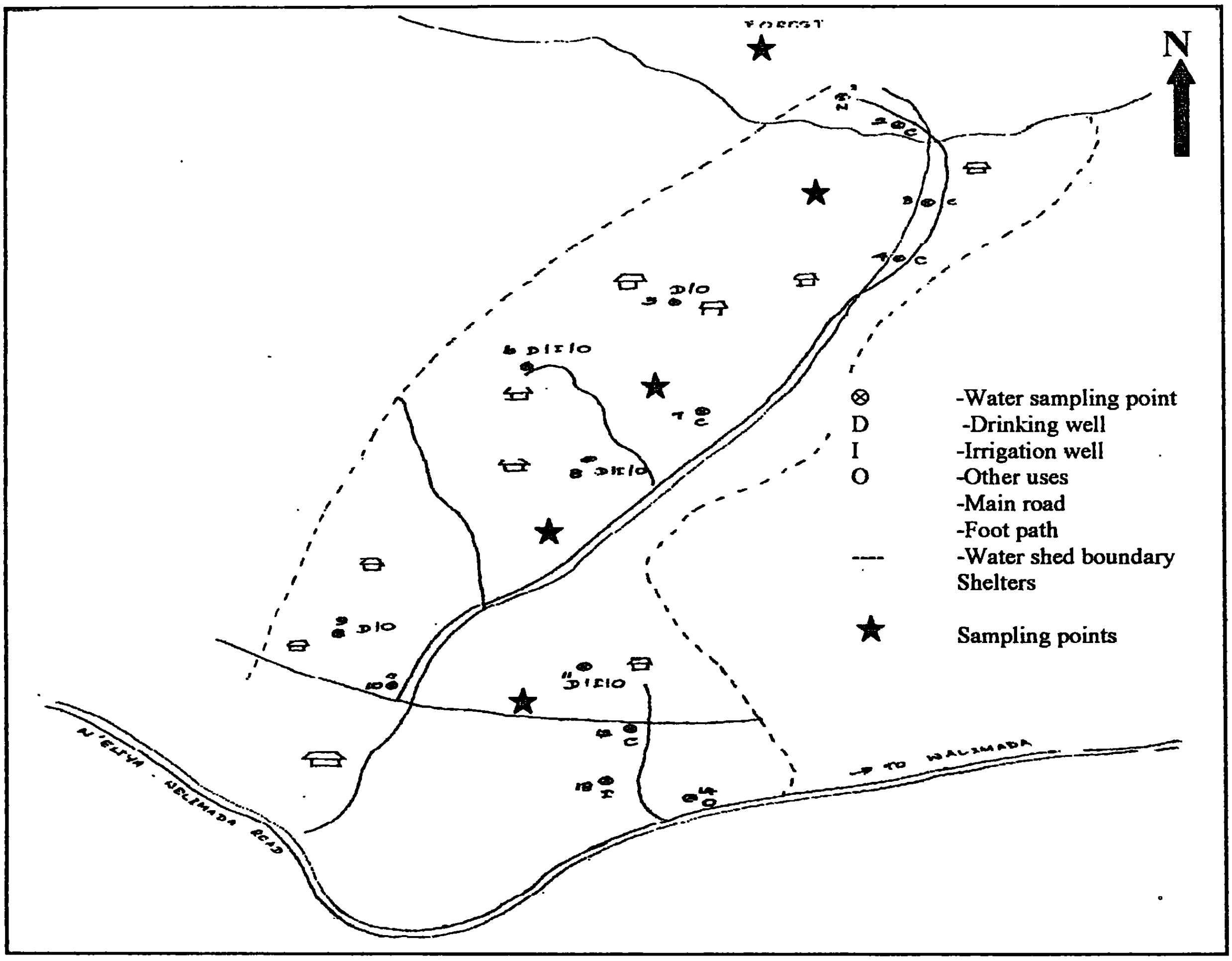



Figure 3.1 Katumanna site

3.1.2 Hulankapolla site

About 7km away from the N' Eliya town along N'Eliya Welimada main road

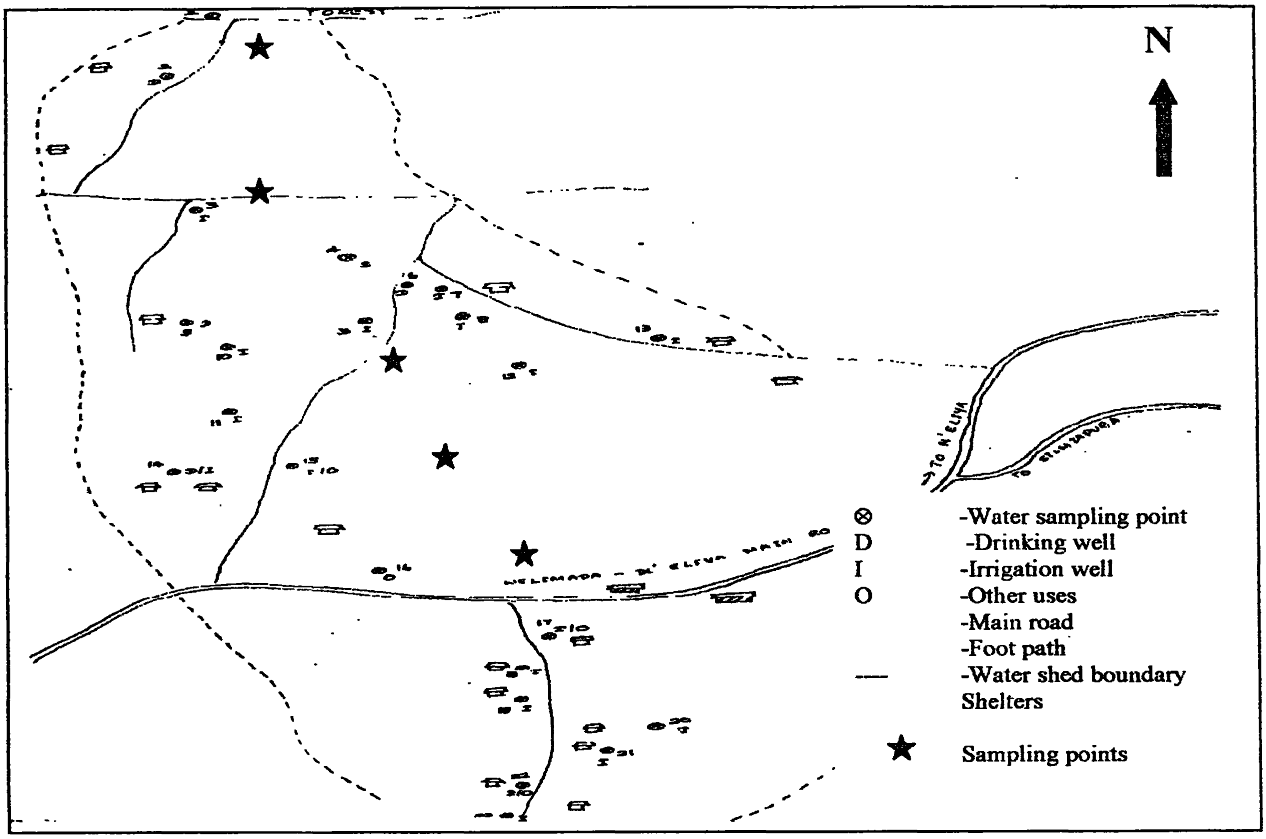



Figure 3.2 Hulankapolla site

3.2 Soil sampling

Along the catena from prescribed distances surface soil samples were collected from 30 cm depth from both locations. There were five sampling locations along the catena and each location had three sampling points. Soil sampling was done monthly for the duration of three months period. Soil samples were brought in to the laboratory and air-dried to pass 2mm screen. Samples were stored in polythine bages until analysis begins.

### 3.3 Determination of chemical parameters

#### 3.3.1 Soil pH

Soil pH was determined by using Glass electrode in 1:2.5 soil: water suspension.

#### 3.3.2 Electrical Conductivity (EC)

Calibrated test jar was filled with distilled water to the "C" mark and the soil to be tested was added until the jar solution reaches the "A" mark. The jar was closed and shaken vigorously for 30 seconds and the suspension was allowed to stand a minute until the large particles settle to bottom. Then electrical conductivity of the soil was measured using conductivity meter.

#### 3.3.3 Cation exchange capacity (CEC)

Ten grams of soil were placed in a conical flask and 250ml of 1N ammonium acetate solution (buffered and pH 7) were added. Soil suspension was shaken for five minute and allowed to stand over night and filtered using a buchnner funnel and washed with ammonium acetate solution until no calcium is detected in the leachate. The filtrate was kept to determine the base saturation. Subsequently soil was leached with 100ml of isopropyl alcohol. Then the soil sample was transferried in to Kjeldhal flask and distilled the solution. Librated NH3 was trapped in 50ml of 4% boric acid solution. Ammonia trapped in boric acid solution was titration against 0.1 HCl (Hesse,1971).

#### 3.3.4 Available Phosphorus

Five grams of air dried, 2mm sieved soil sample weighed in to 250ml conical flask and 100ml of 0.5M $NaHCO_3$ was added. The contents were shaken for 30 minutes using mechanical shaker. The suspension was filtered through a whatman 42 filter paper. Phosphorus concentration of the supernatant solution was measured using the Molybdenum blue method (Olsen and Deen,1965).

### 3.3.5 Sulphur

Using turbidimetry $SO_4^{-2}$-S content of the soil was determined. Soil was extracted with ammonium acetate solution. To develop the turbidity Barium chloride was added in to the soil extract. The turbidity of the suspension was then measured by spectrophotometer at 440nm wave length.

### 3.3.6 Organic matter

Organic matter in the soil was measured using Walkey and Black Method.(ref). Ten ml of 1/6N potassium dichromate [$K_2Cr_2O_7$] and 20ml of conc.$H_2SO_4$ were mixed with soil. After shaking one minute, it was allowed to stand on a sheet of asbestos for one hour. After one hour,200ml of distilled water, 10ml Phosphoric acid and 1ml of diphenylamine indicator solution were added to conical flask. The solution was titrated against ferrous ammonium sulphate solution drop by drop, until the color flashed to dark green. Again 0.5ml of potassium dichromate[$K_2Cr_2O_7$] was added and titrated again until the color flashed to dark green. A blank titration was done simultaneously (Walkey and Black ,1934).

### 3.3.7 Total Nitrogen

Total nitrogen in the soil sample was measured using Kjeldhal method.

Five grams of 2mm sieved soil was transferred in to a digestion tube and 1g of catalyst mixture and 5ml of conc. sulphuric acid were added. The sample was digested using a digestion unit until the solution becomes light blue in color. After cooling to room temperature it was transferred in to a 500ml conical flask using about 150ml distilled water. 20ml of 4% boric acid was placed in a receiving flask and two drops of mixed indicator were added. The receiving flask was kept beneath the condenser. Then 30ml of 10N NaoH was added in to the conical flask containing sample and small quantity of davadas alloy was also added to the sample. Subsequently flask was connected to distillation apparatus. Digest was distilled until the distillate in the receiving flask increased up to about 100ml. It was titrared with the 0.01 N HCl until color changes from green to pink (Bremmer and Mulvany,1992).

### 3.3.8 Potassium, Calcium and Magnesium (K,Ca and Mg)

Potassium, Calcium and Magnesium were determined by Atomic Absorption Spectrometry (AAS) method after extracting with Ammonium acetate.

### 3.3.9 Micro elements and heavy metals

Copper, Cadmium and Zinc were determined by Atomic Absorption Spectrometry (AAS) method.

# CHAPTER 4

# RESULTS AND DISCUSSION

Two locations viz; Katumanna and Hulankapolla of NuwaraEliya and Badulla district respectively were investigated for the nutrients accumulation and changing soil properties along with the catena, over 3 months period .

## 4.1 Soil properties

According to the results, soil properties such as pH,EC,OM,and CEC were significantly varied along the soil catena.

pH was increased from upper crest to bottom valley of the catena in both locations.[table 4.1].

Table 4.1 Changes of some soil properties along the catena of Hulankapolla and Katumanna sites.

| | Level | CEC-H | CEC-K | EC-H | EC-K | pH-H | pH-K | OM-H | OM-K |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 32.12 | 31.93 | 0.1 | 0.1 | 4.14 | 4.2 | 2.61 | 2.87 |
| | 2 | 34.71 | 34.81 | 0.13 | 0.26 | 4.91 | 4.68 | 2.48 | 2.31 |
| November | 3 | 46.21 | 40.71 | 0.26 | 0.36 | 5.16 | 4.95 | 2.11 | 2.57 |
| | 4 | 47.56 | 41.51 | 0.27 | 0.41 | 4.41 | 5.11 | 2.57 | 2.17 |
| | 5 | 39.03 | 35.26 | 0.4 | 0.43 | 5.54 | 5.78 | 1.66 | 2.46 |
| | 1 | 31.91 | 31.88 | 0.13 | 0.06 | 4.21 | 4.1 | 2.74 | 2.92 |
| | 2 | 35.56 | 35.26 | 0.23 | 0.16 | 4.71 | 4.8 | 2.99 | 2.79 |
| December | 3 | 42.03 | 35.27 | 0.26 | 0.36 | 4.91 | 5.33 | 1.66 | 2.54 |
| | 4 | 35.61 | 38.72 | 0.33 | 0.46 | 5.11 | 5.21 | 2.08 | 2.51 |
| | 5 | 39.42 | 39.28 | 0.46 | 0.53 | 5.71 | 5.91 | 1.67 | 2.06 |
| | 1 | 31.73 | 31.96 | 0.06 | 0.03 | 4.18 | 4.7 | 2.52 | 2.81 |
| | 2 | 34.51 | 32.91 | 0.2 | 0.23 | 4.81 | 4.2 | 2.75 | 2.75 |
| January | 3 | 44.11 | 37.86 | 0.26 | 0.36 | 5.38 | 5.23 | 2.11 | 2.64 |
| | 4 | 41.31 | 40.95 | 0.33 | 0.43 | 5.21 | 5.58 | 2.55 | 2.41 |
| | 5 | 42.31 | 35.38 | 0.46 | 0.56 | 5.87 | 5.21 | 1.98 | 2.01 |

H- Hulankapolla and K-. Katumanna At 0.05 significant level.

The increased pH towards the bottom valley of the catena could be attributed to the increase of basic cations in soil of lower part of catena . This is perhaps due to the migration of cations with soil water in catena.

EC was also increased toward the bottom valley of the catena. This is obvious that the increase ion in soil water in lower part of the valley due to the downward movement of water in catena. The EC value range from 0.1 to 0.46 and 0.1 to 0.56 in Hulankapolla and Katumanne locations respectively in the studied period (Table 4.1).

The fertilizer application in the (upper part of the catena ) tends to increase the ionic concentration of soil water in the intensive agriculture system.

CEC was also showed an increasing trend towards the bottom of the catena. However, organic matter (OM) content towards the bottom valley of catena was decreased. The high amount of OM in upper part of the catena is probably due to the influence of natural forest. However with the time in both locations, no significant variations in soil properties was observed.

## 4.2 Soil nutrients content

The macro nutrients such as N, P,K,Ca, Mg and S were analyzed in both locations during the 3 months period. The macro nutrient content were also showed significant increased from upper crest to bottom valley of the catena ( Table 4.2, Table 4.3).

Table 4.2 Changes of some macro nutrients along the catena of Hulankapolla site.

| | Level | N-H | P-H | K-H | Ca-H | Mg-H | S-H |
|---|---|---|---|---|---|---|---|
| | 1 | 0.083 | 0.724 | 61.43 | 14.91 | 4.33 | 1.577 |
| | 2 | 0.107 | 0.319 | 64.63 | 17.11 | 4.55 | 1.879 |
| November | 3 | 0.094 | 0.781 | 109.33 | 46.83 | 6.18 | 2.818 |
| | 4 | 0.185 | 0.896 | 132.5 | 46.49 | 6.54 | 1.466 |
| | 5 | 0.188 | 1.621 | 148.33 | 40.75 | 7.95 | 3.211 |
| | 1 | 0.093 | 0.061 | 43.33 | 10.49 | 5.59 | 2.745 |
| | 2 | 0.111 | 0.252 | 62.73 | 12.47 | 4.65 | 1.899 |
| December | 3 | 0.092 | 0.883 | 95.2 | 17.47 | 6.42 | 3.141 |
| | 4 | 0.091 | 1.123 | 99.46 | 40.52 | 5.53 | 2.473 |
| | 5 | 0.156 | 1.694 | 65.33 | 40.88 | 7.85 | 4.438 |
| | 1 | 0.109 | 0.707 | 66.13 | 11.95 | 4.55 | 1.682 |
| | 2 | 0.111 | 0.375 | 66.06 | 13.12 | 4.52 | 0.453 |
| January | 3 | 0.165 | 0.822 | 87.73 | 16.94 | 5.97 | 1.578 |
| | 4 | 0.179 | 961 | 86.76 | 42.09 | 7.11 | 1.975 |
| | 5 | 0.186 | 1.728 | 130.66 | 42.91 | 8.11 | 4.073 |

Table 4.3 Changes of some soil macro nutrients along the catena of Katumanne site.

| | Level | N-K | P-K | K-K | Ca-K | Mg-K | S-K |
|---|---|---|---|---|---|---|---|
| | 1 | 0.138 | 0.532 | 24.83 | 10.24 | 3.65 | 2.021 |
| | 2 | 0.136 | 0.514 | 69.53 | 36.81 | 5.54 | 3.504 |
| November | 3 | 0.179 | 1.421 | 92.23 | 51.21 | 6.39 | 3.675 |
| | 4 | 0.177 | 1.781 | 80.06 | 42.09 | 7.07 | 5.122 |
| | 5 | 0.191 | 1.432 | 75.61 | 40.44 | 8.35 | 10.404 |
| | 1 | 0.091 | 0.533 | 16.21 | 9.62 | 3.76 | 1.899 |
| | 2 | 0.106 | 0.377 | 45.16 | 11.81 | 5.21 | 3.167 |
| December | 3 | 0.095 | 1.311 | 51.53 | 16.34 | 5.21 | 7.387 |
| | 4 | 0.093 | 1.694 | 60.03 | 24.82 | 5.64 | 6.105 |
| | 5 | 0.148 | 1.747 | 80.26 | 38.73 | 7.71 | 9.511 |
| | 1 | 0.092 | 0.525 | 19.81 | 10.93 | 3.52 | 1.203 |
| | 2 | 0.31 | 0.376 | 36.91 | 21.57 | 6.01 | 1.702 |
| January | 3 | 0.148 | 1.484 | 74.63 | 29.18 | 6.16 | 6.554 |
| | 4 | 0.141 | 1.595 | 63.26 | 32.41 | 6.98 | 4.582 |
| | 5 | 0.213 | 1.445 | 86.93 | 42.78 | 7.66 | 6.554 |

The increasing trend of macro nutrients along the catena indicates that the migrates or down ward movement of nutrients along the catena due to heavy fertilization. The N value range from 0.083 to 0.188 (Hullankapolla site) and 0.092 to 0.213 (Katumanna site). The P and K values range from 0.319 to 1.728 (Hullankapolla site) , 0.377 to

1.781 (Katumanna site) and 61.43 to 148.33 (Hullankapolla site), 16.21 to 86.93 ((Katumanna site) respectively in both locations.

The possible reason for the accumulation of the nutrients in soils is due to the heavy applications of fertilizer in the intensive agriculture system in the area.

4.3 Other elements( Zn, Cd, and Cu)

Zn, Cd and Cu were considered as heavy metals. The amounts of those metals were not significantly changed along the catena with few exception. However, Zn content was changed significantly in Katumanna site (Table 4.4).

The study cleary showed that the enrichment of nutrients in soils of the intensive cultivated areas of Katumanna and Hulankapolla . This is mainly due to the long term applications of heavy doses of fertilizers and manures. The accumulations of elements may badly affect on the environment especially on the ground and surface water bodies.

Table 4.4 Changes of Cd, Zn and Cu along the catena of K and Hsite.

| | Level | Cd-H | Cd-K | Cu-H | Cu-K | Zn-H | Zn-K |
|---|---|---|---|---|---|---|---|
| | 1 | 0.08 | 0.028 | 0.002 | 0.021 | 0.261 | 0.065 |
| | 2 | 0.07 | 0.079 | 0.011 | 0.017 | 0.217 | 0.087 |
| November | 3 | 0.91 | 0.046 | 0.027 | 0.015 | 0.326 | 0.245 |
| | 4 | 0.19 | 0.105 | 0.025 | 0.028 | 0.331 | 0.191 |
| | 5 | 0.16 | 0.238 | 0.053 | 0.031 | 0.344 | 0.681 |
| | 1 | 0.056 | 0.025 | 0.002 | 0.017 | 0.253 | 0.077 |
| | 2 | 0.059 | 0.076 | 0.011 | 0.019 | 0.223 | 0.085 |
| December | 3 | 0.095 | 0.055 | 0.025 | 0.014 | 0.333 | 0.251 |
| | 4 | 0.071 | 0.115 | 0.024 | 0.031 | 0.336 | 0.191 |
| | 5 | 0.201 | 0.256 | 0.048 | 0.032 | 0.354 | 0.705 |
| | 1 | 0.057 | 0.031 | 0.002 | 0.021 | 0.244 | 0.068 |
| | 2 | 0.051 | 0.066 | 0.011 | 0.021 | 0.212 | 0.081 |
| January | 3 | 0.095 | 0.063 | 0.023 | 0.022 | 0.321 | 0.239 |
| | 4 | 0.172 | 0.114 | 0.025 | 0.033 | 0.333 | 0.194 |
| | 5 | 0.236 | 0.241 | 0.46 | 0.035 | 0.351 | 0.707 |

H-Hulankapolla catena, K-Katumanna catena, At 0.05 significant level.

The results obtained, for one season may not be sufficiently enough to make a firm conclusion. However long term monitoring of the nutrients enrichment in these area should be done to gather more information on soil quality deterioration and subsequent water pollution. With the time, there was no such variaton in the nutrient accumulation and the change of soil characters in both locations.

It is advisable, to take precautions when using water resources such as wells in the both valley of the catena, for drinking purposes.

# CHAPTER 5

# CONCLUSION

The accumulation of plant nutrients and heavy metals is evident toward the bottom valley of the catena in both locations in the upcountry. Some soil chemical parameters such as EC were also increased in the bottom valley of the catena. This nutrients build up is associated with excessive application of fertilizer, for intensive vegetable cultivation. Continuous use of fertilizers and manure therefore may negatively affect to soil quality as well as to the water quality.

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## APPENDIX 1

**Measument of Organic Carbon**(Walkey and Black,1934)

**Caculation**

$2\ Cr_2O_7^{-2} + 3C + 16H^+ = 4Cr^{+3} + 3CO_2 + 8H_2O$

Volume of Potassium dichromate used = 10.5ml

Malarity of dicromate = 1/6M

Burette reading (with soil) = V1

Burette reading (blank) = V2

$2\ Cr_2O_7^{-2} + 6Fe^{2+} + 14H^+ = 2Cr^{+3} + 6Fe^{3+} + 7H_2O$

Moles of dicromate used = 1/6 * 10.5/1000 = X moles

Moles of Ferrous ammonium sulphate = 1/6 * 10.5/1000 *6

Molarity of Ferrous ammonium sulphate = 1/6 *10.5/1000 * 6/V2 * 1000 = M1

Moles of dicromate reacted with ferrous = M1 * v1 * 1/6 = Y moles

Moles of dicromate reacted with carbon = X – Y = Z moles

Grams of carbon reacted with dicromate = 3/2 * Z * 12

Organic carbon presentage = 3/2 * Z * 12/2 *100

**APPENDIX 2**

**Measument of Total Nitroben**(Bremmer and Mulvany,1992)

**Calculation**

$NH_4^+ + OH^- \longrightarrow NH_3 + H_2O$

$NH_3 + H_3BO_3 \longrightarrow NH_4^+ + H_2BO_3^-$

$H_2BO_3^- + NH_4^+ + HCl \longrightarrow H_3BO_3 + NH_4Cl$

| | |
|---|---|
| Volume of 0.01 M HCl required | = X ml |
| X m of 0.01 HCl reacts with | = 0.14* Xmg N |
| Precentage of total N in sample | = 0.14 * X * 100%/1000 |

**APPENDIX 3**

The ANOVA Procedure

Dependent Variable: pH Hulankapolla Nov

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 3.84370667 | 0.96092667 | 8.69 | 0.0027 |
| Error | 10 | 1.10626667 | 0.11062667 | | |
| Corrected Total | 14 | 4.9499733 | | | |

| Source | DF | Anova SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| site | 4 | 3.84370667 | 0.96092667 | 8.69 | 0.0027 |
| month | 0 | 0.00000000 | . | . | . |

The SAS System 3

Means with the same letter are not significantly different.

| Duncan Grouping | | Mean | N | site |
|---|---|---|---|---|
| | A | 5.5467 | 3 | 5 |
| | A | | | |
| B | A | 5.1633 | 3 | 3 |
| B | | | | |
| B | C | 4.9133 | 3 | 2 |

Means with the same letter are not significantly different.

| Duncan Grouping | | Mean | N | site |
|---|---|---|---|---|
| | C | | | |
| D | C | 4.4133 | 3 | 4 |
| D | | | | |
| D | | 4.1400 | 3 | 1 |

## APPENDIX 4

Dependent Variable: pH Hulankapolla Dece

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 3.96100000 | 0.99025000 | 6.62 | 0.0072 |
| Error | 10 | 1.49500000 | 0.14950000 | | |

| Source | DF | Anova SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| site | 4 | 3.96100000 | 0.99025000 | 6.62 | 0.0072 |
| month | 0 | 0.00000000 | . | . | . |

Means with the same letter are not significantly different.

| Duncan Grouping | | Mean | N | site |
|---|---|---|---|---|
| | A | 5.7667 | 3 | 5 |
| | A | | | |
| B | A | 5.1167 | 3 | 4 |
| B | | | | |
| B | C | 4.9167 | 3 | 3 |

Means with the same letter are not significantly different.

| Duncan Grouping | | Mean | N | site |
|---|---|---|---|---|
| B | C | | | |
| B | C | 4.7000 | 3 | 2 |
| | C | | | |
| | C | 4.2000 | 3 | 1 |

## APPENDIX 5

The ANOVA Procedure

Dependent Variable: pH Hulancapoll Janu

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 4.21589286 | 1.05397321 | 16.46 | 0.0004 |
| Error | 9 | 0.57625000 | 0.06402778 | | |
| Corrected Total | 13 | 4.79214286 | | | |

| Source | DF | Anova SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| site | 4 | 4.21589286 | 1.05397321 | 16.46 | 0.0004 |
| month | 0 | 0.00000000 | . | . | . |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | site |
|---|---|---|---|
| A | 5.8750 | 2 | 5 |

Means with the same letter are not significantly different.

| Duncan Grouping | | Mean | N | site |
|---|---|---|---|---|
| | B | 5.3833 | 3 | 3 |
| | B | | | |
| C | B | 5.2167 | 3 | 4 |
| C | | | | |
| C | | 4.8000 | 3 | 2 |
| | D | 4.1833 | 3 | 1 |

**APPENDIX 6**

The ANOVA Procedure

Dependent Variable: pH Katumanna No

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 4.06733333 | 1.01683333 | 7.37 | 0.0049 |
| Error | 10 | 1.38000000 | 0.13800000 | | |

| Source | DF | Anova SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| site | 4 | 4.06733333 | 1.01683333 | 7.37 | 0.0049 |
| month | 0 | 0.00000000 | . | . | . |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | site |
|---|---|---|---|
| A | 5.7833 | 3 | 5 |
| A | | | |

Means with the same letter are not significantly different.

| Duncan Grouping | | Mean | N | site |
|---|---|---|---|---|
| B | A | 5.1167 | 3 | 4 |
| B | | | | |
| B | | 4.9500 | 3 | 3 |
| B | | | | |
| B | C | 4.6833 | 3 | 2 |
| | C | | | |
| | C | 4.2000 | 3 | 1 |

## APPENDIX 7

Dependent Variable: pH Katumanna Decem

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 4.99233333 | 1.24808333 | 21.52 | <.0001 |
| Error | 10 | 0.58000000 | 0.05800000 | | |

| Source | DF | Anova SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| site | 4 | 4.99233333 | 1.24808333 | 21.52 | <.0001 |
| month | 0 | 0.00000000 | . | . | . |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | site |
|---|---|---|---|
| A | 5.9000 | 3 | 5 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | site |
|---|---|---|---|
| B | 5.3833 | 3 | 3 |
| B | | | |
| C B | 5.2167 | 3 | 4 |
| C | | | |
| C | 4.8000 | 3 | 2 |
| D | 4.1833 | 3 | |

**APPENDIX 8**

Dependent Variable: pH Katumanna Janu

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 3.37697333 | 0.84424333 | 10.14 | 0.0015 |
| Error | 10 | 0.83260000 | 0.08326000 | | |

| Source | DF | Anova SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| site | 4 | 3.37697333 | 0.84424333 | 10.14 | 0.0015 |
| month | 0 | 0.00000000 | . | . | . |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | site |
|---|---|---|---|
| A | 5.5833 | 3 | 4 |
| A | | | |

Duncan's Multiple Range Test for pH

Means with the same letter are not significantly different.

| Duncan Grouping | | Mean | N | site |
|---|---|---|---|---|
| B | A | 5.2333 | 3 | 3 |
| B | A | | | |
| B | A | 5.2167 | 3 | 5 |
| B | | | | |
| B | | 4.7900 | 3 | 1 |
| | C | 4.2000 | 3 | 2 |

**APPENDIX 9**

The GLM Procedure

Dependent Variable: pH Hulankapolla

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 9 | 7.66091444 | 0.85121272 | 7.58 | <.0001 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| time | 1 | 0.05208333 | 0.05208333 | 0.46 | 0.5003 |
| z1 | 1 | 0.35466722 | 0.35466722 | 3.16 | 0.0842 |
| z2 | 1 | 6.76500833 | 6.76500833 | 60.25 | <.0001 |

Dependent Variable: pH

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| z3 | 1 | 0.00481667 | 0.00481667 | 0.04 | 0.8371 |
| z4 | 1 | 0.35000556 | 0.35000556 | 3.12 | 0.0862 |
| time*z1 | 1 | 0.05418750 | 0.05418750 | 0.48 | 0.4918 |
| time*z2 | 1 | 0.05500139 | 0.05500139 | 0.49 | 0.4886 |
| time*z3 | 1 | 0.01246944 | 0.01246944 | 0.11 | 0.7409 |
| time*z4 | 1 | 0.01267500 | 0.01267500 | 0.11 | 0.7389 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| time | 1 | 0.01126667 | 0.01126667 | 0.10 | 0.7533 |
| z1 | 1 | 0.21295556 | 0.21295556 | 1.90 | 0.1772 |
| z2 | 1 | 0.44881270 | 0.44881270 | 4.00 | 0.0534 |
| z3 | 1 | 0.00005079 | 0.00005079 | 0.00 | 0.9832 |
| z4 | 1 | 0.01425079 | 0.01425079 | 0.13 | 0.7238 |
| time*z1 | 1 | 0.00163333 | 0.00163333 | 0.01 | 0.9047 |
| time*z2 | 1 | 0.01613333 | 0.01613333 | 0.14 | 0.7069 |
| time*z3 | 1 | 0.02340833 | 0.02340833 | 0.21 | 0.6508 |

## APPENDIX 10

The GLM Procedure

Dependent Variable: pH Katu

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| time*z4 | 1 | 0.01267500 | 0.01267500 | 0.11 | 0.7389 |

| Parameter | Estimate | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|
| Intercept | 4.882222222 | 0.29552402 | 16.52 | <.0001 |
| time | -0.043333333 | 0.13680104 | -0.32 | 0.7533 |
| z1 | -0.575555556 | 0.41793407 | -1.38 | 0.1772 |
| z2 | 0.835555556 | 0.41793407 | 2.00 | 0.0534 |
| z3 | -0.008888889 | 0.41793407 | -0.02 | 0.9832 |
| z4 | -0.148888889 | 0.41793407 | -0.36 | 0.7238 |
| time*z1 | 0.023333333 | 0.19346588 | 0.12 | 0.9047 |
| time*z2 | 0.073333333 | 0.19346588 | 0.38 | 0.7069 |
| time*z3 | 0.088333333 | 0.19346588 | 0.46 | 0.6508 |
| time*z4 | -0.065000000 | 0.19346588 | -0.34 | 0.7389 |

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