EFFECT OF HIGHWAY'S ON BHAWAL SAL FOREST AREAS OF BANGLADESH

A THESIS

BY

ZOYNAL ABEDIN
Student No. 1705253
Session: 2017
Semester: January-June, 2019

MASTER OF SCIENCE (M.S.)
IN
AGROFORESTRY AND ENVIRONMENT

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

JUNE, 2019

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Submitted to the Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur in partial fulfillment of the requirements of the degree of

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June, 2019

Dedicated
to
My Wife

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ABSTRACT

The tropical moist deciduous Sal (*Shorea robusta)* forest ecosystem of central Bangladesh is currently in a critical situation due to Dhaka-Mymensingh highway passing over the forest. The present study is an attempt to determine the major problems of Bhawal Sal forest arises due to Dhaka-Mymensingh highway by assessing soil properties and to evaluate the impact upon adjacent vegetation. The study was conducted in three different locations (selected purposively) along Dhaka-Mymensingh highway with different distances like 202m, 152m, 102m, 52m and 2m on both sides of the highway during the period of July 2017 to July 2018. Height and DBH were measured from the sample plots (10m×10m) and 500 g soil samples from the surface soil (0—20 cm) were taken and tested in laboratory. The study revealed that in Bhawal Sal forest the soil moisture content (5.87% to 12.65%), soil pH (4.2 to 5.5), soil organic carbon (0.98% to 2.41%), soil organic matter (1.68% to 4.14%), soil exchangeable nitrogen (0.03% to 0.063%), soil exchangeable phosphorous (0.11 ppm to 0.41 ppm), soil exchangeable potassium (0.12meq/100g to 0 meq/100g all the parameters were decreased with the decreasing distance from the forest to the highway and soil bulk density (1.17g/cc to1.94 g/cc) increased with the decrease in distance from the forest to the highway. Relationship between tree growth variables of Sal forest and chemical properties were found positive and they were strongly correlated with respect to each other. Again it was also observed that if the distance increases from the road to the inside of the forest, trees with increasing height and DBH were found. The Sal forest is under tremendous human interference from all sides and day by day this problem is becoming acute. So for the betterment of the degraded area, it should recover the raised problem related to highway construction.

CONTENTS

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Contd.)

LIST OF ABBREVIATION

BBS	:	Bangladesh Bureau of Statistics
BC	:	Before Christ
DBH	:	Diameter at Breast Height
DOE	:	Department of Environment
EIA	:	Environmental Impact Assessment
ETP	:	Effluent Treatment Plant
FAO	:	Food and Agricultural Organization
gm	:	Gram
GNP	:	Gross National Product
GOB	:	Government of Bangladesh
IEE	:	Initial Environmental Examination

CHAPTER ONE

INTRODUCTION

CHAPTER ONE: INTRODUCTION

1.1 General overview

Bangladesh is a small South Asian country. The absolute location of Bangladesh lies between 20º34´ and 26º38´ north latitude and 88º01´ and 92º41´ east longitude. The total geographic area of Bangladesh is approximately 14.40 million hectares of which 13.46 million hectares are land surface and 0.94 million hectares are rivers and other inland water bodies (GOB, 1992). Motiur, 2006 estimated that the country has only 17.5% (2.52 million hectare) of forest coverage. The Sal forest covers about 0.12 million hectares of land comprising about 4.7% of the total forest area of the country (Motiur, 2006). One of the peculiarities of forest resource distribution in Bangladesh is that the resources are very eccentrically distributed. More than 90% of the government forests are concentrated within 12 districts in the eastern and south eastern regions of the country (Islam, 2005.) The importance of Sal forests lies in the fact that these are the only natural forest resources of the central and northern parts of Bangladesh where the vast majority of the population dwells (Motiur, 2006).

Historically, the agrarian rural people around the forests have been heavily dependent on Sal forests for their livelihood. People living in close proximity to the Sal forest, particularly various ethnic groups such as the Garos and Hajongs, totally depend on its resources to satisfy many of their basic needs. They use these forests for food, fuel, medicinal herbs, raw materials for construction of houses, boats, and furniture, and many other items of trade and commerce (Banglapedia, 2008). This study area has a high population density (975 person/km^2) (FAO, 2003). As a result, demand for lands for both settlement and agricultural use within forested areas has accelerated the rate of deforestation with loss of ecosystem productivity and biological diversity, leading to overall environmental deterioration in the area (Ali, *et al.* 2006).

The tropical moist deciduous Sal (*Shorea robusta)* forest ecosystem of central Bangladesh is currently in a critical situation. Destructive anthropogenic and natural impacts coupled with overexploitation of forest resources have caused severe damage to the forest ecosystem. Sal is usually harvested for construction works, fuel wood, timbers, tannins, pillars, and furniture making purposes. The rapidly expanding agriculture in the forest land is a significant threat to the Sal forest ecosystem. This forest has been rapidly exhausted in recent times due to rubber monoculture and expanding commercial fuel-wood plantations. Due to illegal cutting, encroachment of forest areas, and illegal poaching of wildlife, the Sal forest is losing biodiversity at an alarming rate.

Highway plays a key role in promoting social progress and developing productive forces, not only facilitating better livelihood, but also bringing significant economic benefits for whole society. However, highway construction has dramatic impacts on surrounding natural ecosystems and more and more ecosystems in this area have been affected. Soil is the base for the production of plant and animal and agricultural farming, the primary productivity of ecosystem depends very much on soil quality, which is a comprehensive indicator of soil condition. Soil quality is the ability of soil to provide essential nutrients and biomass production for life in ecosystems, is the ability to accommodating, degrading, and purifying polluted material and maintaining the ecological balance, and is the ability to promoting safety and health of plant, animal and human (Motiur, 2006). Soil quality is the result of interaction of soil parent material, climate, biology, terrain, time and so on, with physical, chemical and biological characteristics response to soil factors, on the other hand, soil quality is significantly changed by human activities.

A number of major urban settlements, such as Gazipur, Tangail sadar, and Mymensignh sadar including Dhaka city, are in close proximity to the main Sal forest areas of the central region. These urban settlements have large populations with high growth rates. Such urban settlements lead to development of road networks and other infrastructures, which degrade the quality of wildlife habitat. For example, two road network improvement projects totaling 62.2 km of length have been undertaken in the Sal forest areas of Mymensingh (GOB, 2008). Such road construction work isolates the population of the wildlife species from feeding grounds and natural migration routes and limits breeding between larger groups. Road construction has made Sal forest more accessible, so anthropogenic disturbances can easily take place in the forest areas. A firing range of the Bangladesh Air Force was established on about 405 hectares of Sal forest land which is a source of noise pollution as well as a serious threat to wildlife habitat (Gain, 2005). Therefore, the decline and degradation of soil quality is a dynamic process, and is the dual cause-effects of natural process and human activity.

1.2 Rationale of the study

Sal Forest is one of the major tropical moist deciduous forests in Bangladesh. This forest faces serious problems due to Dhaka –Mymensingh highway which comprises 62.2 km. Reliable and up-to-date data is required for mitigating the arises problems, but no specific study was so found for this perspective. The present study, thus, is an attempt to determine the major problems of Bhawal Sal forest arises due to Dhaka-Mymensingh highway by assessing soil properties and to evaluate the impact upon adjacent vegetation. The study also aims at encouraging researchers to work towards the improvement of the present conditions through suggestions and recommendations. Government of Bangladesh decided that the existing high way will expanded to four lanes soon. It is anticipated that this study will be helpful for the policy makers to take necessary steps before expansion of the road.

1.3 Objectives of the study

i. To find out the major problems of Bhawal Sal forest arises due to Dhaka-Mymensingh highway by assessing soil properties,
ii. To evaluate the impact of Dhaka Mymensingh highway upon adjacent vegetation and
iii. To recommend some key points on the major aspects to improve the present condition.

CHAPTER TWO

LITERATURE REVIEW

CHAPTER TWO: LITERATURE REVIEW

2.1 Road construction

2.1.1 History of road construction

Crude roads were in use in Mesopotamia in about 3000BC. Italy was connected to Denmark by a roadway early as 2000 BC. One of the first preplanned roads was the Persian Royal Road (about 1500 miles long) built by Darius in 500 BC. The Chinese Silk Road (about 4000 miles long) established around 100 BC, was a series of land routes connecting ancient Rome and China. The Roman road-building era started in 312 BC that ran over 350 miles. Roman advances in road-building techniques included preparation of foundation soils and base courses, brick paving and most importantly, provision for adequate drainage. Important advantages in road-building technology came in the 18^{th} century. Pierre Tresaguet in Finance and Thomas Telford and John Loudon McAdam in Scotland introduced improved methods for creating roads made of stone. McAdam's method stressed the need to keep the subsoil dry by including adequate drainage and waterproof covering in which crushed or broken stone was mechanically locked together by rolling a large weight over the surface (Ubernick, 2000).

2.1.2 Roads and its types

Roads, providing pathways for moving people and goods, range in quality from earth roads to concrete-paved multilane highways. The use of wheeled vehicles encouraged construction of better roads. 18^{th} century inventions included waterproof surfaces and better drainage systems. Modern engineers make use of variety materials and construction techniques to build roads that can handle the high volumes and stresses of modern automobiles and truck traffic. Roads can be classified into three broad categories based on the whole country perspective: Highways, Urban or City streets and rural roads. Highways are high-speed roads designed to connect major cities and built to the highest construction standard generally with two or more lanes for each direction of travel and often include medians to separate traffic moving in opposite directions. Urban streets, which cover cities, towns, and most suburbs, allow vehicles to access properties such as homes and business and also accommodate underground public utility facilities, such as, water and sewage pipes, telecommunications lines etc. Rural roads are also known as feeder roads are found outside cities, towns, and suburbs (Ubernick, 2000).

2.1.3 Road construction strategies

Road construction strategies are the specific actions and standards that will lead to achieving the goals and objectives of this section of the manual.

Roads must be constructed during the time of year when the best results can be achieved with the least damage to the environment. For example, scheduling road construction on steep slopes during the drier months can be an effective erosion control measure.

One of the first steps in forest road construction is clearing and grubbing. These eliminate a safety hazard to anyone working below the road. The clearing and grubbing method used will be consistent with good safety and environmental practices. Trees and other large vegetation within the right-of-way boundaries should be felled and bucked. In addition hazardous snags and unsafe trees adjacent to the right-of way should also be felled at this time. Merchantable logs should be yarded to decking areas that will not interfere with the construction of the road or turnouts. Un-merchantable material should be disposed of according to the design specifications and follow the guidance listed later in this section. During grubbing of the surface, all stumps and protruding objects should be removed from the road prism, and anywhere fills or side cast material will be deposited. If substantial amounts of this material are left in place, the material can create a slip plane for fill or side cast failure when it decomposes.

There are several options for disposing of clearing and grubbing debris**.** Oftentimes contract specifications or the road design will indicate the option that will be used. If an option is not specified, the one that is chosen should match the road design and the onsite conditions.

Most forest roads are built by excavating a roadbed out of naturally sloping ground. Grading is the process of excavating and/or filling the sub grade to final grade. Thus, grading is when the bulk of soil excavation and disturbance occurs. For a given road width, the steeper the ground the greater will be the volume of soil that is excavated or displaced during road construction. Road design and layout (flagging, staking and/or reference points on the ground, together with plans, maps and/or design specifications) show equipment operators the correct alignment and the proper cut slope angle and height to be developed along the new road. Operators may be asked to either construct roads using BCF construction methods on gentle terrain, to use cut-and-fill (with true compaction) on moderate slopes, or to employ full bench construction techniques on steep slopes or where the road is near stream channels. The methods of compaction and where they are to be applied should be specified in the road design specifications. The importance of compacting excavated material cannot be over-emphasized. The specifications for compaction may be as simple as using loaded rock trucks or crawler tractors, or may require special equipment such as vibratory rollers, vibratory compactors, and grid rollers. Always consult the design for compaction methods and specifications.

The condition of the sub grade is critical to the performance of the road surfacing. The shape of the sub grade plays a central roll in providing road drainage. Do not rely on producing the surface shape (crowned, in sloped or out sloped) of the road by shaping the rock surfacing alone. The ditch, if required, should be shaped and clear prior to applying surfacing. The sub grade should be at or near the optimum moisture content for compaction and then shaped and compacted prior to rocking.

Process the rock as specified by the contract. It will enhance performance of the road surfacing. Proper mixing, watering, shaping and compaction of the rock should be done to allow the surface rock to set up correctly. There are several rocking accountability methods available to assure that operators comply with project requirements. Rock is a very valuable resource and accounting for the volume and quality of rock is important to make sure the State gets its value. The "depth measurement" method works well when it easy to verify the new is surfacing from the existing road surface. Un-surfaced roads and roads that will be re-surfaced with a continuous new lift of rock are good candidates for depth measurement. Rock spikes driven into the surfacing or digging test holes in the surfacing and measuring depth can be utilized. Re-surfacing projects that are applying very thin rock lifts or spot-rock are not good candidates to be measured by depth, due to the varying road segment lengths and depths of rock of road being surfaced. An advantage of depth measurement is that it does not require that some one monitor the project 100% of the time. Depth measurement may be performed during and at completion of road rocking. "Rock checking" works well for many types of rocking projects. Rock can be placed where needed only. Rock checkers can direct or monitor the rocking project. Rock checkers track the number of loads of rock and make sure trucks are full. The main drawback with this method is that it is labor intensive and rock checkers are not always available when they are needed. "Rock Load Receipts" can work if rock is purchased from commercial sources and the other two methods are not suitable for accountability. The provider of the rock submits the number of loads of rock provided for the project. One disadvantage is that the state has little control over the volume of rock in each load.

Soil erosion and stream sedimentation can occur during and following road construction. Some erosion is the result of poor road location and design, but some clearly occurs as a result of the road construction phase. Proper construction practices will reduce erosion and stream sedimentation. However, even when roads are properly located, designed and constructed, they will still need erosion control measures to minimize soil loss and sediment production. Both mechanical and vegetative measures are needed to minimize erosion from roads and landings under construction. As mentioned in the design section; effective erosion prevention is also achieved through proper road design and location, preplanning of cuts and fills, minimizing soil exposure, compacting fills, end hauling loose fill materials from steep slopes and streamside areas, developing stable cut and fill slopes, mulching to control surface erosion for the first year. Seeding and planting will provide for longer term erosion prevention. Perhaps the best tool for preventing erosion is to keep vegetation removal and soil disturbance to an absolute minimum during construction. Clearing and grubbing should be limited to the minimum needed to construct the road prism. Cuts and fills on gentle and moderate slopes should be balanced to minimize the amount of excavation and soil exposure. Most construction activities should be conducted during the dry season. Even during the dry season, construction activities should be suspended if rainy weather is occurring. Soils that are saturated with water and would become muddy when disturbed should be allowed to drain before construction resumes.

All road drainage structures (ditches, out sloping, culverts, water bars, dips, etc.) should be in place as soon as possible during the construction of the road. In any event they must be in place before the start of the rainy season. Surface water drainage must also be provided for sites associated with road construction such as waste areas, borrow areas and rock pits. All drainage water should be filtered through natural vegetation before it enters streams. Construction of roads near running water may require silt fences, hay dams or other filtration methods in ditches and streams to prevent eroded material from getting into the water. These structures should be put in place as soon as possible during road construction. Areas of bare soil, which could deliver sediment to waters of the state, should be mulched and/or seeded before the start of the rainy season. This includes un surfaced road grades, cut slopes, fill slopes, waste areas, borrow areas, and rock pits. When the road construction project is partially completed at the start of the rainy period (mid-October), the project should be left in a condition that will minimize erosion and the sedimentation of streams during the rainy period. Drainage measures should be performed on uncompleted sub grades such as smoothing the surface, out sloping, water barring, and installing dips. Mulching and/or grass seeding should be done on all cut and fill slopes that are completed and on any other areas of bare soil where erosion and sedimentation could affect water quality. Silt fences and/or hay dams should be used near streams to prevent sedimentation. The road should be barricaded to prevent unauthorized use. Shallow failures or small slumps on the cut slope or fill slope should be repaired and stabilized. Where the material is blocking a ditch, it should be excavated and removed. Where fill slopes are indicating failure, the fill material may need to excavate and end hauled to a waste area site. To prevent further failure or slumping of cut or fill slopes, rock buttressing or retaining walls may be needed. A geotechnical specialist or engineer should be consulted if these measures are needed.

2.1.4 Highway construction effects on soil

Highway plays a key role in promoting social progress and developing productive forces, not only facilitating better livelihood, but also bringing significant economic benefits for whole society. However, highway construction has dramatic impacts on surrounding natural ecosystems and more and more ecosystems in this area have been affected. Soil is the base for the production of plant and animal and agricultural farming, the primary productivity of ecosystem depends very much on soil quality, which is a comprehensive indicator of soil condition. Soil quality is the ability of soil to provide essential nutrients and biomass production for life in ecosystems, is the ability to accommodating, degrading, and purifying polluted material and maintaining the ecological balance, and is the ability to promoting safety and health of plant, animal and human. Soil quality is the result of interaction of soil parent material, climate, biology, terrain, time and so on, with physical, chemical and biological characteristics response to soil factors, on the other hand, soil quality is significantly changed by human activities. Therefore, the decline and degradation of soil quality is a dynamic process, and is the dual cause-effects of natural process and human activity. Human activities, especially highway construction has negative impacts on ecosystem in study area, especially on soil quality. Soil degradation is one of the most significant impacts of highway construction, which can alter the soil developmental level and soil structure, damage soil texture, lead to loss of the organic matters and inorganic nutrients in soil, reduce soil fertility and water-holding capacity, deteriorate soil quality, cause soil erosion, and limit soil production. Soil is disturbed heavily by highway construction activity, such as slope fill and slope cut, invasion of a large number of artificial soils, and destruction of the original soil and humus layer. Auerbach *et al.* Studied forest soil and vegetation characteristics near Dalton Highway in north of Alaska in two study areas with different soil conditions, acidic (pH<5.0) and no acidic (pH >5.0). His study showed that soil pH and bulk density are higher, soil moisture and nutrient are lower near road, and soil layer thickness is not consistent, which is related much to destruction of soil layer from road construction, dust origin from traffic, and nascent vegetation types. Forman et al. stated that road construction will cause sheet, rill and gully erosions, which are mainly related to road construction, soil type, slope length, flow velocities on slope; and effective measure of erosion control is to strengthen the stability of slope and to change the direction of water flow. Previous studies showed that soil quality changed significantly near highway, the contents of clay particle, soil organic matter and other nutrient contents declined, while pH increased with different degrees and ranges. In recent years, the research on effect of highway construction on soil quality has been initiated; however, the finding or conclusions are not consistent due to the differences in topography, soil parent material, vegetation types and so on. Highway is one of the major transportation systems in LRGR, and its construction mostly cut through mid-mountains, leading to upslope and down slope landscapes. To date, few researches have been done concerning the effect of highway construction on the ecosystem of upslope and down slope of highway. Based on field investigation and laboratory analysis, we examined the effect of highway construction on natural and cultivated soil quality with the method of space-for time substitution, revealed the difference of effect of highway construction on soil quality of upslope and down slope at different distance to road, which was built in different periods, and identified the effect factors and forecasted soil quality remediation. In this context, we expected to provide a theoretical basis for early-warning to other highways in LRGR, and eco-environmental effect assessment on highway construction at macroscopic scale, so as to mitigate negative effects of highway construction on the surrounding ecosystems to some extent (Shuqing, 2008).

2.1.5 Negative environmental impacts of transportation network

2.1.5.1 Energy consumption

Vehicles use more gasoline each year. Cars and trucks are ultimately responsible for most of the pollution and damage caused by the oil extraction industry, including disastrous oil spills and pollution from oil refineries. As transportation network enriches more and more vehicle are brought in from the foreign countries and as a result more energy is consumed due to newer transportation network (Anon, 2003).

2.1.5.2 Land consumption

Huge tracts of land are cleared and locked-up to provide transportation corridors, removing these acres from constructive uses. As the corridors are widened and speed limits increase, it increases land development pressures and traffic congestion. Urban sprawl is rapidly spreading as more and more people move into the countryside to “get away from it all” while still commuting to nearby cities to work, shop, go to school and recreate. In the city, much of the land is devoted to streets and parking lots, rather than livable, walk able places for people to enjoy. Our quality of life declines as more green spaces are covered with concrete (Anon, 2003).

2.1.5.3 Lost farmland

As more homes and businesses are built further a field, they chew-up and isolate farmlands at a rapid pace. Many thousands of acres of fertile farmland are lost forever under concrete, barren median strips and suburban lawns (Anon, 2003).

2.1.5.4 Air pollution

Vehicle emissions are the Number One source of air pollution. Diesel trucks and cars emit a wide variety of unhealthy gases, such as carbon monoxide, nitrous oxides, polyaromatic hydrocarbons (PAHs), and other products of incomplete combustion. Diesel emissions are a leading source of the highly toxic dioxin, which accumulates up our food chain. Many Northeast Wisconsin counties are Ozone Non-Attainment Areas, or nearly so, due primarily to vehicle emissions (with major help from industrial sources). The nitrous oxides are converted by sunlight into unhealthy ground level ozone, especially on hot windless summer days (Anon, 2003).

2.1.5.5 Water and land pollution

Chemical gases and particles which are released by cars and trucks do eventually fall out of the air onto street surfaces and land. Vehicles often leak oil, gas, brake fluid, worn brake linings, windshield detergent, engine coolant and worn metal particles. Car tires leave a residue of zinc and other pollutants, as they wear. Road salt is added to the mix in the winter. Hard pavements, streets and parking lots often provide direct conduits to storm sewers, allowing these pollutants to wash directly into lakes and streams without any filtration (Anon, 2003).

2.1.5.6 Noise pollution

As traffic increases, so does the noise level, adding to the stress of modern city life. Ironically, the increasing noise causes more people to move to the country for peace and quiet, which adds to the number of long-distance commuters who create traffic congestion (Anon, 2003).

2.1.5.7 Impacts of transportation network

2.1.5.7.1 Environmental impacts

Roads and parking facilities impose a variety of environmental costs (Noonan, 1996, Flad, 1997 and Forman, *et al,* 2003). Biologically active lands such as wetlands, forests, farms, and parks (collectively called green space) provide external benefits, including wildlife habitat, improved air and water quality, biological diversity, and social benefits of agricultural production (Brabec, 1992 and Quammen, 1996). Environmental impacts of transportation network can be discussed under two broad categories: positive impacts and negative impacts.

2.2 Bhawal sal forest

The plain land forests of Bangladesh, commonly known as Gazari of Sal forests are located in the Greater Dhaka, Tangail and Maymensingh districts in the central region. The Sal forest areas consist of high lands, locally called Chala intercepted by an intricate network of narrow depressions, called Baid which are cultivated for agricultural crops, especially paddy. The flat ridged chalas are running in the form of a long belt form north-west to south-east forming an irregular mass of high lands with gentle slopes. . This forest is located about 40 km north of the capital city Dhaka, from where it is easily accessible throughout the year by road. It has been kept under IUCN management category as a protected landscape. This Bhawal National park was established and maintained as a national park in 1974 but not declared officially until 1982 under the Bangladesh Wildlife Act, 1974. The area is bounded by Sreepur upazila on the north, Savar upazila on the south, Kaliganz and upganj upazilas on the east Kaliakiar and Saver upazila on the west. Bhawal National Park based on 8 Mousa that consists of 5000 ha of proposed land area. Area of 940 ha of Arysh prashad Mousa constitutes the core zone of Bhawal National Park Rajendrapur Range area comprised with five beats namely Rajendrapur West Beat, Rajendrapur east Beat, Salna Beat, Monipur Beat and Surjanarayanpur Beat with a total area of 6565 ha.

2.2.1 Flora and fauna

The biodiversity of Sal forests includes a wide variety of fl ora and fauna. The dominant tree species found in the Sal forests is Sal *(Shorea robusta)*. Other species include Banyan *(Ficus bengalensis)*, Ashwath *(Ficus religiosa)*, Koroi *(Albizia spp.)*, Ajuli *(Dillenia pentagyna)*, Sonalu *(Cassia fistula)*, Bohera *(Terminalia balarica)*, Haritaki *(Terminalia chebula)*, Kanchan *(Bauhinia acuminata)*, Jarul *(Lagerstroemia speciosa)*, Jam *(Syzygium spp.)*, Mango *(Mangifera indica)*, Jackfruit *(Artocarpus heterophyllus)*, Guava *(Psidium guajava)*, Pineapple *(Ananus sativa)*, Lemon *(Citrus spp.)*, Sharifa *(Anona squamosa)*, and Grape fruit *(Citrus decumana)*. A total of 36 families including 63 common plant species are present in the Sal Forests. According to an inventory estimate, Sal Forests have a growing stock of 3.25 million cubic meters of wood. A massive plantation programme under Social Forestry program is in progress on the basis of benefit sharing mechanism with the local communities residing in and around the forest area.

Important mammals include Jackal *(Canis auveus)*, Bengal Fox *(Vulpes bengalensis)*, Rhesus Macaque *(Macaca mulatta)*, Jungle Cat *(Felis chaus)*. Of the reptiles, Bengal Monitor Lizard *(Varanus bengalensis)* and Common Cobra *(Naja naja)* are important. A total of 220 species of wildlife including 12 amphibians, 25 reptiles, 148 birds and 35 mammal species are available in the Sal forests.

2.2.2 Anthropogenic threats

2.2.2.1 Over-exploitation

Over- exploitation of forests to meet the growing requirements of the expanding population, as explained above, is one of the main threats facing the Sal forests. These forests have been exploited for timber, fuel wood, bark tannin, animal fodder, native medicines and food (e.g., fruits, honey and wild life) for centuries, but recent population pressure has greatly increased the rate of exploitation, leading to serious degradation of the forest. For example, indiscriminate exploitation of the Sal forest over the centuries has converted the thickly stocked forests with numerous tree species of the past, such as sal (*Shorea robusta*), palash (*Butea monosperma*), haldu (*Adina cordifolia*), shidah jarul (*Lagerstroemia parviflora*), bazna (*Zanthoxylum rhetsa*), hargoja (*Dillenia pentagyna*), koroi (*Albizia spp*.), udhal (*Sterculia villosa*), bahera (*Terminalia belerica*), kurchi (*Holarrhena antidysenterica*), haritaki (*Terminalia chebula*), pitraj (*Aphanamixis polystachya*), sonalu (*Cassia fistula*), amlaki (*Phyllanthus emblica*), into a depleted forest (Banglapedia, 2008). These forests formerly covered extensive tracts of the country (Motiur, 2006) but at present, there are wide gaps and grassland areas within the sparse Sal forests. It is reported that more than 60% of these forests were densely wooded in the late 1970s. The area under tree cover has been reported as 36% in 1985 while only 10% remained in the 1990s (Haque, 2007).

2.2.2.2 Illegal cutting

Due to illegal cutting the Sal forest is rapidly disappearing, and consequently biodiversity of the area is shrinking at an alarming rate (Haque, 2007). In the first half of this decade, approximately 25,101 hectares of Modhupur Sal forest were illegally cut, a figure which represents about 12% of Sal forest area (Gain, 2005). The poor livelihood conditions and lack of alternative income-generating opportunities of the population in the Sal forest areas have been exploited by the timber traders to engage them in illicit forest cutting and other activities that are detrimental to the Sal forest ecosystem (Safa, 2005).

2.2.2.3 Encroachment

The encroachment and denudation of forests have usually been led by the local poor and by illegal timber traders. However, more recently, the Sal forests are being illegally occupied by local politically and financially influential individuals, groups of individuals, and institutions (Iftekhar, 2005). A total of 8,869 hectares of forest land have already been encroached and the number of encroachers are about 100,000 (GOB, 1992) the encroachment rate is about 1% yr-1 in the Sal forest area (Iftekhar, 2005).

Rapidly expanding agriculture poses a crucial threat to the Sal forests in Bangladesh. Significant areas of forest land have been illegally converted into agricultural lands. Though an up-to- date forest inventory is unavailable, it is estimated that the forest area has been reduced by more than 50% since the 1970s (FAO, 2003.); much of this land is believed to have been converted into agricultural lands by encroachment.

2.2.2.4 Poaching

Historically, poaching is a major threat to plain land Sal forest. These forests traditionally belonged to feudal lords who took no responsibility for the protection of these resources; rather they had used them as their hunting ground, which has contributed to indiscriminate poaching of wildlife in the area (GOB, 1992.). It has been reported that while some wildlife species such as peacock, tiger, leopard, elephant, clouded leopard, and sambar deer have disappeared from the Sal forests, others such as jackal (*Canis aureus*), civet (*Viverra zibetha*), jungle cat (*Felis chaus*), pythons (*Python* spp.), kraits (*Bungarus fasciatus*), cobras (*Naja* spp), frogs (*Rana tigerina*), and jungle fowl (*Gallus gallus*) have decreased remarkably because of poaching and habitat loss (Kabir, 2005.). The situation has further been exacerbated due to the perception of the forest policy makers that these forests habitats are unimportant for biodiversity conservation and the resultant lack of management strategies and attention to protecting wildlife from poaching (Banglapedia, 2008).

Table 2.1 Population Size and growth rate of major urban settlement near Sal forest area

Name of the urban area	Population size	Annual growth rate (%)
Mymensingh Sadar	225,811	2.5
Tangail	128,785	2.2
Gazipur (Sadar and Tangi)	588,492	4
Dhaka City	6,732,968	4

2.2.2.5 Urbanization

Urbanization destroys the forest and also acts as a barrier to wildlife. A number of major urban settlements, such as Gazipur, Tangail sadar, and Mymensignh sadar including Dhaka city, are in close proximity to the main Sal forest areas of the central region. These urban settlements have large populations with high growth rates (Table 2.1). Such urban settlements lead to development of road networks and other infrastructures, which degrade the quality of wildlife habitat. For example, two road network improvement projects totaling 62.2 km of length have been undertaken in the Sal forest areas of Mymensingh (GOB, 2008). Such road construction work isolates the population of the wildlife species from feeding grounds and natural migration routes and limits breeding between larger groups. Road construction has made Sal forest more accessible, so anthropogenic disturbances can easily take place in the forest areas. A firing range of the Bangladesh Air Force was established on about 405 hectares of Sal forest land (Gain, 2005) which is a source of noise pollution as well as a serious threat to wildlife habitat.

2.2.2.6 Plantations

The Sal forest has been rapidly exhausted in recent times due to commercial rubber monoculture plantations and Asian Development Bank (ADB- funded “social forestry” in the form of woodlots (for production of fuel wood) and agroforestry. The “social forestry” that was initiated in 1989-1990 was preceded by a rubber monoculture that destroyed a significant part of the Sal forest. Rubber plantations in particular are among the major factors that have changed the Sal forest forever. The Modhupur Sal forest is an example; out of 18,623.48 hectares, 3,157.89 hectares were allocated for rubber cultivation in the Tangail area (Gain, 2005) and another 40,000 hectares of Sal forests were planned for woodlots and agoroforestry plantations under the Forestry Sector Project (GOB, 2001). However, introduction of several invasive species in plantation forestry is one of the biggest threats to the biodiversity of natural Sal forest (Gain, 1998). Invasion of exotics may cause major loss of biodiversity and species extinction either due to direct replacement by the exotics or indirect effects on the ecosystem. Over the last forty years, the Sal forests have decreased drastically due to new plantations with exotic species (Hossain, 2005) which disregard the principles of silvicultural systems and the impacts of the invasive species on the Sal forest ecosystem. The Bangladesh government is trying to reforest the area with some fast growing exotic species such as

Akasmoni (*Acacia auriculiformis*) and Eucalyptus (*Eucalyptus camaldulensis*) that are known as invasive species.

Scientists argue that these exotic species are detrimental to biodiversity of the area and may transform the local ecosystem into arid landscape because of their physiological requirement for increased water uptake (Hossain, 2005). Table 2.2 presents a list of species planted in Sal forests including the area covered by each species. It can be seen that about 70% of the area is planted with exotic species while only 30% of the area is planted with indigenous species. Furthermore, the most extensively planted exotic species in Sal forest area are: *Acacia auriculiformis* (26.1%), *Eucalyptus camaldulensis* (24.6%) and *Acacia mangium* (18.7%). The remaining 30% of the area is occupied with all other species including Sal, which is the original climax species in these areas and represents only 12% of the plantation programs (Hossain, 2005).

2.2.2.7 Grazing

It is reported that the degradation of Sal forests resulted from heavy and haphazard grazing (Gautam & Devoe, 2006). Grazing is one of the leading causes of devastation and degeneration of coppiced forests into rooted waste and scrub forests. Grazing also makes the ground compact by constant trampling, which in addition to other types of damage, greatly contributes to erosion of the surface soils. In addition, it is noted that an increase in grazing intensity decreases the fine soil particle content in forest soil (Pandey, 1994).

Table 2.2 Area covered with plantation species in Sal forests of central Bangladesh.

Planted species (Scientific name)	Local name	Area planted (hectare)	% area of the total plantation
Acacia auriculiformis	Akashmoni	818.74	26.1
Eucalyptus camaldulensis	Eucalyptus	773.32	24.6
Acacia mangium	Acacia	587.44	18.7
Shorea robusta	Sal	380.89	12.2
Tectona grandis	Shegun	333.85	10.6
Terminalia arjuna	Arjun	92.35	3
Lagerstroemia speciosa	Jarul	69.25	2.2
Cassia siamea	Minjiri	37	1.2
Swietenia mahagoni	Mehegoni	27.85	0.9
Gmelina arborea	Gamari	15.5	0.5
Total		3136.2	100

2.2.2.8 Pollution

Pollution from chemical contaminants certainly poses a threat to species and ecosystems. Although no published data for the central Sal forest of Bangladesh are available, a study from the Indian portion of the Sal forest revealed that air pollution affects the phenological calendar, soil nutrient status, leaf nutrient concentrations, amount of soil bacteria, fungi, actinomycetes, and soil enzymes. For example, Kosla and Pamer, 1988 found that the dust falls adversely affected the phenological calendar of Sal. Their study revealed that the deposited particulate pollutant on Sal trees caused an increase in soil pH, rendering soil conditions unfavorable for Sal trees. The study noted adverse changes in sulphur, phosphorus, calcium, and potassium contents in Sal forest soil in the polluted areas. Also, quantitative enumeration of soil-microbe studies showed a change in their population levels, depending upon the amount of pollution the site received; ultimately the litter decomposition was also affected. The total sugar content in polluted leaves was reduced while protein and phenol contents registered an increase. The ascorbic acid, chlorophyll, and starch contents were found to be lower in the highly polluted sites. Leaf RNA contents were reported to be increased while leaf DNA contents showed erratic behavior in the polluted sites. Pineapple and banana plantations have expanded in the Sal forest in recent times, with excessive use of pesticides, including DDT and imported hormones to make the fruit grow bigger and ripen quicker, posing a serious concern (Khosla & Pamir, 1988.). These chemicals also kill different varieties of insects that are beneficial to the soil and environment. The soil has taken on a yellowish hue from the overuse of insecticides and experts fear that serious damage has occurred to the upper layer of the forest soil, which may lead to complete loss of soil fertility within a few years (Gain, 2005).

2.2.2.9 Management failure

In the early 1950s and 1960s the Bangladesh Forest Department (BFD) raised Sal plantations over large areas. Over the course of the year's most of these plantations have disappeared, leaving only a few patches. Later, in the 1970s, BFD raised plantations of moderately fast-growing indigenous species on recovered encroached lands. Most of these did not survive either. Then in the 1980s, plantations of eucalyptus and acacia met with the same fate, except some plantations in the Rangpur, Dinajpur, and Rajshahi divisions. Under the "Thana Banayan Plantation Program," enrichment and agroforestry plantations have started again in the Sal forest areas (UNEP, 2001). The Sal forest is disappearing because of three main reasons: failure of officials and institutions to effectively manage Sal forest resources; poor planning and knowledge of forest land use; and implementation of a development plan that does not include environmental protection. Although the Department of Forests has taken control of the Sal forest, the protection of these resources has not been ensured. Rather, a tree-cutting moratorium was put in place in 1972, which stopped neither encroachment nor illicit felling because of the failure of forest officials and the Forest Department as an institution to formulate and implement an appropriate management strategy (GOB, 1992). While research data concluded that the lands in the remnant Sal forests are not suitable for agriculture without irrigation (Gani, *et al,* 1990) and there are no possibilities of extending irrigation facilities in the Sal forest areas (GOB, 1992) agroforesty plantations were undertaken as a management strategy to replenish the Sal forests (Hossain, 1999).

2.2.3 Natural threats

2.2.3.1 Pests and diseases

Sal forests are under threat by an insect infestation, popularly known as Sal borer (*Hoplocerambix spinicornis*). It kills trees silently with the only visible indications the sawdust collected at the stumps of the trees and also slows withering of the branches from the top of the tree. Within a short time the entire tree will dry up and die off (Utkarsh, 1998). Also, die-back of Sal seedlings due to attacks of nematodes and root borer (e.g., *Pammene theristhis*) plays an important role in regeneration failure of Sal forests (Elouard, 1998). *Cylindrocladium floridanum* and *C. scoparium* causing leaf spot and blight in *Shorea robusta* are reported from India (Mehrotra, 2001).

2.2.4 Present management system and its problem

Most of the Sal forests originally belonged to feudal landlords and were not put under scientific management for a long period (Salam and Noguchi, 2005.). The Forest Department gradually assumed responsibility for management after nationalization of these forests in the 1950s. The Sal forests have been managed under two working circles: (a) a community forest working circle, and (b) a commercial forest working circle (Chowdhury, 2006). In both circles, silvicultural prescriptions for Sal forest management include: clear-felling followed by simple coppice, and coppice with a standard system that allows keeping some mature trees as shelter-wood. Thinning is applied on a 10-year cycle to improve the existing crop based on a rotation of 100 years; and afforestation of clearings operated under a taungya (shifting cultivation) system (Banglapedia, 2008). However, the magnitude of deforestation, soil erosion, and degradation of the land in the Sal forest areas has become even worse. None of these silvicultural practices sustained the Sal forests and they continued to deplete in size and stocking (GOB, 1993) with the exception of some plantation programs. Commercial woodlot plantation operations have been carried out extensively throughout the central Sal forest areas without considering the long-term adverse effects on the ecology of the forest. About 16,000 ha of woodlots have been established in degraded and encroached tropical moist deciduous or Sal forests under the Dhaka Forest Division with the primary objective of producing fuel wood for local household consumption (ADB, 1992 and Kabir, *et al* 2005). When woodlot blocks were being established, hundreds of vehicles including trucks were seen carrying logs out of the forest (Gain, 1998). In such practice of forestry, little attention is paid to the regeneration of the natural forests. In 1994, the government initiated participatory forestry in natural degraded forest lands including deciduous Sal forests from the mid-80s of the previous century. Although the results of such a management shift are yet to be assessed, there have been discussions and concerns that due to introduction of fast-growing exotic species and destruction of Sal regeneration, the forest composition and ecological functions of the forests have been changing in ways that will render these forests less sustainable and destroy the habitat of the wildlife (Hossain, 2005).

Current management practices are inadequate and inefficient to manage the Sal forests sustainably. As identified in the Forestry Sector policy document, many of the Sal forest management policies cannot be successfully implemented due to the following main causes: population pressure, poverty, high demand for fuel wood, negative influence of local and political elites, and encroachment of forest land by locals (Gani, *et al* 1990.). Corruption at different levels of management systems, illegal felling of trees, smuggling of wood, and poaching of wildlife are some of the major constraints in successful implementation of development project (BBS, 1996). There are continual claims that the law-enforcement agencies and the management bodies themselves are sometimes engaged in the felonious actions. The antagonistic relationship between the Forest Department and locals is an obstacle for effective Sal forest management. If the situation prevails as it is, no rule, policy, or regulation will be able to resurrect the valuable resources in the Sal forests.

2.2.5 Conservation and sustainable forest management for Sal forest ecosystem

Internationally, forest ecosystem management attention seems now to have been generally shifted from management for a single objective (often wood production) to a sustainable ecosystem approach that tries to incorporate into forest management the principles of equity in resource utilization and participation for sustained production of multiple outputs, by recognizing the hopes and aspirations of different stakeholders interested in the future of the natural forest resources. At the international and national policy levels, it is today accepted that Sustainable Forest Management (SFM) depends upon several factors such as: (1) integrated management for all forest values–wood and other items and services, (2) meaningful participation of all stakeholders, (3) landscape-level planning and management, and (4) comprehensive monitoring, evaluation, and reporting on indicators of sustainability. Most of the Sal forests in Bangladesh are now substantially degraded and poorly stocked (Hossain, 1999). In this crucial time it is necessary to review the current management strategies of Sal forest ecosystem for the future benefit of all stakeholders. The future of this ecosystem depends on the successful and effective implementation of a sustainable forest management plan. For proper management and protection of the existing Sal forest areas from the present threats, a forest management plan should be formulated and implemented based on sustainable forest management (SFM) principles.

2.2.6 Implications for conservation and protection of sal forest

Silvicultural systems must be improved to promote effective regeneration. At the same time, sustainable alternatives to forest-based livelihoods such as home gardening, forest product-based small cottage industry, beekeeping, and poultry farming may be explored. Technical and institutional education and training can also create alternative job opportunities. To formulate such management strategies, growth and yield information should be made available through an appropriate forest inventory that would allow computation of an annual allowable harvest that can be extracted from the Sal forests while still preserving the sustainability of the ecological, economical, and social values of these forests. Also, an accurate inventory of the encroached Sal forest is required to develop a viable land recovery plan. In addition, comprehensive protection measures must be developed to tackle the illicit activities such as forest land encroachment for

Agriculture, illegal tree felling, wood smuggling, and poaching of wildlife. There is an urgent necessity to strengthen the management of the Sal forest through recruiting well-trained and motivated forestry professionals, allocating sufficient budget, and developing infrastructures. The Sal forests must be brought under community reserves where local people can be made partners in conservation and management processes. Currently, there is no organized system of harvesting wood or wild medicinal and aromatic plants. An uncontrolled harvest often results in degradation of forest and quality of habitats. There is a need to formulate policies related to harvest of medicinal plants for the benefit of communities, thereby controlling excessive pressure on the forest land. The future existence of the Sal forest in Bangladesh depends on the development and successful implementation of a sustainable management plan to protect and conserve these important resources. The government has attempted some initiatives to protect these important ecosystems but the sustainability of these resources could not be achieved due to a lack of sound management strategies. A sustainable management plan should be developed by involving all beneficiaries and stakeholders and should be effectively implemented to conserve these substantial ecosystems for present and future generations.

CHAPTER THREE

DESCRIPTION OF THE STUDY AREA

CHAPTER THREE: DESCRIPTION OF THREE STUDY AREA

3.1 General description of the study area

The plain land forests of Bangladesh, commonly known as Gazari of Sal forests are located in the Greater Dhaka, Tangail and Maymensingh districts in the central region. The Sal forest areas consist of high lands, locally called Chala intercepted by an intricate network of narrow depressions, called Baid which are cultivated for agricultural crops, especially paddy. The flat ridged chalas are running in the form of a long belt form north-west to south-east forming an irregular mass of high lands with gentle slopes. The Sal forests have been classified by Champion, Seth and Khattak as tropical moist deciduous forests. These were further subdivided into two types –Moist Sal forest and Sal scrub forests. Bhawal region occupy the moist deciduous forest. The mist Sal forest comprises of areas containing pure Sal in this forest is Bohera, Silkoroi, Ajuli, Gadila and Arjun etc.

Encroachments and illicit removal of timber and firewood from the forests are the major forest consummation problems in the area. The Sal forests are under constant human pressure from all sides. The areas under encroachments estimated at about 29,706 ha in the central regions and the number of encroachers is about 88000 nos. Most of the forests of the area are now severely degraded and poorly stocked. Some three decades ago, more than 60% of these forests were fairly densely wooded. But today, the forest has been reduced both in extent and tree density as well as stand quality. A recent estimate suggests that only about 10% of the forest cover remains.

3.1.1 Location

The study area lies in $24^{0}01'$Latitude $90^{0}20'$Longitude and managed under Dhaka Forest Division. This forest is located about 40 km north of the capital city Dhaka, from where it is easily accessible throughout the year by road. It has been kept under IUCN management category as a protected landscape. This Bhawal National park was established and maintained as a national park in 1974 but not declared officially until 1982 under the Bangladesh Wildlife Act, 1974. The nearby Sal forest area of Rajendrapur range under Dhaka Forest Division was also selected to make a comparison of vegetative structure. The area is bounded by Sreepur upazila on the north, Savar upazila on the south, Kaliganz and upganj upazilas on the east Kaliakiar and Saver upazila on the west. Map of study area is given in Figure 3.1

3.1.2 Area

Bhawal National Park based on 8Mousa that consists of 5000 ha of proposed land area. Area of 940 ha of Arysh prashad Mousa constitutes the core zone of Bhawal National Park Area of different habitat type in Bhawal National park is shown in Table 3.1. Rajendrapur Range area comprised with five beats namely Rajendrapur West Beat, Rajendrapur east Beat, Salna Beat, Monipur Beat and SaSurjanarayanpur Beat with a total area of 6565 ha. Area of different habitat type in Rajendrapur Range is shown in Table 3.2.

Table 3.1: Area of different habitat type in Bhawal National park

Habitat type	**Area (ha.)**
Low Forest	4450
Cultivation/ Grass land	500
Lake and Riverine	50
Total	5000

Table 3.2: Area of different habitat type in Rajendrapur Range

Habitat type	**Area (ha.)**
Forest cover	4347
Encroached land	1467
Woodlot plantation	751
Total	6565

3.2 Physical feature and Climate

3.2.1 Topography

The present feature of the forest area is actually honeycombed with habitation and rice fields. The topography is characterized by low hills, which rise 3.0-4.5 m above the surrounding paddy fields locally known as chalas are intersected by numerous depressions or baids .The drainage pattern of the area is dendritic.

3.2.2 Geology and Soil

Sal forests are found in the plain and hilly areas. In this case it is found in the slanted form on the ridges and grows best on the lower slopes and in valley, where soil is deep moist and fertile. Three major soil types are observed in Sal forest areas: deep red brown terrace soil, shallow red brown terrace soils. About half of the forestland is covered by deep red brown terrace soils. The soil of the study area is yellowish-red brown, sandy clay mixed with scattered manganiferous iron – ore known as Bhawal kankar. The soil is compact when it is dry and become very soft and tenacious when it rain. The porosity of the soil is poor and pH lies between 4.5-6 .Major physical problems of soils are low organic matter content , low fertility and low moister holding capacity. (Rashid, 1991).

3.2.3 Rainfall

The rainfall is not evenly distributed throughout the year .The mean annual rainfall in Bhawal Sal forest of Dhaka region is 2150 mm. The period of maximum rainfall is April – October and the period of minimum rainfall is November – March. At least 80% of the rainfall occurs during May to October.

3.2.4 Temperature and relative Humidity

The temperature continues to be uniform from early March to early October. The highest average maximum temperature is 33.4°C in May and the lowest average minimum temperature is 13.4^{0}C in January .The mean monthly average relative humidity of Bhawal region is high throughout the year. The humidity is very high at the month of August and low in the month of March. Average monthly humidity during wet summer season exceeds 90%, whereas during winter season it goes down to 60% (Ghani *et. al.,* 1990).

Table 3.3: Rainfall and Temperature data in Bhawal forest of the year of 2017

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Rainfall	-	2	15.4	42.4	168.9	233.8	261.7	362.1	215.2	290.8	-	-
Temperature (degree)	23.8	18.9	27.5	28.3	28.6	28.6	28.8	28.8	29.5	27	23.7	20.3

Source: Bangladesh Meteorological Department, Climate Division. Gazipur Station

3.2.5 Topography

The study area is flat to very gently sloping (Hossain et at, 1989). The forest land is more or less triangular in shape and full of ridges and depressions which are locally known as 'Chalas' and 'Baid' (Hossain & Haque, 1977). The drainage pattern of the area is dentritic.

3.2.6 Land use

Primary forest of the hills was cleared long ago and presently covered with secondary vegetation such as woodlot plantation, thickets with a few scattered trees, thatching grasses, cane and some bamboos. The valleys are locally under short grasses and reeds. A large part of them is cultivated mainly for rice. Most of the presently fallow land is cultivated mainly for rice.

3.2.7 Hydrology

The hydrology of the quaternary terraces is regulated by high seasonal rainfall fluctuating groundwater table and free surface drainage conditions. This landscape is drained out by an intricate network of valleys and creeks which ultimately conserve into several local rivers. The purnabhaba, atria and korota occur in the north-west part (barren tract) and the bansi, banar and dhaleshwari occur in the central part (Bhawal-Modhupur tract) as the major rivers.

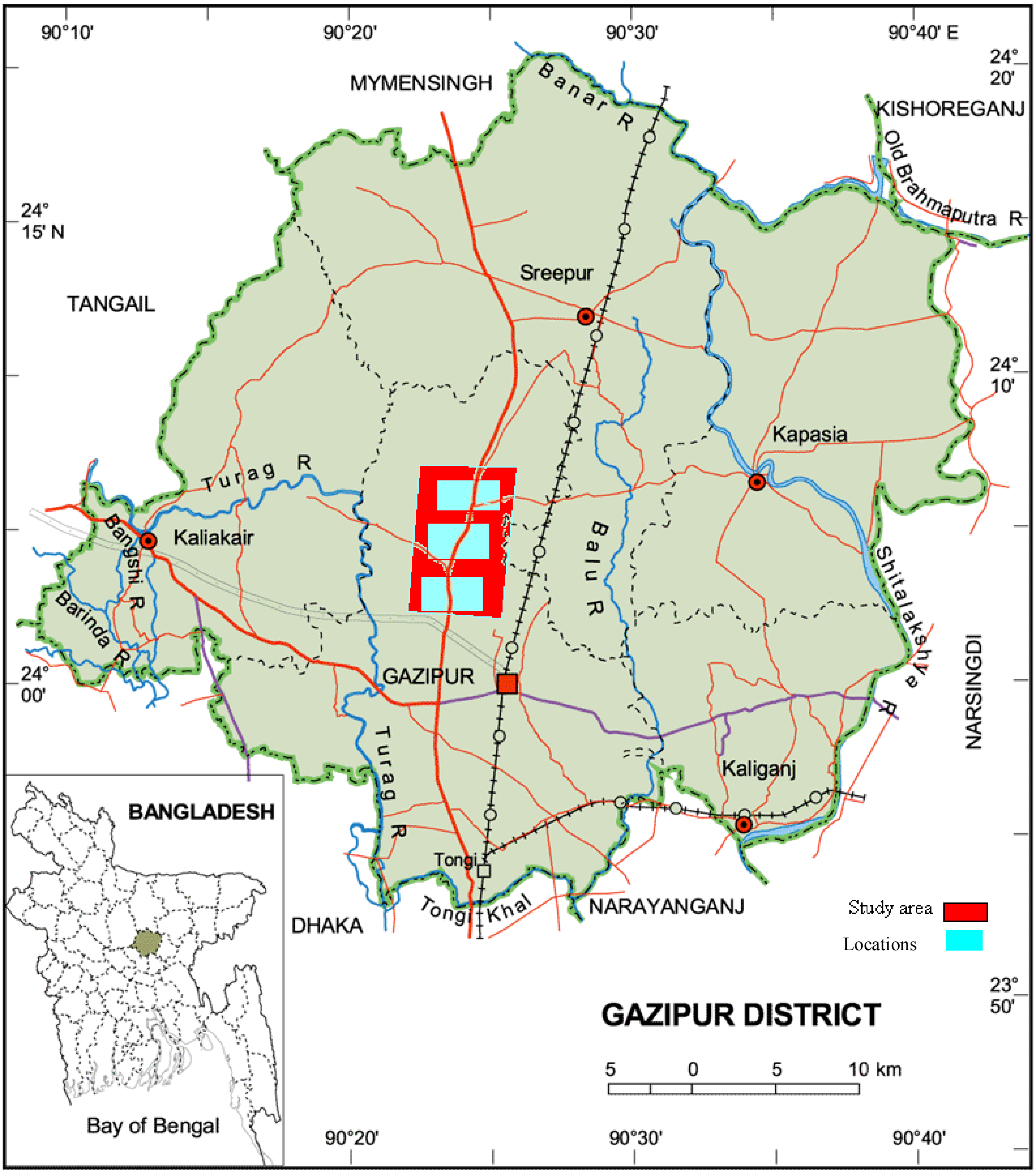

Figure - 3.1 Map of the study area (Source: Banglapedia 2017)

CHAPTER FOUR

METHODOLOGY

CHAPTER FOUR: METHODOLOGY

4.1 Collection of literature

The information and relevant literature, which were required for conducting this dissertation, were collected from different books, journals, published papers, previous review paper, project papers, etc. These materials were collected from Library of the Hajee Mohammad Danesh Science and Technology University, Dinajpur, Roads and highway Department, Bangladesh Forest Department and from different websites through Internet.

4.2 Study design

The study was conducted at three different locations (Salna, Natinal park gate no 4, and near Rajendrapur Range office) along Dhaka Mymensingh highway which were selected purposively. From every location 10 plots (five from both sides of the road) were taken for this study. Distance among each plot was 50 meter that is, 202m, 152m, 102m, 52m and 2m away from the highway. Height and DBH of shal trees were measured from the sample plots (10m×10m) using Spiegel relascope and Diameter tape. 500 g soil samples from the surface soil (0—20 cm) with different distances 2m, 52m, 102m, 150m, 202m, both the sides of the high way by removing grass-roots and large stones were taken. The samples were selected avoiding quarries, rubbish dumps, and other special locations in order to reduce influence of other factors.

Soil sample was air-dried, ground and screened though 2 mm mesh sieve before analyzing.

Fig 4.1 Soil sample collection using an Agar

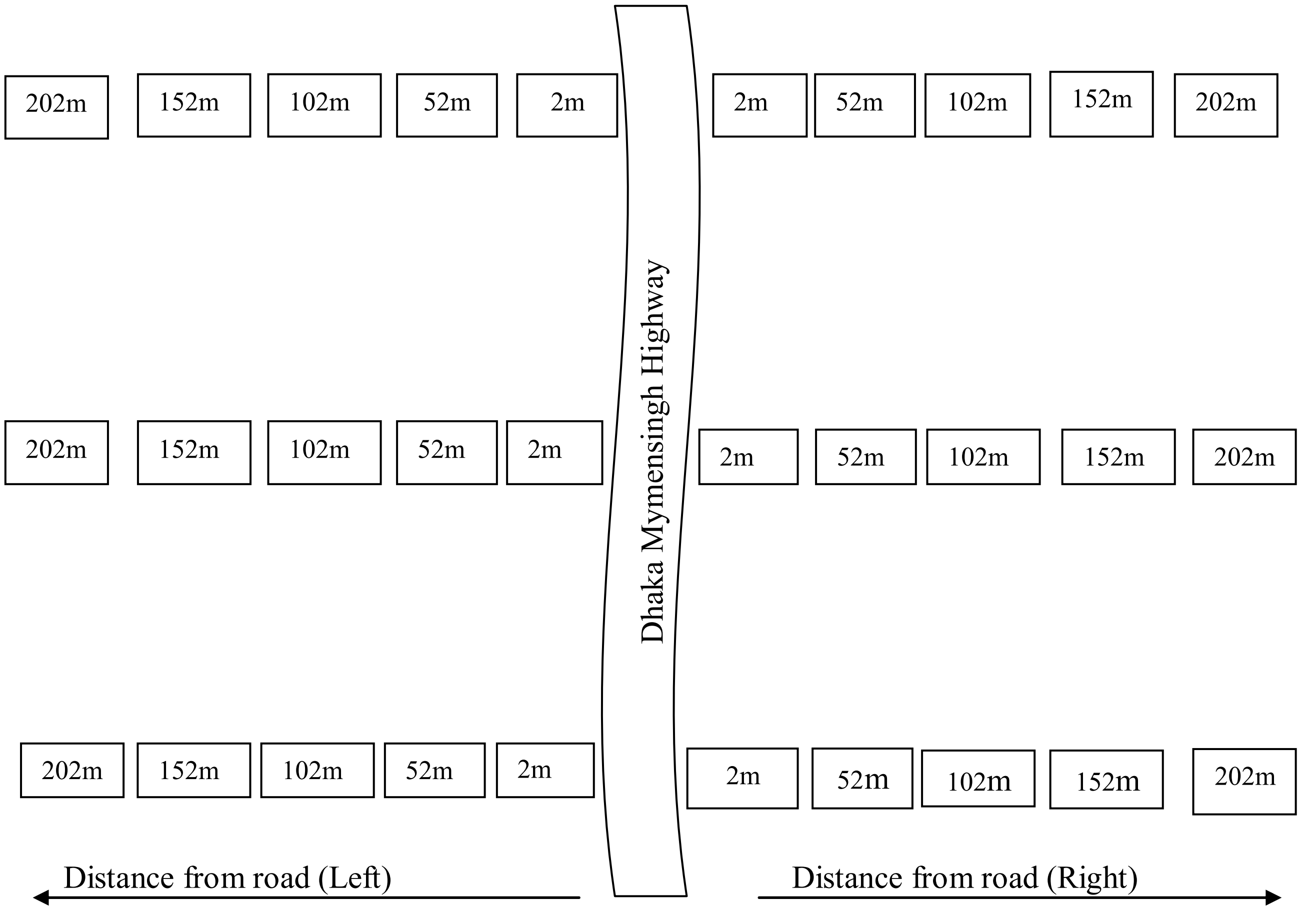

Figure .4.2. Diagram showing the sampling design used for the study of vegetation and soil properties and soil compaction.

4.3 Equipments Used in the Field Study

Following equipments and materials were used during the field study:

1. Measuring Tape
2. Dia Tape
3. Spiegel Relascope
4. Dao and scissor
5. Sharp Knife
6. Agar
7. Core
8. Large polybag
9. Wooden hammer

4.4 Laboratory Methods

4.4.1 Soil sample preparation and analysis

In the laboratory collected moist samples were first sieved through 10 mm mesh sieve to remove gravel, small stones and coarse roots and passed through 2 mm sieve. Sieved sample were then dried under room temperature. Besides some sub samples were dried in an oven at 105^0 c for eight hours. Air dried samples were used to determine pH and oven dry samples to determine organic carbon. Soil samples were then analyzed for moisture content, bulk density, pH, organic carbon, organic matter, total Nitrogen available phosphorus, potassium according to the methods described below:

For characterization of the soils pH, Organic matter, Organic carbon, were determined according to methods of Jackson (1973). Exchangeable N was determined by micro-kjeldahl digestion procedure (Jackson, 1973). Exchangeable K and P were determined by Atomic Absorption Spectro-Photometer (Double Beam AAS-Model No 902, GBC, and Australia).

4.5 Determination of soil physical properties

4.5.1 Moisture content

For determination of moisture of soils soils were taken on the pre weighted Petridis. It keeps in an oven at 105^0C for 8 hours; cooled in a desiccators and weight again (Chowdhury *et. al.*, 1969).For calculating moisture content following calculations were used:

Calculation: Field moisture content (%) $= \frac{\text{W2 - W3}}{W3 - W1} \times 100$

Where, W_1= Weight of petridish

W_2= Weight of petridish + field moist soil

W_3= Weight of petridish + dry soil

4.6 Soil sampling for Bulk density

For determination of bulk density, 30 undisturbed soil cores were collected in the field from 3-5 cm depth by pre weighted cores. Cores were driven vertically into the soil using wooden hammer. The cores were then carefully dug out using a sharp knife and excess soil at both ends removed. Then both the ends of the cores were wrapped two small pieces of clothes and rubber bands and carried in labeled plastic bags to the laboratory for subsequent analysis.

Figure 4.3 Procedure for core sampling

4.6.1 Bulk density Determination

Bulk density was determined from core samples. The field moist soil cores were accurately weighted. they were dried in an oven at 105^0 c for eight hours, cooled in a desiccators and weighted from this value, weight of filled moist and oven dry soils in the cores were then calculated out and dividing separately by the core volume 100 cm^3 moist of bulk densities were determined.

For determination of Bulk density following relationship was made

Bulk density g cm^3 $= \frac{W2-W1}{V}$

Where, W1 = weight of core

W2 = oven dry soil+ weight of core

V = Volume

4.7 Determination of soil chemical properties

4.7.1 Soil pH (1: 2 water)

Exactly 10g moist soil was taken in a clean dry 50 ml beaker and 20ml of distilled water was added. The content was thoroughly stirred with a glass rod for half an hour. The pH of the suspension measured with a digital ph meter. Before taking pH reading of the soil suspension, the meter was standardized using buffer solutions of pH 7 and 4 (Black *et. al.,* 1965). All samples were determined in duplicate**.**

4.7.2 Determination on soil organic carbon and organic matter

Soil organic carbon was determined volumetrically by wet-oxidation method of Black *et al*, 1965. Soil was taken into the crucible and burned into the furnesh for four hours. After burning the soil was cooled and again weight was measured. Loss of ignition was calculated by calculated weight. Following formulae was used to calculate the LOI, Mc and Om,

$$LOI = \frac{W3-W4}{W} \times 100\%$$

Organic carbon = (0.47×LOI %) – 1.87

Organic matter = 1.72× Organic carbon

4.7.3 Determination of soil nitrogen

4.7.3.1 Reagents:

4.7.3.1.1 40%NaOH solution: 200g NaOH crystals were poured in a 500 ml volumetric flask. It was dissolved in distilled water, cooled and made up to the mark with distilled water.

4.7.3.1.2 2% Boric acid solution: 20g H3BO3 was dissolved in a 1000 ml with distilled water.

4.7.3.1.3 Mixed indicator: 0.5 g bromocresol green and 0.1 g methyl red were dissolving in 100 ml rectified sprit. The solution was adjusted at bluish purple mid color with dilute HCl.

4.7.3.1.4 Standard 0.01N HCl solution

Approximately 0.1N HCl solution was prepared by diluting 8.6 ml concentrated HCl into 1 liter. This was titrated against standard 0.1N Na_2CO_3 solution. The required amount of the standard acid was diluted to make 0.01N.

Standardization of acid solution with 0.1N Standard Na_2CO_3 solution:

A clean burette was filled with 0.1N HCl solution. 10 ml 0.1N Na_2CO_3 solution was taken in clean dry 50 ml conical flask and then 2 drops of methyl orange indicator were added. Then the acid solution was run into the Na_2CO_3 solution with constantly rotating the flask. At the end point the color became pale pink. The strength of the acid was calculated with the following formula.

$V_1S_1 = V_2S_2$

Where,

V_1 = ml 0.1N Na_2CO_3 solution
S_1 = Strength of Na_2CO_3 solution (0.1N)
V_2= ml prepared HCl solution required for titration
S_2= Strength of prepared HCl solution

4.7.3.1.5 Micro-Kjeldahl distillation procedure:

10 ml 2% boric acid solution was taken in a 50 ml conical flask and then 3 drops of mixed indicator was added. The conical flask was then placed under the condenser of the distillation apparatus with the tip of the delivery tube just touching the liquid. 5 ml soil extract was poured into the Kjeldal distillation apparatus and then 10 ml 40% NaOH solution was added. During distillation, liberated ammonia was received in boric acid in the conical flask below and the pink color of the indicator turned bluish green. After the initiation of green color the distillation was continued for further 3 minutes. Then the collected ammonia in the conical flask was titrated against 0.01N solution until the color became pink. A blank was also done.

4.7.3.1.6 Calculation:

$$\text{Total N in soil percent} = \frac{(T-B)\times 1.4\times N\times V1}{V2\times W}$$

Where,

N = Normality of standard HCl
T = ml Standard HCl required to titrate the extract distillate
B = ml Standard HCl required to titrated the blank distillate
V_1 = Total volume of extract (ml)

V_2 = ml extract taken for distillation
W =Weight of soil.

4.7.3.1.7 Preparation of extracts for determination of exchangeable nutrients

50 ml of 1N NH_4OAC was added to 5gm of over –dried soil and kept for overnight. The suspension was then faltered (41No.) and diluted at different concentrations as required for nutrient determination.

4.7.4 Determination of soil phosphorous

4.7.4.1 Preparation of reagent for extraction

i) Bray and Kurtz No. 2 extractant: 1N NH_4F was prepared by dissolving 37 g NH_4F to one liter and 5N HCl acid solution was prepared by diluting 450 ml conc. HCl to one litre with distilled water. Bray and Kurtz No. 2 extractant was prepared by diluting 300 ml 1N NH_4F and 200 ml 5N HCl to 10 liters. The resulting solution was 0.03N NH_4F in 0.1N HCl.

4.7.4.2 Extraction and spectro photometric determination

5 g air dry soil was taken in a 150 ml conical flask and 50 ml Bray and Kurtz No. 2 extractant was added. This was thoroughly mixed and stired for exactly one minute, and immediately filtered through Whatman No. 42 filter paper. If the solution was colored it was treated with activated charcoal and filtered again. Available phosphorus was then determined spectrophotometrically according to the $SnCl_2$ reduced molydophosphoric blue color method.

4.7.4.3 Preparation of reagents for spectrophotometric analysis

i) 2.5% Ammonium sulfomolybdate solution: 25 g ammonium hepta molybdate $[(NH_4)_6 MO_7O_{24}. 4H_2O]$ was dissolved in 200 ml of distilled water previously warmed at 50ºC. The solution filtered through Whatman No. 42 filter paper to remove the sediment (if any) then 112 ml of conc. Sulfuric acid (H_2SO_4) was diluted to 500 ml with distilled water and both the solutions were cooled. The Ammonium sulfomolybdate solution was added slowly to the diluted H_2SO_4 solution cooled and made up to 1000 ml with distilled water.

ii) 2.5% stannous chloride solution: 2.5g of fresh stannous chloride (SnCl2) was taken in a 100 ml beaker. Then 10 ml of conc. HCl was added. The contents were warmed until SnCl2 was dissolved. The solution was then cooled and 90 ml distilled water was added. The stannous chloride solution was prepared afresh for each day's determination.

iii) 1000 ppm standard phosphorous solution: A few gram of potassium dihydrogen phosphate (KH_2PO_4) was dried at 105^0C and cooled in desiccators. 4.393g of dried potassium dihydrogen phosphate was taken in a 1000 ml volumetric flask and dissolved in about 100 ml distilled water. Then 5 ml conc. H_2SO_4 was added, shaken well for thorough mixing and the volume was made up to the mark with distilled water. This solution was kept as stock solution. Solutions of suitable concentrations were made from the stock solution by dilution.

4.7.4.4 Preparation of phosphorus standard curve

Firstly, 1 ppm phosphorus solution was made from 1000 ppm stock solution. 0,1,2,4 and 8 ml of 1 ppm standard phosphorus solution were taken in five clean 50 ml volumetric flasks. 2 ml ammonium sulfomolybdate reagent was added accurately and carefully to each volumetric flask. Then distilled water up to the lower neck of the flask and 2 drops of freshly prepared stannous chloride solution were added and mixed thoroughly. The volume was then made up to the mark with distilled water. A blue color developed and the color intensity of each solution was measured within 5 to 15 minutes at 660 nm wavelengths in a spectrophotometer. The absorbance value for each was then plotted on Y-axis against the concentration of the standard solution on X-axis, and a standard curve was prepared. Standard curve was prepared separately on each day of determination.

4.7.4.5 Phosphorous determination from soil extract

5 ml extract was taken in a 50 ml volumetric flask and 2 ml ammonium sulfomolybdate reagent was added. Then distilled water up to the neck of the flask and 2 drops of freshly prepared stannous chloride solution were added. The solution was shaken well and the volume was made up to the mark with distilled water. A blue color developed and its intensity was measured in a spectrophotometer within 5 to15 minutes of color development at 660 nm wavelength. The readings were compared with the standard curve to obtain concentrations of available phosphorus of soil. Available Ca was determined from the following relationship:

Available P (%) = $\frac{R \times P \times V_1 \times 1000 \times V}{V_2 \times W} \div 10^4$

Where, R = Spectrophotometer reading (absorbance)

P = mg phosphorous/ per unit of absorbance

V = Volume made for color development

V_1 = Total volume of extract (ml)

V_2 = ml extract taken for color development

W = Weight of soil taken (g).

4.7.5 Determination of soil potassium (Atomic absorption spectro-photometric method)

Distilled water/ 1N NH_4OAC solution was used to set the AASP scale at zero .With standard K solutions a standard curve was obtained at 766.5nm wavelength. The concentration of K/unit of AASP reading was calculated. Ammonium acetate extract of soil were used after proper dilution for AASP reading.

4.7.6 Calculation

Exchangeable Potassium of soil

Me/100 gm soil = $\frac{\text{ppm} \times 100}{\text{eq.wt} \times 1000}$

Here,

ppm = $\frac{\text{Concentration from standard curve} \times \text{Dillution factor}}{\text{Wt.of soil}}$

4.7.7 Data analysis

The data of chemical and physical properties of soil were carefully recorded, compiled and finally processed in the computer. The data were analyzed by using SPSS software and MS-Excel programme.

CHAPTER FIVE

RESULTS AND DISCUSSION

CHAPTER FIVE: RESULTS AND DISCUSSION

5.1 Physical properties of soil

5.1.1 Soil moisture content

Moisture content found to decrease with the decrease in distance from forest to highway. On right side of the road at 202m mean soil moisture content (12.65%) was found highest and lowest mean value (5.87%) was found on right side from the road at 2 m distance. On right side mean value of moisture content was significantly different at every distance from road to forest. On left side significant difference was found at every distance except between 2m and 52m. On right side significant difference was found at every distance and at and at 102 m and 202 m moisture content was significantly higher than other distances.

The finding is consistent with the study of Hoque et al.,(2008) which was done on seasonal variation of edaphic features of Madhupur sal forest, Bangladesh and they found 5.26% to 7.78% soil moisture content in Madhupur sal forest.

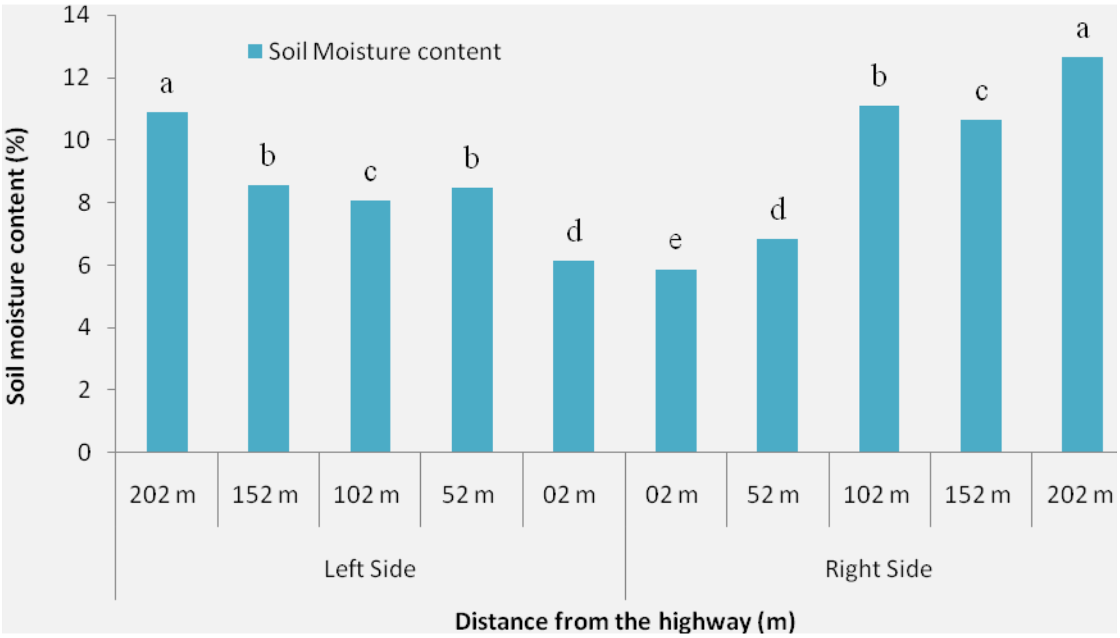

Figure - 5. 1 Soil moisture content with respect to distance from the highway

5.1.2 Soil bulk density

Bulk density was increasing with the decrease in distance from forest to highway. Heights mean value (1.94 g/cc) of bulk density was found on right side adjacent to the road at 2m distance and lowest value (1.17 g/cc) was found within the forest at 202m distance on right side of the road. On left side bulk density was varying significantly for every distance except between 52m and 102m. On the other hand there was no significant difference in bulk density on right side of the road at 202m, 152m, 102m and 52m distance except between 52 and 2 m distance. Bulk density was significantly higher on right side of the road at 2 m distance compared to other distances.

My result findings is consistent with the study of Islam, 2000 who found bulk density 1.22 on his research work entitled Land use effects on soil quality in a tropical forest ecosystem of Bangladesh who reported soils under cultivation had higher bulk densities than the adjacent soils under well-stocked *S. robusta* natural forest, Acacia reforestation and grassland.

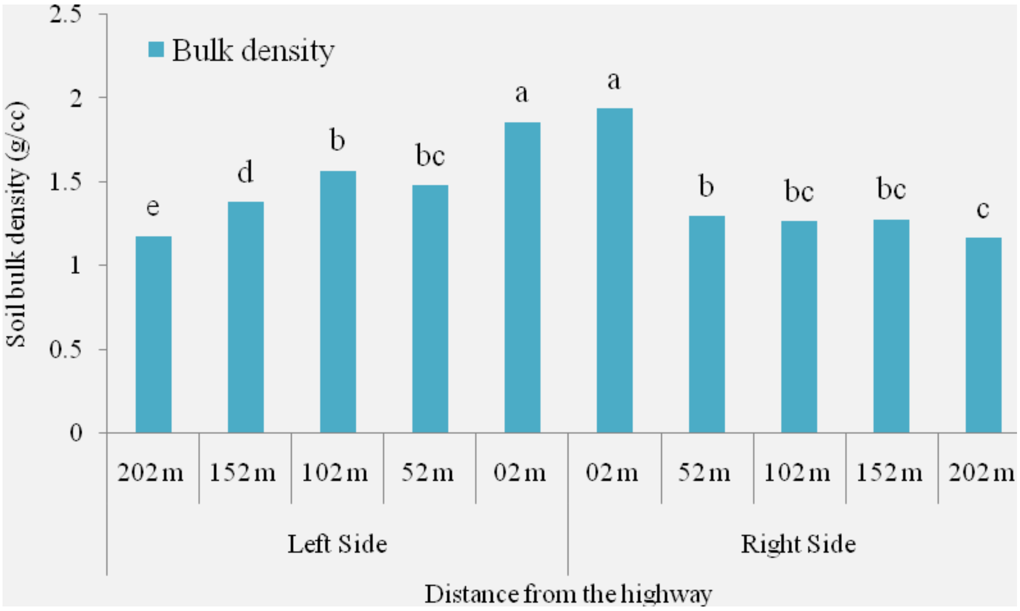

Figure 5.2: Soil bulk density content with respect to distance from the highway

5.2 Chemical properties of soil

5.2.1 Soil pH

Figure 5.3 shows that Soil pH tends to decrease with the decrease in distance from forest to highway. Mean soil pH (5.5) was found to be higher at 202m distance on left side of the road and lowest mean value (4.2) was found on left side from the road at 2 m distance. On left side mean value of pH was significantly different at every distance from road to forest and difference was insignificant between 52m and 102m distance. No significant difference was found on right side at every distance except between 2m and 52m.

My study findings is consistent with the study of Rashid, 1991 that was done on Geography of Bangladesh found the soil pH of Bhawal sal forest was 4.5 to 6.0. My study findings is also consistent with the study of Hoque et al.,2008 which was done on seasonal variation of edaphic features of Madhupur sal forest, Bangladesh found soil pH by 4.6 to 6.28 in Madhupur sal forest.

Figure - 5. 3 Soil pH with respect to distance from the highway

5.2.2 Soil organic carbon

Soil organic carbon found to decrease with the decrease in distance from forest to Highway. On right side of the road at 202m highest mean soil organic carbon (2.41%) was found and lowest mean value (0.98%) was found on left side from the road at 52 m distance. On left side mean value of organic carbon was significantly higher at 202m and 152m distance than other three distances. Organic carbon was significantly higher on right side of the road at 202m and 152 m distance compared to other three distances.

My study findings is consistent with the study of Rashid, 1991 that was done on Geography of Bangladesh found the soil organic carbon of Bhawal sal forest was ranges 1.3% to 2.6%.

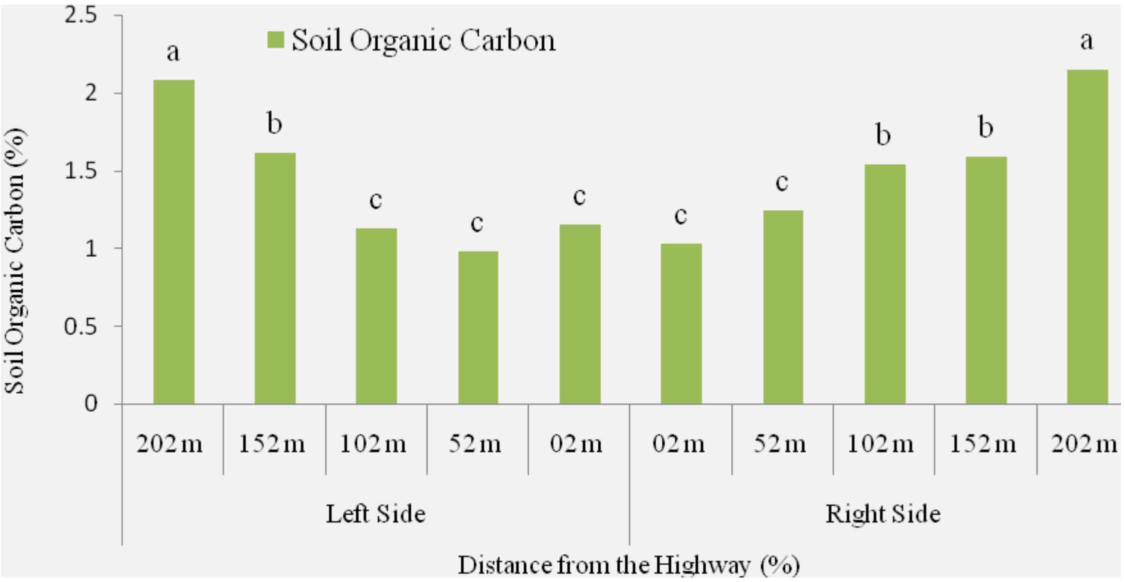

Figure - 5.4 Soil organic carbon with respect to distance from the highway

5.2.3 Soil organic matter

Soil organic matter found to decrease with the decrease in distance from forest to highway. On right side of the road within the forest at 202m highest Mean Soil organic matter (4.14%) was found and lowest mean value (1.68%) was found on left side from the road at 102m distance. On left side Mean value of organic matter was significantly higher at 202m and 152m distance than other three distances. Mean Organic matter was significantly different from each other at every distance and significantly higher at 202m than other distances.

My study findings is consistent with the study of Rashid, 1991 that was done on Geography of Bangladesh found the soil organic carbon of Bhawal sal forest was ranges 2.23% to 4.46%. Soil organic matter content reflects the vegetation status in soil genesis. In the study there were significant trend of organic matter content with respect to distance. The accumulation and decomposition of leaf litters, a major source of nutrient return in the site is hampered by the local people as they are collecting and removing litters for their household cooking. Organic matter content in the forest soil gradually increased with time on plantation or regeneration as litter and ground vegetation residues remains in the forest floor. But the study area due to human interference on the forest and continuous litter collection, organic residues do not remain in the floor any longer.

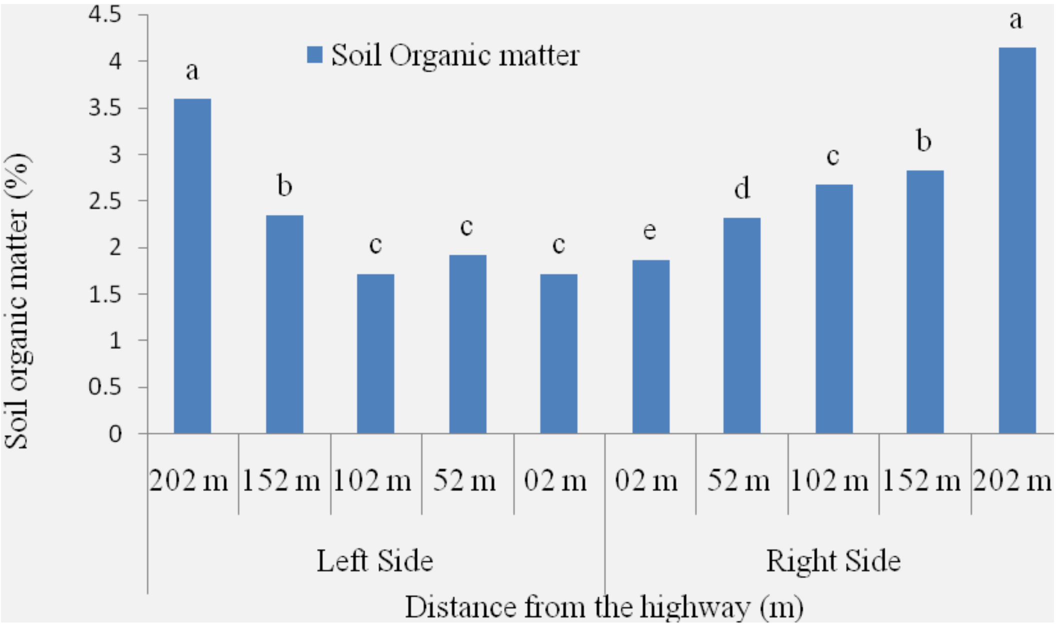

Figure - 5.5 Soil organic matter with respect to distance from the highway

5.2.4 Soil exchangeable nitrogen

Nitrogen tends to decrease with the decrease in distance from forest to highway. Mean soil nitrogen (0.063 %) was found to be higher at 202m distance on right side of the road and lowest mean value (0.03%) was found on 2m distance from the road in both sides and 52m distance at left side. On both the sides mean value of nitrogen was significantly different at every distance from road to forest.

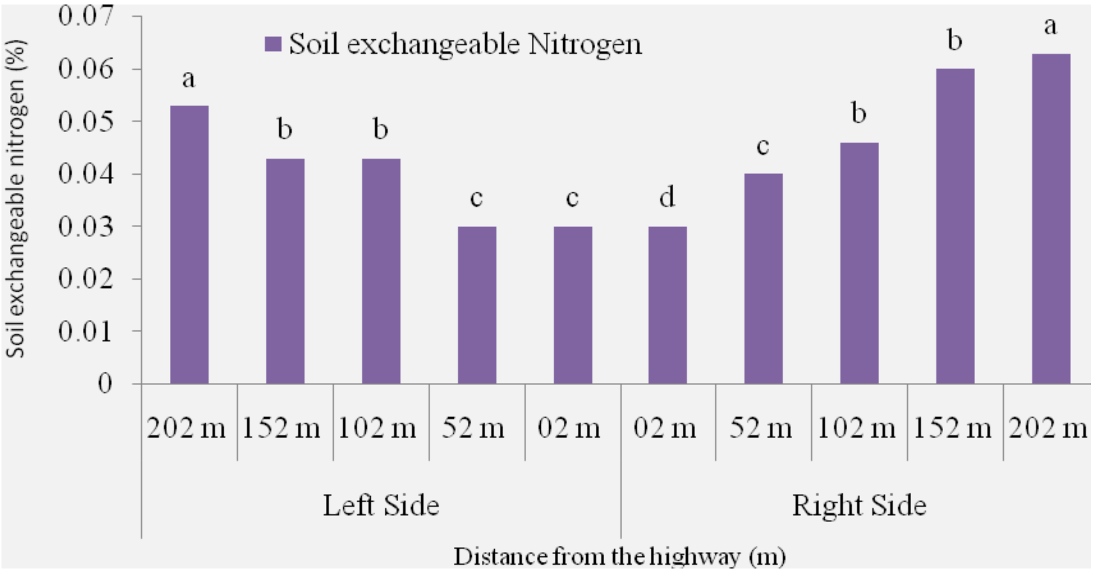

Figure - 5.6 Soil exchangeable nitrogen with respect to distance from the highway

5.2.5 Soil exchangeable phosphorous

Phosphorous tends to decrease with the decrease in distance from forest to Highway. Mean Soil Phosphorous (0.41 ppm) was found to be higher at 202m distance on left side of the road and lowest mean value (0.11 ppm) was found on left side from the road at 52 m distance. On left side Mean value of Phosphorous was significantly different at every distance from road to forest. No significant difference was found on right side at every distance except between 2m and 52m.

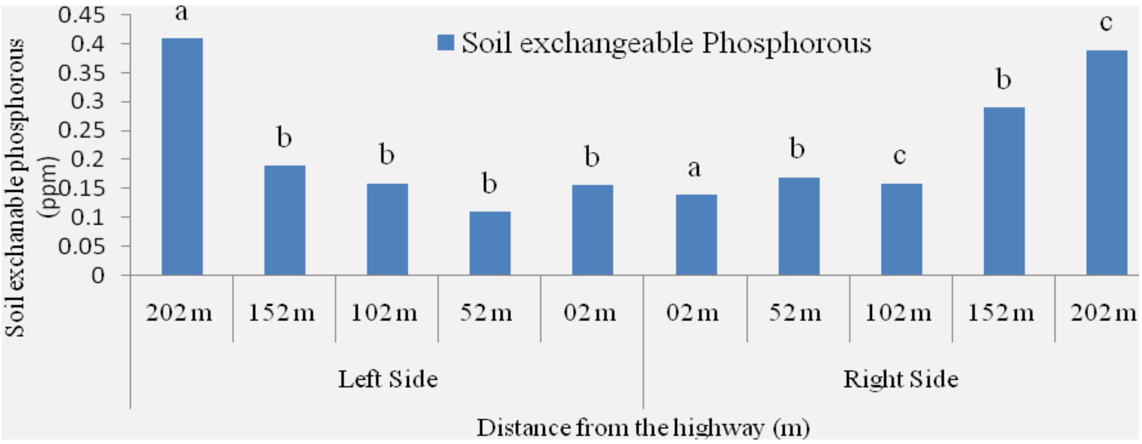

Figure - 5.7 Soil exchangeable phosphorous with respect to distance from the highway

5.2.6 Soil exchangeable potassium

On left side highest potassium (0.12 meq/100g) was found at 202 m distance and lowest value (0 meq /100g) was found at 2 m distance. Significant difference in potassium content was found at 202 m, 102m and 52m distances and no significant difference was found between 102 m and 152m and between 52m and 2 m distances.

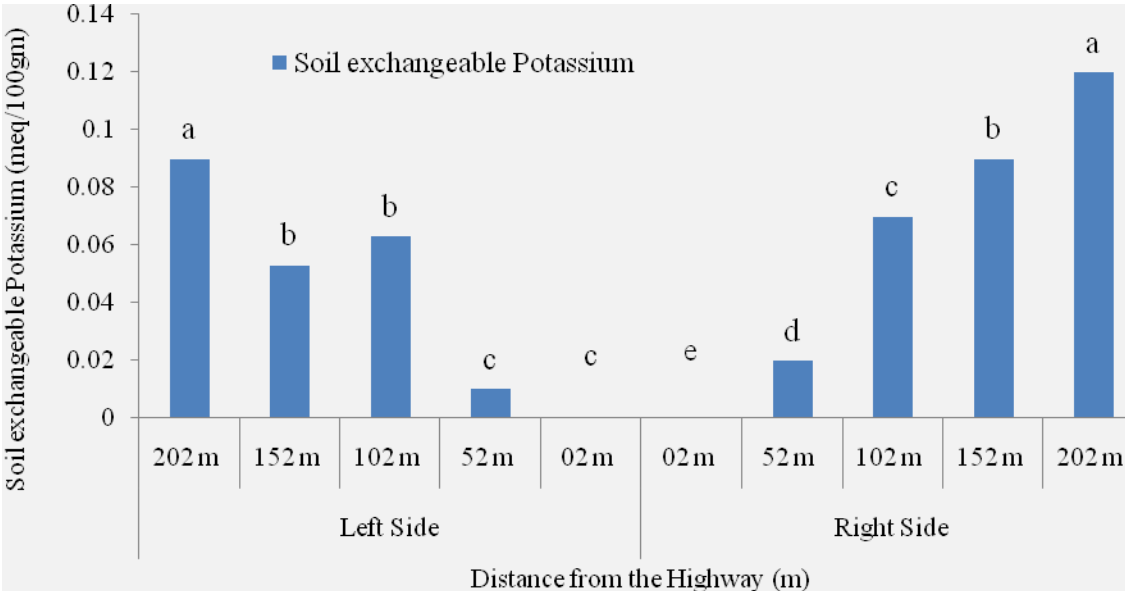

Figure - 5.8 Soil exchangeable potassium with respect to distance from the highway

5.3 Size class distribution of trees

5.3.1 Diameter class distribution

Natural and semi natural forests are structurally stable, maintaining an approximately logarithmic decline in numbers of tree with increasing size and this kind of size class distribution is the consequence of forest dynamics in which the available space constrains the number of trees that can be accommodated in any size (Swaine and Liberman, 1987). Highest percentage of diameter class was found in 20.01-25.00 cm (32.22) at 202 m distance from Dhaka Mymensingh Highway and lowest percentage of diameter class was found in ≤10.00 cm (0%).

The table indicates that if the distance increases from the road to the inside of the forest, trees with increasing height were found.

Table - 5.1 Percentage distributions of trees at different height classes

Height class (m)	Distance from the highway									
	Left side (m)					Right side (m)				
	202	152	102	52	2	2	52	102	152	202
≤5	4.78	11.43	30	26.87	37.31	38.38	39.9	27.65	6.39	0
5. 01-10.00	21.32	36.67	39.63	53.29	36.94	35.1	41.07	33.4	24.17	25.28
10.01-15.00	47.61	35.24	27.03	17.73	22.41	20.71	15.32	22.03	50	42.78
15.01≥	26.14	16.67	4.33	2.78	3.33	5.81	3.7	16.92	19.44	31.94

5.3.2 Vertical distribution of trees

Table – 5.2 revealed that maximum percentage of trees (53.29%) were found dbh ranges from 5.01 to 10.00 cm in 52 m away from the highway in left side and lower (0%) was found at the 202 m (≤5.00 cm) away from the highway in right side. The table indicates that trees with higher dbh were found if the distance increases from the road to the inside of the forest.

Table – 5.2 Percentage distributions of trees at different DBH classes

DBH class (cm)	Distance from the highway									
	Left side(m)					Right side(m)				
	202	152	102	52	2	2	52	102	152	202
≤10.00	4.79	11.43	23.33	26.87	30.28	32.32	31.67	17.42	4.17	0
10.01-15.00	11.95	14.76	22.41	24.39	29.07	26.51	25.74	22.98	15	14.72
15.01-20.00	19.12	21.91	25.74	24.65	22.41	17.68	19.63	22.73	23.47	19.31
20.01-25.00	31.05	24.76	15.93	14.95	11.2	14.65	10.37	14.14	25.56	32.22
25.01-30.00	21.32	15.24	9.81	9.14	7.04	8.84	9.81	14.14	19.03	19.03
30.00≥	11.77	11.91	2.78	0	0	0	2.78	8.59	12.78	14.72

5.3.3 Relationship between growth variables and soil nutrients

5.3.3.1.1 Linear relation of height growth with respect to soil organic matter

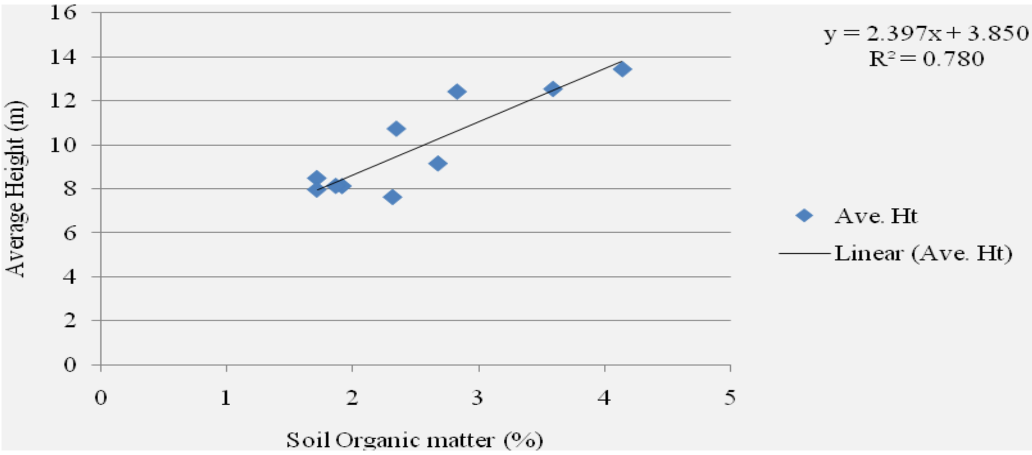

Figure - 5.9 Relations between soil organic matters with average height

Relation between soil organic matter and Average height was found positive (r = 0.88). In this case, regression equation is:

Average height (m) = 2.397 (Soil organic matter) + 3.850 [R^2 = 0.780]

From this regression equation it can be explained that for the addition of a single unit of soil organic matter, average height will be increased by 2.397 m. So, it can be said that with the increasing of soil organic matter, height also increasing proportionately. Average height were found positively correlated with soil organic matter and the value of regression coefficient is r = 0.88 depicts that there were strong correlation between soil organic matter and height of the trees.

5.3.3.1.2 Linear relation of height growth with respect to soil organic carbon

Relation between soil organic carbon and Average height was found positive (r = 0.92). In this case, regression equation is:

Average height (m) = 4.863(Soil organic carbon) + 2.827 [R^2 = 0.839]

From this regression equation it can be explained that for the addition of a single unit of soil organic carbon, average height will be increased by 4.863 m. So, it can be said that with the increasing of soil organic carbon, height also increasing proportionately.

Average height were found positively correlated with soil organic carbon and the value of regression coefficient is R = 0.92 depicts that there were strong correlation between Soil organic carbon and height of the trees.

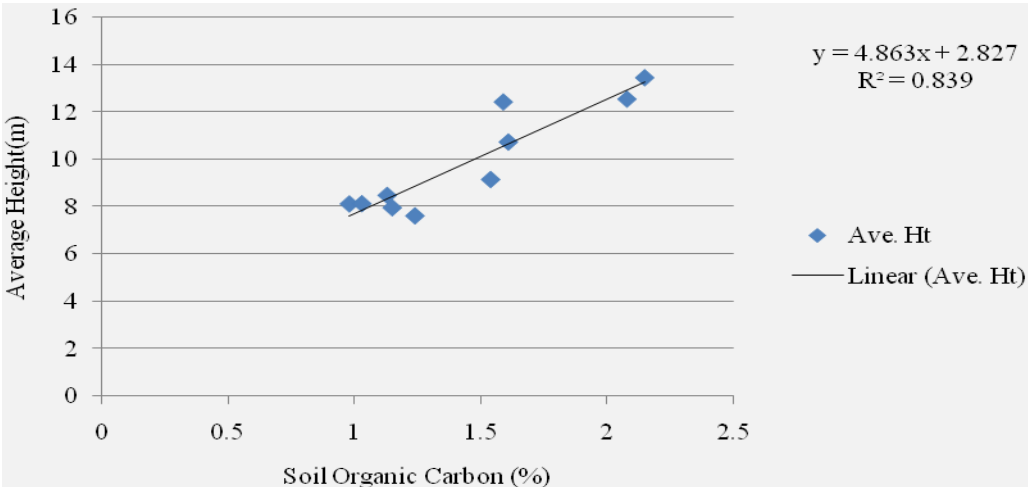

Figure - 5.10 Relations between soil organic carbon with average height

5.3.3.1.3 Linear relation of height growth with respect to soil exchangeable nitrogen

Relation between soil organic matter and Average height was found positive (r = 0.89). In this case, regression equation is:

Average height (m) = 165.4 (Soil exchangeable Nitrogen + 2.63 [R^2 = 0.806]

From this regression equation it can be explained that for the addition of a single unit of soil exchangeable Nitrogen, average height will be increased by 165.4 m. So, it can be said that with the increasing of soil exchangeable Nitrogen, height also increasing proportionately. Average height was found positively correlated with soil exchangeable Nitrogen and the value of regression coefficient is r = 0.89 depicts that there were strong correlation between Soil exchangeable Nitrogen and height of the trees.

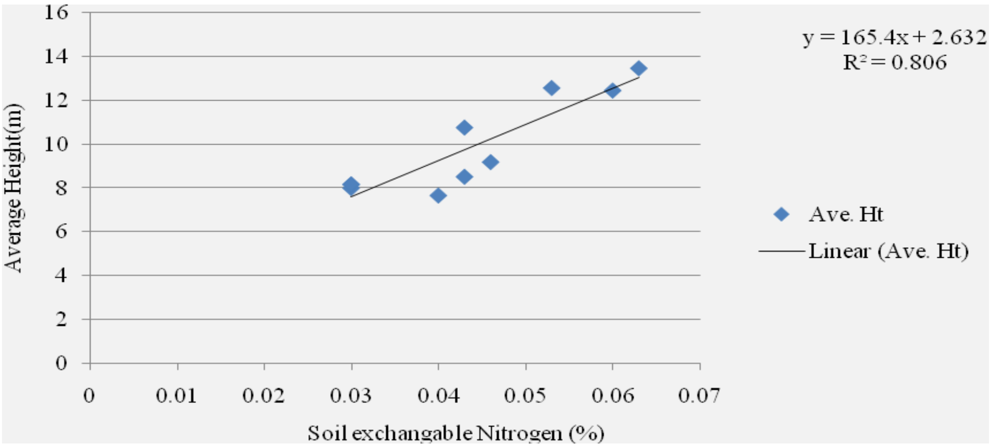

Figure - 5.11 Relations between soil exchangeable nitrogen with average height

5.3.3.1.4 Linear relation of height growth with respect to soil exchangeable phosphorous

Relation between soil exchangeable Phosphorous and Average height was found positive (r = 0.91). In this case, regression equation is:

Average height (m) = 19.01 (Soil exchangeable Phosphorous) + 5.74 [R^2 = 0.840]

From this regression equation it can be explained that for the addition of a single unit of soil exchangeable Phosphorous, average height will be increased by 19.01m. So, it can be said that with the increasing of soil exchangeable Phosphorous, height also increasing proportionately. Average height were found positively correlated with soil exchangeable Phosphorous and the value of regression coefficient is r = 0.91 depicts that there were strong correlation between soil exchangeable Phosphorous and height of the trees.

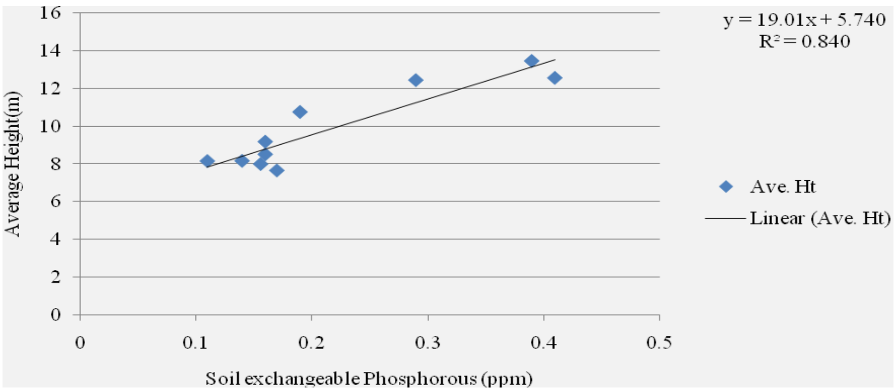

Figure-5.12 Relations between soil exchangeable Phosphorous with average height

5.3.3.1.5 Linear relation of height growth with respect to soil exchangeable potassium

Correlation between soil organic matter and Average height was found positive (r = 0.88). In this case, regression equation is:

Average height (m) = 46.37 (Soil exchangeable Potassium) + 7.48[R^2 = 0.782]

From this regression equation it can be explained that for the addition of a single unit of soil exchangeable Potassium, average height will be increased by 46.37m. So, it can be said that with the increasing of soil exchangeable Potassium, height also increasing proportionately. Average height were found positively correlated with soil exchangeable Potassium and the value of regression coefficient is r = 0.88 depicts that there were strong correlation between soil exchangeable Potassium and height of the trees.

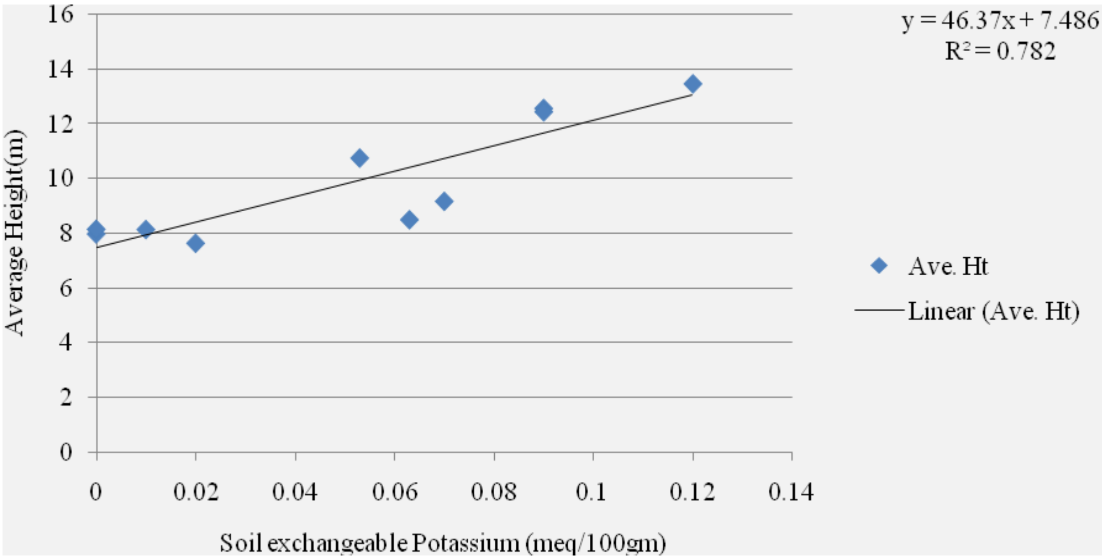

Figure - 5.13 Relations between exchangeable Potassium with average height

5.3.3.2 Linear relation of DBH growth

5.3.3.2.1 Linear relation of DBH growth with respect to soil organic carbon

Relation between soil organic matter and Average DBH was found positive (r = 0.93). In this case, regression equation is:

Average DBH (cm) = 7.14 (Soil organic carbon) + 7.86 [$R^2 = 0.874$]

From this regression equation it can be explained that for the addition of a single unit of soil organic carbon, average DBH will be increased by 7.14 cm. So, it can be said that with the increasing of soil organic carbon, DBH also increasing proportionately. Average DBH were found positively correlated with soil organic carbon and the value of regression coefficient is r = 0.92 depicts that there were strong correlation between soil organic carbon and DBH of the trees.

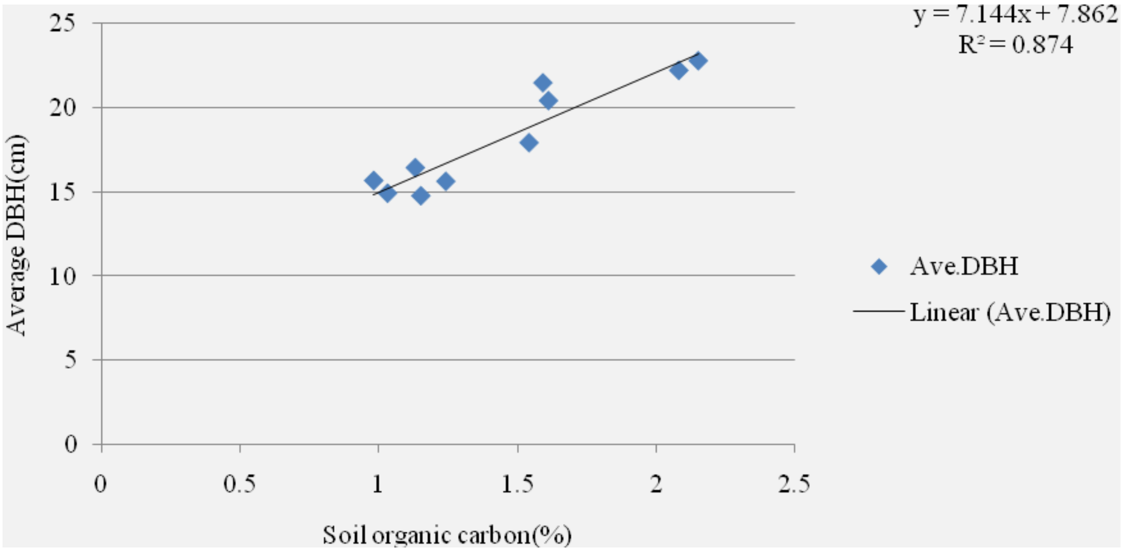

Figure - 5.14 Relations between soil organic carbon with average DBH

5.3.3.2.2 Linear relation of DBH growth with respect to soil organic matter

Correlation between soil organic matter and Average DBH was found positive (r = 0.93). In this case, regression equation is:

Average DBH (cm) = 3.43 (Soil organic matter) + 9.591 [$R^2 = 0.874$]

From this regression equation it can be explained that for the addition of a single unit of soil organic matter, average DBH will be increased by 3.43 cm. So, it can be said that with the increasing of soil organic matter, DBH also increasing proportionately. Average DBH were found positively correlated with soil organic matter and the value of regression coefficient is r = 0. 93 depicts that there were strong correlation between soil organic matter and DBH of the trees

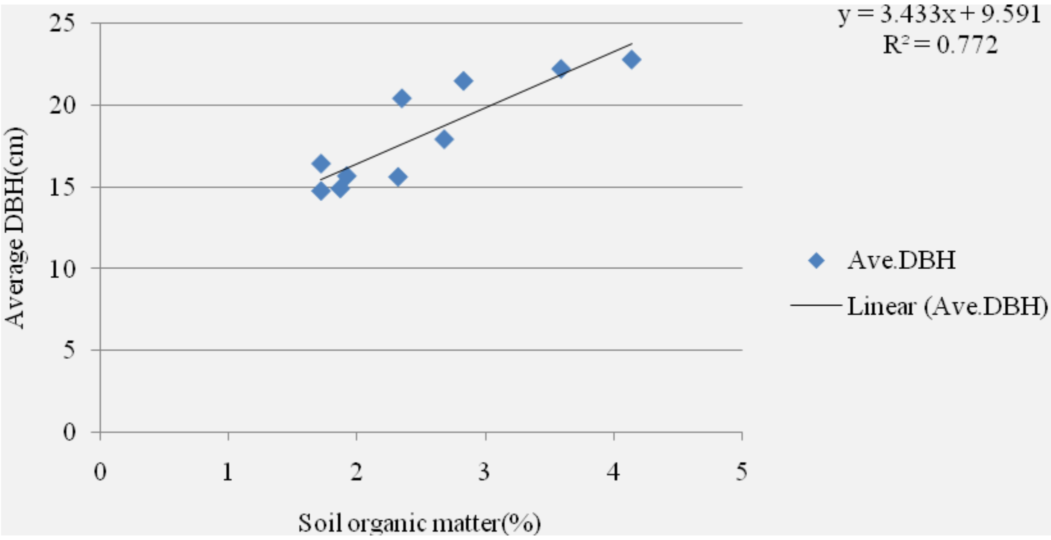

Figure - 5.15 Relations between soil organic matter with average DBH

5.3.3.2.3 Linear relation of DBH growth with respect to Soil exchangeable Nitrogen

Relation between soil exchangeable Nitrogen and DBH was found positive (r = 0.90). In this case, regression equation is:

Average DBH (cm) = 240.8 (Soil exchangeable Nitrogen + 7.675 [R^2 = 0.825]

From this regression equation it can be explained that for the addition of a single unit of soil exchangeable Nitrogen, average DBH will be increased by 240.8 cm. So, it can be said that with the increasing of soil exchangeable Nitrogen, DBH also increasing proportionately. Average DBH was found positively correlated with soil exchangeable Nitrogen and the value of regression coefficient is r = 0.90 depicts that there were strong correlation between soil exchangeable Nitrogen and DBH t of the trees

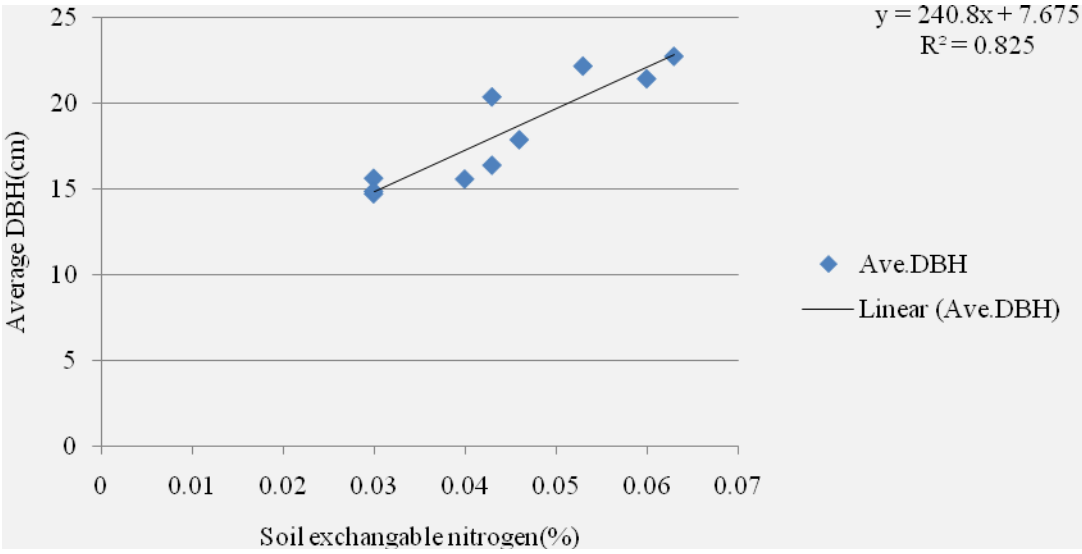

Figure - 5.16 Relations between soil exchangeable nitrogen with average DBH

5.3.3.2.4 Linear relation of DBH growth with respect to soil exchangeable nitrogen

Relation between soil organic matter and Average DBH was found positive (r = 0.88). In this case, regression equation is:

Average DBH (cm) = 26.51 (Soil exchangeable Phosphorous) + 12.47 [R^2 = 0.78]

From this regression equation it can be explained that for the addition of a single unit of soil organic matter, average DBH will be increased by 26.51 cm. So, it can be said that with the increasing of soil organic matter, DBH also increasing proportionately. Average DBH were found positively correlated with soil organic matter and the value of regression coefficient is r = 0.88 depicts that there were strong correlation between Soil exchangeable Phosphorous and DBH of the trees.

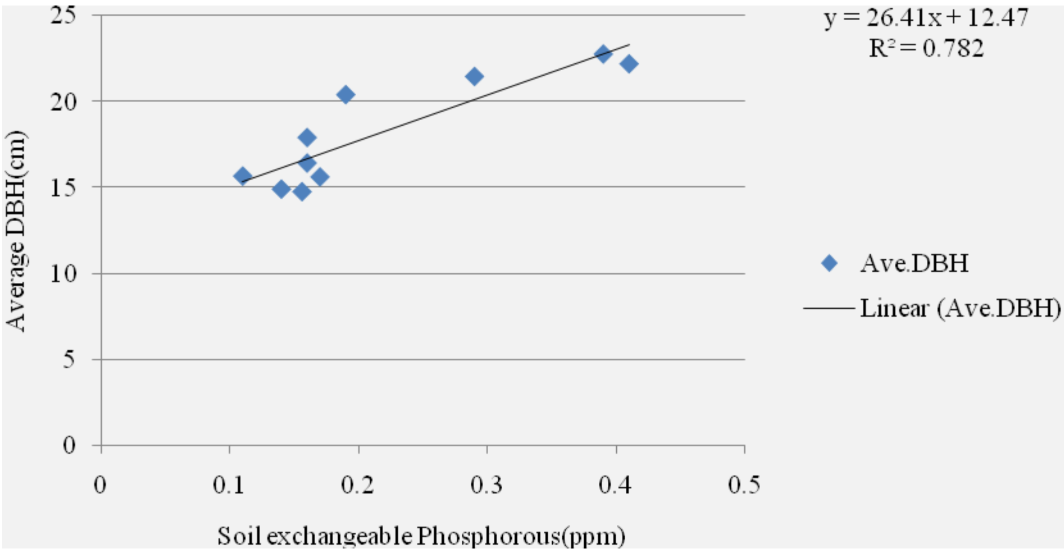

Figure - 5.17 Relations between soil exchangeable Phosphorous with average DBH

5.3.3.2.5 Linear relation of DBH growth with respect to soil exchangeable nitrogen

Relation between soil exchangeable Potassium and Average DBH was found positive (r = 0.90). In this case, regression equation is:

Average DBH (m) = 68.47 (Soil exchangeable Potassium) + 14.68 [R^2 = 0.824]

From this regression equation it can be explained that for the addition of a single unit of soil exchangeable Potassium, average DBH will be increased by 68.47 cm. So, it can be said that with the increasing of soil exchangeable Potassium, DBH also increasing proportionately. Average DBH was found positively correlated with soil exchangeable Potassium and the value of regression coefficient is r = 0.90 depicts that there were strong correlation between Soil exchangeable Potassium and DBH of the trees.

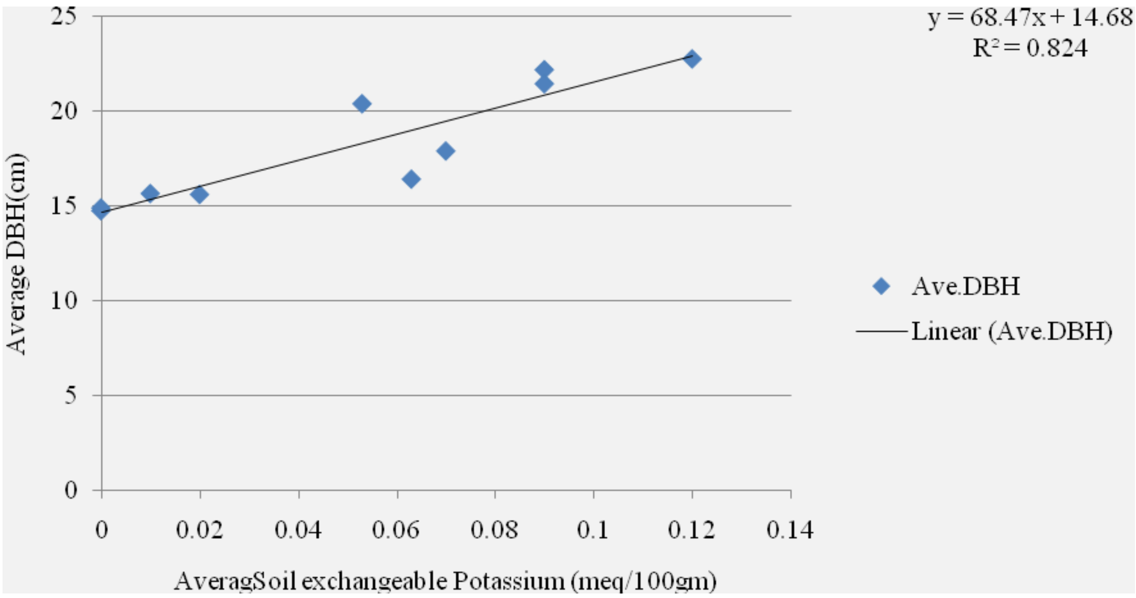

Figure - 5.18 Relations between soil exchangeable potassium with average DBH

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

Conclusion

The study showed the existing scenario (physio-chemical properties of soil) of the Bhawal sal forest due to the construction of Dhaka Mymensingh Highway where soil moisture content, soil pH, soil organic carbon, soil organic matter, soil exchangeable nitrogen, soil exchangeable phosphorous, soil exchangeable potassium were found to decrease with the decrease in distance from the forest to the highway and soil bulk density increased with the decrease in distance from the forest to the highway. Relationship between tree growth variables of sal forest and chemical properties were found positive and they were strongly correlated with respect to each other. Again it was observed that if the distance increases from the road to the inside of the forest, trees with increasing height and DBH were found. The Sal forest is under tremendous human interference from all sides and day by day this problem is becoming acute. About 65% of the Sal forest area is highly degraded and has been encroached. So for the betterment of the degraded area it should recover the encroached forest land and put it under enrichment plantation with the dominant species of Sal forest area. So the authority should have take action to reduce the open access of local people into the forest area.

Recommendations:

1. The most critical problems were the noise and vibration caused by the vehicles operating on the road which have serious bad effect on forest soil quality and interrupt tree growth. So, heavy weight vehicles like lorry, truck, and covered van should be operating in specific rule.
2. Organic materials will decay and reduce the stability of the road. On the other hand compost or organic material is an important component affecting soil fertility. These organic materials were removed due to free movement of local people on the road. Free movement of local people need to be prohibited.
3. Conduct road location reviews before all new construction further expansion and road relocations. Assure the location needs public and agency needs while mitigating environmental impacts upon the forest including land degradation and pollution and land cover changes.
4. Decommission by restoring the road to the original contour when the forest plan mitigating visual impacts or when necessary to assure the elimination vehicular traffic

5. Land use impacts should be considered in transportation planning, including impacts of transportation decisions affect land development patterns.
6. Coordinate reconstruction and construction work between roads and highway and forest department and other agencies to find out economic feasibilities, environmental impacts and effects upon adjacent vegetation and wild life.
7. With the increasing traffic volume and growing congestion, the overall environmental quality for tree growth in the built up high way areas would deteriorate. Thus proper initiatives should be taken by the negotiation between Forest and Roads and High way department.

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APPENDICES

APPENDICES

Appendix: Duncan test and one way anova for Soil moisture content

a. Soil moisture content (left side) Descriptive

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
202	3	10.8800	.12000	.06928	10.5819	11.1781	10.76	11.00
152	3	8.5700	.26000	.15011	7.9241	9.2159	8.31	8.83
102	3	8.0800	.12000	.06928	7.7819	8.3781	7.96	8.20
52	3	8.4800	.10000	.05774	8.2316	8.7284	8.38	8.58
2	3	6.1200	.12000	.06928	5.8219	6.4181	6.00	6.24
Total	15	8.4260	1.57414	.40644	7.5543	9.2977	6.00	11.00

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	34.449	4	8.612	356.471	.000
Within Groups	.242	10	.024		
Total	34.691	14			

Duncan

VAR00002	N	Subset for alpha = .05			
		1	2	3	4
2	3	6.1200			
102	3		8.0800		
52	3			8.4800	
152	3			8.5700	
202	3				10.8800
Sig.		1.000	1.000	.494	1.000

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 3.000.

b. Soil moisture content (right side) Descriptive

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
202	3	12.6500	.22000	.12702	12.1035	13.1965	12.43	12.87
152	3	10.6600	.14000	.08083	10.3122	11.0078	10.52	10.80
102	3	11.0800	.06000	.03464	10.9310	11.2290	11.02	11.14
52	3	6.8333	.15275	.08819	6.4539	7.2128	6.70	7.00
2	3	5.8700	.12000	.06928	5.5719	6.1681	5.75	5.99
Total	15	9.4187	2.70287	.69788	7.9219	10.9155	5.75	12.87

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	102.058	4	25.515	1166.825	.000
Within Groups	.219	10	.022		
Total	102.277	14			

Duncan

VAR00002	N	Subset for alpha = .05				
		1	2	3	4	5
2	3	5.8700				
52	3		6.8333			
152	3			10.6600		
102	3				11.0800	
202	3					12.6500
Sig.		1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 3.000.

Appendix 2: Duncan test and one way anova for Soil bulk density

a. Soil bulk density (left side) Descriptive

VAR00001	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
202	3	1.1800	.02000	.01155	1.1303	1.2297	1.16	1.20
152	3	1.3800	.10000	.05774	1.1316	1.6284	1.28	1.48
102	3	1.5700	.06000	.03464	1.4210	1.7190	1.51	1.63
52	3	1.4800	.05000	.02887	1.3558	1.6042	1.43	1.53
2	3	1.8600	.08000	.04619	1.6613	2.0587	1.78	1.94
Total	**15**	**1.4940**	**.23910**	**.06174**	**1.3616**	**1.6264**	**1.16**	**1.94**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.755	4	.189	41.188	.000
Within Groups	.046	10	.005		
Total	.800	14			

Duncan

VAR00002	N	Subset for alpha = .05			
		1	2	3	4
202	3	1.1800			
152	3		1.3800		
52	3		1.4800	1.4800	
102	3			1.5700	
2	3				1.8600
Sig.		1.000	.100	.134	1.000

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 3.000.

b. Soil bulk density (right side) Descriptive

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
202	3	1.1700	.07000	.04041	.9961	1.3439	1.10	1.24
152	3	1.2800	.08000	.04619	1.0813	1.4787	1.20	1.36
102	3	1.2700	.07000	.04041	1.0961	1.4439	1.20	1.34
52	3	1.3700	.07000	.04041	1.1961	1.5439	1.30	1.44
2	3	1.9400	.08000	.04619	1.7413	2.1387	1.86	2.02
Total	15	1.4060	.29088	.07511	1.2449	1.5671	1.10	2.02

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.130	4	.282	51.344	.000
Within Groups	.055	10	.006		
Total	1.185	14			

Duncan

VAR00002	N	Subset for alpha = .05		
		1	2	3
202	3	1.1700		
102	3	1.2700	1.2700	
152	3	1.2800	1.2800	
52	3		1.3700	
2	3			1.9400
Sig.		.113	.146	1.000

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 3.000.

Appendix: 3 Duncan test and one way anova for Soil pH

a. Soil pH (left side) Descriptives

VAR00001	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
202	3	5.4000	.10000	.05774	5.1516	5.6484	5.30	5.50
152	3	5.0000	.10000	.05774	4.7516	5.2484	4.90	5.10
102	3	4.8000	.10000	.05774	4.5516	5.0484	4.70	4.90
52	3	4.7000	.10000	.05774	4.4516	4.9484	4.60	4.80
2	3	4.3000	.10000	.05774	4.0516	4.5484	4.20	4.40
Total	15	4.8400	.38322	.09895	4.6278	5.0522	4.20	5.50

ANOVA

VAR00001	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.956	4	.489	48.900	.000
Within Groups	.100	10	.010		
Total	2.056	14			

Duncan

VAR00002	N	Subset for alpha = .05			
		1	2	3	4
2	3	4.3000			
52	3		4.7000		
102	3		4.8000		
152	3			5.0000	
202	3				5.4000
Sig.		1.000	.249	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 3.000.

b. Soil pH (right side) Descriptive

VAR00001	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
202	3	5.3000	.10000	.05774	5.0516	5.5484	5.20	5.40
152	3	5.1000	.10000	.05774	4.8516	5.3484	5.00	5.20
102	3	5.0000	.10000	.05774	4.7516	5.2484	4.90	5.10
52	3	4.9333	.15275	.08819	4.5539	5.3128	4.80	5.10
2	3	4.4000	.10000	.05774	4.1516	4.6484	4.30	4.50
Total	15	4.9467	.32484	.08387	4.7668	5.1266	4.30	5.40

ANOVA

VAR00001	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.351	4	.338	26.658	.000
Within Groups	.127	10	.013		
Total	1.477	14			

Duncan

VAR00002	N	Subset for alpha = .05		
		1	2	3
2	3	4.4000		
52	3		4.9333	
102	3		5.0000	
152	3		5.1000	5.1000
202	3			5.3000
Sig.		1.000	.114	.055

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 3.000.

Appendix 4: Duncan test and one way anova for Soil organic carbon

a. Soil organic carbon (left side) Descriptive

VAR00001	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
202	3	2.0867	.00577	.00333	2.0723	2.1010	2.08	2.09
152	3	1.6100	.41569	.24000	.5774	2.6426	1.37	2.09
102	3	1.1367	.19502	.11260	.6522	1.6211	1.00	1.36
52	3	.9800	.12767	.07371	.6628	1.2972	.87	1.12
2	3	1.1533	.18583	.10729	.6917	1.6150	1.00	1.36
Total	15	1.3933	.46209	.11931	1.1374	1.6492	0.87	2.09

ANOVA

VAR00001	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.466	4	.616	11.778	.001
Within Groups	.523	10	.052		
Total	2.989	14			

Duncan

VAR00002	N	Subset for alpha = .05		
		1	2	3
52	3	.9800		
102	3	1.1367		
2	3	1.1533		
152	3		1.6100	
202	3			2.0867
Sig.		.397	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 3.000.

b. Soil organic carbon (Right side) Descriptives Descriptives

VAR00001	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
202	3	2.1533	.47962	.27691	.9619	3.3448	1.60	2.45
152	3	1.5933	.10408	.06009	1.3348	1.8519	1.51	1.71
102	3	1.5400	.13454	.07767	1.2058	1.8742	1.39	1.65
52	3	1.2400	.15716	.09074	.8496	1.6304	1.06	1.35
2	3	1.0367	.11930	.06888	.7403	1.3330	.90	1.12
Total	15	1.5127	.44334	.11447	1.2672	1.7582	.90	2.45

ANOVA

VAR00001	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.156	4	.539	9.046	.002
Within Groups	.596	10	.060		
Total	2.752	14			

Duncan

VAR00001	N	Subset for alpha = .05		
		1	2	3
2	3	1.0367		
52	3	1.2400	1.2400	
102	3		1.5400	
152	3		1.5933	
202	3			2.1533
Sig.		.332	.121	1.000

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 3.000.

Appendix 5: Duncan test and one way anova for soil organic matter

a. Soil organic matter (left side) Descriptive

VAR00001	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
202	3	3.5900	.01000	.00577	3.5652	3.6148	3.58	3.60
152	3	2.3500	.01000	.00577	2.3252	2.3748	2.34	2.36
102	3	1.7200	.08000	.04619	1.5213	1.9187	1.64	1.80
52	3	1.9200	.42000	.24249	.8767	2.9633	1.50	2.34
2	3	1.7200	.18000	.10392	1.2729	2.1671	1.54	1.90
Total	15	2.2600	.74920	.19344	1.8451	2.6749	1.50	3.60

ANOVA

VAR00001	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.427	4	1.857	43.102	.000
Within Groups	.431	10	.043		
Total	7.858	14			

Duncan

VAR00002	N	Subset for alpha = .05		
		1	2	3
102	3	1.7200		
2	3	1.7200		
52	3	1.9200		
152	3		2.3500	
202	3			3.5900
Sig.		.286	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 3.000.

b. Soil organic matter (right side) Descriptive

VAR00001	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
202	3	4.1400	.08000	.04619	3.9413	4.3387	4.06	4.22
152	3	2.6800	.08000	.04619	2.4813	2.8787	2.60	2.76
102	3	2.8300	.11000	.06351	2.5567	3.1033	2.72	2.94
52	3	2.3200	.07000	.04041	2.1461	2.4939	2.25	2.39
2	3	1.8700	.05000	.02887	1.7458	1.9942	1.82	1.92
Total	15	2.7680	.79137	.20433	2.3298	3.2062	1.82	4.22

ANOVA

VAR00001	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.703	4	2.176	336.813	.000
Within Groups	.065	10	.006		
Total	8.768	14			

Duncan

VAR00002	N	Subset for alpha = .05				
		1	2	3	4	5
2	3	1.8700				
52	3		2.3200			
152	3			2.6800		
102	3				2.8300	
202	3					4.1400
Sig.		1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 3.000.

Appendix 6: Duncan test and one way anova for Soil exchangeable Nitrogen
a. Soil exchangeable Nitrogen (Left side) Descriptive

VAR00001	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
202	3	.0533	.00577	.00333	.0390	.0677	.05	.06
152	3	.0433	.00577	.00333	.0290	.0577	.04	.05
102	3	.0433	.00577	.00333	.0290	.0577	.04	.05
52	3	.0300	.00000	.00000	.0300	.0300	.03	.03
2	3	.0300	.00000	.00000	.0300	.0300	.03	.03
Total	15	.0400	.01000	.00258	.0345	.0455	.03	.06

ANOVA

VAR00001	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.001	4	.000	15.000	.000
Within Groups	.000	10	.000		
Total	.001	14			

Duncan

VAR00002	N	Subset for alpha = .05		
		1	2	3
52	3	.0300		
2	3	.0300		
152	3		.0433	
102	3		.0433	
202	3			.0533
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 3.000.

b. Soil exchangeable Nitrogen (Right side) Descriptive

VAR00001	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
202	3	.0633	.00577	.00333	.0490	.0777	.06	.07
152	3	.0600	.00000	.00000	.0600	.0600	.06	.06
102	3	.0467	.00577	.00333	.0323	.0610	.04	.05
52	3	.0400	.00000	.00000	.0400	.0400	.04	.04
2	3	.0300	.00000	.00000	.0300	.0300	.03	.03
Total	15	.0480	.01320	.00341	.0407	.0553	.03	.07

ANOVA

VAR00001	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.002	4	.001	43.250	.000
Within Groups	.000	10	.000		
Total	.002	14			

Duncan

VAR00002	N	Subset for alpha = .05			
		1	2	3	4
2	3	.0300			
52	3		.0400		
102	3			.0467	
152	3				.0600
202	3				.0633
Sig.		1.000	1.000	1.000	.290

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 3.000.

Appendix 7: Duncan test and one way anova for Soil exchangeable Potassium
a. Soil exchangeable Potassium (left side) Descriptive

VAR00001	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
202	3	.0900	.01000	.00577	.0652	.1148	.08	.10
152	3	.0533	.00577	.00333	.0390	.0677	.05	.06
102	3	.0633	.00577	.00333	.0490	.0777	.06	.07
52	3	.0100	.01000	.00577	-.0148	.0348	.00	.02
2	3	.0000	.00000	.00000	.0000	.0000	.00	.00
Total	15	.0433	.03539	.00914	.0237	.0629	.00	.10

ANOVA

VAR00001	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.017	4	.004	79.688	.000
Within Groups	.001	10	.000		
Total	.018	14			

Duncan

VAR00002	N	Subset for alpha = .05		
		1	2	3
2	3	.0000		
52	3	.0100		
152	3		.0533	
102	3		.0633	
202	3			.0900
Sig.		.124	.124	1.000

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 3.000.

b. Soil exchangeable Potassium (right side) Descriptive

VAR0 0001	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
202	3	.1200	.01000	.00577	.0952	.1448	.11	.13
152	3	.0900	.00000	.00000	.0900	.0900	.09	.09
102	3	.0700	.01000	.00577	.0452	.0948	.06	.08
52	3	.0200	.00000	.00000	.0200	.0200	.02	.02
2	3	.0000	.00000	.00000	.0000	.0000	.00	.00
Total	15	.0600	.04614	.01191	.0345	.0855	.00	.13

ANOVA

VAR00001	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.029	4	.007	183.750	.000
Within Groups	.000	10	.000		
Total	.030	14			

Duncan

VAR00002	N	Subset for alpha = .05				
		1	2	3	4	5
2	3	.0000				
52	3		.0200			
102	3			.0700		
152	3				.0900	
202	3					.1200
Sig.		1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

Uses Harmonic Mean Sample Size = 3.000.

Appendix 8 Duncan test and one way anova for Soil exchangeable Phosphorus

a. Soil exchangeable Phosphorus (left side) Descriptive

VAR00001	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
202	3	.4100	.09000	.05196	.1864	.6336	.32	.50
152	3	.1967	.10263	.05925	-.0583	.4516	.11	.31
102	3	.1600	.01000	.00577	.1352	.1848	.15	.17
52	3	.1100	.02000	.01155	.0603	.1597	.09	.13
2	3	.1567	.02517	.01453	.0942	.2192	.13	.18
Total	15	.2067	.12128	.03132	.1395	.2738	.09	.50

ANOVA

VAR00001	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.166	4	.042	10.523	.001
Within Groups	.040	10	.004		
Total	.206	14			

Duncan

VAR00002	N	Subset for alpha = .05	
		1	2
52	3	.1100	
2	3	.1567	
102	3	.1600	
152	3	.1967	
202	3		.4100
Sig.		.146	1.000

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 3.000.

b. Soil exchangeable Phosphorus(right side) Descriptives

VAR00001					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
202	3	.3900	.04000	.02309	.2906	.4894	.35	.43
152	3	.2900	.03000	.01732	.2155	.3645	.26	.32
102	3	.1633	.02517	.01453	.1008	.2258	.14	.19
52	3	.1700	.04000	.02309	.0706	.2694	.13	.21
02	3	.1400	.03000	.01732	.0655	.2145	.11	.17
Total	15	.2307	.10257	.02648	.1739	.2875	.11	.43

ANOVA

VAR00001	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.136	4	.034	30.183	.000
Within Groups	.011	10	.001		
Total	.147	14			

Duncan

VAR00002	N	Subset for alpha = .05		
		1	2	3
02	3	.1400		
102	3	.1633		
52	3	.1700		
152	3		.2900	
202	3			.3900
Sig.		.321	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 3.000.

Appendix 9: Pictorial representation

1. Lower growth, the most significant criteria of road side plots

2.vehicle frequency that has an adverse effects upon plants

3. Dust particles besides the road

4. Natural regeneration of Sal

5. Leaf sedimentation due to vehicle passing

6. Illegal removal of trees beside road

7. Compacted soil

8. Low growth and soil erosion

9. Litter collection from the sal forest

10. Expanding agricultural land

11. Forest fragmentation and opening up

12. Plot inside the forest