IMPACT OF CANE PLANTATION ON THE REGENERATION OF SAL (*Shorea robusta*) FOREST: A CASE STUDY OF DINAJPUR SAL FOREST

A THESIS

BY

JANNATUL FERDOUS JANNAT
Registration No. 1805340
Session: 2018
Semester: July-December, 2019

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

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

DECEMBER, 2019

IMPACT OF CANE PLANTATION ON THE REGENERATION OF SAL (*Shorea robusta*) FOREST: A CASE STUDY OF DINAJPUR SAL FOREST

A THESIS

BY

JANNATUL FERDOUS JANNAT
Registration No. 1805340
Session: 2018
Semester: July-December, 2019

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

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

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

DECEMBER, 2019

IMPACT OF CANE PLANTATION ON THE REGENERATION OF SAL (*Shorea robusta*) FOREST: A CASE STUDY OF DINAJPUR SAL FOREST

A THESIS

BY

JANNATUL FERDOUS JANNAT
Registration No. 1805340
Session: 2018
Semester: July-December, 2019

Approved as to style and contents by

_____	_____
Professor Dr. Md. Shoaibur Rahman	**Professor Dr. Md. Shafiqul Bari**
Supervisor	Co-supervisor

_____
(Professor Dr. Md. Shoaibur Rahman)
Chairman of Examination Committee
and
Chairman
Department of Agroforestry and Environment
Hajee Mohammad Danesh Science and Technology University, Dinajpur.

December 2019

Dedicated

to

My Beloved Parents

and

Honorable Teachers

ACKNOWLEDGEMENT

First of all, the authoress expresses her gratitude to the greatness of Almighty Allah for her blessings to enable the author to complete this research work successfully.

The authoress expresses her sincere gratitude, heartfelt respect and immense indebtedness to her reverend supervisor, ***Prof. Dr. Md. Shoaibur Rahman****, Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his scholastic guidance, valuable suggestions, kind help and providing necessary assistance with logistic support and constant encouragement throughout the period of research work and preparation of this thesis.*

The authoress wishes to extend her deepest gratitude and sincere appreciation to her Co-supervisor, ***Prof. Dr. Md. Shafiqul Bari*** *Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his constant counseling, valuable guidance, constructive suggestions and encouragement in the course of this investigation and in preparation of this dissertation.*

Great appreciation, thanks and gratitude are also extended to the Chairman and all the teachers of the Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur for providing the research facilities, valuable advice and encouragement to conduct the experiments and thesis preparation.

The authoress is also thankful to all the staffs of Department of Agroforestry and Environment, HSTU, Dinajpur and agroforestry field worker Md. Abdul Quddus for their co-operation throughout the course of this study and research work.

Finally, the authoress expresses her sincere gratitude to her beloved parents, brother, sisters, friends, well-wishers, roommates and relatives for their inspiration and cooperation throughout the period of her study.

December, 2019 *The Authoress*

IMPACT OF CANE PLANTATION ON THE REGENERATION OF SAL (*Shorea robusta*) FOREST: A CASE STUDY OF DINAJPUR SAL FOREST

ABSTRACT

Sal (*Shorea robusta*) is an important timber species which is found in the natural Sal forest of Bangladesh. The tropical moist deciduous Sal forest ecosystem of Dinajpur 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. In recent years the problem has assumed serious magnitudes. To protect Sal forest, cane plantation was done in 20 ha. area during 2013-2014 session in Nawabganj Sal forest and also done in some areas of the Singra Sal forest under the management of forest department. Though the program seemed to be successful, but it was not suitable for natural regeneration of Sal tree due to the bushy nature of cane plantation. The present study was an attempt to identify the current status of cane plantation in the Sal forest of Dinajpur and to explore the impact of cane plantation on the regeneration of Sal forest. The study was conducted in the Sal forest of Dinajpur district at two different locations namely Birganj and Nawabganj upazila during September 2018 to November 2019. Ten quadrates were selected randomly inside each Sal forest for this study. Five quadrates were Sal with cane species and five quadrates were only Sal species without cane species. Altogether twenty quadrates were selected in two Sal forest. The size of each quadrate was 20m×20m. Number of big Sal trees greater than 3 feet height, number of Sal seedlings below 3 feet height, number of Sal coppice seedlings below 3 feet height, number of Cane bush, number of germinated seedlings of Sal, number of Sal seeds per sq. m, height of Sal trees, diameter at breast height (DBH) of Sal trees, weight of leaf litter per sq. m etc. were measured from the sample plots (20m×20m). The overall results of the study revealed that all the parameters decreased due to cane plantation in the natural Sal forest which was responsible for poor regeneration of Sal seeds for the bushy structure of cane. Such as the average number of Sal trees (2022 and 1240) and average volume of Sal trees (40882 cft and 36351 cft) found per ha in only Sal and Sal with cane plantation in Dinajpur Sal forest. For better management of Sal forest cane plantation at the floor of forest should be restricted immediately.

CONTENTS

CHAPTER	TITLE	PAGE NO.
	ACKNOWLEDGEMENT	**i**
	ABSTRACT	**ii**
	CONTENTS	**iii**
	LIST OF FIGURES	**vi**
	LIST OF APPENDICES	**vii**
ONE	**INTRODUCTION**	**1-3**
1.1	General overview	1
1.2	Objectives of the study	3
TWO	**LITERATURE REVIEW**	**4-17**
2.1	General Review of Sal Forest	4
2.2	Categories of Sal Forest	5
2.3	Regeneration	6
2.4	Types of Regeneration	6
2.4.1	Natural Regeneration	6
2.4.2	Artificial Regeneration	7
2.5	Natural regeneration of Sal	7
2.6	Natural regeneration of Sal with cane plantation	8
2.7	Artificial regeneration of Sal	9
2.8	Anthropogenic threats	10
2.8.1	Over-exploitation	10
2.8.2	Illegal cutting	11
2.8.3	Encroachment	11
2.8.4	Poaching	11
2.8.5	Urbanization	12
2.8.6	Plantations	12
2.8.7	Pollution	13
2.8.8	Grazing	13
2.8.9	Management failure	13
2.9	Natural threats	14
2.9.1	Pests and diseases	14
2.10	Present management system and its problem	14

CONTENTS (Contd.)

CHAPTER	TITLE	PAGE NO.
2.11	Conservation and sustainable forest management for Sal forest ecosystem	15
2.12	Implications for conservation and protection of Sal forest	16
THREE	**MATERIALS AND METDODS**	**18-22**
3.1	Collection of literature	18
3.2	Study area	18
3.2.1	Singra Sal Forest Birganj	19
3.2.2	Nawabganj Sal Forest	19
3.3	Study design	20
3.4	Equipments Used in the Field Study	21
3.5	Time of data collection	22
3.6	Laboratory Methods	22
3.7	Data processing and analysis	22
FOUR	**RESULTS AND DISCUSSION**	**23-35**
4.1	Total number of Sal trees of Singra Sal forest in Birganj	23
4.1.1	Number of Sal trees greater than 3 feet height	23
4.1.2	Number of Sal seedlings less than 3 feet height	24
4.1.3	Number of Sal coppice seedlings less than 3 feet height	24
4.2	Number of Sal seeds found per sq. m in Singra Sal forest	25
4.3	Weight (g) of leaf litter per sq. m in Singra Sal forest	26
4.4	Number of cane bush in Singra Sal forest	27
4.5	Number of germinated Sal seedlings in Singra Sal forest	28
4.6	Total number of Sal trees of Nawabganj Sal forest	29
4.6.1	Number of Sal trees greater than 3 feet height	29
4.6.2	Number of Sal seedlings less than 3 feet height	29
4.6.3	Number of Sal coppice seedlings less than 3 feet height	30
4.7	Number of Sal seeds found per sq. m in Nawabganj Sal forest	31
4.8	Weight (g) of leaf litter per sq. m in Nawabganj Sal forest	32
4.9	Number of cane bush in Nawabganj Sal forest	32

CONTENTS (Contd.)

CHAPTER	TITLE	PAGE NO.
4.10	Number of germinated Sal Seedlings in Nawabganj Sal forest	33
4.11	Average number of Sal trees per ha.	34
4.12	Average volume (cft) of Sal tree per ha.	35
FIVE	**CONCLUSION AND RECOMMENDATIONS**	**36-37**
5.1	Conclusion	36
5.2	Recommendations	36
	REFERENCES	**38-42**
	APPENDICES	**43-51**

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE NO.
2.1	Natural regeneration of Sal forest.	8
2.2	Natural regeneration of Sal forest with cane plantation.	9
2.3	Artificial regeneration of Sal	10
3.1	GIS map of study area	20
3.2	Equipments used in the field study	21
4.1	Number of Sal trees greater than 3 feet height	23
4.2	Number of Sal seedlings less than 3 feet height	24
4.3	Number of Sal coppice seedlings less than 3 feet height	25
4.4	Number of Sal seeds found per sq. m	26
4.5	Weight (g) of leaf litter per sq. m	27
4.6	Number of cane bush in different quadrates of Birganj Sal forest	27
4.7	Number of germinated Sal Seedlings	28
4.8	Number of Sal trees greater than 3 feet height	29
4.9	Number of Sal seedlings less than 3 feet height	30
4.10	Number of Sal coppice seedlings less than 3 feet height	31
4.11	Number of Sal seeds found per sq. m	31
4.12	Weight (g) of leaf litter per sq. m	32
4.13	Number of cane bush	33
4.14	Number of germinated Sal Seedlings	34
4.15	Average number of Sal trees per ha	34
4.16	Average volume (cft) of Sal tree per ha	35

LIST OF APPENDICES

APPENDIX NO.	TITLE	PAGE NO.
I	Dinajpur Sal forest	43-47
II	A Field Observation Sheet	48
III	Some Plates of the Research	49-51

CHAPTER ONE

INTRODUCTION

1.1 General overview

Bangladesh is a tropical country. It is a rural-based developing country that lies in the northeastern part of South Asia between 20°34′ and 26°38′ North latitude and 88°01′ and 92°41′ 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 (Abedin, 2019). The percentage of forest cover in relation to total land area is 10.2%; forest plantations were 625,000 ha in 2000 (FAO 2005). The area of forestland is 2.53 million ha which is 17.5% of the country's total area. Bangladesh Forest Department (BFD) manages 1.53 million hectares of forestland (Roy 2004). The natural forests of Bangladesh are considered as one of the richest and biologically diverse forest resources due to its unique geo-physical location (Hossain 2001). On the basis of geographical location, climate, topography, and management principles, the forests of Bangladesh can broadly be classified into Hill forests, Unclassed State Forests (USF), Plain land deciduous Sal forests, Mangrove forests, Coastal forests and Homegardens (Khan 2003, GOB 2007, FAO 1998, Rahman 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 (Abedin, 2019).

Sal forests are distributed mainly in South and Southeast Asia, occurring along the base of the tropical Himalayas from Assam to Punjab, in the eastern districts of Central India, and on the Western Bengal Hills. Sal forests have the widest distribution amongst all Dipterocarps, extending over an estimated area of 13 million hectares in India alone, with Bangladesh and Nepal together adding another one million hectares (Alam *et al.,* 2008).

Sal (*Shorea robusta*) is an important timber species which is in the natural Sal forest of Bangladesh. Total area of Sal forest of Bangladesh is 0.12 million ha which is distributed over the central and north-western region of the country (Islam and Sato, 2012). The tropical moist deciduous forests are popularly known as Sal forests. These occur in Dhaka, Gazipur, Tangail, Mymensingh, Sherpur, Jamalpur, Netrokona, Dinajpur, Rangpur, Naugaon, and in degraded form in Comilla (Chowdhury, 1994). About 86% of

the total forest land is situated in the districts of Dhaka, Mymensingh, Tangail and Comilla (central region) with the remaining 14% in the greater districts of Rangpur, Dinajpur and Rajshahi (north western region). The north-western region and Comilla district have little denuded scattered areas of forests at present. Of the total 122012 ha forest land, 68,140 ha is reserved, 31,198ha is acquired, 2,689 ha is protected and 19,985 ha is vested. The flora of this Sal forest type includes about 271 species of which 41 are tree species (FMP 1992).

Dinajpur district is a district in the Rangpur Division of northern Bangladesh. Total area 3437.98 sq. km, located in between 25°10' and 26°04' north latitudes and in between 88°23' and 89°18' east longitudes (Wikipedia, 2019). According to Social Forest Department, Dinajpur, the area of forestland is 18360.73 acre or 74 sq. Km. which is 2.15% of the total district area. Dinajpur has a tropical wet and dry climate. Sal forest is situated in the Biral, Birganj, Birampur, Nawabganj, Parbatipur upazila in Dinajpur.

The biodiversity of Sal forests includes a wide variety of flora and fauna. The dominant tree species found in the Sal forests is Sal (*Shorea robusta*) about 90%, the other common trees are palash (*Butea monosperma*), haldu (*Adina cordfolia*), jarul (*Lagerstroemia parviflora*), bazna, hargoja (*Dillenia pentagyna*), koroi, menda (*Litsea monopetala*), kushum, udhal, dephajam, bahera, kurchi, haritaki, pitraj, sonalu, amlaki and adagash (*Croton oblongifolius*). Climbers like kanchan lata, kumari lata, gajpipal, pani lata, Dioscorea species, satamuli, and gila occur in these forests. Few epiphytes are also recorded. Legumes, euphrobias and convolvulous plants also occur (Banglapedia, 2015). A massive plantation program 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.

Sal forests are classified as tropical moist deciduous forests (Champion *et al.* 1965). FAO (2000) categorizes Sal forest into two subtypes, pure Sal and mixed Sal, on the basis of soil type and tree canopy. In the past pure Sal stands had a canopy that was nearly 100 percent and the growth of the trees was so rapid that these forests were considered inexhaustible (Khan 1998). Sal grew on shallow, dry, and less productive soils but such pure Sal forests now exist only in coppice form with sparse under-storey and a relatively small number of species.

Canes or Rattans are climbing spiny palms with characteristic scaly fruits of the palmae family. Cane known in bangla as 'Bet' (Wikipedia, 2018). They naturally grow in the tropical forests of Southeast Asia and western Africa and have been associated with the development of indigenous cultures in these regions (INBAR, 2001). Presently they are mainly used to produce furniture items and the market for these is growing steadily. Cultivation of rattans is only practiced on a relatively small scale. Because they are climbing plants they must be inter-planted with trees up which they can climb. Based on this properties government has taken some steps for protecting the Sal forest. It is done for preventing the stealing and protection of the Sal trees. To protect Sal forest, cane plantation was done in 20 ha. area during 2013-2014 session in Nawabganj Sal forest and also done in some areas of the Singra Sal forest under the management of forest department as social forestry program.

The tropical moist deciduous Sal forests ecosystem of Dinajpur 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. Natural regeneration of Sal has always been poor due to short viability of seeds, dependence on monsoon rains and high disturbance (Islam *et al.*, 2016; Tewari, 1995). In recent years the problem has assumed serious magnitudes. To protect Sal forest, cane plantation was done under the management of forest department as social forestry program in the Sal forest of Bangladesh. Though the program seemed to be successful, but it was not suitable for natural regeneration of Sal tree due to the bushy nature of cane plantation.

Though many works have been done on the Sal forest (e.g. Al Faruq *et al.*, 2016; Islam *et al.*, 2016; Abdullah *et al.*, 2015) but research about the impact of Cane plantation on the regeneration of Sal forest is rare.

1.2 Objectives of the study:

Considering the above fact, the following objectives are taken for the present study:

1) To identify the present status of cane plantation in the Sal forest of Dinajpur,
2) To explore the impact of cane plantation on the regeneration of Sal forest.

CHAPTER TWO
LITERATURE REVIEW

Review is a required part of grant of research works and often a chapter in thesis. The reviews of literature of the past studies related to the present experiment collected through reviewing of journals, thesis, internet browsing, reports, newspapers, periodicals and other form of publications are presented and discussed in this chapter.

2.1 General Review of Sal Forest
2.2 Categories of Sal Forest
2.3 Regeneration
2.4 Types of Regeneration
2.5 Natural regeneration of Sal
2.6 Natural regeneration of Sal with cane plantation
2.7 Artificial regeneration of Sal
2.8 Anthropogenic threats
2.9 Natural threats
2.10 Present management system and its problem
2.11 Conservation and sustainable forest management for Sal forest ecosystem
2.12 Implications for conservation and protection of Sal forest

2.1 General Review of Sal Forest

Sal (*Shorea robusta*) is an important timber species which is in the natural Sal forest of Bangladesh. Total area of Sal forest of Bangladesh is 0.12 million ha which is distributed over the central and north-western region of the country (Islam and Sato, 2012). About 86% of the total forest land is situated in the districts of Dhaka, Mymensingh, Tangail and Comilla (central region) with the remaining 14% in the greater districts of Rangpur, Dinajpur and Rajshahi (north western region).

Sal (*Shorea robusta*) forest is a threatened ecosystem in Bangladesh. Until the beginning of the 20th century Sal forests existed as a large continuous belt with rich biological resources, but increasing pressure has been placed on them since then due to the ever-increasing population. Most of the forest area at present is under occupation by encroachers and the remaining stands are stocked poorly. Biodiversity has declined rapidly and many animal species have become locally extinct. The Forest Department

has established agroforestry and woodlot plantations as sustainable production system in the encroached and degraded forest area using a participatory approach. Some protected areas have also been established for conservation. Nevertheless, it is predicted that the present trend of management is inadequate and an intensive management policy is essential to restore the forest ecosystem (Alam *et al.*, 2008).

Present land uses in this deciduous tropical forest include agroforestry, woodlot, and Sal coppice management, and recreation and conservation area management through establishment of Eco parks and national parks in different locations e.g. Singra forest. These new management tools are bringing barren, degraded and encroached lands under forest cover by engaging local people in management recent years the problem has assumed serious magnitudes. To protect Sal forest, cane plantation was done in 20 ha. area during 2013-2014 session in Nawabganj Sal forest and also done in some areas of the Singra Sal forest under the management of forest department. Though the program seemed to be successful, but it was not suitable for natural regeneration of Sal tree due to the bushy nature of cane plantation. Regeneration of Sal forest from seed is very important because viability of Sal seed lasts only 3-5 days. Good seed years occur every 3-5 years depending on the locality (Hossain, 2015). If Sal seed do not get proper environment due to cane bush, Sal forest will be destroyed gradually.

2.2 Categories of Sal Forest

Sal forests are classified as tropical moist deciduous forests (Champion et al. 1965). FAO (2000) categorizes Sal forest into two subtypes, pure Sal and mixed Sal, on the basis of soil type and tree canopy.

(i) Pure Sal

In past, these forests, even under natural conditions, had a canopy that was nearly 100 percent Sal and grew on shallow, dry and less productive soils in the region to the north of Dhaka and was frequently burned. Such pure Sal forests now exist only in coppice form with sparse understory and the relatively few number of species.

(ii) Mixed Sal

These forests are dominated by Sal in the canopy but include many other associated species like *Terminalia bellerica, Albizzia procera, Lagerstroemia spp*. and *Ficus*

species. They grow on the deeper, moister and more productive soils of the Madhupur and Barind tract. The understory is more complex and includes a variety of deciduous and evergreen species. The flora of the Barind Tract in this Sal forest type includes about 271 species out of which 41 are tree species. Sal forests also include a high number of climbers and woody perennials of medicinal value.

Champion, Seth and Khatak (1968) classify these forests as Tropical Moist Deciduous Forests and subdivide the same into two sub-types; (a) Moist Sal forests and (b) Sal Scrub Forests. The Moist Sal forests are severely depleted leaving some sporadic intact patches of natural and coppiced Sal forests. The Sal scrub forests are the result of extreme human interference. The Sal has been coppiced many times and many stumps have lost their coppicing power, creating small and big blanks.

2.3 Regeneration

Regeneration is a process in which one tree produces new generation of its own kind. By this process tree canopy develops in the natural forest. regeneration naturally occurs through seeds, coppice, vegetative propagation, root, shoot, leaf etc. Example-Sal seed regenerates by seed and also in coppice form.

2.4 Types of Regeneration

There are two types of regeneration. They are –

1. Natural regeneration
2. Artificial regeneration

2.4.1 Natural Regeneration

Natural regeneration is a process in which regeneration is occurred by seeds and coppice of that tree species. Natural regeneration can follow different trajectories and velocities according to how the different variables act in the system that is undergoing recovery. Variables such as light, humidity, temperature, availability of seeds and young trees, predation, and the structure of initial vegetation determine the successional trajectory of each site.

2.4.2 Artificial Regeneration

Artificial regeneration is a process in which regeneration is occurred by seeds and other vegetative part of tree species by artificial process. Such as regeneration of seeds in poly beg, nursery bed etc. Artificial regeneration is done in the degraded site having too much biotic pressure, having less rainfall, light management, unfavorable condition etc.

2.5 Natural regeneration of Sal

Sal (*Shorea robusta*) is an important timber species which is in the natural Sal forest of Bangladesh. Sal is a moderate seeder, having an average seed year every two years and a good seed year every 3-5 years depending on the locality. The seed ripens from third week of May to first week of July, following the commencement of monsoon in different regions. Seeds production varies from year to year and tree to tree. Winged Sal seed production per tree varies from 2 kilograms to 35 kilograms. Regeneration of Sal forest from seed is very important because viability of Sal seed lasts only 3-5 days (Hossain, 2015).

Sal (*Shorea robusta*) regenerates naturally through seeds and coppice. Sal grew on shallow, dry, and less productive soils but such pure Sal forests now exist only in coppice form with sparse under-storey and a relatively small number of species. The inland Sal (*Shorea robusta*) forests were managed under a coppicing system with a rotation of 25 years. Areas where Sal trees are comparatively fewer are managed under a clear-felling system followed by artificial regeneration mostly with Sal and other suitable species. Natural regeneration of Sal has always been poor due to short viability of seeds, dependence on monsoon rains and high disturbance (Islam *et al.*, 2016; Tewari, 1995). In recent years the problem has assumed serious magnitudes.

Sal (*Shorea robusta*) is the key tree species of the plain land Sal forests. It is locally called Gajari (having coppicing power) for which the Sal forest is also known as the Gajari forest. This Sal forest is now under heavy population pressure as it is easily convertible into agricultural land. The Forest Department started participatory Sal coppice management from 2001 under the Forestry Sector Project. An area of 5,850 ha of Sal forest has been brought under coppice management through participatory social forestry.

The 'coppice with standard' system was also followed where mature trees were felled and the areas were protected for coppice regeneration (Hossain,1999). After the India-Pakistan partition in 1947, forest departments divided these forests into two working circles. One was a timber and conversion working circle where clear felling followed artificial plantation keeping the rotation to 70-80 years, and the second was a coppice working circle, with a rotation to 25 years. Asian Development Bank (ADB) had actively promoted the destruction of the Sal forests by financing projects for tree monoculture plantations using Eucalyptus and rubber among other species (Kabir and Ahmed 2005). Local people became concerned about gaining access to the goods and services they were used to obtaining from the Sal forest.

Fig. 2.1 Natural regeneration of Sal forest.

2.6 Natural regeneration of Sal with cane plantation

Sal (*Shorea robusta*) is the key tree species of the plain land Sal forests. The tropical moist deciduous Sal forests 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. There are many forces responsible for forest degradation, collectively and individually and the trends of these forces are very complex. The major causes of forest degradation in Bangladesh are agricultural expansion, over-extraction of wood and non-wood resources, infrastructure development, population growth, deforestation, settlement, urbanization and wrong management practices (Hossain, 1999; Salam *et al.*, 1999). Some new forest management systems have also been added to address new concepts in forest management such as agroforestry, participatory social forestry on encroached forest land.

To protect Sal forest, cane plantation was done in 20 ha. area during 2013-2014 session in Nawabganj Sal forest and also done in some areas of the Singra Sal forest under the management of forest department as social forestry program. Because they are climbing plants they must be inter-planted with trees up which they can climb. Based on this properties government has taken some steps for protecting the Sal forest. It is done for preventing the stealing and protection of the Sal trees in the natural Sal forest.

Natural regeneration of Sal has always been poor due to short viability of seeds, dependence on monsoon rains and high disturbance. In recent years the problem has assumed serious magnitudes. Though the program seemed to be successful, but it was not suitable for natural regeneration of Sal tree due to the bushy nature of cane plantation. If the Sal seed cannot get proper environment due to cane bush, they cannot germinate. As a result, Sal forest will be destroyed gradually one day.

Fig. 2.2 Natural regeneration of Sal forest with cane plantation.

2.7 Artificial regeneration of Sal

Sal (*Shorea robusta*) regenerates naturally through seeds and coppice. Direct seed sowing is the cheapest and best method of artificial propagation. But it can be practiced in an area with assured rainfall over 1200 mm. to 1500 mm. In the degraded Sal forest which has too much biotic pressure and where rainfall is below 1500 mm. where regeneration is almost impossible. Artificial regeneration of *S. robusta* can be practiced to major extent primarily within its native habitat (Keshav and Naithani, 2013).

Artificial propagation (Plantation) of Sal is difficult due to three reasons.

1. Short viability of Sal seeds.
2. Sal seedling and Saplings have root shoot ratio 3:1 and after 5 months it is 6:1

3. Sal seedling and Sapling are moisture Sensitive.

In the degraded site having too much biotic pressure, having rainfall less than 1200 mm. artificial plantation is required to improve Sal forest. Sal seedling and sapling have constraints, small period of viability of seeds, they are moisture sensitive, root shoot ratio is 3:1 to 6:1, Adopting above technique constraints of Sal seedling are solved. Artificial plantation of Sal can be done successfully.

Fig. 2.3 Artificial regeneration of Sal

2.8 Anthropogenic threats

2.8.1 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, haldu, shidah jarul, hargoja, koroi, bahera, haritoki, sonalu, amlaki 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 (Abedin, 2019).

2.8.2 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). 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).

2.8.3 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. 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 (Abedin, 2019).

2.8.4 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 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).

2.8.5 Urbanization

Urbanization destroys the forest by affecting the regeneration and also acts as a barrier to wildlife. A number of urban settlements, such as Nawabganj, Birganj, and Biral upazila are in close proximity to the main Sal forest areas. 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 natural Sal forest and wildlife habitat of that area.

2.8.6 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. 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). 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*, *Eucalyptus camaldulensis* and *Acacia mangium*. 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).

2.8.7 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. These chemicals also kill different varieties of insects that are beneficial to the soil and environment. 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). In this way the natural regeneration of Sal forest was hampered day by day (Abedin, 2019).

2.8.8 Grazing

It is reported that the degradation of Sal forests resulted from heavy and haphazard grazing (Gautam and 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).

2.8.9 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 and there are no possibilities of extending irrigation facilities in the Sal forest areas agroforestry plantations were undertaken as a management strategy to replenish the Sal forests (Abedin, 2019).

2.9 Natural threats

2.9.1 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).

2.10 Present management system and its problem

Natural regeneration of Sal has always been poor due to short viability of seeds, dependence on monsoon rains and high disturbance. In recent years the problem has assumed serious magnitudes. To protect Sal forest, government has taken some steps and cane plantation was done as social forestry program in the Sal forest of Bangladesh. Though the program seemed to be successful, but it is not suitable for natural regeneration due to the bushy nature cane plantation. 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 Sal forest areas of Dinajpur districts without considering the long-term adverse effects on the ecology of the forest.

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: regeneration problem, 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). To protect Sal forest, cane plantation was done under the management of forest department as social forestry program in the Sal forest of Bangladesh. Though the program seemed to be successful, but it is not suitable for natural regeneration due to the bushy nature cane plantation.

2.11 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.

2.12 Implications for conservation and protection of Sal forest

As social forestry program cane plantation was done to protect the Sal forest. Because they are climbing plants and must be inter-planted with trees up which they can climb. It is done for preventing the stealing of the Sal trees. Though the program seemed to be successful, but it is not suitable for natural regeneration due to the bushy nature cane plantation. So for the better management of Sal forest cane plantation at the floor of forest should be restricted immediately. 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 (Chowdhury *et al.*, 2010). 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 the bushy nature cane plantation. For better management of Sal forest cane plantation at the floor of forest should be restricted immediately. A sustainable management plan should be developed by natural Sal forest without cane plantation in Sal forest for natural regeneration involving all beneficiaries and stakeholders and should be effectively implemented to conserve these substantial ecosystems for present and future generations.

CHAPTER THREE

MATERIALS AND METDODS

3.1 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, Forest Department and from different websites through Internet.

3.2 Study area

The tropical moist deciduous forests are popularly known as sal forests. These occur in Dhaka, Gazipur, Tangail, Mymensingh, Sherpur, Jamalpur, Netrokona, Dinajpur, Rangpur, Naugaon, and in degraded form in Comilla (Chowdhury, 1994). About 86% of the total forest land is situated in the districts of Dhaka, Mymensingh, Tangail and Comilla with the remaining 14% in the greater districts of Rangpur, Dinajpur and Rajshahi. 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. Dinajpur region occupy the moist deciduous forest. The moist Sal forest comprises of areas containing pure Sal, sometimes with Bohera, Silkoroi, Ajuli, Arjun, Minjiri, Teak, Akasmani, Ghoranim, Harataki, Amalaki etc.

The study was conducted in the Sal forest of Dinajpur, Bangladesh. There are 13 upazila in Dinajpur district. Among them natural Sal forest scatters in 6 upazila. The natural forest situated in the Biral, Birganj, Birampur, Nawabganj, Parbatipur and Ghoraghat upazila. The dominant tree species found in the natural forests is Sal (*Shorea robusta*) about 90% that's why it is called Sal forest. Among them I was conducted my study in the two different Sal forest of Dinajpur district namely Singra Sal forest (Birganj) and Nawabganj Sal forest of Dinajpur, Bangladesh.

3.2.1 Singra Sal Forest Birganj

Singra National Park is a reserved forest situated at Dinajpur in Bangladesh. Locally it is known as Singra Sal Forest. The total area of this forest is 355 ha and among them the National Park is 305.69 ha. (Fig. 3.1). In 10 October 2010, the forest department declared it as National Park forest for the development of natural environment, wild life conservation and for the betterment of excursion. In this forest the dominant tree is Sal, the other common trees are Bohera, Silkoroi, Ajuli, Arjun, Minjiri, Teak, Akashmoni, Ghoranim, Horitaki, Amaloki, Jarul, Sonalu, etc. (Rahman, M.S. 2017). Climber like kanchan lata, kumari lata, pani lata, Dioscorea species, satamuli, and gila occur in these forests. Legumes, euphrobias and convolvulous plants also occur (Banglapedia, 2015). Once upon a time Tiger, Nilgai, with various species of animals were found in the Sal forest. Encroachments and illicit removal of timber and firewood from the forests with constant human pressure from all sides was responsible for destroying the habitat of the wildlife. Now rabbits, foxes, snakes and of various species birds and insects can be found in the Sal forest (Rahman, M.S. 2017).

3.2.2 Nawabganj Sal Forest

Nawabganj is an Upazila of Dinajpur District in the Division of Rangpur, Bangladesh. Nawabganj is located at 25.4167°N 89.0833°E. It has 34999 households and total area 314.68 km² (fig. 3.1). It was declared as National forest under the Name "Nawabganj National Forest" at 24/10/2010 by the People's Republic of Bangladesh. The current area of this forest is about 517.61 ha. (Rahman, M.S. 2017).

In this forest the dominant tree is Sal, the other common trees are Berry, Gama, Arjun, Teak, Akashmoni, Ghoranim, Amaloki, eucalyptus, including 20 to 30 various species of trees are native to different classes of orchids (Rahman, M.S. 2017). In animals, fox, forest cat, several species of snakes, parakeets, kingfisher, many species of birds, including water fowl exist named Ashurar Beel. The upazila administration at Nawabganj upazila in Dinajpur has built a kilometer-long wooden bridge made from timber of the Sal tree, in a bid to promote tourism in the area. The bridge is named after Sheikh Fazilatunnesa. It is said to be the longest wooden bridge in North Bengal, according to the upazila office.

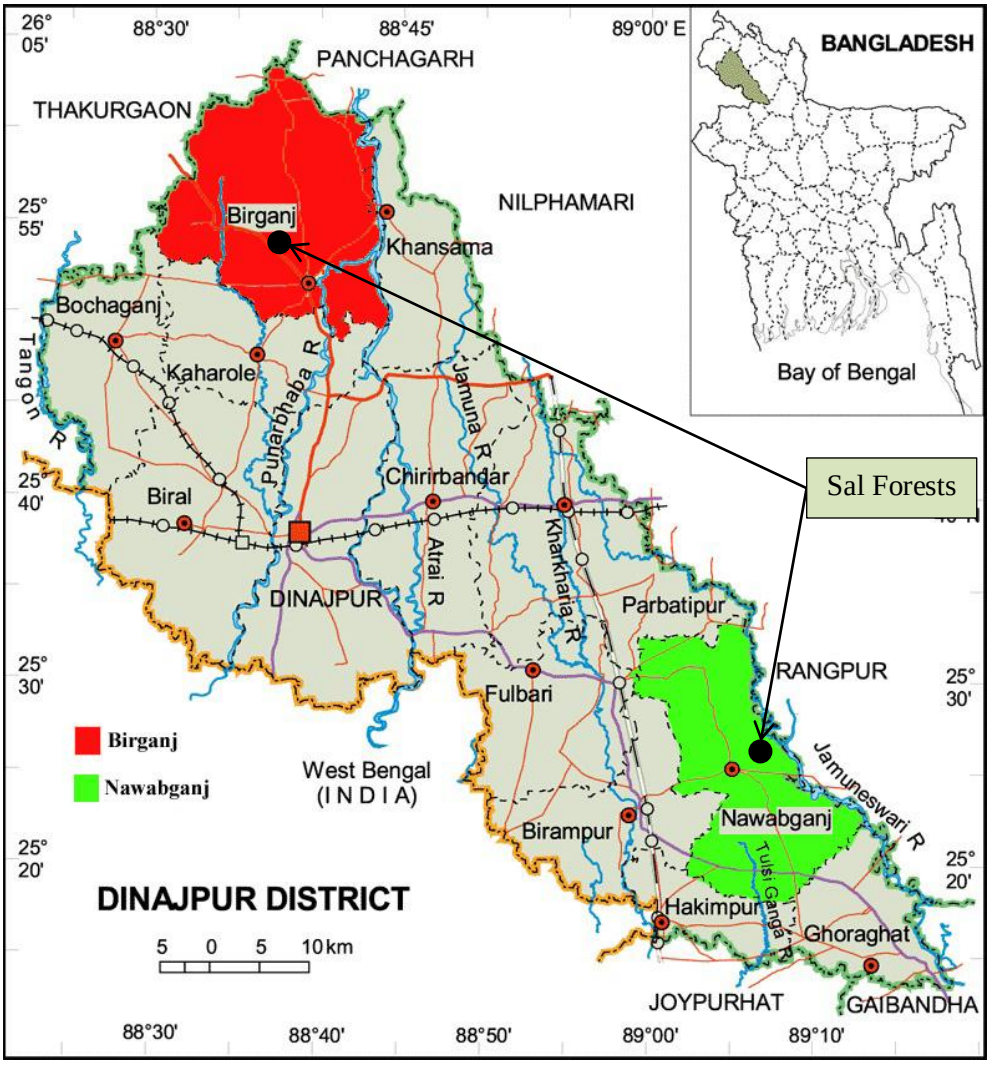

Fig. 3.1 GIS map of study area

3.3 Study design

The study was conducted in the Sal forest of Dinajpur district at two different locations namely Birganj and Nawabganj upazila. Ten quadrates were selected randomly inside each Sal forest for this study. Five quadrates were Sal with cane species and five quadrates were only Sal species without cane species. Altogether twenty quadrates were selected in two Sal forest. The size of each quadrate was 20m×20m. Within the quadrates following data were collected-

- Number of Sal trees greater than 3 feet height,
- Number of Sal seedlings less than 3 feet height,
- Number of Sal coppice seedlings less than 3 feet height,

- Number of Cane bush,
- Weight of leaf litter per sq. m,
- Number of Sal seeds per sq. m,
- Number of germinated seedlings of Sal,
- Height of Sal trees,
- Diameter at breast height (DBH) of Sal trees etc.

Height and DBH of Sal trees were measured from the sample quadrates (20m×20m) using Haga Altimeter and Diameter tape. Soil leaf litter was collected in polythene bag from the forest floor of an area 1m x 1m and measured it in the laboratory.

3.4 Equipments Used in the Field Study

Following equipments and materials were used during the field study:

1. Measuring Tape,
2. Diameter Tape,
3. Haga Altimeter,
4. Large polybag,
5. Weight measuring scale etc.

Figure - 3.2 Equipments used in the field study

3.5 Time of data collection

The extensive survey was conducted during the period of September 2018 to November 2019. Data was collected from two different Sal forest of Dinajpur district by using some field observation sheet.

3.6 Laboratory Methods

Soil leaf litter was collected in polythene bag from the forest floor of an area 1m x 1m. In the laboratory collected soil leaf litter was measured and recorded carefully.

3.7 Data processing and analysis

The collected data were recorded, compiled and finally analyzed carefully in the computer according to the objectives of the study. The data were analyzed by using the Statistics 10 software with descriptive analysis program and MS-Excel program. In addition, graphs and tables were also used to interpret the findings. The mean was separated by using standard error of mean with an error bar.

CHAPTER FOUR

RESULTS AND DISCUSSION

The findings of the study and discussion of the results have been presented in this chapter.

4.1 Total number of Sal trees of Singra Sal forest in Birganj

4.1.1 Number of Sal trees greater than 3 feet height

The number of Sal trees greater than 3 feet height found in Singra Sal forest varied between quadrates of natural Sal and Sal with cane plantation. The quadrates of the natural Sal forests showed a higher number of Sal trees than the quadrates of Sal with cane plantation (Fig. 4.1). The average number of Sal trees found in the Sal forest was significantly higher (78.8) than Sal with Cane plantation (49.6). The number of Sal trees are decreasing due to cane plantation in the natural Sal forest which is responsible for poor regeneration of Sal seeds for its bushy structure.

A study of Abedin, (2019) that was done on effect of highway's on Bhawal Sal forest areas of Bangladesh and found that if the distance increases from the road to the inside of the forest, trees with increasing height were found. But the present study was conducted with average height of Sal trees in only Sal and Sal with cane plantation.

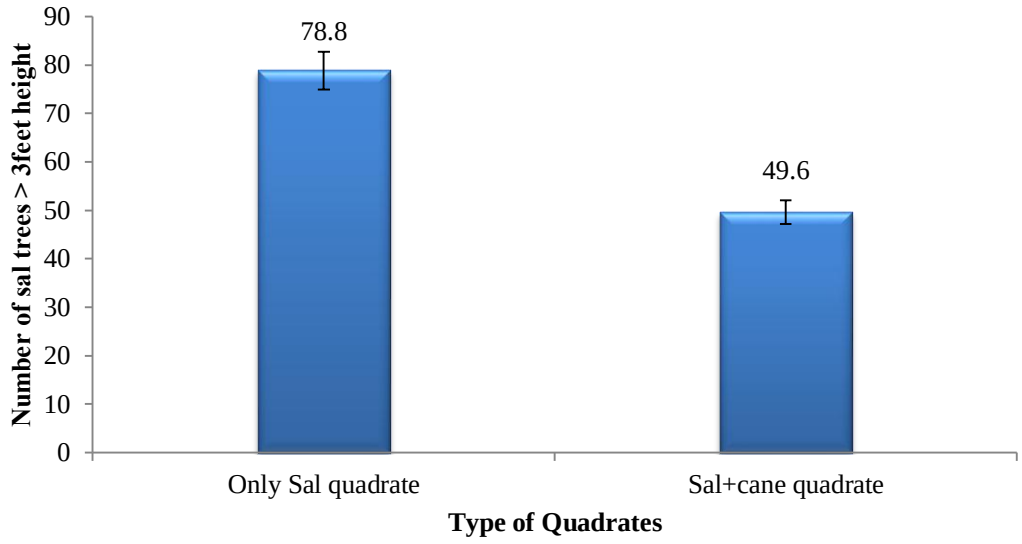

Figure - 4.1 Number of Sal trees greater than 3 feet height

4.1.2 Number of Sal seedlings less than 3 feet height

The number of Sal seedlings less than 3 feet height found in Singra Sal forest varied between quadrates of natural Sal and Sal with cane plantation. The quadrates of the natural Sal forests showed a higher number of Sal seedlings than the quadrates of Sal with cane plantation (Fig. 4.2). The average number of Sal seedlings found in the Sal forest was significantly higher (474.4) than Sal with Cane plantation (38.4). The number of Sal seedlings are decreasing due to cane plantation in the natural Sal forest which is responsible for poor regeneration of Sal seeds for its bushy structure. For this reason, Sal seeds cannot get favorable condition as well as germination. Even we found some quadrates without any Sal seedlings where cane plantation was done with natural Sal forests for its high bushy structure.

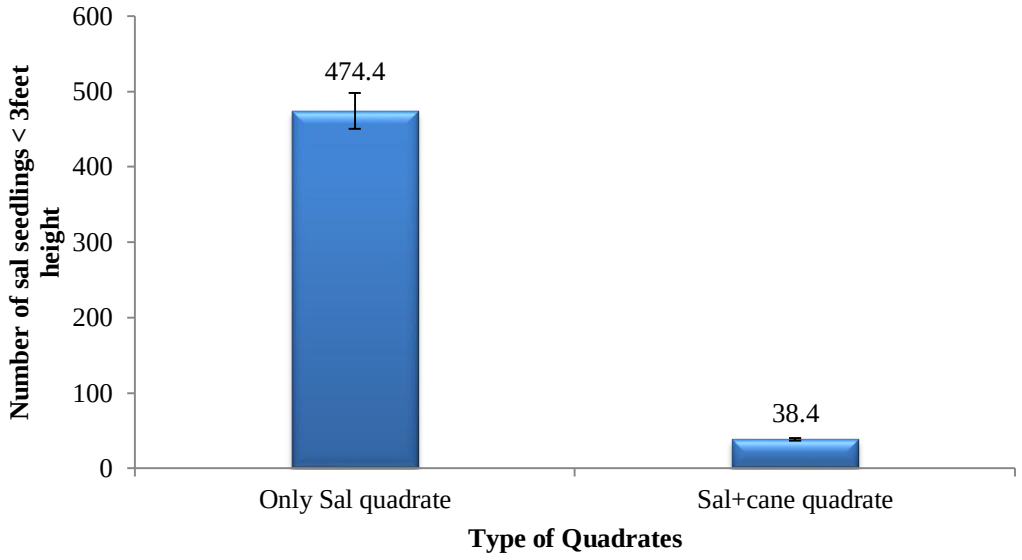

Figure - 4.2 Number of Sal seedlings less than 3 feet height

4.1.3 Number of Sal coppice seedlings less than 3 feet height

The number of Sal coppice seedlings less than 3 feet height found in Singra Sal forest varied between quadrates of natural Sal and Sal with cane plantation. The quadrates of the natural Sal forests showed a higher number of Sal coppice seedlings than the quadrates of Sal with cane plantation (Fig. 4.3). The average number of Sal coppice seedlings found in the Sal forest was significantly higher (71.2) than Sal with Cane plantation (7.2). The number of Sal coppice seedlings are decreasing due to cane plantation in the natural Sal forest which is responsible for poor regeneration of Sal seeds for its bushy structure. For this reason, Sal seeds cannot get favorable condition as well

as germination. Even we found some quadrates without any Sal coppice seedlings where cane plantation was done with natural Sal forests for its high bushy structure.

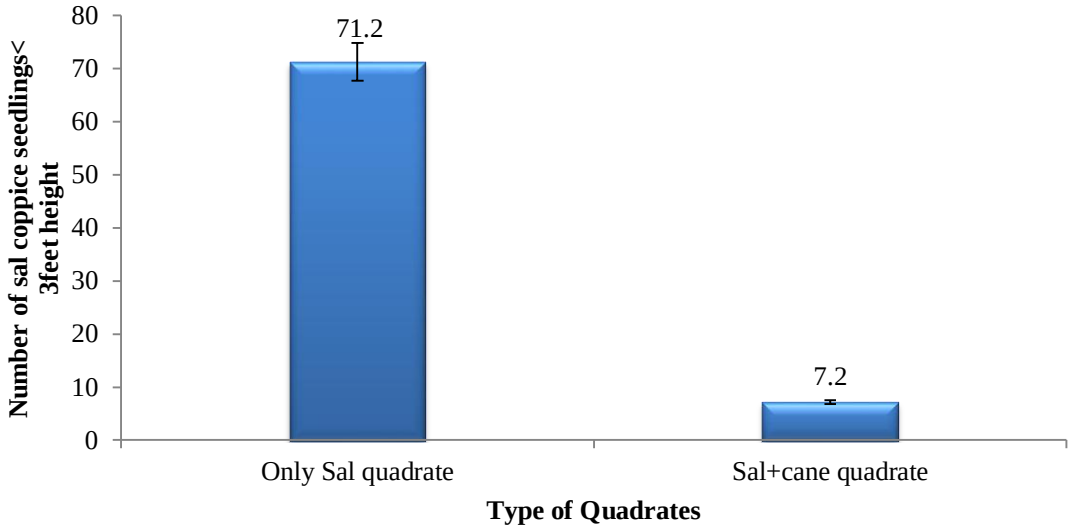

Figure - 4.3 Number of Sal coppice seedlings less than 3 feet height

4.2 Number of Sal seeds found per sq. m in Singra Sal forest

The number of Sal seeds found in Singra Sal forest varied between quadrates of natural Sal and Sal with cane plantation. The quadrates of the natural Sal forests showed a higher number of Sal seeds than the quadrates of Sal with cane plantation (Fig. 4.4). The average number of Sal seeds found in the Sal forest was significantly higher (3.4) than Sal with Cane plantation (1.2). The number of Sal seeds are decreasing due to cane plantation in the natural Sal forest which is responsible for its high bushy structure and seeds cannot contact with soil for getting favorable conditions as well as germination.

The findings of our study is consistent with the study of Tewari, (1995). Seeds production varies from year to year and tree to tree. Winged Sal seed production per tree varies from 2 kilograms to 35 kilograms (Tewari, 1995).

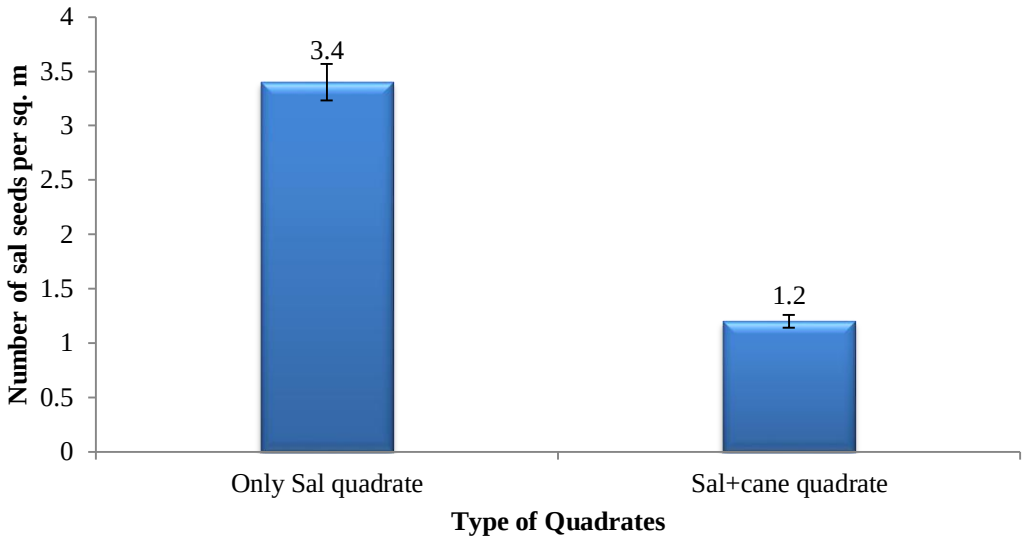

Figure - 4.4 Number of Sal seeds found per sq. m

4.3 Weight (g) of leaf litter per sq. m in Singra Sal forest

The weight of leaf litter per sq. m found in Singra Sal forest varied between quadrates of natural Sal and Sal with cane plantation. The quadrates of the natural Sal forests showed a higher weight of leaf litter of Sal trees than the quadrates of Sal with cane plantation (Fig. 4.5). The average weight of leaf litter found per sq. m in the Sal forest was significantly higher (160.6g) than Sal with Cane plantation (95.6g). The weight of leaf litter of Sal trees is decreasing due to cane plantation in the natural Sal forest for its bushy structure.

A study of Abedin, (2019) that was done on effect of highway's on Bhawal Sal forest areas of Bangladesh and found the soil organic matter of Bhawal Sal forest was ranges 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. But our findings were on weight(g) of leaf litter per sq. m. of Sal trees in only Sal and Sal with cane plantation.

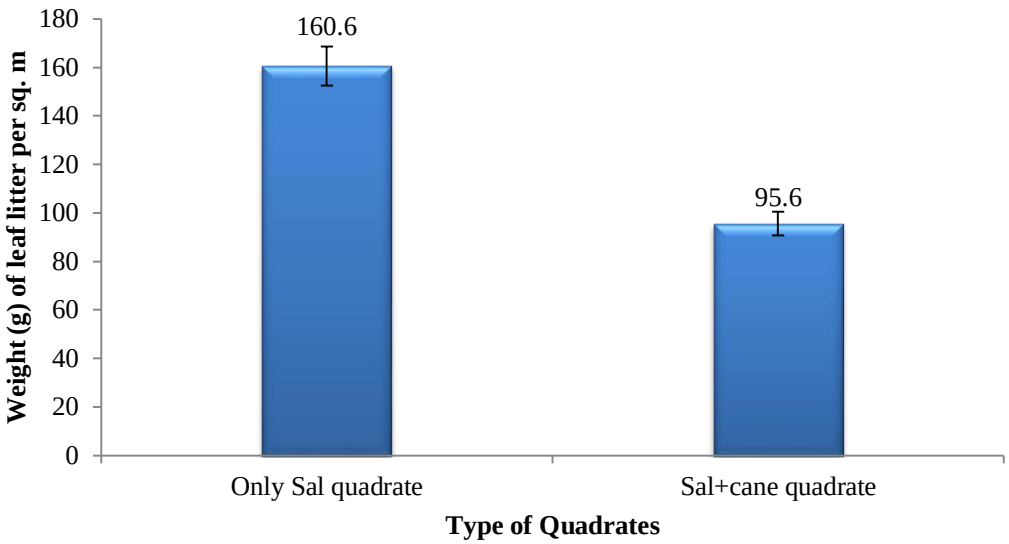

Figure - 4.5 Weight (g) of leaf litter per sq. m

4.4 Number of cane bush in Singra Sal forest

To protect Sal forest, cane plantation was done as social forestry program in the Sal forest of Bangladesh. Though the program seemed to be successful, but it was not suitable for natural regeneration due to the bushy nature cane plantation. In the research work we found 15, 20, 33, 40, 35 cane bush in the quadrate1, quadrate2, quadrate3, quadrate4, quadrate5 respectively which were densely arranged and covered the whole quadrate (Fig. 4.6). That was responsible for poor regeneration of Sal seeds for its bushy structure. For this reason, Sal seeds cannot get favorable condition as well as germination.

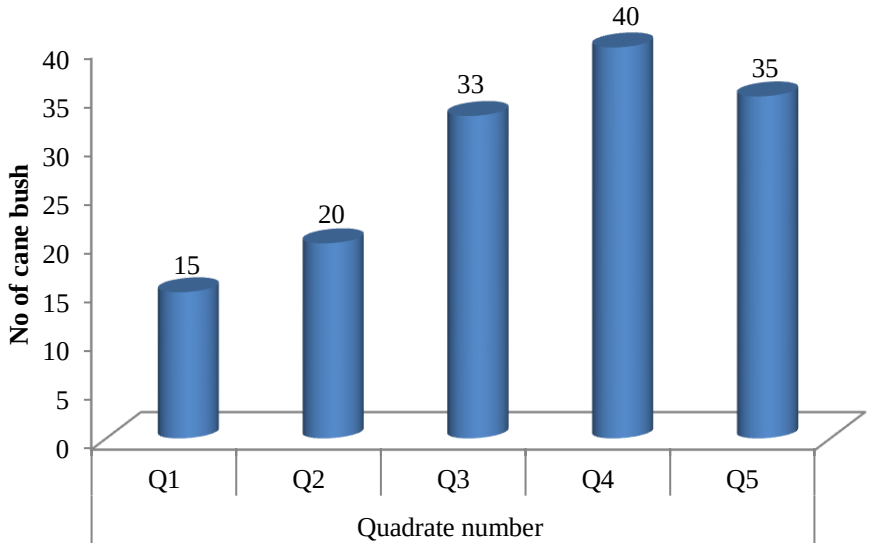

Figure - 4.6 Number of cane bush in different quadrates of Birganj Sal forest

4.5 Number of germinated Sal seedlings in Singra Sal forest

The number of germinated Sal seedlings found in Singra Sal forest varied between quadrates of natural Sal and Sal with cane plantation. The quadrates of the natural Sal forests showed a higher number of Sal seedlings than the quadrates of Sal with cane plantation (Fig. 4.7). The average number of germinated Sal seedlings found in the Sal forest was significantly higher (310.4) than Sal with Cane plantation (37.6). The number of germinated Sal seedlings are decreasing due to cane plantation in the natural Sal forest which is responsible for poor regeneration of Sal seeds for its bushy structure. For this reason, Sal seeds cannot get favorable condition as well as germination. Even we found some quadrates without any germinated Sal seedlings where cane plantation was done with natural Sal forests for its high bushy structure.

Our study findings are consistent with the study of the coverage of the existing forests is decreasing at a rate of 2.1% per year (Choudhury 2003) and the growing stock is depleting at a rate of 3.38% per year (GOB 1992).

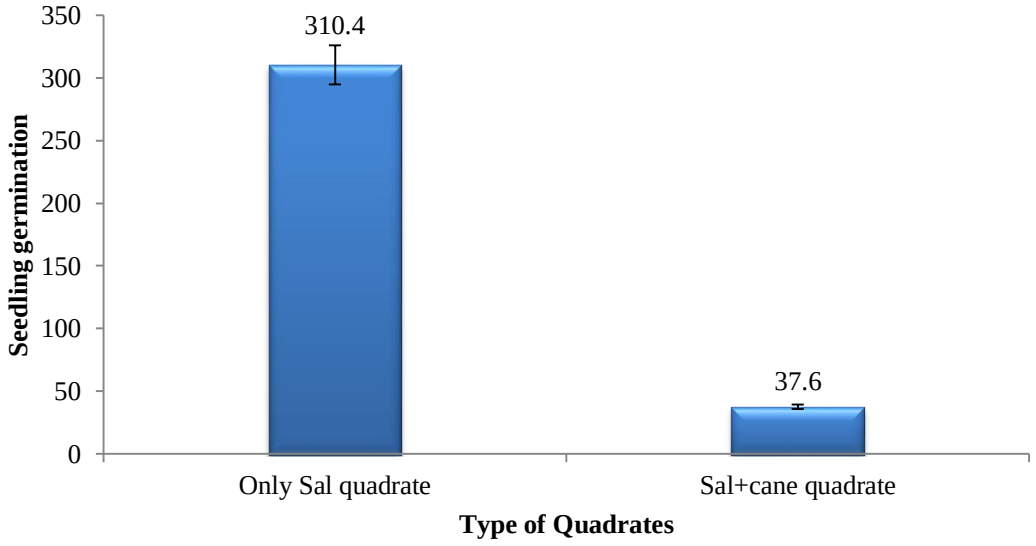

Figure - 4.7 Number of germinated Sal Seedlings

4.6 Total number of Sal trees of Nawabganj Sal forest

4.6.1 Number of Sal trees greater than 3 feet height

The number of Sal trees greater than 3 feet height found in Nawabganj Sal forest varied between quadrates of natural Sal and Sal with cane plantation. The quadrates of the natural Sal forests showed a higher number of Sal trees than the quadrates of Sal with cane plantation (Fig. 4.8). The average number of Sal trees found in the Sal forest was significantly higher (89.4) than Sal with Cane plantation (49.6). The number of Sal trees are decreasing due to cane plantation in the natural Sal forest which is responsible for poor regeneration of Sal seeds for its bushy structure.

A study of Abedin, (2019) that was done on effect of highway's on Bhawal Sal forest areas of Bangladesh and found that if the distance increases from the road to the inside of the forest, trees with increasing height were found. But the present study was conducted with average height of tree of only Sal and Sal with cane plantation.

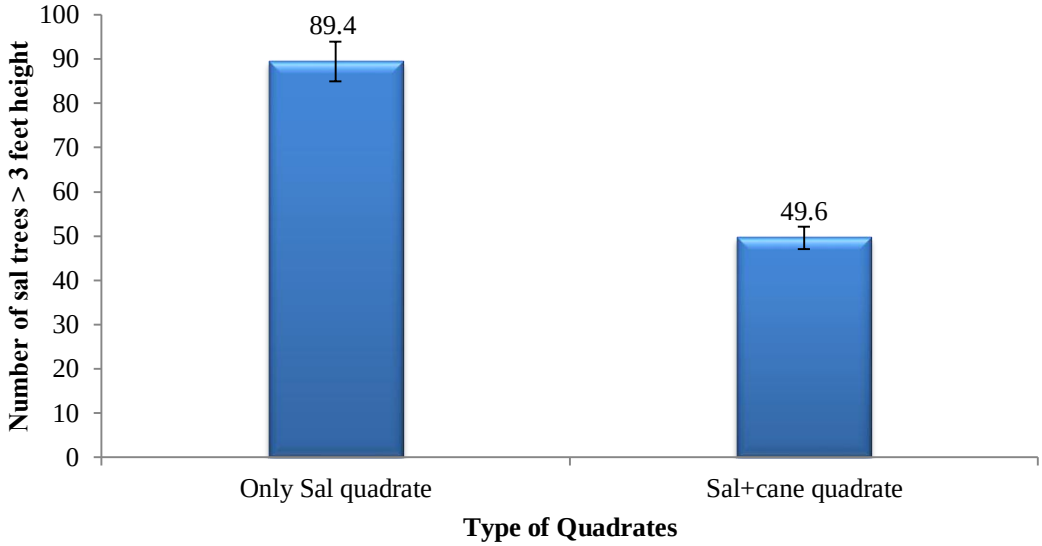

Figure - 4.8 Number of Sal trees greater than 3 feet height

4.6.2 Number of Sal seedlings less than 3 feet height

The number of Sal seedlings less than 3 feet height found in Nawabganj Sal forest varied between quadrates of natural Sal and Sal with cane plantation. The quadrates of the natural Sal forests showed a higher number of Sal seedlings than the quadrates of Sal with cane plantation (Fig. 4.9). The average number of Sal seedlings found in the Sal forest was significantly higher (445) than Sal with Cane plantation (63.6). The number of

Sal seedlings are decreasing due to cane plantation in the natural Sal forest which is responsible for poor regeneration of Sal seeds for its bushy structure. For this reason, Sal seeds cannot get favorable condition as well as germination. Even we found some quadrates without any Sal seedlings where cane plantation was done with natural Sal forests for its high bushy structure.

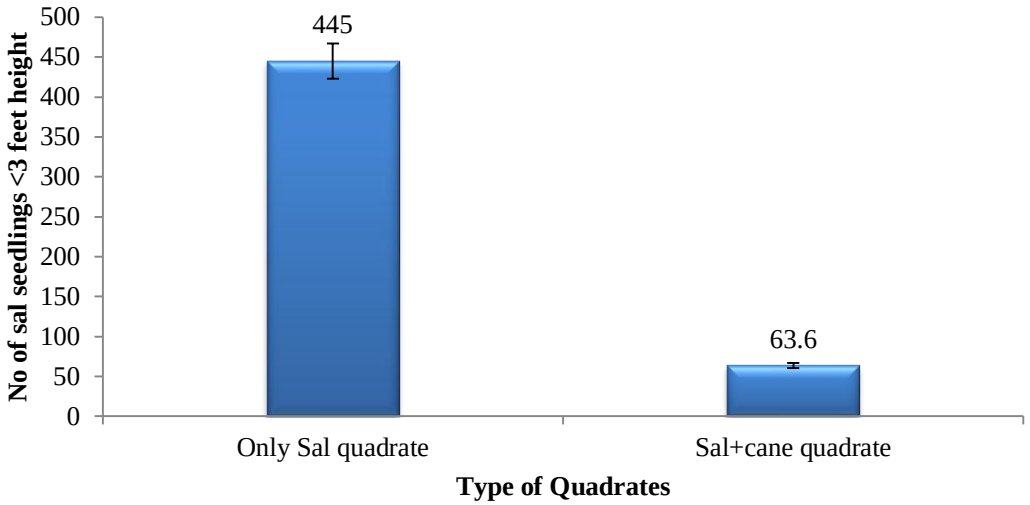

Figure - 4.9 Number of Sal seedlings less than 3 feet height

4.6.3 Number of Sal coppice seedlings less than 3 feet height

The number of Sal coppice seedlings less than 3 feet height found in Nawabganj Sal forest varied between quadrates of natural Sal and Sal with cane plantation. The quadrates of the natural Sal forests showed a higher number of Sal coppice seedlings than the quadrates of Sal with cane plantation (Fig. 4.10). The average number of Sal coppice seedlings found in the Sal forest was significantly higher (71.2) than Sal with Cane plantation (19.8). The number of Sal coppice seedlings are decreasing due to cane plantation in the natural Sal forest which is responsible for poor regeneration of Sal seeds for its bushy structure. For this reason, Sal seeds cannot get favorable condition as well as germination. Even we found some quadrates without any Sal coppice seedlings where cane plantation was done with natural Sal forests for its high bushy structure.

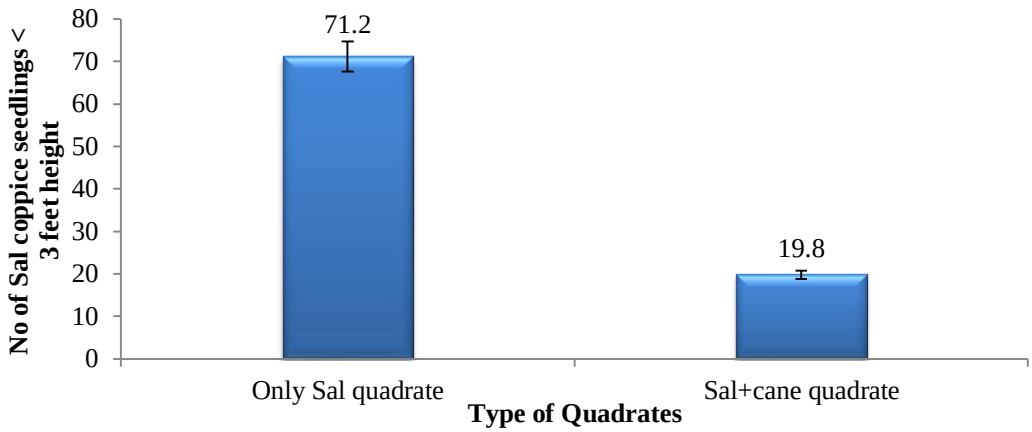

Figure - 4.10 Number of Sal coppice seedlings less than 3 feet height

4.7 Number of Sal seeds found per sq. m in Nawabganj Sal forest

The number of Sal seeds found in Nawabganj Sal forest varied between quadrates of natural Sal and Sal with cane plantation. The quadrates of the natural Sal forests showed a higher number of Sal seeds than the quadrates of Sal with cane plantation (Fig. 4.11). The average number of Sal seeds found per sq. m in the Sal forest was significantly higher (3.8) than Sal with Cane plantation (1.0). The number of Sal seeds are decreasing due to cane plantation in the natural Sal forest which is responsible for its high bushy structure and seeds cannot contact with soil for getting favorable conditions as well as germination.

The findings of the study are consistent with the study of Tewari, (1995). Seeds production varies from year to year and tree to tree. Winged Sal seed production per tree varies from 2 kilograms to 35 kilograms (Tewari, 1995).

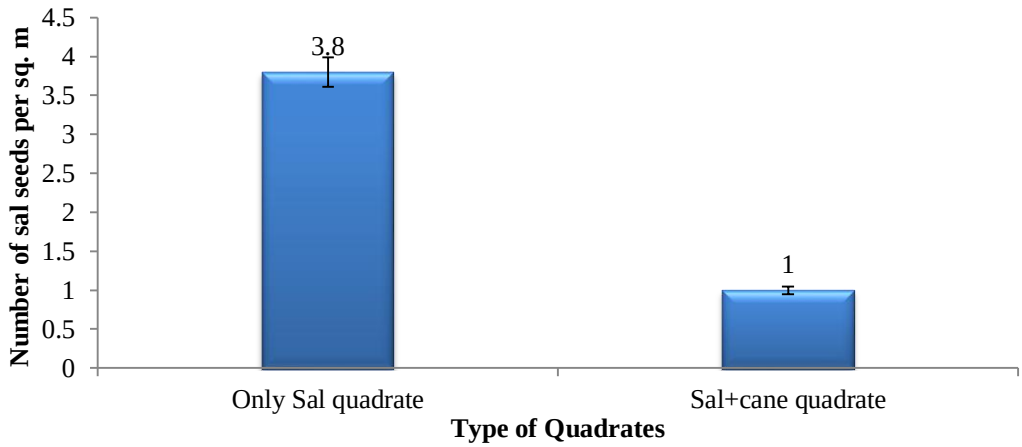

Figure - 4.11 Number of Sal seeds found per sq. m

4.8 Weight (g) of leaf litter per sq. m in Nawabganj Sal forest

The weight of leaf litter per sq. m found in Nawabganj Sal forest varied between quadrates of natural Sal and Sal with cane plantation. The quadrates of the natural Sal forests showed a higher weight of leaf litter of Sal trees than the quadrates of Sal with cane plantation (Fig. 4.12). The average weight of leaf litter found per sq. m in the Sal forest was significantly higher (162.6g) than Sal with Cane plantation (95g). The weight of leaf litter of Sal trees is decreasing due to cane plantation in the natural Sal forest for its bushy structure.

A study of Abedin, (2019) that was done on effect of highway's on Bhawal Sal forest areas of Bangladesh and found the soil organic matter of Bhawal Sal forest was ranges 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. But our findings were on weight(g) leaf litter per sq. m. of Sal forest and Sal with cane plantation.

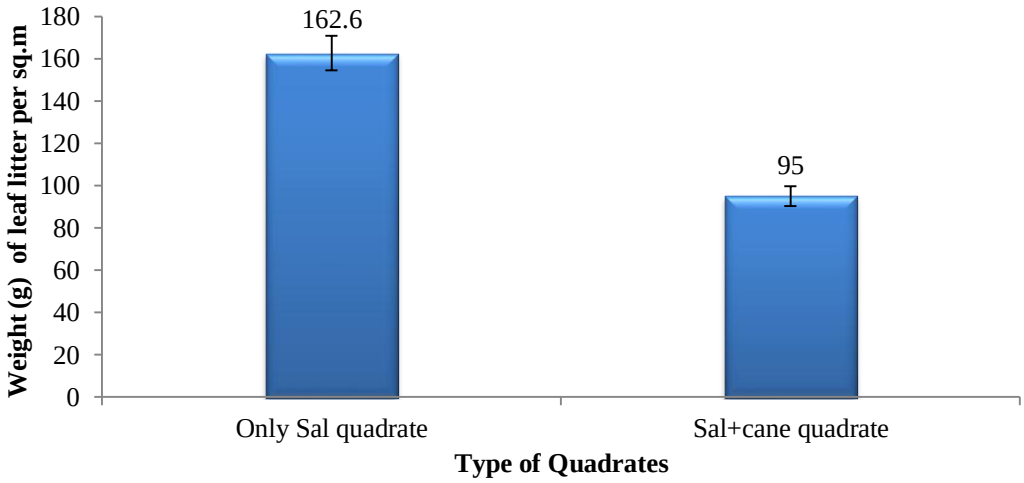

Figure - 4.12 Weight (g) of leaf litter per sq. m

4.9 Number of cane bush in Nawabganj Sal forest

To protect Sal forest, cane plantation was done as social forestry program in the Sal forest of Bangladesh. Though the program is successful, but it is not suitable for natural regeneration due to the bushy nature cane plantation. In the research work we found 12, 18, 35, 27, 48 cane bush in the quadrate1, quadrate2, quadrate3, quadrate4, quadrate5 respectively which were densely arranged and covered the whole quadrate (Fig. 4.13).

That was responsible for poor regeneration of Sal seeds for its bushy structure. For this reason, Sal seeds cannot get favorable condition as well as germination.

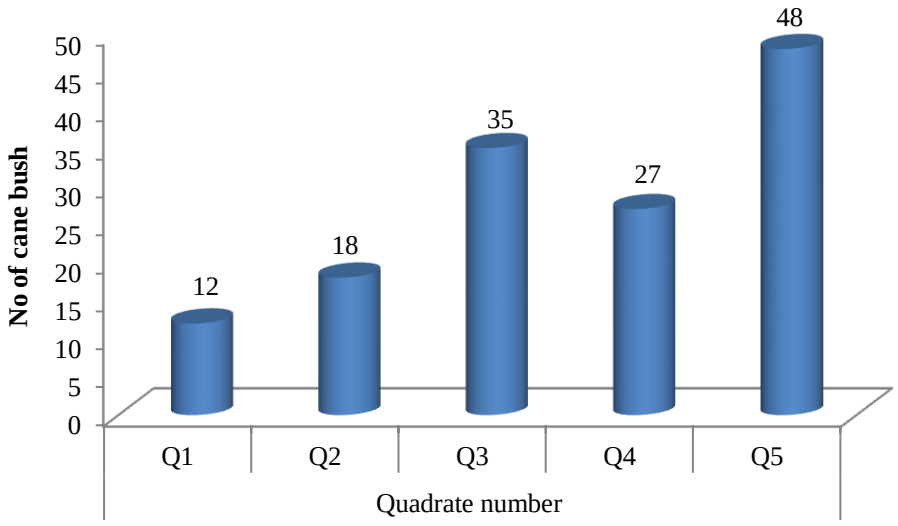

Figure - 4.13 Number of cane bush

4.10 Number of germinated Sal Seedlings in Nawabganj Sal forest

The number of germinated Sal seedlings found in Nawabganj Sal forest varied between quadrates of natural Sal and Sal with cane plantation. The quadrates of the natural Sal forests showed a higher number of Sal seedlings than the quadrates of Sal with cane plantation (Fig. 4.14). The average number of germinated Sal seedlings found in the Sal forest was significantly higher (368) than Sal with Cane plantation (51.2). The number of germinated Sal seedlings are decreasing due to cane plantation in the natural Sal forest which is responsible for poor regeneration of Sal seeds for its bushy structure. For this reason, Sal seeds cannot get favorable condition as well as germination. Even we found some quadrates without any germinated Sal seedlings where cane plantation was done with natural Sal forests for its high bushy structure.

Our study findings are consistent with the study of the coverage of the existing forests is decreasing at a rate of 2.1% per year (Choudhury 2003) and the growing stock is depleting at a rate of 3.38% per year (GOB 1992).

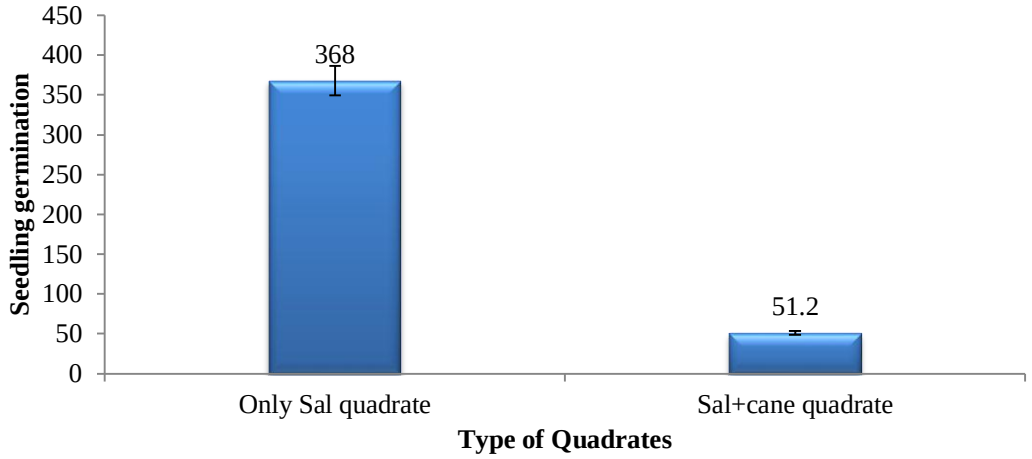

Figure - 4.14 Number of germinated Sal Seedlings

4.11 Average number of Sal trees per ha.

The number of Sal trees per ha. found in Sal forest varied between natural Sal forest and Sal with cane plantation. The natural Sal forests showed higher number of Sal seeds, Sal seedlings, Sal coppice seedlings, Sal trees than the forest of Sal with cane plantation. For this reason, the number of Sal trees was higher in natural Sal forests than Sal with cane plantation per ha. (Fig. 4.15). The average number of Sal trees found in the Sal forest was significantly higher (2022) than Sal with Cane plantation (1240). The number of Sal trees are decreasing due to cane plantation in the natural Sal forest which is responsible for poor regeneration of Sal seeds for its bushy structure.

The findings of our study are consistent with the study of Iftekhar, (2006) that was done on Forestry in Bangladesh: An Overview, found the forest area and growing stock were above 2 million ha. in 2001 and would be lower than 1 million ha. in 2050 in the future scenario of cover and growing stock of state forests.

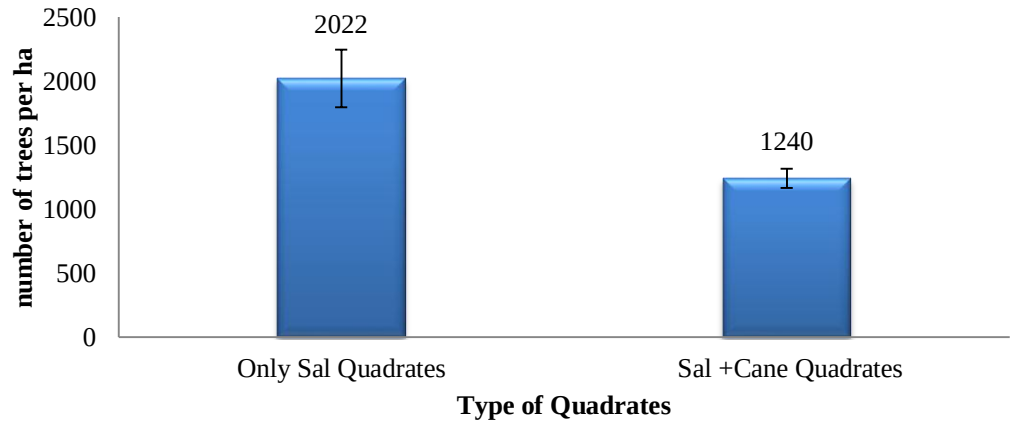

Figure - 4.15 Average number of Sal trees per ha.

4.12 Average volume (cft) of Sal tree per ha.

The average volume (cft) of Sal tree per ha. found in Sal forest varied between natural Sal and Sal with cane plantation. The natural Sal forests showed higher number of Sal seeds, Sal seedlings, Sal coppice seedlings, Sal trees than the forest of Sal with cane plantation. For this reason, the volume (cft) of Sal tree was higher in natural Sal forests than Sal with cane plantation (Fig. 4.16). The average volume (cft) of Sal trees found in the Sal forest was significantly higher (40882 cft) than Sal with Cane plantation (36351 cft). The volume of Sal trees is decreasing due to cane plantation in the natural Sal forest which is responsible for poor regeneration of Sal seeds for its bushy structure.

A study of Abedin, (2019) that was done on effect of highway's on Bhawal Sal forest areas of Bangladesh and found that if the distance increases from the road to the inside of the forest, trees with higher DBH were found. But the present study was conducted with average DBH of Sal trees and Sal with cane plantation.

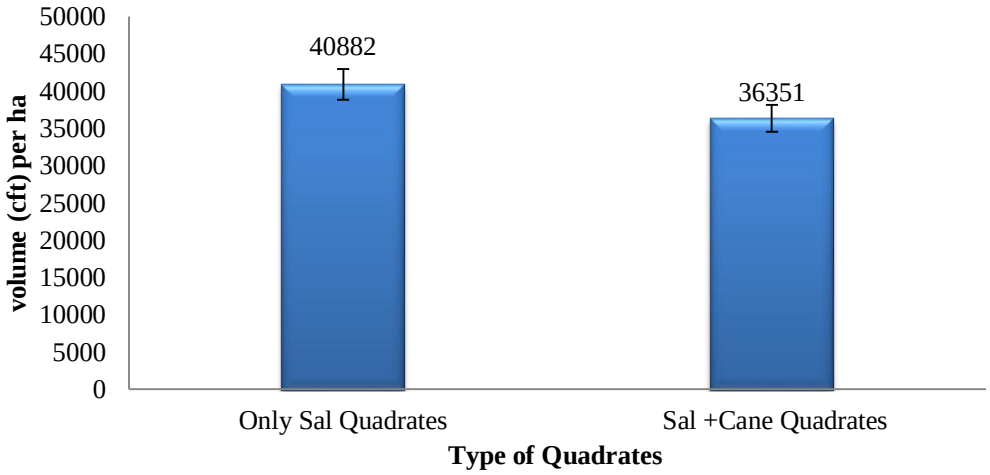

Figure - 4.16 Average volume (cft) of Sal tree per ha.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Sal (*Shorea robusta*) is the key tree species of the plain land Sal forests. Destructive anthropogenic and natural impacts coupled with overexploitation of forest resources have caused severe damage to the forest ecosystem. To protect Sal forest, cane plantation was done under the management of forest department as social forestry program but it was not suitable for natural regeneration due to the bushy nature of cane plantation. The overall results of the study revealed that all the growth parameters were decreased due to cane plantation in the natural Sal forest. The present status is better in the Nawabganj Sal forest than Singra Sal forest of Birganj. Because the average number of Sal trees, Sal seedlings, Sal coppice seedlings, germinated Sal seedlings, are higher and number of cane bush is lower in the Nawabganj Sal forest than Singra Sal forest of Birganj. Therefore, present study conveys the message to the policy makers for the future plan about the sustainability of Sal forest. For better management of Sal forest cane plantation at the floor of forest should be restricted immediately. Judicious management can save the Sal forest land and its resources.

5.2 Recommendations

Based on the present research results the following recommendation may be considered.

1. Encroachment and illicit removal of forest resources can be reduced to an extent by demarcation and protection of forest land through boundaries, canal excavation and buffer zone management.
2. For better management of Sal forest cane plantation at the floor of forest should be restricted immediately.
3. Natural management can save the Sal forest land and its resources.
4. To protect Sal forest cane plantation should be done around the Sal forest as boundary.

5. Protection zones in the name of National Parks and Eco Parks can be expanded and more recreational facilities can be provided to tourists by maintaining the unique biodiversity.

6. Where possible, replanting/vacancy filling with *Shorea robusta* and its natural associate species like *Terminalia bellerica, Dillenia pentagyna, Albizzia procera* and, *Lagerstroemia parviflora* should be examined. Naturally the Sal forest in Bangladesh harbours a large number of species of medicinal plants. Identification, protection and detailed study of the state of medicinal plants of the forest is also required.

7. Reforestation programs should be concluded around the Sal forest as social forestry program e.g. Akashmoni plantation, Bamboo plantation etc.

REFERENCES

Abdullah, H.M., Mahboob, M.G., Rahman, M.M. and Ahmed, T. (2015). Monitoring natural Sal forest cover in Modhupur, Bangladesh using temporal Landsat imagery during 1972–2015. Int. J. Environ. 5: 1-7.

Abedin, Z. (2019). Effect of highways on Bhawal Sal forest areas of Bangladesh. MS Thesis (Unpublished). Department of Agroforestry and Environment. HSTU. Dinajpur.

Alam, M., Furukawa, Y., Sarker, S. K. and Ahmed, R. (2008). Sustainability of Sal (*Shorea robusta*) forest in Bangladesh: past, present and future actions. International Forestry Review. 10(1): 29-37.

Al Faruq, M.A., Zaman, S. and Katoh, M. (2016). Analysis of Forest Cover Changes Using Landsat Satellite Imagery: A Case Study of the Madhupur Sal Forest in Bangladesh. Journal of Forest Planning. 21(2): 29-38.

Banglapedia. (2008). National encyclopedia of Bangladesh, Sal forest, Banglapedia. Retrieved February 10, 2009.

Banglapedia. (2015). National encyclopedia of Bangladesh, Sal forest, Banglapedia. Retrieved 15 March 2015.

BBS. (1996). Zila Series Tangail, Government of the People's Republic of Bangladesh.

Champion, H.G. and Seth, S.K. (1968). Forest Types of India, Government of India Publications, Delhi.

Champion, H.G., Seth, S.K. and Khattak, G.M. (1965). Forest Types of Pakistan, Pakistan Forestry Institute, Peshawar.

Choudhury, J.K. (2003). Country report—Bangladesh. P. 14-48 in An overview of forest policies in Asia, Enters, T., M. Qiang, and R.N. Leslie (eds.). EC-FAO partnership programme (2000-2002), European Commission and Food and Agriculture Organization, Rome.

Chowdhury, J.A. (2006). Towards better forest management. Oitijjhya Prokashoni, Dhaka, Bangladesh.

Chowdhury, M.S.H. and Koike, M. (2010). An overview on the protected area system for forest conservation in Bangladesh. Journal of Forestry research. 21(1): 111-118.

Chowdhury, R.A. (1994). History and Importance of Sal Forests and Current Management Status, In: Agroforestry for the degraded 'Sal' forest, Proceedings of national workshop held at Bangladesh Agricultural Research Council, BARC and Forest Department with the financial assistance of APAN, Dhaka.

Elouard, C. (1998). Pest and diseases of dipterocarpaceae. In: A review of dipterocarps*:* Taxonomy, ecology and silviculture. Appanah, S. and Turnbull, J.M. (Eds.), pp. 115-131. Center for International Forestry Research, Bagor, Indonesia.

FAO. (1998). Wood fuel in Bangladesh-production and marketing. Food and Agricultural Organization of the United Nations, Bangkok.

FAO. (2000). FRA 2000 Forest Resource of Bangladesh Country Report. Food and Agriculture Organization, Rome.

FAO. (2003). *State of World's Forests*. Food and Agriculture Organization, Rome, Italy.

FAO. (2005). State of the World's Forest 2005. Food and Agriculture Organization, Rome, Italy.

FMP. (1992). Forest Management. Forestry Master Plan. Ministry of Environment and Forest, Government of Bangladesh. UNDP/FAO BGD 88/025.

Gain, P. (1998). The last forest of Bangladesh. Society for Environment and Human Development (SEHD), Dhaka, Bangladesh.

Gain, P. (2005). Bangladesher Biponno Bon, Eds. (in Bengali), SEHD, Dhaka, Bangladesh.

Gani, C.Q., Alim, A. and Stevens, P.R. (1990). Rehabilitation and Land Use Planning of Sal Forests, part II. Forestry Sector Project Report (FAO/UNDP Project BGD/85/085). Bangladesh Forest Department, Dhaka.

Gautam, K. and Devoe, N. (2006). Ecological and anthropogenic niches of Sal (*Shorea robusta* Gaertn. f.) forest and prospects for multiple-product forest management a review. Forestry. 79: 81-101.

GOB. (1992). Forestry Master Plan (Participatory Forestry), Ministry of Environment and Forests, Peoples Republic of Bangladesh, Dhaka.

GOB. (1993). Forestry Master Plan (Main Plan), Ministry of Environment and Forests, Peoples Republic of Bangladesh, Dhaka.

GOB. (2007). Forest Department official website: http://www. bforest.gov.bd/agro.php, Dhaka: Government of People's Republic of Bangladesh. Accessed January 25, 2007.

Haque, N. (2007). Depletion of Tropical Forests with Particular Reference to Bangladesh. Retrieved February 10, 2009, from http://www.eb2000.org/ shortnote10.htm

Hossain, M.K. (2001). Overview of the Forest Biodiversity in Bangladesh in Assessment, Conservation and Sustainable Use of Forest Biodiversity. Secretariat of the Convention on Biological Diversity. Montreal. (CBD Technical Series no. 3).

Hossain, M.K. (2005). Conversion of dipterocarp-dominant natural forests to short rotation plantations- an unrecoverable threat to the native dipterocarps in Bangladesh, APAFRI, Malaysia.

Hossain, M.K. (2015). Silviculture of Plantation Trees of Bangladesh. Arannayk Foundation, Dhaka, Bangladesh, 361 pp.

Hossain, S. (1998). Participatory forest management in Bangladesh. Retrieved February 10, 2009, from http://www.iges.or.jp/en

Hossain, S. (1999). Participatory forest management in Bangladesh. Retrieved February 10, 2009, from http://www.iges.or.jp/en

Iftekhar, M.S. (2006). Forestry in Bangladesh: An Overview. Journal of Forestry. 104(3): 148-153.

Iftekhar, M.S. and Hoque, A.K.F. (2005). Causes of forest encroachment: An analysis of Bangladesh. GeoJournal. 62: 95-106.

INBAR (International Network for Bamboo and Rattan). (2001). Interplanting Rattans in Tree Plantations. Forest Research Institute Malaysia, Kepong, Kuala Lumpur, Malaysia. p. 6.

Islam, K. and Sato, N. (2012). Deforestation, land conversion and illegal logging in Bangladesh: the case of the Sal (*Shorea robusta*) forests. iForest-Biogeosciences and Forestry. 5(3): 171.

Islam, M., Salim, S.H., Kawsar, M.H. and Rahman, M. (2016). The effect of soil moisture content and forest canopy openness on the regeneration of *Dipterocarpus turbinatus* CF Gaertn (Dipterocarpaceae) in a protected forest area of Bangladesh. Tropical Ecology. 57(3): 455-464.

Kabir, D.S. and Ahmed, A.Z. (2005). Wildlife Biodiversity in Bhawal National Park: Management Techniques and Drawbacks of Wildlife Management and, Nature Conservation. Our Nature. 3: 83-90.

Keshav, S.K. and Naithani, S.C. (2013). Seed biology lab school of science – Pandit Ravishankar University Raipur "Die back in Sal seedling."

Khan, N.A. (1998). A political economy of forest resource use: Case studies of social forestry in Bangladesh. Ashgate Publishing Ltd. Aldershot.

Khan, N.A. (2003). Regional study of forest policy and institutional reform final report of the Bangladesh case study. Asian Development Bank, Mandaluyong City.

Khosla, P.K. and Parmar, Y.S. (1988). Studies on the effect of particulate air pollution on Sal (*Shorea robusta*) forest ecosystem. Retrieved February 10, 2009, from http://envfor.nic.

Mehrotra, A. (2001). Cylindrocladium leaf spotting and blight, a new disease of *Shorea robusta*. Indian Journal of Forestry. 10: 267-274

Motiur, M.R. (2006). Management and economics of homestead forests in Bangladesh. PhD thesis submitted to United Graduate School of Agricultural Sciences, Ehime University, Matsuyama, Japan.

Pandey, C.B. (1994). Influence of grazing on soil properties and tree sapling in a dry tropical savanna in India. Range Management and Agroforestry. 15: 69-77.

Rahman, M.M. (2005). Management and economics of homestead forests in Bangladesh. PhD thesis submitted to United Graduate School of Agricultural Sciences, Ehime University, Ehime.

Rahman, M.S. (2017). Gazettian (chapter) of Dinajpur District of Bangladesh.

Roy, M.K. (2004). Designing a Co-management Model for Protected Areas in Bangladesh. International seminar on Protected Area Management, University of Montana, USA.

Safa, M.S. (2005). Poverty-environment interaction through participatory forest management in Bangladesh: an evidence of poverty reduction, Published in: 17th Commonwealth Forestry Conference Proceedings. Colombo, Sri Lanka.

Salam, A.M., Noguchi, T. and Koike M. (1999). The causes of forest cover loss in the hill forest in Bangladesh. Geo. Journal. 47: 539-549.

Salam, M.A. and Noguchi, T. (2005). On Sustainable Development of Social Forestry in Bangladesh: Experiences from Sal (*Shorea robusta*). Forests, Environment, Development and sustainability 7:209-227.

Tewari, D.N. (1995). A Monograph on Sal (*Shorea robusta Gaertn. f.*) International Book Distributors, Dehradun. pp 26-27.

UNEP. (2001). Bangladesh: state of the environment, Dhaka, Bangladesh.

Utkarsh, G. (1998). The Sal borer epidemic on Madhya Pradesh questions in ecology and politics; decision, Centre for Ecological Sciences, Indian Institute of Science, Banglore, India.

Wikipedia contributors. (2018). Cane plants. In Wikipedia, The Free Encyclopedia. Retrieved 08:57, October 17, 2018.

Wikipedia contributors. (2019). Dinajpur district. In Wikipedia, The Free Encyclopedia. Retrieved 09:35, September 11, 2019.

APPENDICES

Appendix I

Dinajpur Sal forest:

Singra Sal forest in Birganj:

1. Number of big Sal trees greater than 3 feet height : Descriptive analysis

Variables	N	Mean	SE Mean	C.V.
Only Sal quadrate	5	78.8	4.0175	11.4
Sal + Cane quadrate	5	49.6	3.5581	16.041

2. Number of Sal seedlings less than 3 feet height : Descriptive analysis

Variables	N	Mean	SE Mean	C.V.
Only Sal quadrate	5	474.4	27.081	12.764
Sal + Cane quadrate	5	38.4	18.659	108.65

3. Number of Sal coppice seedlings less than 3 feet height : Descriptive analysis

Variables	N	Mean	SE Mean	C.V.
Only Sal quadrate	5	71.2	8.0399	25.25
Sal + Cane quadrate	5	7.2	3.2	99.381

4. Number of Sal seeds / sq. m : Descriptive

Variables	N	Mean	SE Mean	C.V.
Only Sal quadrate	5	3.4	0.2449	16.109
Sal + Cane quadrate	5	1.2	0.3742	69.722

5. Weight of leaf litter/ sq. m : Descriptive analysis

Variables	N	Mean	SE Mean	C.V.
Only Sal quadrate	5	160.6	12.424	17.298
Sal + Cane quadrate	5	95.6	6.4931	15.187

6. Number of germinated seedlings of Sal : Descriptive analysis

Variables	N	Mean	SE Mean	C.V.
Only Sal quadrate	5	310.4	31.435	22.645
Sal + Cane quadrate	5	37.6	20.692	123.06

7. Number of cane bush :

System	No. of cane bush					Avg. Number
	Q1	Q2	Q3	Q4	Q5	
Only Sal quadrate						
Sal+cane quadrate	15	20	33	40	35	28.6

Nawabganj Sal forest:

1. Number of big Sal trees greater than 3 feet height : Descriptive analysis

Variables	N	Mean	SE Mean	C.V.
Only Sal quadrate	5	89.4	5.02	12.55
Sal + Cane quadrate	5	49.6	5.31	23.92

2. Number of Sal seedlings less than 3 feet height : Descriptive analysis

Variables	N	Mean	SE Mean	C.V.
Only Sal quadrate	5	445	58.91	29.6
Sal + Cane quadrate	5	63.6	36.58	128.59

3. Number of Sal coppice seedlings less than 3 feet height : Descriptive analysis

Variables	N	Mean	SE Mean	C.V.
Only Sal quadrate	5	71.2	8.04	25.25
Sal + Cane quadrate	5	19.8	9.66	109.05

4. Number of Sal seeds / sq. m : Descriptive analysis

Variables	N	Mean	SE Mean	C.V.
Only Sal quadrate	5	3.8	0.37	22.02
Sal + Cane quadrate	5	1	0.45	100

5. Weight of leaf litter/ sq. m : Descriptive analysis

Variables	N	Mean	SE Mean	C.V.
Only Sal quadrate	5	162.6	32.34	44.48
Sal + Cane quadrate	5	95	3.54	8.32

6. Number of germinated seedlings of Sal : Descriptive analysis

Variables	N	Mean	SE Mean	C.V.
Only Sal quadrate	5	368	20.86	12.68
Sal + Cane quadrate	5	51.2	26.00	113.54

7. Number of cane bush :

System	No. of cane bush					Avg. Number
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	
Only Sal quadrate						
Sal+cane quadrate	12	18	35	27	48	28

Descriptive Statistics of V006 by V001

7. Volume (cft) per ha of Only Sal Quadrates :

Only Sal Quadrates	N	Volume (cft) per ha	SD	Variance	SE Mean	C.V.
Q1	3	28846	12475	1.556E+08	7202.2	43.25
Q2	3	47640	25455	6.479E+08	14696	53.43
Q3	3	42990	17249	2.975E+08	9958.7	40.12
Q4	3	45547	22336	4.989E+08	12895	49.04
Q5	3	39385	18379	3.378E+08	10611	46.67
Average	3	40882	19179	387540000	11073	47

8. Number of trees per 400 sq. m quadrate of Only Sal Quadrates :

Only Sal Quadrates	N	Number of trees per 400 sqm quadrate	SD	Variance	SE Mean	C.V.
Q1	3	84.67	16.74	280.33	9.67	19.78
Q2	3	78.67	10.07	101.33	5.81	12.80
Q3	3	76.67	24.85	617.33	14.35	32.41
Q4	3	86.67	19.01	361.33	10.98	21.93
Q5	3	77.67	7.37	54.33	4.26	9.49
Average	3	80.87	15.61	282.93	9.01	19.28

9. Volume (cft) per ha. of Sal + Cane Quadrates :

Sal + Cane Quadrates	N	Volume (cft) per ha	SD	Variance	SE Mean	C.V.
Q1	2	42702	1321.6	1.75E+06	934.5	3.09
Q2	2	41768	4147.2	1.72E+07	2932.5	9.93
Q3	2	33464	3630.3	1.32E+07	2567	10.85
Q4	2	35235	8644.4	7.47E+07	6112.5	24.53
Q5	2	28586	3153.7	9.95E+06	2230	11.03
Average	2	36351	4179.44	23360600	2955.3	11.89

10. Number of trees per 400 sq. m quadrate of Sal +Cane Quadrates :

Sal + Cane Quadrates	N	Number of trees per 400 sq. m quadrate	SD	Variance	SE Mean	C.V.
Q1	2	62.5	3.5355	12.5	2.5	5.66
Q2	2	55	0	0	0	0.00
Q3	2	45	7.0711	50	5	15.71
Q4	2	46.5	2.1213	4.5	1.5	4.56
Q5	2	39	8.4853	72	6	21.76
Average	2	49.6	4.24264	27.8	3	9.54

Appendix II

A Field Observation Sheet

Impact of Cane plantation on the regeneration of Sal *(Shorea robusta)* forest: a case study of Dinajpur Sal forest

Quadrat No:

Size	**20m**
20 m	Quadrate =Sal+Cane

Total no of Sal trees:

a) no of Big trees:

b) No of seedlings <3 ft. height:

c) No of coppice seedlings< 3ft height:

No of cane bush:

No of Sal seeds found per sq.m=

Weight of leaf litter per sq.m=

Size	**20m**
20 m	Quadrate =Only Sal

Tree girth and height per 20m* 20 m quadrat

1	girth (inch)	Height (ft.)
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Name of surveyor

Appendix III

Some Plates of the Research

Figure: Data Collection




Figure: Data Collection

Figure: Sal forest