STUDY REPORT

Evaluation of SMC Measures at Three Divisional Management Units (DMUs) Under Odisha Forestry Sector Development Project (OFSDP)

Supported by

Odisha Forestry Sector Development Project (OFSDP)
Bhubaneswar, Odisha

Central Soil & Water Conservation Research & Training Institute (CSWCRTI)
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Impact of SMC Measures Under Odisha Forestry Sector Development Project

CSWCRTI, Research Centre, Koraput, Odisha

STUDY REPORT

2014

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FOREWARD

Soil, water, vegetation, etc are the vital natural resources to support the livelihood security of 55% of our population. Conservation and upkeep of these resources without further degradation are the responsibility of each one of us to ensure a better living for our future generation. The extent of land degradation in Odisha state is about 3.72 M ha, which is about 25% of the total geographical area accounting per capita degraded land of 0.088 ha against 0.14 ha of net sown area and 0.13 ha forest and tree cover area. Land degradation constitutes one of the greatest threats for food and environmental security. Degradation of soil and/or vegetative cover is caused by a variety of anthropogenic pressures including development of big hydro-power projects, deforestation, over-grazing, unsustainable agricultural practices and industrial activities. Clearing of forest vegetation by tribal community for practicing shifting cultivation in the tribal dominated state of Odisha leading to loss of vegetation cover and biodiversity is the major concern.

Community participation through Joint Forest Management approach yielded significant impact both on forest protection and livelihood security of the forest dependant rural community. The good effort of State Forest Department under Odisha Forestry Sector Development Project (OFSDP) in improving the forest cover and living standard of the community through Van Samrakshna Samiti (VSS) at village level following community participation is worthy towards achieving ultimate goal of National Forest Policy. This study report presents the impacts of soil moisture conservation measures on performance of different forest land uses at three Divisional Management Units (DMUs) Under OFSDP. The field study information provides valuable information on role and importance of soil and water conservation measures in forest plantations and may useful to the wider section of the people who are working in the field of forest plantation. I acknowledge the support of OFSDP for this study and hard work of the study team.

December 5, 2014
Dehradun

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FOREWARD

Land, water and forest are the most precious natural resources, the importance of which in human civilization needs no elaboration. Sustainable management of the natural resource with ecosystem approach is essentially required for maintaining the ecological balance and human wellbeing. As per the State of Forest Report 2013, published by the Forest Survey of India, Ministry of Environment and Forests, Government of India, is concerned, the forest covers area in Odisha state accounts for 50,347 km2, which is 32.33 per cent of the total geographical area of the state. The decadal growth rate of forest has shown significant increase in the state, but the growth rate varied greatly amongst the districts of the state. The pressure on forest and land is increasing day by day, due to various developmental activities. The change in need and lifestyle of the local communities have further increased dependency on forest resources for their livelihood security leading to degradation of forest ecosystem, which is adversely impacting the flow of ecosystem services and life support system of local communities. The Odisha Forestry Sector Development Project (OFSDP) is launched with the support from the Japan International Cooperation Agency (JICA) with an objective to restore and halt the degradation of forests and improve the livelihood opportunity of local communities with their active participation. One of the important physical interventions under the project has been the Soil and Moisture Conservation (SMC) to improve the moisture regime and reduction of soil erosion to improve the health of degraded forests. Moisture levels in soils are crucial to plant and soil health.

This study report presents the impact of SMC measures on soil, vegetation and carbon sequestration potential due to the intervention under the project in three project divisions, viz. Rayagada, Koraput and Jeypore. While acknowledging the excellent work by CSWCRTI, Research Centre, Sunabeda, Koraput, I am sure the outcome of the study and the recommendations would be extremely useful for under taking soil and moisture conservation works in the degraded forests of the state.

December 5, 2014
Bhubaneswar

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Executive Summary

The degradation of forest has resulted into the vicious poverty cycle wherein absence of livelihood options encouraged the local people for more and more removal of forest produce in an unsustainable manner leading further degradation of forest with spread of poverty and unemployment. The Odisha state government has launched the Odisha Forestry Sector Development Project (OFSDP) with the support of Japan International Cooperation Agency (JICA) with the overall goal of restoration of degraded forests and improve the income level of villagers by promoting sustainable forest management on JFM mode and community/tribal development, with the improving environment and alleviating poverty of the community.

In order to restoration of degraded forests (Forest Management under JFM & Non-JFM Mode & Farm Forestry), OFSDP has planned and implemented activities like Assisted Natural Regeneration (ANR), Block Plantation with teak (BP), Non-Timber Forest Products (NTFP), fuel and fodder species in Joint Forest Management and artificial regeneration have been implemented in eight districts of Odisha through Van Samrakshna Samiti (VSS) at village level under each Divisional Management Unit (DMU). Soil and Moisture Conservation (SMC) measures like trenching (Staggered and continuous), basin work for each plant/seedling at plantation sites and gully control measures like loose boulders check dams (LBCDs) in the gullies/streams which are adjacent to the plantation sites were implemented for conserving the rainwater and reducing soil erosion from the degraded forest areas. The CSWCRTI, Research Centre has taken up a consultancy study for evaluation of SMC measures in three DMU namely Koraput, Jeypore and Rayagada by selecting five VSS from each DMU. The study aims to assess the impact of SMC measures on growth performance of plantation, soil moisture content, runoff, soil lose, soil properties, microbial biomass, etc., under Assisted Natural Regeneration (ANR), Block Plantation with teak (BP), Non-Timber Forest Products (NTFP), other plantations like bamboo, fuel and fodder in JMF areas implemented by OFSDP.

A total of 15 sites were selected for the study covering Koraput, Jeypore and Rayagada forest divisions. There are five sites (VSS) from each forest division. The climate is hot and moist sub humid in Rayagada, where in warm and humid climate in Koraput and Jeypore. The normal annual rainfall is 1599 mm and 1522 mm received mainly during monsoon season in Rayagada and Koraput, respectively. The technical plan of the study was finalised in presence of RCCF, DFOs, APDs, ACFs, Resident Consultant of OFSDP and the study team of CSWCRTI, RC, Sunabeda on November 1st, 2012 at CSWCRTI, Research Centre, Sunabeda, Koraput. Accordingly, a total of 15 sites were selected from three forest divisions namely Koraput, Rayagada and Jeypore.

There are five study sites from each forest division covering the plantation year's viz., 2008,2009,2010,2011 and 2012. The study sites were selected based on year of plantation, plantation types with SMC measures and rainfall distribution pattern. Sites were selected after preliminary discussion with the concerned forest divisions. Hydrological monitoring was carried out from five sites covering all the plantation years i.e., 2008 to 2012 and located at Koraput, Rayagada and Jeypore DMU.A two day capacity building training programme on "Hydrological Monitoring" was organized at CSWCRTI, Research Centre, Sunabeda, Koraput for the Animators and members of five selected VSS. Hydrological data viz., rainfall, runoff, soil loss, infiltration study, deposition of silt behind the gully control structure was collected during the study period to assess the impacts. Soil sampling was done at two depths (0-20 & 20-40 cm) from all the 15 sites for assessing physical, chemical and biological properties of soil. The performance of block plantation of teak and NTFP species was assessed through their survival rate (Initial & final), height and basal diameter. The land slope varied between 5.2% and as high as 42.44% in the study sites. The physical health of all the sites is medium to good in terms of plant growth in spite of their position in high slope. Among the various forest land uses, NTFP showed good soil physical health followed by ANR+Gap Plantation. Due to the balance amount of sand, silt and clay in the soils of ANR+Gap Plantation sites are having good soil physical health. The opposite trend has been observed for the ANR without Gap Plantation land use. The soil moisture content at FC varied between 14.2 % and 38.8 % with the average value of 25.2 %. A well distributed and textured soil found in the land use ANR+Gap Plantation has made the condition conducive for plant growth by providing more water easily.

The overall variation of soil pH is following the trend of ANR+GP>NTFP>BP>ANR without Gap Plantation. Therefore, ANR+Gap Plantation and NTFP showed its potentiality to neutralize soil acidity. The DHA of surface soil is higher than sub-surface soil for all the land uses. NTFP and ANR+Gap Plantation showed significantly higher DHA than BP and ANR without Gap Plantation. The overall fertility status of all the land uses is medium to good and followed the trend of NTFP> ANR+Gap Plantation>BP>ANR without Gap Plantation. The sites of NTFP showed higher soil organic carbon than all other land use. Therefore, it's desirable that all the forest land uses to be protected from any type of biotic and abiotic disturbances. SMC measures help in a substantial amount to achieve this purpose. The amount of microbial biomass carbon is also following the trend that of SOC i.e., NTFP> ANR+Gap Plantation >Black Plantation>ANR without Gap Plantation. Continuous litter deposition and root growth in addition to higher soil moisture content have made the ANR+Gap Plantation and NTFP sites more conducive for the growth and development of microorganisms.

At all the study sites average runoff was minimum under ANR+Gap Plantation followed NTFP, BP and it was maximum under ANR-without Gap Plantation. The block plantation of teak was done mostly on degraded sites devoid of vegetation cover and poor soil properties contributed to the more runoff than the other forest vegetation land use systems. RWCE under ANR+Gap Plantation was the highest (81.55%) followed by NTFP (45.86%) and block plantation (31.84%). Among the five hydrological monitoring sites, second phase plantation (2009) at Santabadigaon conserved more rainwater followed by first phased plantation (2008) at Maliguda, Khudpee (2011), Bhitarguda (2012) and Gunthaguda (2010). Soil loss varied between 159 to 537 kg/ha under ANR+Gap Plantation, 350 to 1125 kg/ha under NTFP, 1145 to 1725kg/ha under the block plantation of teak and 2506 to 2979 kg/ha under ANR-without Gap Plantation across the five different sites. The average soil loss under ANR+Gap Plantation was the littlest of 88% compared to ANR-without Gap Plantation.

The average depth of silt deposition behind the LBCD during 2013 varied between 2.33 cm at Santabadigaon and 5.21 cm at Maliguda in Jeypore DMU. The average silt deposition in all the structure since from their construction was in the range of 7.8 cm to 23.8 cm behind the structure with the average silt retention rate per structure per year was ranged between 0.6 cum at Khudpee (0.6 cum/year) in Jeypore DMU and it was maximum of 9.24 cum/year observed in Gunthaguda at Koraput DMU. The average cost of retention of silt varied between Rs.196/- and Rs.581/- per cum with the overall average cost of Rs.375/- per cum. The land slope varied between 5.2% and as high as 42.44% in the study sites. The physical health of all the sites is medium to good in terms of plant growth in spite of their position in high slope. Among the various forest land uses, NTFP showed good soil physical health followed by ANR+Gap Plantation. Due to the balance amount of sand, silt and clay in the soils of ANR+Gap Plantation sites are having good soil physical health. The opposite trend has been observed for the ANR without Gap Plantation land use. The soil moisture content at FC varied between 14.2 % and 38.8 % with the average value of 25.2 %. A well distributed and textured soil found in the land use ANR+Gap Plantation has made the condition conducive for plant growth by providing more water easily.

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Teak is planted in all the selected study sites except in two VSS namely Alubadi and Gunthaguda in Rayagada and Koraput DMU, respectively. The average initial survival percent varied between 65% at Harishchandraguda (Jeypore) and 100% at Khudpee (Jeypore) with the overall survival rate of 87%. The final survival percent was highest at Khudpee (100%) followed by Bhaliabhata (93%), Badapukel (93%), Malikarchi (93%) Maliguda (92%) and Chintalguda (91%). Under NTFP the species like Simarouba glauca (Simarouba), Pongamia pinnata (Karanj), Cassia obtusifolia (Chakunda), Gmelina arborea (Gamhar), Emblica officinalis (Aonla), Anacardium occidentale (Cashew) and Acacia auriculiformis (Acacia) were planted in the selected study sites. The initial survival percent varied between 28% and 100%, the final survival percent was varied from 33% to 100%. The overall survival rate of all the species was ranged from 46% at Harishchandraguda to 80% at Timajhola (Koraput DMU).

The better performance of survival rate was noticed in Timajhola (Koraput DMU) followed by Badapukel (Rayagada) and Bhaliabhata (Rayagada). The survival rate of all the NTFP planted species was better for Accacia and Cashew. Different planting phase wise survival percent of NTFP species revealed that, lower rate of survival of afforested species was observed for the year 2012 followed by 2011 and 2010. The first and second phase plantations were good with respect to survival rate. The maximum incremental in height was observed in Cassia (1.2m) followed by Simarouba (1.7m), Karanj (0.7m) and Gamhar (0.8m). The slow growth rate was observed in Accacia, Cashew and Aonla. The species like Karanj, Aonla and Cashew showed lower range of basal diameter. The maximum incremental growth of basal diameter was observed in Cassia (4.5 cm) followed by Accacia (29%), Gamhar (29%) and Simarouba (27%). However, the percent increase in basal diameter over initial diameter was maximum in Karanj (47%) followed by Anola (36%), Cassia (30%) and Simarouba (26%).

In order to have cumulative effect of forest management activities, all the planned activities are to be taken up on micro-catchment area/micro-watershed basis. Block plantation of teak may be replaced with NTFP on degraded sites to improve the soil condition and to enhance diversity of vegetation with suitable SMC measures. Planting on degraded sites require micro-site condition improvement through the addition of organic materials or good soil or use of water absorbing polymers to increase water holding capacity of soil. All the activities are to be implemented on micro-watershed/catchment basis to have cumulative impacts. The chapter 1.0 and 2.0 presents the background information and detailed description of the study area under OFSDP. Methodology adopted for impact assessment of SMC is presented in chapter 3.0. The detailed impact of SMC measures is presented in chapter 4.0. Salient findings and recommendations are detailed in chapter 5.0.

Summary of parameter wise performance matrix table for different forest land uses

S.No	Parameter	ANR+GP					ANR-GP					BP					NTFP				
		2008	2009	2010	2011	2012	2008	2009	2010	2011	2012	2008	2009	2010	2011	2012	2008	2009	2010	2011	2012
1	Slope	L	M	H	H	H	L	M	H	H	H	L	L	M	L	H	L	M	H	H	H
2	Runoff	L	L	H	M	L	M	L	M	M	L	M	M	M	M	M	M	L	M	M	L
3	Soil loss	L	L	L	L	L	H	H	H	H	H	M	M	M	M	M	L	L	H	L	L
4	Bulk Density	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
5	Soil Texture	p	M	M	G	P	G	P	G	G	G	G	M	G	M	P	M	G	G	G	P
8	pH	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
9	EC	M	M	H	M	M	L	M	M	L	L	M	M	M	M	M	M	M	M	M	H
10	Nitrogen	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	M	L	L	M	L
11	Phosphorus	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
12	Potassium	H	H	H	H	H	M	H	H	L	M	M	H	H	H	H	M	H	H	H	H
13	Soil Organic Carbon	H	H	H	H	H	H	H	M	H	L	H	H	H	H	L	H	H	H	H	H
14	Soil Carbon Stock	M	M	M	M	M	L	L	L	L	L	L	L	L	L	L	H	H	H	H	H
15	Microbial Biomass Carbon	H	H	H	H	H	H	H	M	H	L	H	H	H	H	L	H	H	H	H	H
16	Dehydrogenase Activity	H	M	M	H	H	M	H	L	L	L	H	L	L	H	L	H	H	H	H	H
17	Overall Soil Physical Prop.	P	M	M	G	P	G	P	G	G	G	G	M	G	G	P	M	G	G	G	P
18	Overall Soil Chemical Prop.	M	M	M	M	M	M	M	M	P	M	M	M	M	M	P	M	M	M	M	M
19	Overall Soil Biological Prop.	G	M	M	G	G	G	G	P	M	P	G	M	M	G	P	G	G	G	G	G
20	Total Score	33	32	28	33	32	30	29	25	26	24	31	29	29	32	22	35	35	32	35	32
21	Maximum score	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
22	Performance Index (PI)	0.79	0.76	0.67	0.79	0.76	0.71	0.69	0.6	0.62	0.57	0.74	0.69	0.69	0.76	0.52	0.83	0.83	0.76	0.83	0.76
23	Mean PI	0.75					0.64					0.68					0.80				

L:Low ; M:Medium; H:High ; G:Good ; P: Poor

Summary Note: Forest land use wise data of different parameters were assessed and rated. The parameter with green background denotes the higher performance with the score of 3; yellow background denotes the medium performance with the score of 2 and red background denotes the poor performance with the score of 1. The performance index is the ratio of score obtained to the maximum possible score. The overall performance revealed that NTFP and ANR+GP performed better and the performance of Block Plantation and ANR without GP is medium.

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Abbreviations used in the report

ACF	:	Assistant Conservator of Forest
AET	:	Actual Evapotranspiration
ANR	:	Assisted Natural Regeneration
APD	:	Assistant Project Director
BP	:	Block Plantation
CSWCRTI	:	Central Soil &Water Conservation Research & Training Institute
Cum	:	Cubic Meter
DFO	:	Divisional Forest Officer
DG	:	Director General
DHA	:	Dehydrogenese Activity
DMU	:	Divisional Management Unit
EC	:	Electrical Conductivity
F	:	Final
FC	:	Field Capacity
FMU	:	Field Management Unit
I	:	Initial
ICAR	:	Indian Council of Agricultural Research
JFM	:	Joint Forest Management
JFMC	:	Joint Forest Management Committee
JICA	:	Japan International Cooperation Agency
K	:	Potassium
L	:	Lower
LBCD	:	Loose Boulder Check Dam
LGP	:	Length of Growing Period
M	:	Middle
MBC	:	Microbial Bio-mass Carbon
MoU	:	Memorandum of Understanding
MSD	:	Multi Slot Deviser
N	:	Nitrogen
NFP	:	National Forest Policy
NRM	:	Natural Resource Management
NTFP	:	Non Timber Forest Products
OC	:	Organic Carbon
OFSDP	:	Odisha Forestry Sector Development Project
P	:	Phosphorus
PET	:	Potential Evapotranspiration
PWP	:	Permanent Wilting Point
RC	:	Research Centre
RCCF	:	Regional Chief Conservator of Forest
SMC	:	Soil Moisture Conservation
SMCC	:	Soil Moisture Characteristic Curve
SOC	:	Soil Organic Carbon
TOC	:	Total Organic Carbon
TTC	:	Triphenyl Tetrazolium Chloride
U	:	Upper
VSS	:	Van Samrakshna Samiti
WD	:	Water Deficit
WS	:	Water Surplus

Common/Local Name	Scientific Name
Accacia	*Acacia auriculiformis*
Aonla	*Emblica officinalis*
Asan	*Terminalia tomentosa*
Bahada	*Terminalia bellirica*
Cashew	*Anacardium occidentale*
Chakunda	*Cassia obtusifolia*
Dhaura	*Anogeissus latifolia*
Gamhar	*Gmelina arborea*
Jamun	*Syzygium cumini*
Kasi	*Bridelia retusa*
Kendu	*Diospyros melanoxylon*
Kurum	*Schleichera oleosa*
Mahul	*Madhuca latifolia*
Moi	*Lannea coromandelica*
Mundi	*Mitragyna parvifolia*
Piasal	*Pterocarpus marsupium*
Pitamal	*Syzygium operculatum*
Karanj	*Pongamia pinnata*
Sal	*Shorea robusta*
Salai	*Boswellia serrata*
Semul	*Bombax ceiba*
Sidha	*Lagerstroemia parviflora*
Simarouba	*Simarouba glauca*
Sisoo	*Dalbergia sissoo*

1.0 Introduction

1.1 Background

The Odisha state government has launched the Odisha Forestry Sector Development Project (OFSDP) with the support from Japan International Cooperation Agency (JICA). The major objective of the project is to restore degraded forests and improve the income level of villagers by to promoting sustainable forest management JFM and community/tribal development, with the improving environment and alleviating poverty of community is the overall goal.

The degradation of forest has resulted into the vicious poverty cycle wherein absence of livelihood options encouraged the local people for more and more removal of forest produce in unsustainable manner leading further degradation of forest with spread of poverty and unemployment. Thus the project is necessary for improving the living condition of the people residing in and around the forest by providing them livelihood options consistent with conservation of forest and its sustainable management. This is consistent with the development policy of the state particularly in forestry sector and in accordance with National Forest Policy (NFP). Conservation of forest resources and its sustainable management in supporting livelihood to people living in and around the forest besides amelioration of environment is well recognized.

In order to restoration of degraded forests (Forest Management under JFM & Non-JFM Mode & Farm Forestry), OFSDP has planned and implemented activities like Assisted Natural Regeneration (ANR), Block Plantation with teak (BP), Non-Timber Forest Plantation (NTFP) and artificial regeneration in eight districts of Odisha through Van Samrakshna Samiti (VSS) at village level under each Divisional Management Unit (DMU). Soil & Moisture Conservation (SMC) measures like trenching (Staggered and continuous), basin work for each plant/seedling at plantation sites and gully control measures like loose boulders check dams (LBCDs) in the gullies/streams which are adjacent to the plantation sites were implemented for conserving the rainwater and reducing soil erosion from the degraded forest areas. OFSDP has requested the CSWCRTI, Research Centre for evaluation of SMC measures in three DMU namely Koraput, Jeypore and Rayagada by selecting five VSS from each DMU. The CSWCRTI accepted the offer to carry out the impact evaluation of SMC measures from 15 sites covering three DMUs on consultancy basis.

1.2 Scope and Objectives

The conservation and sustainable use of natural ecosystems and biodiversity is essential to support sustainable development with biological resources providing raw materials for livelihoods, sustenance, trade, medicine and industrial development. Protecting forests and other natural ecosystems can provide a host of services that reduce human vulnerability to natural hazards along with the benefits of global value such as carbon sequestration, hydrological and geochemical cycling of essential elements etc. Protected areas, which form the corner stone of biodiversity and the natural habitats within them, can protect watersheds and regulate the water flow, prevent soil erosion, influence the rainfall regime and local climate, conserve genetic reservoirs etc. Richness of biodiversity is fundamental to agricultural production and food security besides being a valuable ingredient of environmental conservation.

With the above points in view, the study aims to assess the impact of SMC measures on growth performance of plantation, soil moisture content, runoff, soil lose, soil properties, microbial biomass, carbon sequestration potentials etc., under Assisted Natural Regeneration (ANR), Block Plantation with teak (BP), Non-Timber Forest Plantation (NTFP) implemented by OFSDP.

The following are the major objectives of this study

- Technical assessment of soil and moisture conservation measures taken up in the VSS area (would include hills, slopes and foot hills/plain or sloping land in degraded and not-so degraded sites)
- Impact of SMC measures on survival and growth parameter of plantation under block plantation and NTFP.
- Assessment of silt deposition data and soil moisture content during the study period.
- Advice and design of appropriate SMC measures for VSS area in OFSDP being treated through ANR (Assisted Natural Regeneration) and Block Plantations

1.3 MoU and Terms of References

This study is aimed at evaluating the impact of SMC measures on silt deposition, moisture retention, survival and growth parameter of plantation besides designing cost effective SMC measure for the future.

The work envisaged shall include:

- The CSWCRTI involvement would be in survey, evaluation, redesign of soil and water conservation measures in consultation with Odisha Forestry Sector Development Project, Govt of Odisha.
- Base maps of the area and other required technical information shall be provided by OFSDP.
- The task will be carried out in the three forest divisions namely Koraput, Jeypore and Rayagada and five VSS (JFMC) sites in each Division.

A copy of the MoU signed between CSWCRTI and the OFSDP is appended in Appendix I.

2.0 Description of study sites

2.1 Location

A total of 15 sites were selected for the study covering Koraput, Jeypore and Rayagada forest divisions. There are five sites (VSS) from each forest division. The forest division wise locations details are presented in figure 2.1.

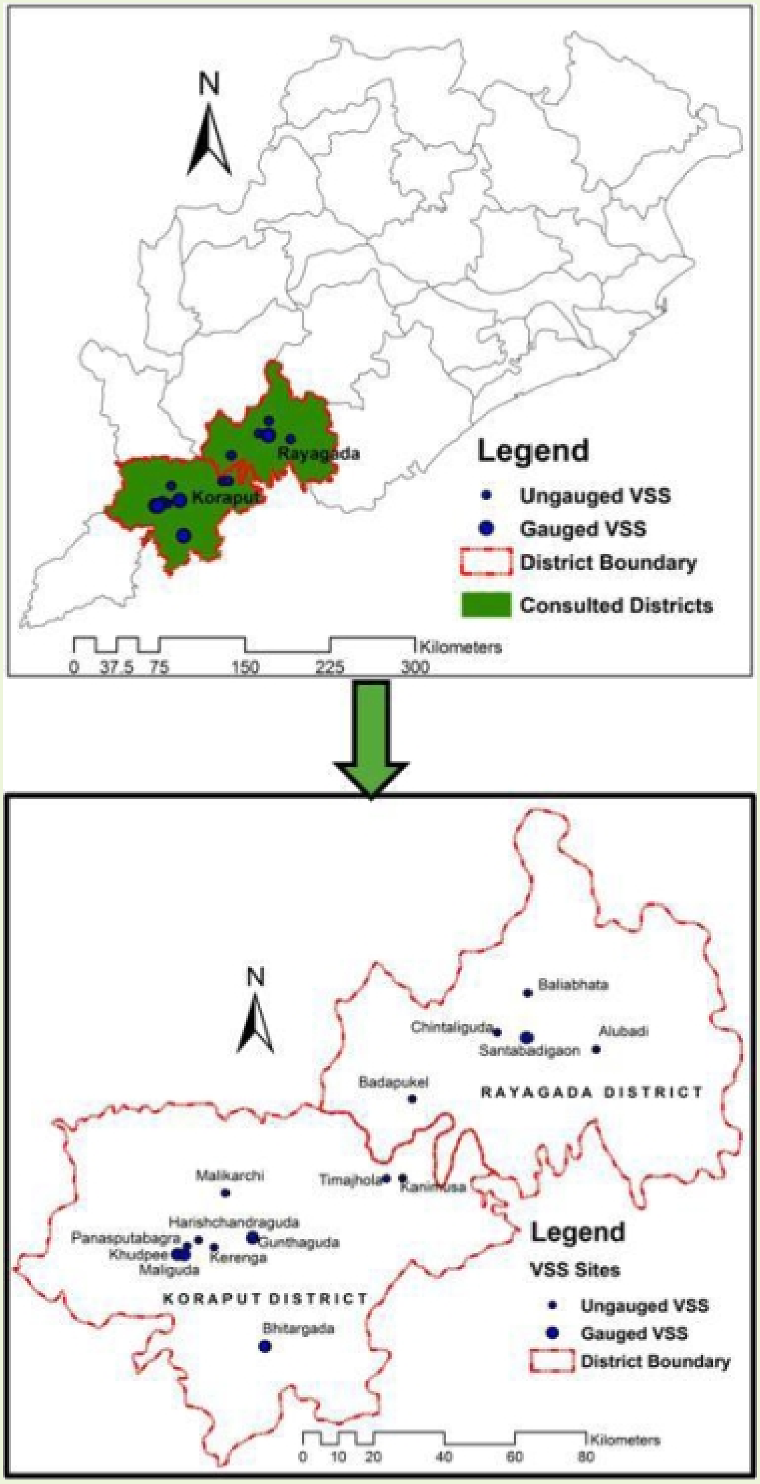


Figure 2.1: Location details of the study sites

2.2 General Climate

The study area comes under two agro-climatic zones of Odisha state namely North Eastern Ghats (Rayagada) and Eastern Ghats high lands (Koraput and Jeypore). The climate is hot and moist sub humid in Rayagada, where in warm and humid climate in Koraput and Jeypore. The normal annual rainfall is 1599 mm and 1522 mm received mainly during monsoon season in Rayagada and Koraput, respectively. About 81% of the total rainfall is received through June to September (South-West monsoon). Bright sunshine hours vary from 1.84 to 3.98 and 6.29 to 9.04 during the monsoon and the post monsoon season, respectively. The average evaporation rate is 3.7 mm day^{-1} with maximum in May (6.2 mm day^{-1}) and minimum during the month of August (2.1 mm day^{-1}). Water balance diagram showed that, surplus water is available for agricultural use between the month of May and October with a length of growing period is about 170 days (Figure 2.2).

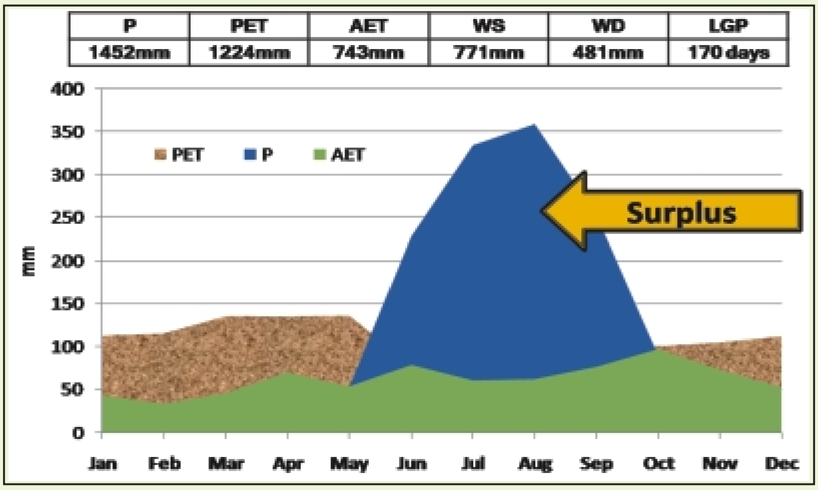


Figure 2.2: Water balance diagram of the study area

2.3 Physiography and Drainage

The study area is undulating and rolling tophographic conditions and dominated with Highland plateau and hill ranges of the Eastern Ghats are the key topographical features. Due to undulating topographic conditions, rainwater draining ultimately into Jhola system and finally drains into the Kolab, Telingi, and Nagavali rivers. The drainage pattern is having fine texture of dendrite pattern. This indicates that the rock formations are impervious and permeability is low. Soils formed in such areas are deep, heavy and slowly permeable. Thus, the area is very prone to severe erosion hazards forming gullies.

2.4 Geology and Geo-hydrology

The area possesses lithology mainly composed of shale, slate and sand stones showing faults and fissures. The weathered and fractured granite/ granitoid gneiss constitutes the major repository of ground water. Besides these aquifers, weathered and fractured Khondalites, journalists Shale etc. also form aquifers about the small areal extent of low to moderate yield. Ground water occurs in unconfined to confined conditions. Ground water from shallow and deeper aquifers is suitable for irrigation, drinking and other purposes.

2.5 Vegetation

The vegetation type is tropical scrub forest. Very high intensity uncontrolled grazing and browsing by livestock, heavy extraction of trees for fuel wood and practice of shifting cultivation is the major threat to vegetation in the study areas. Extensive dependence on forest for fuel and fodder are the primary reasons for causing degradation of natural vegetation in this area.

2.6 Broad Soil Characteristics

Soils of the study sitess are derived from charnokites and khandolites. The soils of these areas are classified under Entisols (Typic Ustorthent and Typic Ustifluvent); Inceptisols (Dystric Ustochrept and Typic Haplaquept) and Alfisols (Udic Paleustalf) (Ray, 1979).

2.7 General Land Use Pattern

The study area is dominated with forest area which accounts for 29% of the total geographical area followed by net sown area (27%), area under non-agricultural use and barren uncultivable land (27%), fallow land (6%). Area under other land uses accounts for 11% which includes miscellaneous trees and groves, permanent pasture and cultivable waste lands (Figure 2.3).

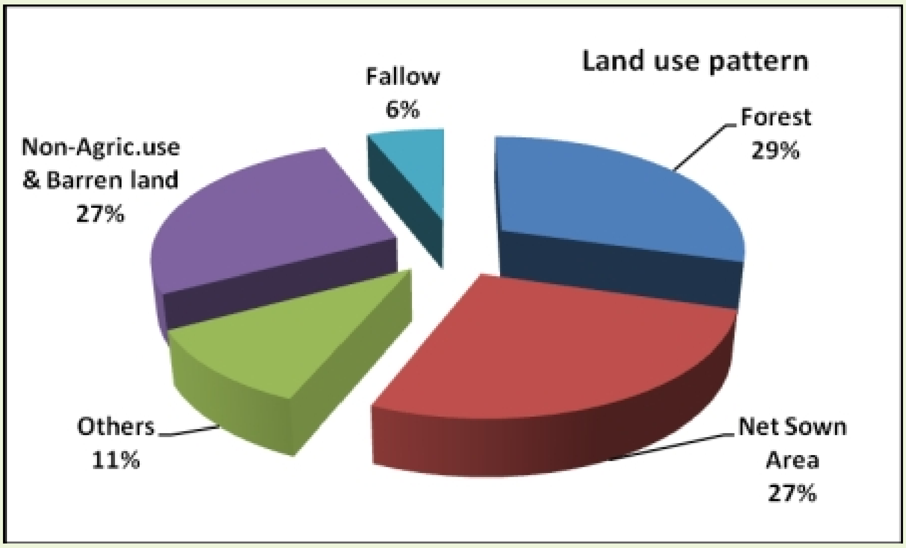


Figure 2.3: Land use pattern in the study area

3.0 Methodology for Evaluation of SMC Measures under Afforested Sites

3.1 Selection of Sites

A research planning meeting was held on November 1st, 2012 at CSWCRTI, Research Centre, Sunabeda, Koraput for finalization of technical plan of the study. This meeting was participated by RCCF, DFOs, APDs, ACFs, Resident Consultant of OFSDP, study team of CSWCRTI, RC, Sunabeda. After detailed deliberations, the following technical programme was developed.

Treatments (4):

1. Assisted Natural Regeneration + Gap Plantation (ANR+GP)
2. Block Plantation with Trenches (BP+SMC)
3. Assisted Natural Regeneration + without Gap Plantation (ANR-GP) (ANR-No under growth vegetation)
4. NTFP

Years: 1. 2008; 2. 2009; 3. 2010; 4. 2011; 5. 2012

At each DMU, one set of treatment (4) with each year was be monitored for runoff and soil loss using Multi Slot Deviser (MSD) fitted with collection tank. In all there were 20 monitoring plots covering five years with the treatments detailed above.

Accordingly, a total of 15 sites were selected from three forest divisions namely Koraput, Rayagada and Jeypore. There are five study sites from each forest division covering the plantation year's viz., 2008,2009,2010,2011 and 2012. The study sites were selected based on year of plantation, plantation types with SMC measures and rainfall distribution pattern. Sites were selected after preliminary discussion with the concerned forest divisions. The details of sites selected for the study is presented in table 3.1.

Table 3.1: Details of site selected for the impact evaluation of SMC measures in selected VSS under OFSDP.

Year	Koraput DMU		Rayagada DMU		Jeypore DMU	
	FMU	VSS	FMU	VSS	FMU	VSS
2008	Laxmipur	Kanimusa	Tikri	Badapukel	Patroput	Maliguda
2009	Laxmipur	Timajhola	Rayagada	Santabadigaon	Jaynagar	Malikarchi
2010	Koraput	Gunthaguda	Rayagada	Chintalguda	Patroput	Pansput Bagra
2011	Koraput	Kerenga	Muniguda	Bhaliabhata	Patroput	Khudpee
2012	Semiliguda	Bhitarguda	Gunpur	Alubadi	Patroput	Harishchandraguda

3.2 Hydrological Data Monitoring

Hydrological data viz., rainfall, runoff, soil loss, silt deposition in trenches and LBCDs were monitored from the five selected sites out of 15 total sites. These five site covering all the plantation years i.e., 2008 to 2012 and located at Koraput, Rayagada and Jeypore DMU. The details of selected sites for hydrological data monitoring is given in the right hand side.

Year	DMU	FMU	VSS
2008	Jeypore	Patroput	Maliguda
2009	Rayagada	Rayagada	Santabadigaon
2010	Koraput	Koraput	Gunthaguda
2011	Jeypore	Patroput	Khudpee
2012	Koraput	Semiliguda	Bhitarguda

A two days capacity building training programme on "Hydrological Monitoring" was organized at CSWCRTI, Research Centre, Sunabeda, Koraput for the Animators and members of five selected VSS. The training content and the participation list are presented in Annexure 3.1. Participatory data monitoring technique was followed in collection of hydrological parameters by involving respective VSS members and animators.

3.2.1 Rainfall

Daily rainfall was monitored from ordinary rain gauge installed at each five selected sites for hydrological monitoring. The daily data at respective sites were collected and maintained in the note book. The respective site rainfall data was used to calculated per cent runoff from each treatment for comparisons.

3.2.2 Runoff and soil loss

Runoff and soil loss data from each selected sites were monitored by installing Multi Slot Deviser (MSD) fitted with drums. The dimension of 10 m X 5 m was demarcated with earthen bunds within the each treatment and runoff was channelized to MSD. Rainfall event wise depth of runoff water collected in the tank was measured by using wooden scale and based on the quantity of water collected, runoff expressed in mm and percent to the total rainfall.

For assessing treatment wise soil loss, runoff event wise one litter of runoff sample was collected from each tank after stirring the runoff water in the tank. Runoff collection bottles were labeled immediately as per the treatments in each site. Dry weight of soil/silt content in the runoff samples were determined by filtration technique using filter paper followed by drying in the oven. Soil loss was calculated and expressed in kg ha^{-1} or t ha^{-1} based on the plot size, volume of runoff water and dry weight of silt in the sampled runoff water.

3.2.3 Silt deposition in trenches and LBCDs

Silt deposition in the trenches in the plantation sites and behind the LBCDs in the nearby gullies was assessed through erosion pin techniques. Wooden pegs were installed in the trenches and behind the LBCDs before onset of monsoon 2013. The final depth measurement was taken after the monsoon season. By considering the catchment area and bulk density of deposited silt and average depth of silt deposition data, soil/silt deposited in these conservation structures were assessed and expressed in kg ha^{-1}. The effective life span of the trenches and LBCDs were worked out based on the annual silt deposition rate.

3.3 Soil Parameters

3.3.1 Soil sampling and analysis

Site and soil characteristics, combined with disturbances (human or natural) act to control the survival, health, density, and growth of the plants. If age and management is similar, "Good" sites are capable of supporting more species of trees, higher densities of trees, and larger, faster growing trees as compared to "poor" sites. "Good" sites also tend to support diverse wildlife populations and "Good" sites tend to be more flexible in terms of management options. Therefore it's important that to consider just what soil and site characteristics comprise a "good" site.

To measure the effect of different types of forest plantation on soil physical, chemical and biological quality, soil sampling and analysis was done. The fertility status of the selected soils was also assessed. The soil samples were collected from all the four forest vegetation/land uses i.e., ANR with Gap Plantation, ANR without Gap Plantation, Block Plantation and Non Timber Forest Plantation (NTFP) sites and from all the VSSs. To get the vertical distribution of soil moisture and various ions, soil samples were collected from two soil depths viz., surface (0-20 cm) and sub-surface (20-40 cm). To assess the variation of different soil properties under various slope conditions, soil samples were also collected from three different hill slope condition under a topo-sequence under each land uses viz., upper, middle and lower. The representation of the soil sampling schedule is given in table 3.2.

Table 3.2: Soil sampling schedule in the OFSDP sites

Parameter	Depth (cm)	Location / Topo-sequence	Frequency
Soil moisture	0-20 and 20-40	Top/Middle/Low	Monthly
pH	0-20 and 20-40	Top/Middle/Low	One time
EC	0-20 and 20-40	Top/Middle/Low	One time
SOC	0-20 and 20-40	Top/Middle/Low	Initial and Final
Available N	0-20 and 20-40	Top/Middle/Low	One time
Available P	0-20 and 20-40	Top/Middle/Low	One time
Available K	0-20 and 20-40	Top/Middle/Low	One time
SMCC/FC/PWP	0-20 and 20-40	Top/Middle/Low	One time
Texture	0-20 and 20-40	Top/Middle/Low	One time
Structure	0-20 and 20-40	Top/Middle/Low	One time
Plasticity/Stickiness	0-20 and 20-40	Top/Middle/Low	One time
Bulk density	0-20 and 20-40	Top/Middle/Low	One time
Infiltration	Surface	Top/Middle/Low	One time
MBC	0-20 and 20-40	Top/Middle/Low	One time
DHA	0-20 and 20-40	Top/Middle/Low	One time

The collected soil samples were labeled properly and brought to the laboratory of CSWCRTI, Research Centre, Koraput. The samples were shade dried and analyzed for their physical, chemical and biological properties. The analytical methods used for various parameters are detailed in table 3.3

Table 3.3: Methods uses for analysis of the soil parameters

Parameter	Method/Procedure	Reference
Soil moisture	Gravimetric method	Black, 1965
pH	pH meter	Rayment and Higginson, 1992
EC	EC meter	Piper, 1942
SOC	Walkley and Black method	Walkley and Black, 1934
N	Kjehldal method	Subbiah and Asija, 1956
P	Bray method	Bray and Kurtz, 1945
K	Flame photometer	Jackson, 1967
Bulk density	Standard core method	Black, 1965
SMCC/FC/PWP	Pressure plate apparatus	Black, 1965
Texture	Hydrometer method	Bouyoucos, 1962
Structure	Field method	Black, 1965
Plasticity/Stickiness	Field method	Black, 1965
Infiltration	Double ring infiltrometer	1965
MBC	Fumigation-extraction method	Tate et al., 1988
DHA	TTC method	Pepper et al., 1995

There are total 15 VSS covering five phases of plantation viz., 2008, 2009, 2010, 2011 and 2012 cover three VSS each phase. The soil properties are presented and compared for each phase/year taking the average value of the three VSSs.

3.4 Growth Performance of Afforested Species

3.4.1 Survival rate

Survival rate of afforested species under block plantation and NTFP blocks in all the fifteen sites was studied at different reaches viz., lower, middle and upper. Species wise enumeration was done following Quadrant of 10 m x 10 m at each site and reaches within the site. The species wise and overall survival percent was worked out from the field data.

3.4.2 Height and basal diameter

Height and basal diameter of species under block and NTFP blocks were studied at each selected sites (lower, middle and upper reaches). Randomly five plants of each species were selected at each site for measuring plant height and basal diameter. Plant height was measured using measuring tape from ground to growing tip of plant and basal diameter was measured at about 10 cm above the ground surface of the plant. Selected study site wise and year of plantation wise data is analyzed and presented in tabular and bar diagrams.

3.5 Data Analysis and Interpretation

The raw fields data was compiled and mean values were worked out. The standard deviation and co-efficient of variation was also worked and presented for some of the parameters wherever applicable. The different parameters wise data is presented in graphical and tabular form. The data was interpreted based on mean values for different study sites, land use/vegetation types, year of plantation and aspects.

4.0 Impact of SMC Measures

4.1 Runoff and Soil Loss

The hydrologic cycle is the process of water movement through the environment. On a worldwide basis, the amount of water is essentially constant, but the amount of water present at any given locale at any given instant varies depending upon how much water enters the system, the mode and rate of transit within the system, and how the water exits the system. Rain is the main source of water for all uses and therefore it need to be conserved and managed for well being of the mankind without degrading ecosystem and environment. The hydrology of any land use system is governed by the amount and intensity of rainfall, climatic factors, soil surface cover, soil properties, land slope, aspects, management practices, etc. In the present study is aimed to quantify the surface runoff under different forest land uses with management practices.

The land slope of the study sites: The land slope under different forest land uses for the study sites is presented in table 4.1.1. The land slope varied between 5.2% and as high as 42.44% in the study sites. The study sites at Santabadigaon, Gunthaguda, Khudpee and Bhitarguda are relatively high slope compared to the sites of Maliguda. It was also observed that, all the ANR sites are located on higher slopes and located interior area, therefore it's not subjected to much degradation due to less biotic disturbances. On the contrary, the block plantation of teak and NTFP sites are located relatively on lower slopes which are degraded due to biotic disturbances. Among the block plantation of teak and NTFP, the sites of block plantation of teak were degraded more due to biotic stress by community and uncontrolled grazing by domestic animals.

Table 4.1.1: Land slope (%) under different land use and study locations of OFSDP

Land Use	Maliguda (2008)	Santabadigaon (2009)	Gunthaguda (2010)	Khudpee (2011)	Bhitarguda (2012)
ANR+GP	>13.5	>19.5	42.44	26.8-36.4	40.4
ANR-GP	>13.5	>19.5	42.44	26.8-36.4	40.4
BP	7.8-11.4	5.2-11.4	14.95	7-10.5	29.62
NTFP	9.6-12.3	17.6	24	20-25	24.9

Runoff: Runoff data collected from the four forest land use treatments in all the five study sites are presented in table 4.1.2 and figure 4.1.1, figure 4.1.2 and figure 4.1.3. The number of runoff causing rainfall events was maximum in Maliguda (35) followed by Khudpee (32), Bhitarguda (31), Santabadigaon (27) and Gunthaguda (22). At all the study sites average runoff was maximum under ANR-without GP followed the block plantation of teak and NTFP plantation. It was observed that, ANR + GP gave minimum runoff compared to other forest land use treatments at all the study sites. This was attributed to good canopy rainfall interception at different heights by the vegetation contributed an increase in intake rate of soils, thus resulted in lower runoff compared to other land use treatments. The runoff is mainly influenced by the intensity of rainfall, vegetation cover, soil physico-chemical properties, soil organic matter content and land management practices like soil moisture conservation practices. From the soil analysis result revealed that, the sites with ANR+GP and NTFP have better soil properties and vegetation cover resulted in maximum rainwater conservation and low runoff. The block plantation of teak was done mostly on degraded sites devoid of vegetation cover and poor soil properties contributed to the more runoff than the other forest vegetation land use systems. The study site at Gunthaguda is having a courser soil texture and relatively gravely soil condition contributed for more runoff in all the forest vegetation land use systems compared to other study sites.

Table 4.1.2: Runoff range under different land use and at different location during 2013

Vegetation	Maliguda (2008)	Santabadigaon (2009)	Gunthaguda (2010)	Khudpee (2011)	Bhitarguda (2012)
ANR+GP	0.2-6.7	0.06-2.6	0.32-13.7	0.25-7.3	0.53-3.0
ANR-GP	0.9-15.6	0.2-13.4	0.97-14.0	0.95-13.0	0.43-6.9
BP	0.6 -15.6	0.08-10.8	0.86-13.7	0.59-14.6	0.64-8.0
NTFP	0.14-15.6	0.21-2.1	0.64-13.9	0.26-7.3	0.64-4.1

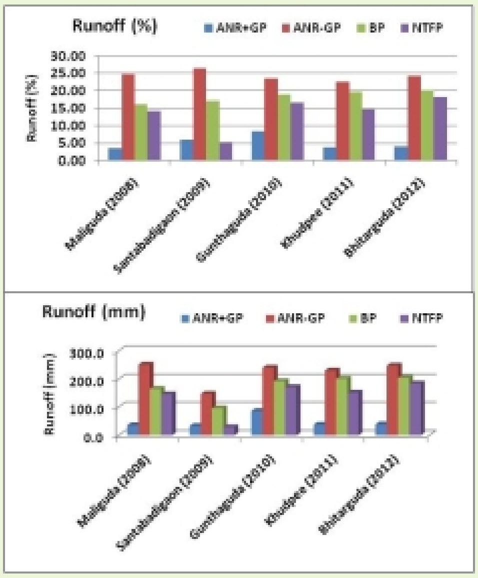


Figure 4.1.1: Runoff under different vegetation types and study sites of OFSDP

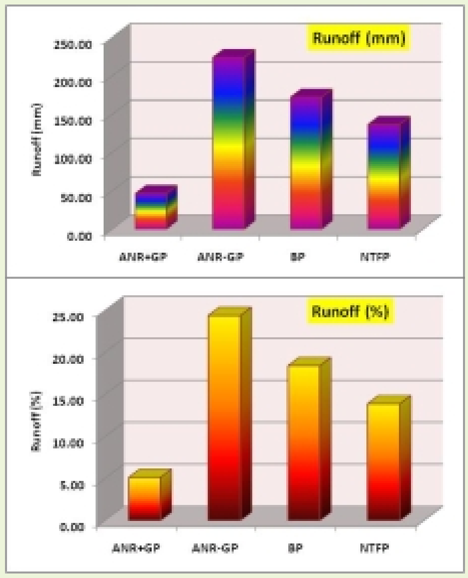


Figure 4.1.3: Runoff of under different vegetation types

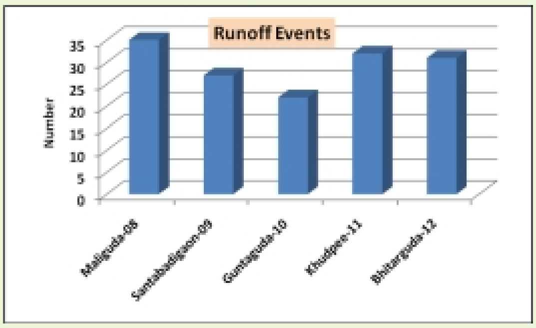


Figure 4.1.2: Total number of runoff events under study sites

Rainwater conservation efficiency (RWCE): RWCE was worked out for different land use/vegetation treatments and at five hydrological monitoring sites under OFSDP (Figure 4.1.4). Among the different treatments, ANR+GP recorded higher RWCE at all the sites (66 % at Gunthaguda to 87% at Santabadigaon) compared to block plantation (19 % to 62%) and NTFP plantation (27%to 88%). Among the five hydrological monitoring sites, second phase plantation (2009) at Santabadigaon conserved more rainwater followed by first phased plantation (2008) at Maliguda, Khudpee (2011), Bhitarguda (2012) and Gunthaguda (2010). RWCE under ANR+GP was the highest (81.55%) followed by NTFP (45.86%) and Block Plantation (31.84%). This was attributed to better interception of raindrops by thick and varied canopy levels under ANR+GP coupled with surface litter and organic matter content resulted in increased intake rate of soil thereby conserved more rainwater than the other treatments. This will increases the stream water flow depth and duration particularly during the lean season (post monsoon) and thereby reducing the risk of flood in the lower region and sustains the water availability and storage capacity of water bodies.

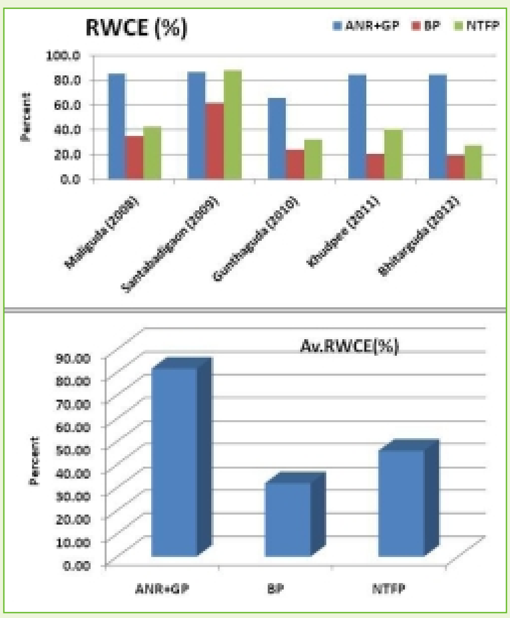


Figure 4.1.4: Rainwater conservation efficiency under study sites and vegetation sites (Compared to ANR-No GP)

Soil Loss: Soil loss data collected from the four forest land use treatments in all the five study sites are presented in table 4.1.3 and figure 4.1.5. Soil loss varied between 159 to 537 kg/ha under ANR+GP, 350 to 1125 kg/ha under NTFP, 1145 to 1725kg/ha under the block plantation of teak and 2506 to 2979 kg/ha under ANR-GP across the five different sites. The soil loss was also followed the trend that of runoff under different forest land uses. Average soil loss under ANR+GP was lesser by 88% compared to ANR-GP. However, NTFP and block plantation recorded soil loss less by 72% and 47%, respectively over ANR-GP. It was observed that at all the sites the soil loss was below the critical limit but it's very important that conservation of soil is more critical at degraded sites particularly under block plantation. Under this situation SMC measures are to be intensified on degraded sites to retain precious soil and conservation of rainwater for plant growth. Due to poor undergrowth particularly in teak plantation needs SMC measures.

Table 4.1.3: Soil loss under different forest land use and at different study sites during 2013

Forest land use	Maliguda (2008)	Santabadigaon (2009)	Gunthaguda (2010)	Khudpee (2011)	Bhitarguda (2012)	Mean of forest land use
ANR+GP	159	522	537	165	326	342
ANR-GP	2980	2649	2807	2506	2785	2745
BP	1146	1161	1498	1705	1726	1447
NTFP	726	351	1126	763	826	758
Mean for site	1253	1170	1492	1285	1415	1415

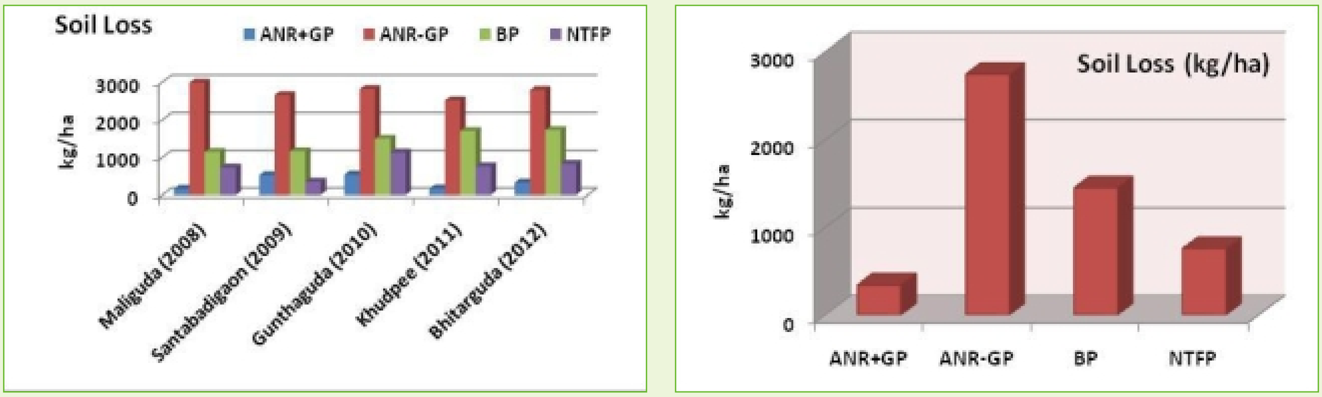


Figure 4.1.5: Soil loss under different study sites and vegetation types

4.2 Performance of LBCDs

The process of water erosion starts with rainfall. Raindrops, which do not touch plants, will have the splash effect, defined as the impact of raindrops on the soil surface. Soil aggregates are smashed and their particles thrown in all directions. From the surface, water can infiltrate the soil through pores, as long as they are not saturated. Excess water moves as overland flow ("runoff") down slope and detaches additional soil particles. When runoff is evenly distributed, sheet erosion occurs. Water usually tends to concentrate along the lowest parts of a soil surface and forms small channels called rills. Overland flow that concentrates on channels leads to the formation of rills and gullies. Rills are usually small and can be easily removed by tillage. Rill erosion is much more easily noticed than inter rill erosion. If unchecked, rills may extend into the subsoil resulting in gully erosion. Another cause of gully erosion is an increase in flood flow, which may be caused by deterioration of vegetation in a catchment, and the concentration of flow in roads, footpaths, poorly maintained cut off drains, waterways and cattle tracks, etc.

Gully erosion is the erosion process whereby water concentrates in narrow channels and over short periods removes the soil. Gully erosion produces channels larger than rills. As the volume of concentrated water increases and attains more velocity on slopes, it enlarges the rills into gullies. Gully can also originate from any depression such as cattle trails, footpaths, cart tracks, and traditional furrows and indicates neglect of land over a long period of time. The rate of gully erosion depends primarily on the runoff producing characteristics of the watershed, soil characteristics, alignment, size and shape of the gully and the slope in the channel. Most of the gullies are formed due to human activities. Some of the major causes of gully formation are overgrazing due to high cattle population, expansion of cultivation in steeper or marginal lands, cultivation without taking care of surplus runoff water, deforestation due to clearing of vegetation, unsatisfactory waterways and improper design of culverts and other structures. Generally a gully is caused by a rapid expansion of the surface drainage system in an unstable landscape. Gully erosion is affected by several factors. Some factors determine the potential hazard while others determine the intensity and rate of gully advance.

In gully control, the three methods must be applied in order of priority viz., (a) Improvement of gully catchments to reduce and regulate the runoff volume and peak rates; (b) Diversion of runoff water upstream of the gully area; (c) Stabilization of gullies by structural measures and accompanying re-vegetation. In gully control, temporary physical structural measures such as gully reshaping, brushwood, sandbag, loose stone, gabion and arc-weir check-dams are used to dissipate the energy of runoff and to keep the stability of the gully. Check-dams are constructed across the gully bed to stop channel/bed erosion. By reducing the original gradient of the gully channel, check-dams diminish the velocity of water flow of runoff and the erosive power of runoff. Run-off during peak flow is conveyed safely by check-dams. Temporary check-dams, which have a lifespan of three to eight years, collect and hold the soil and moisture in the bottom of the gully. To give vegetation an opportunity to establish, runoff control structures may be needed in the gully. The structures can be either temporary or permanent. The choice of the measures and the extent of their use will depend on the amount of the runoff and the status of the gully whether young and actively eroding or mature and establishing naturally. Good judgment is required in determining what measures to use and it would be a mistake to use expensive measures were more economical ones would do.

Loose stone check-dam is a structure made of relatively small rocks and placed across the gully or small stream, which reduces the velocity of runoff and prevents the deepening and widening of the gully. In the study areas, a series of loose boulder check dam are constructed at various intervals along the gully. To measure the depth of silt deposition in the upstream of the structure, erosion pin was installed in the gully bed before the onset of monsoon. The no's of erosion pin per loose boulder check dam varies from 7 to 9 and height above the present ground level is 30 cm. Periodical inspection was made during the monsoon period. After the end of monsoon period, the depth of soil deposition in each structure is measured and total volume of silt deposition is calculated by considering the area of silt deposition. Study site wise details of LBCDs are presented in table 4.2.1.

Table 4.2.1: Details of LBCDs at different study sites with their average specification

S.No	VSS	DMU	No. of LBCDs	Average Specification (m)		
				Length	Top width	Height
1	Maliguda	Jeypore	20	7.46	1.74	1.81
2	Timajhola	Koraput	7	5.1	0.93	0.91
3	Malikurchi	Jeypore	10	5.65	1.42	1.18
4	Santabadigaon	Rayagada	13	6.63	0.82	0.61
5	Bhaliabhata	Rayagada	23	5.61	0.98	1.14
6	Badapukel	Rayagada	22	4.80	1.00	1.00
7	Panasput Bagra	Jeypore	6	11.83	1.00	0.78
8	Kanimusa	Koraput	14	13.7	0.75	0.7
9	Kerenga	Koraput	5	7.68	0.6	0.5
10	Khudpee	Jeypore	15	4.04	1.1	0.88
11	Chintalguda	Rayagada	4	9.53	0.97	1.2
12	Alubadi	Rayagada	7	10.3	0.93	0.68
13	Gunthaguda	Koraput	12	5.34	0.8	0.74
14	Harishchandraguda	Jeypore	17	5.47	0.8	0.92
15	Bhitargada	Rayagada	8	6.18	1.06	0.93

The average length is varied between 4.04 m and 13.7 m, top width is 0.60 m to 1.74 m and height is 0.5 to 1.81 m. All together a total of 183 LBCDs was constructed in the gullies during the project period in 15 study sites. The maximum number was maximum in Maliguda (20) in Jeypore block and was lowest in Chintalguda (4) in Rayagada.

Details of silt deposition behind the gully control structures in the study site are presented in table 4.2.2. The average depth of silt deposition behind the LBCD during 2013 varied between 2.33 cm at Santabadigaon and 5.21 cm at Maliguda in Jeypore DMU. The maximum silt deposition depth was in the range of 10.5 cm to 30.0 cm. Similarly, the total silt deposition during the year 2013 was in the range of 2.72 to 27.93 cum in all the structures. The average silt deposition in all the structure since their construction was in the range of 7.8 cm to 23.8 cm behind the structure. However, the average silt retention rate per structure per year was ranged between 0.6 cum at Khudpee (0.6 cum/year) in Jeypore DMU and it was maximum of 9.24 cum/year observed in Guntaguda at Koraput DMU. This varied silt retention rate was attributed to the variation in vegetation canopy cover in the catchment area, extent of catchment area, degree of slope, rainfall pattern, etc. The attempt has been made to calculate the cost of retention of silt trough construction of LBCDs by assuming the average cost of the structure is Rs.5000/-. The average cost of retention of silt varied between Rs.196/- and Rs.581/- per cum with the overall average cost of Rs.375/- per cum. The effective life span of the structure is varied from 5 to 10 depending on the size of the structure and the catchment area of each structure in the study sites.

Table 4.2.2: Silt deposition during 2013 and total silt deposition since construction in the study sites

Name of VSS	DMU	Year	Total LBCD	Silt deposition during 2013		Silt deposition since construction			Catchment area (ha)	
				Average Depth (cm)	Total deposition (Cum)	Total (cum)	Average/ year (cm)	Average/ year (cm)	Range	Average
Maliguda	Jeypore	2008	20	5.21 (18.5)*	27.93	840.88	23.8	140.14 (7.0)**	1.5-15.0	7.16
Santabadigaon	Rayagada	2009	13	2.33 (20.0)	14.63	265.77	13.4	53.15 (4.1)	2.3-10.0	6.1
Gunthaguda	Koraput	2010	12	4.75 (10.5)	2.72	28.27	9.9	9.24 (0.8)	0.2-3.0	1.02
Khudpee	Jeypore	2011	15	4.62 (30.0)	14.21	26.55	18.2	8.85 (0.6)	1.5-8.0	4.32
Bhitarguda	Koraput	2012	8	4.02 (14.5)	8.9	13.24	7.8	6.62 (0.8)	1.6-10	5.52

*Maximum depth of silt deposit in upstream of structure; ** Volume of silt deposit In Cum/year/structure

4.3 Soil Properties

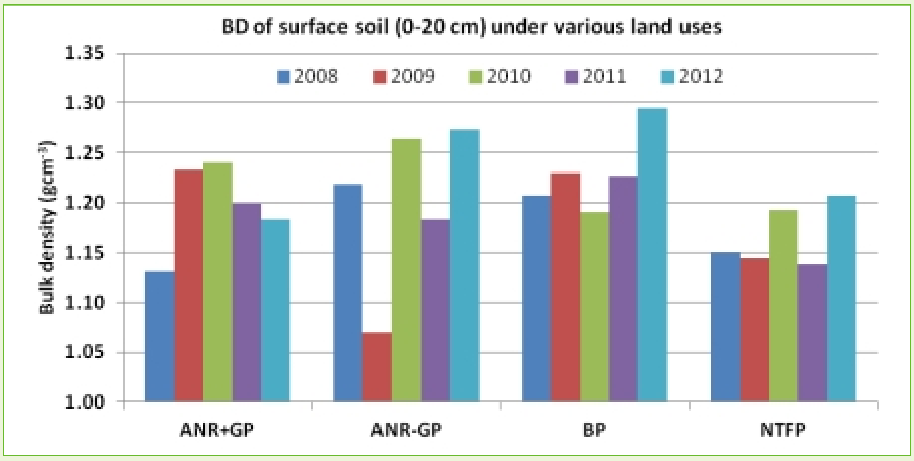
4.3.1 Physical properties

Among the various soil physical properties the prominent are the soil bulk density, soil particle density, soil porosity, soil texture, soil structure, soil moisture at field capacity and permanent wilting point, soil available moisture and soil moisture characteristic curve. The variations of these soil properties under various forest vegetation/land uses are described below:

Bulk density: Bulk density is one of the very important soil properties determine the physical health of the soils. Bulk density is an indicator of soil compaction. It is calculated as the dry weight of soil divided by its volume. This volume includes the volume of soil particles and the volume of pores among soil particles. Bulk density is typically expressed in gcm^{-3}.It directly influences the plant growth by influencing the moisture movement through soils. For a particular mineral soil lower the value of bulk density, better is the soil physical quality.

Bulk density reflects the soil's ability to function for structural support, water and solute movement, and soil aeration. Bulk density above some thresholds indicate impaired soil and plant function. Bulk density is also used to convert between weight and volume of soil. It is used to express soil physical, chemical and biological measurements on a volumetric basis for soil quality assessment and comparisons between management systems. This increases the validity of comparisons by removing error associated with differences in soil density at time of sampling.

The bulk density of surface soils varied between 1.02 g cm^{-3} and 1.38 g cm^{-3} with average value of 1.19 g cm^{-3}. The temporal variation of bulk density for the surface soil under various forest land uses is presented in figure 4.3.1.



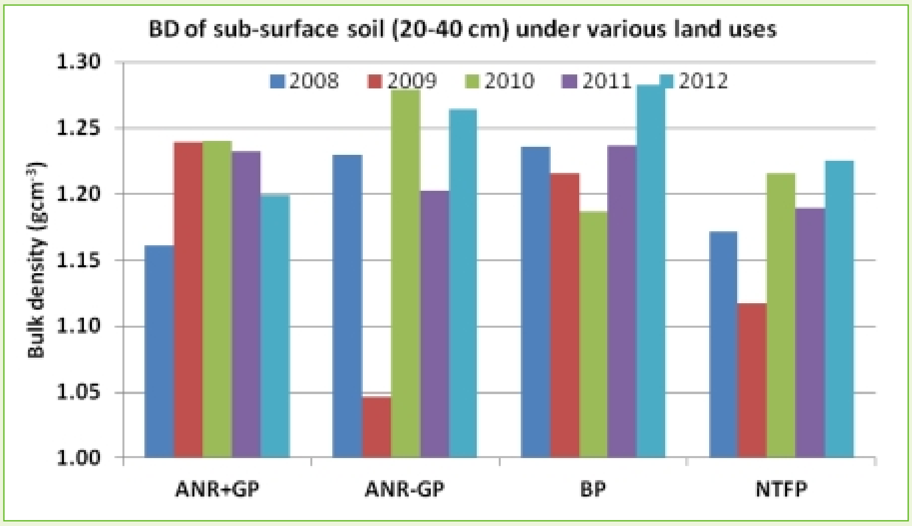


Fig. 4.3.1: Bulk density of soils under various forest land uses

Although soil bulk density is an intrinsic soil property and do vary under temporal and spatial scale but various land uses by virtue of their different root geometry and condition and also by their variable nature of litter deposits can make some change in the value of bulk density. From Figure 4.3.1 it's clear that ANR+GP and NTFP land uses showed considerable low surface soil bulk density than ANR-GP and BP (Block Plantation) sites. Among all the land uses, BP showed highest bulk density because of the initial soil disturbance during plantation, tap root system of the teak plantation which contributes very less root exudates necessary for the formation of stable aggregates and very less litter fall from the teak plantation. Moreover, teak plantation was done on a degraded site which was devoid of vegetation. On the other hand NTFP land use, which comprises of a mixture of various trees and shrubs and having profound undergrowths showed considerable low bulk density. ANR+GP also impressed with the soil physical property in terms of bulk density because of its higher undergrowths. The undergrowths found in these two land uses add significant amount of aboveground litter which contributed significantly to the soil organic matter, and hence reduce the soil bulk density. The same trend has been found for the sub-surface soil also (Figure 4.3.1). In the sub-surface soils the bulk density varied between 1.12 g cm^{-3} and 1.36 g cm^{-3} with average value of 1.20 g cm^{-3}.

High bulk density is an indicator of low soil porosity and soil compaction. It may cause restrictions to root growth, and poor movement of air and water through the soil. Compaction can result in shallow plant rooting, poor plant growth, poor survival percent which is influencing on biomass and reducing vegetative cover available to protect soil from erosion. By reducing water infiltration into the soil, compaction can lead to increased runoff and erosion from sloping land may lead to highly susceptible to drought like conditions. In general, some soil compaction to restrict water movement through the soil profile is beneficial under arid conditions, but under humid conditions compaction decreases yields.

From the figure 4.3.2 it revealed that, the overall change of soil bulk density for all the study sites, then it's evidenced that the block plantation sites showed considerably high bulk density than other sites. NTFP sites, due to active root systems and higher litter fall showed significantly lower bulk density (Figure 4.3.2).

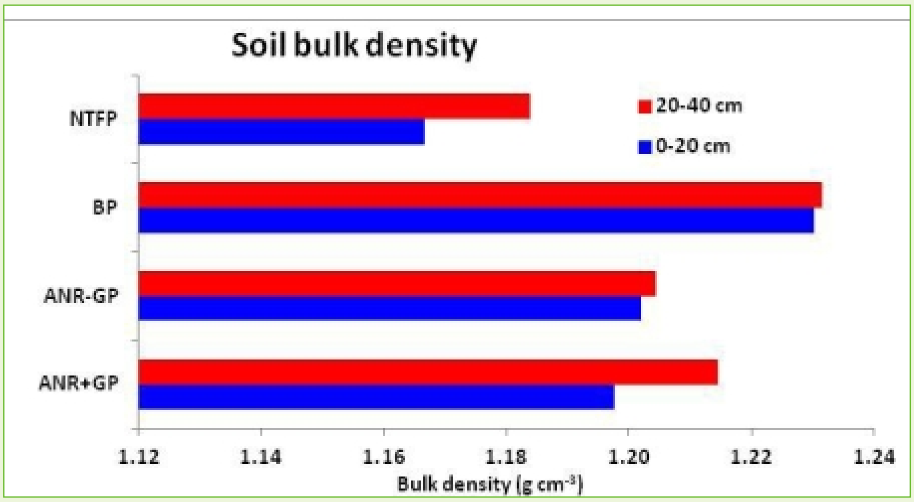


Fig. 4.3.2: Overall variation of soil bulk density under various forest land uses

Soil texture: Soil texture refers to the relative amounts of inorganic particles, that is, sand, silt and clay. While sand grains are large and coarse and clay particles are very fine and smooth, silt particles are intermediate. Many of the important soil properties are related to texture. Clayey soils show high water holding capacity, high plasticity, and stickiness and swelling whereas sandy soils are conspicuous by the absence of these properties. The most important way in which soil texture influence plant growth through availability of soil water and nutrients apart from providing aeration and drainage. There are 12 textural class and those classes are formed by the combination of three soil particles viz. sand, silt and clay. Therefore the content of sand, silt and clay is the most important to govern the above said parameters. The amount of sand, silt and clay vary with the variation of land uses, soil depth and with topo-sequence.

The sand content of surface soils varies between 29.20% and 82.40% with average value of 61.25%. The variation of sand content in different forest land uses follows the following trend: ANR-GP>BP>NTFP>ANR+GP (Figure 4.3.3). The physical disturbance rendered during clearance and plantation of new forest trees in the ANR-GP and Block Plantation sites has made the soil more prone to soil erosion. The finer clay and silt particles have been eroded down and left only the coarser sand particles. In ANR+GP land use, higher litter has increased the soil organic matter content and made stable aggregates which are less prone to soil erosion. Higher canopy density of the forest vegetation also contributed as umbrella effect and reduced soil erosion. The less amount of sand is an indicator of less soil erosion and better soil physical health. The sub-surface soil has also followed the same trend.

Silt is the most susceptible soil particle for water erosion. So it can be used as an indicator of soil erosion status and indirectly of soil physical health. Lower the silt content, higher the soil erosion. In our study area the variation of silt content follows the following order: ANR+GP>NTFP>BP>ANR-GP (Figure 4.3.4). So here it can be inferred that ANR+GP is the best land use in terms of soil erosion potential and ANR-GP is the worst site. The other two land uses are intermediate between these two. The silt content of surface soils varies between 8.00% and 31.80% with average value of 16.93%.

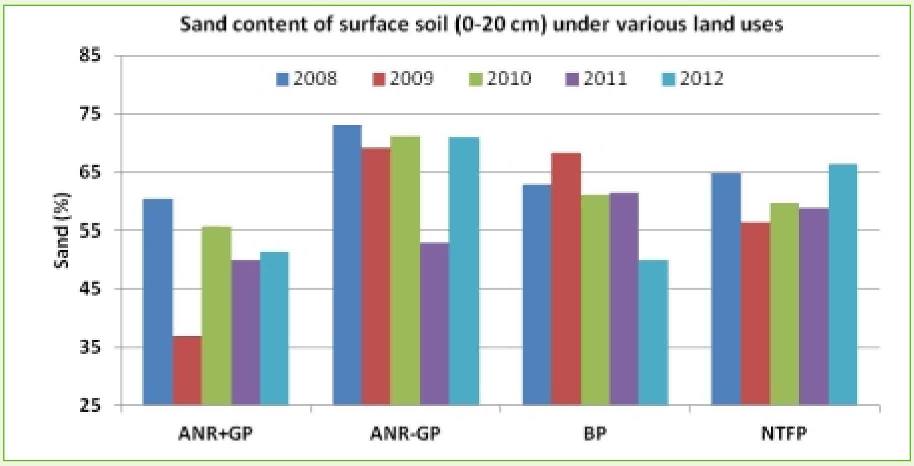


Fig. 4.3.3: Sand content of surface soil under various forest land uses

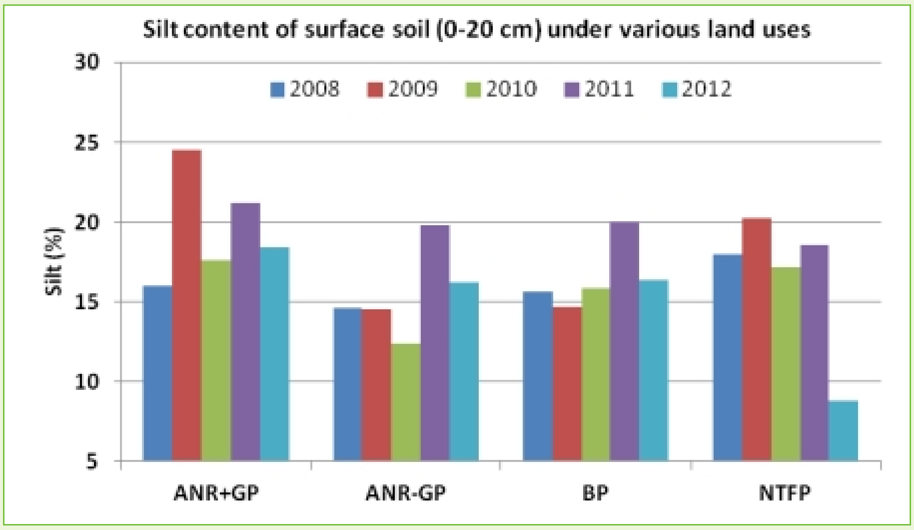


Fig. 4.3.4: Silt content of surface soil under various forest land uses

Clay, by virtue of its electronegative charge can act as an active soil material which react with other soil materials and soil organic matter to produce water stable aggregates. In a highly eroded soil the clay content will be less and higher clay content is an indicator of good soil health and implies less soil erosion. Among the four studied forest land uses, ANR+GP showed promise by showing its lower potential to soil erosion. On the other hand, ANR-GP was more prone to soil erosion by virtue of its less clay content (Figure 4.3.5). In fact, the clay material has been eroded from this land use by soil erosion process namely splash, sheet and rill erosion. NTFP and Block Plantation are intermediate between these two. The clay content of surface soils varied between 9.60% and 53.60% with average value of 21.55%.

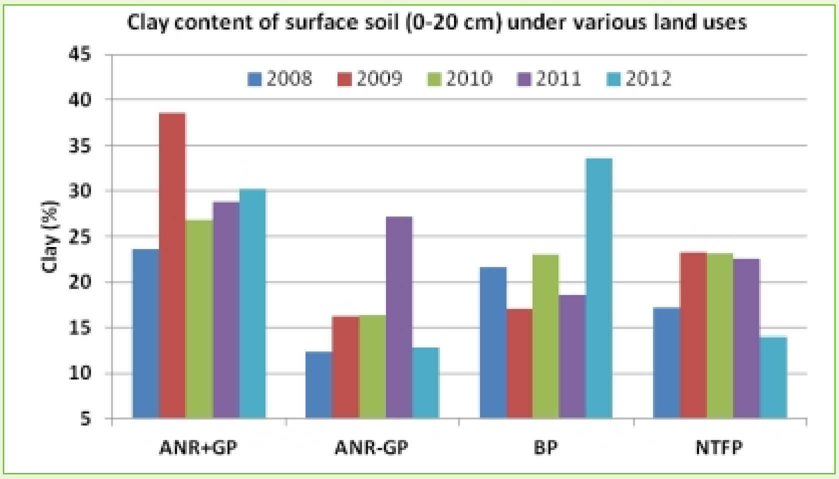


Fig. 4.3.5: Clay content of surface soil under various forest land uses

Figure 4.3.6 clearly indicates that ANR+GP has the highest clay and lowest sand content among all the forest land uses. The opposite trend has been observed for the ANR-GP land use. Therefore to improve soil physical condition ANR+GP to be promoted followed by NTFP.

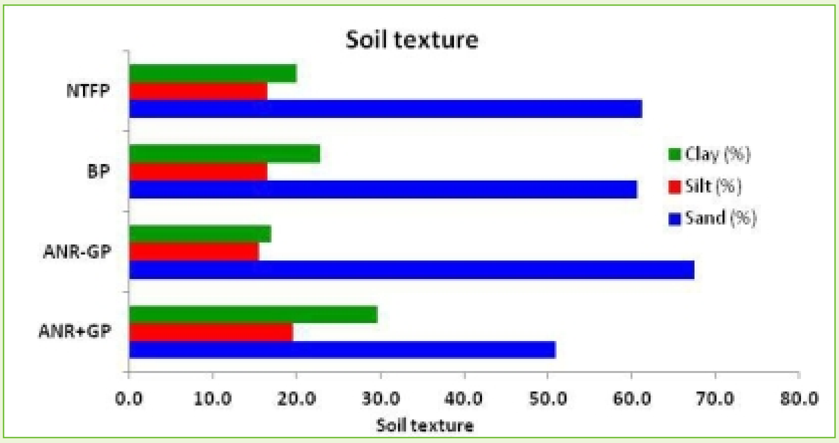


Fig. 4.3.6: Overall variation of soil texture under various forest land uses

Soil structure: Soil structure influences plant growth rather indirectly. The pores are the controlling factors governing water, air and temperature in soil, which intern, govern plant growth. One of the best effects of soil structure on plant growth is the emergence of seedlings in the seedbed. The seedlings are very sensitive to soil physical condition so that there should not be any hindrance to the emergence of tender seedlings and there should be optimum soil water and soil aeration. The soil in the seedbed should have a crumb structure so that the peds are soft and porous and roots of the seedling can penetrate it easily. The hard compact layer impedes root growth. Similarly, under the natural condition, good crumby soil structure helps to emerge more forest seedlings and assist regeneration of degraded forests. In all the study sites, the soil structure was found to be sub-angular blocky except in few ANR+GP sites at Alubadi, the surface soil structure was sub-angular blocky and crumb as well.

4.3.2 Soil moisture

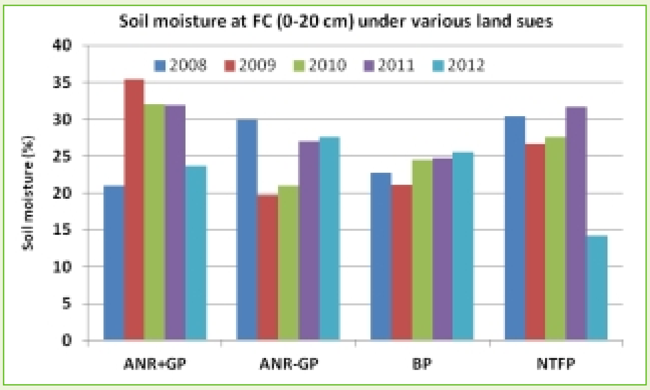
Available water content

The amount of water in soil is based on the rainfall amount, what proportion of rain infiltrates into the soil, and the soil's storage capacity. Available water capacity is the maximum amount of plant available water a soil can provide. It's an indicator of a soil's ability to retain water and make it sufficiently available for plant use. Available water capacity is the water held in soil between its field capacity and permanent wilting point. Field capacity is the water remaining in a soil after it has been thoroughly saturated and allowed to drain freely, usually for one to two days. Permanent wilting point is the moisture content of a soil at which plants wilt and fail to recover when supplied with sufficient moisture. Water holding capacity is usually expressed as a volume fraction or percentage, or as a depth (in or cm).

Soil water content at field capacity (FC) is very important. It's the measurement that has to do with the ability of soil in a given area to absorb water, once all excess and surface water has been drained from the area. Assessing the field capacity of soil is very important in determining the type of vegetation to grow in a particular land, as well as judging the capacity of that land to support buildings of various types. The result of these assessments is usually presented as a percentage.

Field capacity soil moisture content varies with soil texture, which intern varies with land use, topography and depth. In the study area the soil moisture content at FC varied between 14.2% and 38.8% with the average value of 25.2%. This wide variation is because of wide textural variation among the forest land uses. Within the various land uses the FC values follows the following trend of: ANR+GP>NTFP>ANR-GP>BP (Figure 4.3.7). The high clay content in the soils particularly at ANR+GP and NTFP forest areas is the responsible for higher soil moisture at FC.

Besides FC, soil moisture at permanent wilting point (PWP) is also very important for plant survival and growth point of view. After rainfall or irrigation, little by little, the water stored in the soil is taken up by the plant roots or evaporated from the topsoil into the atmosphere. If no additional water is supplied to the soil, it gradually dries out. The dryer the soil becomes, the more tightly the remaining water is retained and the more difficult it is for the plant roots to extract it. At a certain stage, the uptake of water is not sufficient to meet the plant's needs. The plant looses freshness and wilts; the leaves change its colour from green to yellow and finally the plant dies. The soil water content at the stage where the plant dies is called permanent wilting point. The soil still contains some water, but it is too difficult for the roots to suck it from the soil. For normal field crops it is the soil moisture at 15 bar potential. At this stage forest trees can draw water, but for initial survival of the forest trees it is very much important.



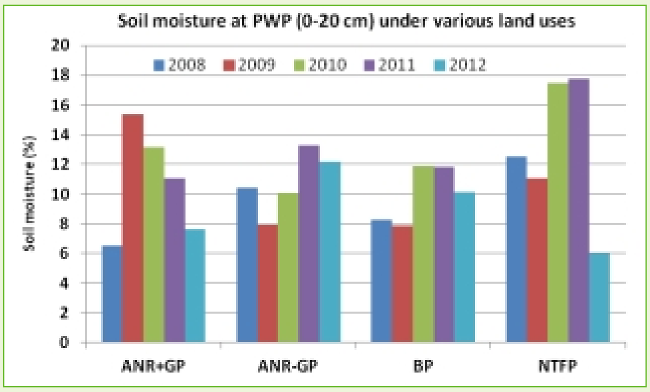


Fig. 4.3.7: Soil moisture at field capacity and permanent wilting point of surface soil under various forest land uses

PWP soil moisture content varies with soil texture also, which intern varies with land use, topography and depth. In the study area the soil moisture content at PWP varied between 4.8% and 17.8% with the average value of 10.8%. The clay content in the soils of four different land uses varies widely, thereby influence the PWP value. Within the various land uses the FC values follows the following trend: NTFP>ANR+GP>ANR-GP>BP (Figure 4.3.7). The high clay content in the soils of ANR+GP and NTFP forest areas is the responsible for higher soil moisture at PWP.

Soil is a major storage reservoir for water. Water availability is an important indicator because plant growth and soil biological activity depend on water for hydration and delivery of nutrients in solution. Runoff and leaching volumes are also determined by storage capacity and pore size distribution. In areas where rain falls daily and supplies the soil with as much or more water than it's removed by plants, available water capacity may be of little importance. However, in areas where plants remove more water than is supplied by precipitation, the amount of water held by the soil may be critical. Water held in the soil may be necessary to sustain plants between rainfall or irrigation events. By holding water for future use, soil buffers the plant root environment against periods of water deficit. Available water capacity is used to develop water budgets, predict doughtiness, design and operate irrigation systems, design drainage systems, protect water resources, and predict yields.

The available soil moisture used to be calculated as the difference of soil moisture between FC and PWP. In the study area the available soil water content varied between 8.2% and 27.9% with the average value of 14.4%. The plant available moisture is somewhat low because of steep slope and less clay content, which triggers the importance of adoption of soil and water conservation measures to improve the soil moisture content for longer duration. Among the various land uses the FC values follows the following trend: ANR+GP>ANR-GP>NTFP>BP (Figure 4.3.8). The inherent nature of ANR with and without GP is same. Therefore the available soil moisture for both the land uses is high.

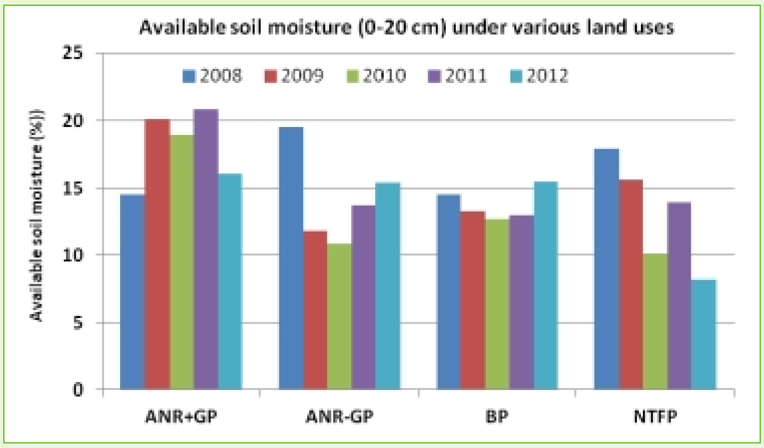


Fig. 4.3.8: Available soil moisture under various forest land use

If we analyze the overall soil moisture content under various land uses some interesting findings are emerging out. The moisture content at field capacity is following the trend like this: ANR+GP>NTFP>ANR-GP>BP. But for available moisture content the trend is not alike. It's ANR+GP>ANR-GP>BP>NTFP (Figure 4.3.9). As the available moisture content depends on both FC and PWP, the higher value of PWP for the NTFP land use has brought down the availability of soil moisture in that land use. The moisture availability is strongly dependent on the ratio of sand, silt and clay present in the soil. A well distributed and textured soil found in the land use ANR+GP has made the condition conducive for plant growth by providing more water easily.

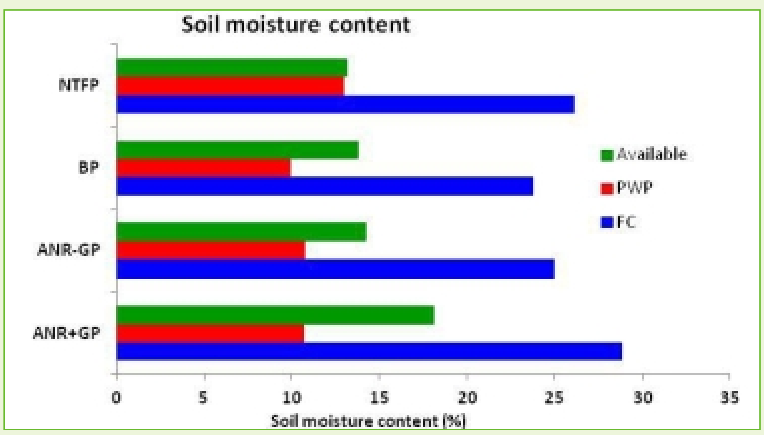


Fig. 4.3.9: Overall variation of soil moisture under various forest land uses

Soil moisture characteristic curve (SMCC)

Water retention curve or SMCC is the relationship between the water content (.) and the soil water potential (.). This curve is characteristic for different types of soil, and is also called the soil moisture characteristic. It's used to predict the soil water storage, water supply to the plants (field capacity) and soil aggregate stability. Due to the hysteretic effect of water filling and draining in the pores, different wetting and drying curves may be distinguished. Sandy soils will involve mainly capillary binding, and will therefore release most of the water at higher potentials, while clayey soils, with adhesive and osmotic binding, will release water at lower (more negative) potentials. At any given potential, peaty soils will usually display much higher moisture contents than clayey soils, which would be expected to hold more water than sandy soils. The water holding capacity of any soil is due to the porosity and the nature of the bonding in the soil.

The SMCC of the surface soil (0-20 cm) for four different forest land uses is presented in figure 4.3.10. From the figure it's clear that NTFP performed better than all the other three land uses to retain soil moisture at all the suction range. At low suction, ANR+GP and ANR-GP performed similarly, but with the increasing suction, ANR+GP outperformed ANR-GP. The performance of Black Plantation is poorer than all the other land uses. At higher suction, ANR-GP and BP performed similarly. This indicates that both the land use was disturbed at recent past.

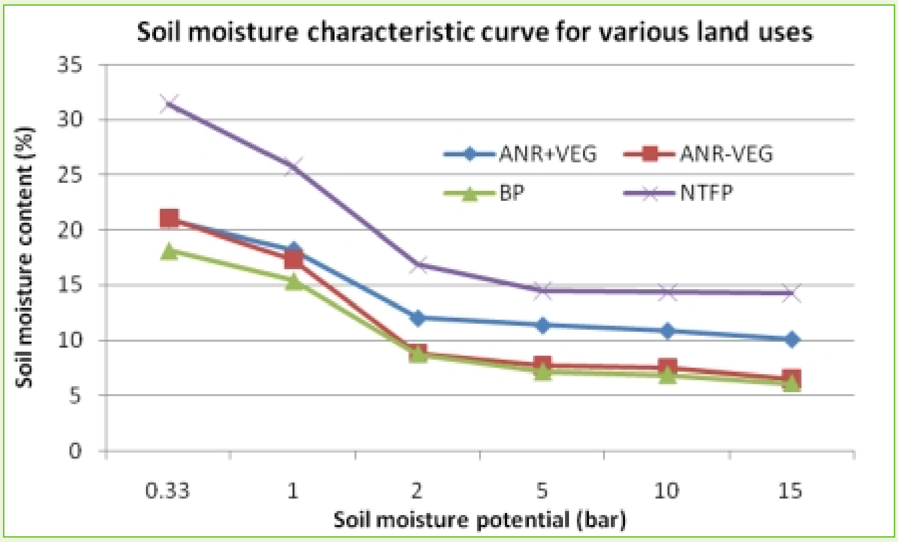


Fig. 4.3.10: Soil moisture characteristic curve under various forest land uses

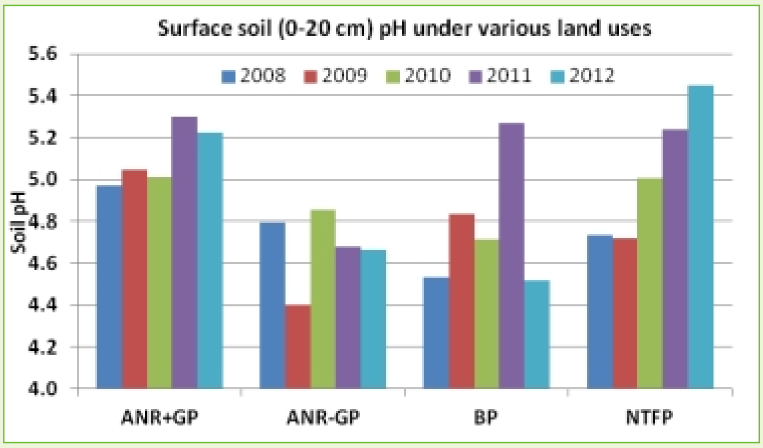
4.3.3 Chemical properties

Soil chemical properties are very important to determine the soil quality and its resistance to erosion. Among the various soil chemical properties, the most important are soil pH, Electrical Conductivity (EC) and Soil Organic Carbon (SOC). All these soil chemical properties vary with land use, soil depth and topo-sequence. The variation of the soil chemical properties with forest land uses under different time scale is presented below:

pH :The soil pH is a measure of the acidity or alkalinity in soils. pH is defined as the negative logarithm (base 10) of the activity of hydronium ions (H+) in a solution. In water, it normally ranges from 1 to 14, with 7 being neutral. A pH below 7 is acidic and above 7 is alkaline. Soil pH is considered a master variable in soils as it controls many chemical processes that take place. It specifically affects plant nutrient availability by controlling the chemical forms of the nutrient. The optimum pH range for most plants is between 5.5 and 7.0, however many plants have adapted to thrive at pH values outside this range.

When soil acidity changes the solubility of metal ions also changes. Plant growth is really affected by the varying concentration of these metals in solution rather than by the acidity itself. Under acidic conditions, many soil minerals dissolve and increase the concentration of metal ions to toxic levels. The primary toxic metal is aluminum, but high levels of manganese and iron can also inhibit plant growth under these conditions. The nutrients phosphorus and molybdenum are less available in acidic soils and calcium and/or magnesium may also be deficient. Under alkaline conditions, the solubility of minerals decreases to the point that nutrient deficiencies occur. Plant growth is therefore limited by deficiencies in iron, manganese, zinc, copper and boron. Phosphorus is also less available in alkaline soils and high levels of calcium may inhibit the uptake of potassium and magnesium.

The aim in managing soil pH is not to achieve a particular pH value, but to adjust the acidity to the point where there are no toxic metals in solution and the availability of nutrients is at its maximum. This condition is usually achieved when the soil pH is between 5.8 and 6.5, however some plants have special acidity requirements. Limestone is used to treat acidic soils, but the soil pH value alone does not indicate the amount needed. An exchangeable acidity analysis must also be done to determine the amount of limestone required, and the soil calcium and magnesium levels must be analyzed to determine which type of limestone (dolomitic or calcitic) is required. Some alkaline soils can be acidified using sulfur or acid forming fertilizers, but soils with free calcium carbonate cannot be easily acidified. It is often easier to manage the nutrient deficiencies that occur on alkaline soils than to acidify the soil.



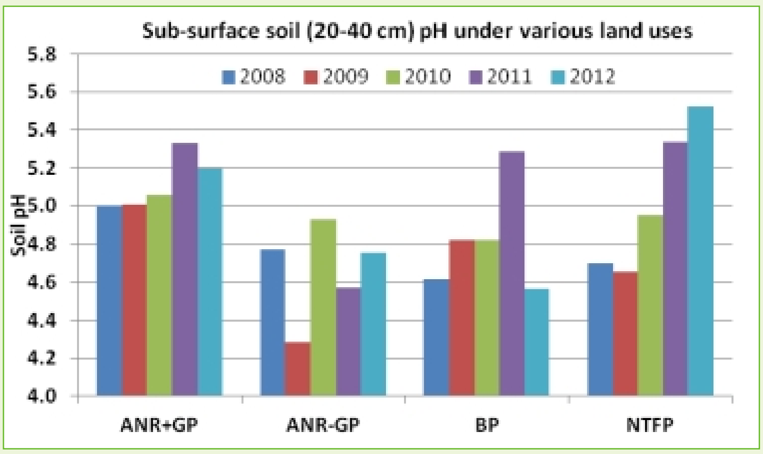


Fig. 4.3.11: pH of soils under various forest land uses

The pH of all the study sites is acidic in nature, which is natural, keeping in mind the prevailing geological condition and the rainfall pattern of the area. The pH of surface soils varied between 4.27 and 5.64 with average value of 4.93. Among the various forest land uses, ANR-GP showed highest acidity (Figure 4.3.11). This is because of the leaching of the basic cations with runoff water from the bare soil surface of this land use coupled with low buffering capacity due to poor organic matter content. The same pattern has been found for the sub-surface soil also (Figure 4.3.11). In the sub-surface soils, the pH varies between 4.12 and 5.73 with average value of 4.94, which is slightly higher than the surface soils.

The overall variation of soil pH is following the trend like this: ANR+GP>NTFP>BP>ANR-GP (Figure 4.3.12). The litter and the leaves of the trees grown in the forests contain calcium where the tree root system draws from the deeper soil layers. After these organics mixed with the surface soil system, it increases the soil pH owing to high calcium in leaves. Therefore ANR+GP and NTFP showed its potentiality to neutralize soil acidity.

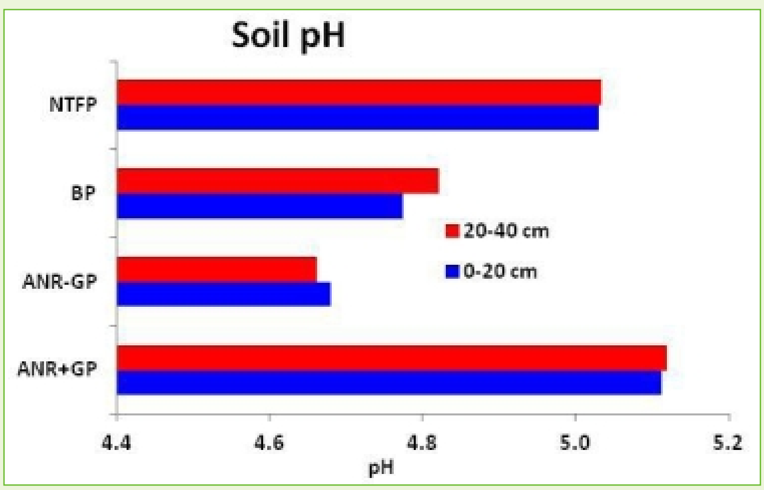


Fig. 4.3.12: Overall variation of soil pH under various forest land uses

Electrical conductivity (EC): Soil electrical conductivity is an indirect measurement that correlates very well with several soil physical and chemical properties. Electrical conductivity is the ability of a material to conduct (transmit) an electrical current and it is commonly expressed in units of milliSiemens per meter (mS/m). Alternatively, electrical conductivity measurements can be expressed in deciSiemens per meter (dS/m), which is 100 times greater than milliSiemens per meter.

In the study area the EC varied considerably among the land uses. The soil salinity in terms of EC is following the following trend: ANR+GP>NTFP>Block Plantation>ANR-GP(Figure 4.3.13). The study area is situated in high rainfall zone and the salts are being leached down the slope from the bare soil of ANR-GP land use. The high canopy cover and high litter fall of ANR and NTFP made the salts dissolved in soil solution in higher amount and increases the salinity. Overall the soils are slightly saline in nature for all the sites.

Similarly the trend is same for the sub-surface soils but with different magnitude (Figure 4.3.13). For BP and NTFP the salinity increases with time. But this statement may be redundant as the VSS are different for different plantation year.

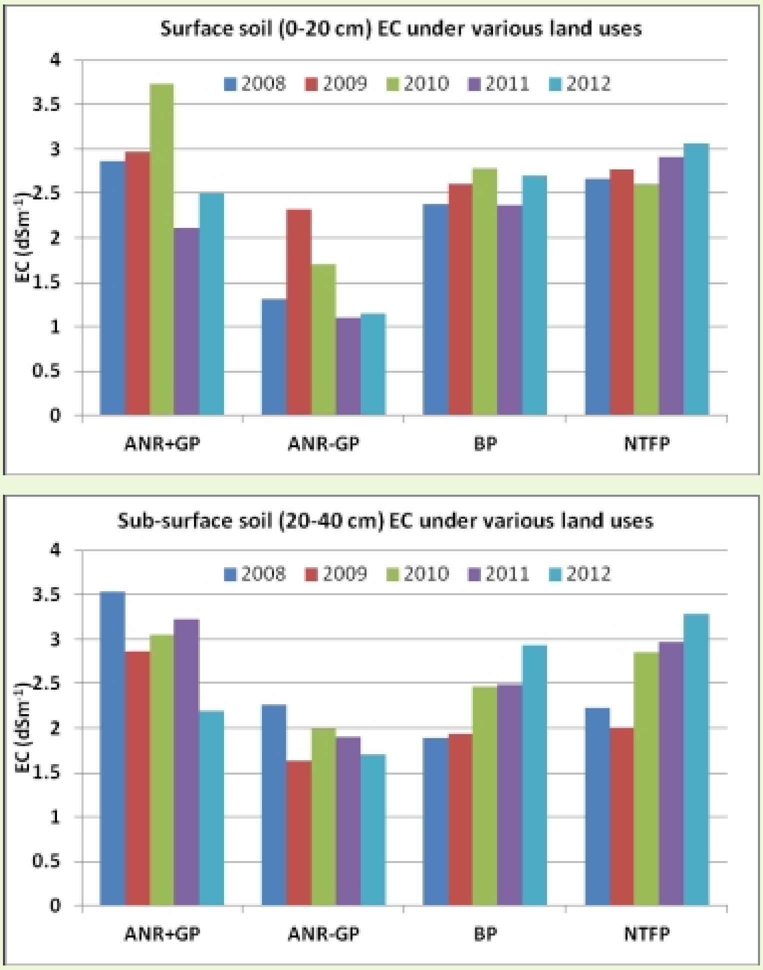


Fig. 4.3.13: EC of soils under various forest land uses

Soil EC varies with the variation of other soil properties. Since sands have low conductivity and clays have high conductivity, soil electrical conductivity correlates very strongly with particle size and soil texture. Soils prone to drought or excessive water will show variations in soil texture that can be delineated using soil electrical conductivity. Since water-holding capacity is intimately linked to plant growth and development, there is enormous potential to use soil electrical conductivity measurements to delineate areas with different production potential. Soil electrical conductivity also can delineate differences in organic matter content and cation exchange capacity. Perhaps the greatest difficulty with a measurement as inclusive as soil electrical conductivity is to conclude what is causing the variation seen in soil electrical conductivity in any given area.

Electrical conductivity is a measurement of soil salinity. High EC means high salt content in the soil solution. The EC of forest soils used to be higher than the bare soils because of higher dissolution of salt carried out by the acid produced from the decomposition of the litter fall.

4.3.4 Biological properties

Soil enzyme activity: Soil enzymes increase the reaction rate at which plant residues decompose and release plant available nutrients. The substance acted upon by a soil enzyme is called the substrate. For example, glucosidase (soil enzyme) cleaves glucose from glucoside (substrate), a compound common in plants. Enzymes are specific to a substrate and have active sites that bind with the substrate to form a temporary complex. The enzymatic reaction releases a product, which can be a nutrient contained in the substrate. Sources of soil enzymes include living and dead microbes, plant roots and residues, and soil animals. Enzymes stabilized in the soil matrix accumulate or form complexes with organic matter (humus), clay, and humus-clay complexes, but are no longer associated with viable cells.

It's thought that 40 to 60% of enzyme activity can come from stabilized enzymes, so activity does not necessarily correlate highly with microbial biomass or respiration. Therefore, enzyme activity is the cumulative effect of long term microbial activity and activity of the viable population at sampling. However, an example of an enzyme that only reflects activity of viable cells is dehydrogenase, which in theory can only occur in viable cells and not in stabilized soil complexes.

Enzymes respond to soil management changes long before other soil quality indicator changes are detectable. Soil enzymes play an important role in organic matter decomposition and nutrient cycling. Some enzymes only facilitate the breakdown of organic matter (e.g., hydrolase, glucosidase), while others are involved in nutrient mineralization (e.g., amidase, urease, phosphatase, sulfates). With the exception of phosphatase activity, there is no strong evidence that directly relates enzyme activity to nutrient availability or crop production. The relationship may be indirect considering nutrient mineralization to plant available forms is accomplished with the contribution of enzyme activity.

Dehydrogenase activity: Soil dehydrogenases are the major representatives of the Oxidoreductase enzymes class. Among all enzymes in the soil environment, dehydrogenases are one of the most important, and are used as an indicator of overall soil microbial activity, because they occur intracellular in all living microbial cells. Moreover, they are tightly linked with microbial oxido-reduction processes. What is important that dehydrogenases do not accumulate extracellular in the soil system.

Dehydrogenases play a significant role in the biological oxidation of soil organic matter (SOM) by transferring hydrogen from organic substrates to inorganic acceptors. Many specific dehydrogenases transfer hydrogen to either nicotinamide adenine dinucleotide or nicotinamide adenine dinucleotide phosphate. Throughout mentioned co-enzymes hydrogen atoms are involved in the reductive processes of biosynthesis. Due to this fact, the overall DHA of a soil depends on the activities of various dehydrogenases, which are fundamental part of the enzyme system of all living microorganisms, like enzymes of the respiratory metabolism, the citrate cycle, and N metabolism. Thus, DHA serves as an indicator of the microbiological redox-systems and could be considered a good and adequate measure of microbial oxidative activities in soil.

Active dehydrogenases can utilize both O_2 and other compounds as terminal electron acceptors, although anaerobic microorganisms produce most dehydrogenases. Therefore, DHA reflects metabolic ability of the soil and its activity is considered to be proportional to the biomass of the microorganisms in soil. However, the relationships between an individual biochemical property of soil DHA and the total microbial activity is not always obvious, especially in the case of complex systems like soils, where the microorganisms and processes involved in the degradation of the organic compounds are highly diverse. Therefore the measurement of DHA in soil system is very important to know the quality of that soil.

As the dehydogenase activity (DHA) indicates the present microbial activity in the soil, therefore the soil which is under constant supply of substrate like organic matter and root exudates definitely show higher DHA. NTFP outperformed all the other land uses in terms of DHA (Figure 4.3.14). Because, the higher undergrowth facilitate higher litter fall and higher root activity. ANR+GP is also performed similarly like NTFP, but its slight higher plant growth makes the root go below 1.0 m distance of soil surface and thereby reduces its activity in the above soil. Only the falling litter contributed significantly for the DHA. Block Plantation and ANR-GP are not much active in terms of microbial activity as compared to NTFP and ANR+GP. As these two land uses were disturbed to establish teak tree and made clean, respectively, the upper soil has been eroded and reduced the microbial activity. Similar trend has also been found for the sub-surface (20-40 cm) soil also (Figure 4.3.14). The value of DHA for surface soil varies between 66.9 and 183.7 mg TPF kg^{-1} d^{-1} with the average value of 109.8 mg TPF kg^{-1} d^{-1}. The value for the sub-surface soil is bit lower than the surface soil and lies between 65.4 and 174.4mg TPF kg^{-1} d^{-1} with the average value of 103.7 mg TPF kg^{-1} d^{-1}.

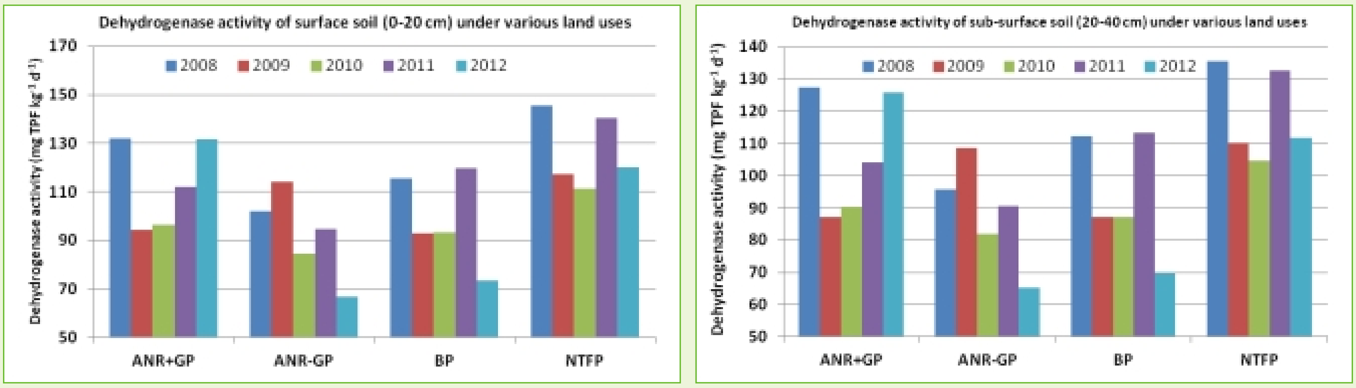


Fig. 4.3.14: Soil dehydrogenase activity under various forest land uses

The DHA of surface soil is higher than sub-surface soil for all the land uses. NTFP and ANR with vegetation showed significantly higher DHA than BP and ANR-GP (Figure 4.3.15). The relatively shallower active root system of NTFP trees have made the microbes active hence showed high DHA.

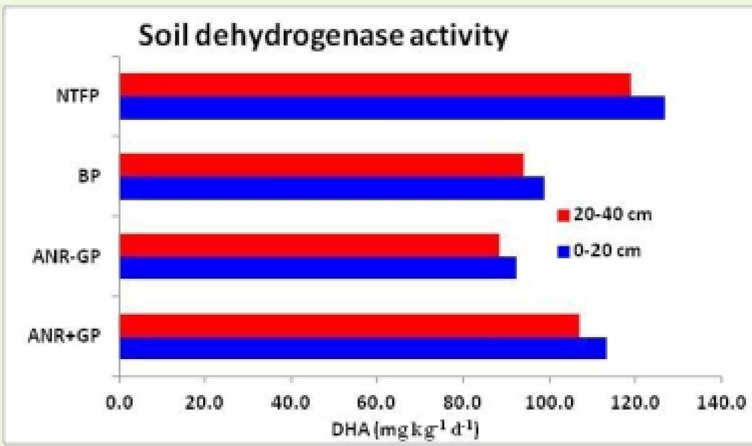


Fig. 4.3.15: Overall variation of soil dehydrogenase activity under various forest land uses

4.3.5 Soil fertility status

The fertility of soil can be considered in many ways, depending on land use. In intensively managed agricultural/horticultural/forestry systems, soil fertility can be defined in terms of the value of products produced relevant to inputs used (including economic aspects of nutrient budgeting). Alternatively, the emphasis may be on quality or productivity. The fertility of soil is related to its capacity to produce a product. In many natural ecosystems, the value of land use may not be clearly defined, and a different definition of soil fertility may be more suitable. The fertility of soil is related to its capacity to support a particular natural community of plants. Another view might emphasize the concept of sustainability. The fertility of a soil is related to its capacity to maintain consistent output with minimal input. Thus, the concept of soil fertility is most useful when it is used in a specific context. However, in all contexts, soil fertility depends on physical, chemical and biological characteristics.

When soil fertility is considered in terms of the highest practical level of productivity, the focus is mostly on physical and chemical aspects of soil. It's important to note that some aspects of the biological component of soil fertility can be overridden by addition of fertilizers, but this is not a simple phenomenon, because increased plant growth associated with addition of fertilizer can increase other aspects of the biological activity in soil. When sustainability of the soil resource is emphasized in the context of soil fertility, biological components may become more relevant because long-term productivity is taken into account. A change in focus from the highest practical level of productivity to a lower, profitable and persistent level of production has the potential to depend to a greater extent on soil biological processes.

In a sustainable forest ecosystem, soil fertility can be considered in terms of the amount of input relative to the amount of output over a long period, using a budgeting approach. This definition is different to one that defines fertility in relation to a maximum level of productivity in the short-term or at one point in time. A definition that focuses on short-term productivity is based on the capacity of soil to immediately provide plant nutrients. In forest land uses it directly dependent on soil physical, chemical and biological properties but the most important are available N, P and K.

Available nitrogen status: The availability of nitrogen limits production in many forest ecosystems. The N availability refers to the extent to which the plant growth, development and economic production is constrained by the limited supply of N. In forest ecosystem, difference in species composition, stand age, root behavior, land slope and soil moisture play an important role to determine the availability of soil N to the tree.

Figure 4.3.16 depicts the variation of available nitrogen in soil. Among the four forest land uses, the availability of N follows the following trend: NTFP>ANR+GP>Black Plantation>ANR-GP. As the ANR+GP and NTFP sites are undisturbed, the N loss is very low, thereby increases the availability is more. Side by side these two land uses contain higher SOC, which may also contributed to higher available N. The ANR-GP and BP sites are disturbed sites, leading to higher loss of N and lower amount of SOC and available N.

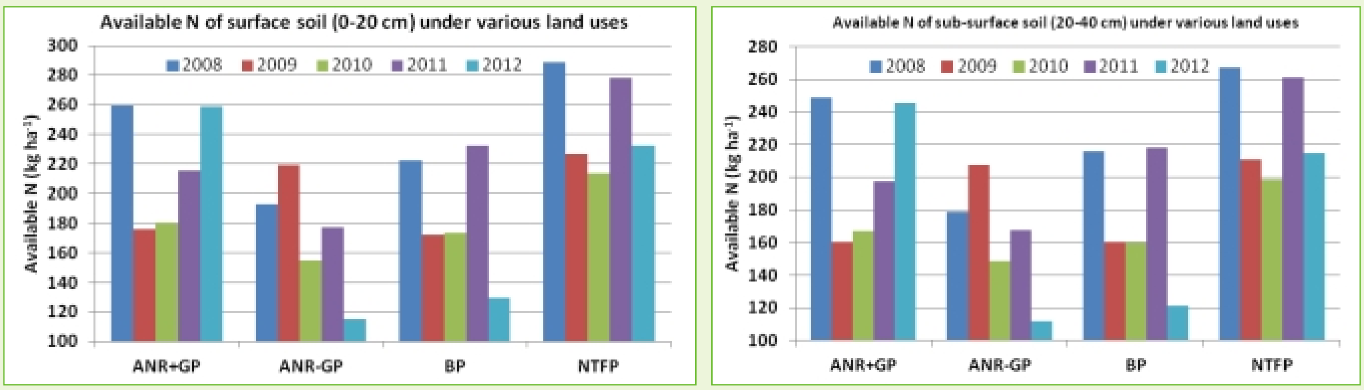


Fig. 4.3.16: Available nitrogen of soils under various forest land uses

The trend is similar for the sub-surface soil also (Figure 4.3.16), but the magnitude is somewhat lower than the surface soil. The value of available N for surface soil varies between 115.4 and 373.6 kg ha^{-1} with the average value of 210.3 kg ha^{-1}. The value for the sub-surface soil is bit lower than the surface soil and lies between 111.9 and 353.1 kg ha^{-1} with the average value of 196.7 kg ha^{-1}.

Available phosphorus status: Soil phosphorus (P) is the most common macronutrient limiting plant growth under natural conditions. Inventories of global soil P found that soil P amount is lowest in the tropical and subtropical regions that account for about 40% of the global gross primary production and net carbon uptake over the past two decades. It's generally accepted that the total soil P gradually decreases as the result of weathering, ecosystems may decline at their advanced stage, which resulting in a decrease of biomass and diversity due to soil P limitation. Available soil P reduced the responses of tropical forests to increasing CO_2 concentrations. Under global increasing atmospheric CO_2 and N deposition in the future, P limitation of net primary production (NPP) in terrestrial ecosystems, particularly tropical and subtropical forests, will likely exacerbate.

The soil available P in the soil of the study area is low to medium observed in all the land uses. In this agro-climatic zone the soils are acidic in nature and rich in iron and aluminum. Thereby the soil P has the tendency to fix in the soil as iron and aluminum phosphate. Under different forest land use system the NTFP showed highest surface soil P content. All other land uses are statistically at par in terms of available P content (Figure 4.3.17). Higher organic acids produced by the decomposition of soil micro organisms made the soil P available in NTFP system.

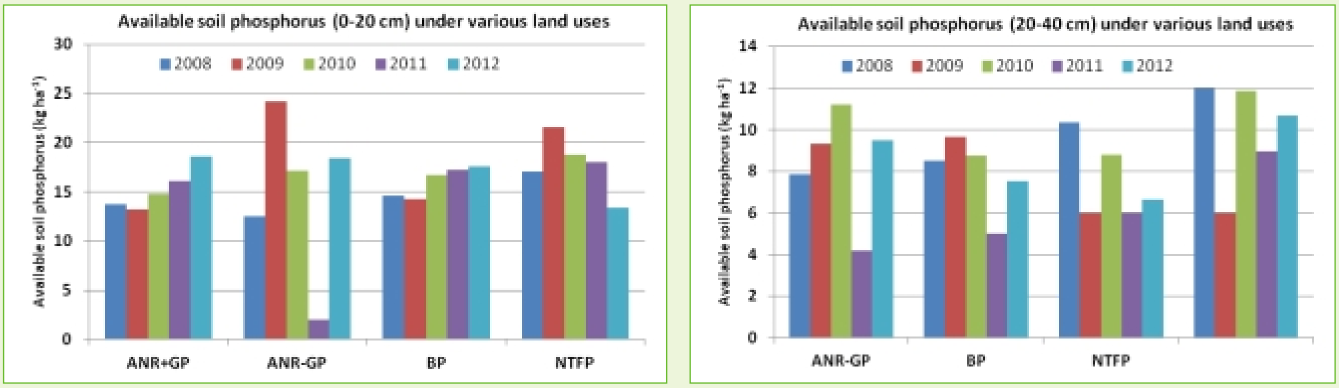


Fig. 4.3.17: Available phosphorus of soils under various forest land uses

The sub-surface soil of all the land uses except NTFP and ANR+GP of few VSS showed low available P (Figure 4.3.17). The magnitude of P is lower than the P content of surface soil. The decomposing litter produced acid content is low in the sub-surface soil as evidenced from low DHA and MBC content of the sub-surface soils. Therefore the available P content is lower in sub-surface soils. The value of available P for surface soil varies between 2.1 and 24.5 kg ha^{-1} with the average value of 16.3 kg ha^{-1}. The value for the sub-surface soil is bit lower than the surface soil and lies between 1.5 and 21.3 kg ha^{-1} with the average value of 8.54 kg ha^{-1}.

Available potassium status: Potassium (K) is one of the essential nutrients in plants and is one of three (including nitrogen and phosphorus) that are commonly in sufficiently short supply in the soil to limit forest production on many soil types in Eastern India. Potassium is commonly found in plants at levels above all other macro nutrients except carbon, oxygen, hydrogen and occasionally nitrogen. Potassium has many functions including the regulation of the opening and closing of stomata which are the breathing holes found on plant leaves and therefore regulate moisture loss from the plant. For this reason potassium is known as poor-mans irrigation because it helps crops finish better. Potassium is associated with movement of water, nutrients, and carbohydrates in plant tissue. If K is deficient or not supplied in adequate amounts, growth is stunted and productivity is reduced. Various research efforts have shown that potassium stimulates early growth, increases protein production, improves the efficiency of water use, is vital for stand persistence and longevity, and improves resistance to diseases and insects. These roles or functions are general; but all are important to profitable forest production.

The soil of the region is generally rich in available potassium because of the illitic type of parent material which is reflected in all the sites of the study area. The trend of availability of K under various land uses are like this: NTFP>ANR+GP>Black Plantation>ANR-GP(Figure 4.3.18). The low availability under ANR-GP may be due to removal of top soil during cleaning and subsequent water erosion, which leads to the exposure of sub-soil where the K availability is less.

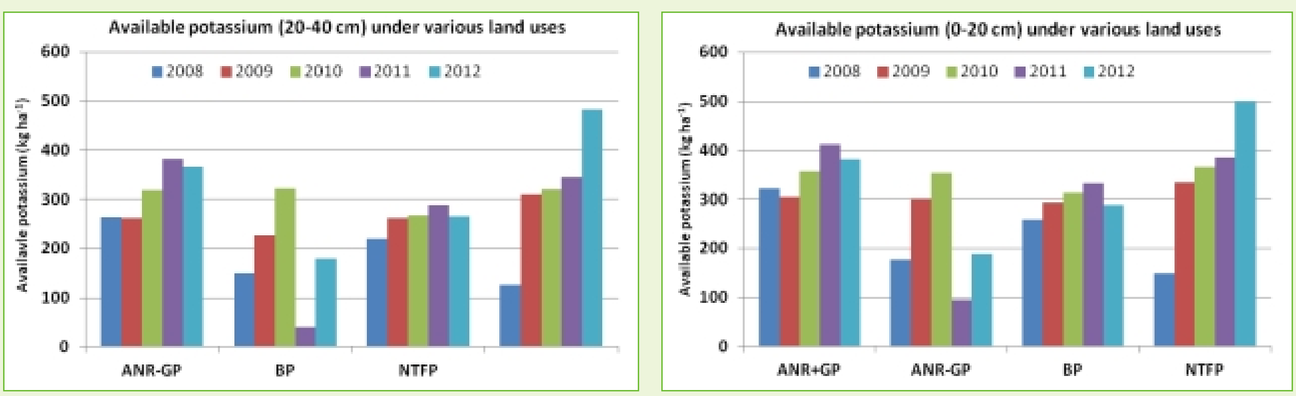


Fig. 4.3.18: Available potassium of soils under various forest land uses

The trend is similar for the sub-surface soil also (Figure 4.3.18), but the magnitude is somewhat lower than the surface soil. The value of available K for surface soil varies between 94.8 and 558 kg ha^{-1} with the average value of 325.2 kg ha^{-1}. The value for the sub-surface soil is bit lower than the surface soil and lies between 40.5 and 537.7 kg ha^{-1} with the average value of 289.8 kg ha^{-1}.

Overall fertility status of all the land uses is medium to good and followed the following trend: NTFP>ANR+GP>BP>ANR-GP (Figure 4.3.19).

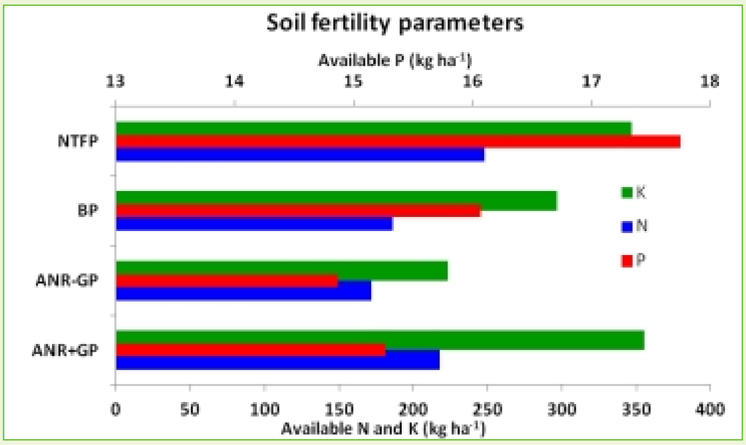


Fig. 4.3.19: Overall variation of soil fertility parameters (N,P,K) under various forest land uses

4.3.6 Soil carbon

Soil organic carbon: Total organic carbon (TOC) is the carbon (C) stored in soil organic matter (SOM). Organic carbon (OC) enters the soil through the decomposition of plant and animal residues, root exudates, living and dead microorganisms, and soil biota. SOM is the organic fraction of soil exclusive of non decomposed plant and animal residues. Nevertheless, most analytical methods do not distinguish between decomposed and non-decomposed residues. SOM is a heterogeneous, dynamic substance that varies in particle size, C content, decomposition rate, and turnover time. Soil Organic Carbon (SOC) is the main source of energy for soil microorganisms. SOM contains approximately 58% C; therefore, a factor of 1.72 can be used to convert SOC to SOM. There is more inorganic C than TOC in calcareous soils. TOC is expressed as percent C per 100 g of soil.

SOC is one of the most important constituents of the soil due to its capacity to affect plant growth as both a source of energy and a trigger for nutrient availability through mineralization. SOC fractions in the active pool, previously described, are the main source of energy and nutrients for soil microorganisms. Humus participates in aggregate stability, and nutrient and water holding capacity.

SOC compounds, such as polysaccharides (sugars) bind mineral particles together into micro aggregates. Glomalin, a SOM substance that may account for 20% of soil carbon, glues aggregates together and stabilizes soil structure making soil resistant to erosion, but porous enough to allow air, water and plant roots to move through the soil. Organic acids (e.g., oxalic acid), commonly released from decomposing organic residues and manures, prevents phosphorus fixation by clay minerals and improve its plant availability, especially in subtropical and tropical soils. An increase in SOM, and therefore total C, leads to greater biological diversity in the soil, thus increasing biological control of plant diseases and pests. Data also reveals that interaction between dissolved OC released from manure with pesticides may increase or decrease pesticide movement through soil into groundwater.

Figure 4.3.20 depicts the variation of SOC in soil. Among the four forest land uses, the content of SOC follows the following trend: NTFP>ANR+GP>Black Plantation>ANR-GP. As the ANR+GP and NTFP sites are undisturbed, the C loss is very low, thereby increases the content. Side by side these two land uses produce higher litter because of higher under growths, which may also contributed to higher SOC content. The higher activity of roots also played a major role to contribute to higher SOC. The ANR-GP and BP sites are disturbed sites, leading to higher loss of SOC. In BP site, the litter fall is limited and in ANR-GP there was no above ground biomass at all.

The trend is similar for the sub-surface soil also (Figure 4.3.20), but the magnitude is somewhat lower than the surface soil. The value of SOC for surface soil varied between 0.38% and 2.11% with the average value of 1.01%. The value for the sub-surface soil is bit lower than the surface soil and lies between 0.36% and 1.96% with the average value of 0.92%.

Overall, for both the depths, NTFP showed higher soil organic carbon than all other land uses (Figure 4.3.21). NTFP along with ANR+GP clearly depicts that in tropical condition soil disturbance create a negative balance in SOC pool by increasing the carbon mineralization. Therefore, it's desirable that all the forest land uses to be protected from any type of biotic and abiotic disturbances. SMC measures can help in a substantial amount to achieve this purpose.

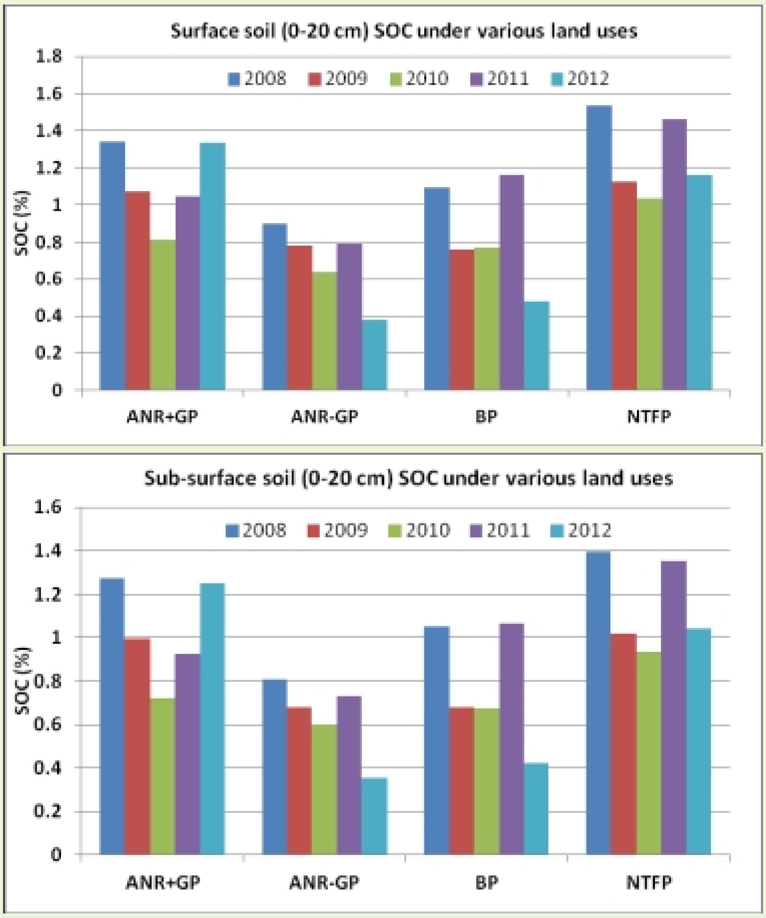


Fig. 4.3.20: Soil organic carbon under various forest land uses

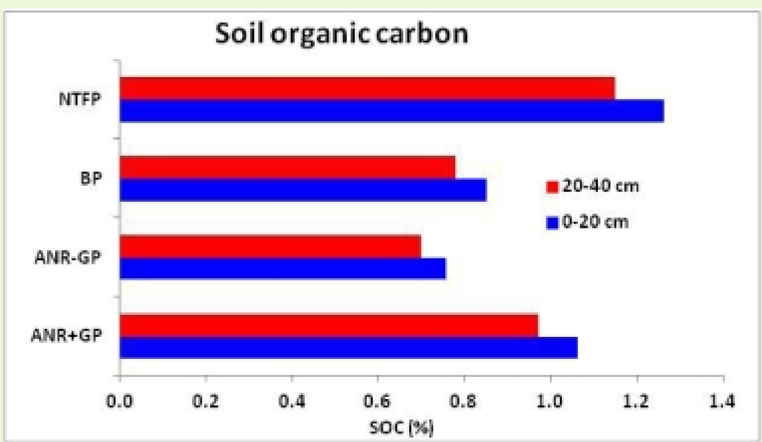


Fig. 4.3.21: Overall variation of soil organic carbon under various forest land uses

4.3.7 Soil organic carbon stock and sequestration

Soil organic carbon stock is an important parameter to understand the health of the soil. While aboveground biomass can be estimated using remote sensing (Goetz et al. 2009), the measurement of soil organic carbon stocks over large areas is much more onerous. Verifying changes in soil organic matter due to management is even more problematic. Measurement techniques for assessing soil organic matter (SOM), and by extension soil carbon, are relatively straightforward. The measurement of soil carbon requires the assessment of three variables: (i) soil carbon content; (ii) soil depth; and (iii) soil bulk density. Depth and bulk density together estimate soil mass per unit area, and soil carbon content determines what proportion of the mass is carbon.

Past long-term experimental studies have shown that soil organic C is highly sensitive to changes in land use, with changes from native ecosystems such as forest to agricultural systems almost always resulting in a loss of SOC (Jenkinson 1977, Paul et al. 1997). Likewise, the way in which land is managed following land use change has also been shown to affect SOC stocks. We therefore have the opportunity in the future to change to land use and land management strategies that lead to C storage in the soil, thereby mitigating GHGs effects and improving soil fertility.

In the study area for all the land uses, surface soil showed high soil organic carbon stock than the sub-surface soils. Among the various land uses, the rank to store SOC is following the order: NTFP > ANR with GP > BP > ANR without GP (Fig. 4.3.22). Only ANR+GP and NTFP showed higher SOC stock than the system average value.

Atmospheric concentrations of carbon dioxide can be lowered either by reducing emissions or by taking carbon dioxide out of the atmosphere and storing in terrestrial, oceanic, or freshwater aquatic ecosystems. A sink is defined as a process or an activity that removes greenhouse gas from the atmosphere. The long-term conversion of grassland and forestland to cropland (and grazing lands) has resulted in historic losses of soil carbon worldwide but there is a major potential for increasing soil carbon through restoration of degraded soils and widespread adoption of soil conservation practices. Land degradation does not only reduce crop yields but often reduces the carbon content of agro-ecosystems.

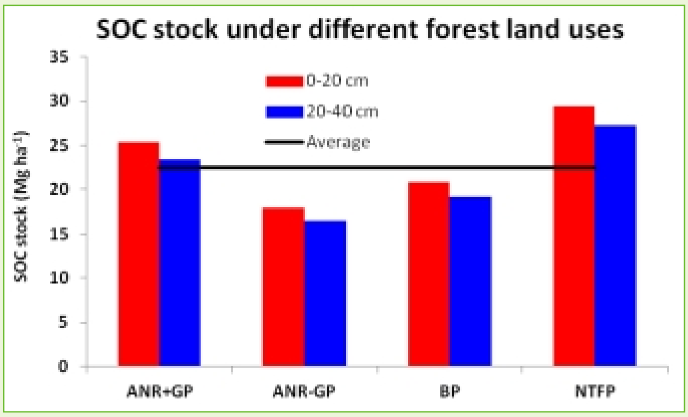


Fig. 4.3.22: Soil organic carbon stock under various forest land uses

The rate of soil carbon sequestration is an indicator of the efficiency of that land use system to sequester inorganic from the atmosphere to the more stable soil organic carbon. This rate varies from land use to land use. Among the various forest land uses in the study area NTFP showed the highest SOC sequestration rate which is one and half time higher than the system average rate. ANR with GP is showing the rate which is at per the system average but the BP showed very low SOC sequestration rate which is half of the system average rate. The less vegetation cover in the BP sites made the SOS sequestration rate less than the ANR+GP and NTFP. The active root system and higher litter fall of the NTFP system has made this very effective in terms of SOC sequestration. The SOC sequestration rate is higher in the surface soil than the sub-surface soils for all the land uses.

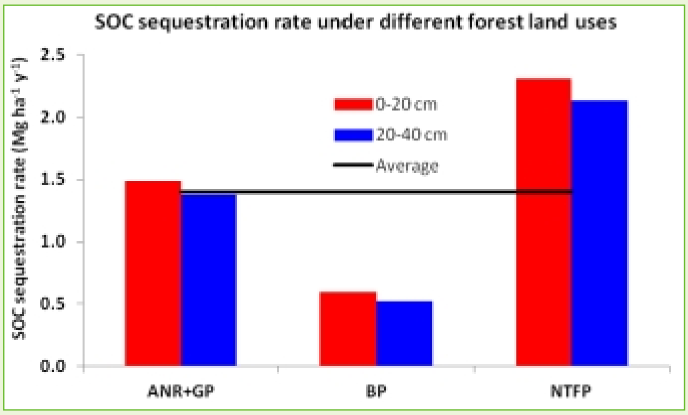
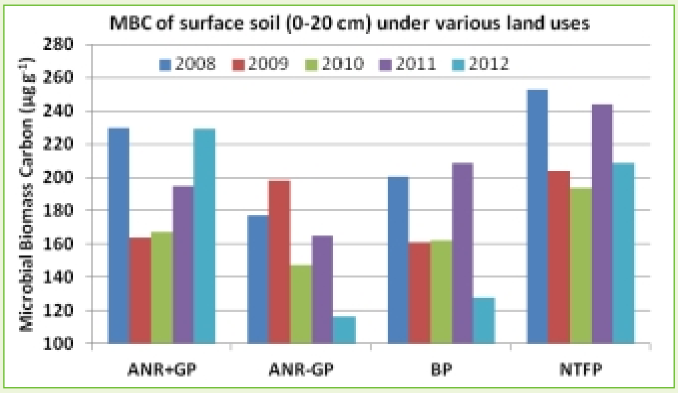


Fig. 4.3.23: Soil organic carbon sequestration rate under various forest land uses

4.3.8 Microbial biomass carbon

Soil organic matter is an important component of soil quality and productivity; however, its measurement alone does not adequately reflect changes in soil quality and nutrient status. Measurements of biologically active fractions of organic matter, such as microbial biomass carbon (MBC) and nitrogen (MBN), and potential C and N mineralization, could better reflect changes in soil quality and productivity that alter nutrient dynamics. These fractions can also provide an assessment of soil organic matter changes induced by management practices, such as forest, tilling, and cropping. The importance of microorganisms in ecosystem functioning has led to an increased interest in determining soil microbial biomass. The soil microbial biomass is the active component of the soil organic pool, which is responsible for organic matter decomposition affecting soil nutrient content and, consequently, primary productivity in most biogeochemical processes in forest ecosystems.

The amount of microbial biomass carbon is also following the trend that of SOC *i.e.* NTFP>ANR+GP>Black Plantation>ANR-GP (Figure 4.3.24). This is quite obvious, keeping in mind the climatic and topographic characteristics of the sites. ANR+GP and NTFP sites are the comparatively active sites in terms of microorganisms are concerned than ANR-GP and BP sites. Continuous litter deposition and root growth in addition to higher soil moisture content have made the ANR+GP and NTFP sites more conducive for the growth and development of microorganisms.



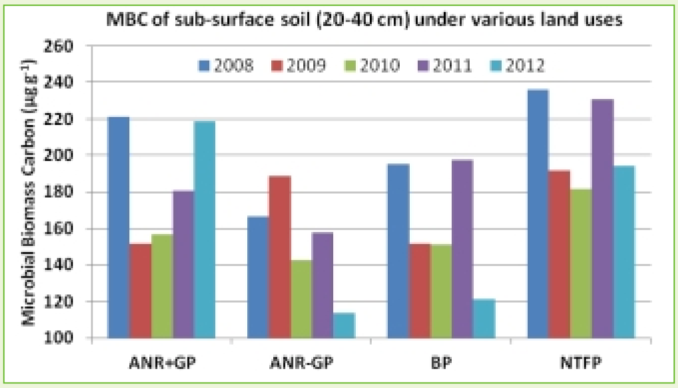


Fig. 4.3.24: Soil microbial biomass carbon under various forest land uses

The trend is similar for the sub-surface soil also (Figure 4.3.24), but the magnitude is somewhat lower than the surface soil. The value of MBC for surface soil varied between 116.4 µg g^{-1} and 319.4 µg g^{-1} with the average value of 191.1 µg g^{-1}. The value for the sub-surface soil is bit lower than the surface soil and lies between 113.7 µg g^{-1} and 303.3 µg g^{-1} with the average value of 180.4 µg g^{-1}.

In nutshell, the trend of soil microbial biomass carbon is following the similar trend of soil organic carbon for all the depth and for all the land uses. Higher MBC in NTFP and ANR+GP (Figure 4.3.25) is due to higher amount of SOC. Therefore a good relation may be established between the two for each land use.

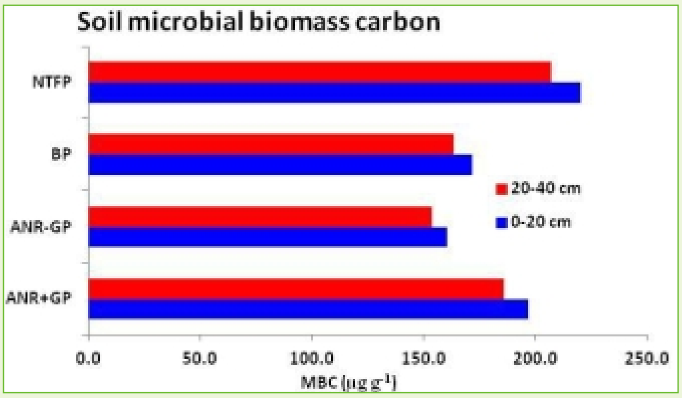


Fig. 4.3.25: Overall soil microbial biomass carbon under various forest land uses

4.3.9 Infiltration study

Infiltration is the process by which water on the ground surface enters the soil. Infiltration rate is a measure of the rate at which soil is able to absorb rainfall or irrigation. It's measured in inches per hour or millimeters per hour. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier. It's related to the saturated hydraulic conductivity of the near-surface soil. The rate of infiltration was measured using an infiltrometer. Infiltration is governed by two forces namely gravity and capillary action. While smaller pores offer greater resistance to gravity, very small pores pull water through capillary action in addition to and even against the force of gravity.

The rate of infiltration is determined by soil characteristics including ease of entry, storage capacity, and transmission rate through the soil. The soil texture and structure, vegetation types and cover, water content of the soil, soil temperature, and rainfall intensity all play a role in controlling infiltration rate and capacity. For example, coarse-grained sandy soils have large spaces between each grain and allow water to infiltrate quickly. Vegetation creates more porous soils by both protecting the soil from pounding rainfall, which can close natural gaps between soil particles, and loosening soil through root action. This is why forested areas have the highest infiltration rates of any vegetative types.

In the study area, we selected five VSS for the infiltration study under four forest land uses keeping the topographic condition same for the different land uses.

ANR with gap planting showed very high infiltration rate in Bhitarguda site and medium to low infiltration rate in Maliguda site. The other three VSS showed medium to high infiltration rate (Figure 4.3.26).

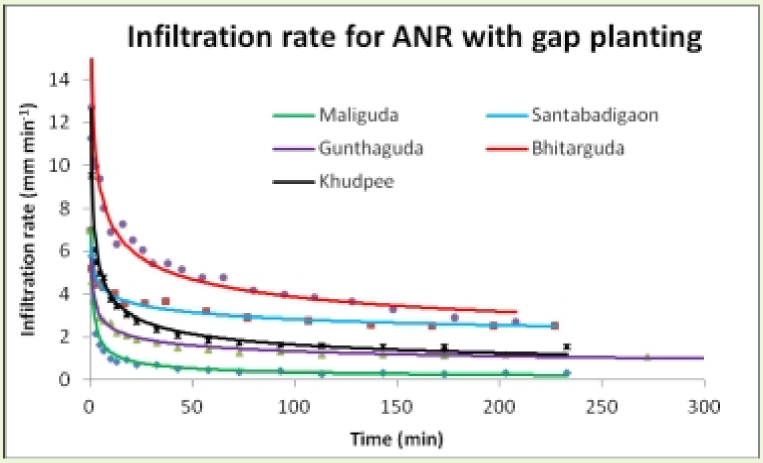


Fig. 4.3.26: Soil infiltration rate under ANR with gap planting in five different VSS

High sand and pebble content in the Bhitarguda site is responsible for high infiltration rate. Higher slope also aggravated the situation. Maliguda soils are clay dominated, thereby showed lower infiltration rate. The top layer of leaf litter that is not decomposed protects the soil from the pounding action of rain; without this the soil can become far less permeable. Once water has infiltrated the soil it remains in the soil, percolates down to the ground water table, or becomes part of the subsurface runoff process.

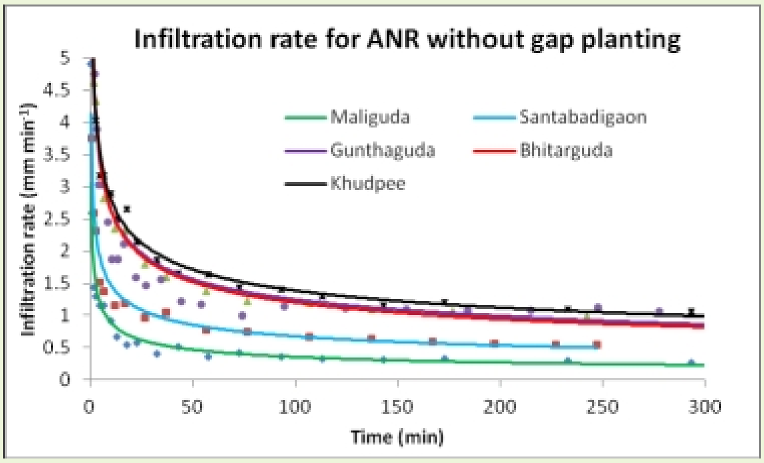


Fig. 4.3.27: Soil infiltration rate under ANR without gap planting in five different VSS

The ANR-GP land use showed low infiltration rate in all the sites. Among the VSS Khudpee showed comparatively higher and Maliguda showed lower infiltration rate. The other three VSS showed low to medium infiltration rate (Figure 4.3.27). In this land use the soil is bare and disturbed to make it clean. During the process of cleaning and subsequent rains the top soil has been eroded and the sub-soil has been exposed which is not as much porous as the top soil. Thereby this process reduced the infiltration rate for all the VSS. Maliguda soils are basically clay dominated, thereby showed lower infiltration rate.

For the Block Plantation land use, except for the Bhitarguda VSS, all other sites showed very low infiltration rate. Maliguda and Khudpee sites showed very low infiltration rate. The basic nature of Maliguda soils is non-porous, thereby showed lower infiltration rate. Among the VSS Gunthaguda showed comparatively higher infiltration rate (Figure 4.3.28).

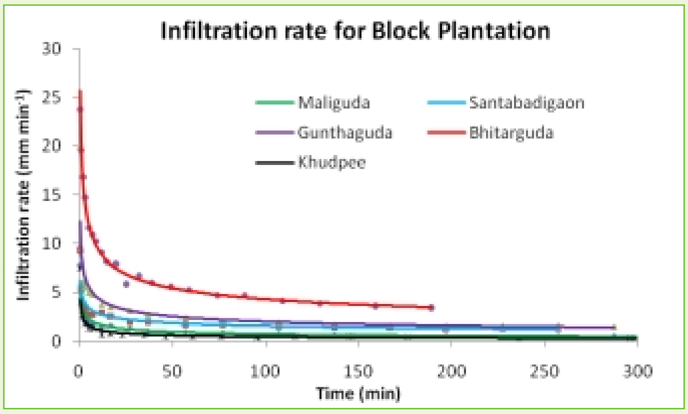


Fig. 4.3.28: Soil infiltration rate under Block Plantation in five different VSS

In this land use, the soil is partially bare and disturbed to make for new plantation. During the process of cleaning and subsequent rains the top soil has been eroded and the sub-soil has been exposed which is not as much porous as the top soil. Thereby this process reduced the infiltration rate for all the VSS. The Bhitarguda site is basically sand and stone dominated and thereby showed higher infiltration rate.

As expected, the NTFP land use showed higher infiltration rate than other land uses and which is comparable to ANR+GP land use. Among the sites, Santabadigaon, Maliguda and Bhitarguda VSS showed considerable higher infiltration rate than Khudpee and Gunthaguda VSS sites (Figure 4.3.29). The interesting part is that Maliguda site has shown consederablly high infiltration rate, although in other land uses it constatnly showed low infiltration rate. Higher litter fall and the cracks created by the active root system contributed towards the higher infiltration rate to this land use. Therefore it can be concluded from the infiltration study that ANR+GP and NTFP land uses arer better to accumulate rain water than the other two land uses.

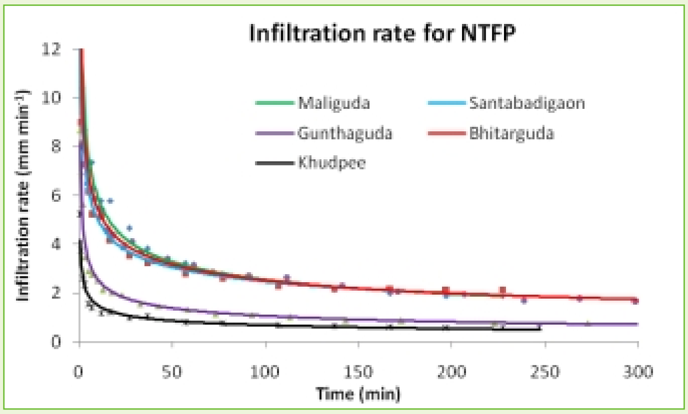


Fig. 4.3.29: Soil infiltration rate under NTFP in five different VSS

Basic infiltration rate: It is the infiltration per unit time per unit surface area under the steady state condition. For all practical purposes basic infiltration rate is equal to the saturated hydraulic conductivity of the soil. It is very important for determination of groundwater recharge, amount of surface runoff to be generated after a rain and what type of SMC measure to be undertaken in a given situation. Basic infiltration rate is highly dependent on soil texture and water stable aggregates which in turn dependent on land use and slope.

In the study area, basic infiltration rate is high to very high for all the land uses and for all the VSS except Maliguda. If we consider the variation of basic infiltration rate under various land uses, it is found that ANR with vegetation outperformed all other land uses (Figure 4.3.30). The high amount of water stable aggregates formed with the interaction of soil separates with organic matter has made huge amount of soil macro pores. These macro pores are the path of water to move faster downward. ANR without vegetation performed poorly because of the disturbed site condition which may clog the soil pores and reduce infiltration rate. BP and NTFP performed in between these two land uses.

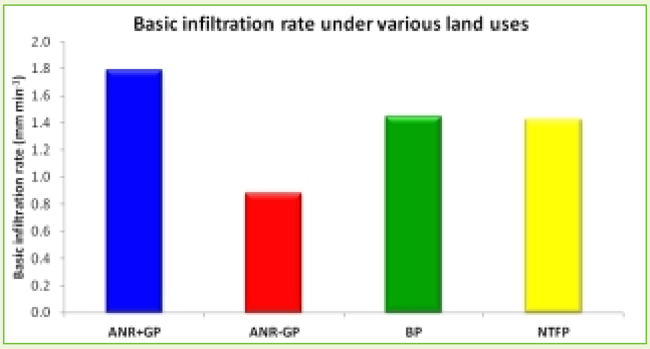


Fig. 4.3.30: Basic infiltration rate under various forest land uses

On the other hand if we consider the trend of basic infiltration rate under different VSS, it may be concluded that Bhitargada site outperformed all the other sites (Figure 4.3.31). The high stoneyness and high slope of the site contributed to high basic infiltration rate. On the contrary, the Maliguda site which contain high clay in the soil profile performed poorly to the basic infiltration rate. So we can expect high surface runoff from Maliguda site. The oder of performance is Bhitarguda > Santabadigaon > Gunthaguda > Khudpee > Maliguda.

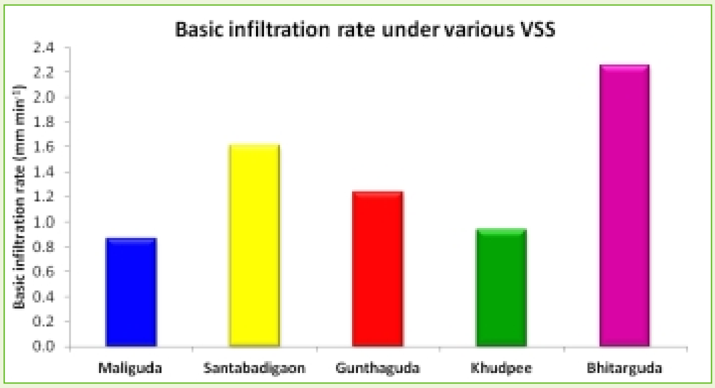


Fig. 4.3.31: Basic infiltration rate under different VSS sites

4.3.10 In-Situ soil moisture content

In situ soil moisture content was measured for both the depths and for all the land uses. The land use wise variation of gravimetric soil moisture is presented in figure 4.3.32.

From the figure it is clear that there is a profound influence of land use on the soil moisture. The gravimetric soil moisture content under various land uses is following the trend: ANR+GP > NTFP > ANR-GP> BP. ANR+GP with its high clay and organic matter content has showed the higher soil moisture content. NTFP is also following just behind ANR+GP. NTFP sites are also rich in organic matter because of high litter fall and their subsequent conversion to soil organic carbon. ANR+GP and NTFP, both the sites contain high canopy cover, which provide shade to the soil surface resulting lowering the rate of soil moisture depletion due to evaporation. Both these land uses also showed higher microbial activity, therefore reduce the capillary movement of water from sub-surface soils to the surface, resulting low evaporation loss. The litters on the soil surface of these sites also act as an insulator of the heat and thereby maintain a good soil temperature conducive for the growth and development of soil macro and micro organisms.

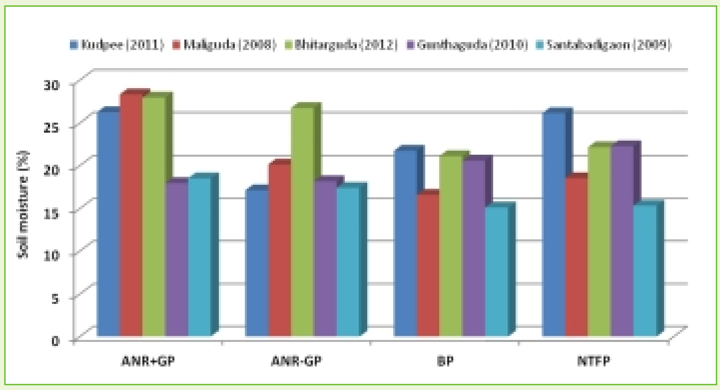


Fig. 4.3.32: Land use wise variation of in-situ soil moisture content

On the other hand the sites under ANR-GP and BP are degraded and showed very low clay and organic matter content. These resulted lower in-situ soil moisture content for these land uses mainly due to high evaporation loss. These land uses need proper soil moisture conservation measures for the growth of new plantation and development of the existing plantation.

4.4 Growth Performance of Afforested Species under Block Plantation and NTFP

4.4.1 Block plantation

Teak is planted in all the selected study sites except in two VSS namely Alubadi and Gunthaguda in Rayagada and Koraput DMU, respectively. The study sites cover all the five years of planting from 2008 to 2012. From the selected sites survival percent, plant height and base diameter were studied before the monsoon (May to July) and after the monsoon period of 2013 (January to February). The teak was planted in 2.5 m x 2.5 m at all the study sites. To conserve rainwater, half moon/ semi-circular basin/terraces were made to each teak plant at the time of planting. The performance of teak under block plantation is presented below.

4.4.2 Survival percent of teak

The average initial survival percent varied between 65% at Harishchandraguda (Jeypore) and 100% at Khudpee (Jeypore) with the overall survival rate of 87%. The final survival percent was highest at Khudpee (100%) followed by Bhaliabhata (93%), Badapukel (93%), Malikarchi (93%) Maliguda (92%) and Chintalguda (91%). The survival percent less than 80% was observed in Timajhola (76%), Kanisuma (68%), Bhitarguda (78%) and Harishchandraguda (65%). The overall survival percent did not differ significantly between the initial and the final observation. The topo-sequence wise survival percent indicates that, the survival percent was better at middle and lower slopes in comparison to upper reach due to better soil moisture availability at middle and lower reaches (Table 4.4.1 and 4.4.2, Figure 4.4.1)

Among the planting years, the survival rate of teak was maximum during 2011 planting followed by 2008, 2009, 2010 and 2012. The low survival rate during 2012 planted sites might be attributed to newly planted and the observation was made without any gap filling. Infilling might be the reason for better survival rate of teak planted during early phases (Table 4.4.3 and Figure 4.4.2)

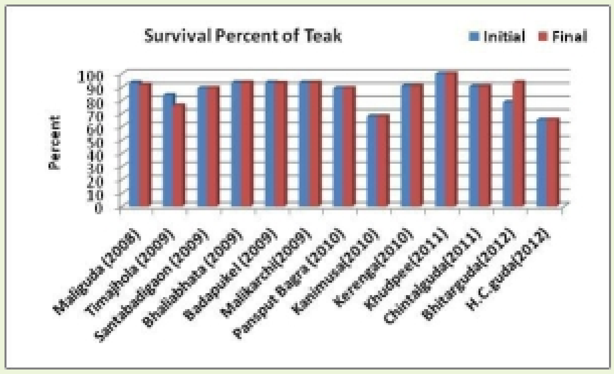


Figure 4.4.1: Survival prcent of teak at different study site

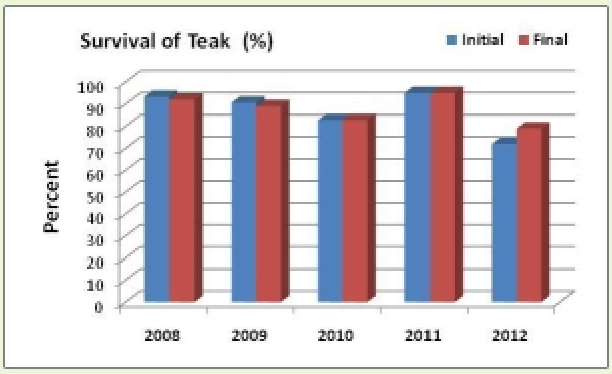


Figure 4.4.2: Plantation year wise survival percent of teak

Aspect wise survival percent of teak was also studied and presented in table 4.4.4 and figure 4.4.3. Study sites of southern aspects followed by eastern aspects sites recorded better survival rate than western and northern aspects.

Height of teak: The mean height of teak under block plantation varied between 0.3 to 3.3 m at initial and 0.5 m to 4.9 m at the final observation from the selected study sites (Table 4.4.2). Percent increase in teak height was maximum in Khudpee (133%) followed by Kanimusa (129%), Chintalguda (73%), Bhitarguda (69%) and Harichandraguda (67%). In general, teak plants at middle and lower slopes recorded better growth performance due to better soil moisture availability as compared to plants at upper slopes (Table 4.4.5 and Figure 4.4.4). The overall increase in plant height was 0.86 m which is 47 % increase in height across the selected study sites under OFSDP.

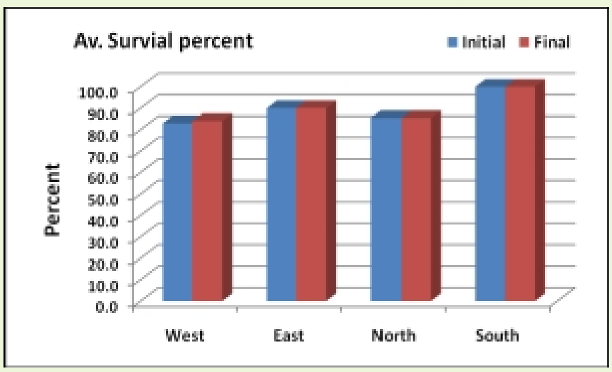


Figure 4.4.3: Aspectwise servival percent of teak

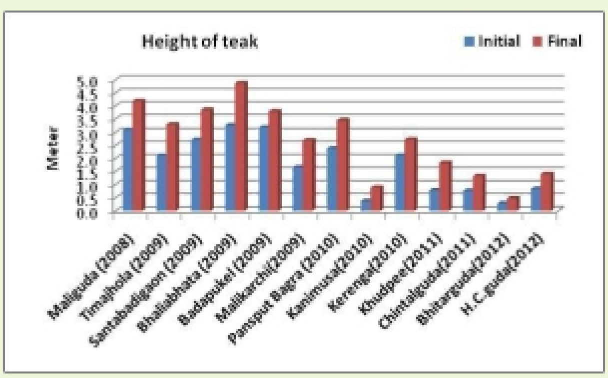


Figure 4.4.4: Height of teak at different study sites

Across the year of planting, teak height varied between 1.4m to 3.1m at initial and 2.2m to 4.2m at the final observation (Table 4.4.3). The maximum height increment was observed in teak planted during 2012 followed by 2010 and 2009. Incremental increase in plant height was decreased with increase in age of the plantation.

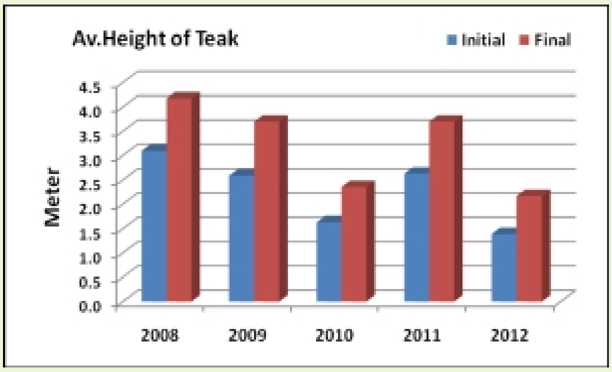


Figure 4.4.5: Plantation year wise height of teak

Aspect wise height of teak was also studied and presented in table 4.4.4 and figure 4.4.6. Study sites of southern aspects followed by eastern aspects sites recorded better plant height than western and northern aspects.

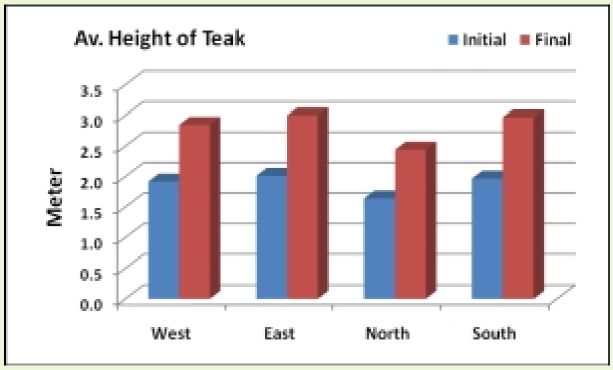


Figure 4.4.6: Aspect wise height of teak

Basal diameter of teak: Data on basal diameter of teak for the selected sites is presented in table 4.4.2,table 4.4.5 and figure 4.4.7. Mean basal diameter of teak varied from 2.1cm to 18.4cm at initial observation and at final observation it was varied from 4.0cm to 22.2cm. In general, increased in basal diameter with increase in age of the plantation was observed. Incremental increase in basal diameter of teak plant followed the growth trend of plant height. Percent increase in basal diameter varied between 11.11% at Bhitarguda to as high as 88.57% at Khudpee with an overall average increase of 30.8%.

Basal diameter of teak was also studied on different slope/ reaches and revealed that middle and lower slopes favored better growth of teak in terms of basal diameter due to better soil moisture availability as compared to plants at upper slope (Table 4.4.5). This also indicates the need of soil moisture conservation measures, particularly on the upper reaches to control surface runoff. Plantation year wise comparison revealed that, percent increase in basal diameter varied between 20.7% for 2008 plantation to as high as 32 and 31% in 2009 and 2012 plantation. This variation may be due to variability in site characteristics with respect to soil and availability of soil moisture (Table 4.4.3 and Figure 4.4.8)

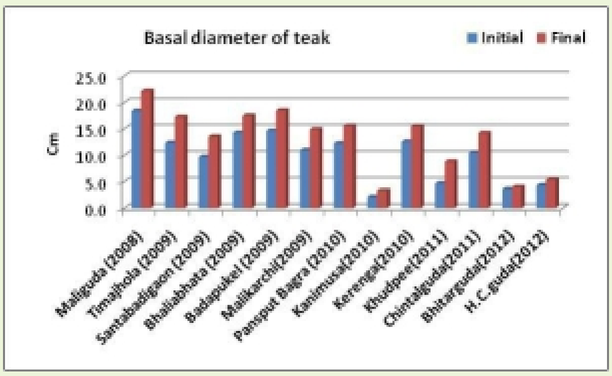


Figure 4.4.7: Basal diameter of teak at different study sites

Aspect wise analysis on plant basal diameter of selected study sites revealed that, teak plants in Southern and Eastern aspects gave higher incremental growth compared to plants in Western and Northern aspects However, plants on Western aspects showed a slower growth rate compared to other aspects (Table 4.4.4 and Figure 4.4.9).

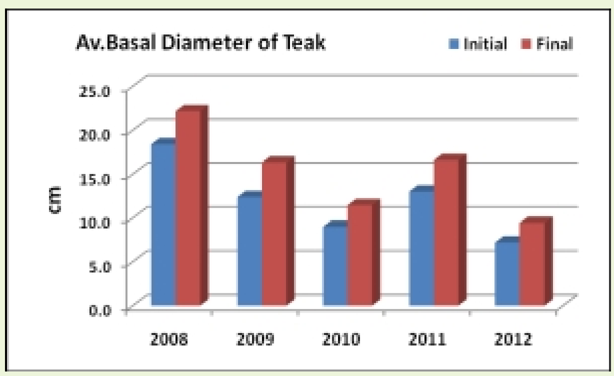


Figure 4.4.8: Plantation yearwise basal diameter of teak

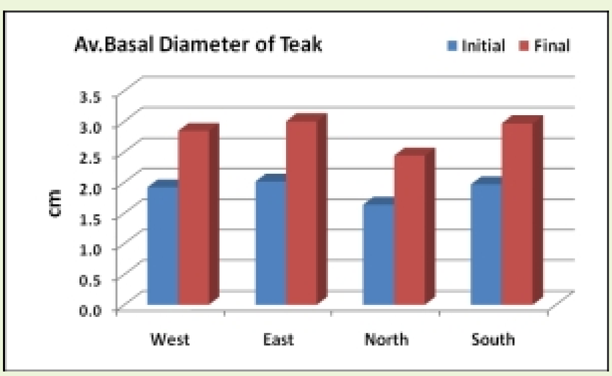


Figure 4.4.9: Aspects wise basal diameter of teak

Table 4.4.1: Survival percent of teak under block plantation at different VSS and year of planting

S.No	VSS	DMU	Year of Planting	Survival (%)							
				Initial				Final			
				U	M	L	Mean	U	M	L	Mean
1	Maliguda	Jeypore	2008	96	96	88	93	92	96	88	92
2	Timajhola	Koraput	2009	88	80	84	84	64	80	84	76
3	Santabadigaon	Rayagada	2009	80	92	96	89	80	92	96	89
4	Bhaliabhata	Rayagada	2009	96	92	92	93	96	92	92	93
5	Badapukel	Rayagada	2009	92	96	92	93	92	96	92	93
6	Malikarchi	Jeypore	2009	92	100	88	93	92	100	88	93
7	Pansput Bagra	Jeypore	2010	88	88	92	89	88	88	92	89
8	Kanimusa	Laxmipur	2010	60	72	72	68	60	72	72	68
9	Kerenga	Koraput	2010	96	92	84	91	96	92	84	91
10	Khudpee	Jeypore	2011	100	100	100	100	100	100	100	100
11	Chintalguda	Rayagada	2011	92	92	88	91	92	92	88	91
12	Bhitarguda	Koraput	2012	76	76	84	79	76	76	83	78
13	Harishchandraguda	Jeypore	2012	48	68	80	65	48	68	80	65
14	Alubadi	Rayagada	No Block Plantation								
15	Gunthaguda	Koraput	No Block Plantation								
Average				85	88	88	87	83	88	88	86

U: Upper, M: Middle, L: Lower

Table 4.4.2: Average survival percent, height and basal diameter of teak under block plantation.

S.No	VSS	DMU	Year of Planting	Survival (%)		Height (m)		Basal Diameter (cm)	
				Initial	Final	Initial	Final	Initial	Final
1	Maliguda	Jeypore	2008	93	92	3.1	4.2	18.4	22.2
2	Timajhola	Koraput	2009	84	76	2.1	3.3	12.4	17.3
3	Santabadigaon	Rayagada	2009	89	89	2.7	3.8	9.7	13.5
4	Bhaliabhata	Rayagada	2009	93	93	3.3	4.9	14.2	17.5
5	Badapukel	Rayagada	2009	93	93	3.2	3.8	14.6	18.5
7	Malikarchi	Jeypore	2009	93	93	1.7	2.7	11.0	14.9
6	Pansput Bagra	Jeypore	2010	89	89	2.4	3.4	12.3	15.5
8	Kanimusa	Laxmipur	2010	68	68	0.4	0.9	2.1	3.3
9	Kerenga	Koraput	2010	91	91	2.1	2.7	12.6	15.5
10	Khudpee	Jeypore	2011	100	100	0.8	1.8	4.7	8.8
11	Chintalguda	Rayagada	2011	91	91	0.8	1.3	10.5	14.2
12	Bhitarguda	Koraput	2012	79	93	0.3	0.5	3.6	4.0
13	Harishchandraguda	Jeypore	2012	65	65	0.8	1.4	4.3	5.4
14	Alubadi	Rayagada	No Block Plantation						
15	Gunthaguda	Koraput	No Block Plantation						
Mean				87	86	1.8	2.7	10.0	12.8

Table 4.4.3: Planting year wise performance of teak under block plantation

Year	Survival (%)		Height (m)		Basal Diameter (cm)	
	Initial	Final	Initial	Final	Initial	Final
2008	93	92	3.1	4.2	18.4	22.2
2009	91	89	2.6	3.7	12.4	16.3
2010	83	83	1.6	2.4	9.0	11.5
2011	95	95	2.6	3.7	13.0	16.6
2012	72	79	1.4	2.2	7.2	9.4

Table 4.4.4: Aspect wise performance of teak under block plantation

Aspect	Survival (%)		Height (m)		Basal Diameter (cm)	
	Initial	Final	Initial	Final	Initial	Final
West	83	84	1.9	2.8	10.6	12.5
East	90	90	2.0	3.0	9.7	12.9
North	83	83	1.6	2.4	9.0	11.5
South	100	100	2.0	3.0	9.7	12.3

Table 4.4.5: Growth performance of teak under block plantation at upper, middle and lower reach of planted sites

S.No	VSS	DMU	Yr. of Planting	Height(m)								Basal diameter (cm)							
				Initial				Final				Initial				Final			
				U	M	L	Mean	U	M	L	Mean	U	M	L	Mean	U	M	L	Mean
1	Maliguda	Jeypore	2008	3.5	2.3	3.4	3.1	5.0	3.4	4.2	4.2	21.8	14.4	19.0	18.4	25.4	18.2	23.0	22.2
2	Timajhola	Koraput	2009	1.3	2.2	2.8	2.1	2.9	3.2	3.8	3.3	8.8	11.2	17.2	12.4	14.4	15.8	21.6	17.3
3	Santabadigaon	Rayagada	2009	2.1	3.5	2.6	2.7	3.1	4.8	3.6	3.8	3.6	13.9	11.6	9.7	7.4	19.0	14.2	13.5
4	Bhaliabhata	Rayagada	2009	4.1	2.8	3.0	3.3	5.0	5.7	3.9	4.9	16.4	11.2	15.0	14.2	19.0	15.2	18.2	17.5
5	Badapukel	Rayagada	2009	3.4	3.14	3	3.2	3.9	3.8	3.6	3.8	14.4	15.2	14.2	14.6	18	19.4	18	18.5
6	Malikarchi	Jeypore	2010	1.3	1.3	2.5	1.7	2.4	2.1	3.6	2.7	10.8	10.6	11.6	11.0	15.6	14.0	15.0	14.9
7	Pansput Bagra	Jeypore	2010	2.1	2.5	2.6	2.4	3.1	3.5	3.8	3.4	11.6	12.2	13.0	12.3	13.8	15.2	17.6	15.5
8	Kanimusa	Laxmipur	2010	0.8	0.2	0.2	0.4	1.1	0.9	0.7	0.9	1.6	2.2	2.6	2.1	3.8	3.2	3.0	3.3
9	Kerenga	Koraput	2010	2.2	2.3	1.8	2.1	2.8	2.9	2.4	2.7	11.6	15.2	11	12.6	14.0	18.4	14.0	15.5
10	Khudpee	Jeypore	2011	0.7	0.6	1.1	0.8	1.8	1.7	2.0	1.8	4.0	3.6	6.4	4.7	9.0	8.2	9.2	8.8
11	Chintalguda	Rayagada	2011	0.5	0.7	1.1	0.8	0.8	1.1	2.0	1.3	9.6	11.5	10.3	10.5	12.6	15.4	14.5	14.2
12	Bhitarguda	Koraput	2012	0.3	0.3	0.3	0.3	0.3	0.7	0.4	0.5	4.2	3.2	3.4	3.6	4.7	3.9	3.7	4.1
13	Harishchandraguda	Jeypore	2012	0.4	0.5	1.6	0.8	1.0	1.1	2.1	1.4	0.5	1.2	11.2	4.3	0.9	1.8	13.4	5.4
14	Alubadi	Rayagada		No Block Plantation															
15	Gunthaguda	Koraput		No Block Plantation															

U: Upper, M: Middle, L: Lower

4.4.3 NTFP

Under NTFP the species like Simarouba glauca (Simarouba), Pongamia pinnata (Karanj), Cassia obtusifolia (Chakunda), Gmelina arborea (Gamhar), Emblica officinalis (Aonla), Anacardium occidentale (Cashew) and Acacia auriculiformis (Acacia) were planted in the selected study sites. Majority of the NTFP sites were planted with Simarouba, Karanj and Cassia. The spacing of 2m x 2m, 2.5m x 2.5m and 5.0m x 5.0m was followed for the above listed species. The performance of NTFP species was assessed through their survival percent, plant height and basal diameter. The results are presented below under the following sub-headings.

Survival percent: The selected study sites wise and species wise the survival percent in table 4.4.6, table 4.4.7 and figure 4.4.10. The initial survival percent varied between 28% and 100%, the final survival percent was varied from 33% to 100%. The overall survival rate of all the species was ranged from 46% at Harishchandraguda to 80% at Timajhola (Koraput DMU). The better performance of survival rate was noticed in Timajhola (Koraput DMU) followed by Badapukel (Rayagada) and Bhaliabhata (Rayagada). The survival rate of all the NTFP planted species were better for *Accacia and Cashew.*

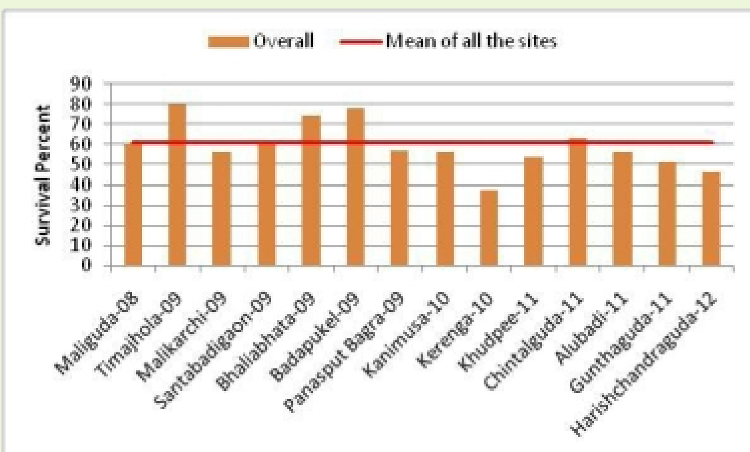


Figure 4.4.10: Study site wise overall survival percent under NTFP

Upper, middle and lower slope/ reach wise survival percent is presented in Table 4.4.6 & 4.4.7 and it revealed that no clear trend was observed. However, it was noticed that upper and middle slopes also recorded better survival percent and this may be due to less biotic disturbance. Different phase wise survival percent revealed that, lower rate of survival of afforested species was observed for the year 2012 followed by 2011 and 2010. The first and second phase plantations were good with respect to survival rate. This might be due to gap filling in the early phased plantation coupled with care and protection measures by the community at the initial stage of the project period . Aspect wise performance was also studied and presented in table 4.4.13 and figure 4.4.11. The data revealed that better survival rate under NTFP plantation was observed in western and southern aspects.

Table 4.4.6: Average survival percent under NTFP plantation at different VSS of OFSDP

S.No	VSS	DMU	Aspect	Yr. of Planting	Initial				Final			
					U	M	L	Mean	U	M	L	Mean
1	Maliguda	Jeypore	South	2008	75	65	50	62	74	60	49	60
2	Timajhola	Koraput	West	2009	82	78	44	81	80	77	74	79
3	Santabadigaon	Rayagada	North	2009	64	53	54	72	62	53	52	56
4	Bhaliabhata	Rayagada	East	2009	55	67	63	63	56	61	59	61
5	Badapukel	Rayagada	West	2009	78	78	67	74	78	78	67	74
6	Malikarchi	Jeypore	North	2009	67	78	89	78	67	78	89	78
7	Pansput Bagra	Jeypore	East	2010	56	67	44	56	56	67	56	58
8	Kanimusa	Laxmipur	North	2010	56	56	58	57	56	55	50	54
9	Kerenga	Koraput	North	2010	44	36	32	37	44	36	32	37
10	Khudpee	Jeypore	East	2011	0	55	52	54	0	55	52	54
11	Chintalguda	Rayagada	West	2011	73	60	56	61	73	60	56	61
12	Bhitarguda	Koraput	South	2011	78	56	56	60	78	56	56	60
13	Harishchandraguda	Jeypore	East	2011	47	54	53	51	47	54	53	51
14	Alubadi	Rayagada	West	2012	0	33	33	36	0	56	56	56
15	Gunthaguda	Koraput	West	2012	Poor Performance							
Overall Mean					55	60	54	60	55	60	57	60

U: Upper, M: Middle, L: Lowe

Table 4.4.7: Species wise average survival rate under NTFP plantation.

S.No	VSS	DMU	Yr. of Planting	*Simarouba*		*Karanj*		*Cassia*		*Aonla*		*Cashew*		*Accacia*		*Gamhar*	
				I	F	I	F	I	F	I	F	I	F	I	F	I	F
1	Maliguda	Jeypore	2008	61	60	100	100	63	57							62	62
2	Timajhola	Koraput	2009	63	63	63	63	100	89	100	100	56	56	66	66		
3	Santabadigaon	Rayagada	2009	72	71	55	56					35	33				
4	Bhaliabhata	Rayagada	2009	67	67	74	75	67	60								
5	Badapukel	Rayagada	2009														
6	Malikarchi	Jeypore	2009	78	78	56	56										
7	Pansput Bagra	Jeypore	2010	56	60	62	62										
8	Kanimusa	Laxmipur	2010					71	68					40	33		
9	Kerenga	Koraput	2010	36	39	51	51							36	39		
10	Khudpee	Jeypore	2011	60	60					51	51						
11	Chintalguda	Rayagada	2011	63	63												
12	Bhitarguda	Koraput	2011									56	56				
13	Harishchandraguda	Jeypore	2011	50	52	44	56	50	52								
14	Alubadi	Rayagada	2012									28	56				
15	Gunthaguda	Koraput	2012			63	65										
Overall Mean				61	61			70	65	76	76	44	50	47	46	62	62
				61													

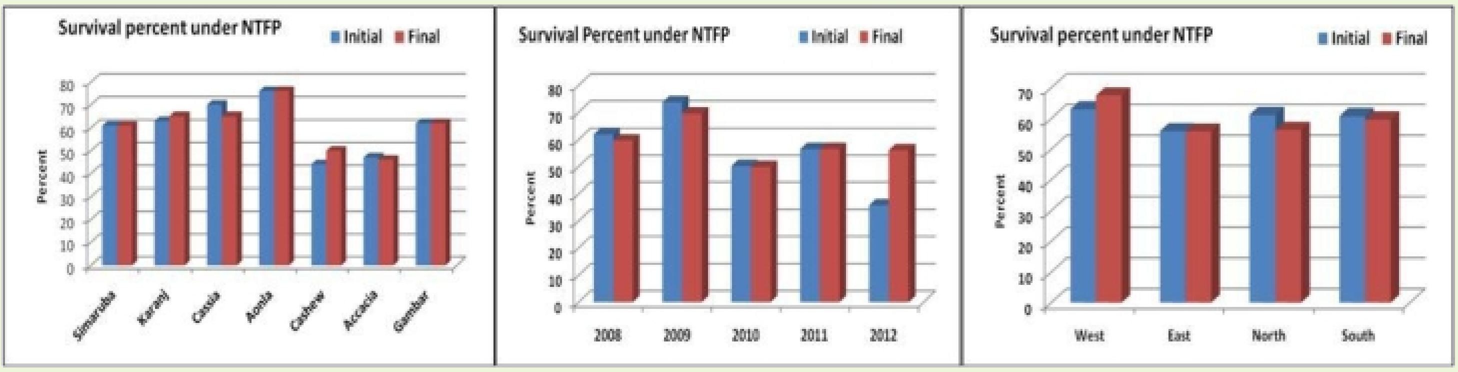


Figure 4.4.11: Species wise, plantation year wise and aspects wise survival rate under NTFP

Height: Topho-sequence wise and afforested species wise plant height is presented in table 4.4.8, table 4.4.9 and figure 4.4.12. The average initial plant height varied from 0.5m to a maximum of 3.3m and final height varied from 1.1m to a maximum of 4.3m. The average incremental height was maximum at Kanimusa (157%) followed by Khudpee (104%) and Harishchandraguda (124%) with the overall increase in height was 0.6m (41%) during the study period. However, the increase in height during the study period was 0.2m at Gunthaguda to a maximum of 1.2m at Santabadigaon. The overall increase in height varied from 20% to a maximum of 157%. The height performance was better at middle slope compared to upper and lower slopes. The wider variation in plant height is attributed to individual species growth rate coupled with favorable soil and climatic conditions.

The species wise study was also made for different study sites and data presented in table 4.4.7 and figure 4.4.13. The maximum incremental height was observed in Cassia (1.2m) followed by Simarouba (1.7m), Karanj (0.7m) and Gamhar (0.8m). The slow growth rate was observed in Accacia, Cashew and Aonla. Planting year wise plant height was analysis for all the study sites and presented in table 4.4.12 and figure 4.4.13. The data revealed that the maximum growth rate of plant was for the year 2008 followed by 2010 and 2009, and minimum incremental growth for the year 2011 and 2012. This variation may be due to better management and care for the early phased plantation coupled with better site characteristics and climatic suitability compared to plantation of the recent past. Aspect wise study revealed that, the incremental growth in plant height was better for the sites with southern and eastern aspects compared to that of western and northern aspects (Table 4.4.13 and figure 4.4.13). The average different in plant height was 0.15 which is about 27% higher plant height in southern and eastern aspects over other aspects.

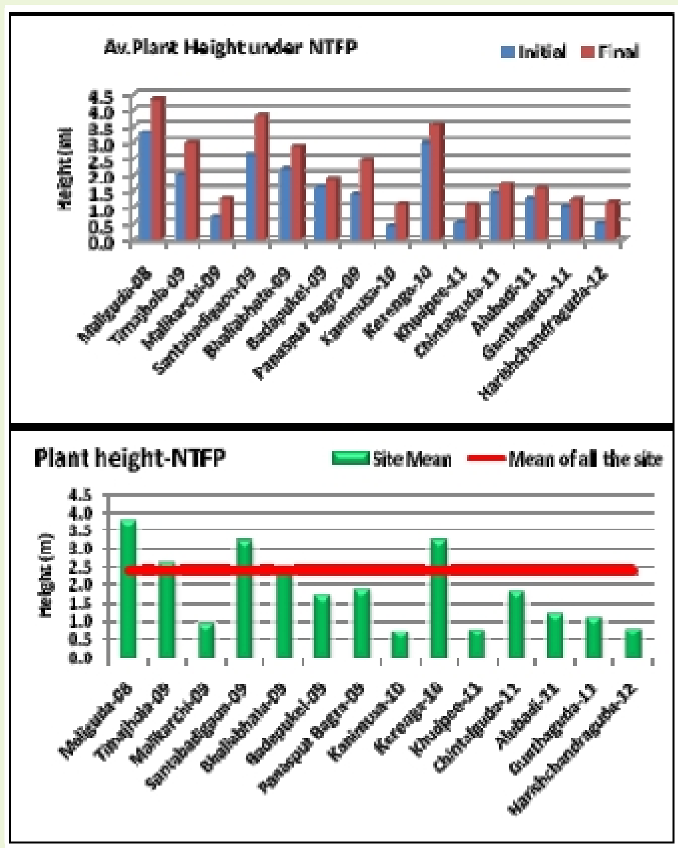


Figure 4.4.12: Study site wise initial & final plant height and overall mean plant height under NTFP

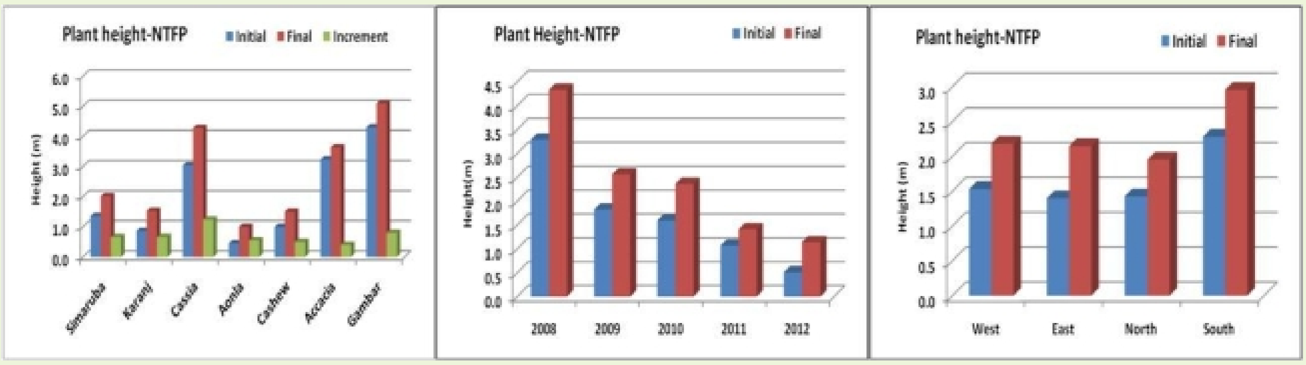


Figure 4.4.13: Species wise, plantation year wise and aspects wise plant height under NTFP

Table 4.4.8: Average height of afforested species under NTFP plantation at different VSS of OFSDP

S.No	VSS	DMU	Aspect	Yr. of Planting	Initial (m)				Final (m)			
					U	M	L	Mean	U	M	L	Mean
1	Maliguda	Jeypore	South	2008	2.9	3.6	2.9	3.3	4.0	4.9	3.8	4.3
2	Timajhola	Koraput	West	2009	2.3	3.0	1.9	2.0	3.3	4.5	3.1	3.0
3	Santabadigaon	Rayagada	North	2009	0.8	0.6	0.7	0.7	1.4	1.2	1.3	1.3
4	Bhaliabhata	Rayagada	East	2009	3.1	2.6	3.2	2.6	5.3	3.7	4.3	3.8
5	Badapukel	Rayagada	West	2009	2.1	2.2	2.2	2.2	2.9	2.9	2.8	2.9
6	Malikarchi	Jeypore	North	2009	1.5	1.7	1.7	1.6	1.8	1.9	1.9	1.9
7	Pansput Bagra	Jeypore	East	2010	1.6	1.4	0.9	1.4	2.5	2.2	1.7	2.4
8	Kanimusa	Laxmipur	North	2010	0.5	0.3	0.6	0.4	1.5	0.9	1.3	1.1
9	Kerenga	Koraput	North	2010	2.8	2.8	3.3	3.0	3.4	3.3	3.9	3.6
10	Khudpee	Jeypore	East	2011	0.0	0.6	0.5	0.5	0.0	1.2	1.0	1.1
11	Chintalguda	Rayagada	West	2011	1.6	1.5	1.3	1.4	2.0	1.8	1.6	1.7
12	Bhitarguda	Koraput	South	2011	1.6	1.5	0.9	1.3	2.0	1.8	1.3	1.6
13	Harishchandraguda	Jeypore	East	2011	0.9	1.2	1.1	1.0	1.2	1.2	1.4	1.2
14	Alubadi	Rayagada	West	2012	0.0	0.3	0.6	0.5	0.0	1.1	1.1	1.1
15	Gunthaguda	Koraput	West	2012	Poor Performance							
Overall Mean					1.6	1.7	1.5	1.6	2.2	2.3	2.2	2.2

U: Upper, M: Middle, L: Lower

Table 4.4.9: Species wise average plant height (m) under NTFP plantation.

S.No	VSS	DMU	Yr. of Planting	*Simarouba*		*Karanj*		*Cassia*		*Aonla*		*Cashew*		*Accacia*		*Gamhar*	
				I	F	I	F	I	F	I	F	I	F	I	F	I	F
1	Maliguda	Jeypore	2008	1.4	2.2			4.1	5.8							4.3	5.1
2	Timajhola	Koraput	2009	1.4	2.6	0.4	1	4.4	5.9	0.3	0.8	1.9	2.5	5.1	5.1		
3	Santabadigaon	Rayagada	2009	1	1.6	0.6	1.1					0.6	1.1				
4	Bhaliabhata	Rayagada	2009	2.3	3.5	1	1.6	4.5	6.4								
5	Badapukel	Rayagada	2009			2.2	2.9										
6	Malikarchi	Jeypore	2009	1.6	1.9												
7	Pansput Bagra	Jeypore	2010	1.3	2	1.5	2.8										
8	Kanimusa	Laxmipur	2010			0.2	0.6	0.8	1.8					0.3	0.9		
9	Kerenga	Koraput	2010	1.6	2.2									4.3	4.9		
10	Khudpee	Jeypore	2011	0.6	1.2	0.4	0.9			0.6	1.2						
11	Chintalguda	Rayagada	2011	1.7	2												
12	Bhitarguda	Koraput	2011									1.1	1.4				
13	Harishchandraguda	Jeypore	2011	0.7	1			1.4	1.5								
14	Alubadi	Rayagada	2012			0.6	1.3					0.4	1				
15	Gunthaguda	Koraput	2012														
Overall Mean				1.4	2.0	0.9	1.5	3.0	4.3	0.5	1.0	1.0	1.5	3.2	3.6	4.3	5.1
				2.4													

I: Initial, F: Final

Basal diameter: The basal diameter of different species planted under NTFP in the selected study sites are presented in table 4.4.10 and figure 4.4.14.

The data revealed that, the average basal diameter at the initial stage ranged from 0.3 cm to a high of 20.4 cm and at the final stage, it was ranged between 0.7 and 24.6 cm. The incremental increase in basal diameter was observed in the range of 0.4 cm to 4.2cm and percent increase was varied between 19 to 125% at different study location with an average increase of 2.6 cm (29%).

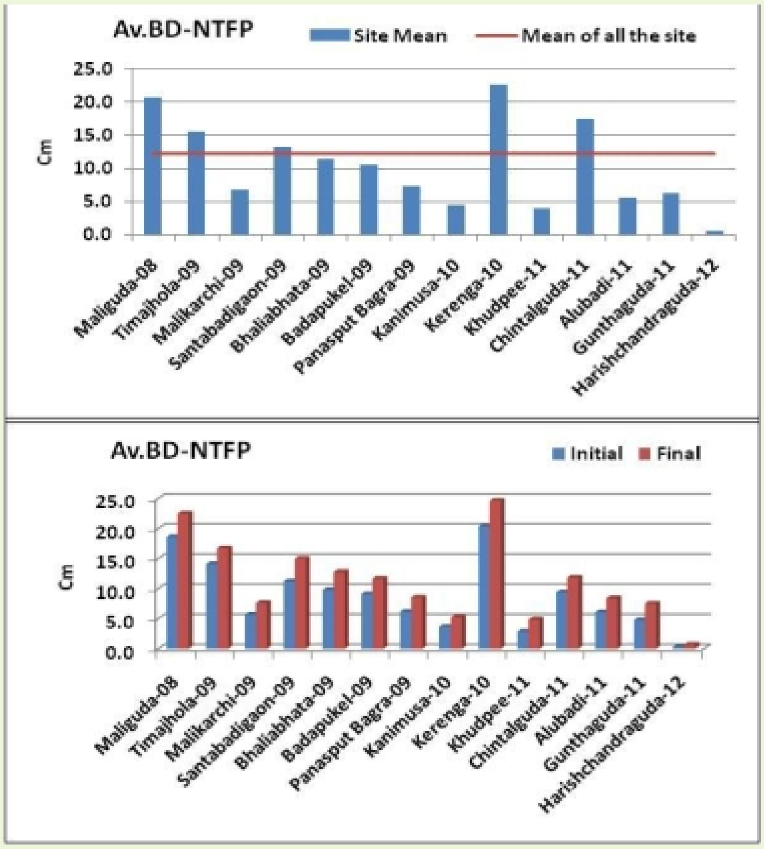


Figure 4.4.14: Study site wise initial & final and overall mean basal diameter of species under NTFP

The species wise study was also made and it revealed that, the basal diameter was maximum in *Gamher* followed by *Accacia*, *Cassia* and *Simarouba* (Table 4.4.11 and Figure 4.4.15). The species like *Karanj*, *Aonla* and *Cashew* showed lower range of basal diameter. The maximum incremental growth of basal diameter was observed in Cassia (4.5 cm) followed by *Accacia* (29%), *Gamhar* (29%) and *Simarouba* (27%). However, the percent increase in basal diameter over initial diameter was maximum in *Karanj* (47%) followed by *Anola* (36%), *Cassia* (30%) and *Simarouba* (26%)

The phase wise planting on basal diameter revealed that, the mean basal diameter of all the species was increasing trend from 2008 to 2012. The first, second and third phase plantation had maximum basal diameter over 2011 and 2012 plantation. The average increase in basal diameter was maximum for the 2008 plantation (3.9 cm) and it was decreasing after and the lowest was in 2012 plantation (0.4 cm) (Table 4.4.12).

Aspect wise data revealed that, Southern and Northern aspects sites had maximum basal diameter compared to Western and Eastern aspect (Figure 4.4.15 and Table 4.4.13). However, incremental growth of basal diameter was higher in Southern and Eastern aspect sites 3.1-3.2cm) compared to other two aspects. The percent incremental growth of basal diameter was maximum when plants under the Eastern aspect (51%) followed by Northern aspects (26%), Southern and Western aspects (25%)

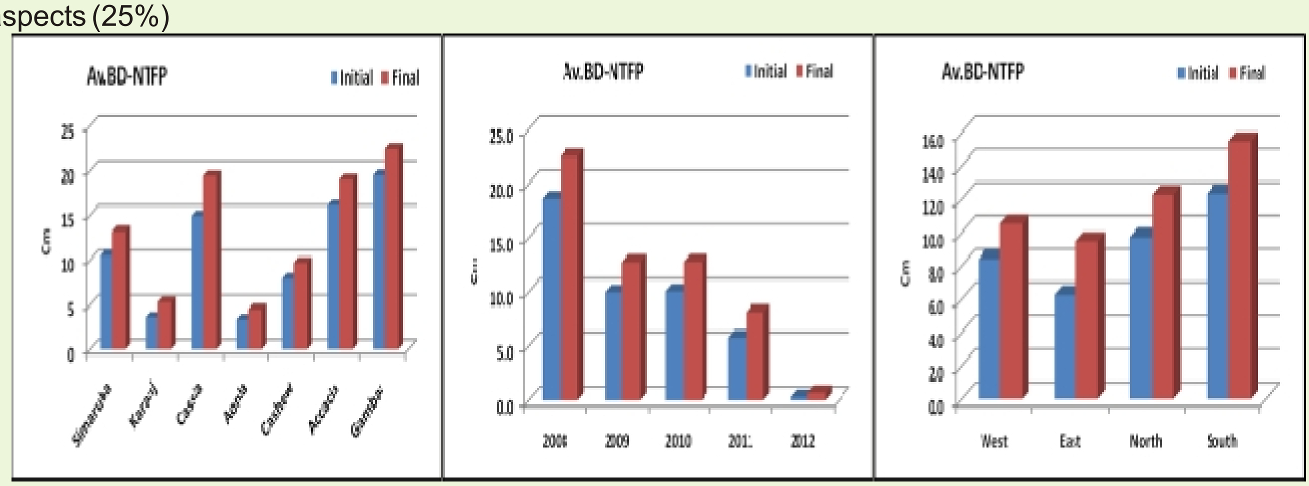


Figure 4.4.15: Species wise, plantation year wise and aspects wise basal diameter of species under NTFP

Table 4.4.10: Average basal diameter of afforested species under NTFP plantation at different VSS of OFSDP

S.No	VSS	DMU	Aspect	Yr. of Planting	Initial (cm)				Final			
					U	M	L	Mean	U	M	L	Mean
1	Maliguda	Jeypore	South	2008	17.8	21.4	16.0	18.6	22.0	25.5	19.9	22.5
2	Timajhola	Koraput	West	2009	15.2	15.3	16.1	14.1	17.9	19.9	18.5	16.7
3	Santabadigaon	Rayagada	North	2009	6.2	4.3	6.5	5.7	7.7	6.5	8.6	7.6
4	Bhaliabhata	Rayagada	East	2009	18.2	10.2	13.0	11.2	25.0	14.4	16.7	15.0
5	Badapukel	Rayagada	West	2009	9.2	9.8	10.4	9.8	13.0	12.8	12.5	12.8
6	Malikarchi	Jeypore	North	2009	8.0	9.4	10.0	9.1	10.2	12.2	12.6	11.7
7	Pansput Bagra	Jeypore	East	2010	6.8	8.0	6.2	6.2	8.9	10.8	9.0	8.5
8	Kanimusa	Laxmipur	North	2010	5.1	2.3	4.7	3.7	7.6	3.5	6.2	5.2
9	Kerenga	Koraput	North	2010	19.2	20.4	21.5	20.4	23.2	24.3	26.3	24.6
10	Khudpee	Jeypore	East	2011	0.0	2.9	2.9	2.9	0.0	4.9	4.8	4.9
11	Chintalguda	Rayagada	West	2011	12.1	11.3	7.4	9.4	15.0	13.5	9.9	11.9
12	Bhitarguda	Koraput	South	2011	9.8	7.3	3.8	6.1	13.0	9.4	6.0	8.4
13	Harishchandraguda	Jeypore	East	2011	3.4	6.6	4.3	4.8	6.5	9.3	6.7	7.5
14	Alubadi	Rayagada	West	2012	0.0	0.1	0.4	0.3	0.0	0.7	0.7	0.7
15	Gunthaguda	Koraput	West	2012	Poor Performance							
Overall Mean					9.4	9.2	8.8	8.7	12.1	12.0	11.3	11.3
					10.4							

U: Upper, M: Middle, L: Lower

Table 4.4.11: Species wise average basal diameter (cm) under NTFP plantation.

S.No	VSS	DMU	Yr. of Planting	*Simarouba*		*Karanj*		*Cassia*		*Aonla*		*Cashew*		*Accacia*		*Gamhar*	
				I	F	I	F	I	F	I	F	I	F	I	F	I	F
1	Maliguda	Jeypore	2008	13.4	16.7			23	28.4							19.5	22.4
2	Timajhola	Koraput	2009	14.5	17.5	3.8	5.8	20	24.5	4.6	5.6	20.4	23	21.2	24		
3	Santabadigaon	Rayagada	2009	7.1	9.1	3.5	5.5					6.4	8.3				
4	Bhaliabhata	Rayagada	2009	10.6	13.6	2.2	3.9	21	27.5								
5	Badapukel	Rayagada	2009			9.8	12.8										
6	Malikarchi	Jeypore	2009	9.1	11.7												
7	Pansput Bagra	Jeypore	2010	7.7	10.3	4.6	6.8										
8	Kanimusa	Laxmipur	2010			1.9	2.6	6.5	9.5					2.6	3.6		
9	Kerenga	Koraput	2010	16.3	19.7									24.4	30		
10	Khudpee	Jeypore	2011	4.3	6.9	2.3	4.4			2	3.3						
11	Chintalguda	Rayagada	2011	16.1	18.8												
12	Bhitarguda	Koraput	2011									4.5	6.6				
13	Harishchandraguda	Jeypore	2011	5.4	8.1			4.1	6.9								
14	Alubadi	Rayagada	2012			0.4	0.7					0.3	0.7				
15	Gunthaguda	Koraput	2012														
	Overall Mean			10.5	13.2	3.6	5.3	14.9	19.4	3.3	4.5	7.9	9.7	16.1	19.0	19.5	22.4
				12.1													

I: Initial, F: Final

Table 4.4.12: Planting year wise average survival rate, height and basal diameter of afforested species under NTFP plantation.

Year	Survival (%)		Height (m)		Basal Diameter (cm)	
	Initial	Final	Initial	Final	Initial	Final
2008	62	60	3.3	4.3	18.6	22.5
2009	74	69	1.8	2.6	10.0	12.8
2010	50	50	1.6	2.4	10.1	12.8
2011	56	56	1.1	1.4	5.8	8.2
2012	36	56	0.5	1.1	0.3	0.7

Table 4.4.13: Aspect wise average survival rate, height and basal diameter of afforested species under NTFP plantation

Aspect	Survival (%)		Height (m)		Basal Diameter (cm)	
	Initial	Final	Initial	Final	Initial	Final
West	63	67	1.5	2.2	8.4	10.5
East	56	56	1.4	2.1	6.3	9.5
North	61	56	1.4	2.0	9.7	12.3
South	61	60	2.3	3.0	12.3	15.5

4.5 Projected Biomass and Carbon Sequestration Potential

4.5.1 Block plantation of teak

The projected biomass of different phased plantation for 10, 15 and 20 years after planting was estimated along with the carbon sequestration potential (Table 4.5.1). The biomass production was the highest for first phased plantation and it was decreased with increase in plantation phases. In general the below ground biomass was about 28% of the above ground biomass. The projected total carbon sequestration potential varied between 128 and 273 t/ha for 10 and 20 year projected period, respectively for the first phased plantation of teak (2008). On the other hand, total carbon sequestration potential of 2012 phased teak plantation was varied from 12 to 157 t/ha for 10 and 20 year projected period, respectively. Figure 4.5.1 presents the phase wise total carbon sequestration potential of teak plantation for the projected period of 10, 15 and 20 years and it revealed that carbon sequestration potential of block plantation of teak was the highest during the first phased plantation (2008) and decreased for subsequent plantation years.

Table 4.5.1: Projected biomass and carbon sequestration potential of block plantation of teak plantation of different phases

Year	Projected Biomass (t/ha)						Projected Carbon Sequestration Potential (t/ha)								
	Above Ground			Below Ground			Above Ground			Below Ground			Total		
	10	15	20	10	15	20	10	15	20	10	15	20	10	15	20
2008	222	390	474	62	109	133	100	175	213	28	49	60	128	225	273
2009	142	235	370	40	66	104	64	106	166	18	30	47	82	135	213
2010	117	200	297	33	56	83	53	90	134	15	25	37	67	115	171
2011	71	164	310	20	46	87	32	74	139	9	21	39	41	95	178
2012	22	92	272	6	26	76	10	42	122	3	12	34	12	53	157

4.5.2 NTFP plantation

The projected biomass of different phased plantation for 10, 15 and 20 years after planting was estimated along with the carbon sequestration potential (Table 4.5.2). The biomass production was the highest for first phased plantation and it was decreased with increase in plantation phases except 2010 plantation. In general, the below ground biomass was about 28% of the above ground biomass. The projected total carbon sequestration potential varied between 512 and 2727 t/ha for 10 and 20 year projected period, respectively for the first phased plantation of NTFP(2008). On the other hand, total carbon sequestration potential of 2012 phased NTFP plantation was varied from 41 to 536 t/ha for 10 and 20 year projected period, respectively. Figure 4.5.2 presents the phase wise total carbon sequestration potential of NTFP plantation for the projected period of 10, 15 and 20 years and it revealed that carbon sequestration potential of NTFP was the highest during the first phased plantation (2008) and decreased for subsequent plantation years except during 2010.

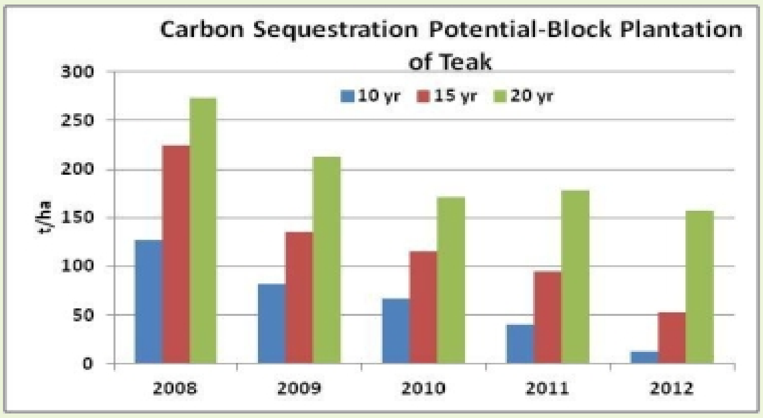


Figure 4.5.1: Projected total carbon sequestration potential (t/ha) of block plantation of teak for different phases

Table 4.5.2: Projected biomass and carbon sequestration potential of NTFP plantation of different phases

Year	Projected Biomass (t/ha)						Projected Carbon Sequestration Potential (t/ha)								
	Above Ground			Below Ground			Above Ground			Below Ground			Total		
	10	15	20	10	15	20	10	15	20	10	15	20	10	15	20
2008	961	2208	5018	269	618	1405	400	926	2130	112	259	597	512	1185	2727
2009	180	434	1293	50	122	362	79	192	574	22	54	161	101	245	735
2010	442	1250	3139	124	350	879	188	540	1373	53	151	384	240	691	1757
2011	324	684	1774	91	191	497	135	285	757	38	80	212	172	364	969
2012	72	274	930	20	77	260	32	123	418	9	35	117	41	158	536

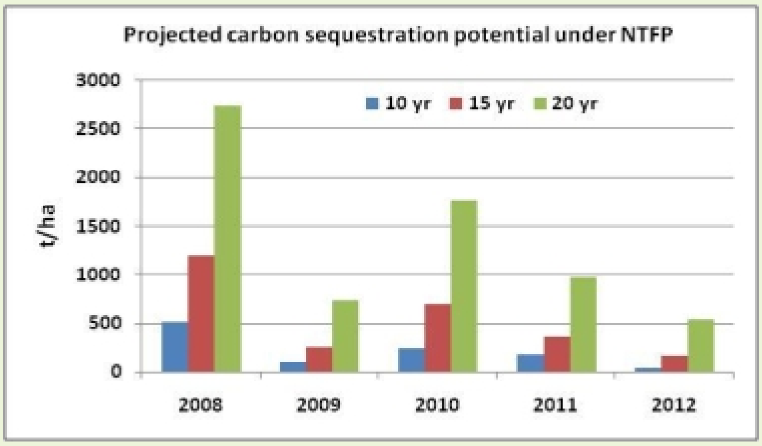


Figure 4.5.2: Projected total carbon sequestration potential (t/ha) of NTFP for different phases

5.0 Silent observations and Recommendations

5.1 Silent observations

- The land slope varied between 5.2% and as high as 42.44% in the study sites. The study sites at Santabadigaon, Gunthaguda, Khudpee and Bhitarguda are relatively high slope compared to the sites of Maliguda.
- The physical health of all the sites is medium to good in terms of plant growth in spite of their position in high slope. Among the various forest land uses, NTFP showed good soil physical health followed by ANR+GP. The block plantation sites showed considerably higher bulk density (1.23 g cm-3) than other sites. NTFP sites, due to active root systems and higher litter fall showed significantly lower bulk density (1.18 g cm-3)
- Texture is a very important soil property to determine the state of soil erosion. Due to the balance amount of sand, silt and clay in the soils of ANR+GP, this land use can be considered best in terms of soil physical health. ANR+GP has the highest clay (29.61 %) and lower sand (50.84 %) content among all the forest land uses. The opposite trend has been observed for the ANR-GP land use.
- In the study area the soil moisture content at FC varied between 14.2 % and 38.8 % with the average value of 25.2 %. Simillarly, the moisture content at PWP varied between 4.8 % and 17.8 % with the average of 10.8%. It is ANR+GP>ANR-GP>BP>NTFP. As the available moisture content depends on both FC and PWP, the higher value of PWP for the NTFP land use has brought down the availability of soil moisture in that land use. The moisture availability is strongly dependent on the ratio of sand, silt and clay present in the soil. A well distributed and textured soil found in the land use ANR+GP has made the condition conducive for plant growth by providing more water easily.
- The overall variation of soil pH is following the trend of ANR+GP>NTFP>BP>ANR-GP. The litter and the leaves of the trees grown in the forests contain calcium where the tree root system draws from the deeper soil layers. After these organics mixed with the surface soil system, it increases the soil pH owing to high calcium in leaves. Therefore ANR+GP and NTFP showed its potentiality to neutralize soil acidity.
- The DHA of surface soil is higher than sub-surface soil for all the land uses. NTFP and ANR+GP showed significantly higher DHA than BP and ANR without GP. The relatively shallower active root system of NTFP trees have made the microbes active hence showed high DHA.
- Overall fertility status of all the land uses is medium to good and followed the trend of NTFP>ANR+GP>BP>ANR-GP.
- The sites of NTFP showed higher soil organic carbon than all other land use. NTFP along with ANR+GP clearly depicts that in tropical condition soil disturbance create a negative balance in the SOC by increasing the carbon mineralization. Therefore, it's desirable that all the forest land uses to be protected from any type of biotic and abiotic disturbances. SMC measures help in a substantial amount to achieve this purpose.
- The amount of microbial biomass carbon is also following the trend that of SOC i.e., NTFP>ANR+GP >Black Plantation>ANR-GP. ANR+GP and NTFP sites are the comparatively active sites than ANR without GP and BP sites. Continuous litter deposition and root growth in addition to higher soil moisture content have made the ANR+GP and NTFP sites more conducive for the growth and development of microorganisms.
- ANR+GP showed a very high infiltration rate in Bhitarguda site and medium to low infiltration rate in Maliguda site. The other three VSS showed medium to high infiltration rate. The ANR-GP land use showed a low infiltration rate in all the sites. Among the VSS Khudpee showed comparatively higher and Maliguda showed low infiltration rate. The other three VSS showed low to medium infiltration rate.
- The number of runoff causing rainfall events was maximum in Maliguda (35) followed by Khudpee (32), Bhitarguda (31), Santabadigaon (27) and Gunthaguda (22). At all the study sites average runoff was minimum under ANR+GP followed NTFP, BP and it was maximum under ANR-

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- The amount of microbial biomass carbon is also following the trend that of SOC i.e., NTFP>ANR+GP >Black Plantation>ANR-GP. ANR+GP and NTFP sites are the comparatively active sites than ANR without GP and BP sites. Continuous litter deposition and root growth in addition to higher soil moisture content have made the ANR+GP and NTFP sites more conducive for the growth and development of microorganisms.
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5.1 Silent observations

- The land slope varied between 5.2% and as high as 42.44% in the study sites. The study sites at Santabadigaon, Gunthaguda, Khudpee and Bhitarguda are relatively high slope compared to the sites of Maliguda.
- The physical health of all the sites is medium to good in terms of plant growth in spite of their position in high slope. Among the various forest land uses, NTFP showed good soil physical health followed by ANR+GP. The block plantation sites showed considerably higher bulk density (1.23 g cm-3) than other sites. NTFP sites, due to active root systems and higher litter fall showed significantly lower bulk density (1.18 g cm-3)
- Texture is a very important soil property to determine the state of soil erosion. Due to the balance amount of sand, silt and clay in the soils of ANR+GP, this land use can be considered best in terms of soil physical health. ANR+GP has the highest clay (29.61 %) and lower sand (50.84 %) content among all the forest land uses. The opposite trend has been observed for the ANR-GP land use.
- In the study area the soil moisture content at FC varied between 14.2 % and 38.8 % with the average value of 25.2 %. Simillarly, the moisture content at PWP varied between 4.8 % and 17.8 % with the average of 10.8%. It is ANR+GP>ANR-GP>BP>NTFP. As the available moisture content depends on both FC and PWP, the higher value of PWP for the NTFP land use has brought down the availability of soil moisture in that land use. The moisture availability is strongly dependent on the ratio of sand, silt and clay present in the soil. A well distributed and textured soil found in the land use ANR+GP has made the condition conducive for plant growth by providing more water easily.
- The overall variation of soil pH is following the trend of ANR+GP>NTFP>BP>ANR-GP. The litter and the leaves of the trees grown in the forests contain calcium where the tree root system draws from the deeper soil layers. After these organics mixed with the surface soil system, it increases the soil pH owing to high calcium in leaves. Therefore ANR+GP and NTFP showed its potentiality to neutralize soil acidity.
- The DHA of surface soil is higher than sub-surface soil for all the land uses. NTFP and ANR+GP showed significantly higher DHA than BP and ANR without GP. The relatively shallower active root system of NTFP trees have made the microbes active hence showed high DHA.
- Overall fertility status of all the land uses is medium to good and followed the trend of NTFP>ANR+GP>BP>ANR-GP.
- The sites of NTFP showed higher soil organic carbon than all other land use. NTFP along with ANR+GP clearly depicts that in tropical condition soil disturbance create a negative balance in the SOC by increasing the carbon mineralization. Therefore, it's desirable that all the forest land uses to be protected from any type of biotic and abiotic disturbances. SMC measures help in a substantial amount to achieve this purpose.
- The amount of microbial biomass carbon is also following the trend that of SOC i.e., NTFP>ANR+GP >Black Plantation>ANR-GP. ANR+GP and NTFP sites are the comparatively active sites than ANR without GP and BP sites. Continuous litter deposition and root growth in addition to higher soil moisture content have made the ANR+GP and NTFP sites more conducive for the growth and development of microorganisms.
- ANR+GP showed a very high infiltration rate in Bhitarguda site and medium to low infiltration rate in Maliguda site. The other three VSS showed medium to high infiltration rate. The ANR-GP land use showed a low infiltration rate in all the sites. Among the VSS Khudpee showed comparatively higher and Maliguda showed low infiltration rate. The other three VSS showed low to medium infiltration rate.
- The number of runoff causing rainfall events was maximum in Maliguda (35) followed by Khudpee (32), Bhitarguda (31), Santabadigaon (27) and Gunthaguda (22). At all the study sites average runoff was minimum under ANR+GP followed NTFP, BP and it was maximum under ANR-

6.0 References

Ray, M.N (1979). Soil survey, classification and land use capability of Agril. Research Station, Semiliguda. M.Sc. (Ag.) Thesis, Dept. of Soil Science and Agril. Chemistry, O.U.A.T.

Piper, C.S (1942). Soil and Plant Analyses. University of Adelaide.

Rayment, G.E. and Higginson, F.R (1992). Australian Laboratory Handbook of Soil and Water Chemical Methods, Melbourne, Inkata Press. (Australian Soil and Land Survey Handbooks, vol 3).

Walkley, A. and Black, I.A (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37, 2938.

Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for estimation of available nitrogen in soils. Current Sciece, 25: 259260.

Bray, R.H. and Kurtz, L.T (1945). Determination of total, organic, and available forms of phosphorus in soils. Soil Science, 59: 39-45.

Jackson, M.L. (1967). Soil Chemical analysis. Prentice Hall of India, Pvt. Ltd., New Delhi : 498.

Bouyoucos, G.J. (1962). Hydrometer method improved for making particle size analysis of soil. Agron. J., 54:464-465.

Black, C.A. (ed) (1965). Methods of Soil Analysis, part 1, American Society of Agronomy.

Pepper, I.L., Gerba, C.P. and Brendecke, J.W. (1995). Environmental microbiology: a laboratory manual. Academic Press, Inc. New York, USA.

Tate K.R., Ross D.J. and Feltham C.W. (1988). A direct extraction method to estimate soil microbial C: effects of experimental variables and some different calibration procedures. Soil Biology and Biochemistry, 20: 329-335.

Technical plan finalization meeting

Trained animators on hydrological monitoring

Ordinary rain gauge installed at study site

Runoff and soil loss monitoring unit

MSD fitted with drums for runoff & soil loss monitoring

Hydrological monitoring unit at block plantation

Inspecting the LBCD by the team in the study area

NTFP plantation in the study area

Installation of erosion pins on U/S of LBCD

Growth monitoring at study site

View of LBCD constructed in the gully

Monitoring of siltation in trenches

Soil sampling for soil moisture determination

Soil sampling for laboratory analysis


Infiltration study at selected site under OFSDP


Sampling for estimating above & below ground biomass

Annexure-3.1 : Evaluation of SMC Measures at 15 Sites of Three Divisional Management Units (DMUs) under Odisha Forestry Sector Development Project

Training on Hydrological Monitoring

DMU,FMU and VSS wise - Participation's List: 13-14th May,2013

S. No.	Name of the DMU	Designation	Name of VSS	Mobile No.
		I. Rayagada DMU		
1	Sabana Hikoka	Animator	S.Badigam	8763011747
2	Satrupa Hikoka	Member	S.Badigam	9439507396
		II. Jeypore DMU		
1	Laxman Ray	Animator	Khudupi	9937847790
2	Ratnakan Soura	Member	Khudupi	
3	Niladunja Mali	Animator	Maliguda	9777221051
4	Bhubani Mali	Member	Maliguda	
		III. Koraput DMU		
1	Ghasi Pitai	Animator	Bhitargurh	9692814194
2	Siru Khora	Member	Bhitargurh	9778233763

CENTRAL SOIL AND WATER CONSERVATION RESEARCH AND TRAINING INSTITUTE
RESEARCH CENTRE, P. B. No-12, SUNABEDA-763002, Dist. KORAPUT, ODISHA

Training Schedule

Two Days Training Programme on Hydrological Monitoring under OFSDP

Date	Time	Topic	Instructor
13.05.2013	9:30 - 10:00am	Registration	
	10:00 - 11:00am	Runoff and soil loss monitoring: i. Site selection, Measurement ii. Demarcation of plot iii. Preparation for installation of MSD iv. Measurement of depth v. Sampling for silt determination vi. Maintenance of MSD by cleaning, etc.	**Er B.K. Dash**
	10:00 - 11:30am	Tea Break	
	11:30 - 1:00pm	Runoff and soil loss monitoring: i. Site selection, Measurement ii. Demarcation plot iii. Preparation for installation of MSD iv. Measurement of depth v. Sampling for silt determination vi. Maintenance of MSD by cleaning, etc.	**Er B.K. Dash**
	1:00 - 2:00pm	Lunch Break	
	2:00 - 3:30pm	Filtration and storing of filter paper	**Mr N.K.Dash**
	3:30 - 4:00pm	Tea Break	
	4:00 - 5:00pm	Rain-gauge installation and measurement: i. Site selection for installation ii. Installation iii. Measurement and maintenance of data	**Mr G.W. Barla**
14.05.2013	9:30 - 10:00am	Soil sampling for analysis	**Mr N.K.Dash**
	11:00 - 11:30am	Tea Break	
		Soil sampling for soil moisture determination: i. Selection of site ii. Sampling and labeling, initial weight and storing	**Er B.K. Dash & Mr N.K.Dash**
		Monitoring growth parameters	**Mr G.W. Barla**

Appendix - I

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Agreement

This agreement is made on 10th day of April, 2013 at Bhubaneswar

BETWEEN

Odisha Forestry Sector Development Society (OFSDS), Govt. of Odisha (Autonomous Society under Forest and Environment Department) having its office at SFTRI Campus, Ghatikia, Bhubaneswar 751003, District: Khurda represented by Sri Prakash Chandra Mishra, Deputy Project Director, OFSDP, (herein after called as the **First Party**) which expression shall where the context so requires or admits also includes its successor and assignees of one part.

AND

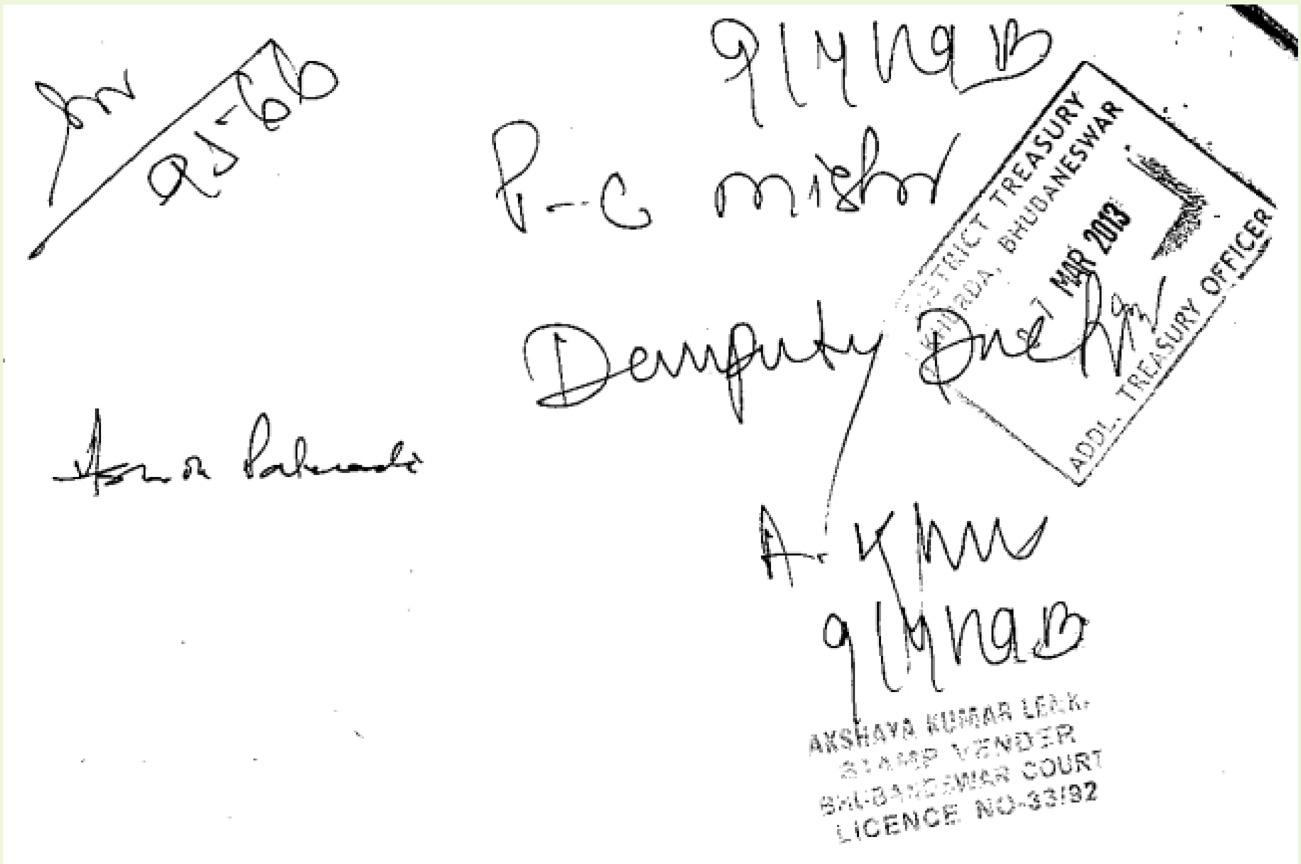
The Indian Council of Agricultural Research, having its office at Dr. Rajendra Prasad Road, Krishi Bhavan, New Delhi, a Society registered under the Societies Registration Act XXI of 1860 (herein after called the "Council") represented by Dr Prasanta Kumar Mishra, Director, CSWCRTI, Dehradun on the other part (herein after called as the **Second Party**) which expression shall where the context so requires or admits also includes its successor and assignee.

Whereas the CSWCRTI have expertise in advising, planning, management and evaluation of soil conservation works and watershed projects and also developed/demonstrated new technologies for land use, soil conservation and watershed management and evaluation of various related programmes.

AND

Dy. Project Director (FT& Trg.) OFSDP 10.04.13

Dr. P. K. Mishra Director Central Soil & Water Conservation Research and Training Institute 218-Kaulagarh Road Dehradun-248195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Whereas the said Odisha Forestry Sector Development Society (OFSDS), Govt of Odisha (Autonomous Society under Forest and Environment Department) is in need of consultancy Services for evaluation of Soil Moisture Conservation measures undertaken at 15 sites of three Divisional Management Units (DMUs) under OFSDP as per the Terms of Reference (Annexure-A) requested the Council/Institute and the Council/ Institute is agreeable to act as a Consultant through experts from Central Soil and Water Conservation and Research and Training Institute(CSWCRTI), Research Centre, Sunabeda, Koraput District, Odisha State.

Dy. Project Director (FT&...) OFSDP 10.04.13

AND

Whereas the First Party and the Second Party had a series of negotiations on all aspects of technical, financial and contractual matters and as a result of negotiations, this contract agreement has been produced including Terms of Reference (ToR) as Annexure-A attached hereto.

Now therefore, in consideration of the mutual covenant herein contained, this agreement witness as under:-

1. The CSWCRTI, Research Centre, Sunabeda shall be the Consultant of the First Party in respect of the matters covered under this agreement as per the terms of reference (ToR) defined in Annexure- A.

2. The consultancy service shall cover technical advice and assistance relating to:

Evaluation of SMC measures at 15 sites of three Divisional Management Units (DMUs) *under Odisha Forestry Sector Development Project as per the ToR.*

Dr. P. K. Mishra
Director
Central Soil & Water Conservation Research and Training Institute
218-Kaulagarh Road
Dehradun-248195, Uttarakhand

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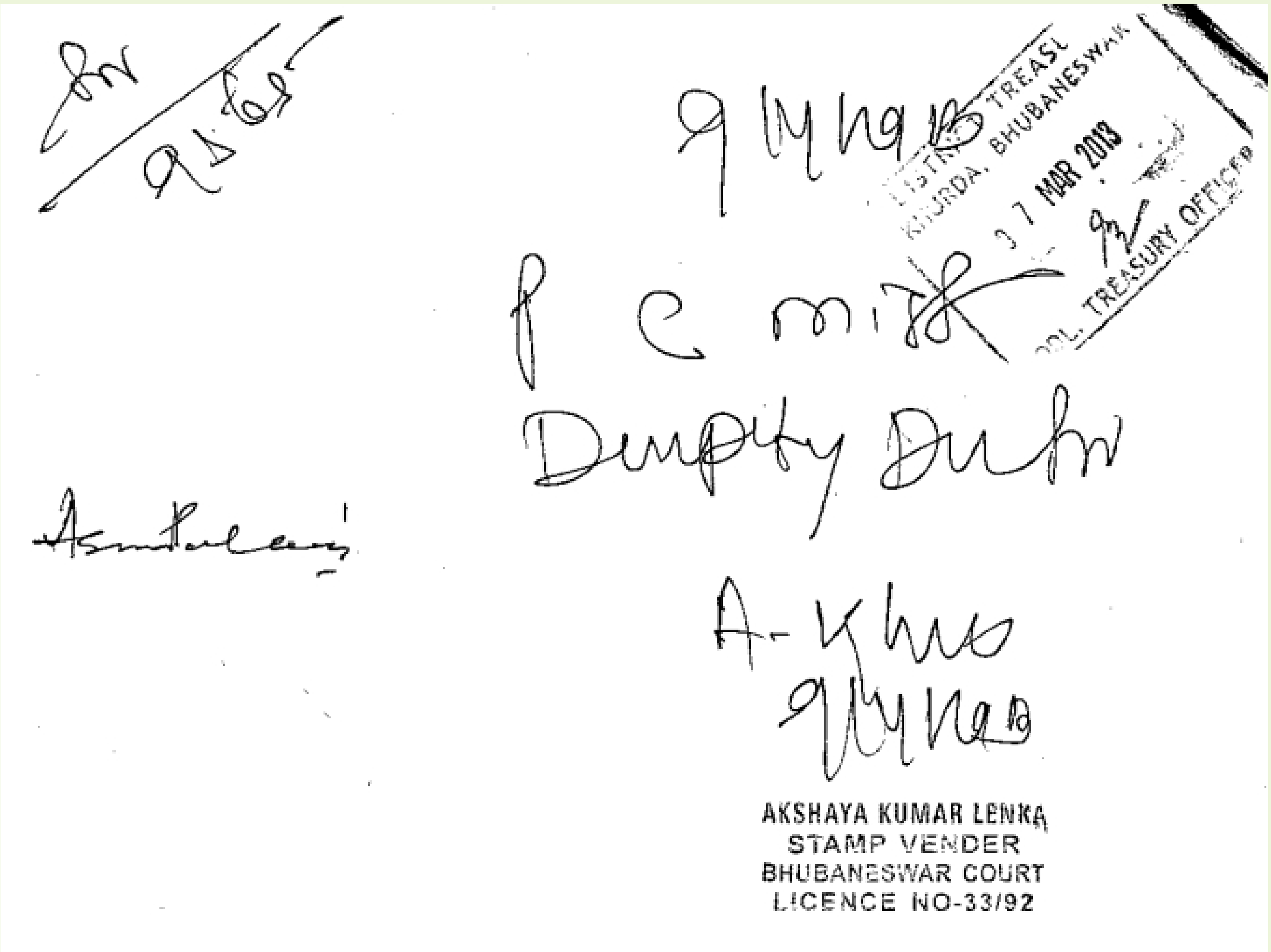
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Dy. Project Director (FT& Trg.) OFSDP
10-04-13

3. This agreement shall be for a period of **one year** and commences from the date of signing by both the parties. On the expiry of the aforesaid period it can be extended for further period on such terms and conditions as may be decided or agreed mutually between the parties (First Party and Second Party) on execution of a fresh agreement for the extended period.

4. The First Party shall provide all basic data available with them and afford all assistance to the Council's/Institute's Consultant for fulfilment of the consultancy under this agreement.

5. At no circumstances the Second Party shall without the permission of the First Party assign the contract to any third party in part or full to carry out any part of the work.

6. The Consultant shall prepare and submit its detailed plan of operation and scheduled work plan within one fortnight of deposition of first installment i.e., 100% of Physical inputs cost (Rs.3,45,845/-) and 50% of the remaining consultancy cost (Rs. 10,86,655/-). Consultant shall plan out all field works in advance as per ToR given in Annexure-A and inform the work scheduled to the First Party and to the concerned Divisional Management Units.

7. That the Consultant shall submit quarterly progress reports (3 Hard Copies + 1 Soft Copy) on the status of work progress to the First Party. However, that the First Party shall have the right to inspect the progress of the work at all reasonable time for monitoring and its smooth completion.

Dr. P. K. Mishra
Director
Central Soil & Water Conservation
Research and Training Institute
218-Kaulagarh Road
Dehradun-248195

8. That if at any time during continuance of this contract the work is delayed because of war, civil commotion/natural hazards, epidemics and earthquake etc., it must be reported by the Second Party to the First Party within one week of such incidence(s) with full details and its impact on the work schedule mentioning therein additional time required for the completion of works under this agreement. The Force Majeure shall not include delays due

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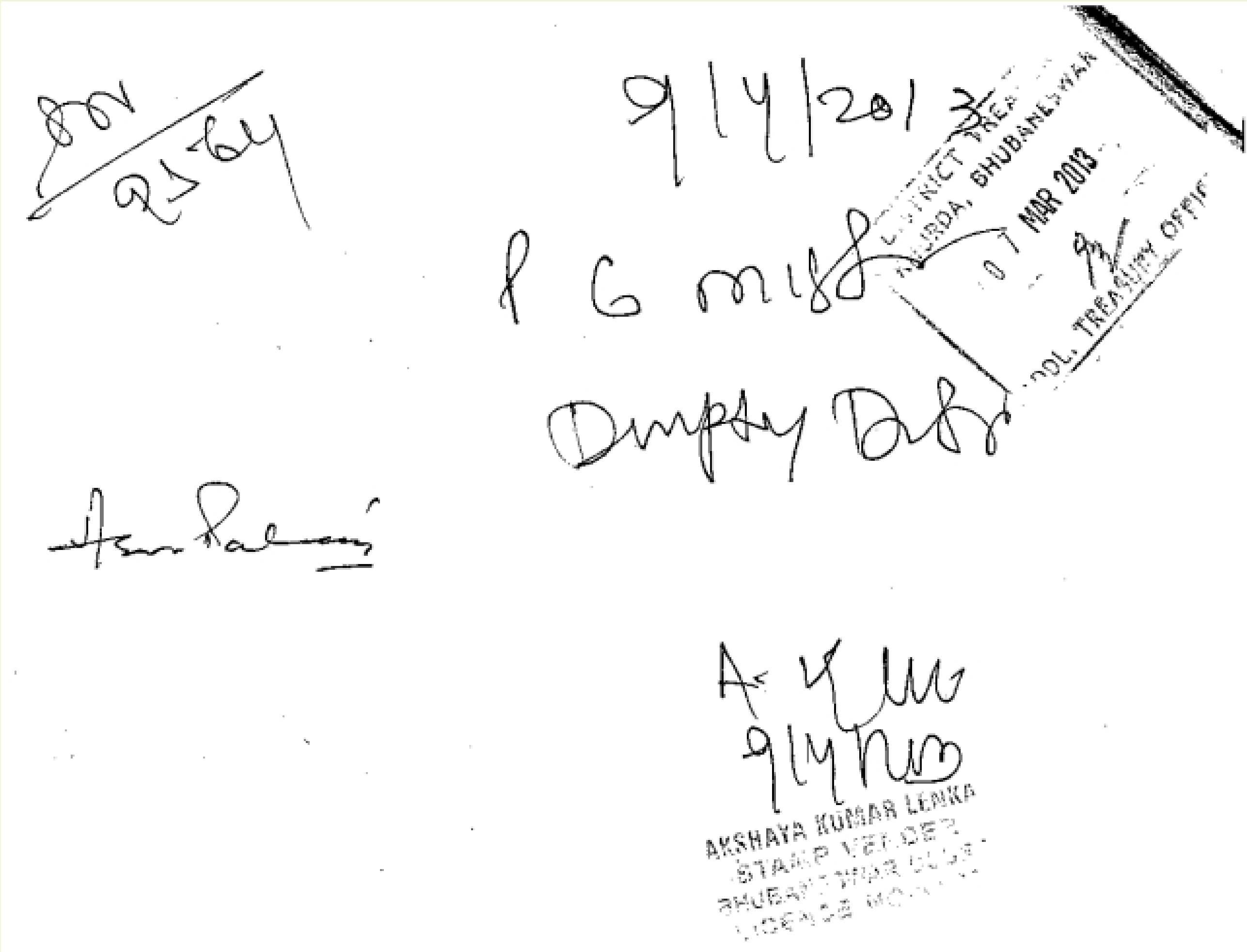
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to negligence or internal action of the Second Party or insufficiency of funds. The working period may be extended by the First Party if it feels the reason of delay reported by the Second Party found to be genuine and beyond the control of the Consultant.

9. The Second Party shall employ competent technical personnel for implementation of the advice and consultancy provided. The decision of the Director of the Consultant Institute referred above shall be final in this regard.

10. The responsibility of the Consultant Institute shall be limited to the technical advice on matters prepared to and covered under this agreement. All procedural/legal/operational matters will be responsibility of the First Party.

11. The amount of consultancy fee shall be a maximum of Rs. 14,32,500/-(Rupees Fourteen Lakh Thirty Two Thousands and Five Hundred only) including service tax as applicable (Annexure-B), for the scope of work as mentioned elsewhere in this document. The First Party shall pay 100% of the physical inputs cost (Rs.3,45,845/-) and 50% of the remaining consultancy cost (of Rs. 10,86,655/-) at the time of commencement of the project, 30% of the remaining consultancy cost (of Rs. 10,86,655/-) after submission of the draft report and 20% of the remaining consultancy cost (of Rs. 10,86,655/-)after submission of final report. All instalments of deferred payment are to be backed by bank guarantees.

12. This agreement shall come into force with effect from the date written herein above and shall be for a period of one year from the date of commencement of services. On the expiry of the aforesaid period it can be extended for further period on such terms and conditions as may be decided or agreed mutually between the parties on execution of a fresh agreement for the extended period.

10-04-13
Dy. Project Director (FT& Trg.)
OFSDP

Dr. P. K. Mishra
Director
Central Soil & Water Conservation
Research and Training Institute
218-Kaulagarh Road
Dehradun-248195, Uttarakhand

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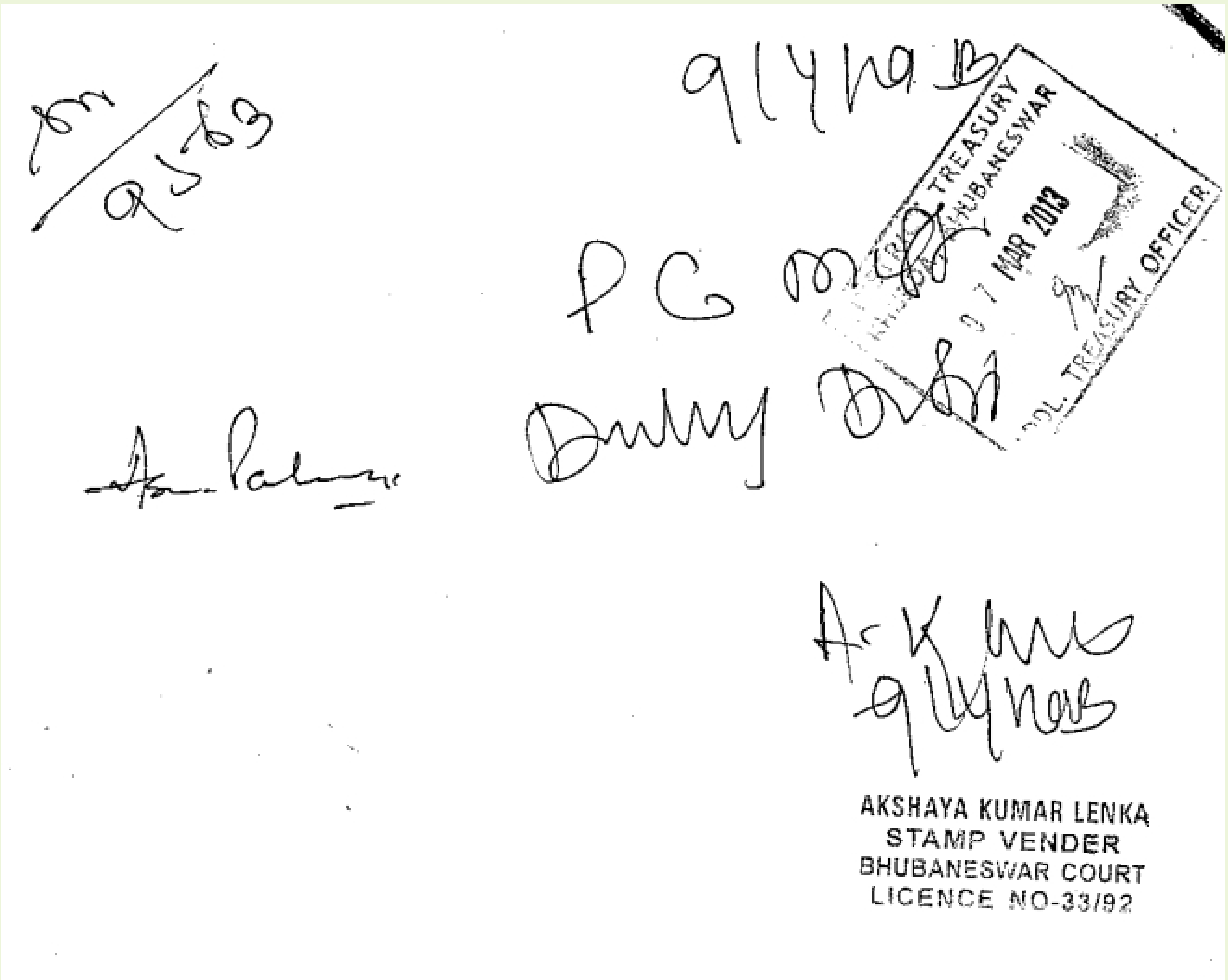

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13. Either party may at any time terminate this agreement by giving one calendar months' notice in writing to the other party by specifying in detail the causes of dissatisfaction. A notice required to be sent personally under this agreement shall be sufficiently served on the parties if delivered to them personally or despatched by the address herein given under registered post.

14. The Council/Consultant Institute shall at the request of the **First Party**, depute Consultant for advice at the work of project area for which TA/DA be payable by the First Party, if not included in the consultancy fee.

15. The Council and the Consultant Institutes shall not, if any be responsible for any damage to the property /plant/material of the **First Party** during the course of or consequent to the consultancy services being provided.

16. Any dispute between the parties arising out of or in connection with this agreement shall be referred to the sole arbitration of the Director General of the Council or any officer appointed by him as the case may be and the award of the arbitration shall be final and binding on both the parties.

NOW THEREFORE the parties hereto shall be deemed to form an integral part of this agreement.

The following document attached hereto shall be deemed to form an integral part of this Agreement.

Annexure - A: Terms of Reference (ToR)
Annexure - B: Cost Estimate of the Study

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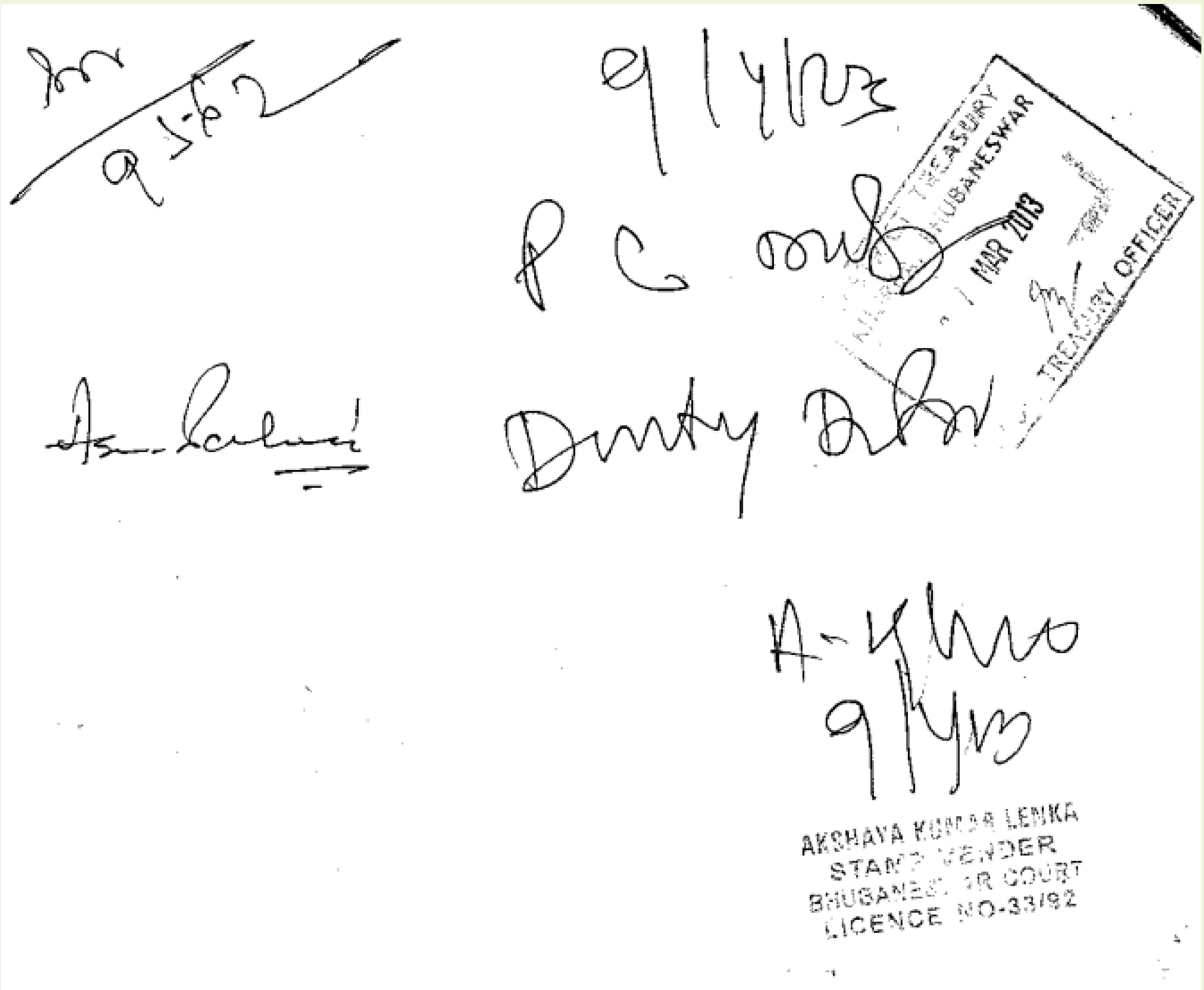
Dy. Project Director (FT& Trg.)
OFSDP
10.04.13

Dr. P. K. Mishra
Director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In witness whereof the above named parties have set their hands Dr P. K. Mishra, Director, CSWCRTI, Dehradun acting for the Council and Sri. P. C. Mishra, Deputy Project Director acting for the OFSDS as on the day and the year first above written.

For and on behalf of the OFSDS (The First Party)	For and on behalf of the Council/ Institute (The Second Party)
10.04.13 Dy. Project Director (FT& Trg.) OFSDP	
Sri Prakash Chandra Mishra Deputy Project Director Odisha Forestry Sector Development Project SFTRI Campus, Ghatikia, Bhubaneswar	Dr. Prasanta Kumar Mishra Director CSWCRTI, Dehradun Dr. P. K. Mishra Director
Witness	Witness
1. Marga Ku. Bag Stenographer	1. (M. Madhu)
2. Jagannath Das Stenographer	2.

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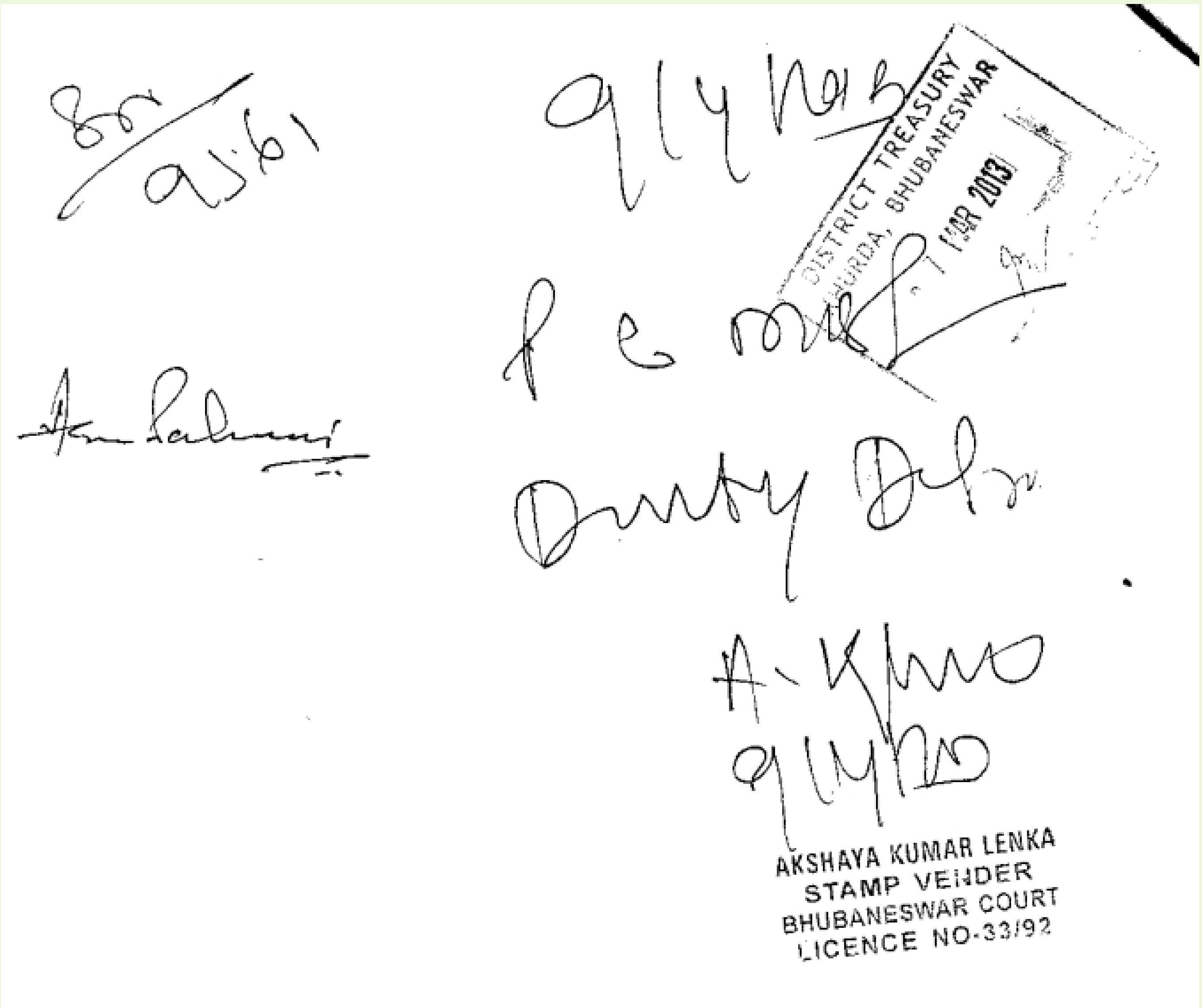
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Annexure-"A"

TERMS OF REFERENCE

A. Specific Terms of Reference:

1 Outline of work envisaged under project

This study is aimed at evaluating the impact of SMC measures on silt deposition, moisture retention, survival and growth parameter of plantation besides designing cost effective SMC measure for the future.

The work envisaged shall include:

a) The CSWCRTI involvement would be in survey, evaluation, redesign of soil and water conservation measures in consultation with Odisha Forestry Sector Development Project, Govt of Odisha.

b) Base maps of the area and other required technical information shall be provided by OFSDP.

c) The task will be carried out in the three forest divisions namely Koraput, Jeypore and Rayagada and five VSS (JFMC) sites in each Division.

2 Scope of Work

2.1 Technical assessment of soil and moisture conservation measures taken up in the VSS area (would include hills, slopes and foot hills/plain or sloping land in degraded and not-so degraded sites)

2.2 Impact of SMC measures on survival and growth parameter of plantation.

2.3 Assessment of silt deposition data and soil moisture content during the study period.

2.4 Advice and design of appropriate SMC measures for VSS area in OFSDP being treated through ANR (Assisted Natural Regeneration) and block plantations

3 Key Tasks

3.1 **Research Planning Meeting:** A meeting between the study team (Consultant) and project officials (OFSDP) at CSWCRTI, Research Center, Sunabeda to finalize the sampling, parameters to be studied and methodology to be followed.

3.2 **Selection of Sites:** Five sites from each DMU will be selected in consultation with the respective DFOs and other field level officers of Koraput, Rayagada and Jeypore DMUs. Totally 15 sites will be monitored for different impact parameters. Sub sampling sites will be demarcated (topo-sequence wise) for collection of soil sample, soil moisture and vegetation study.

3.3 **Approach:** Depending upon impact parameter, before-after and with-without approach will be followed to quantify the different onsite impacts

3.4 **Field study and Data collection:** The study team shall visit sample VSS sites and collect the following data

3.4.1 **Site Characteristics:** Each site characteristics will be collected. The identified few site characteristics are listed below

a) Location: Latitude and Longitude and average Altitude
b) Area (ha) of VSS
c) Slope (%)
d) Year of plantation/construction of the structure & SWC measures
e) Specification of SMC measures / DLTs
f) List of species
g) Spacing of the structure/plantation
h) Aspects etc.

-:1:-

10.04.13
Dy. Project Director (FT& Trg)
OFSDP

3.4.2 **Soil properties:** The different soil parameters to be monitored during the study period are presented in the following table with frequency of sampling and method followed for analysis.

Parameter	Depth	Location/ Toposequence	Frequency	Method
1. Soil Moisture	0-20 cm &20-40 cm	Top /Middle/Low	Monthly	Gravimetric
2. Bulk Density	0-20 cm &20-40 cm	Top /Middle/Low	One time	Soil Core Sampler
3. Soil Texture	0-20 cm &20-40 cm	Top /Middle/Low	One time	Feel/Hydrometer
4. SMCC/WHC/ FC/PWP	0-20 cm &20-40 cm	Top /Middle/Low	One time	Pressure Plate Apparatus
5. Soil pH	0-20 cm &20-40 cm	Top /Middle/Low	One time	pH meter
6. Soil EC	0-20 cm &20-40 cm	Top /Middle/Low	One time	EC Bridge
7. Soil OC	0-20 cm &20-40 cm	Top /Middle/Low	Initial & Final	CHN Analyzer
8. NPK	0-20 cm &20-40 cm	Top /Middle/Low	One time	Standard Procedure
9. Infiltration	Surface	Top /Middle/Low	One time	Infiltrometer
10. Soil Structure	0-20 cm &20-40 cm	Top/Middle/Low	One time	Standard Procedure
11. Plasticity / Stickiness	0-20 cm &20-40 cm	Yes	One time	Standard Procedure
12. Carbon Stock				
a) A/G Biomass	One time under different age groups of plantation			Possibility shall be explored following standard procedure
b) B/G Biomass				
c) A/G/B OC				
d) B/G/B OC				
13. Microbial Biomass Carbon	0-20 cm	One time under different age groups of plantation		Standard Procedure
14. Dehydrogenase Activity	0-20 cm			

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OFSDP

3.4.3 Hydrological Monitoring:

There will be four types of situation (treatment) where hydrological Monitoring will be carried out

a) Assisted Natural Regeneration + SMC measures (ANR+SMC)
b) Block Plantation with SMC Measures (BP+SMC)
c) ANR without SMC measures
d) Block Plantation without SMC measures

The sites will have to be selected from different batches of plantation

a) 2008 – 1st Batch
b) 2009 – 2nd Batch
c) 2010 – 3rd Batch
d) 2011 – 4th Batch
e) 2012 – 5th Batch

At each DMU, one set of situation (treatment) with each year (as per site availability) will be monitored for runoff and soil loss using MSD (Multi-Slot Divisors) fitted with collection tank. In all there will be 20 monitoring plots covering five years with the treatments.

3.4.4 Growth Parameters of Afforested Species

Average survival percent will be calculated based on the plants planted initially and plants survived at initial and at final date of observation. Plant height and basal diameter/dbh will be collected from the randomly selected plants on topo-sequence wise at each sites.

Growth parameters of afforested species will be monitored as per the details given in the table below.

Parameter	Location/ Toposequence	Frequency	Method/Remarks
1. Survival rate	Top/Middle/Low	Initial & Final	Will be done for all the sites
2. Plant Height	Top/Middle/Low	Quarterly	
3. Basal diameter	Top/Middle/Low	Quarterly	

3.4.5 Data Analysis and interpretation

The different set of parameters will be compared with the initial data and also with the controlled site depending up on the parameters. The data will be interpreted based on the percentage, Standard Deviation, standard error etc.

3.5 Submission of Report

3.5.1 Based on the above, the consultant will prepare and submit a draft report as per the contents finalized in consultation with the PMU.

3.4.2 OFSDP may organize a workshop for sharing of the report among project staff and other peers (at the cost of OFSDP). Based on the feedbacks from the workshop and comments of draft report by the project, draft report will be revised and final report will be submitted to the Project.

4. General Terms and Conditions

4.1 That the Second Party shall abide by all laws of the State/ Central Government and fulfill the obligations relating to the prevailing Labour Laws. The Second Party shall indemnify the First Party for any breach of law committed by it during the period of the agreement. The Second

-:3:-

10.04.13
Dy. Project Director (FT& Trg.)
OFSDP

Dr. P. K. Mishra
Director

Party shall take adequate measures to ensure continuous and unhindered output of the work as mentioned herewith in the agreement. That for all time there cannot be any relation of employer and employee between the parties or the persons engaged by the Second Party to carry out any part of the above mentioned assignment and the First Party. The disputes inter-se between the Second Party and its engaged persons shall be the sole responsibility of the Second Party.

4.2 Both the parties shall nominate a contact person as their authorized representative for the purpose of this agreement. All notices, request, approval, consent required or permitted to be given or made pursuant to this contract should be addressed by/to the contact person in writing.

4.3 TIME FRAME (Contract Period)

Activities	1	2	3	4	5	6	7	8	9	10	11	12
Finalizing MoU	■											
Finalization of site for study at each forest division in consultation with OFSDP	■	■										
Redesign soil and water conservation measures as per the site requirement in consultation with nodal officer of Odisha Forestry Sector Development Project, Govt of Odisha.		■	■									
Field visits for baseline survey and data collection (Location details, slope, orientation/aspects, initial soil sampling for analysis, area, year of plantation, species, spacing, type of SMC measure with specifications, year of execution, associated vegetations, soil profile study, etc) Planning for monitoring of sites specific data		■	■	■								
Installation of runoff and soil loss monitoring devices at selected sites			■	■								
Monitoring of data on soil moisture, runoff, soil loss, rainfall, growth parameters of afforested species, other vegetations, deposition of silt in trenches, initial and final soil properties etc.				■	■	■	■	■	■			
Data analysis and report writing										■	■	
Submission of draft report											■	
Submission of final report												■

5. Terms of Payment

5.1 Payment of 100% of Physical inputs cost (Rs.3,45,845/-) and 50% of the remaining consultancy cost (Rs. 10,86,655/-)at the time of commencement of the project.

5.2 30% of the remaining consultancy cost (Rs. 10,86,655/-)after submission of draft report

5.3 20% of the remaining consultancy cost (Rs. 10,86,655/-)after submission of final report.

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10-04-13

Dy. Project Director (FT& Trg)
OFSDP

Dr. P. K. Mishra
Director