

**CARBON SEQUESTRATION POTENTIAL
IN COMMUNITY MANAGED FORESTS IN
MAHOTTARI DISTRICT OF CENTRAL NEPAL**



**A THESIS SUBMITTED TO THE
CENTRAL DEPARTMENT OF BOTANY
INSTITUTE OF SCIENCE AND TECHNOLOGY
TRIBHUVAN UNIVERSITY
NEPAL**

**FOR THE AWARD OF
DOCTOR OF PHILOSOPHY
IN BOTANY**

**BY
RAM ASHESHWAR MANDAL
JANUARY, 2015**

LETTER OF RECOMMENDATION

This is to recommend that Ram Asheshwar Mandal has carried out research entitled “**Carbon Sequestration Potential in Community Managed Forests in Mahottari District of Central Nepal**” for the award of Doctor of Philosophy (Ph.D.) in Botany under our supervision. To our knowledge, this work has not been submitted for any other degree.

He has fulfilled all the requirements laid down by the Institute of Science and Technology (IOST), Tribhuvan University, Kirtipur for the submission of the thesis for the award of Ph.D. degree.

.....
Prof. Dr. Siddhi Bir Karmacharya
Supervisor
Department of Botany, Trichandra College
Tribhuvan University
Kirtipur, Kathmandu,
Nepal

.....
Prof. Dr. Ishwar Chandra Dutta
Co-Supervisor
Chairman, Tribhuvan University Service Commission
Kirtipur, Kathmandu,
Nepal

LETTER OF APPROVAL

On the recommendation of Prof. Dr Siddhi Bir Karmacharya and Ishwar Chandra Dutta of supervisor and co-supervisor of this Ph. D. thesis submitted by Ram Asheshwar Mandal, entitled “**Carbon Sequestration Potential in Community Managed Forests in Mahottari District of Central Nepal**” is forwarded by Central Department Research Committee (CDRC) to the Dean, IOST, T.U.

.....

Dr. Pramod Kumar Jha

Professor,

Head,

Central Department of Botany

Tribhuvan University

Kirtipur, Kathmandu,

Nepal

August 11, 2015

DECLARATION

Thesis entitled “**Carbon Sequestration Potential in Community Managed Forests in Mahottari District of Central Nepal**” which is being submitted to the Central Department of Botany, Institute of Science and Technology (IOST), Tribhuvan University, Nepal for the award of the degree of Doctor of Philosophy (Ph.D.), is a research work carried out by me under the supervision of Prof. Dr Siddhi Bir Karmacharya, Department of Botany, Trichandra College, Tribhuvan University and co supervised by Prof. Dr Ishwar Chandra Dutta, Chairman of Tribhuvan University Service Commission, Kathmandu, Nepal.

This research is original and has not been submitted earlier in part or full in this or any other form to any university or institute, here or elsewhere, for the award of any degree.

.....
Ram Asheshwar Mandal

January, 2015

Letter of Approval

(Next File to Print in Letter Head)

DEDICATION

This thesis is dedicated to my parents for their love and affection

ACKNOWLEDGEMENTS

It is a great pleasure to thank all persons and organizations who supported me during the Ph.D. research work.

I would like to express my gratitude to Central Department of Botany, Tribhuvan University for providing me the opportunity for Ph.D. research on "Carbon Sequestration Potential in Community Managed Forest in Mahottari, Tarai District of Central Nepal". In addition, I would like to thank Department of Botany, Trichandra College for providing all the facilities including administration support as well.

I would like to express sincere gratitude to Professors, Dr. Sidhi Bir Karmacharya, Ishwar Chandra Dutta and Pramod Kumar Jha for their continuous guidance and encouragement to accomplish the Ph.D. research. They have cordially supported me through whole period from proposal writing to thesis development. Their critical reviews enabled me to synthesize the research thesis. Similarly, I thank Prof. Dr. Krishna Kumar Shrestha, Prof. Dr. Ram Prasad Chaudhary, Prof. Dr. Mohan Siwakoti, Dr. Sangeeta Rajbhandari, Dr. Bijaya Pant, Dr. Ram Kailash Yadav, Dr. Suresh Kumar Ghimire, Dr. Bharat Babu Shrestha, Dr. Chitra Bahadur Baniya, Dr. Anjana Devkota, Dr. Sanjay Jha and Dr. Chandra Pokhrel for their support. At the same time my sincere thanks go to Mrs. Geeta Khadka, Pabitra Bhakta Manandhar and all academic and administrative staff of Trichandra college for their continuous support. I would like to thank to all the non teaching staff of Central Department of Botany and Department of Botany in Trichandra college, TU for kind cooperation during my research work.

I would like to express my heartiest gratitude to Mr. Ram Dular Yadav, undersecretary, directorate of regional soil research, Hetauda. Without his laboratory support and guidance, it was impossible to analyze the soil and plants samples to infer the results. My sincere thanks go to the seniors, especially to Dr. A.L. Karna, Dr. A. L. Das, Dr. K.P. Awasthy, Dr. Rajan Kotru, Dr. Bijay Kumar Singh, Dr. Narendra Bahadur Chand, Dr. Nagendra Prasad Yadav, Dr. Chudamani Joshi, Mr. B.N. Oli, Dr. Bishnu Hari Pandit, Dr. A.N. Das, Dr. Naya Sharma, Dr. Bhupendra Devekota, Dr. Sushila Nepali, Professor Dr. T.N. Marasheni, Dr. Sunil Sharma, Mr. Subhash Devkota, Mr. S. M. Mishra, Mr. Dadhi Kandel, Mr. Rajesh Koirala, Mr. Yogendra

Karna, Mr. Utsaw Thapa, Mr. H.N. Mandal, Mr. A.B. Mathema, Mr. Laxmi Dutta Bhatta, Mr. Bishnu Bhandari, Mrs. Tshering Dolma Lama and Mr. Ram Hari Pantha for their kind cooperation.

My special thanks go to my Ph.D. fellow Narayan Prasad Ghimire, Mukti Ram Paudel, Shreeti Pradhan, Binod Kumar Basnet, Sanjeev Kumar Rai, Jyoti Prasad Gajurel, Hari Prasad Aryal, Laxmi Joshi and Nirmala Joshi. Parallel thanks go to Professor Mohmad Samshul Haque and Mr. Yogendra Yadav for their support in field activities. I also thank my close friend Geeta Manandhar who always inspires me to study for the educational career development.

I thank to Mr. Sanjay Sah, Bijay Kumar Yadav, Roshan Kafle, Ajit Jha, Ram Ashish Yadava, Ram Jiban Yadav, Manoj Thakur, Manoj Mahato, Ashok Chaudhary for their help in the field data collection, they are really helpful persons.

Last but not least, I would like to thank my parents Mr. S. Mandal and Mrs R. Devi and to my wife S. Devi, son Ranjeet and daughters Ranjeeta, Renu and Susmita and my brother R. Mandal and all family members for their moral supports and passions. I also like to express my gratitude to all my friends of home village who encouraged me for further study.

.....
Ram Asheshwar Mandal

ABSTRACT

Forest carbon sequestration plays a significant role in mitigation and adaptation to the impacts of the climate change. The carbon sequestration is accounted as carbon credit for reducing emission from deforestation and forest degradation (REDD+) programme. On the other hand, increasing concentration of CO₂ emission contributes to green house gases (GHGs), which are mainly responsible for global warming and consequence is impacts of climate change. These, both need intensive scientific records to assess them, the former needs the records of carbon stock change while the latter one needs the record of sources of GHGs emission particularly the CO₂ and CH₄ emission. Such researches are very limited in Nepal. Thus, this study is objectively carried out to assess the specieswise Importance value index (IVI) and carbon stock; to assess the carbon stock in community managed forests; to identify the carbon sequestration potential and confrontation for carbon trade; to evaluate the carbon stocks for sustainable management of forests; to appraise the plant biodiversity status and its relationship with the forest carbon stock; to identify drivers of deforestation and forest degradation and its effects on carbon stocks in community managed forests and to quantify the CO₂ and CH₄ emission from domestic fuel and livestock keeping of household living near to forest and distant from the forests.

For this study, two types of data specifically biophysical and socio-economic data were collected. The biophysical data were collected from community managed forests like three from each collaborative and community forests as well as public plantations and community planted forests of Mahottari district. In addition, socio-economic data collection was focused on drivers of deforestation and forest degradation, which were collected from workshop with key informants. Meanwhile, Sahodawa and Maisthan villages were selected for assessing the CO₂ and CH₄ emission from fuel consumption and cattle keeping respectively, which are sources of climate change process drivers. The maps of forest areas were prepared and stratified using GPS coordinates. Latter, altogether 96, 80, 28 and 24 permanent sample plots were distributed randomly on the maps of collaborative forests, community forests, public plantations and community planted forests respectively. The randomized block design (RBD) was set so the data were collected using stratified random sampling from collaborative and community forests. Meanwhile, the complete random design (CRD) was set to gather data applying simple random sampling from public and community planted forests. Similarly, altogether 138 households were sampled randomly after well-being ranking such as rich, medium and poor, then the quantity of fuel consumption was recorded in the morning and evening for seven days during summer and winter seasons setting RBD. Next, the record of cattle keeping was noted in order to determine the CH₄ and CO₂ emissions. At the same time list of drivers of deforestation and forest degradation were also gathered. The biophysical data were analyzed using the biomass equation of Chave *et al.* The species wise IVI was also calculated and their ranking was evaluated

to know the effect of carbon on IVI. Same biophysical data were used to find out the relationship between biodiversity and forest carbon. Moreover, soil carbon was calculated applying Walkley and Black Method. Meanwhile, the carbon stocks of community forests and collaborative forests were checked applying Biolley's "Check Method" - Method du-Control and Biolley's sustainable principle. Additionally, the relationships were evaluated between carbon stocks and species richness and between carbon stocks and Simpson's evenness. The socio-economic data were analyzed using descriptive analysis.

It showed that, IVI of *Shorea robusta* was the highest about 68.59 in Tuteshwarnath CFM while this value of *Gmelina arborea* was the lowest 0.4 in Gadhanta- Bardibash CFM. Meanwhile, the carbon stock of *Shorea robusta* was the highest $50.43 \pm 0.43 \text{ t ha}^{-1}$ and this of *Desmodium oojinense* was the lowest 0.01 t ha^{-1} in Gadhanta-Bardibash CFM. In addition, there was effect of carbon stock in species ranking. It was found that the estimated carbon stock was the highest 274.67 t ha^{-1} in Gadhanta-Bardibash CFM while it was the lowest in 30.34 t ha^{-1} in Bisbitty public plantation. The estimated current annual carbon increment (CACI) was found to be highest 2.85 t ha^{-1} at third year in Chyandanda community forest. However, annual carbon loss (ACL) was recorded as leakage -1.68 t ha^{-1} from Banke- Maraha CFM. The net value of carbon sequestration potential was US\$ 5967.62. Therefore, these community managed forests can be avenue for carbon trade under the REDD+ programme. Neither community forests nor collaborative forest showed sustainability performance based on Biolley's "Check Method" - Method du-Control and Biolley's sustainable principle. Here, the issues of sustainable forest management and biodiversity should be balanced equally. The estimated R^2 values indicated that there is very weak relationship between species richness and carbon stock, however, the hump- shaped relationship was exist between them. The over exploitation, grazing and forest fire were major drivers of deforestation and forest degradation, which are affecting the carbon stock. Total quantities of CO_2 emission were 4792.25 t and 9235.68 t in Maisthan and Sahodawa villages respectively from firewood consumption. The CH_4 emissions were 160.58 and 157.66 t yr^{-1} in Maisthan and in Sahodawa villages respectively from the livestock keeping, which together may emit 7367.59 t CO_2 equivalents but managing the CH_4 emission through biogas can offer US\$ 47568.35 certified emission reduction. Therefore, it can be concluded that community managed forests are potential for carbon trade. On the other it is essential to determine the drivers of deforestation and forest degradation to address them for REDD+ programme in Nepal as well as to determine the sources of CO_2 and CH_4 clearly to reduce them as measures of climate change adaptation and mitigation.

Keywords: Carbon sequestration, CO_2 and CH_4 emission, REDD+, biodiversity, community forests, collaborative forests, public plantation, community planted forest.

TABLE OF CONTENTS

	Page No.
Declaration	i
Letter of Recommendation	ii
Letter of Approval	iii
Dedication.....	iv
Acknowledgements	v
Abstract.....	vii
List of Acronyms and Abbreviation	ix
List of Tables	xi
List of Figures.....	xiii
Table of Contents	xv
CHAPTER 1	1
1. INTRODUCTION	1
1.1 Background.....	1
1.2 Rational of the Study	2
1.3 Research Objectives	7
1.3.1 Specific Objective.....	7
CHAPTER 2	8
2. LITERATURE REVIEW.....	8
2.1 Forest Carbon Stock Variation	8
2.1.1 Global Forest Carbon Stock Variation	8
2.1.2 Carbon Stock Variation in Nepal.....	9
2.1.3 Ecological Value and Carbon Stock of Forest Species	11
2.2 Context of Forest Carbon Sequestration.....	13
2.3 Forest Carbon, Ecosystem, Environmental Services and Livelihood	15
2.4 Policies for Forest Carbon Trade.....	17
2.4.1 Reducing Emission from Deforestation and Forest Degradation (REDD)	18

2.4.2	Strength of National Policies to Restore Forest Resources	19
2.4.3	Conflicting Policy and Practices.....	21
2.5	Sustainable Forest Management and Forest Carbon	23
2.6	Collective Actions and Community Managed Forests	24
2.7	Biodiversity Status and its Relationship with Forest Carbon	27
2.8	Drivers of Deforestation and Forest Degradation.....	28
2.8.1	Drivers of Deforestation and Forest Degradation and Their Effects on Forest Carbon	29
2.8.2	Forest Cover Change Context.....	30
2.9	Emission due to Energy Consumption and Cattle Keeping	31
CHAPTER 3		35
3.	MATERIALS AND METHODS	35
3.1	Description of Research Site	35
3.1.1	Location of the Research Site	35
3.1.2	Climate.....	36
3.1.3	Demography	37
3.2	Research Sites	37
3.2.1	Studied Site for Biophysical Data	37
3.2.1.1	Collaborative Forests	38
3.2.1.2	Community Forests.....	40
3.2.1.3	Community Planted Forests and Public Plantations.....	42
3.2.2	Study Site for Socio-Economic Data	44
3.3	Method of Data Collection and Analysis	46
3.3.1	Biophysical Data Collection and Analysis	47
3.3.1.1	Mapping, Stratification and Experimental Design	47
3.3.1.2	Sampling Process.....	47
3.3.1.3	Data Collection	56
3.3.1.4	Data Analysis.....	56
3.3.1.4.1	Calculation of Forest Carbon Stock.....	56
3.3.1.4.2	Calculation of IVI and Forest Biodiversity	61
3.3.1.4.3	Evaluation of Carbon Stock for Sustainability	61

3.3.2	Socio-Economic Data Collection and Analysis.....	62
3.3.2.1	Data Collection	62
3.3.2.1.1	Sampling Process of Assessing Drivers of Deforestation and Forest Degradation.....	62
3.3.2.1.2	Sampling Process to Collect Firewood Consumption and Cattle Keeping	63
3.3.2.1.3	Sampling Process for Scope and Challenges of Forest Carbon Trade	64
3.3.2.2	Data Analysis.....	65
3.3.2.2.1	Analysis of Firewood Consumption and CO ₂ Emission	65
3.3.2.2.2	Calculation of CH ₄ Emission.....	65
3.3.2.2.3	Determination of CO ₂ Saving Through Biogas Plant	66
3.3.3	Statistical Analysis	66
CHAPTER 4		68
4.	RESULTS AND DISCUSSION.....	68
4.1	Plant Specieswise Carbon Stock and Their Ecological Values	68
4.1.1	List of Plant Species Found in Community Managed Forests	69
4.1.2	Specieswise Carbon Stock and IVI in Collaborative Forests	70
4.1.3	Specieswise Carbon Stock and IVI in Community Forests.....	77
4.1.4	Specieswise Carbon Stock and IVI in Public Plantation and Community Planted Forests.....	83
4.2	Carbon Stock in Community Managed Forests.....	83
4.2.1	Carbon Stock in Collaborative Forests	84
4.2.1.1	Above Ground Carbon Stock	84
4.2.1.2	Below Ground Carbon Stocks	87
4.2.1.3	Statistical Analysis of Carbon Stock	89
4.2.2	Total Carbon Stock in Community Forests	90
4.2.2.1	Above Ground Carbon Stock	92
4.2.2.2	Carbon Stock of Below Ground	93
4.2.2.3	Statistical Analysis	94
4.2.3	Comparison of Carbon Stock in Collaborative and Community Forests.....	95

4.2.4	Total Carbon Stocks in Public Plantations and Community Planted Forests.....	96
4.2.4.1	Carbon Stock of Pole and Sapling.....	97
4.2.4.2	Carbon Stock of LHG and Root.....	99
4.2.4.3	Soil Carbon.....	99
4.2.4.4	Statistical Analysis of Carbon Stock.....	101
4.2.4.5	Comparison of Carbon Stock of Same Aged Plantations.....	102
4.3	Carbon Sequestration its Potential.....	103
4.3.1	Current Annual Carbon Increment (CACI) in Collaborative and Community Forests.....	103
4.3.2	Curent Annual Carbon Increment in Public Plantations and Community Planted Forests.....	105
4.3.3	Carbon Sequestration Status in Community and Collaborative Forests.....	108
4.3.4	Carbon Sequestration Status in Public Plantations and Community Planted Forests.....	111
4.3.5	Carbon Sequestration Potential in Collaborative and Community Forests.....	112
4.3.6	Monetary Value of Carbon Sequestration and its Eligibility for Carbon Trade.....	113
4.3.7	Monetary Value of Carbon Sequestration Potential.....	116
4.3.8	Criteria for Carbon Trade.....	118
4.3.9	Confrontation in Carbon Trade.....	122
4.4	Sustainability in Carbon Stock of Community Managed Forests	127
4.4.1	Sustainability in Carbon Stock of Collaborative and Community Forests.....	127
4.4.1.1	De Liocourt’s Law and Diameter Class Distribution of CF and CFM.....	127
4.4.1.2	Biolley’s “Check Method” — Method Du-control.....	128
4.4.1.3	Checking Carbon Stocks with Biolley’s (Modified) Principle.....	129
4.4.1.4	Mean Annual Carbon Increment (MACI) in Collaborative and Community Forests.....	131

4.4.2	Sustainability in Carbon Stock of Public Plantations and Community Planted Forests.....	132
4.4.2.1	Mean Annual Carbon Increment in Public Plantations and Community Planted Forests.....	134
4.5	Plant Biodiversity Status and its Relationship with Forest Carbon.....	135
4.5.1	Biodiversity Status of Collaborative and Community Forests	135
4.5.2	Biodiversity Status of Public Plantations and Community Planted Forests.....	136
4.5.3	Relationship Between Biodiversity and Carbon Stock.....	137
4.6	Effects of Drivers of Deforestation and Forest Degradation in Community Managed Forests.....	143
4.6.1	Drivers of Deforestation and Forest Degradation in Collaborative and Community Forests.....	144
4.6.1.1	Drivers of Deforestation and Forest Degradation in Collaborative Forests.....	144
4.6.1.2	Effects of Drivers of Deforestation and Forest Degradation on Carbon Stocks in Collaborative Forests	148
4.6.2	Drivers of Deforestation and Forest Degradation in Community Forests.....	148
4.6.2.1	List of Drivers of Deforestation and Forest Degradation	149
4.6.2.2	Effect of Drivers of Deforestation and Forest Degradation in Community Forests.....	151
4.6.3	Drivers of Deforestation and Forest Degradation in Public plantation and Community Planted Forests.....	151
4.6.4	Options to Address the Drivers of Deforestation and Forest Degradation	152
4.7	CO ₂ and CH ₄ Emission from Domestic Fuel and Livestock	152
4.7.1	Fuel Wood Consumption in Maisthan and Sahodawa Villages	153
4.7.2	Comparison of Annual CO ₂ Emission Among Rich, Medium and Poor Family.....	154
4.7.3	CH ₄ Emission from Maisthan and Sahodawa Villages	156
4.7.4	Comparison of CH ₄ Emission in Maisthan and Sahodawa Villages	158

4.7.5	Sources of CO ₂ and CH ₄ Emission	159
4.7.6	Management and Policy of CO ₂ and CH ₄ Emission.....	160
CHAPTER 5.....		163
5.	CONCLUSION AND RECOMMENDATION.....	163
5.1	Conclusion	163
5.2	Recommendation	165
CHAPTER 6		167
6.	SUMMARY	167
6.1	Carbon Stock Status and Dynamic	167
6.2	Issues of Sustainable Forest Carbon Management	168
6.3	Opportunity and Challenges of Forest Carbon Trade.....	169
6.4	Relationship Between Biodiversity and Forest Carbon.....	170
6.5	Drivers of Deforestation and Forest Degradation	170
6.6	CO ₂ and CH ₄ Emission From Domestic Fuel and Cattle	171
6.7	List of Published Articles Based on The Research.....	173
REFERENCES		175
ANNEXES		193

LIST OF TABLES

	Page No.
Table 1: Record of carbon stock of REDD+ piloting in TAL areas, Nepal	10
Table 2: Examples showing Specieswise C stock	12
Table 3: Relationship between carbon and biodiversity under different types of management	28
Table 4: Context of Forest cover change	31
Table 5: Emission and removal from different sectors in Nepal	32
Table 6: Sources of energy consumption in Nepal	33
Table 7: Conversion factor into C and CO ₂ emission	65
Table 8: CH ₄ emission factor	66
Table 9: Species found in community managed forests	69
Table 10: Carbon stock of plant species in collaborative forests	71
Table 11: Comparison of carbon of major species	73
Table 12: Ranking of plant species in collaborative forests	75
Table 13: Effect of carbon on mix ranking in collaborative forests	77
Table 14: Specieswise carbon stock in community forests	78
Table 15: Statistical comparison of specieswise carbon stock	80
Table 16: Ranking of plant species	81
Table 17: Effect of carbon on mix ranking in community forests	83
Table 18: Descriptive analysis of carbon stock in collaborative forests	89
Table 19: ANOVA showing differences in carbon stocks in collaborative forests	90
Table 20: Tukey HSD Test showing differences carbon stock in CFM	90
Table 21: Descriptive statistics of carbon stock in CFs	94
Table 22: ANOVA of carbon stocks in CFs	95
Table 23: Tukey HSD test in carbon stock variation in CFs	95
Table 24: Comparison of carbon stock of community and collaborative forests	96
Table 25: Carbon stock in public and community planted forests	97
Table 26: Descriptive statistics of carbon stock in public plantation and community planted forests	102
Table 27: Comparison of carbon stock between public plantation and community planted forests	103
Table 28: Current annual carbon increment in collaborative and community forests	104
Table 29: Current Annual Carbon Increment (t ha ⁻¹) in plantations	107
Table 30: Carbon sequestration in collaborative and community forests	109

Table 31: Carbon sequestration in public plantation and community planted forests.....	112
Table 32: Cumulative carbon sequestration potential in collaborative and community forests	112
Table 33: Cumulative carbon sequestration potential.....	113
Table 34: Valuation of carbon sequestration	115
Table 35: Expected cumulative monetary net values of carbon sequestration potential in collaborative and community forests.....	117
Table 36: Cumulative Expected Monetary Value of Plantations	117
Table 37: CO ₂ Additionality in CFMs and CFs	119
Table 38: CO ₂ additionality in Public plantations and Community Planted Forests.....	119
Table 39: Change in carbon in year 2011 to 2013	123
Table 40: Benefit sharing according to forest management regime	126
Table 41: Evaluation of carbon stock of CF and CFM with Bioley's modified stock	130
Table 42: Biodiversity indices in collaborative and community forests	136
Table 43: Biodiversity indices in collaborative and community forests	137
Table 41: R ² values of relationship between biodiversity and carbon stocks.....	137
Table 42: Tukey's test showing differences in carbon stocks in collaborative forests.....	148
Table 43: Effect of drivers of deforestation and forest degradation on different stages of plants	151
Table 44: Options to address the drivers of deforestation and forest degradation	152
Table 45: CO ₂ emission from fuelwood consumption.....	154
Table 46: One way ANOVA of CO ₂ emission according to family types	155
Table 470: Tukey's Honestly Significant Difference (HSD)	155
Table 51: Two-tail z test showing differences in CO ₂ emission in two villages.....	155
Table 52: CH ₄ emission from Maisthan and Sahodawa villages.....	157
Table 53: One-way ANOVA of HH based CH ₄ emission from Maisthan and Sahodawa villages.....	158
Table 54: Tukey's HSD test of household based CH ₄ emission	159
Table 48: Independent samples two tail t-test of CH ₄ emission according to family types	159
Table 49: Sources of domestic emission.....	160
Table 50: Valuation of CO ₂ saving from biogas.....	161

LIST OF FIGURES

	Page No.
Figure 1: Annual Temperature and Rainfall in Mahottari	37
Figure 2: Maps of collaborative forests	40
Figure 3: Maps of community forests.....	40
Figure 4: Maps of public plantations and community planted forests.....	43
Figure 5: Studied site for domestic emission.....	44
Figure 6: Flow diagram of research method.....	46
Figure 7: Sample plots distribution on Banke-Maraha CFM	49
Figure 8: Sample plots distribution on Tuteshwanath CFM.....	49
Figure 9: Sample plots distribution on Gadhanta- Bardibash CFM	50
Figure 10: Sample plots distribution on Baudh CF	50
Figure 11: Sample plots distribution on Chure Parwati CF.....	51
Figure 12: Sample plots distribution on Chyandanda CF.....	51
Figure 13: Sample plots distribution on Banauta PP	52
Figure 14: Sample plots distribution on Bisbity PP.....	52
Figure 15: Sample plots distribution on Shreepur PP.....	53
Figure 16: Sample plots distribution on Sita CPF	53
Figure 17: Sample plots distribution on Jogikuti CPF.....	54
Figure 18: Sample plots distribution on Ramnagar CPF	54
Figure 16: Graph showing maximum required number of sample plots	55
Figure 17: IVI of different species in collaborative forests	73
Figure 18: IVI of plant species in community forests	79
Figure 19: Forest Carbon Stock (C t ha ⁻¹) in CFMs	85
Figure 20: Soil carbon according to depth.....	88
Figure 21: Carbon stocks in community forests	91
Figure 22: Soil carbon in community forests	94
Figure 23: Soil carbon in public plantation and community planted forests	101
Figure 24: Comparison of diameter distribution of community managed forest with De Liocourt's law	128
Figure 25: Mean Annual Carbon Increment in CFs and CFMs.....	131
Figure 26: DBH class distribution of public plantations and community planted forests	132
Figure 27: Carbon stock distribution in public plantations and community planted forests	133

Figure 28:	Mean Annual Carbon Increment of public plantations and community planted forests	134
Figure 29:	Relationship between carbon stock and biodiversity in CFMs	139
Figure 30:	Relationship between biodiversity and carbon stock in community forests	140
Figure 31:	Relationship between biodiversity and carbon stock in public plantations	141
Figure 32:	Relationship between biodiversity and carbon stock in CPFs	142
Figure 33:	Collection of timber from different CFMs	144
Figure 34:	Drivers of deforestation and forest degradation in collaborative forests	147
Figure 35:	Timber collection from community forests.....	149

LIST OF ACRONYMS AND ABBREVIATION

ACL	Annual Carbon Loss
ACOFUN	Association of Collaborative Forest Users, Nepal
ANSAB	Asia Network for Sustainable Agriculture and Bioresources
BISEP-ST	Biodiversity Sector Programme for Siwalik and Tarai
CACI	Current Annual Carbon Increment
CER	Certified emission reduction
CFM	Collaborative Forest Management
CFs	Community Forests
CFUGs	Community Forest Users Groups
COP	Conference of Parties
CPF	Community planted forests
DBH	Diameter at Breast Height
DFCC	District Forest Coordination Committee
DFOs	District Forest Officers
DFRS	Department of Forest Research and Survey
DNPWC	Department of National Park and Wildlife Conservation
DoF	Department of Forests
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organization of United Nations
FCPF	Forest Carbon Partnership Facility
FECOFUN	Federation of Community Forest Users, Nepal
FRA	Forest Resource Assessment
GHGs	Green House Gases
GIS	Geographical Information System
GO	Governmental Organization
GPS	Geographical Positioning System
HDI	Human Development Index
HR	Human Resource
HSD	Honesty Significant Difference
ICIMOD	International Center for Integrated Mountain Development
IEE	Initial Environmental Examination
INGO	International Non-governmental Organization
IoF	Institute of Forestry

LHG	Litter, Herbs and Grass
LRMP	Land Resource Mapping Project
MACI	Mean Annual Carbon Increment
MEA	Millennium Ecosystem Assessment
MoA	Ministry of Agriculture
MoE	Ministry of Environment
MoFSC	Ministry of Forests and Soil Conservation
MRV	Monitoring, Reporting and Verification
NEFIN	Nepal Federation of Indigenous Nationalities
NFA	Nepal Foresters' Association
NFI	National Forest Inventory
NGOs	Non-governmental Organizations
NORAD	Norwegian Agency for Development Cooperation
NRM	Natural Resource Management
NRs	Nepali Rupees
NSCFP	Nepal Swiss Community Forestry Project
NTFPs	Non-Timber Forest Products
PP	Public plantation
REDD	Reducing Emissions from Deforestation and Forest Degradation
REL	Reference Emission Level
RL	Reference Level
R-PP	Readiness Preparation Proposal
RS	Remote Sensing
RWG	REDD Working Group
SDC	Swiss Development Cooperation
SES	Social and Environmental Standard
SESA	Strategic Environmental and Social Assessment
TAL	Tarai Arc Landscape
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nations REDD
USAID	United States Assistance for International Development
VDC	Village Development Committee
WB	The World Bank
WWF	World Wildlife Fund