Forest Carbon Partnership Facility (FCPF)
Carbon Fund
Emission Reductions Program Idea Note (ER-PIN)

NEPAL

Country: ____

People and Forests – An SMF Based Emission Reduction Program in Nepal's Terai Arc Landscape

ER Program Name: ______________________________________

March 7, 2014

Date of Submission or Revision: ___________________________

Annexes ONLY

Please also refer to main ER-PIN document

Table of Contents

Annex A: Letter of endorsement from Minister for Forests and Soil Conservation and Chair of the Apex Body

Government of Nepal

Mahesh Acharya
Minister
Forests and Soil Conservation

Phone No.: 4211882, 4211660
Fax : 977-1-4211784
Singh Darbar, Kathmandu
Nepal

Ref. No.

Date: March 13, 2014
Kathmandu, Nepal

The Facility Management Team
Forest Carbon Partnership Facility
The World Bank
Washington DC

The Government of Nepal (GoN) is committed to maintain forty percent of forest cover in the country. To protect existing forests from further deforestation and degradation, Ministry of Forests and soil Conservation has envisioned ***Forests for Prosperity agenda.*** This agenda has been mainstreamed into various forest related policies, programs and interventions. In this regard, may I take this opportunity to acknowledge the support provided by the World Bank Forest Carbon Partnership Facility (FCPF) to assist Nepal for REDD+ implementation. Nepal is also keen to participate in Emission Reduction Program at sub-national level as a performance based REDD+ piloting in 12 districts of Terai landscape.

The government of Nepal is fully committed to integrate REDD+ provisions into its wider development agenda, national priorities, and policies. For example, REDD+ is one of the strongest pillars of low carbon economic development strategy that is being developed as envisioned by Climate Change Policy, 2011. Similarly, REDD+ is also integrated into other key strategies such as Agriculture Development Strategy.

In the context of these new developments, Nepal seeks support from the World Bank and other development partners to become one of the countries of World Bank FCPF Carbon Fund to pilot REDD+ at sub-national level. Nepal presents an unique opportunity for other REDD+ Countries to learn from its multi-stakeholder process and ownership of the program, and application of lessons from community-based forest management model as building blocks of Nepal's REDD+ programs, among others.

As the chair of the Apex Body of an inter-ministerial institution of 11 ministries, IPs, civil society and private sector formed to implement REDD+ in the country, I express our strong commitment to undertake a sub-national REDD+ piloting program to reduce deforestation and forest degradation, provide carbon and non-carbon benefits to local communities and other national stakeholders, and share valuable lessons to the global community in the meanwhile.

Thank you.

Mahesh Acharya
....
Mahesh Acharya
Minister

Annex B: Letter of Endorsement from Secretary, Ministry for Forests and Soil Conservation and Chair of the REDD Working Group

Government of Nepal
Ministry of Forests and Soil Conservation

Ph. 4211567, 4211892, 4211928, 4211936, 4211742
Fax. 4211862, 4211868

P.O.Box No. 3987
Singha Durbar, Kathmandu

Government of Nepal, Ministry of Forests & Soil Conservation, Singhadurbr, Kathmandu

Ref. No. 3969

Date :- March 13, 2014
Kathmandu, Nepal

The Facility Management Team
Forest Carbon Partnership Facility
The World Bank
Washington DC

The Government of Nepal (GoN) has shown consistently strong political commitment to REDD+, through its participation in the World Bank Forest Carbon Partnership Facility (FCPF). The GoN has been preparing itself for REDD+ at national level by implementing Readiness Preparation Proposal (R-PP) under the support of World Bank FCPF REDD Readiness Grant and other bilateral donors active in forestry sector in Nepal. Now Nepal would like to move to the next phase of REDD+ subnational performance based REDD+ piloting in 12 districts of its Terai region.

The government fully understands the multi and cross sectoral nature of REDD+. As a result, REDD+ agenda is in the process of being integrated into other national policies and strategies such as Agriculture Development Strategy, Forest Strategy, and Biodiversity Strategy. As the country seeks to move to low carbon economic development, REDD+ is considered as one of the strongest pillar.

Hence, Nepal anticipates support and collaboration from the World Bank and Carbon Fund Participants to be selected as one of the countries of FCPF Carbon Fund to pilot REDD+ at subnational level. Nepal has demonstrated multi-stakeholder process and ownership in the REDD+ since the beginning of REDD+ Readiness preparation, and has achieved tremendous progress in community based forest management which we are continuously applying to the REDD+ process.

As a chair of the REDD Working Group, a multistakeholder body including, IPs, and civil society formed to implement REDD+ in the country, I express strong commitment and ownership to fully develop and implement subnational REDD+. As Nepal commits to reduce carbon emissions from avoided deforestation and forest degradation and maximize carbon and non-carbon benefits to Indigenous peoples, local communities and other national stakeholders, I firmly believe Nepal presents unparallel opportunity for other REDD+ Countries and donors to learn from its uniqueness.

We look forward to working with you.

Ganesh R. Joshi

Dr. Ganesh Raj Joshi
Secretary

Annex C: Commitment and support to the ER Program by from Ministry of Finance

Government of Nepal
MINISTRY OF FINANCE

SINGHADURBAR
KATHMANDU, NEPAL

Government of Nepal
Ministry of Finance

Ref. No: 1988

April 3, 2014

Mr. Johannes Zutt
Country Director
The World Bank
Kathmandu, Nepal

Ref: Letter of support and commitment to Nepal's ER Program

Dear Mr. Zutt,

Nepal has been preparing for REDD+ Readiness since 2010 under World Bank FCPF Readiness Grant and proposes an emission reductions program in 12 jurisdictional districts of the Terai Arc Landscape to be piloted under World Bank FCPF Carbon Fund. As a first step of accessing of the Carbon Fund, the government has developed the Emission Reduction Program Idea Note to be presented at the ninth meeting of the Carbon Fund.

The proposed emission reduction program is logical continuation of ongoing REDD+ Readiness efforts in Nepal, and the program intends to achieve significant development outcomes such as poverty reduction and biodiversity conservation in addition to reducing emissions from avoided deforestation and forest degradation. REDD+ is one of the high priority program of the government, and it is being integrated into Nepal's development agenda, national priorities, and policies such as low carbon economic development strategy, agriculture development strategy, forest strategy, and biodiversity strategy.

In this context, Ministry of Finance is fully committed and supportive of this emission reduction program, and seeks support from the World Bank to select Nepal as one of the countries of the Carbon Fund to pilot REDD+ at subnational level.

Thank you

Mr. Shanta Raj Subedi
Secretary

Annex D: Commitment and support to the ER Program by from Ministry of Agriculture Development

Government of Nepal
Ministry of Agricultural Development

☎ 4211639
4211808
4211932
4211665
4211687
4211915
4211940
Fax: 4211935

Singha Durbar,
Kathmandu, Nepal.

Ref.: 2434

Date: April3, 2014

Subject: Letter of support and commitment to Nepal's ER Program.

The Facility Management Team
Forest Carbon Partnership Facility
The World Bank, Washington DC

I am pleased to note that the Ministry of Forest and Soil Conservation (MoFSC), Government of Nepal, has developed Emissions Reduction Program Idea Note (ER-PIN) covering 12 districts of Nepal's Tarai, as the first step of performance based REDD+ piloting under FCPF Carbon Fund. I am glad to share that the ER-PIN has been prepared through a participatory process with relevant stakeholders, finalized and submitted to FCPF for formal consideration by Carbon Fund Participants.

Ministry of Agricultural Development was engaged in the process of developing the ER-PIN. To the best of my knowledge the ER-PIN was finalized in series of consultations among Governmental and non Governmental stakeholders. I am delighted to inform you that Agriculture Development Strategy, now in the process of final endorsement, has integrated REDD+ agenda in agriculture sector. Ministry of Agricultural Development has been contributing in developing Low Carbon Economic Development Strategy and Biomass Energy Strategy, which are based upon emission mitigation.

We would like to assure our Ministerial support to MoFSC in the implementation of Nepal's ER Program and is committed to harmonize agricultural sector policy with forest sector policy and ER Program activities to make Redd+ successful in Nepal.

Thank You

....
Jaya Mukunda Khanal
Secretary

Annex E: Commitment and support to the ER Program by from Ministry of Science, Tecnnology and Environment

Government of Nepal

Ministry of Science, Technology and Environment

Ref. No : 2405

2 April, 2014
Kathmandu, Nepal

The Facility Management Team
Forest Carbon Partnership Facility
The World Bank, Washington DC

Letter of support and commitment to Nepal's ER Program

I am pleased to learn that the REDD Cell of Ministry of Forests and Soil Conservation (MoFSC) has developed Emissions Reduction Program Idea Note (ER-PIN) covering 12 districts of Nepal's Terai, as the first step of performance-based REDD+ piloting under FCPF Carbon Fund. I am delighted that the ER-PIN has been submitted to FCPF for formal consideration by Carbon Fund Participants in the upcoming meeting in Brussels.

Ministry of Science, Technology and Environment (MoSTE) was engaged in the process of developing and endorsing the ER-PIN, and such engagement will continue while developing the Emissions Reduction Program Document.

MoSTE, which is the national focal point for UNFCCC, is closely involved in the REDD+ process in Nepal as a member of the REDD Working Group. We are fully committed to support and work together with MoFSC to develop ER program and harmonize REDD+ with Climate Change Policy, 2011 towards making REDD+ successful in Nepal.

With best regards.

Sincerely yours,

Dr. Som Lal Subedi

Secretary

Office Address :
Singhadurbar
Kathmandu, Nepal

Tel. No.
4211734, 4211641, 4211996
4211946, 4211894, 4211737
4211586, 4211698

Fax :
977-1-4211954

Email :
info@moste.gov.np

Website :
www.moste.gov.np

Annex F: Commitment and support to the ER Program by from Ministry of Energy

Government of Nepal
Water and Energy Commission
Secretariat

Phone No. 4211422 4211429 4211415 4211417
Fax No: 4211425

Singh Durbar
Kathmandu, Nepal

Ref.:-

Date: March 31, 2014
Kathmandu, Nepal

Subject:-

The Facility Management Team

Forest Carbon Partnership Facility

The World Bank, Washington DC

Ref: Letter of support and commitment to Nepal's ER Program

I am pleased to note that the Ministry of Forest and Soil Conservation (MoFSC), Government of Nepal, has developed Emissions Reduction Program Idea Note (ER-PIN) covering 12 districts of Nepal's Tarai, as the first step of performance based REDD+ piloting under FCPF Carbon Fund. I am delighted to share that the ER-PIN has been prepared through a participatory process with relevant stakeholders, finalized and submitted to FCPF for formal consideration by Carbon Fund Participants in its upcoming meeting in Brussels.

Water and Energy Commission Secretariat (WECS), an apex body of the Government of Nepal was consulted in the process of developing the ER-PIN, and as I understand such engagement and consultation will be even more intensive while developing Emission Reduction Program Document.

Heavy dependency on fuel-wood (approximately 70% of domestic cooking energy in rural Nepal), is one of the major causes of deforestation and forest degradation in Nepal. To address this driver, WECS is engaged in developing Biomass Energy Strategy together with the MoFSC and would like to assure our support to MoFSC in reducing demand of fuel wood by expanding alternative energy sources as well developing energy efficiency technologies.

We are fully committed to work together with MoFSC to address drivers of deforestation and degradation that are related to household energy consumption in Nepal. We will harmonize energy sector policy with forestry sector strategy, national REDD+ strategy and ER Program activities to make REDD+ successful in Nepal.

Thank you,

....

Dr. Krishna Chandra Paudel
Secretary

Annex G: Relevant policies, their objectives, and relation to REDD+ and ER Program

Policies relevant to REDD+	Key objective of the policy	Relation to REDD+/ER Program
Low Carbon Emission Development strategy (LEDS) (in process, 2014)	Identify the key approaches to drive Nepal towards low carbon development path while fostering economic growth opportunities	Forestry/REDD+ is identified as one of the six leading sectors to promote low carbon growth. Measure to expand SMF and private forestry are proposed.
National Forestry Sector Strategy (in process, 2014)	Develop long-term National Forest Sector Strategy	ER program can demonstrate ways to harmonize between National Forestry Sector Strategy and National REDD+ Strategy.
National Biodiversity Strategy Action Plan revision (2013)	Identify the drivers of biodiversity loss, set national target, design capacity development plan and develop indicators and monitoring approach	ER program is centered in Nepal's most biodiverse landscape and promotes Aichi targets through REDD+ safeguards.
Forest Products Sales Authority ((in process, 2013)	Improve the existing governance system of timber sales and distribution through increased transparency and competitive practices	Policy separates authority for timber sales from forest management, making forestry professionals responsible for forest management and regulation. This will improve forestry governance and reduce illegal logging.
National Land Use Policy (2012)	Classify all land in the country and plan for optimized long-time use. Commit to maintaining 40% forest cover nationally.	Policy has provisions for land pooling for development projects and supports measures to halt forest conversion to unplanned development activities and expand forest cover.
National Land Use Plan (under preparation)		Plan will develop institutional and policy framework for the implementation of National Land Use Policy.
Climate Change Policy (2011), including NAPA and LAPA	Improve livelihoods by mitigating impacts of climate change with low carbon emission development and adapting to adverse impacts.	Policy requires that at least 80% of the climate change funds will be allocated to local communities.
Terai Arc Landscape (TAL) Strategy and Action Plan 2015-2025 (under preparation)		This strategy will propose an adaptive and updated strategy for the TAL, which will focus on biodiversity conservation and address DD.
Forest Act (1993)	Initiate a community based management approach with the major goals of reversing widespread deforestation and increase supply of various forest products for subsistence need	ER Program will build on lessons learned from community based forest management and broadly expand community and collaborative forestry models

Annex H: Summary of drivers of deforestation and forest degradation in the program area

Summary of drivers of deforestation and forest degradation identified in various studies in ER program area

Studies (Reports)	Drivers identified	Summary of the underlying causes
Terai Arc Landscape Nepal 2004 -2014, Broad Strategy Document (MoFSC, 2004) (Used Root Cause Analysis, RCA method)	(Direct causes of environmental degradation and biodiversity loss in the TAL): **1.** Forest conversion, **2.** Uncontrolled grazing in forests, **3.** Unsustainable timber harvesting, **4.** Unsustainable fuel wood extraction, **5.** Forest fires, **6.** Churia watershed degradation and **7.** Wildlife-poaching and human-wildlife conflict	• Migration and population growth • Low agricultural productivity • The struggle for land • Lack of off-farm livelihood opportunities • Inadequate access to and management of forest resources • Cross border issues
R-PP (MoFSC, 2010)	Drivers of deforestation and forest degradation: **1.** High dependency on forests and forest products (timber, firewood, and other NTFPs) **2.** Illegal harvest of forest products **3.** Unsustainable Harvesting Practices **4.** Forest fire **5.** Encroachment **6.** Overgrazing **7.** Infrastructure development **8.** Resettlement **9.** Expansion of invasive species	• Poverty and lack of livelihood alternatives; • Weak governance mechanisms and weak law enforcement • Inefficient distribution mechanism for timber and firewood • High cross-border demand for forest products • Inadequate budget for research and development • Political interference • Unclear land tenure, policy and planning
Biological and socioeconomic study in corridors of Terai Arc landscape (WWF Nepal/ Hariyo Ban Program, 2012)	Major threats to habitat and species: **1.** Land use alterations, **2.** Forest encroachment, **3.** Forest Fire, **4.** Livestock grazing **5.** Illegal logging and wildlife trade (poaching)	Underlying causes of the threats are not specifically provided.

	6. Human Wildlife Conflict **7.** Invasive species **8.** Infrastructure and **9.** Climate induced threats	
Drivers of Deforestation and Forest Degradation and responses to address them in Nepal (UN-REDD Program, 2013)	Drivers of deforestation and forest degradation: 1. Illegal logging, 2. Encroachment, 3. Fuel-wood consumption , 4. Roads 5. Mining, 6. Grazing	• Poverty and high dependency on forests; • Increase demand for forest products; • Weak low enforcement; • Corruption • Population growth • Political instability • Poor technology in forest management • Low agriculture productivity
Multi stakeholder consultations conducted for ER-PIN development at national and sub-national level (2013)	Drivers of deforestation and forest degradation: 1. Encroachment 2. Open grazing 3. Firewood collection 4. Resettlement and Infrastructure development 5. Illegal cutting of trees 6. Forest fires	• Population growth and migration from hills • Poverty • Unemployment • Political instability • Weak law enforcement • Lack of coordination among the various government agencies • Floods • Lack of resources in DFOs to control illegal activities • Lack of land use policy • Corruption

Annex I: Calculation of potential emission reductions from SMF

TAL ER-PIN: Estimates of emission reductions from proposed activities

Sustainable management and protection of forests

Approach: we use IPCC default value or adjusted TAL EF to calculated reduced degradation based on spatial extent of new management regime

PARAMETERS		carbon (tons/ha)		**comments**
avoided degradation (Tier 1)		1.75	-	IPCC AFOLU Special Report Table 4.4 value for forestland management, dry tropical, reduced degradation/conservation
avoided degradation (Tier 2)		1.172		CO_2 difference between intact and degraded SAL forest (2014 TAL RL Table) divided by 3.67 (convert to C) divided by estimated succession time

end of..	Protected area management	existing ha CF/CFM under SFM lowlands	existing ha CF/CFM under SFM hills	new CF/CFM SFM lowlands	new CF/CFM SFM hills	enforcement national forests	t/C/ha yr protected area mgt	tC/ha/yr lowland SMF	t/C/ha/yr hills SMF	national forest enforcement	total C reduced annually
Year 1		-	-				1.000	1.75	0.875	0.5	-
Year 2	300,000	18,000	38,200	31,429	11,429	51,429	1.000	1.75	0.875	0.5	455,639
Year 3	300,000	36,000	76,400	62,857	22,857	136,000	1.000	1.75	0.875	0.5	627,850
Year 4	300,000	54,000	114,600	94,286	34,286	102,857	1.000	1.75	0.875	0.5	741,204
Year 5	300,000	72,000	152,800	125,714	45,714	102,857	1.000	1.75	0.875	0.5	871,129
Year 6	300,000	90,000	191,000	157,143	57,143	85,714	1.000	1.75	0.875	0.5	992,482
Year 7	300,000	90,000	191,000	188,571	68,571	42,857	1.000	1.75	0.875	0.5	1,036,054
Year 8	300,000	90,000	191,000	220,000	80,000	-	1.000	1.75	0.875	0.5	1,079,625
Year 9	300,000	90,000	191,000	220,000	80,000	-	1.000	1.75	0.875	0.5	1,079,625
Year 10	300,000	90,000	191,000	220,000	80,000	-	1.000	1.75	0.875	0.5	1,079,625
Year 11	300,000	90,000	191,000	220,000	80,000	-	1.000	1.75	0.875	0.5	1,079,625
Year 12	300,000	90,000	191,000	220,000	80,000	-	1.000	1.75	0.875	0.5	1,079,625
Year 13	300,000	90,000	191,000	220,000	80,000	-	1.000	1.75	0.875	0.5	1,079,625
Year 14	300,000	90,000	191,000	220,000	80,000	-	1.000	1.75	0.875	0.5	1,079,625
Year 15	300,000	90,000	191,000	220,000	80,000	-	1.000	1.75	0.875	0.5	1,079,625
		5 years	**10 years**					**15 years**			
Total C benefit		2,695,821	7,963,232					13,361,357			
Total CO_2 benefit		9,893,665	29,225,062					49,036,181			

Annex J: Calculation of potential emission reductions from Biogas plants and improved cook stoves

TAL ER-PIN: Estimates of emission reductions from proposed activities

Biogas plants and improved cook stoves (ICS)

Approach: we use fluxes based approach to estimate reduced emissions per unit/year assuming wood not collected for cooking is on much slower emissions pathway

PARAMETERS	carbon (tons/unit)		**comments**								
biogas (one plant)	1.4		estimated saving (tC) from one plant. one plant replaces 4 tons fuelwood/year. Assume 30% moisture content and then 50%								
ICS (one stove)	0.220		estimated saving (tC) per unit assuming 1 per household. fuelwood consumption in TAL 0.4 t/person/yr (Kanel et al 2012) * 4								
	Biogas					**Cook stoves**					**Biogas + Co**
end of..	plants installed	total plants	reduced C/plant (tC)	total C reduced annually		ICSs installed	total ICS installed	reduced C/stove	total C reduced annually		
Year 1	12,000	12,000	1.4	16,800		24,000	24,000	0.220	5,280		22,080
Year 2	12,000	24,000	1.4	33,600		24,000	48,000	0.220	10,560		44,160
Year 3	12,000	36,000	1.4	50,400		24,000	72,000	0.220	15,840		66,240
Year 4	12,000	48,000	1.4	67,200		24,000	96,000	0.220	21,120		88,320
Year 5	12,000	60,000	1.4	84,000		24,000	120,000	0.220	26,400		110,400
Year 6	12,000	72,000	1.4	100,800		24,000	144,000	0.220	31,680		132,480
Year 7	12,000	84,000	1.4	117,600		24,000	168,000	0.220	36,960		154,560
Year 8	12,000	96,000	1.4	134,400		24,000	192,000	0.220	42,240		176,640
Year 9	12,000	108,000	1.4	151,200		24,000	216,000	0.220	47,520		198,720
Year 10	12,000	120,000	1.4	168,000		24,000	240,000	0.220	52,800		220,800
Year 11	-	120,000	1.4	168,000		-	240,000	0.220	52,800		220,800
Year 12	-	120,000	1.4	168,000		-	240,000	0.220	52,800		220,800
Year 13	-	120,000	1.4	168,000		-	240,000	0.220	52,800		220,800
Year 14	-	120,000	1.4	168,000		-	240,000	0.220	52,800		220,800
Year 15	-	120,000	1.4	168,000		-	240,000	0.220	52,800		220,800
	5 years	**10 years**	**15 years**			**5 years**	**10 years**	**15 years**			
Total C benefit	252,000	924,000	1,764,000			79,200	290,400	554,400			
Total CO2 benefit	924,840	3,391,080	6,473,880			290,664	1,065,768	2,034,648			

Annex K: Calculation of potential emission reductions from Improved land use planning

TAL ER-PIN: Estimates of emission reductions from proposed activities

Improved land use planning to reduce deforestation from infrastructure and resettlemen

Approach: We estimate that improved land use planning will prevent deforestation of approx 2,000 ha/year TAL-wide. Here we use Tier 2 RL numbers from intact forests and assume approximately 80% stock loss is avoided

PARAMETERS	carbon (tons/ha)		**comments**			
avoided deforestation	75.8	took average C stock value for intact forests (3 types) and assumed we avoid 80% loss to deforestation				
end of..	new hectares under intervention	hectares/year avoidedd deforestation	tC/ha/yr	total C reduced annually		sum Has
Year 1	NA	-	75.8	-		-
Year 2		1,000	75.8	75,813		1,000
Year 3		3,000	75.8	227,440		4,000
Year 4		3,000	75.8	227,440		7,000
Year 5		3,000	75.8	227,440		10,000
Year 6		4,000	75.8	303,253		14,000
Year 7		4,000	75.8	303,253		18,000
Year 8		4,000	75.8	303,253		22,000
Year 9		4,000	75.8	303,253		26,000
Year 10		4,000	75.8	303,253		30,000
Year 11		4,000	75.8	303,253		34,000
Year 12		4,000	75.8	303,253		38,000
Year 13		4,000	75.8	303,253		42,000
Year 14		4,000	75.8	303,253		46,000
Year 15		4,000	75.8	303,253		50,000
	5 years	**10 years**	**15 years**			
Total C benefit	758,133	2,274,400	3,790,667			
Total CO2 benefit	2,782,349	8,347,048	13,911,747			

Annex L: Calculation of potential emission reductions from private forestry operations

TAL ER-PIN: Estimates of emission reductions from proposed activities

Incentives to expand private forestry operations

Approach: new policy incentives will expand private forestry operations on former agricultural land. We use Tier 2 EM based on regeneration and assuming no loss

PARAMETERS	carbon (tons/ha)	**comments**
Tier 1 "improved natural regen	0.55	IPCC Special Report (2000), Section on Forest Management, Table 4.4
Tier 2 for TAL RL	2.375	Average stock of intact Sal, Sal mixed, and mixed = 95 tons C/ha. We estimate linear regenaration over 40 years
average Tier 1/Tier 2	1.4625	

end of..	new hectares under intervention	total hectares under intervention	tC/ha/yr	total C reduced annually
Year 1	-	-	1.463	-
Year 2	-	-	1.463	-
Year 3	3,000	3,000	1.463	4,388
Year 4	4,000	7,000	1.463	10,238
Year 5	5,000	12,000	1.463	17,550
Year 6	5,000	17,000	1.463	24,863
Year 7	3,000	20,000	1.463	29,250
Year 8	3,000	23,000	1.463	33,638
Year 9	3,000	26,000	1.463	38,025
Year 10	-	26,000	1.463	38,025
Year 11	-	26,000	1.463	38,025
Year 12	-	26,000	1.463	38,025
Year 13	-	26,000	1.463	38,025
Year 14	-	26,000	1.463	38,025
Year 15	-	26,000	1.463	38,025
	5 years	**10 years**	**15 years**	
Total C benefit	32,175	195,975	386,100	
Total CO2 benefit	118,082	719,228	1,416,987	

Annex M: Capacity of the agencies and organizations involved in implementing the proposed ER Program

Table. Key institutions, their strength and capacity in general and role in the ER Program management

Name and contact of actors/ institutions	Capacity and strength	Potential role in ER program
Government agencies (ministries, departments and district offices)		
MoFSC	- Highest forestry sector authority in Nepal mandated for sustainable development of country's forests, landscapes and watersheds including wildlife, biodiversity and NTFPs conservation - Four technical divisions (Planning and HR, Foreign Aid Coordination, Environment and M&E) and five departments [1) Forests (DoF), 2) Forest Research and Survey (DFRS), 3) National Parks and Wildlife Conservation (DNPWC), 4) Soil Conservation and 5) Plant Resources]	- Primary institution responsible for implementation of ER-Program through sub-national and district agencies and relevant stakeholders. - Coordinate ER- program development, and implementation with various national and international stakeholders
Ministry of Finance	- The central authority of Government of Nepal responsible for allocation of public finance; management of public expenditure; enhanced mobilization of both internal and external resources; greater performance in public investments and strengthening of public enterprises productive capacity; open and simple foreign exchange policies and regulation, and prudent fiscal and monetary policies	- Liaise with donors to harmonize finance and support MoFSC to implement the ER program - Raise funds, as needed, for the program implementation - Play the necessary functions per the evolving national REDD+ framework, particularly establishing special fund for REDD+ benefit sharing
Ministry of Science, Technology and Environment	- Principal ministry in charge of formulation and implementation of policies, plans and programs pertaining to science, technology and environment including climate change; - Five of its sections are directly related to environment/REDD+: Environment Standard Section, Environment Assessment Section, Climate Change Section, Sustainable Development and Adaptation Section, Clean Development Mechanism Section, Scientific Research and Development Section	- As a Nepal focal point at UNFCCC, take the REDD+ learning to negotiations - Provide advice and feedback to MoFSC on effective implementation of ER program - Play necessary functions agreed in evolving national REDD+ framework - As a DNA to approve CDM projects

	- Special semi-government agency related to alternative energy promotion (AEPC) to reduce pressure on forests from fuel and energy demand.	
Ministry of Energy	- Principle ministry to promote energy production through hydropower.	- Play necessary role to reduce drivers related to energy demand and construction of hydropower.
Ministry of Agriculture	- Improve the standard of living of the people through sustainable agricultural growth by transforming the subsistence farming system to a competitive and commercialized one.	- Improved crop variety and livestock for increasing production and productivity while exploring ways to minimize additional pressures on TAL forests; - Supplementary activities to support agro-forestry in private farm land.
Ministry of Land Reform	- Responsible to implement land use policy to reduce future conversion of forest land, e.g., related to resettlement	- Implementation of land use policy with the coordination of MoFSC.
Department of Forests	- The oldest and largest department of MoFSC mandated to operationalize forest management and develop forest policies of Nepal. - Has three technical divisions e.g. i) national forests, ii) planning and monitoring and iii) community forestry in the center and district forest offices (DFOs) in all districts. - Each DFO has one or more sub-district or Ilaka offices with a team of field level staff led by a forest ranger.	- Implementation of the ER program at district level through district forest offices - Liaise with REDD Cell to implement program activities with partners and local stakeholders.
Department of National Parks and Wildlife Conservation	- In each National Park and Reserve, the Buffer Zone Councils are functioning to support buffer zones CFUGs, anti-poaching actions and implement alternative energy programs.	- Implement emission reduction strategies mainly related to conservation of forest and enhancement of forest carbon stocks in protected areas, within ER program boundary, through the Warden's offices and Buffer Zone Councils.
Department of Soil Conservation and Watershed Management	- Has district office to implement watershed conservation program through CBFM	- Implement soil conservation and erosion control measures in ER program area, in liaison with REDD Cell.

Department of Forest Research and Survey		- Measurement and monitoring of carbon and non-carbon benefits, liaising with DoF.
Projects/Programs		
Hariyo Ban Program	- Partnership between WWF Nepal, CARE Nepal, FECOFUN and NTNC which use their comparative strength for the sustainable management of forest in TAL	- Provide financial and technical support to the government on ER program implementation and ensure harmonization of program activities.
Multi-Stakeholders Forestry Program (MSFP)	- The product of a multi-stakeholder design process undertaken in Nepal's forest sector, the Multi Stakeholder Forestry Programme (MSFP) aims to improve livelihoods and resilience of poor and disadvantaged people in Nepal. It will also develop the contribution of Nepal's forestry sector to inclusive economic growth, poverty reduction, and tackling climate change. It builds on the achievements of over 20 years of forestry work of the Government of Nepal (GoN) supported by the Finland, Switzerland, and UK (e.g. LFP, NSCFP). MSFP is funded jointly by the Government of Finland (GoF), Swiss Agency for Development and Cooperation SDC, and UK Department for International Development (DFID).	- Provide financial and technical support to the government on ER program implementation, including harmonization of synergistic program activities, particularly in districts where MSFP and ER Program overlap.
TAL Program		- Provide financial and technical support to the government and communities on ER program implementation
Federations/Associations (related to forestry and social issues)		
FECOFUN	- A nation-wide network of CFUGs to strengthen their role in forestry sector policy making and implementation process - Advocacy of CFUGs' rights and safeguards	- Help the government in training, awareness raising and capacity building of CFUGs in REDD+ and its safeguards - Support the government to mobilize CFUG members in measurement of forest carbon and non-carbon benefits in the CFs. - Collaborate with government in the process of maintaining transparency and integrity, in REDD+ activities implementation in the

		field; - Contribute in the process of FPIC, on behalf of CFUGs.
ACOFUN	- Advocates for the rights of Collaborative Forest User Groups, especially those who are distant and excluded from forest use rights - Active in ER Program districts	- Help the government in training, awareness raising and capacity building of collaborative forest user groups - Support the government to mobilize collaborative forest user groups in measurement of forest carbon and co-benefits in the CFs. - Advocacy of collaborative forest user groups rights and safeguards - Contribute in the process of FPIC, on behalf of collaborative forest user groups
NEFIN	- NEFIN is an autonomous national level umbrella organization of indigenous peoples/nationalities, which is also a member of the United Nations Working Group on Indigenous Populations. - 48 indigenous member organizations from all over Nepal are under its umbrella - Advocates IP's rights and safeguards at policy level and works on capacity building of IPs on REDD+ at ground level	- Help the government in training, awareness raising and capacity building of IPs - Support the government to mobilize IPs in measurement of forest carbon and co-benefits in the CFs. - Advocacy of IPs' rights and safeguards - Contribute in the process of FPIC, on behalf of IPs
Dalit NGO Federation (DNF)	- DNF is a national level federation of around 4,000 Dalit NGOs working on the issue of Dalit rights and capacity building - advocates for dalits' rights over natural resources particularly land, forest and water	- Help the government in training, awareness raising and capacity building of Dalits - Advocacy of Dalit rights and safeguards
NIWF	- National Indigenous Women Federation	- To be further discussed in design phase
HIMAWANTI	- An NGO that aims to promote women access to natural resources and benefits accruing from NRM to women - organizes capacity building and networking activities for women to raise their awareness in REDD+ policy processes and active in knowledge sharing on various policies, including REDD+	- Help the government in training, awareness raising and capacity building of women - Support the government to mobilize women in measurement of forest carbon and co-benefits in the CFs. - Advocacy of women rights and safeguards - Contribute to the government in the process of FPIC, on behalf of women

INGOs working on forestry sector		
WWF, Nepal	- Has been active in wildlife and habitat conservation and livelihood improvement of local communities - Capable of providing technical and financial support to the government	- Provide technical support to the government in development and implementation of ER-program - Assist the government raising funds for full implementation of the program
ICIMOD	- Technical capacity on GIS, remote sensing and land use change analysis	- Provide technical assistance to the government on reference level and MRV
IUCN	- Technical capacity on PES and landscape approach	- Provide technical assistance to the government on PES and landscape management
RECOFTC	- Implement grassroots level capacity building activities in 2/3rd of the TAL districts (Kanchanpur, Kailali, Bardiya, Banke, Dang, Kapilvastu, Rupandehi and Nawalparasi) - Develop the capacity building materials on REDD+	- Continue to support REDD Cell and communities on capacity building and awareness raising in ER program districts
CSOs, IPOs, CBOs and NGOs working on Forestry and REDD+		
REDD+ CSOs & IPOs Alliances Nepal	- Forty CSOs/IPOs/ CBOs/NGOs are affiliated with this alliance for rights-based advocacy in REDD+ policy process - ACOFUN, COFSUN, COLARP, DNF DANAR, ECARDS, ERI, FECOFUN, FenFIT, FEPFOS, FEWUN, FONIJ Forest Action, Forest for Transformation, GEFONT, Green Governance Nepal, Green Foundation, HIMWANTI, INWYN, IDS Nepal, NEFIN, NIWF, NGO-FONIN, NEHHPA NFA, NAFAN, NRCTCN, PSPL, RAN, RRN, Rupantaran Nepal, WOCAN, YNF, YFIN are active members of the alliance	- Coordinate with CSOs, IPOs, CBOs and NGOs interested in REDD+ to help the government in training, awareness raising and capacity building of relevant stakeholders - Policy advocacy on REDD+ and climate change mitigation and adaptation
NAFAN	- A common forum of rights-based NGOs working on socio-economic development, gender equality and access of underprivileged and marginalized communities to natural/environmental resources	- Coordinate with NGOs interested in REDD+ to help the government in training, awareness raising and capacity building of relevant stakeholders - Policy advocacy on REDD+ and climate change
DANAR	- advocates for Dalits' rights over natural resources	- Help the government in training, awareness raising and capacity building of Dalits - Support the government to mobilize Dalits in

		measurement of forest carbon stocks and co-benefits in the CFs. - Advocacy of Dalits' rights and safeguards - Contribute in the process of FPIC, on behalf of Dalit community
Academic and research institutions		
Academic Institutions (e.g., TU, KU, PU, Agricultural and Forestry University)	- Produces trained human resources on forestry and natural resource management - Have capacity and facility to conduct independent research and analysis	- Conduct independent research and analysis of ER program implementation - Provide technical inputs and feedback to the government to better manage ER program implementation
Research institutions (e.g. ANSAB, Forest Action)	- These are research think-tanks actively engaged in influencing public policy process and empowering forest and natural resource dependent communities - Have been playing an active role since the beginning of REDD+ process, primarily through research, piloting and publications	- Conduct independent research and analysis of ER program implementation - Provide technical inputs and feedback to the government to better manage ER program implementation

Annex N: Financing plan summary table

Expected uses of funds	Description	Breakdown per year (US$ Million)									
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Costs related to developing the ER Program (e.g., monitoring costs)	*(please explain)*										
	PDD Development	0.750									
	Validation, verification	0.100				0.150					
	Field Measurements					0.250					0.300
	Image Procurement, Analysis, Reporting	0.100	0.105	0.110	0.116	0.122	0.128	0.134	0.141	0.148	0.155
Operational &implementation costs	*Operational Cost (meeting, travels, office running costs)*	0.150	0.158	0.165	0.174	0.182	0.191	0.201	0.211	0.222	0.233
Program Implementation	*Bringing sustainable management of forest (SMF) to government and community-managed forests*	2.940	5.409	8.118	11.084	14.327	16.575	19.011	21.047	22.100	23.205
	Reducing demand with expansion of biogas plants and cooking stoves	7.080	7.434	7.806	8.196	8.606	9.036	9.488	9.962	10.460	10.983
	Land use planning to reduce forest conversion	0.400	1.281	1.411	1.551	2.188	2.399	2.627	2.870	3.132	3.413
	engaging private sector to bring new forest production to degraded lands	0.500	0.525	1.323	1.852	2.431	2.553	1.608	1.689	1.773	1.862
	Diversify alternative livelihood options, on a demand-driven basis, for forest dependent poor community	1.000	1.050	1.103	1.158	1.216	1.276	1.340	1.407	1.477	1.551

Financing costs (e.g., interest payments on loans)											
Other costs	*Field Monitoring and Reporting*	0.050	0.053	0.055	0.058	0.061	0.064	0.067	0.070	0.074	0.078
	Total uses	**13.070**	**16.014**	**20.091**	**24.189**	**29.532**	**32.222**	**34.476**	**37.398**	**39.386**	**41.779**

Expected sources of funds	**Description**										
Government funding	*Ministry of Forests and Soil Conservation*	1.862	1.955	2.053	2.156	2.263	2.377	2.495	2.620	2.751	2.889
	Ministry of Agriculture and Ministry of Land reform	0.904	0.949	0.996	1.046	1.098	1.153	1.211	1.272	1.335	1.402
	President's Chure Conservation Program	1.500	1.575	1.654	1.736	1.823	1.914	2.010	2.111	2.216	2.327
	AEPC (biogas and cookstove)	3.600	3.780	3.969	4.167	4.376	4.595	4.824	5.066	5.319	5.585
Grants	*MSFP*	1.042	1.094	1.149	1.206	1.267	1.330	1.397	1.466		
	Hariyo Ban	0.350	0.350								
	WWF (TAL)	1.000	1.050	1.103	1.158	1.216	1.276	1.340	1.407	1.477	1.551
Loans											
Revenue from non - REDD+ carbon activities	*WWF Nepal Gold Standard Biogas VER Project*	0.540	0.524	0.310	0.301	0.292	0.283	0.275	0.267	0.259	0.251
Revenue from non - REDD+ carbon activities (not yet contracted)		0.033	0.066	0.099	0.132	0.165	0.198	0.231	0.264	0.297	0.330
	Total sources (before taxes)	**10.831**	**11.343**	**11.333**	**11.903**	**12.500**	**13.127**	**13.783**	**14.472**	**13.655**	**14.335**

Net revenue before taxes (=total sources – total uses)	-2.239	-4.671	-8.758	-12.286	-17.031	-19.095	-20.693	-22.926	-25.731	-27.445

Annex O: Technical paper on RL calculation

Baseline Reference Level for a Sub-National REDD+ Program: Terai Arc Landscape, Nepal

DRAFT

RL Team

February, 2014

Executive summary

In preparation for participation in funding mechanisms established under the United Nations' framework for reduced emissions from deforestation and forest degradation (REDD+), the Government of Nepal has developed a sub-national reference level for the Terai Arc Landscape (TAL) in partnership with the World Wildlife Fund-Nepal, WWF-US and Arbonaut Ltd., Finland. This paper documents the results of this innovative effort that utilizes government data, extensive field surveys, satellite imagery, and airborne LiDAR data to track deforestation and degradation, as well as regrowth and maintenance of forests, and the resulting emissions of CO_2 in the TAL for the period 1999-2011.The RL analysis found extensive deforestation and forest degradation during the reference time period, resulting in average annual net emissions of 4,353,833 tons of CO_2 equivalent (CO_2e).The RL analysis also tracks a sharp increase in deforestation and forest degradation in the later years of the reference period when average annual emissions reached 11,412,396 tons CO_2e, more than two and a half times the annual average for the entire reference period. Nepal, like many countries developing REDD+ programs, has limited historical field and other data to track deforestation and forest degradation. This paper describes a process to develop a highly-accurate RL by combining a variety of data sources and utilizing the best available scientific methodologies and processes. This effort was designed to create a RL that meets the highest international standards for integrity and transparency and followed closely the guidelines of the UN and other international bodies and the experience of the leading scientific work in the field. The results presented here reflect the first iteration of the TAL RL and a major milestone in an ongoing development process that will further refine and improve the RL in the months ahead based on external review and input and additional field verification and data analysis.

Introduction

Greenhouse gas (GHG) emissions from deforestation and forest degradation contribute about 15% of total annual global greenhouse gas (GHG) emissions, making them the second largest source of global GHG emissions (IPCC 2007). To reduce these emissions, especially CO_2 (carbon dioxide) emissions, from the forestry sector, the United Nations has established a program that would provide payments for the reduction of emissions from deforestation and forest degradation (REDD+). REDD+ will provide countriesperformance-based payments for reduced emission rates tied to an agreed reference level or baseline. The baseline reference emission level (RL) is the estimated amount of CO_2emitted from the forest sector in a business-as-usual (BAU) scenario. The BAU scenario must be based on historical emissions and, in a limited number of cases, adjustments based on national circumstances. The guidance on modalities relating to development of reference levels (RLs) – the key initial element of terrestrial carbon modeling, -was provided in late 2011 by the UNFCCC. Most importantly, for the first time the UNFCCC explicitly stated that RLs would be the essential metric to assess performance and must be reported in tons of carbon dioxide equivalent per year (tCO_2e/year)The UNFCCC further stated that the process to develop an RL must be transparent, complete, consistent, and verifiable at national and sub-national scales(UNFCCC2011). The UNFCC, however, left many important decisions about development of REDD RLs to countries, such as which carbon fluxes to account for, what timeframes constitute appropriate historical periods and how to make any adjustments.

Bilateral and multilateral donor agencies are moving away from funding REDD+ readiness preparations to providing performance-based payments for successful implementation of REDD+ initiatives at sub-national and national levels. The Forest Carbon Partnership Facility (FCPF) at the World Bank recently published a Methodological Framework (MF) to guide development of emission reduction programs. The MF requests that submitted RLs be based on Intergovernmental Panel on Climate Change(IPCC)*Good Practice Guidelines for National Greenhouse Gas Inventories* (2006) and provides further guidelines for building country-level REDD+ readiness activities to gain credits for Emission Reductions (FCPF MF document, Dec. 2013).

Nepal is one of the first countries to receive REDD+ funds from the FCPF to achieve REDD+ readiness and is now completing the process with the preparation of the final REDD+ readiness document. Toward that end, Nepal must develop their baseline RL as per the *Good Practice Guidelines* (GPG). The government of Nepal (GoN) is concurrently developing RL sat 2 scales, national and subnational. At the national scale, it is designing a national framework for establishing a baseline RL as well as monitoring, reporting and verification (MRV) system, at a coarser level, using country specific remote sensing data and published emission factors, but without field data collection or verification. At the subnational scale, the government is piloting a cutting edge technology, using the combination of LiDAR (Light Detection and Ranging) data, field vegetation plots, official government data, and satellite data, to develop a baseline carbon stocks map and an RL for the GoN-designated Emission Reduction Program Area that includes 12 districts of the Terai Arc Landscape (TAL). The area consists primarily of lowland habitats, with some district boundaries extending to the Siwalik Hills (Figure 1).

The purpose of this report is to document the process being utilized for this sub-national REDD+ program in the TAL in accordance with the IPCC GPG and the FCPF's Methodological Framework.

1.1Objectives:

Overall objective of this study is to develop a RL for the TAL sub-national REDD+ program following GPG. The specific objectives are:

1. To develop a baseline carbon stocks map for the TAL using satellite data, LiDAR data, field vegetation plots and official Government of Nepal datasets.
2. To derive mean carbon densities for each of 4 major forest types in different structural conditions as a basis for emissions factors.
3. To generate activity data that can be used to calculate historic emissions between 1999 and 2011 (time period selected for RL calculation).
4. To calculate an RL for the TAL and each of the 12 districts based on changes in forest carbon stocks between 1999 and 2011.

2. Study area and scope:

The study area (Figure 1) includes 12 districts (administrative units of proposed Emission Reduction Program Area) of the Terai Arc Landscape (hereafter called TAL), which spreads across 23,300 $km^2$and is home for 6.7 million people. TAL is situated along the foothills of the Himalayas in the southernmost part of Nepal, ranging from the lowlands of the Terai region up to the southern slopes of the Himalayas in Churia hills. The altitude in the study area varies from less than 100 to 2,200 meters. The area is influenced by tropical and subtropical climate. About half of the study area is covered by subtropical, mainly deciduous forests. The dominating forest types are Sal (*Shorea robusta*) Terai mixed hardwood, Khair-sisau (*Acacia catechu/Dalbergia sissoo*) and chirpine (*Pinus roxburghii*). The TAL is one of the priority landscapes in Nepal, both for the conservation of its biodiversity and the protection of the ecological services it provides.

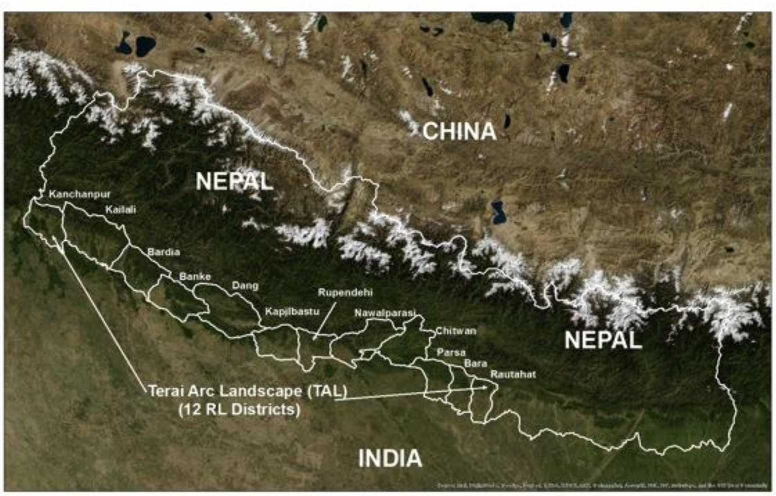

Figure 1. Study area, Terai Arc Landscape (TAL) with 12 RL districts

The scope of this study is to develop a sub-national RL for the TAL which will be integrated into the national RL. The RL period for the TAL will be from 1999 to 2011, a 12-year period. The Government of Nepal (REDD cell)recommended using 1994 as the RL base year because the

Department of Forest Resources and Survey (DFRS) carried out first National Forest Inventory (NFI) in 1994.Due to various issues with the archived data from NFI, digital data were not available to provide the basis for the RL using the 1994 inception date. The earliest available Landsat satellite data post-1994 that meet seasonality and cloud cover standards for calculating an RL was from 1999, the inception year chosen for calculating the RL. Likewise, 2011was selected as the end year for the RL because LiDAR scanning and field data collection was conducted in 2011. To estimate the historic deforestation rate as required by the IPCCGPG, four time intervals -- 1999-2002, 2002-2006, 2006-2009 and 2009-2011 -- were chosen because Landsat 5 satellite imagery that meets cloud cover and seasonality requirements was available only for 1999, 2002, 2006, 2009, and 2011. Although Landsat 7 satellite imagery was available more frequently, Landsat 5 imagery was chosen for the analyses because there are data gaps in the Landsat 7 imagery after 2003 due to scan line corrector (SLC) error. We believe this choice of defining a reference period, based on best availability of high-quality data, complies with the FCPF Carbon Fund's Methodological Framework requirement for the reference period to have an end date as soon as possible prior to 2013 and has a beginning date about 10 years and no more than 15 years earlier.

2.1 Carbon Pools

The IPCC GPG requires addressing all 5 carbon pools: Above-ground Biomass, Below-ground Biomass, Dead wood, Litter and Soil Organic Matter (SOM). However, for the current iteration of RL calculations, only the above-ground and below-ground carbon pools have been used. The above-ground biomass accounts for over 80% of forest biomass and the below-ground biomass was calculated as 20% of the above-ground biomass as per the IPCC GPG (IPCC 2006).The other 3 carbon pools were not considered in this iteration of RL due to lack of funds and time. However, all 5 carbon pools will be addressed in the future iterations. The RL is based on a net carbon accounting framework and account for CO_2 emissions from activities such as deforestation and forest degradation as well as CO_2 sequestration from regeneration and stock enhancement for each time interval. The RL does not distinguish between emissions and sequestrations due to natural disturbances (erosion, flood, wind, fire, etc.) and those due to anthropogenic disturbances. The RL includes only forested areas as delineated by the government of Nepal in its 1998 forest mask and only accounts for change in land-cover within this forest mask.

2.2 Definition of Forest

The National Forest Inventory (NFI), 1994 defined "forests" as having a crown cover >10% and an area > 1 hectare, and the GoN Survey Department followed this definition in delineating forests and non-forests in the Topographic Base Maps in 1998. The 1998 Topographic Map, as the only available government published map, was used to establish forest boundaries (hereafter "forest mask") for the RL inception date. Within this government-delineated forest area, the RL team further delineated the forest into intact and degraded structural classes to calculate emissions when the forest changes from one structural class to another. The process was refined after experimentation with different vegetation indices and programs that use Normalized Difference Vegetation Index (NDVI) or its variant, such as Advance Vegetation Index (AVI, Canopy Density Mapper) and NDFI (ImgTools), to stratify forest structures based on percent canopy cover. These tools had significant shortcomings, including lack of height dimension in the satellite data to differentiate trees from grasslands and agriculture lands, land-cover types with large differences in carbon density and consequently the correlation between these classifications and field-measured above-ground carbon (AGC) was very weak. Subsequently, through advanced remote sensing tools and Landsat satellite data (detailed in Figures 5 and 6), we generated forest structural classes (intact forest, degraded forest, and non-forest), for each of the four major types of forests in the TAL: Sal forest, Sal dominated mixed forest, other mixed forest and Riverine forest. These different structural classes for each of the four forest types were then quantified in terms of average carbon density utilizing LiDAR-based carbon estimates (see Section 3.5), a process that enabled defining the structural classes in terms of average carbon density, validating the classification through correlation to LiDAR-based surrogate plots, and estimating the error of the classification at various scales. In each forest type the mean carbon stock for intact forest was higher than degraded forest, for example intact Sal forest has mean carbon stock of 235.6 tC/ha while degraded forest has 173.2 tC/ha (Table 5).Although non-forest areas may have varying amount carbon stocks, depending upon the landuse (grasslands, agriculture, etc.), for the purpose of developing RL we assumed carbon stocks to be zero. In addition, we use time-series analysis to define those areas of the forest undergoing regeneration. The IPCC default value of regenerative growth of 2.8 tC/ha/yr (6 tAGB/ha/yr) for Dry tropical natural forests in continental Asia, under 20 years of age (IPCCC 2006, Vol. 4, Table 4.9) was used for calculating carbon stocks in the regenerating areas.

3. Methods:

The reference level (RL) is calculated as Emission Factors multiplied by the Activity Data. Therefore to generate RL we need to know 1) emission factors which is how much carbon will be emitted when the forest changes from one class to another. To calculate emission factor we first need to know how much biomass is there in each forest type and structural class. 2) How much land changed in each forest type from one structural class to another in a given time period, i.e. activity data. A wide variety of field vegetation sampling designs and protocols have been used to calculate above-ground biomass (AGB) in different forest types and structural classes. In general, the diameter at the breast-height (DBH) and the height of the tree are measured and then allometric equations specific to forest types (dry, wet, temperate, tropical, etc.) are used to calculate live AGB. The AGB is then converted into carbon stock by multiplying AGB by 0.47. In recent years, airborne LiDAR (Light Detection and Ranging) technology has been used to sample large areas more efficiently and accurately than manual field measurements, providing the numerous samples required to provide statistically valid AGB estimates. LiDAR has become an integral part of operational forest inventory in Scandinavian countries (Næsset 2007) and has also been used as a sampling tool to generate a high-resolution carbon distribution in tropical countries (Asner *et al.* 2009, Asner *et al.* 2012, Asner *et al.* 2013). The process used in the TAL, the LiDAR-Assisted Multi-source Programme (LAMP),combines LiDAR sample data with field plots and satellite data to develop stratified aboveground carbon estimates down to one-hectare resolution and with high accuracy levels when utilized at appropriate scales. The detailed steps of this process are described below.

3.1 LiDAR survey design

To produce a LiDAR sample that reflects the full range of variation in biomass over the study area and that covers not only the most common forest types but also the rare ones, different weights were assigned to the grid cells based on importance of forest types and amount of remaining forest in each type. These weights were assigned utilizing theforest classification of Terai Arc Landscape (TAL) based on LANDSAT 7 satellite data from 2001 by Joshi et al (2003) as a base map. This is the latest available forest classification of the TAL that has been field verified with an overall accuracy of 84.5 % with a Kappa value of 0.75. Then 5 km by 10 km grids (LiDAR blocks) were laid over the entire TAL; probability proportional-to-variation sampling (Särndal *et al.* 1992) was used to select the areas for LiDAR data collection, resulting in 20 LiDAR blocks representing 5% of the study area selected for LiDAR data collection (Fig 2).

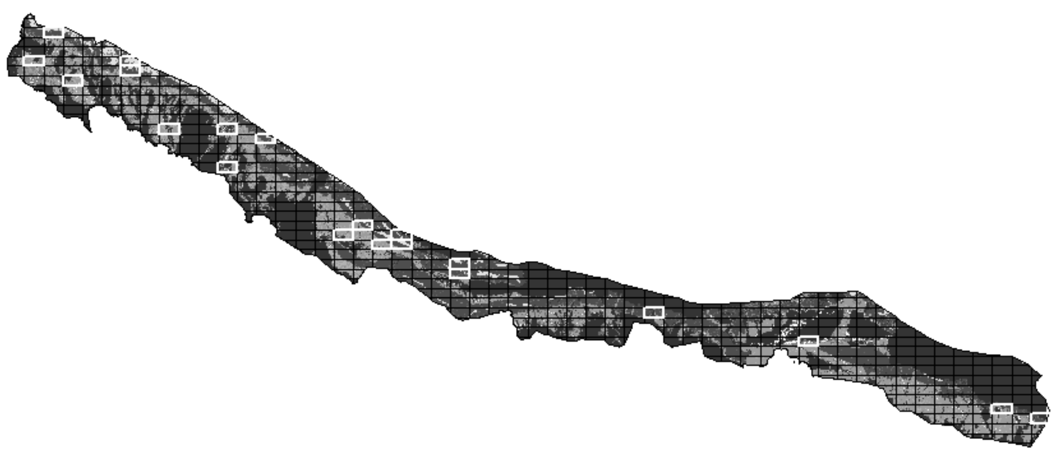

Figure 2. Grid of 5km x10km blocks used for sampling, and location of sampled blocks (white boundaries) in the study area. Background map: Vegetation types with assigned weights in grey-scale (dark = low weights, bright = high weights).

3.2 LiDAR data collection and processing

All 20 LiDAR blocks were scanned wall-to-wall from 2,200 meters average height above ground. Airborne LiDAR raw data were classified by the vendor into three categories: ground, vegetation and error returns. Further pre-processing included calculation of an exact Digital Terrain Model (DTM) from the ground returns, removal of the overlaps from the raw data, and conversion of height coordinates (z-values) of the vegetation returns from absolute elevation into distance-to-ground using the DTM. From the pre-processed LiDAR data, several LiDAR features were calculated for building the LiDAR-to-AGB model. The features have been taken from Junttila et al. (2010) and are an extended and modified version of those published by Næsset (2002). They include: 1) different height percentiles for the first-pulse and last-pulse returns, 2) mean height of first-pulse returns above 5 meters (high-vegetation returns), 3) standard deviation for first-pulse returns, 4) ratio between first-pulse returns from below 1 meter and all first-pulse returns, and 5) ratio between last-pulse returns from below 1 meter and all last-pulse returns.

3.3 Field data collection for LiDAR calibration

The location of sample plots was designed using a systematic cluster sampling within LiDAR blocks. Each LiDAR block contained six clusters of eight sample plots each. The distance between cluster centers was 3,333 meters in west-east and 2,500 meters in north-south direction. Within the clusters, the sample plots were aligned in two parallel columns in north-south direction, with 4 plots per column (Figure 3). The distance between plots was 300 meters in west-east direction, and 300 and 150 meters in north-south direction in Terai and Siwaliks, respectively. The smaller north-south distance for Siwaliks was chosen because of the large variation of altitude in this undulating and dissected hilly region. The plots are of fixed circular shape with a radius of 12.62 meters (500 m^2).Field sample plots were collected with sub-meter accuracy using a differential L1 GPS with Ashtech Magellan ProMark 3 and MobileMapper CX devices, and corrected in post-processing mode (GNSS Solutions software and MobileMapper Office software).

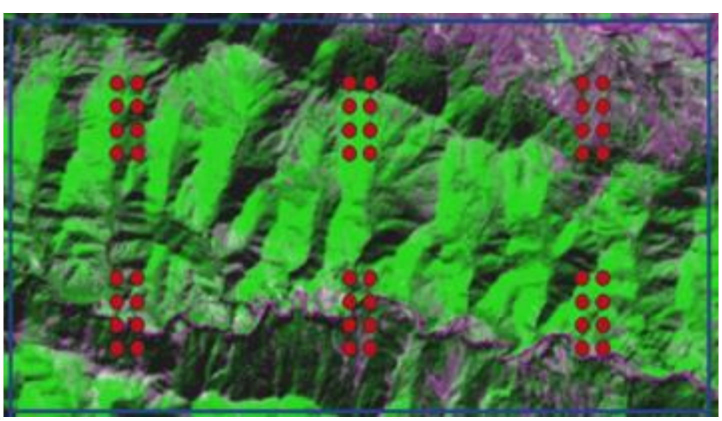

Figure 3. LiDAR block with six clusters of eight field plots each

Data were collected from 738 vegetation plots (12.6-meter radius).In each plot diameter of all the tress with Diameter at Breast Height (DBH) > 5m were measured and species were recorded. The tree heights were measured for every 5thtallied tree. If there are some tree species that were tallied, but heights were not measured for any trees in that species, then additional trees were selected for each of such species for height measurements.Mean tree height per plot was then calculated using species group-specific height-diameter relationships. Above-ground biomass for each plot was computed using tree height and diameter at breast height, based on species group-specific volume equations published by Sharma and Pukkala (1990).The equations from Sharma and Pukkala (1990) were used because these were developed for Nepal and widely used by the government.

3.4 Field data collection for LiDAR validation

For ground verification purposes, 48 plots of 30-meter radius were collected in 2013 as verification plots in two LiDAR blocks. In each plot diameter of all the tress with Diameter at Breast Height (DBH) > 5m were measured and species were recorded. The heights all trees with DBH > 5 cm were measured. Above-ground biomass for each plot was computed using tree height and diameter at breast height, based on species group-specific volume equations published by Sharma and Pukkala (1990).

3.5 LiDAR-to-AGB model

In the first phase of LAMP, a Sparse Bayesian method was used to develop a LiDAR-to-AGB model. A regression model was generated based on the relationship between LiDAR metrics (height and density distribution) and field measurement based biomass training data. It has been shown that Sparse Bayesian methods offer a flexible and robust tool for regressing LiDAR pulse histograms with forest parameters. While performing comparably to traditional regression methods, they are computationally more efficient and allow better flexibility than step-wise regression (Junttila et al. 2008, Junttila et al. 2010). The model showed strong correlation with field measured AGB when validated against an independent set of 46 field plots with 30-meter radius (2,826 m^2). The Relative Root Mean Square Error (RMSE) was 0.19 (19%), and the achieved coefficient of determination (R^2) was 0.90. No significant bias was present (Relative bias 0.016). Full validation results are shown in Figure 4 and Table 1. The model was then used to predict AGB for all 20 LiDAR blocks.

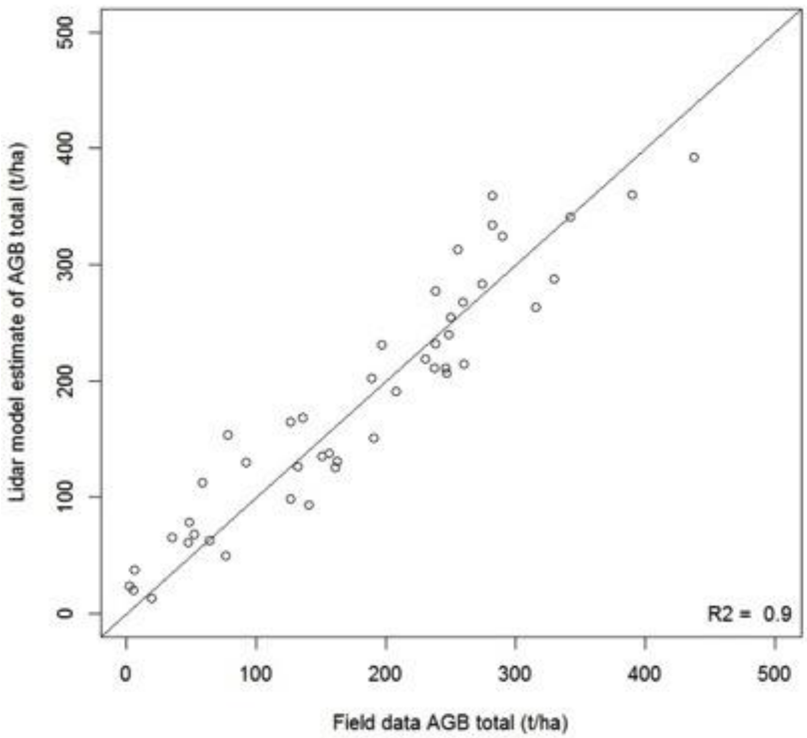

Figure 4: Scatterogram showing aboveground biomass (AGB) from independent field data against the estimates of the linear model from LiDAR data.

Table 1 -Statistics for the LiDAR estimates of aboveground biomass validated against independent field data.

Total AGB (t/ha)	**LiDAR (Phase 1)**
Standard deviation of estimates	103.1
Mean of reference plots	180.4
SD of reference plots	108.5
RMSE	34.5
Relative RMSE (%)	19.1
Bias	2.9
Relative bias (%)	1.6
R^2	0.9
Mean of estimates	183.3

3.6 Satellite data acquisition

The best available Landsat5 and Landsat7 data, based on minimizing cloud cover from 1999, 2002, 2006, 2009 and 2011, were used as the raw data for generating activity data. Landsat TM data were obtained from the USGS website (Http://glovis.usgs.gov) for the years 1999, 2002, 2006, 2009 and 2010/11. Landsat 5 data for the years after 2002 were chosen against Landsat 7 because the Landsat 7 data after 2002 have strips of data missing due to failure of its Scan Line Corrector (SLC).The less frequent coverage from Landsat 5, the requirement of four satellite scenes to cover the TAL, and the selection of scenes only from the leaf-on time period (Oct-Feb) limited the analysis to the five time periods selected. For 2006 TM 5 data for one scene from the far western part of TAL was not available therefore it was replaced with Landsat 7.

3.7Computer software used for satellite data analysis

ImgTools software was used to conduct Spectral Matrix Analysis (SMA) of Landsat satellite imagery and provide an initial unsupervised classification of forest structural classes (intact or undisturbed forest, degraded forest and non-forest) for each satellite scene for each time period. ImgTools was developed for identifying forest disturbance from selective logging and forest fires in Brazilian Amazon forests (Souza Jr. et al. 2005, Souza Jr. and Siqueira 2013). It has also been used for studying historical emissions from deforestation and forest degradation in Mato Grosso, Brazil (Morton et al. 2011). Imazon, a non-profit research institute, has been using ImgTools to monitor forest management projects and develop deforestation and forest degradation maps in the Amazon, Brazil (Monteiro & Souza Jr., 2012).

The decision trees built in the software for forest classification and forest change analysis were based on the forest structure of the Amazon; therefore these modules had to be adjusted for the TAL. We adjusted the decision tree based on natural break points for forest structure classification within the ImgTool, to conduct an initial classification of forest structure into intact, deforested and degraded classes. These classified maps were then processed in the ERDAS Imagine software to generate transitional matrix for the time-series analysis at the pixel level.

3.8Image pre-processing

The following steps were carried out in each satellite scene to minimize variations due to atmospheric conditions and geographic position errors.

1. Co-registration - Image-to-image co-registration was done with 20-30 points per image to ensure that the same scenes from different time periods overlapped precisely. For this process we used ERDAS Imagine software with low mean root squared (RMS) error of less than 1 pixel.
2. Haze Correction – For haze correction we used a module of ImgTools that applies techniques proposed by Carlotto (1999) to account for spatially variable atmospheric contaminations (noises) due to haze and smoke.

3. Radiometric correction – The digital sensors in the Landsat Thematic Mapper (TM) satellite records the intensity of electromagnetic radiations from each spot viewed on the Earth's surface as a digital numbers that ranges from 0-255 for each spectral band. The values are image specific, i.e. they are dependent on the viewing geometry of the satellite at the moment image was taken, the position of Sun, specific weather conditions and so forth. Therefore, spectral signature derived from digital numbers for a vegetation type (Sal forest) from one area might not be transferable to images from different areas or even for images from same area taken at different times. To address this issue digital numbers are converted into at the sensor spectral units using calibration curves provided by the vendor of the satellite data. We used a radiometric calibration module of ImgTools that uses the gains and offset values, provided in the Landsat imagery metadata file, to convert raw digital numbers in the scene into at the sensor radiance values.
4. Atmospheric correction – The spectral radiances obtained from the radiometric calibration only accounts for the spectral radiance measured at the satellite sensor. In reality by the time electromagnetic radiation is recorded by a satellite sensor, it has already passed through the Earth's atmosphere twice (Sun to target and target to sensor). During this passage, the radiation is affected by two processes: absorption which reduces its intensity and scattering which alters its direction. Absorption occurs when electromagnetic radiation interacts with gases such as water vapor, carbon dioxide and ozone. Scattering results from interactions between electromagnetic radiation and both gas molecules and airborne particulate matter (aerosols). To minimize these atmospheric noises we used the FLAASH (Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes) module (Kaufman et al., 1997) in the ENVI software, to convert spectral radiance at the sensor to the Surface Reflectance using following parameters:
    a. Atmospheric model – Tropical
    b. Aerosol model – Rural
    c. Aerosol retrieval – 2-Band(K-T) (KT = Kaufman – Tanre Aerosol Retrieval)
    d. Water column multiplier – 1
    e. KT Upper channel – Landsat band 7
    f. KT Lower channel – Landsat band 3

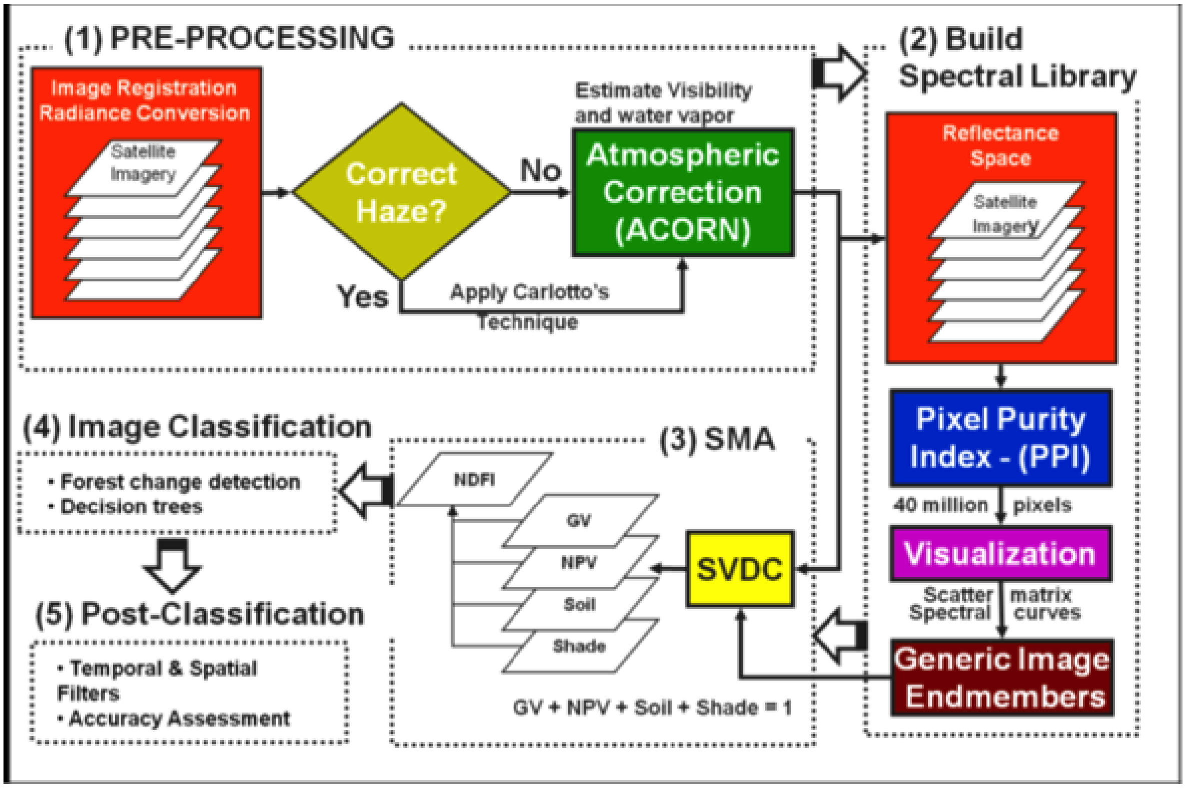

Figure 5. Basic image processing steps in ImgTools (taken from Souza and Siqueira, 2013 with permission)

3.9 Image processing

Image processing was done using different modules in ImgTools which are described below (Figure 5).

1. Spectral Mixture Analysis (SMA): ImgTools was used to carry out spectral mixture analysis for each Landsat scene. The SMA module of ImgTools decomposes the spectral mixture, commonly found in the pixel reflectance values of remotely sensed data, into fractions with natural break points, known as end members. SMA module uses these end members to develop generic spectral libraries for green vegetation (GV), non-photosynthetic vegetation (NPV), bare soil and clouds (Souza Jr. et al., 2005, Souza and Siqueira, 2013).
2. Water Mask: This module creates a water mask as a layer using fractional image.
3. Cloud and Shade Mask: This module creates a cloud and shade mask layer that is used in deriving NDFI.
4. Normalized Difference Factional Index (NDFI): In this module, the fractions developed from the SMA analysis: GV, NPV, Soil are processed to quantify the percentage of pixels lying outside the range of zero to 100% and to evaluate fraction value consistency for pixels over time (i.e., that pixels with intact forest values were similar over time). Only pixels with at least 98% of the values within zero to 100% and those that showed mean

fraction value consistency over time were used by the software algorithm for computing Normalized Difference Fraction Index (Souza Jr. et al., 2005).

$$NDFI = \frac{GV_{Shade} - (NPV + Soil)}{GV_{Shade} + NPV + Soil}$$

Where GV_{Shade} or (GVs) is the shade-normalized GV fraction given by,

$$GV_{Shade} = \frac{GV}{100 - Shade}$$

3.10 Image Classification

A decision tree to provide the unsupervised classification of forest structure built in ImgTools was adjusted for the TAL (Figure6) based on the spectral curves of SMA components, to classify images into forest, non-forest, water bodies using fractional cover and GVs. The forest was further classified into intact and degraded forest using NDFI values. In order to avoid spectral confusion in areas previously deforested or degraded, this historical contextual information was used in combination with spectral curves to delineate areas of regrowth.

1) Non-Forest - An area is classified as non-forest when it meets one of following criteria:
    a. GVs > 53 and < 65
    b. GVs > 65 and GV > 68
    c. GVs < 52 but soil + NPV >14
2) Water –
    a. GVs < 52 but soil + NPV < 15
3) Forest - a pixel with
    a. GVs ≥ 66 and GV < 69
       (Justification here is forest will have shade from tall trees but the grassland will have virtually no shade)
    b. Intact forest
        i. GV >66 and <69 (Criteria in # a above) and NDFI > 168
    c. Degraded forest –
        i. GV >66 and <69 (Criteria in # a above) and NDFI < 168
4) Regeneration
    a. Classified as intact forest in step "3" above and classified in previous time period as non-forest or degraded
    b. Classified as degraded forest in step "3" above and classified in previous time period as deforested

The classification results from the decision tree analysis were verified with an independent Persistent Change Monitoring (PCM) dataset from MDA Information Systems LLC for deforested areas only. RapidEye imagery, panchromatic band of Landsat and HAG (Height Above Ground) model derived using LiDAR data and Landsat data for TAL (J. Stoker, unpublished) to spot check validity of deforested and degraded classes. A Monte Carlo simulation of field measured and LiDAR predicted AGB supports separation of distinct deforestation and degradation classes based on mean AGB (see section 5.2 for detail process). The decision tree classification was then used to classify each satellite image into 5 classes: intact (undisturbed) forest, degraded forest, non-forest, water and cloud-shadow classes.

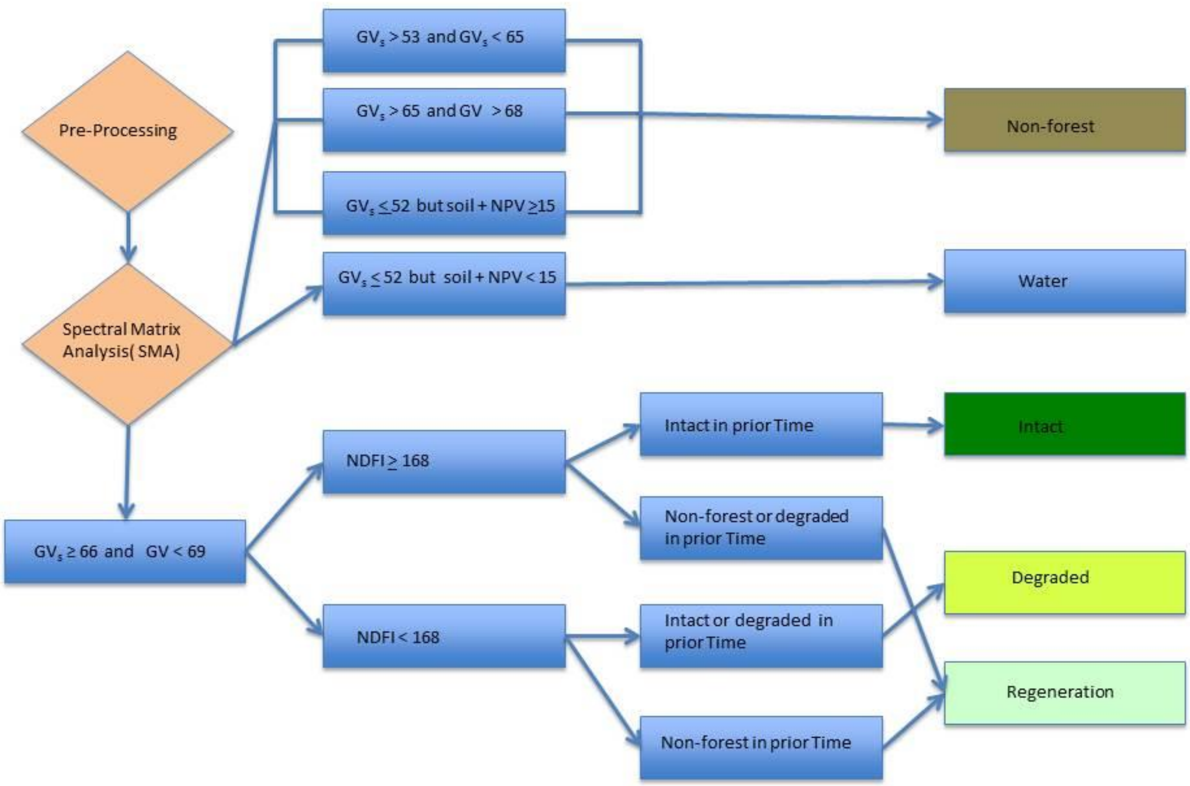

Figure 6. Decision Tree and Definition of Forest for Terai Arc Landscape

3.11Generating forest types and conditions map

The forest classification in the sections 3.10 provides only the structural classes, intact, degraded, or non-forest. However, carbon stocks in the forest vary by both forest types as well as forest structure. The only available forest type classification map that has been ground verified (based on 2001 data by Joshi et al. 2003) was used to extract forest polygons for four major forest types of TAL: 1) Sal forest, 2) Sal dominated mixed forest, 3) other than Sal dominated forest (here after "other forest") and 4) Riverine. These four forest types were overlaid on the forest structural map to generate forest types and conditions maps for each time period. The study assumed forest types do not change from one type to another type (i.e., from Sal forest to mixed forest or riverine forest or vice versa) in 10-20 years.

3.12 Calculating AGB for different forest types and conditions

The forest types and conditions map from 2011 was overlaid on all LiDAR blocks with model predicted AGB. In this second phase of the LAMP approach, 1,000 forest type and class-specific "surrogate plots" (simulated field plots) of 1-hectare size were randomly generated within the LiDAR blocks. If a plot had 50 per cent or more of its area outside forest or LiDAR coverage, it was removed.

To capture units that represent only one forest class, the remaining 7,710 surrogate plots were sub-divided to rectangular cells with size corresponding to that of field calibration plots ($500m^2$). The regression model based on LiDAR features was applied to predict above-ground biomass for the cells. To avoid bias, only those cells where the center belonged to same class as the original intended forest class were used. As the surrogate plots contained a varying number of cells, the final results were aggregated as area-weighted mean. Statistics of the results at 1 –hectare scale are shown in Table 2. The mean biomass values calculated from LiDAR area for each forest condition and type were applied for respective classes in the classified satellite imagery, to map biomass over the whole study area.

Table 2 - Statistics of the forest class- specific estimations for above-ground biomass

Class	No. of plots	Mean	Min	Max	StD
1-Sal intact	988	235.6	20.4	509.5	84.1
2-Sal degraded	969	173.2	0.0	425.3	72.9
3-Salmix intact	966	183.2	0.0	556.9	84.7
4-Salmix degraded	946	146.4	0.0	539.6	106.2
5-Othermix intact	985	186.1	5.5	479.5	94.0
6-Othermix degraded	943	143.2	0.4	461.6	86.8
7-Riverine intact	934	171.1	0.0	405.5	46.8
8-Riverine degraded	979	99.4	0.0	505.6	57.9

3.13 Time series Analysis

To delineate areas of deforestation, degradation and regeneration, we completed a time-series analysis of forest change for the TAL for four time periods, 1999-2002, 2002-2006, 2006-2009 and 2009-2011, using the classified images (Section 3.10). A pair of classified images for the same satellite scene was run through a change detection algorithm in the ERDAS Imagine, to produce a change matrix at pixel level. This resulted in a 25-class matrix for the first set of image pairs, time periods T1 and T2. Any forested area under the cloud and cloud shadow (could-shadow class) was considered as unchanged between the two periods for the purpose of this study. Likewise areas remaining in same classes between the two periods were also considered unchanged. The change classes derived from the change matrix are listed below (Table3) as Deforestation 1-3, Degradation, and Regeneration 1-3.

Table 3 - New classes derived from the change matrix.

Change Matrix	Change Class
Intact forest to non-forest	Deforestation 1
Intact forest to degraded forest	Degradation
Degraded forest to non-forest	Deforestation 2
Non-forest to dense regenerating forest	Regeneration 1
Non-forest to sparse regenerating forest	Regeneration 2
Degraded forest to regenerating forest	Regeneration 3
Regeneration forest to non-forest	Deforestation 3

For the subsequent time-series analysis the base classified image for that series (time T1) was adjusted to reflect changes in the previous time period; for example change classes derived in Table 3 as a change between T1 and T2 were delineated and re-coded in the T2 scene. All three types of deforestation were merged into one deforestation class because they represent areas going from forest to non-forest. Therefore, each base image potentially has nine classes: Intact

Forest, Degraded Forest, Non-forest, Water, Cloud/Shadow, Deforestation, Regeneration 1, Regeneration 2, and Regeneration 3. The change analysis between 2002 and 2006 resulted in a 45-class change matrix with nine classes (described above) representing actual change in forest conditions. These nine change classes were adjusted in the base image (2006) for analyzing time series 2006 to 2009. The same process was repeated for 2009 to 2011 series. The areas under each activity (Deforestation 1-3, Degradation, and Regeneration 1-3) for each time series analysis were used to generate activity data (Table 4). Activities Regeneration 1 - 3 were combined to a single Regeneration activity because all these activities were differentiated only based on activities in the previous time period that resulted in regeneration in the current period, thus their growth rates and mean carbon content are assume to be same.

4. Results:

4.1 Calculation of activity data and carbon stocks

Spectral mixture analysis and decision tree classification of Landsat satellite data from five time periods (1999, 2002, 2006, 2009, 2011) provide snap shots of forest status of the TAL for each period (Figure 7-11). Time series analyses of these snap shots organized in four time intervals (1999-2002, 2002-2006, 2006-2009, 2009-2011) was used to calculate the amount of area that was changed by each forest activity (Table 4). Forest activities, viz., deforestation, degradation, and regeneration varied by region and time (Figure12-14) across the TAL though overall the amount of area affected by forest activities increased significantly during each time-period. In the first time interval deforestation was concentrated in the far western TAL, in the second time interval it was scattered across the TAL, in third interval it was mostly in the central TAL and in the fourth interval it was higher both in the western and eastern ends than in the central TAL. Deforestation was followed by regeneration in subsequent time intervals in many areas. Forest degradation occurred in smaller scales than deforestation and regeneration in the TAL. However, the overall carbon stock in the TAL decreased substantially between 1999 and 2011 and this rate of loss increased dramatically between 2006 and 2011 (Figure 15). To provide overall picture of deforestation in TAL between 1999 and 2011 at the higher resolution, we selected a few areas where deforestation is high. Deforestation in four time periods was overlaid on the Rapid Eye imagery with 5 m x 5 m resolution for the Basanta Forest in the Far-western TAL (Figure 16). The image on the left shows deforestation and image on the right show how it looks on the ground in 2010 (focus on circles). Likewise, Figures 17 – 19 show deforestation in Western, Central and eastern TAL in specific areas. The process also documented historic deforestation very accurately as illustrated in the Figure 20, in Chitwan where residence from Pardampur Village, Chitwan National Park was relocation by clearing national forest.

Table 4 - Activity data for different forest types between 1999 and 2011

Forest Type	Transition	Activity	Activity data(ha) 1999-2002	2002-2006	2006-2009	2009-2011	12-yr Total
Sal Forest	Intact to Deforested	Deforestation 1	11,583	2,085	9,488	17,914	41,070
	Degraded to Deforested	Deforestation 2	4,322	679	615	1,651	7,268
	Regenerated to Deforested	Deforestation 3		905	2,117	6,655	9,677
	Intact to Degraded	Degradation	10,831	1,342	3,141	17,488	32,803
	Deforested to regrowth	Regeneration	24,635	35,951	6,313	10,008	76,907
Sal Mixed	Intact to Deforested	Deforestation 1	8,487	2,291	10,588	20,332	41,697
	Degraded to Deforested	Deforestation 2	7,632	1,395	964	1,927	11,918
	Regenerated to Deforested	Deforestation 3		1,996	3,405	12,821	18,222
	Intact to Degraded	Degradation	10,186	1,661	10,003	10,375	32,225
	Deforested to forest	Regeneration	32,597	40,999	4,995	11,886	90,477
Other Mixed	Intact to Deforested	Deforestation 1	2,029	273	2,661	3,308	8,271
	Degraded to Deforested	Deforestation 2	674	175	514	284	1,647
	Regenerated to Deforested	Deforestation 3		174	870	1,536	2,580
	Intact to Degraded	Degradation	1,570	216	380	1,250	3,417
	Deforested to regrowth	Regeneration	2,483	5,239	1,251	3,461	12,434
Riverine	Intact to Deforested	Deforestation 1	918	160	255	1,663	2,995
	Degraded to Deforested	Deforestation 2	458	59	39	163	719
	Regenerated to Deforested	Deforestation 3		76	147	752	974
	Intact to Degraded	Degradation	697	81	225	877	1,881
	Deforested to regrowth	Regeneration	2,202	3,306	510	244	6,262

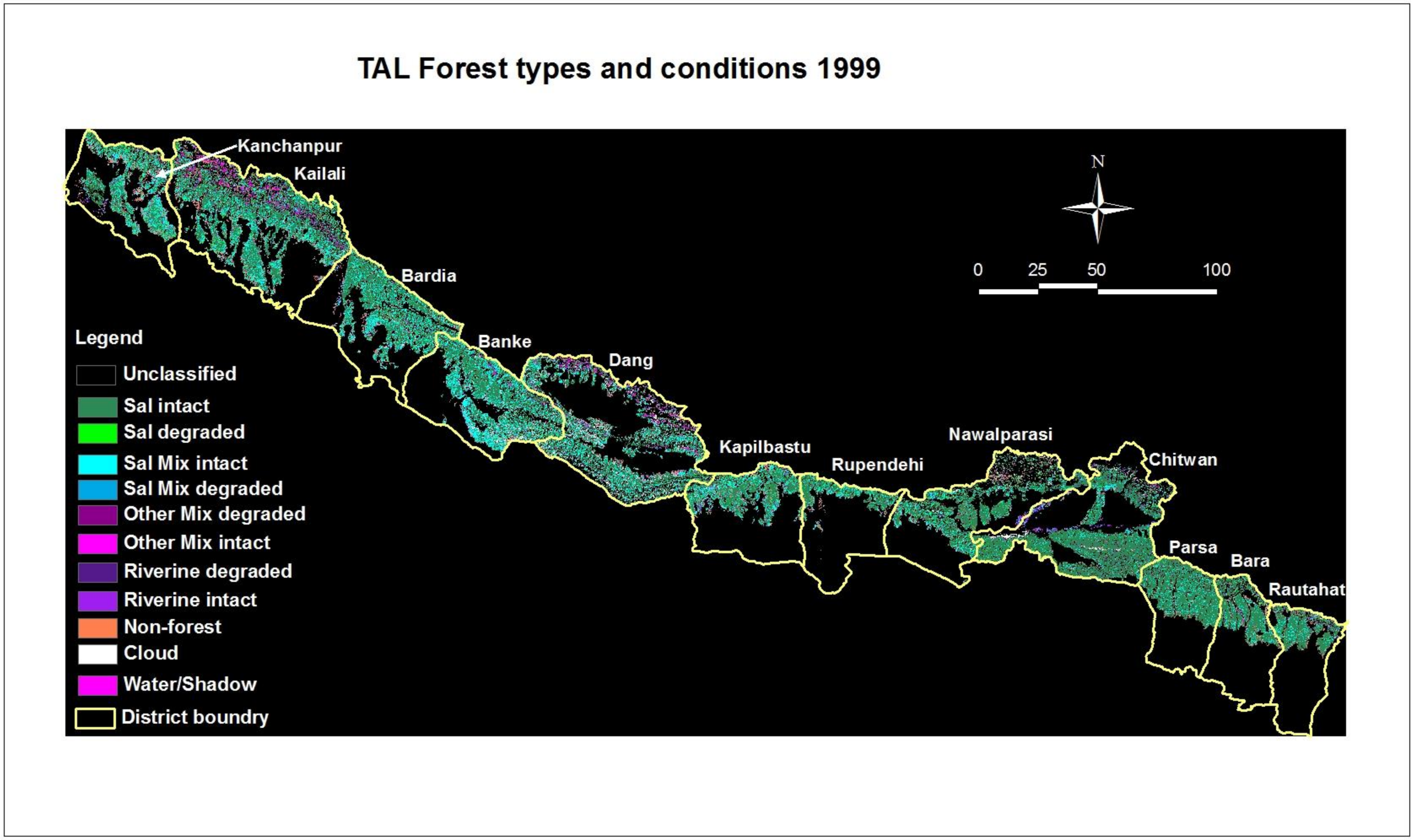

Figure 7. Forest types and conditions in Terai Arc Landscape (TAL) in 1999

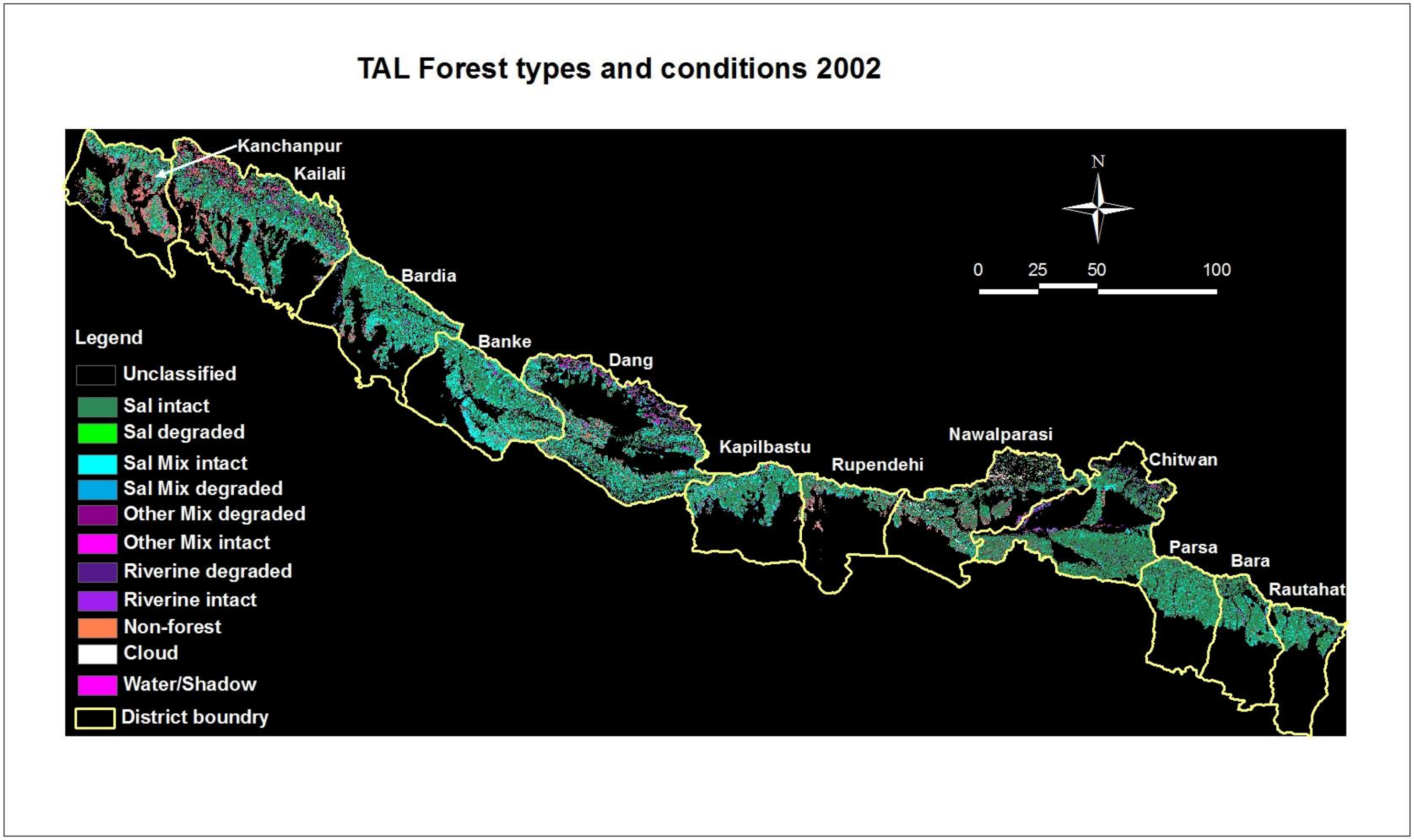

Figure 8. Forest types and conditions in Terai Arc Landscape (TAL) in 2002

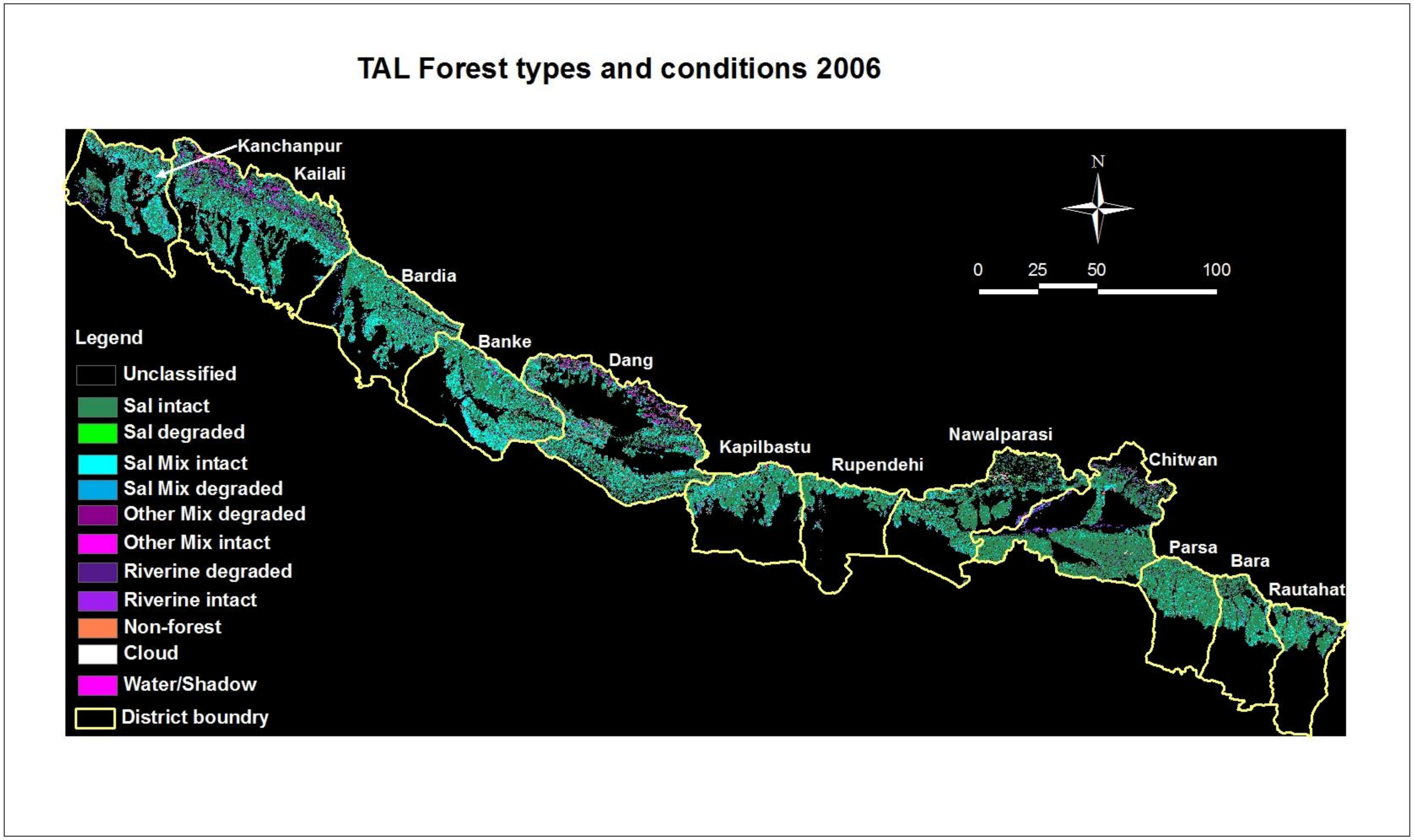

Figure 9. Forest types and conditions in Terai Arc Landscape (TAL) in 2006

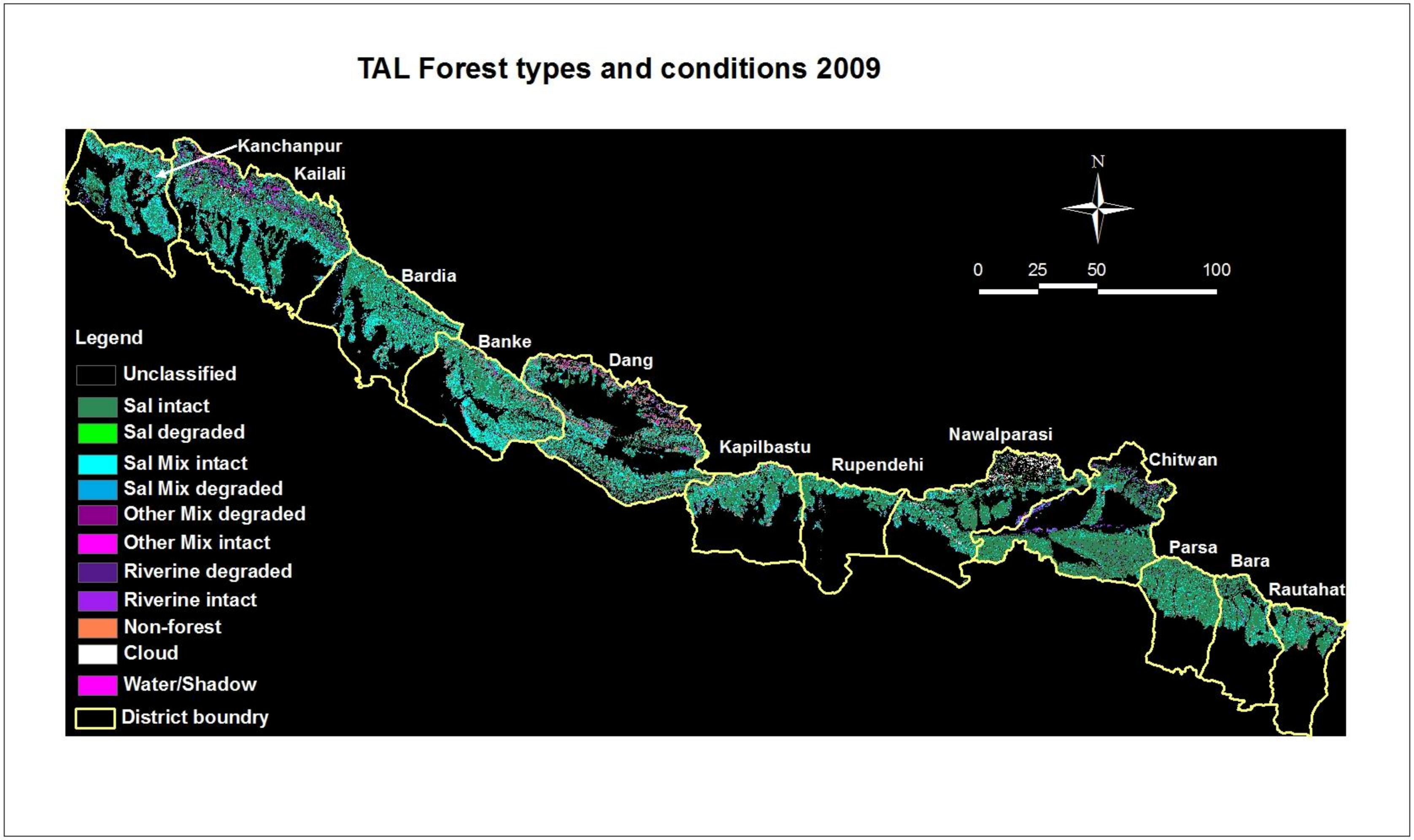

Figure 10. Forest types and conditions in Terai Arc Landscape (TAL) in 2009

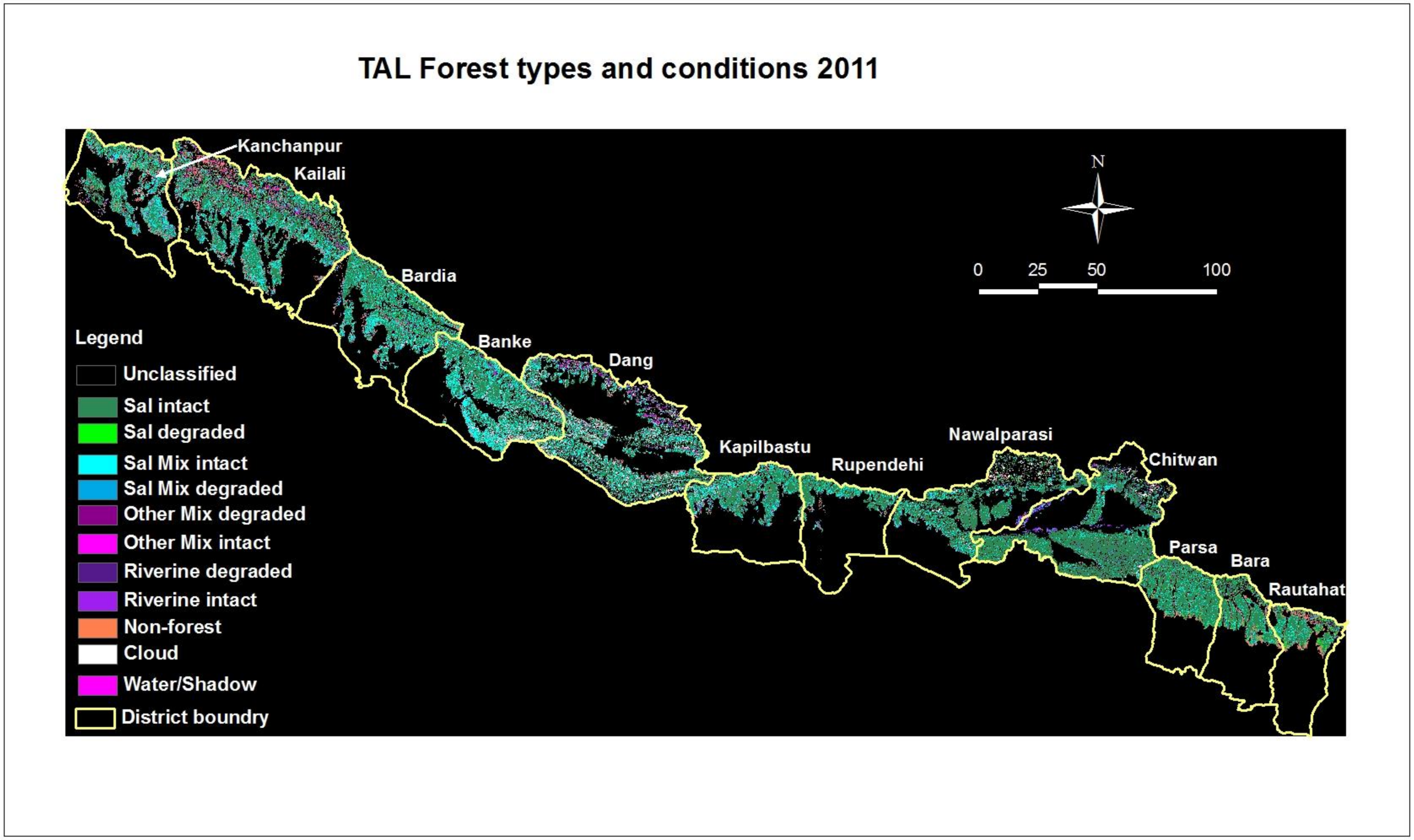

Figure 11. Forest types and conditions in Terai Arc Landscape (TAL) in 2011

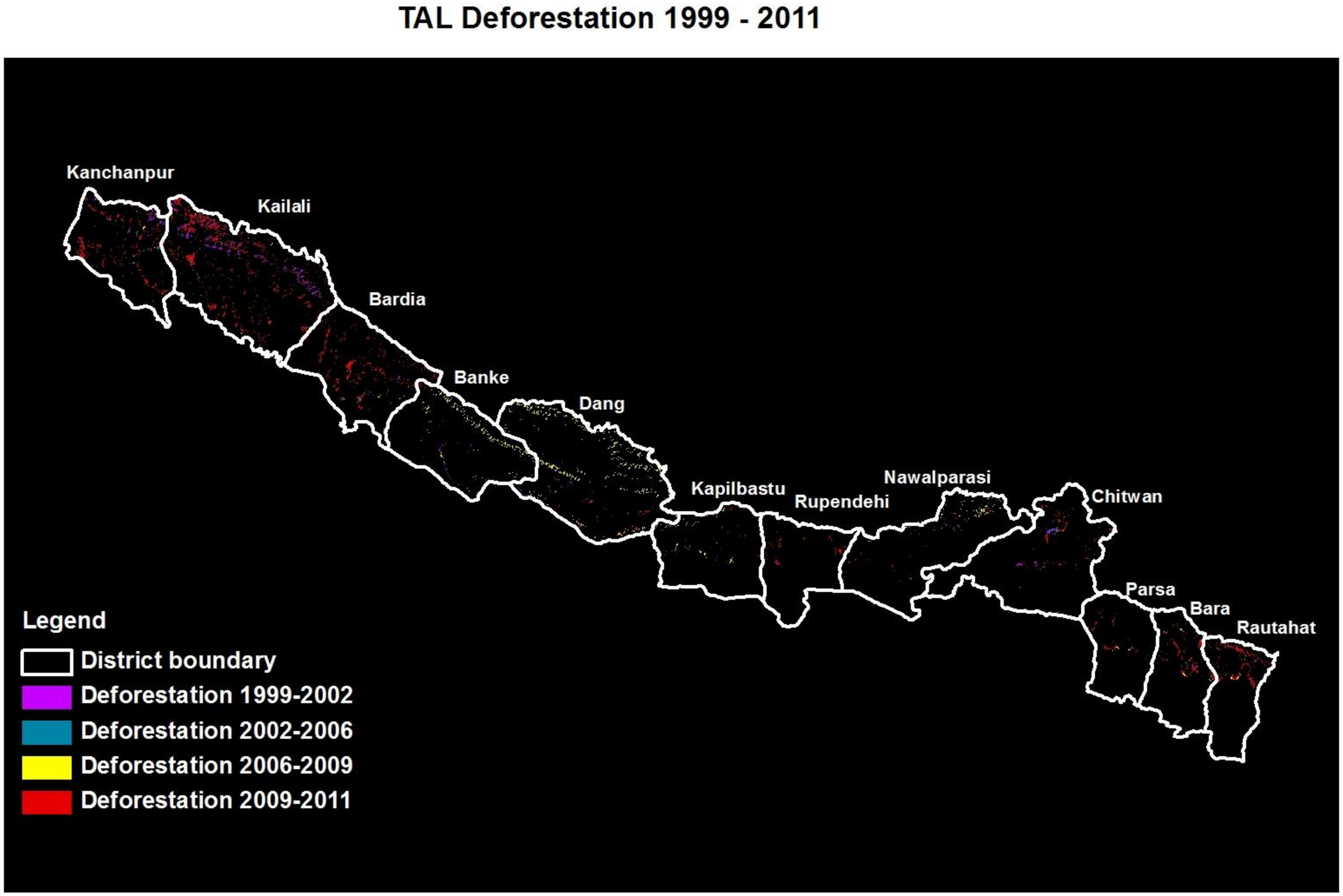

Figure 12. Deforestation in Terai Arc Landscape (TAL) between 1999 and 2011

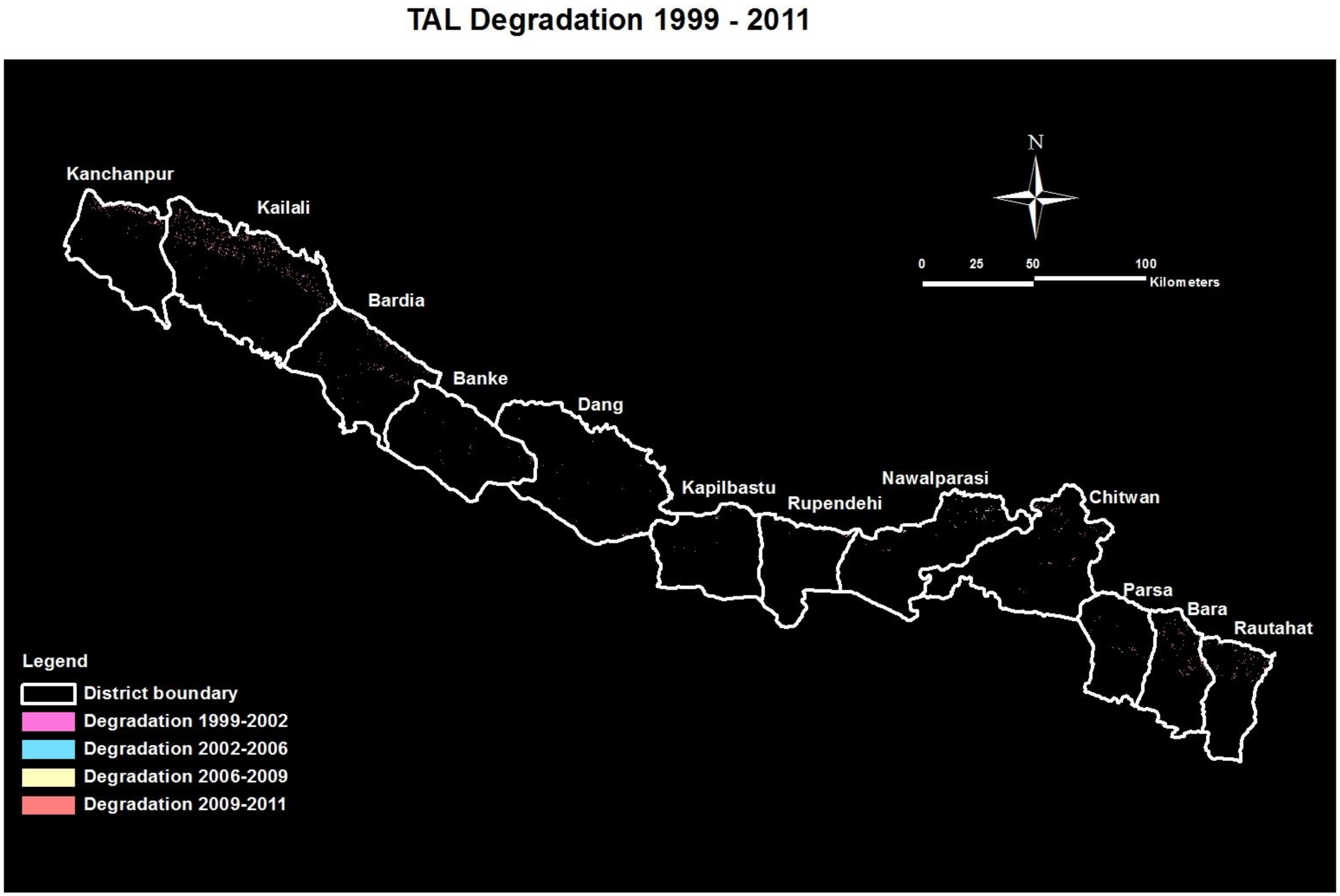

Figure 13. Degradation in Terai Arc Landscape (TAL) between 1999 and 2011

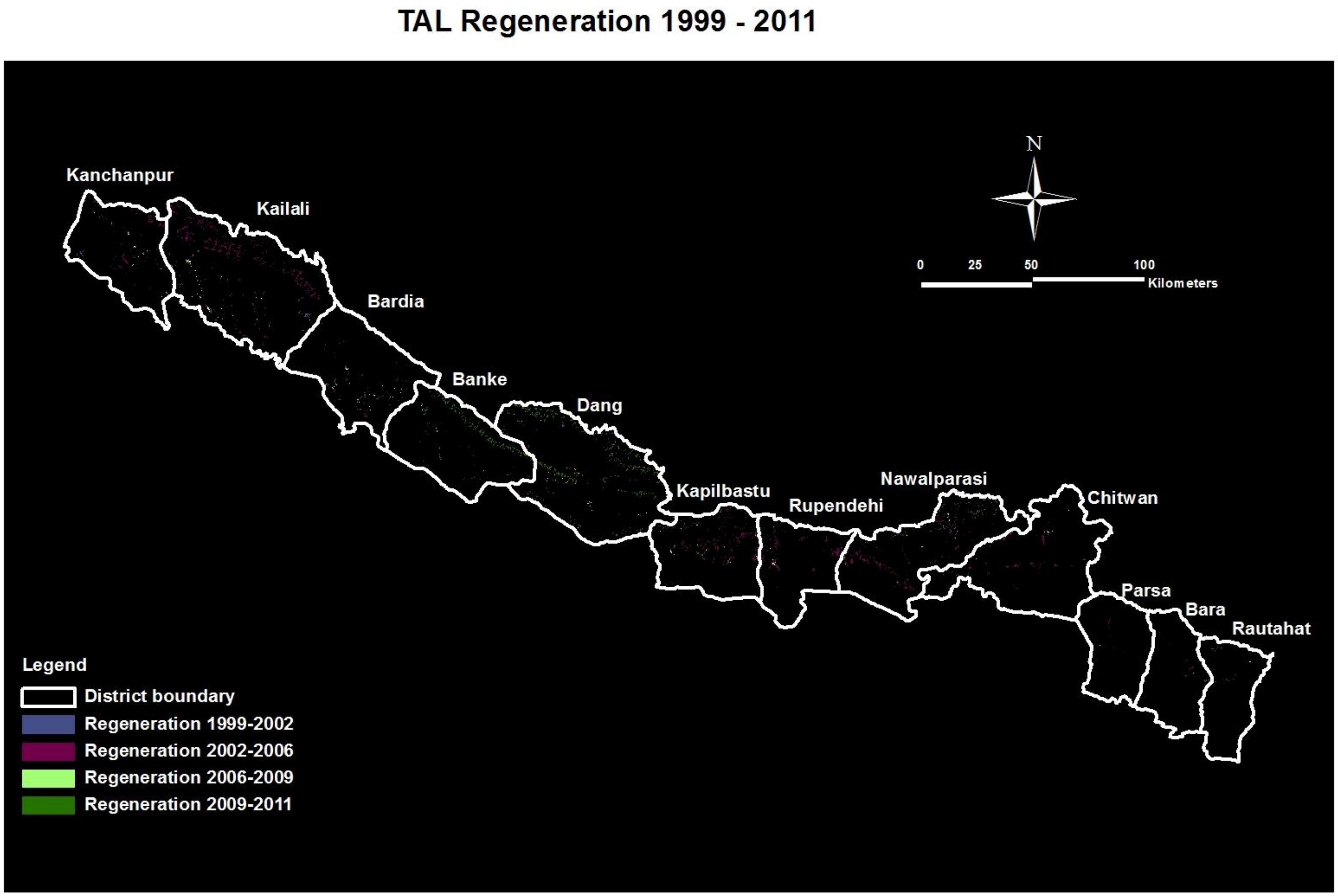

Figure 14. Regeneration in Terai Arc Landscape (TAL) between 1999 and 2011

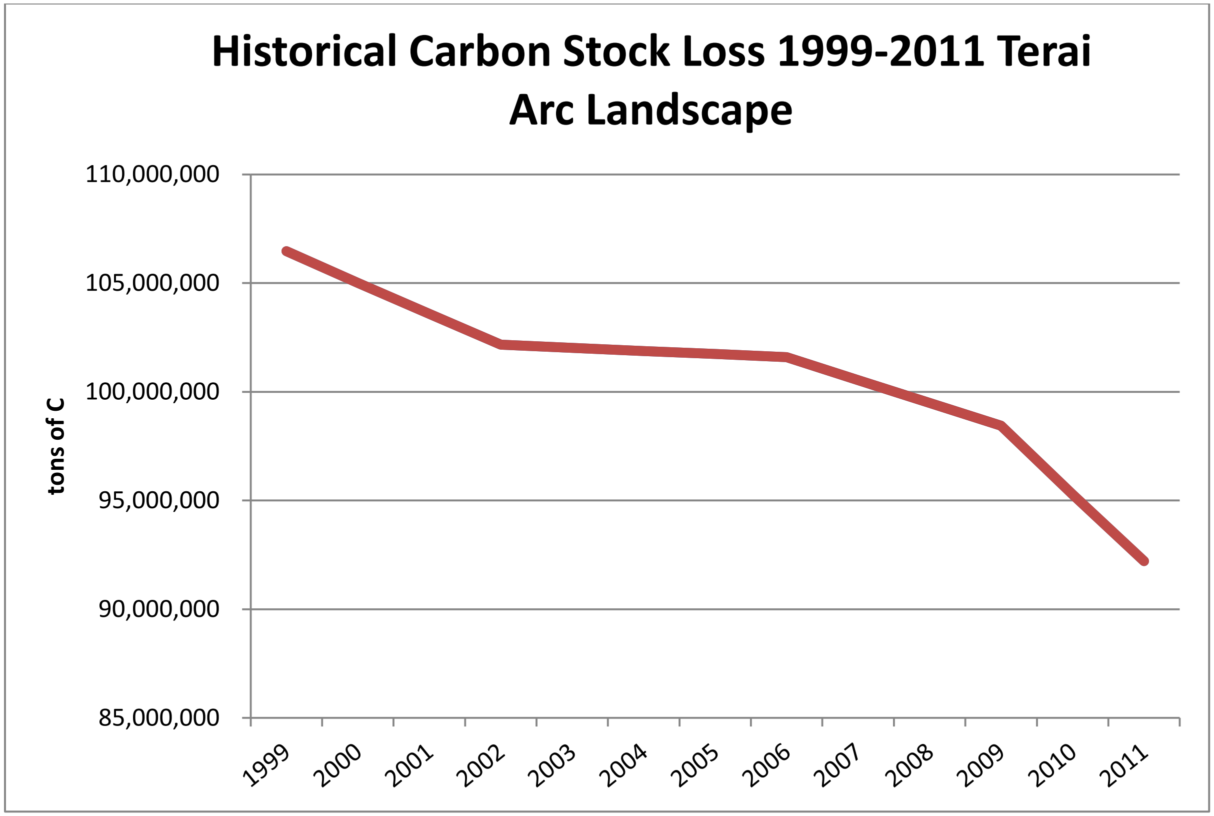

Figure 15.Carbon stock loss between 1999 and 2011.

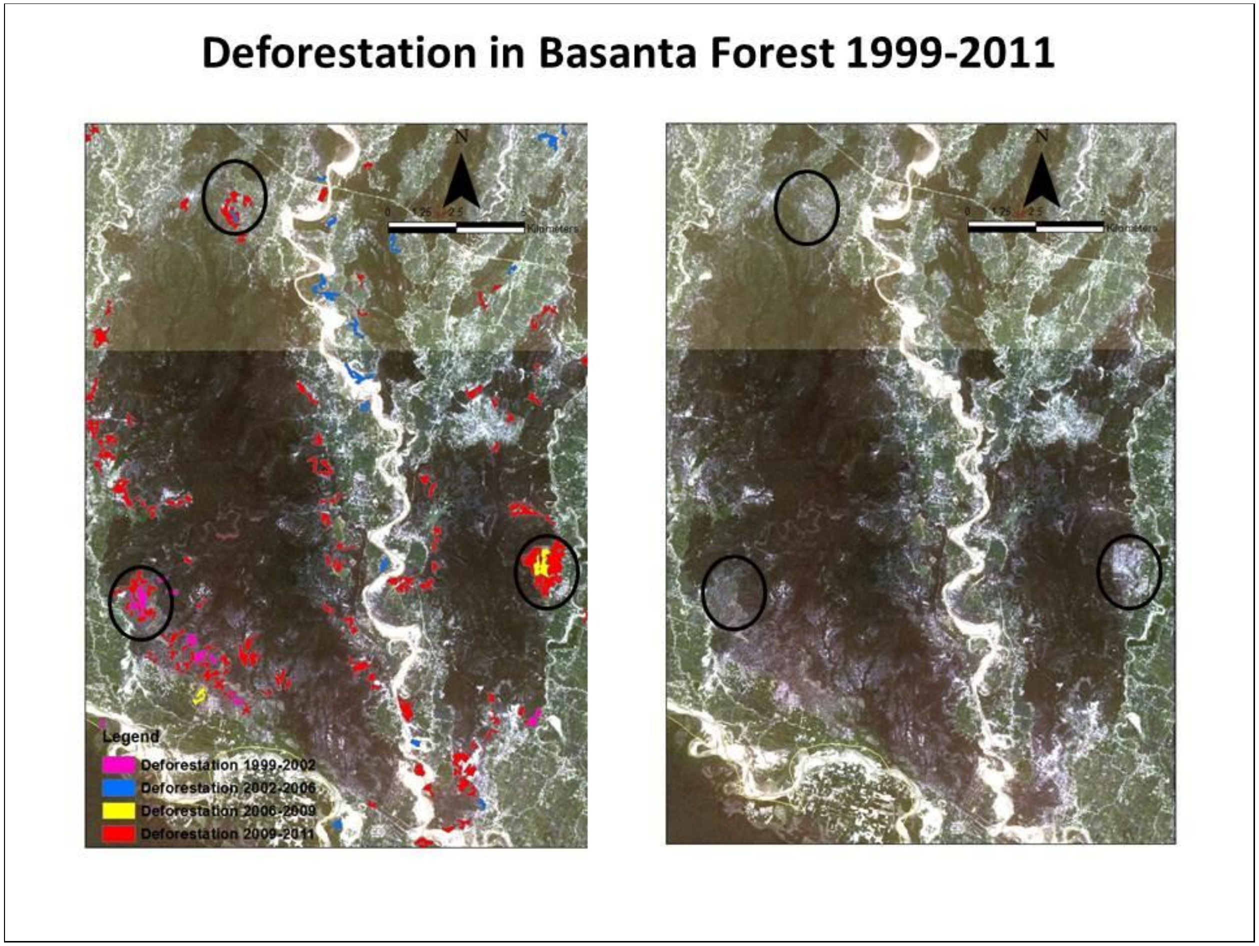

Figure 16. Deforestation in the Basanta Forest in the Far-western TAL overlaid on the Rapid Eye imagery with 5 m x 5 m resolution. The image on the left shows deforestation in different time periods and image on the right show how it looks on the ground (focus on circles).

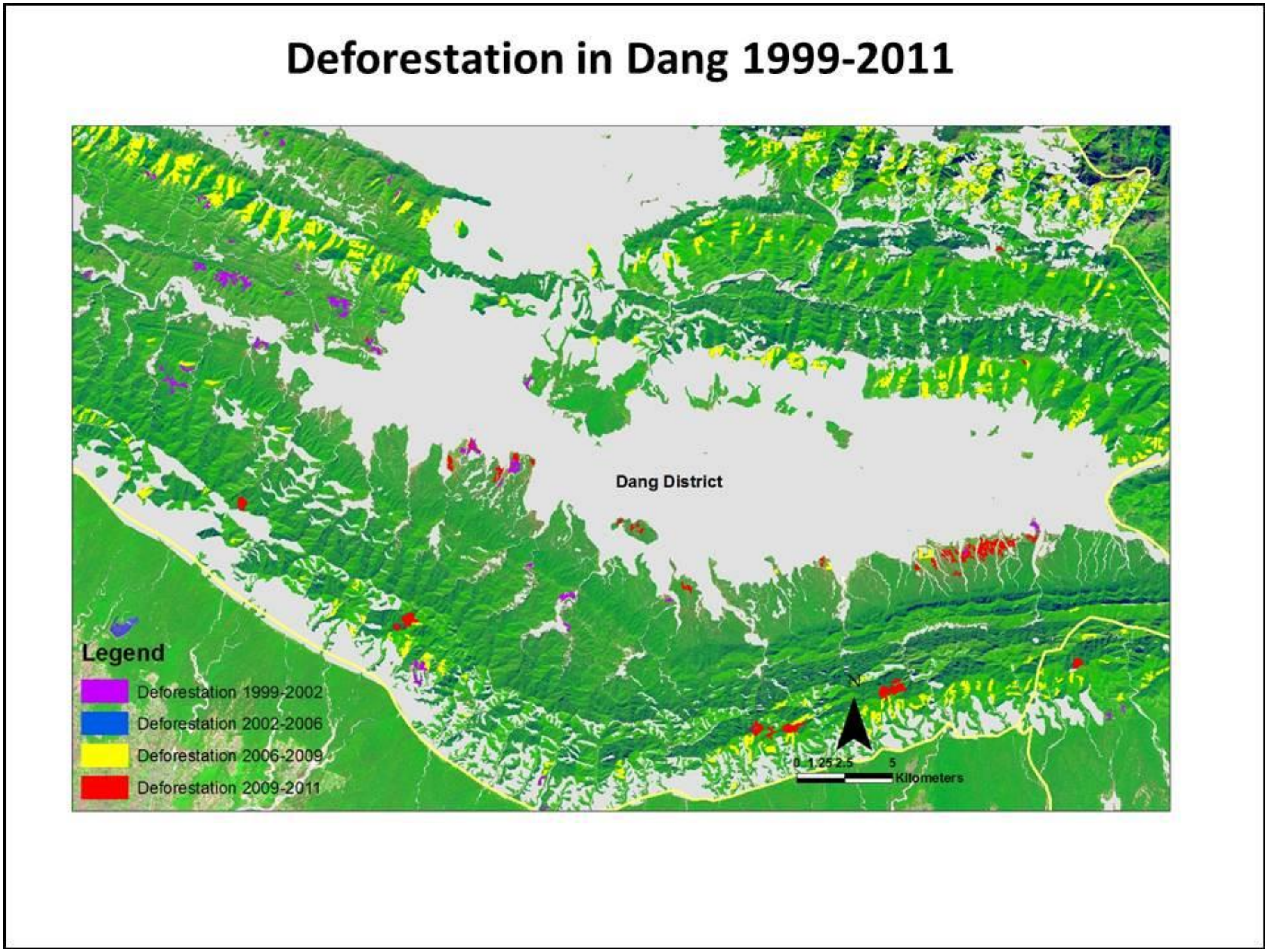

Figure 17.Deforestation in Dang distict (Western TAL) was larger in 2006-2009 time-period than other time periods.

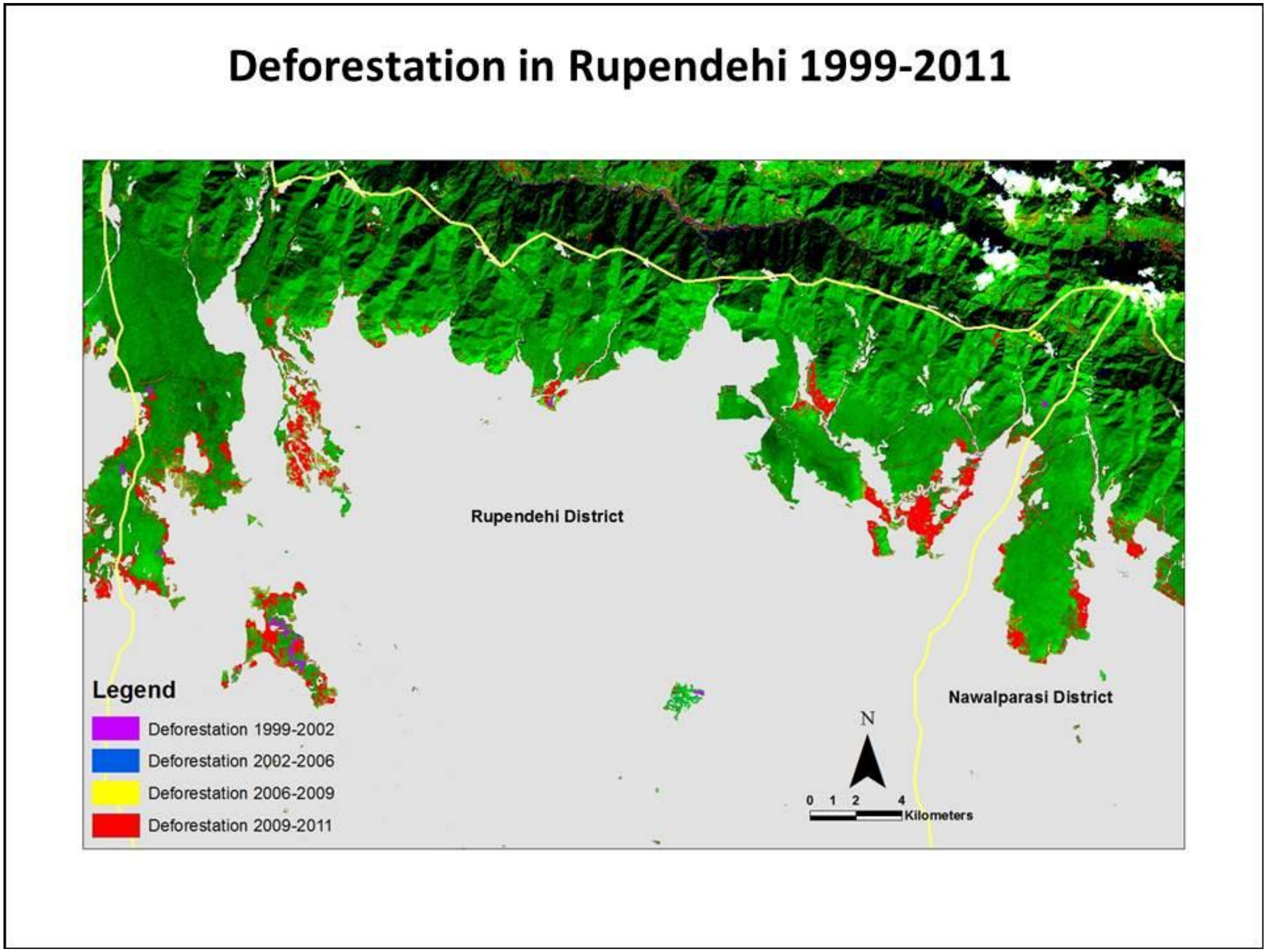

Figure 18. Deforestation in Rupendehi district increased in the 2009-2011 time-period.

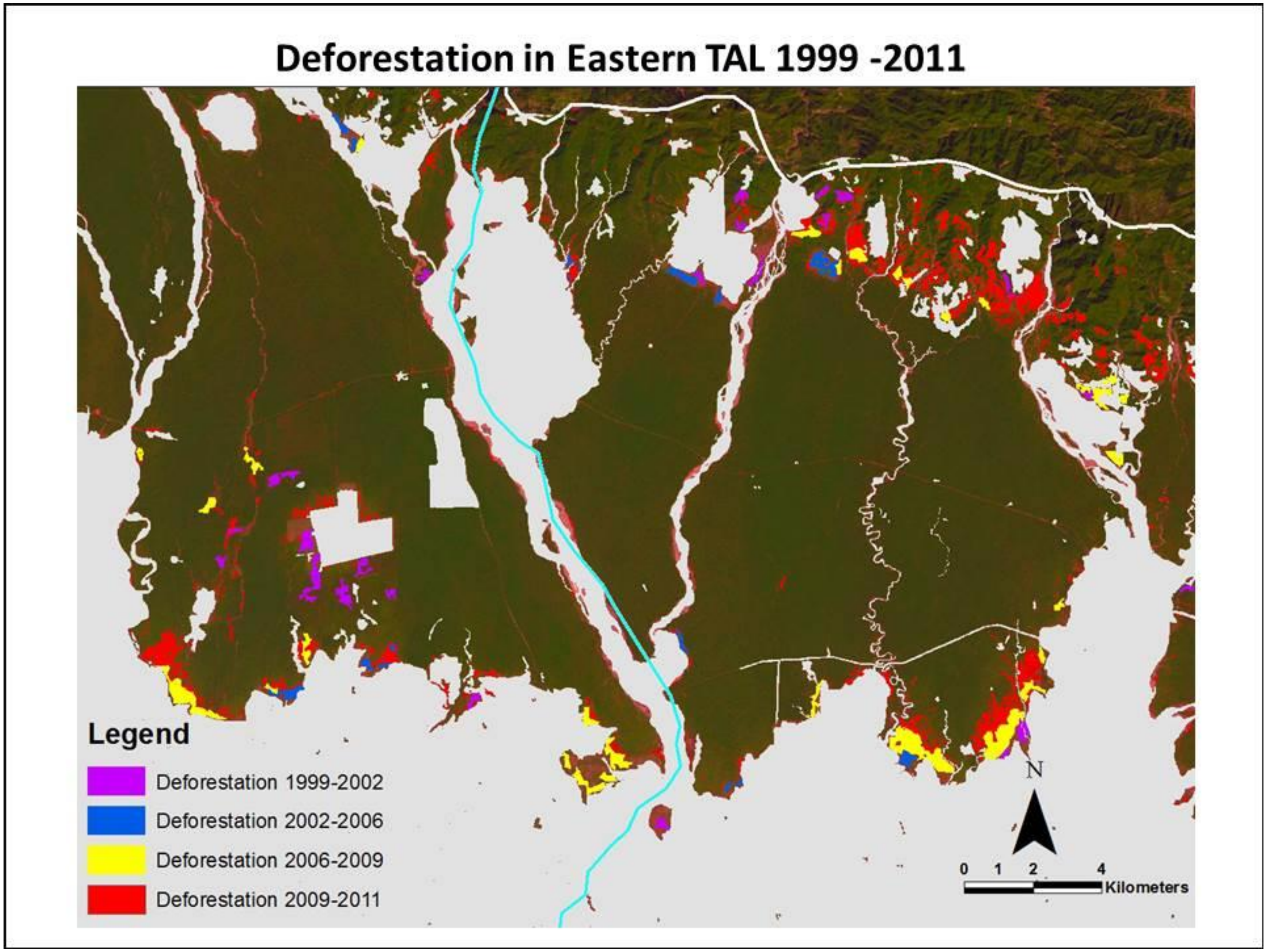

Figure 19. Deforestation in the Eastern TAL increased in last two time periods (2006-2009 & 2009 – 2011).

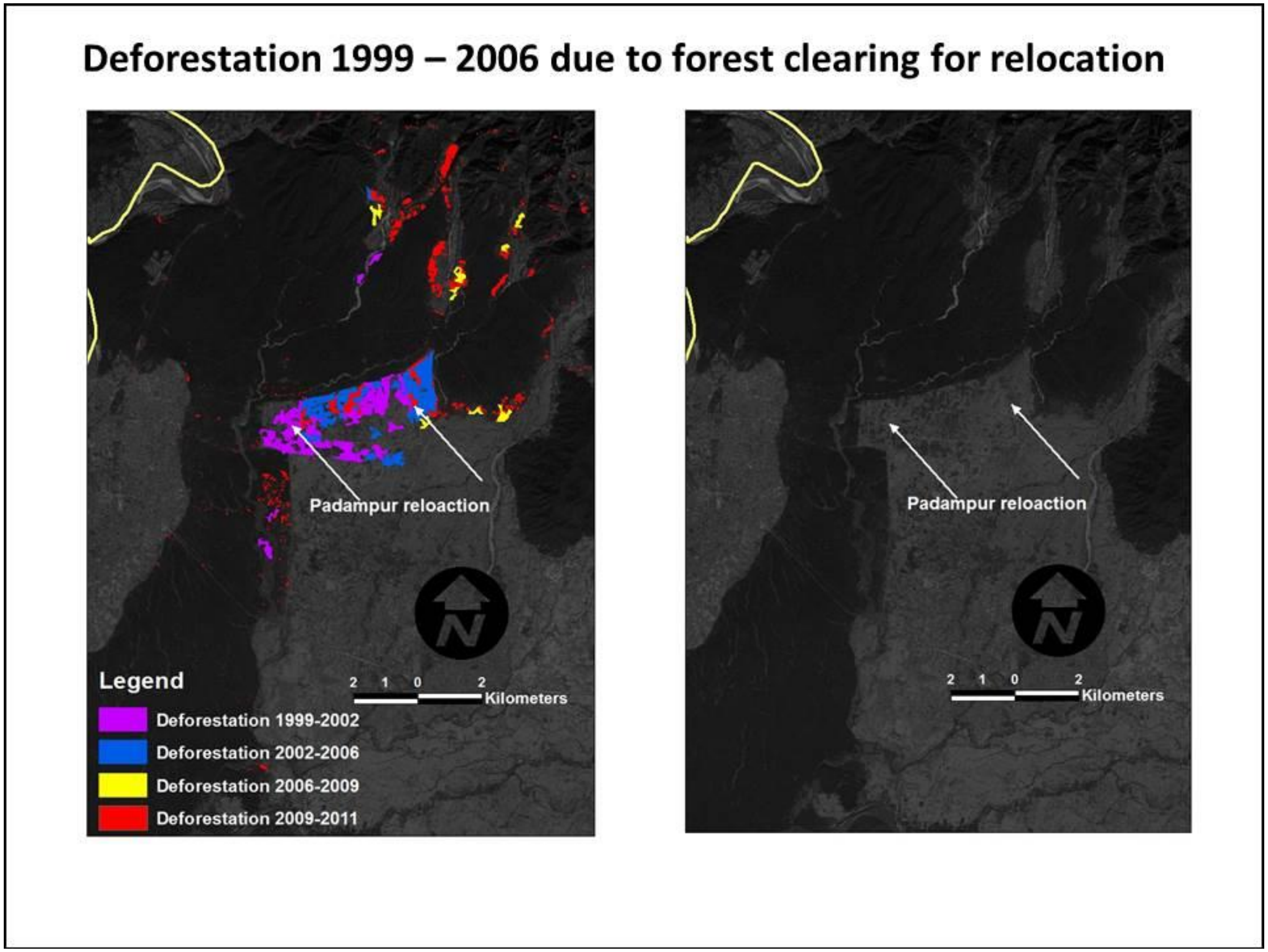

Figure 20.Forest clearing for relocation of Padampur village inside Chitwan National Park shown as deforestation between 1999 and 2006. Image in the left shows clearing as deforestation and image on the right is current status as seen in the panchromatic band of Landsat 8, 2013.

4.2Calculation of Emission Factors from above-ground biomass

The carbon stock was calculated as 47% of the above-ground biomass consistent with GPG (Chapter 4, Table 4.4). Therefore, the emission factors for each forest type and condition were calculated multiplying the AGB by 0.47 (Table 5). When the forest changes from intact or degraded forest to deforestation all carbon was assumed to be released. But when forest goes from intact to degraded the difference in the mean carbon contents between intact and degraded forest is assumed to be emitted, for example when intact Sal forest changes to degraded Sal forest, 29.3 tC/ha or 107.5 tCO_2/ha are emitted. For the emission factors for regeneration forest changing to deforestation or degradation, and sequestrations due to regeneration are calculated with the IPCC default value of 2.8 tC/ha/yr or 10.3 tCO_2/ha/yr.

Emissions factors were derived by calculating the difference between the carbon and CO_2e values in Table 5 to reflect the loss of carbon or amount of emissions when land area containing various forest types transitions from one structure to another.

4.3 Calculation of Emissions from below-ground biomass

Based on IPCC GPG we used 20% of above-ground CO_2 emissions as the below-ground emissions. Below-ground biomass was assumed to result in emissions at the time of mortality.

Table 5 - The mean carbon density and CO_2e values for different forest types and conditions

Forest type and Condition	C and CO_2e Values	
	tC/ha	tCO_2e/ha
Sal intact	110.7	406.0
Sal degraded	81.4	298.5
Sal mixed intact	86.1	315.7
Sal mix degraded	68.8	252.3
Other mix intact	87.4	320.7
Other mix degraded	67.3	246.8
Riverine intact	80.4	294.9
Riverine degraded	46.7	171.3

4.4 Generating reference level (RL)

The RL is generated by multiplying areas changed under each activity by the appropriate emission factor, i.e. mean carbon stocks in each forest type to calculate amount of CO_2 emission due to that particular activity.

$$RL = Activity\ data\ X\ Emission\ factors$$

The amount of CO_2released due to loss of forest carbon resulting from deforestation and degradation is termed as gross emissions while intake of CO_2 by growing plants during forest regeneration is called sequestration. Therefore, net carbon loss is equal to gross emissions minus sequestrations. The reference emissions level (RL) for TAL is based on net carbon accounting process.

4.5 Calculating Net Emissions Level

Following formula was used to calculate RL d for TAL.

$$Reference\ Level = \frac{\sum Em_{def1} + \sum Em_{def2} + \sum Em_{def3} + \sum Em_{deg} - \sum Seq_{reg}}{y}$$

Where,

$\sum Em_{def1}$ - is the sum of emissions from deforestation of intact forest over "y" years,

$\sum Em_{def2}$- is the sum of emissions from deforestation of degraded forest over "y" years,

$\sum Em_{def3}$- is the sum of emissions from deforestation of regenerated forest over "y" years,

$\sum Em_{deg}$ - is the sum of emissions from degradation over "y" years,

$\sum Seq_{reg}$ - is the sum of sequestrations from regeneration over "y" years

4.5 Reference Emissions Level (RL)

The RL analysis shows that during the 12-year period between 1999 and 2011 total of 52,245,991 tons CO_2 (tCO_2e) was emitted from the forest sector in the TAL, an average emission of 4,353,833 tons CO_2e per year (Table 6). In the period 2006-2011, emissions averaged 6,879,686 tCO_2e per year, an increase of 58% over the 12-year average, and in the period 2009-2011, emissions increased even more dramatically, averaging11,412,396 tCO2e per year or 162% higher than the 12-year average (Figure 21).

Table 6 -Forest-related CO_2 emissions in TAL between 1999 and 2011

	CO_2 Emissions(tCO_2e)		
Period	**Above-ground**	**Below-ground**	**Total**
1999-2002	13,136,430	2,627,286	15,763,716
2002-2006	1,736,537	347,307	2,083,845
2006-2009	9,644,698	1,928,940	11,573,637
2009-2011	19,020,661	3,804,132	22,824,793
Total 12-yr	**43,538,325**	**8,707,665**	**52,245,991**
Average annual	**3,628,193.79**	**725,639**	**4,353,833**

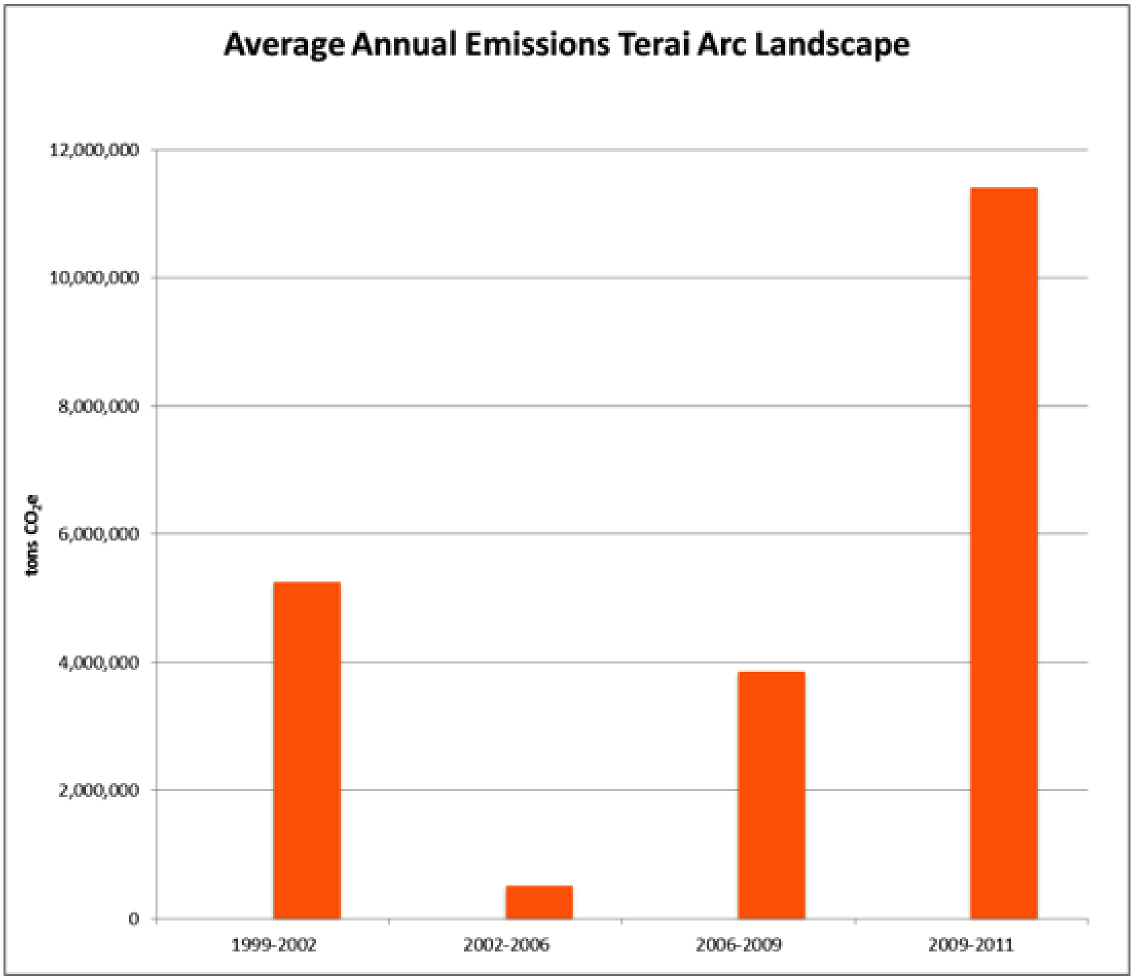

Figure 21. Average annualCO_2 Emissions (tCO2e) in TAL between 1999 and 2011

4.6 RL at District Level

TAL falls under 12 districts or administrative units so district-level analysis was conducted to better understand geographic trends. District-level RL analysis is presented in Table 7. In addition to the significant differences in rates of deforestation and degradation for the various time intervals, there are also significant geographic variations in the distribution of forest-related emissions. Three of the 12 districts – Kailali, Kachnapur and Dang – accounted for 51% of the carbon loss of the TAL during the RL period (Tables 7).

Table 7 -Total CO_2 emission (tCO_2e) by districts for 4 time intervals

	1999-2002	2002-2006	2006-2009	2009-2011	12-year emissions
Kahchanpur	1,326,570	120,105	296,008	3,499,486	5,242,169
Kailali	3,736,460	93,151	911,511	7,891,560	12,632,682
Bardia	425,756	151,066	312,516	3,116,150	4,005,488
Banke	1,227,909	304,491	2,515,125	567,689	4,615,215
Dang	2,600,210	582,332	4,759,420	892,183	8,834,146
Kapilbastu	1,594,386	113,716	1,025,029	380,993	3,114,124
Rupandehi	597,963	(24,121)	72,593	224,251	870,686
Nawalparasi	1,869,896	171,651	758,771	456,103	3,256,421
Chitwan	1,388,989	267,881	250,988	1,315,372	3,223,230
Parsa	189,225	76,152	142,864	872,272	1,280,513
Bara	395,579	96,825	207,383	1,615,801	2,315,588
Rautahaut	410,772	130,596	321,429	1,992,933	2,855,730

5. Accuracy assessments, errors, and uncertainties

The processes used to generate RL include data from several sources collected at different times, scales and resolutions. At different stages of the process several assumptions were made, therefore results presented inherently have several errors and uncertainties. Some of the errors may cancel out while others may be additive. In this section we layout potential sources of errors and present accuracy assessments, errors and uncertainties at different steps of the process. To reiterate, we used the LiDAR-Assisted Multi-source Programme (LAMP), which combines LiDAR sample data with field plots and satellite data to develop stratified aboveground carbon estimates. The potential sources of errors are:

1. Field measurements - measurement error, error in AGB estimates
2. Sampling - sampling error
3. Geographical location - spatial inaccuracy of field sample plot location and LiDAR measurement location
4. LiDAR-to-AGB model - model-error
5. Forest classification - misclassification
6. Surrogate plots - sampling error

5.1 Accuracy assessment for Emission Factors

The standard error (Eq. 1) and 95 percent confidence intervals (Eq. 2) of LiDAR estimations could be calculated for each class using class-specific mean and standard deviation, extracted from the independent sample of 46 plots. The standard error (SE) of the mean is the standard deviation of the error in the sample mean, relative to the true mean:

$$SE = \frac{sd}{\sqrt{n}} \qquad \text{Eq.1}$$

$$CI = mean\ AGB\ \mp 1.96 * SE \qquad \text{Eq.2}$$

Where SD is standard deviation, n is sample size, CI is confidence interval and mean AGB is the mean aboveground biomass.

As a non-stratified regression model was used to arrive on LiDAR-based biomass estimates for all forest classes, the within-class uncertainty in predictions was considered by calculating the mean error of an estimator ME (θ) for each class. The ME (θ) assesses the quality of an estimator in terms of its variation and unbiasedness (Lebanon 2010, Moore et al. 2001). It is calculated as the root of the sum of the variance and the squared bias of the estimator:

$$\text{ME}(\theta) = \sqrt{var(\theta)\ +\ bias(\theta)^2} \qquad \text{Eq.3}$$

5.2 Monte Carlo analysis of the Emission Factors prediction errors

Monte Carlo analysis was used to produce a distribution of estimations for above-ground biomass, in order to detect the range of all possible outcomes and to quantify the error that comes from various sources within LAMP process. In general, Monte Carlo simulation can be used for risk analysis by building models of possible results. It works by substituting a range of values – a probability distribution – for any factor that has inherent uncertainty. It then calculates results over and over, each time using a different set of random values from the probability functions. This can involve thousands or tens of thousands of recalculations before the simulation is complete.

A Monte Carlo analysis was applied to run a joint error validation of field sample measurement error, plot location error, sampling error and model error. The assumption is that the first four error sources (listed above) can be estimated by simulating sub-samples from field measurements, creating a LiDAR-to-AGB model using them, and then cross-validating the results with the remaining field plots.

This process was implemented by randomly dividing the 738 LiDAR field plots in two sets for 1,000 times. A new model was created each time. A sub-set of 538 distinct random plots (no replacement) from the 738 candidate plots, were iteratively sampled as the training data. The LiDAR features and field measurements of training data were used to estimate the model parameters. Then the AGB values of the remaining 200 plots left out from the training set were predicted using the model. Thus, we obtained 1000 × 200 predicted plots, from which the plot level residual distribution could be estimated (see Figure 22). The mean statistics from simulations are presented in Table 8.

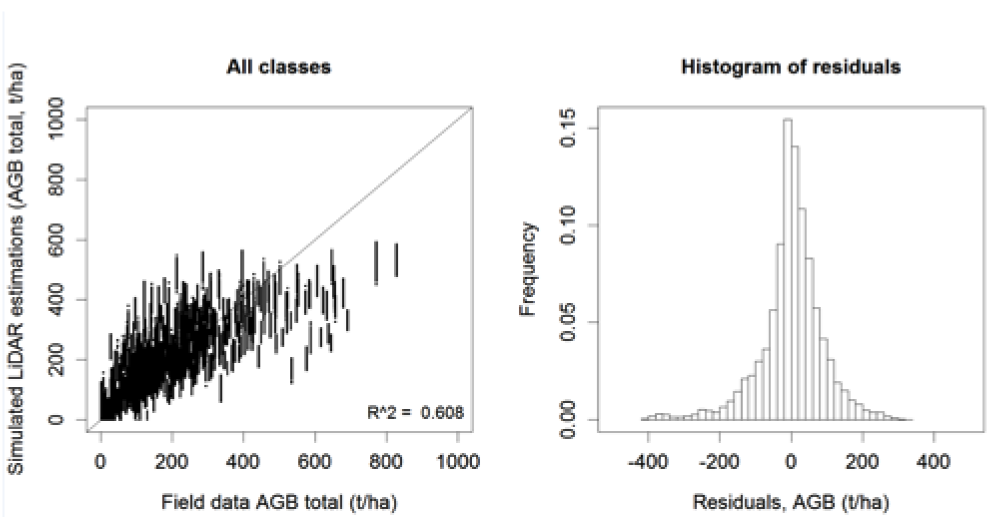

Figure 22: AGB predictions versus field measurements (left) and residual histogram (right) of N_{sim} = 1000 simulations with random training set of N − 200 = 538 plots.

Table 8. Mean statistics for the simulated LiDAR estimates of aboveground biomass. The results are validated with iterative cross-validation.

Total AGB (t/ha)	**LiDAR (Phase 1)**
Standard deviation of estimates	113.08
Standard deviation of reference plots	143.0
Mean of estimates	189.8
Mean of reference plots	188.98
RMSE	89.5
Relative RMSE (%)	0.47
Bias	0.82
Relative bias (%)	0.00
R^2	0.61
Adj. R^2	0.61

Since a new model was created during each iteration, median amount of explanatory variables was used to calculate the adjusted R^2 value. The average amount of variables for prediction was 9.6, median 10, minimum 6 and maximum 15. The initial pool of variables was the same as specified in Table 2.

The results from Monte Carlo analysis (statistics extracted from the distribution of estimates) could also be used in analyzing the stratification error in forest condition (section 5.4).

5.3 Spatial scaling of error measures

Scaling of mean error by size of estimation area decreases the error associated with corresponding average AGB in proportion to the square root of the area. Thus, each forest type and condition class was spatially scaled up to the area of each class on the LiDAR blocks. This way the maximum level of error was revealed for each class (Table 9)

In order to derive the mean error at different spatial scales, the formula of ME (θ) was modified by replacing variance with the square of the standard error (Eq. 1) of the mean (Kandel *et al.* 2013). Using the sample size as an indicator of the spatial scale (area) at which a mean estimate is produced, the scale-dependent mean error was calculated as:

$$\text{ME}(\theta)_n = \sqrt{SE^2 + bias(\theta)^2} \qquad \text{Eq. 4}$$

Bias was calculated from 738 field verified plots for classes intact and degraded and assumed to be close to each other between the four forest types.

The confidence intervals were scaled as a function of standard error as in Equation 2.

Table 9 - Confidence intervals (CI) and Mean error (ME) of LiDAR-based linear regression model for each forest type and condition class on the minimum spatial scale of each class, i.e. the area of each class on 5 x 10km LiDAR blocks.

Class	Mean AGB, ton/ha	Area on blocks, ha	CI, ton/ha	CI, % of the mean AGB	ME, ton/ha
Sal intact	235.6	36549	0.14	0.06	6.36
Sal degraded	173.2	1661	0.65	0.37	4.01
Sal mixed intact	183.2	11074	0.25	0.14	6.36
Sal mixed degraded	146.4	946	0.86	0.58	4.02
Other mixed intact	186.1	1129	0.78	0.42	6.37
Other mixed degraded	143.2	125	2.35	1.64	4.18
Riverine intact	171.1	478	1.20	0.70	6.39
Riverine degraded	99.4	58	3.46	3.48	4.37

5.4 Accounting for stratification error in forest conditions

Stratification error in forest condition is substantial at high spatial resolution, but since Reference Levels are calculated initially at regional level only, the impact of stratification error in forest condition should be assessed over the corresponding spatial scales. The histograms of above-ground biomass estimations were scaled to spatially larger units in order to establish a level of spatial resolution where the two forest condition classes, intact and degraded, could be confidently separated.

At initial level of 1 hectare, the distribution of intact and degraded forest overlapped heavily in all forest types. The distributions of intact and degraded AGB cease to overlap latest at the level of 70 hectares and larger (Figure 23). This means that RL calculations can be confidently calculated at the district level.

Moreover, the confidence is strengthened when comparing LiDAR-predicted and field measured AGB separately for two condition classes. Figure 24shows that estimates are unbiased also when condition classes are studied separately.

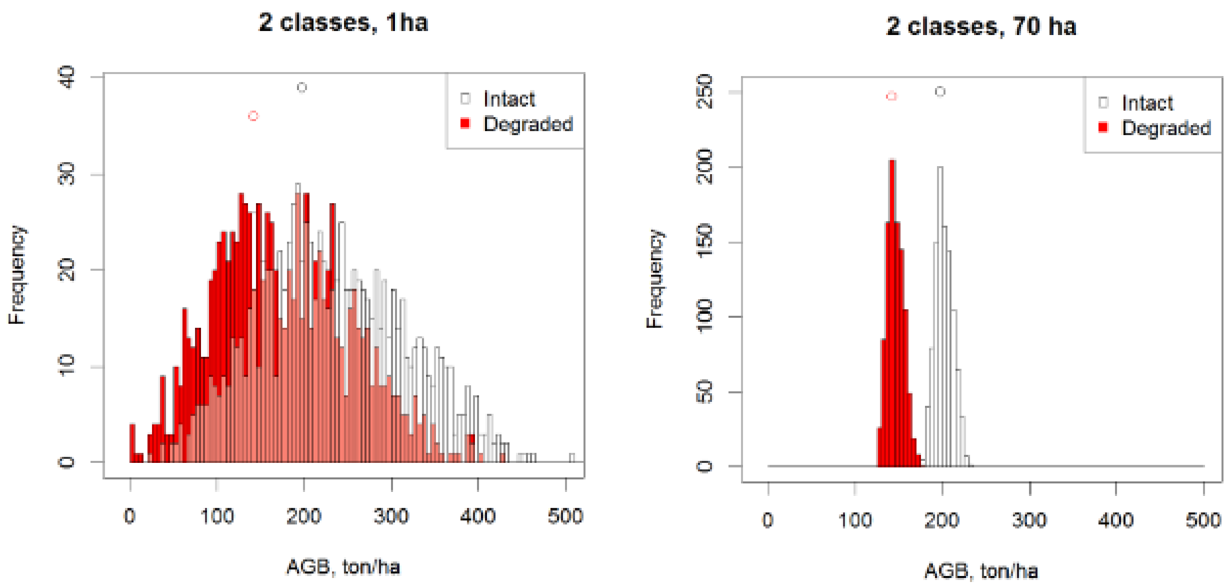

Figure 23: Histograms of estimated AGB for two forest condition classes at different spatial scales. The mean biomass of each class is indicated with a circle.

The spatial level where condition classes were not overlapping was discovered in the following way. When the size of the scale is increased the area of one cell in relation to the whole area is decreased. The initial sample size of 1 hectare was scaled according to the following relation:

$$n_c = \frac{A_c}{A} * n \qquad \text{Eq.5}$$

Where n_c is sample size of scale size c, A_c is area of one cell and A is area of whole area of the class.

The testing was done starting from 1 ha. The CIs are used to scale the plot AGB values so that they would represent the value with a larger spatial scale. This scaling of plot values is done as in Eq. 6:

$$x_c = \frac{(CI\_up_c - CI\_low_c)(x - CI\_low_1)}{CI\_up_1 - CI\_low_1} + CI\_low_c \qquad \text{Eq. 6}$$

Where x_c is the scaled plot biomass value with spatial scale c, CI_up_c is the upper confidence interval with spatial scale c, CI_low_c is the lower confidence interval with spatial scale c, x is the original plot biomass value, CI_low_1 is the lower confidence interval with original 1 ha spatial scale, CI_up_1 is the upper confidence interval with original 1 ha spatial scale. Monte Carlo analysis was applied for the calculation of CIs. For this purpose, equation 1 was modified by using the standard deviation that represents the mean of simulated AGB predictions (Figure 23, left).

By using the scaled plot biomass values the histograms get narrower the higher the spatial scale is. The point where the histograms are not overlapping indicates a spatial scale where condition classes can be separated with confidence.

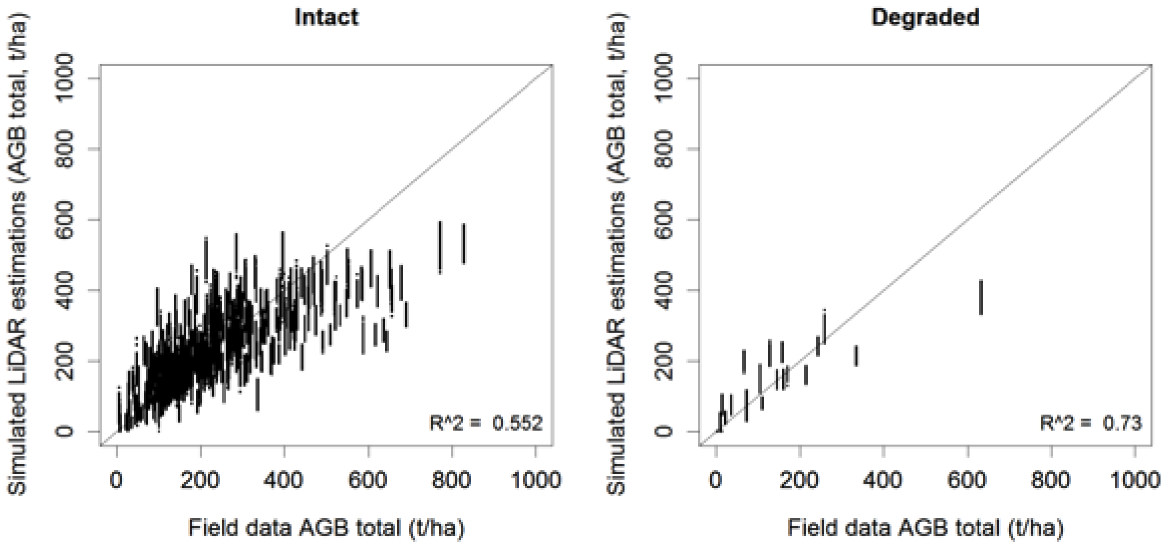

Figure 24: Scattergrams of LiDAR-predicted and field measured AGB in intact and degraded forest classes of N_{sim} = 1000 simulations with random training set of N − 200 = 538 plots.

5.5 Accuracy Assessment of Activity Data

The accuracy assessment of activity data is limited to the last time period (2009-2011) due to lack of reference data for previous time periods. Although accuracy assessment for previous time periods could potentially be done using high-resolution satellite data such as RapidEye or WorldView, it is currently cost prohibitive. Accuracy assessment was designed to be carried out in two phases, first using available high resolution satellite imagery, RapidEye, Panchromatic band of Landsat 8, and preliminary secondary data, such as HAGs (Height Above Ground) model developed by J. Stoker for TAL using LiDAR and Landsat data. The second phase of accuracy assessment would be field verification which is planned for the spring of 2014.

5.6 Phase I - Using high resolution satellite data and visual interpretation

For the phase 1 of the accuracy assessments RapidEye data that was available for the entire TAL from the year 2010 was used. Five percent of change polygons for each activity: intact (no change), deforested, degraded, regenerated and enhanced areas which are equal or greater than 5 hectares were randomly chosen using a random function. A center point for each polygon was extracted as a point layer in the ArcGIS. The points were plotted over the RapidEye imagery along with the HAGs layer, panchromatic band of Landsat 8, and raw Landsat5 scenes. Each point was then visually verified. The accuracy assessment accounts for the proportion of each category based on mapped area as per referenced data (Olofsson et al. 2013). The overall accuracy, user's and producer's accuracies along with confidence intervals are presented in the Table 10.

Table 10 - An error matrix showing accuracy of forest change between 2009 and 2011 with 95% confidence intervals

Activity	Intact	Deforestation	Degradation	Regeneration	Total	Mapped Area (ha)	Proportion Wi (ha)
Intact	0.704	0.016	0.008	0.142	0.871	858910	0.871
Deforestation	0.008	0.063	0.001	0.002	0.074	72700	0.074
Degraded	0.003	0.005	0.024	0.000	0.032	31398	0.032
Regeneration	0.001	0.003	0.001	0.020	0.024	23623	0.024
Total	0.716	0.086	0.034	0.164	1.000	986631	1.000
Overall accuracy	0.81 ± 0.09						
Producer's accuracy	0.98±0.065	0.73± 0.024	0.72± 0.017	0.87± 0.061			
User's accuracy	0.81 ± 0.092	0.86 ± 0.007	0.76 ±0.009	0.82 ± 0.004			

The error-adjusted changes in each category with confidence intervals are presented in Table 11. The deforestation and degradation areas from the change analysis between 2009 and 2011 falls within the confidence interval of error adjusted changes for those categories (Table 10 & 11). On the other hand the areas for unchanged forest (intact) and regeneration forest fall outside the range of confidence interval of error adjusted change, which warns that there might be confusion between these two classes during classification. The omission error of 0.142 (14.2%) of regeneration (164,172 ha) arising from the intact (unchanged) category is responsible for increase in area of regeneration and decrease in area of intact forest.

Table 11 - Error adjusted forest change between 2009 and 2011

	Area in ha			
	Changed	**95% CI**	**Low**	**High**
Intact	706,027	63,666	642,361	769,693
Deforestation	85,338	22,798	62,540	108,136
Degradation	33,086	16,497	16,589	49,582
Regeneration	162,180	59,775	102,405	221,955

5.7Phase II - Using field verification

A field team will visit locations selected using the stratified random sampling protocol for each activity type. Five percent of polygons for each activity, intact (no change), deforested, degraded, and regenerated areas which are equal or greater than 5 hectares will be selected. Using GPS the field crew will visit the site and collected information on forest conditions such as age of forest, % crown closure, human activities such lopping of branches, signs of recently cut trees, etc. The field team will also talk with locals on any other activities such as recent forest fires, floods, clear cutting, plantations, etc., and use a clear protocol for reporting results back in a uniform and comparable manner.

6. Conclusion

The technical process we used in developing RL for a sub-national REDD+ program, TAL in Nepal demonstrates that historical deforestation and degradation rates can be generated retro-prospectively, even in the countries lacking regular forest monitoring data, to develop a creditable RL that is reliable and transparent. The RL for the TAL has been subjected to rigorous review and accuracy assessment, and the results are highly reliable for reporting carbon flux at scales above 70 ha. In the TAL, the RL provides highly accurate estimates of historical carbon emissions for the 12 administrative districts and will enable stakeholders in Nepal to better target interventions to curb deforestation and forest degradation. The RL provides a stark view of an alarming trend of increasing deforestation and forest degradation in the TAL, particularly in recent years, and this understanding can provide a strong foundation for mobilizing appropriate and effective actions to halt and reverse this trend and for monitoring the success of these actions in the future.

7. Literature cited

Asner, G.P., Hughes, R.F., Varga, T.A., Knapp, D.E., and Kennedy-Bowdoin, T. (2009).Environmental and biotic controls over aboveground biomass throughout a tropical rain forest.*Ecosystems*, *12*, 261-278.

Asner, G.P., Clark, J.K., Mascaro, J., Vaudry, R., Chadwick, K.D., Vieilledent, G., and Knapp, D.E. (2012).Human and environmental controls over aboveground carbon storage in Madagascar. *Carbon Balance and Management*, *7*, 2.doi:10.1186/1750-0680-7-2

Asner, G.P., Mascaro, J., Anderson, C., Knapp, D.E., Martin, R.E., Kennedy-Bowdoin, T., Breugel, M.V., Davies, S., Hall, J.S., Muller-Landau, H.C., Potvin, C., Sousa, W., Wright, J. and Bermingham, E. (2013). High-fidelity national carbon mapping for resource management and REDD+. Carbon Balance and Management, 8:7. http://www.cbmjournal.com/content/8/1/7

Carlotto, M. J. (1999). Reducing the effects of space varying, wavelength dependent scattering in multispectral imagery. International Journal of Remote Sensing.20(17). 3333-3344p.

FCPF (2013). Carbon Fund Methodological Framework. Forest Carbon Partnership Facility, World Bank, Washington, D.C. Dec., 2013.

Intergovernmental Panel on Climate Change.(2006). Guidelines for National Greenhouse Gas Inventories. Retrieved from http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf

Intergovernmental Panel on Climate Change. (2007). *Climate Change 2007: Synthesis Report.* The Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge and New York: Cambridge University Press. Retrieved fromhttp://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm.

Joshi, A.R., Shrestha, M., Smith, J.L.D., and Ahearn, S. (2003). Forest classification of Terai Arc Landscape (TAL) based on Landsat7 satellite data. A Final Report submitted WWF-US. 2003.

Junttila, V., Maltamo, M., and Kauranne, T. (2008). Sparse Bayesian Estimation of Forest Stand Characteristics from Airborne Laser Scanning. *Forest Science*, *54*, 543-552.

Junttila, V., Kauranne, T., and Leppänen, V. (2010). Estimation of Forest Stand Parameters from Airborne Laser Scanning Using Calibrated Plot Databases. *Forest Science*, *56*, 257-270.

Kandel P.N., Awasthi K., Shrestha S.M., Hawkes M., Kauranne T., Gautam B., Gunia K., and Dinerstein E. (2013). Monitoring Aboveground Forest Biomass: A Comparison of Cost and Accuracy between LiDAR-Assisted Multisource Programme (LAMP) and Field-Based Forest Resources Assessment (FRA) in Nepal. International Conference in Forest, People and Climate: Changing Paradigm, 28.-30. August 2013, Pokhara, Nepal.

Kaufman, Y. J., Wald,A. E., Remer, L. A.,Gao,B.-C., Li, R.-R. , and Flynn, L. (1997). The MODIS 2.1-□m Channel-Correlation with Visible Reflectance for Use in Remote Sensing of Aerosol. IEEE Transactions on Geoscience and Remote Sensing. Vol. 35, pp. 1286-1298.

Lebanon G. (2010).Bias, Variance, and MSE of estimators. http://www.cc.gatech.edu/~lebanon/notes/estimators1.pdf.

Monteiro, A., and Souza Jr., C. (2012).Remote Monitoring for Forest Management in the Brazilian Amazon. In: J. J. Diez (Org.), Sustainable Forest Management - Current Research, p.67-86. InTech.2012. Disponívelem: <http://www.intechopen.com/books/howtoreference/sustainable-forest-management-current-research/remotemonitoring-for-forest-management>. Acessoem: 9 nov. 2012.

Moore, D.S. and McCabe, G.P. (2001). Introduction to the practice of statistics. ISBN: 0-7167-3409-5. The third edition.www.whfreeman.com/statistics.

Morton, D. C., Sales,M. H., Souza, C. M., and Griscom, B. (2013). Historic emissions from deforestation and forest degradation in Mato Grosso, Brazil: 1) source data uncertainties. Carbon Balance and Management 2011, 6:18, 1-13.

Næsset, E. (2002). Predicting forest stand characteristics with airborne scanning laser using a practical two-stage procedure and field data. *Remote Sensing of Environment, 80,* 88-99.

Næsset, E. (2007). Airborne laser scanning as a method in operational forest inventory: status of accuracy assessments accomplished in Scandinavia. *Scandinavian Journal of Forest Research, 22,* 433-442.

Olofsson, P., Foody,G.M., Stehman, S. V., and Woodcock,C.E. (2013). Making better use of accuracy data in land change studies: Estimating accuracy and area and quantifying uncertainty using stratified estimation. Remote Sensing of Environment, 129:122-131.

Särndal, C.-E., Swensson, B., and Wretman, J. (1992).*Model assisted survey sampling.* Springer.

Sharma, E.R., and Pukkala, T. (1990). Volume Equations and Biomass Prediction of Forest Trees of Nepal. *Publication series of the Ministry of Forests and Soil Conservation of Nepal, Forest Survey and Statistics Division, 47,* 1-16.

Souza Jr., C., Roberts, D. A. and Cochrane, M. A. (2005). Combining spectral and spatial information to map canopy damage from selective logging and forest fires. Remote Sensing of Environment.98 329-343p. Doi: 10.1016/j.rse.2005.07.013.

Souza Jr., C. and Siqueira, J. V. (2013). ImgTools: a software for optical remotely sensed data analysis. In: XVI Simpósio Brasileiro de Sensoriamento Remoto (SBSR). Foz do Iguaçu-PR. 8p.

UN FCCC (2011). Guidance for modalities relating to forest reference levels and forest reference emissions levels - a contribution in response to SBSTA's invitation to submit views (see FCCC/SBSTA/2011/L.14, para.4 and annex 1, para.2) September 2011. http://unfccc.int/resource/docs/2011/smsn/ngo/332.pdf.

Appendix 1: Data sets used

The following data sets were used to generate activity data and emission factors to derive the RL:

1 Forest/non-forest Base Map 1999: The 1998 GoN Topographic and Land cover, land use maps with forest and non-forest classes were used to derive the forest/non-forest areas for the 1999 inception date of the reference level period. The forest area was used as a forest mask for deriving forest for each time period between 1999 and 2011.

2 Forest/non-forest Base Map 2011: The GoN Forest Resource Assessment (FRA) based on 2011 data will be used to delineate the forest/non-forest areas for the 2011 end year of the reference level period and as a base forest mask for future monitoring.

3 Forest Classification Map: Forest classification of Terai Arc Landscape (TAL) based on LANDSAT 7 satellite data (2001) by Joshi et al (2003) which was the latest available forest classification of the TAL that has been field verified. After discussion with the REDD cell, the forest classification of 2001 for TAL was regrouped into 4 major forest classes: Sal forest (*Shorearobusta*), Sal dominant mixed forest, Riverine forest, and other forests (not dominated by Sal). The accuracy assessment for the 4 major forest classes were recomputed with the field data collected from 2002. The overall accuracy was 84.5 % with a Kappa value of 0.754. The boundaries of the forest classes in 2001 were considered to remain the same for entire RL period. In other words, our assumption was that forest types are not likely to change from one type to another in 10-20 years but forest condition within each forest type (intact, degraded, deforested) may change due to human activity (Activity DATA).

4 LiDAR data: LiDAR data were acquired from twenty 5 km by 10 km blocks called LiDAR Blocks, which cover about 5 per cent of the study area. All blocks were scanned wall-to-wall from 2,200 meters average height above ground.

5 Vegetation plots for LiDAR calibration: Field data collected from 738 vegetation plots (12.6-meter radius) by Arbonaut Ltd. in 2011 in a collaborative effort with the FRA and WWF Nepal were used to develop LiDAR-to-biomass. Above-ground biomass for each plot was computed using tree height and diameter at breast height, based on species group-specific volume equations published by Sharma and Pukkala (1990).

6 Vegetation plots for LiDAR validation: For ground verification purposes, 48 plots of 30-meter radius were collected in 2013 as verification plots in two LiDAR blocks. In each plot diameter of all the tress with Diameter at Breast Height (DBH) > 5m were measured and species were recorded. The heights all trees with DBH > 5 cm were measured. Above-ground biomass for each plot was computed using tree height and diameter at breast height, based on species group-specific volume equations published by Sharma and Pukkala (1990).

7 Satellite data: The best available Landsat5 and Landsat7 data, based on minimizing cloud cover from 1999, 2002, 2006, 2009 and 2011, were used as the raw data for generating activity data. Landsat TM data were obtained from the USGS website (Http://glovis.usgs.gov) for the years 1999, 2002, 2006, 2009 and 2010/11. Landsat 5 data for the years after 2002 were chosen against Landsat 7 because the Landsat 7 data after 2002 have strips of data missing due to failure of Scan Line Correction (SLC) instrument. The downside with using Landsat 5 is it is less frequently available. Four satellite scenes are required to cover TAL. For 2006 TM 5 data for one scene from the far western part of TAL was not available therefore it was replaced with Landsat 7. All the scenes were selected from the leaf-on time period (Oct-Feb).

8 Forest growth values: We used IPCC default values for forest growth of natural dry tropical forests, for forests under 20 years of age in continental Asia,6.0tons of dry aboveground biomass per hectare (2.8 tons of carbon per hectare) to calculate sequestration from regeneration and enhancement of forests in a prior time period (IPCC 2006).

9 Land change verification – Persistent Change Monitoring: Land change data from MDA Information System's Persistent Change Monitoring (PCM) global dataset was also used to verify changes in landcover classes derived from the IMGTools analysis, mainly deforestation.

10 Land change verification – High resolution satellite imagery: Five-meter resolution RapidEye satellite data from 2010 was used to cross-check and validate forest conditions and landcover change. RapidEye. (2012). Satellite Imagery Product Specifications. Version 4.0. Retrieved from http://www.rapideye.com/upload/RE_Product_Specifications_ENG.pdf

11 Carbon stock base map for generating emission factors
Map of forest types and conditions from 2001 (Joshi, et. al., 2003) was used as the base map to delineate forest types and conditions.

12 Height Above Ground (HAG) model
Height above ground (HAG) model was developed for TAL by J. Stoker using LiDAR data collected for TAL and Landsat 7 satellite data. The model provides the vegetation height above the ground.

Appendix 2a: Carbon stocks in TAL districts during the RL period (includes both Above-ground and Below-ground pools)

	1999	2002	2006	2009	2011
Kahchanpur	7,000,200	6,638,408	6,605,653	6,524,923	5,570,518
Kailali	17,133,454	6,114,419	16,089,014	15,840,420	13,688,177
Bardia	10,235,757	10,119,641	10,078,442	9,993,210	9,143,351
Banke	11,586,631	11,251,747	11,168,704	10,482,760	10,327,936
Dang	12,580,179	11,871,031	11,712,213	10,414,189	10,170,867
Kapilbastu	6,329,630	5,894,798	5,863,784	5,584,231	5,480,324
Rupandehi	2,872,747	2,709,666	2,716,244	2,696,446	2,635,287
Nawalparasi	8,570,418	8,060,446	8,013,632	7,806,695	7,682,303
Chitwan	14,602,788	14,223,973	14,150,915	14,082,463	13,723,726
Parsa	7,451,418	7,399,811	7,379,042	7,340,079	7,102,187
Bara	4,450,993	4,343,108	4,316,701	4,260,142	3,819,469
Rautahaut	3,650,271	3,538,242	3,502,625	3,414,963	2,871,435

Appendix 2b: Carbon emissions (tC) by district for each of 4 time intervals (includes both Above-ground and Below-ground pools)

District	1999-2002	2002-2006	2006-2009	2009-2011	Total
Kahchanpur	361,792	32,756	80,729	954,405	1,429,682
Kailali	1,019,035	25,405	248,594	2,152,244	3,445,277
Bardia	116,115	41,200	85,232	849,859	1,092,406
Banke	334,884	83,043	685,943	154,824	1,258,695
Dang	709,148	158,818	1,298,024	243,323	2,409,312
Kapilbastu	434,833	31,013	279,553	103,907	849,307
Rupandehi	163,081	(6,579)	19,798	61,159	237,460
Nawalparasi	509,972	46,814	206,937	124,392	888,115
Chitwan	378,815	73,059	68,451	358,738	879,063
Parsa	51,607	20,769	38,963	237,892	349,231
Bara	107,885	26,407	56,559	440,673	631,524
Rautahaut	112,029	35,617	87,662	543,527	778,835

Appendix 2c: Percent of Carbon stock loss (tC) by district for 4 time intervals (includes both Above-ground and Below-ground pools)

	1999-2002	2002-2006	2006-2009	2009-2011	Loss in 12 years	Annual lost
Kahchanpur	5.2%	0.5%	1.2%	14.6%	21.5%	1.8%
Kailali	5.9%	0.2%	1.5%	13.6%	21.2%	1.8%
Bardia	1.1%	0.4%	0.8%	8.5%	10.9%	0.9%
Banke	2.9%	0.7%	6.1%	1.5%	11.2%	0.9%
Dang	5.6%	1.3%	11.1%	2.3%	20.4%	1.7%
Kapilbastu	6.9%	0.5%	4.8%	1.9%	14.0%	1.2%
Rupandehi	5.7%	-0.2%	0.7%	2.3%	8.4%	0.7%
Nawalparasi	6.0%	0.6%	2.6%	1.6%	10.7%	0.9%
Chitwan	2.6%	0.5%	0.5%	2.5%	6.1%	0.5%
Parsa	0.7%	0.3%	0.5%	3.2%	4.7%	0.4%
Bara	2.4%	0.6%	1.3%	10.3%	14.7%	1.2%
Rautahaut	3.1%	1.0%	2.5%	15.9%	22.5%	1.9%

Appendix 3 – Distribution of forest types in 12 TAL districts for 2011 in hectares

Classes	Kahchanpur	Kailali	Bardia	Banke	Dang	Kapilbastu	Rupendehi	Nawalparasi	Chitwan	Parsa	Bara	Rautahaut
Unclassified	93,993.8	155,987.6	110,431.8	90,309.6	168,016.2	106,866.4	107,910.1	137,877.0	125,280.2	62,652.2	85,952.6	82,100.8
Sal intact	30,522.8	76,787.4	49,737.6	56,456.1	58,108.9	35,282.8	16,999.5	50,595.8	94,325.5	47,430.8	24,873.3	17,986.8
Sal degraded	2,088.7	5,214.9	1,993.1	309.7	1,508.0	543.9	254.6	1,637.7	838.0	1,639.0	2,339.3	2,645.6
Salmixed intact	19,586.8	38,374.5	27,022.6	35,506.4	32,843.5	14,242.0	5,948.5	15,336.6	13,614.2	6,757.5	4,298.4	3,509.8
Salmix degraded	1,751.7	3,340.2	1,976.9	452.8	1,670.0	902.7	458.7	1,732.1	473.9	528.5	1,060.2	762.8
Othermix intact	369.1	5,782.7	390.3	964.7	6,179.1	375.3	37.7	0.0	581.9	2.9	0.5	0.0
Othermix degraded	81.5	881.1	50.0	13.4	1,253.0	203.7	1.5	0.0	255.0	0.8	0.3	0.0
Riverine intact	1,884.1	1,380.6	497.5	290.8	365.2	1,589.9	369.0	1,824.2	6,747.4	390.2	273.0	539.8
Riverine degraded	75.5	83.7	71.6	2.1	9.4	29.9	14.6	165.8	125.2	28.8	102.9	214.7
Non-forest	12,209.7	27,498.0	8,862.7	3,552.0	7,679.1	3,742.8	1,883.5	3,891.2	2,592.5	3,022.0	4,924.0	6,112.3
Cloud	1,243.3	3,175.6	1,721.0	9,188.1	17,185.1	1,945.3	454.1	3,246.9	1,935.1	229.6	105.0	75.6
Water/Shadow	1,199.9	3,453.7	644.2	441.7	1,299.4	434.7	180.3	760.3	735.6	119.3	126.7	120.1

Appendix 4 – Details on the Reference Emission Level (RL) calculations for Above- and Below-ground carbon pools

	Activity data(ha)				Emission	Carbon Emission (tC)				Total
Activity	**1999-2002**	**2002-2006**	**2006-2009**	**2009-2011**	**Factor tC/ha**	**1999-2002**	**2002-2006**	**2006-2009**	**2009-2011**	**Emission(tC)**
Sal Forest										
Deforestation 1	11,583	2,085	9,488	17,914	110.7	1,282,589	230,880	1,050,673	1,983,659	4,547,800
Deforestation 2	4,322	679	615	1,651	81.4	351,819	55,270	50,083	134,431	591,604
Deforestation 3		905	2,117	6,655	2.8	-	2,553	5,969	18,767	27,289
Degradation	10,831	1,342	3,141	17,488	29.3	317,648	39,361	92,132	512,898	962,039
Regeneration	24,635	35,951	6,313	10,008	(2.8)	(69,470)	(101,382)	(17,804)	(28,223)	(216,879)
Sal Mixed Forest										
Deforestation 1	8,487	2,291	10,588	20,332	86.1	730,734	197,260	911,642	1,750,642	3,590,278
Deforestation 2	7,632	1,395	964	1,927	68.8	525,124	95,969	66,312	132,623	820,028
Deforestation 3		1,996	3,405	12,821	2.8	-	5,628	9,603	36,155	51,385
Degradation	10,186	1,661	10,003	10,375	17.3	176,171	28,737	173,003	179,443	557,355
Regeneration	32,597	40,999	4,995	11,886	(2.8)	(91,923)	(115,616)	(14,087)	(33,520)	(255,146)
Other Mixed Forest										
Deforestation 1	2,029	273	2,661	3,308	87.5	177,451	23,876	232,752	289,376	723,455
Deforestation 2	674	175	514	284	67.3	45,358	11,763	34,618	19,111	110,850
Deforestation 3		174	870	1,536	2.8	-	491	2,454	4,331	7,276
Degradation	1,570	216	380	1,250	20.2	31,664	4,355	7,662	25,209	68,890
Regeneration	2,483	5,239	1,251	3,461	(2.8)	(7,003)	(14,774)	(3,527)	(9,760)	(35,063)
Riverine Forest										
Deforestation 1	918	160	255	1,663	80.4	73,794	12,854	20,518	133,699	240,865
Deforestation 2	458	59	39	163	46.7	21,418	2,754	1,800	7,619	33,591
Deforestation 3		76	147	752	2.8	-	214	413	2,120	2,747
Degradation	697	81	225	877	33.7	23,499	2,733	7,594	29,559	63,385
Regeneration	2,202	3,306	510	244	(2.8)	(6,210)	(9,322)	(1,439)	(688)	(17,659)
Total Above-ground carbon						**3,582,663**	**473,601**	**2,630,372**	**5,187,453**	**11,874,089**
				Total Above-ground carbon (tC) 12-yr time period						**11,874,089**
				Total Below-ground carbon (tC) 12-yr time period						**2,374,818**
				Total Above- and Below-ground carbon (tC) 12-yr time period						**14,248,907**
				Total Above- and Below-ground emissions (tCO2e) 12-yr time period						**52,245,991**
				Total Above- and Below-ground emissions (tCO2e) annual average						**4,353,833**