REDD Development in Cambodia— Potential Carbon Emission Reductions in a REDD Project

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Abstract: Foreseeing the importance of managing forests for climate change mitigation and sustainable development, the Royal Government of Cambodia has put strong commitment to managing its remaining forests under the new anticipated international climate change agreement on REDD+ mechanism. Forestry Administration in collaboration with Community Forestry International, and Terra Global Capital started a REDD project for Community Forestry sites in the northern province of Oddar Meanchey in 2007. Here, we report the methods and findings from our project and propose an appropriate framework for effective implementation in Cambodia. Ten drivers and six agents of deforestation and forest degradation were identified and each driver could be reduced by adopting appropriate project actions. Changes in deforestation, carbon stocks, and project emissions were estimated under baseline and project scenarios. Our results suggest that the project is likely to lead to the reduction of about 8.6 million tonne CO2 over 30-year project. Although policies and methods are available for implementing the project, sustained commitment and law enforcement play an increasingly important role in achieving real emission reduction and sustainable development.

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1. Introduction

As the implementation of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) is approaching the end in 2012, negotiations to replace the Kyoto protocol have been intensified in recent years. Amongst many other issues, avoiding emissions from tropical forests under the anticipated reduced emissions from deforestation and forest degradation, sustainable forest management, forest conservation, and enhancement of carbon sinks (REDD+ hereafter) mechanism have brought much international attention (Gullison *et al.*, 2007, Kindermann *et al.*, 2008, Sasaki and Putz, 2009, Sasaki and Yoshimoto, 2010). This is because tropical forests are responsible for the release of about 1.5-2.2 PgC year^{-1} or about up to 25% of the global carbon emissions (Houghton, 2003) and because the reduction costs are cheaper than that from other sectors (Sasaki and Yoshimoto, 2010). Due to concern over cross-border leakages, REDD+ agreements will be at national level but the REDD+ projects can be at national, regional or project (i.e. community) level provided that the amount of carbon emission reductions or verified emission reductions are large enough for project developers to be profitable.

REDD+ projects are relatively new concept of managing tropical forests for achieving multiple objectives such as reducing carbon emissions, increasing carbon sinks, improving ecosystem functioning, improving the living condition of forest-dependent communities, and generating carbon-based revenues for sustainable development. Since the adoption of Bali Action Plan in 2007, many REDD+ projects have been initiated or implemented across the tropics (see The Climate, Community and Biodiversity Project Design Standards at http://www.climate-standards.org for ongoing approved and reviewed projects). Nevertheless, how deforestation and forest degradation can be avoided and the potential amounts of carbon emission reductions resulting from such

avoided actions are not widely known.

Here, we describe and analyse ongoing REDD+ project activities in Cambodia with special emphasis on a project being implemented in the northern province of Cambodia near border with Thailand. Aiming at providing a first analysis of REDD project in Cambodia, our analysis could form a basis for further project development and assessment of related carbon reductions from the REDD+ project activities. As Cambodian government is very committed to sustainable management of its remaining forest resources under the new climate agreements, our findings could help inform the decision making with regards to REDD+ implementation and impacts. The paper is structured as follow: recent REDD development and projects are reviewed following by a case study in Cambodia. The latter starts by a brief introduction to forest resources and on-going REDD projects in Cambodia. After describing methods for data collection and analysis, results, discussions, and conclusion are described.

2. Forests in Cambodia

Covering 10.7 million ha or about 59.1% of the country's total land area, five major forest types are recognized in Cambodia. They are evergreen, semi-evergreen, deciduous, inundated and mangrove forests. Inundated and mangrove forests are strictly prohibited from commercial logging because of their importance to multiple ecosystem services. Annual deforestation rate was estimated at 0.7% between 1993 and 2003 (Sasaki, 2006) and 0.5% between 2002 and 2006.

Permanent forest estate in Cambodia is classified as production forest, protection forest, and conversion forestland. Production forest includes concession and non-concession forests for commercial timber harvesting, forests for rehabilitation, reserve forestland for reforestation or plantation, reserved forest for restoration or regeneration, logged-over

forest (degraded) and community forests with agreements. Protection forest includes reserved forest for special ecosystem services, forest for research, forest for water regulation, forest for watershed protection, recreational forest, botanical gardens, and religious forest. Conversion forest includes secondary vegetation that has not been designated for use by any governmental sector. Cambodia imposed commercial logging ban in 2002 and this ban remains effective until today. However, illegal logging has been frequently reported, suggesting if timber supply is cut off (due to REDD policy) in light of economic development, alternative sources of supply must be sought, otherwise illegal logging could not be halted.

Three REDD projects have been initiated in Cambodia, namely Community Forestry Carbon Project covering 67,853 ha in Oddar Meanchey (OM) Province, the REDD Carbon Project in Seima Protected Forest covering 187,000 ha in Mundulkiri Province, and the REDD Carbon Project in Prey Long Production Forest covering 520,000 ha in Kampong Thom Province. Only Project Design Document for REDD project in OM province was submitted to the Voluntary Carbon Standard (VCS) and the Climate, Community and Biodiversity Alliance (CCBA) for validation.

3. Methods and Materials

3.1. Location

Located in the North bordering with Thailand, Oddar Meanchey province (see Fig.1) is a heavily forested province having a total forest cover of 457,131 ha or about 68.8% of the provincial area. Four major forest types are recognized in this province, namely dry evergreen forest semi-evergreen forest, deciduous forest, and open forest. Semi-evergreen and evergreen forests lost about 5.7% and 2.7% annually

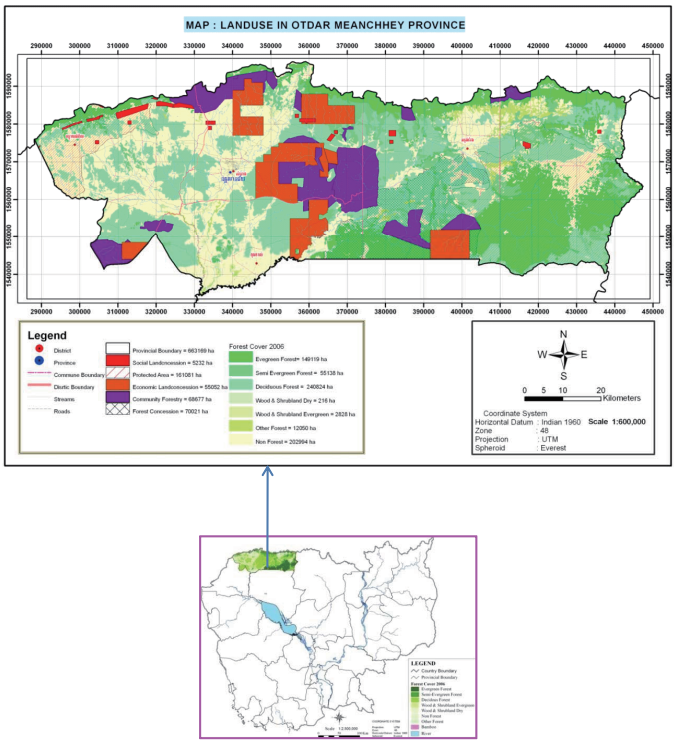

Figure 1. Location map of Oddar Meanchey province

between 2002 and 2006, respectively (Tab.1). In contrast, area of open forest increases about 27.5% per year over the same period suggesting logging was carried out in the area. On average, area of all forests declined about 1.9% annually between 2002 and 2006.

Forest degradation in the province has been initiated since the area was logged by Thai logging concessions between 1991 and 1995 (Poffenberger *et al.*, 2009). Population in this province was low before 1998 when the area was still part of the stronghold Khmer Rouge guerrilla. However as Khmer Rouge guerrilla movement came to an end in

Table 1. Forest area changes in Oddar Meanchey province (2002-2006)

Land type	2002 (ha)	2006 (ha)	Change (%) Total	Annual
Total forest				
Area	495,725	457,131	-7.8	-1.9
Percentage (%)	*74.8*	*68.9*		
Evergreen forest	166,935	149,119	-10.7	-2.7
Semi-evergreen forest	71,319	55,138	-22.7	-5.7
Deciduous forest	251,728	240,824	-4.3	-1.1
Open forest	5743	12,050	109.8	27.5
Barren land	167,440	206,034	23.0	5.8
Total	**663,165**	**663,165**	**0.0**	**0.0**

1998, the province's forests became the most popular destination for migrants from more populated areas of Cambodia. The rural population in Oddar Meanchey province increased from 56,198 people in 1998 to 166,609 people in 2008 representing an annual growth rate of 9.2%. This rapid growth is likely to lead to more destruction of the remaining forests if appropriate policies and management are not in place.

3.2. Project Description

In 2007, Community Forestry International (CFI, an international NGOs) presented a REDD design concept for 60,245 ha of forests in Oddar Meanchey province to the Forestry Administration (FA) and the Technical Working Group on Forests and Environment (TWG-FE), a joint government-donor coordinating group. FA and donor-community endorsed the project and the project design work began in January 2008 by CFI with support from the TWG-FE provided in April 2008.

Table 2. Forest communities and total land areas inside the project site

Name	CF Size	Forest Area						Non-forest
		Evergreen		Mix/Deciduous		Total Forest Area		
	(ha)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(%)
Angdoung Bor	6,114.0	0.0	0.0	5,930.6	97.0	5,930.6	97.0	3.0
Chhouk Meas	383.0	302.6	79.0	72.8	19.0	375.4	98.0	2.0
Dung Beng	1,843.0	737.2	40.0	976.8	53.0	1,714.0	93.0	7.0
Ou Yeay Kaov	960.0	873.6	91.0	0.0	0.0	873.6	91.0	9.0
Phaav	2,025.0	1,923.8	95.0	20.3	1.0	1,944.1	96.0	4.0
Prey Srorng	6,344.0	4,567.7	72.0	1,205.4	19.0	5,773.1	91.0	9.0
Prey Srors	1,605.0	1,508.7	94.0	0.0	0.0	1,508.7	94.0	6.0
Ratanak Ruka	12,733.0	509.3	4.0	11,459.7	90.0	11,969.0	94.0	6.0
Rolus Thom	6,443.0	3,994.7	62.0	193.3	3.0	4,188.0	65.0	35.0
Romdoul Veasna	6,009.0	3,545.3	59.0	60.1	1.0	3,605.4	60.0	40.0
Samaky	1,079.0	992.7	92.0	64.7	6.0	1,057.4	98.0	2.0
Sangkrous Preychheu	4,151.0	3,694.4	89.0	249.1	6.0	3,943.5	95.0	5.0
Sorng Rokavorn	18,164.0	1,634.8	9.0	15,439.4	85.0	17,074.2	94.0	6.0
Total	67,853.0	24,284.8	35.8	35,672.2	52.6	59,957.0	88.4	11.6

The formal authorization of the project was issued by the Council of Ministers in May 2008. As reported in our project design document (PDD) currently under validation by the CCBA (http://www.climate-standards.org/projects/) and the VCS, total area covered by this project is 67,823 ha. The project consists of 13 forest communities whose total areas range from 383 ha to as high as 18,164 ha (Tab.2).

Table 3. Partners and their roles in the project

Partner	Role
Forestry Administration (FA)	Seller of carbon on behalf of Royal Government of Cambodia. Participate in project design. Responsible for implementation of project actions, administering project funds and conducting monitoring activities. Support forest protection and enforcement, guarantee security of CF areas, capacity building for local communities, stakeholder consultation and conducting forest inventories. Daily administration of all project activities.
PACT	Assisting the FA with coordination of project actions. Participate in project design. Facilitation between various stakeholders, ensuring accountability, transparency in use of revenues, and good governance. Support with training of local communities, stakeholder consultation and integration. Designing and conducting social appraisals, and support with conducting forest inventories.
Children's Development Association (CDA)	Support with implementation of project actions in the field. Support with training of local communities, stakeholder consultation and integration.
Terra Global Capital (TGC)	Participate in project design. Carbon calculations, development of Project Design Documents, creation of management system to gather monitoring data, technical assistance. Designing forest inventory plan. Monetization and marketing of project carbon credits as a broker.
Clinton Climate Initiative (CCI)	Technical partner and funder.
Sonnenschein Nath & Rosenthal LLP	Legal advice on Emission Reduction Purchase Agreement
Community Forestry International (CFI)	Project identification and design, research and monitoring
TWG-FE	Project review and control, approval of future project actions.
Buddhist Monk Association	Facilitate cooperation with Sorng Ruka Vonn CF
Communities of Oddar Meanchey	Protect and manage forest/CF resources. Assist in planning and implementing activities to improve livelihoods and forest quality.

Two types of forests are found in the project site (Tab.2). This project is aimed at demonstrating that empowered communities can control drivers of deforestation, demonstrating that REDD revenues can have an impact in alleviating poverty with delivery of benefits to the local level, and developing sufficient capacity for local implementation of

REDD post 2012. The project has 10 partners and their names and roles are given in Table 3.

3.3. Methods

There are several technical components for REDD+. However, baseline and additionality are the most important, and therefore we focus these two elements in more details.

3.3.1 Baseline

Carbon stocks estimate: Forest inventory was carried out in evergreen and semi-evergreen (mixed and deciduous forest) forests in the project site. Totally, 206 plots of 50m × 50m size were successfully measured. Carbon stocks (CS) are the product of dry wood biomass obtained from this inventory and carbon content (0.5 MgC Mg^{-1}). Respectively, MgC is converted to MgCO2 by a factor of 44/12 or 3.67.

Baseline Deforestation: baseline deforestation or deforestation without the project was estimated using remote sensing technique. Data of forest cover changes in the project site were available for 1990, 2000, 2003, 2004, and 2006. The rates of Baseline Deforestation (BD) for this project are assumed to be the same rates for forests in the OM province. Changes in forest area of each forest type is estimated by

[1] $$FA_i(t) = FA_i(0) \times e^{-k*t}$$

and

[2] $$BD_i(t) = \Delta FA_i(t)$$

where

$FA_i(t)$: Area of forest i at time t (ha). i is evergreen or mixed forests

k: Rate of deforestation. k is assumed to decrease 50% when

$FA_i(t) = BD_i(t)$

Based on available data of forest area in 1990, 2000, 2003, 2004, and 2006, average deforestation rates are 2.7% (k=0.027) and 5.7% (k=0.057) for evergreen and mixed forests, respectively.

Project Deforestation: In order to predict the change in forest covers under the project activities in the project site, the following equations developed by Terra Global Capital are used

[3] $$PD_i(t) = RPI(t) \times BD_i(t)$$

[4] $$RPI(t) = 1 - \sum_{d=1}^{nd} RDI_d(t)$$

[5] $$RDI_d(t) = \sum_{a=1}^{na} r_a(t) \times E_{a,d} \times C_d$$

where

$PD_i(t)$: Project rate of deforestation in stratum i at year t (within the project area) in ha yr^{-1}

$RPI(t)$: relative impact of all project activities on deforestation at time t in %

$BD_i(t)$: baseline rate of deforestation in stratum i at time t (ha yr^{-1}). $BD_i(t)$ was obtained based on remote sensing analysis on Landsat images available in 1990, 2000, 2003, 2004, and 2006

$RDI_d(t)$: relative impact of a driver d on deforestation for year t of the crediting period

nd: total drivers of deforestation (see Tab.4)

na: total number of project actions (activities to reduce the driver of deforestation) (see Tab.5a, Tab.5b)

$r_a(t)$: adoption rate or relative degree of activity for action a during year t. If a is 100%, it indicates that the activity can not be more efficient in reducing deforestation (see Tab.6)

$E_{a,d}$: the effectiveness of project action a to reduce deforestation driver d (see Tab.4)

C_d : the relative importance of driver d in deforestation (see Tab.7)

Table 4. Effectiveness of project action a to reduce deforestation driver d ($E_{a,d}$ in Eq. [5])

Driver of Deforestation (d)	Project Actions a (unit: %) 1	2	3	4	5	6	7	8	9	10	Total
1. Forest clearing for land sales	0	0	100	0	0	0	0	0	0	0	100
2. Conversion to cropland	0	50	0	5	0	0	30	0	10	0	95
3. Conversion to settlements	0	75	0	0	0	0	0	0	0	0	75
4. Fuel-wood gathering	0	0	25	0	8	25	0	0	0	0	58
5. Annual Forest fires induced to clean the land	0	20	20	0	0	0	0	25	0	25	90
6. Hunters inducing forest fires	0	0	50	0	0	0	0	0	0	25	75
7. Illegal logging for commercial on-sale	0	0	90	0	0	0	0	0	0	0	90
8. Timber harvesting for local use	0	20	50	20	0	0	0	0	0	0	90
9. Economic land concessions	100	0	0	0	0	0	0	0	0	0	100
10. Timber concessions	100	0	0	0	0	0	0	0	0	0	100
Total reduction in deforestation	0	27	39	2	1	3	8	3	3	4	

Note
Project Actions (na=1, 2, …, 10) refers to
1. Reinforcing land-tenure, 2. Land-use plans, 3. Forest Protection, 4. ANR,
5. Fuel-efficient Stoves, 6. Mosquito Nets, 7. Agricultural Intensification,
8. Water Resource Development Projects, 9. NTFP Development,
10. Fire Prevention, and Total Impact Reduction

Carbon emissions due to deforestation can be therefore estimated by

[6] $$CE_{baseline}(t) = BD_i(t) * CS_i$$

[7] $$CE_{project}(t) = PD_i(t) * CS_i$$

where

$CE_{baseline}(t)$: carbon emissions without project (baseline emissions due to deforestation)

$CE_{project}(t)$: carbon emissions under the project (project emissions due to deforestation)

Table 5a. Project actions and resulting reductions of the drivers of deforestation and forest degradation

Project Actions	Description	Reduction in Driver
Project Action 1: Strengthening Land-tenure	The land-tenure is enforced through Community Forestry Agreements. These were signed in May 2009, during the second year of the crediting period. Therefore, a rate of 50% was assumed for this year. They are automatically renewed for 15 years unless the land is not managed according to the agreement.	This action is likely to result in 100% reduction of drivers 9, 10 and 11
Project Action 2: Land-use Plans	Land-use plans are fully supported by the project proponents from the first year of the project. However, it is expected that a period of 5 years is necessary before the full effect (rate) of land use plans is reached due to the often challenging negotiations to design a broadly accepted land-use plan.	This action is likely to result in reductions of 25% for driver 2, 50% for driver 3, 25% for driver 5 and 25% for driver 8
Project Action 3: Forest Protection	Forest protection measures are fully funded for the whole project period. It is assumed that full effect, or rate, of forest protection will be reached after 3 years, when all participating communities will have acquired experience to protect the forests most effectively.	This action is likely to result in reductions of 100% for driver 1, 25% for driver 4, 20% for driver 5, 50% for driver 6, 90% for driver 7, and 50% for driver 8
Project Action 4: Assisted Natural Regeneration	Assisted natural regeneration activities consist of (1) silvicultural activities such as thinning, removal of exotic and invasive species, and coppicing, and (2) enrichment planting. Silvicultural activities are planned for years 3-20, while enrichment planting is planned for years 3-30. During the first year, a number of pilot activities are planned to find out the most effective way to optimize the regeneration. Therefore, the rate of the first year is set to 50%.	This action is likely to result in reductions of 5% for driver 2, 20% for driver 8
Project Action 5: Introduction of Fuel-efficient Stoves	The project plans to distribute 500 fuel-efficient stoves annually for year 3 until 10. It is assumed that a fuel efficient stove has a lifetime of about 3 years. Therefore, from year 5 onwards, when the project activity has the greatest effect, on average 1,500 stoves will be active. During years 3-10, 500 stoves are anticipated to become defunct while still 500 stoves are introduced by the project. After 10 years, no more stoves are distributed, and the activity rate will go down with 500 per year. However, around 10 years, it is assumed that 33% of the people that once had a fuel-efficient stove will purchase or maintain a fuel-efficient stove due to the higher efficiencies, and the fewer time required to gather fuel-wood. This represents around 5% of all the households in the project area.	This action is likely to result in reductions of 7.5% for driver 4

Table 5b. Project actions and resulting reductions of the drivers of deforestation and forest degradation

Project Actions	Description	Reduction in Driver
Project action 6: Introduction of Mosquito Nets	Analogously to fuel-efficient stoves, mosquito nets are introduced from years 3 until 10. About 700 mosquito nets per year will be distributed. Similarly to fuel-efficient stoves, a lifetime of 3 years is anticipated, while no mosquito nets will remain in use in the project after subsidizing by the project has terminated.	This action is likely to result in reductions of 25% for driver 4
Project Action 7: Agricultural Intensification	Agricultural intensification measures are planned from years 3-20. Every year, 60 new farmers will be introduced in the system. In addition, it will take time to build out marketing networks for alternative crops and commodities. Therefore, the effect of agricultural intensification will increase linearly until year 20.	This action is likely to result in reductions of 30% for driver 2
Project Action 8: Water Resource Development Projects	Natural resource management practices are fully planned from year 3 until the end of the project. Due to the nature of the projects, measures will be instantly effective.	This action is likely to result in reductions of 20% for driver 5
Project Action 9: NTFP Development	Non-timber forest product development activities are supported during years 3-20. Similar as to agricultural intensification measures, a period of 10 years is assumed before these will be fully effective because marketing networks must be developed, etc. A final adoption rate of 50% is assumed after terminating the project's support for these activities.	This action is likely to result in reductions of 10% for driver 2
Project Action 10: Fire Prevention	Fire prevention activities are planned from year 4 of the crediting period until the end of the project. A learning period of 5 years is assumed until fire prevention activities are fully effective.	This action is likely to result in reductions of 25% for driver 5, and 25% for driver 6

3.3.2 Major Project Emissions

Project emissions refer to emissions from the project implementing activities such as emissions from vehicles for patrolling the whole project site, clearing a proportion of land for fire prevention, emissions from agricultural intensification (use of fertilizers), and biomass removal for carrying out assisted natural regeneration (ANR) and other enrichment planting activities. Based on Project Design Doc-

Table 6. Relative degree of activity and adoption rates during the project course ($r_a(t)$ in Eq. [5])

Year	Project Action a (unit: %)									
	1	2	3	4	5	6	7	8	9	10
2007	0	0	0	0	0	0	0	0	0	0
2008	0	20	20	0	0	0	0	0	0	0
2009	50	40	40	0	0	0	0	0	0	0
2010	100	60	60	100	33	33	10	100	100	100
2011	100	80	80	100	66	66	20	100	100	100
2012	100	100	100	100	100	100	30	100	100	100
2013	100	100	100	100	100	100	40	100	100	100
2014	100	100	100	100	100	100	50	100	100	100
2015	100	100	100	100	100	100	60	100	100	100
2016	100	100	100	100	100	100	70	100	100	100
2017	100	100	100	100	100	100	80	100	100	100
2018	100	100	100	100	66	66	90	100	100	100
2019	100	100	100	100	33	33	100	100	100	100
2020	100	100	100	100	33	0	100	100	100	100
2021	100	100	100	100	33	0	100	100	100	100
2022	100	100	100	100	33	0	100	100	100	100
2023	100	100	100	100	33	0	100	100	100	100
2024	100	100	100	100	33	0	100	100	100	100
2025	100	100	100	100	33	0	100	100	100	100
2026	100	100	100	100	33	0	100	100	100	100
2027	100	100	100	100	33	0	100	100	100	100
2028	100	100	100	50	33	0	90	100	66	100
2029	100	100	100	50	33	0	80	100	33	100
2030	100	100	100	50	33	0	70	100	33	100
2031	100	100	100	50	33	0	60	100	33	100
2032	100	100	100	50	33	0	50	100	33	100
2033	100	100	100	50	33	0	40	100	33	100
2034	100	100	100	50	33	0	30	100	33	100
2035	100	100	100	50	33	0	30	100	33	100
2036	100	100	100	50	33	0	30	100	33	100
2037	100	100	100	50	33	0	30	100	33	100

ument (PDD) currently being reviewed and validated by the CCBA (http://www.climate-standards.org/projects/), total carbon emissions from the above activities are 403,263 MgCO2, 150,168 MgCO2, 128,003 MgCO2, and 250,947 MgCO2 year^{-1} per project timeframe

Table 7. The Relative importance of driver in deforestation (C_d in Eq. [5])

Driver of Deforestation	Contribution (C_d)
1. Migrant encroachment	30%
2. Conversion to cropland	30%
3. Conversion to settlements	10%
4. Fuel-wood gathering	10%
5. Forest fires induced to clean the land	5%
6. Hunters inducing forest fires	5%
7. Illegal logging for commercial on-sale	5%
8. Timber harvesting for local use	5%
9. Large economic land concessions	-
10. Timber concessions	-

or about 13,442.1 MgCO2 year^{-1}, 5,005.6 MgCO2 year^{-1}, 4,266.8 MgCO2 year^{-1}, and 8,364.9 MgCO2, respectively for emissions from vehicles, fire prevention, agricultural intensification, and ANR and enrichment planting activities.

4. Results

Our study focuses only on carbon emissions from deforestation. Carbon increases through improved forest management, fire prevention, enrichment plantings, and assisted natural regeneration are not included. Further, carbon emissions due to leakages are also excluded.

4.1. Carbon Stocks

Analytical results of the inventory data indicate that, on average carbon stocks in the project site range from 448.8 MgCO2 ha^{-1} in evergreen forest to 230.3 MgCO2 ha^{-1} mixed forests (semi-evergreen). Carbon stocks in non-forest land are estimated at 9.7 MgCO2 (Tab.8).

Table 8. Dry wood biomass and carbon stocks in project site

Forest	Dry Wood Biomass (Mg ha^{-1})	Number of Plots	Standard Error of the Mean (Mg ha^{-1})	Carbon Stocks (CS) (MgCO2 ha^{-1})
Evergreen forest	244.8	65	20.5	448.8
Mixed forest	125.6	92	7.0	230.3
Non-forest	5.3	49	1.8	9.7
Total		206		

Carbon stocks in both forests are within the range of previous studies in Cambodia where average carbon stocks are between 393.0 to 478.9 MgCO2 ha^{-1} (Sasaki, 2006). The values of carbon stocks in table 8 are used for calculating carbon emissions or emission reductions in the project site.

4.2. Drivers of deforestation

In order to estimate carbon emission reduction potentials with or without project activity, drivers of deforestation and forest degradation need to be analyzed. Drivers of deforestation has strong influence on the success of the REDD project activities. In Oddar Meanchey community forests (the project site), we identified 10 drivers of deforestation, namely forest clearing for land sales, conversion to cropland, conversion to settlements, fuel-wood gathering, annual forest fires induced to clean the land, hunters inducing forest fires, illegal logging for commercial on-sale, timber harvesting for local use, large economic land concessions, and timber concessions. Agents of the drivers include migrants, private companies, local community itself, hunters, soldiers, and outsiders (non-community member) (Tab.9). Agents of deforestation include migrants, private companies, local communities, hunters , soldiers, and other non-local communities (Tab.10).

Table 9. Agents and drivers of deforestation

Active Deforestation Driver	Deforestation Agents					
	Migrants	Private Companies	Local Communities	Hunters	Soldiers	Other Non-local
1. Forest clearing for land sales	yes		yes			
2. Conversion to cropland	yes	yes	yes			
3. Conversion to settlements	yes		yes			
4. Fuel-wood gathering	yes		yes			
5. Annual forest fires induced to "clean" the land			yes			
6. Hunters inducing forest fires				yes		
7. Illegal logging for commercial on-sale		yes			yes	yes
8. Timber harvesting for local use	yes		yes		yes	
9. Large economic land concessions		yes				
10. Timber concessions		yes				

4.3. Baseline deforestation and emissions

During the 30-year project cycle between 2008 and 2038 under the baseline scenario (without project), evergreen forest loses, on average about 437.4 ha year^{-1} while mixed forest loses about 886.8 ha year^{-1}. As forest area decline, rate of deforestation also decreases to 274.3 ha in 2038 from 616.5 ha in 2008, the starting year of the project (Fig.2). Totally under the baseline scenario, forest area in the project site decreases about 1,324.2 ha year^{-1} or 39,727.4 ha for 30-year project cycle. In terms of carbon emissions, evergreen forest emits 5.89 TgCO2 or about 196,303.7 MgCO2 year^{-1}, while mixed forest emits 6.13 TgCO2 or 204,241.5 MgCO2 year^{-1} (Fig.3) over the same period.

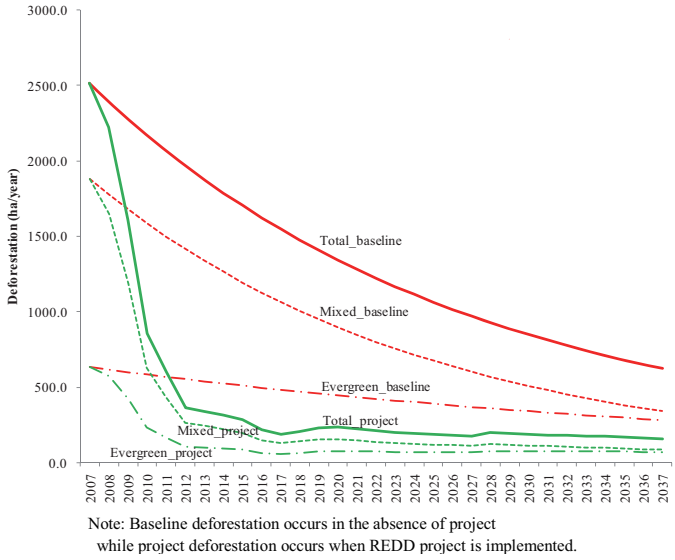

Figure 2. Annual deforestation under the baseline and project scenarios

4.4. Project deforestation

In order to reduce the drivers of deforestation, ten project actions are proposed. Each project action contributes to the reduction of the drivers of deforestation as shown in Table 4, Table 5a, Table 5b, Table 6 and Table 7. Based on variables in these tables, Relative Driver Impact (RDI) and Relative Project Impact (RPI) were calculated and their values are given in Table 10. Using the values of RPI, deforestation and carbon emissions under project activities were derived. Total deforestation over this 30-year project timeframe is estimated at 4,094.9 ha and 9,908.9 ha or about 136.5 and 330.3 ha year^{-1} for evergreen and mixed forests, respectively (Fig.2). In terms of carbon emissions, about 1,837,803.0 MgCO2 (61,260.1 MgCO2 year^{-1}) and 2,282,014.2 MgCO2 year^{-1} (76,067.1 MgCO2 year^{-1}) are emitted from the loss of

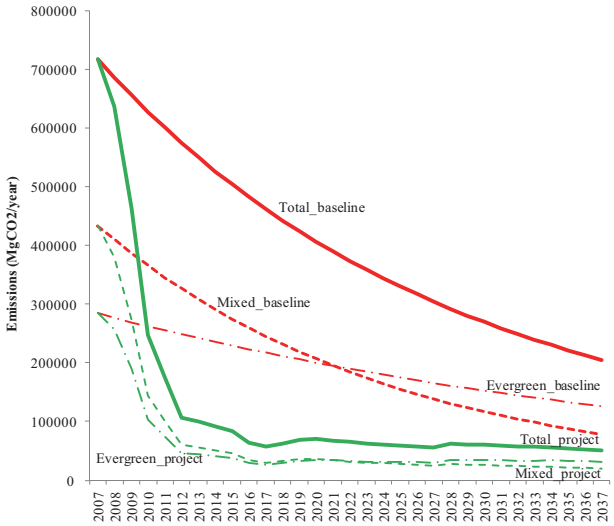

Figure 3. Annual emissions due to deforestation without project (baseline) and with project (project)

evergreen and mixed forests, respectively under the project activities. Altogether, project activities result in carbon emissions of 4,119,817.2 ha or 137,327.2 ha year^{-1} (Fig.3)

4.5. Emissions due to project activities

As stated early, total emissions from all project activities are 932,381 MgCO2 or about 31,079.4 MgCO2 year^{-1}. Since similar emissions also occur under the baseline (business as usual) scenario, it is therefore assumed that emissions under both scenarios are equal (no gain or no loss) for calculating carbon credits from avoided emissions (additionality).

4.6. Avoided carbon emissions

Our findings suggest that the project leads to 4,261,436.8 MgCO2 and 4,331,064.9 MgCO2 in evergreen and mixed forests or about 137,465.7

Table 10. Deforestation and carbon emissions under the project scenario

Year	Relative Deforestation Impacts for driver *d* (RDI_d) (unit: %)										RDI(t)	RPI(t)
	1*	**2***	**3***	**4***	**5***	**6***	**7***	**8***	**9***	**10***		
2007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
2008	0.0	5.7	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2	92.8
2009	15.0	11.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.4	70.6
2010	30.0	17.1	4.5	5.8	1.5	1.2	0.5	0.0	0.0	0.0	60.6	39.4
2011	30.0	22.8	6.0	5.8	3.0	2.5	0.9	0.0	0.0	0.0	70.9	29.1
2012	30.0	28.5	7.5	5.8	4.5	3.8	1.4	0.0	0.0	0.0	81.4	18.6
2013	30.0	28.5	7.5	5.8	4.5	3.8	1.8	0.0	0.0	0.0	81.9	18.2
2014	30.0	28.5	7.5	5.8	4.5	3.8	2.3	0.2	0.0	0.0	82.5	17.5
2015	30.0	28.5	7.5	5.8	4.5	3.8	2.7	0.7	0.0	0.0	83.4	16.6
2016	30.0	28.5	7.5	5.8	4.5	3.8	3.2	3.5	0.0	0.0	86.7	13.3
2017	30.0	28.5	7.5	5.8	4.5	3.8	3.6	4.1	0.0	0.0	87.7	12.3
2018	30.0	28.5	7.5	5.8	3.0	2.5	4.1	4.7	0.0	0.0	85.9	14.1
2019	30.0	28.5	7.5	5.8	1.5	1.2	4.5	4.7	0.0	0.0	83.7	16.3
2020	30.0	28.5	7.5	5.8	1.5	0.0	4.5	4.8	0.0	0.0	82.5	17.5
2021	30.0	28.5	7.5	5.8	1.5	0.0	4.5	4.8	0.0	0.0	82.6	17.4
2022	30.0	28.5	7.5	5.8	1.5	0.0	4.5	4.9	0.0	0.0	82.6	17.4
2023	30.0	28.5	7.5	5.8	1.5	0.0	4.5	4.9	0.0	0.0	82.7	17.3
2024	30.0	28.5	7.5	5.8	1.5	0.0	4.5	4.6	0.0	0.0	82.4	17.6
2025	30.0	28.5	7.5	5.8	1.5	0.0	4.5	4.4	0.0	0.0	82.1	17.9
2026	30.0	28.5	7.5	5.8	1.5	0.0	4.5	4.2	0.0	0.0	81.9	18.1
2027	30.0	28.5	7.5	5.8	1.5	0.0	4.5	4.2	0.0	0.0	81.9	18.1
2028	30.0	28.5	7.5	2.9	1.5	0.0	4.1	4.2	0.0	0.0	78.6	21.4
2029	30.0	28.5	7.5	2.9	1.5	0.0	3.6	4.2	0.0	0.0	78.1	21.9
2030	30.0	28.5	7.5	2.9	1.5	0.0	3.2	4.2	0.0	0.0	77.7	22.3
2031	30.0	28.5	7.5	2.9	1.5	0.0	2.7	4.2	0.0	0.0	77.2	22.8
2032	30.0	28.5	7.5	2.9	1.5	0.0	2.3	4.2	0.0	0.0	76.8	23.2
2033	30.0	28.5	7.5	2.9	1.5	0.0	1.8	4.2	0.0	0.0	76.3	23.7
2034	30.0	28.5	7.5	2.9	1.5	0.0	1.4	3.7	0.0	0.0	75.4	24.6
2035	30.0	28.5	7.5	2.9	1.5	0.0	1.4	3.5	0.0	0.0	75.2	24.8
2036	30.0	28.5	7.5	2.9	1.5	0.0	1.4	3.5	0.0	0.0	75.2	24.8
2037	30.0	28.5	7.5	2.9	1.5	0.0	1.4	3.4	0.0	0.0	75.1	24.9

Note:
*: Project Actions (*na*) undertaken to reduced the drivers of deforestation.
These project actions include
1. Reinforcing Land-tenure, 2. Land-use Plans, 3. Forest Protection,
4. Assisted Natural Regeneration (ANR), 5. Fuel-efficient Stoves, 6. Mosquito Nets,
7. Agricultural Intensification, 8. Water Resource Development Projects,
9. NTFP Development, and 10. Fire Prevention,

and 139,711.8 MgCO2 $year^{-1}$ for both forests. Altogether, total carbon emissions that could be avoided for the entire 30-year project are 8,592,501.7 MgCO2 or 277,177.5 MgCO2 $year^{-1}$ (Fig.4).

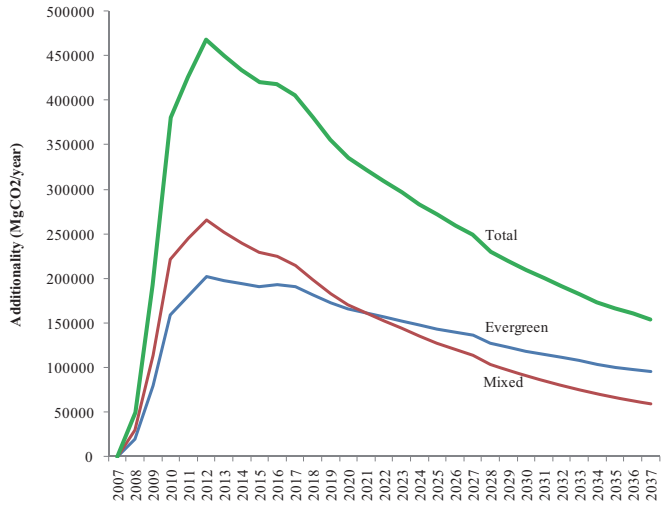

Figure 4. Avoided carbon emissions (additionality) due to REDD project

5. Discussions and Conclusion

Actual emission reductions depend on the assumptions of the future implementation of project actions in order to reduce the drivers of the deforestation. Such assumptions will have to be corrected when experience from the project is obtained, and therefore estimates of emission reductions would be affected. Furthermore, the carbon price volatility and uncertainty of carbon under REDD after 2012, as well as political uncertainty will also likely affect the implementation of the project. For example, the invasion of foreign troops along Cambodian border where the project site is will interrupt the ground implementation, monitoring and reporting activities.

Our study attempted to analyse the impacts of REDD project on carbon emission reductions through avoiding deforestation and forest degradation in community forests in northern Cambodia. The project

will result in reduction of carbon emissions at 8,592,501.7 MgCO2 per 30 years project cycle or about 277,177.5 MgCO2 annually. Carbon-based revenues from carbon sales will protect and improve the ecosystem functions of the forests, benefits to local communities and government as resource manager and owner. The Royal Government of Cambodia has fully supported the REDD (including REDD+) development in Cambodia. Therefore, this REDD can be implemented and replicated throughout Cambodia where up to 2 million ha of forests will be allocated to local communities for management under the REDD scheme.

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