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FOREST COVER TRENDS IN THE NORTHERN PLAINS OF CAMBODIA 2002-2010

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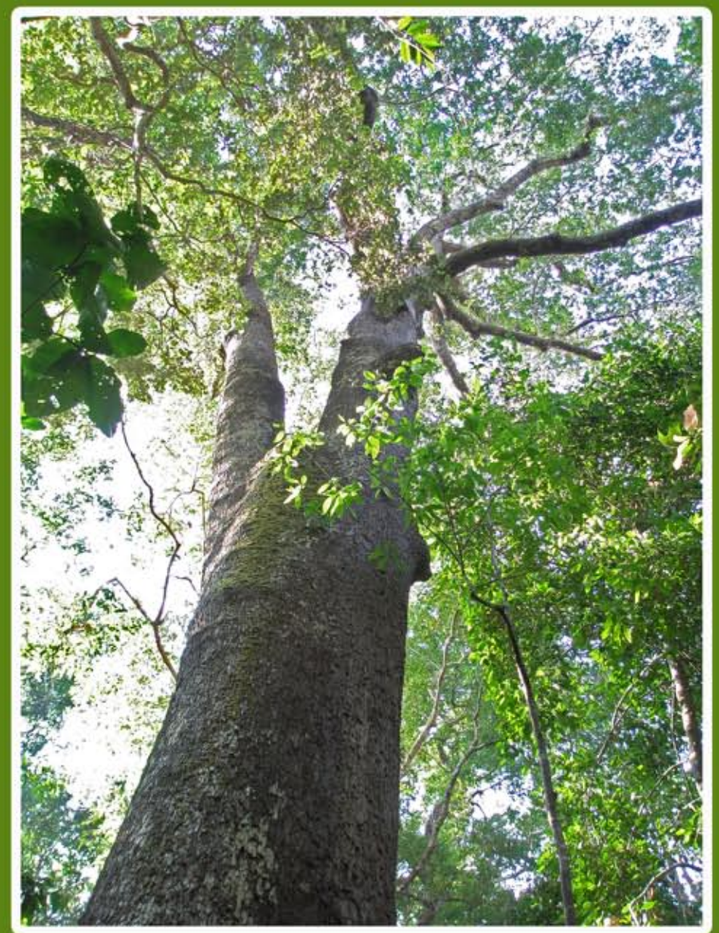

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Forest Cover Trends In The Northern Plains Of Cambodia 2002-2010

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CONTENTS

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Cover photograph: An emergent tree in the Northern Plains forests by Hugo Rainey.

ឯកសារស្តីពីអត្រាបំរែបំរួលគម្របព្រៃឈើភូមិភាគខាងជើងប្រទេសកម្ពុជា ពីឆ្នាំ ២០០២-២០១០

របាយការណ៍នេះនឹងបង្ហាញពីលទ្ធផលវិភាគនៃបំរែបំរួលគម្របព្រៃឈើនៅភូមិភាគខាងជើងនៃប្រទេសកម្ពុជាចាប់ពីឆ្នាំ ២០០២ ដល់ឆ្នាំ ២០១០ ។ ហើយក៏អាចយកទៅប្រើប្រាស់ជាវិធីសាស្ត្រក្នុងគម្រោងកាត់បន្ថយឧស្ម័នផ្ទះកញ្ចក់ផងដែរ។ ការសិក្សាគម្របព្រៃនេះគឺធ្វើឡើងនៅក្នុងតំបន់ពីរនៃព្រៃការពាររួមទាំងអតីតព្រៃសម្បទានចិន្តាប្លាយរូត និងតំបន់ក្រៅព្រៃការពារមួយចំនួនដែលតំបន់ទាំងនេះអាចស្ថិតក្នុងតំបន់ការពារទេសភាពភូមិភាគខាងជើង ព្រមទាំងត្រូវបានគ្រប់គ្រង និងការពារដោយគម្រោងព្រៃការពារចាប់តាំងពីឆ្នាំ ២០០២ និងពង្រឹងការគ្រប់គ្រងបន្ថែមទៀតចាប់តាំងពីឆ្នាំ ២០០៦ មក។ ការសិក្សាក៏បានផ្តោតទៅលើ ៦តំបន់ដែលនៅជុំវិញព្រៃការពារបន្ថែមទៀតព្រោះជាតំបន់ទ្រនាប់ដែលគម្រោងពុំទាន់បានធ្វើការគ្រប់គ្រងអោយបានល្អិតល្អន់នៅឡើយ។ ផ្ទាយរណបរូបភាពបានប្រមូលផ្តុំចំនួន ៤ ចំនុចចាប់តាំងពីឆ្នាំ (២០០២ ២០០៦ ២០០៩ និង ២០១០) ដើម្បីចាប់យកចំនុចប្រែប្រួលនៃគម្របព្រៃឈើ។ វិធីសាស្ត្រនៃការសិក្សាគម្របព្រៃនេះត្រូវបានធ្វើឡើងតាមរយៈនៃការប្រមូលផ្តុំពីរូបភាពដែលទទួលបានពីចំនុចនិមួយៗរួចបង្កើតបានជារូបភាពធំមួយ រូបភាពទាំងនេះក៏បានបញ្ចូលផងដែរនូវទិន្នន័យពិតមានវិទ្យាផ្សេងៗទៀតដើម្បីធ្វើការប៉ាន់ប្រមាណពីអត្រាថយចុះគម្របព្រៃឈើប្រចាំឆ្នាំទៅលើចំនុចនិមួយៗ នៃផ្ទាយរណបខាងលើ។

តាមការសិក្សាបានអោយដឹងថាអត្រាគម្របព្រៃថយចុះប្រចាំឆ្នាំនៅក្នុងតំបន់សិក្សាក្នុងរយៈពេលពីឆ្នាំ (២០០២-២០១០)គឺ 0.៧៩ %ហើយបើយើងពិនិត្យអត្រាថយចុះគម្របព្រៃប្រចាំឆ្នាំនៅក្នុងគម្រោងព្រៃការពារទាំងមូល គឺ 0.១៥% ហើយនៅក្នុងតំបន់ទ្រនាប់គឺ ១.៦៧% ។ សរុបមកទូទាំងតំបន់សិក្សាក្នុងគម្រោងតំបន់ទេសភាពភូមិភាគខាងជើង គម្របព្រៃដែលបានបាត់បង់ក្នុងរយៈពេលពីឆ្នាំ ២០០២ ដល់ ២០១០ គឺ ៧៥១១ ហិកតា (ស្មើនិង ១.៤៨% នៃផ្ទៃដីទាំងមូលដែលបានសិក្សា)ហើយដោយឡែកក្នុងតំបន់ទ្រនាប់គម្របព្រៃថយចុះ ១២.៥៥% ស្មើនិង ៤៦៤១៦ ហិកតា ហើយការកាប់រានដីព្រៃក្នុងតំបន់សិក្សាគឺតែងកើតមានជានិច្ច ។ អត្រានៃការថយចុះគម្របព្រៃឈើនៅ ក្នុងគម្រោងព្រៃការពារត្រូវបានវិភាគជាពីរដំណាក់កាលគឺពីឆ្នាំ ២០០២-២០០៦ មាន 0.១៦% និងពីឆ្នាំ ២០០៦-២០១០ មាន 0.២១% ហើយរយៈពេលដូចគ្នានេះដែរអត្រាថយចុះគម្របព្រៃឈើក្នុងតំបន់ទ្រនាប់ពីឆ្នាំ ២០០២-២០០៦ មាន ១.0៧ % និង ២.២៧ % ហើយទាំងពីរតំបន់រួមគ្នាតំបន់ព្រៃការពារ និងតំបន់ទ្រនាប់អត្រានៃការថយចុះគម្របព្រៃក្នុងឆ្នាំ ២០០៩-២០១០ គឺមានកំរិតខ្ពស់ជាងឆ្នាំមុនៗ ។

ដោយមានជំនួយពីថវិការបស់គម្រោងគឺបានកាត់បន្ថយច្រើនអត្រានៃការថយចុះគម្របព្រៃឈើក្នុងព្រៃ

ការពារពិសេសពីឆ្នាំ ២០០៦-២០០៩ ថ្វីបើអត្រានៃការថយចុះគម្របព្រៃក្នុងតំបន់ទ្រនាប់មានការកើនឡើងពិសេសចាប់ពីឆ្នាំ ២០០៩-២០១០ ដែល គម្រោងពិបាកគ្រប់គ្រងក្នុងរយៈពេលនេះ ។

រូបភាពចំនួនប្រាំពីរទីតាំងត្រូវបានបញ្ចូលរួមគ្នាដើម្បីវិភាគពីការបាត់បង់គម្របព្រៃឈើរួមមានដូចជាទីប្រជុំជន ភូមិដែលមានស្រាប់ ភូមិថ្មីដែលកាប់រានដោយជនចំណូលថ្មី តំបន់ដីសម្បទានសង្គមកិច្ចសំរាប់គ្រួសារទ័ពនិងទីបញ្ជាការ សំរាប់ធ្វើផ្លូវ ព្រៃឈើ ប្រភេទដី និងដីសម្បទានកសិឧស្សាហកម្ម ។ ដោយឡែកតំបន់ដាច់ស្រយាលមួយចំនួនការវិភាគអត្រានៃការថយចុះគម្របព្រៃឈើគឺមានកំណត់ ហើយក៏ដូចគ្នាដែរថវិកាដែលត្រូវចំណាយលើការគ្រប់គ្រងអត្រាថយចុះគម្របព្រៃឈើក៏មានគ្រប់គ្រាន់ល្មមផងដែរ ។ បើពិនិត្យមើលបច្ចុប្បន្ននេះទូទាំងតំបន់ការពារ តំបន់ដាច់ស្រយាលមួយចំនួនត្រូវបានកាត់បន្ថយជាបណ្តើរៗតាមរយៈនៃការអភិវឌ្ឍន៍ផ្លូវដែលនាំមកនូវការថយចុះនៃគម្របព្រៃឈើច្រើនហួស តំបន់ទ្រនាប់ព្រៃការពារនៅភូមិភាគខាងជើងប្រទេសកំពុងតែមានអត្រាថយចុះគម្របព្រៃឈើយ៉ាងឆប់រហ័សទាំងបច្ចុប្បន្ននិងនាឆ្នាំខាងមុខ។ ការដាក់សម្ពាធលើព្រៃឈើហាក់ដូចជាមានកាន់តែខ្លាំង ដូចមានលទ្ធផលបង្ហាញឆ្នាំ ២០០៩-២០១០ ស្រាប់ ហើយអត្រានៃការកាប់រានក៏អាចកើនឡើងផងដែរ ។ ឧទាហរណ៍ការ គំរាមកំហែងលើព្រៃឈើនៅទីតាំងព្រៃសម្បទាន និងទីតាំងទ័ពនៅក្នុងតំបន់ព្រៃការពារគឺអាចមានការកើនឡើង។ ការធ្វើអោយប្រសើឡើងវិញនូវគម្របព្រៃគឺជាប្រភពប្រាក់ចំណូលដែលបានតាមរយៈការលក់ឥណទានការបោន គឺជាវិធីសាស្ត្រតែមួយគត់ដែលអាចកាត់បន្ថយការថយចុះគម្របព្រៃឈើទៅថ្ងៃអនាគត ។

SUMMARY

Forest Cover Trends in the Northern Plains of Cambodia 2002-2010

We present results of an analysis of forest cover trends in the Northern Plains landscape in Cambodia from 2002 to 2010. This report will be used to inform development of a REDD project although the impact of this report will be influenced by the REDD methodology selected. The study focuses on two protected areas, a logging concession and an adjacent unzoned area in Preah Vihear province (together referred to as the CALM landscape), all of which have been under conservation management since 2002 with more intensive management since 2006. The study also focuses on six adjacent sectors (together referred to as the Buffer Area), which are not managed intensively for conservation. Satellite imagery was compiled from four points in time (2002, 2006, 2009 and 2010) to assess forest cover at each time period. The mosaic method was used to combine the various images from different sources into one single image for each year. Imagery was combined with other datasets to estimate annual deforestation rates across the landscape and for each sector.

The annual rate of deforestation across the study area for the whole period (2002-2010) was 0.79%. There is an order of magnitude difference in the annual rate of forest loss between the CALM landscape (0.19%) and the Buffer Area (1.67%). In the CALM landscape the total area of forest lost between 2002 and 2010 was 7,511 ha (1.48% of the original total forest area). The corresponding loss in the Buffer Area was 12.59% (46,416 ha). Deforestation has accelerated in the study area over time. Existing differences in the rates of forest loss at the start of the project have been magnified. From 2002-2006 the CALM landscape lost forest at an annual rate of 0.16% and from 2006-2010 it lost forest at an annual rate of 0.21%. In the same two periods the Buffer Area lost forest at an annual rate of 1.07% and 2.27% respectively. In both regions the rate of loss from 2009-2010 was much higher than in preceding years. The additional financing available for the project probably helped reduce the rate of forest loss inside the CALM landscape boundaries from 2006-2009. This was despite rates of forest loss increasing in the Buffer Area suggesting that there was increased pressure on the forest from drivers of deforestation. This pressure increased greatly from 2009-2010 and exceeded the capacity of the CALM project to cope during this period.

Seven main landscape features associated with deforestation were identified from a qualitative analysis: towns; existing villages; new villages created by immigrants; military concessions and bases; roads; forest and soil type; and agro-industrial concessions. Remoteness of each landscape sector appears to be a key characteristic, which limits the rate of deforestation. Adequate finance for management is also a necessary characteristic to control deforestation. As a whole, the landscape is becoming less and less remote due to road improvements, leading to increased levels of deforestation over time. Buffer Areas in the Northern Plains landscape may continue to suffer high rates of deforestation in future years. Pressures on the forest are likely to increase, as experiences in 2009 and 2010 show, and the rates of clearance could increase further. For example, pressure to place concessions and military bases within conservation areas may increase. Improving motivation for maintaining the integrity of conservation areas by generating revenue from sales of carbon credits from such sites may be an effective tool for limiting future deforestation.

ACRONYMS

AoI	Area of Interest
CALM	Conservation Areas through Landscape Management
CCBA	Climate, Community, Biodiversity Alliance
GIS	Geographic Information Systems
GDANCP	General Department Administration for Nature Conservation and Protection
FA	Forestry Administration
KPWS	Kulen Promtep Wildlife Sanctuary
Lao PDR	Lao People's Democratic Republic
MAFF	Ministry of Agriculture, Fisheries and Forestry
MLMUPC	Ministry of Land Management, Urban Planning and Construction
MoE	Ministry of Environment
MPWT	Ministry of Public Works and Transport
NTFPs	Non-timber forest products
ODM	Oddar Meanchay
PVH	Preah Vihear
PVPF	Preah Vihear Protected Forest
REDD	Reduced Emissions from Deforestation and Forest Degradation
RGC	Royal Government of Cambodia
SR	Siem Reap
ST	Stung Treng
VCS	Voluntary Carbon Standard
WCS	Wildlife Conservation Society

INTRODUCTION

The Wildlife Conservation Society (WCS) works with the Royal Government of Cambodia in two protected areas in the Northern Plains landscape, as part of the Conservation Areas through Landscape Management (CALM) Project[1] funded by the United Nations Development Programme/Global Environment Facility. The Northern Plains landscape is comprised of a mosaic of unique habitats that have disappeared from much of South-East Asia. Deciduous dipterocarp forests which once covered a large part of the region are now almost entirely restricted to Cambodia: the Northern Plains contain the largest expanse of this forest. Evergreen and semi-evergreen forests here form an important refuge for many threatened species, which have disappeared as a result of forest clearance in neighbouring countries. Important wetlands in the landscape are rejuvenated by annual floods and these are essential to the diversity of the landscape. This landscape supports a very diverse assemblage of over 40 of the world's most threatened species including Asian Elephants, wild cattle, Giant Ibis and three species of Critically Endangered vultures. Wildlife and natural resources in the Northern Plains landscape face a number of growing threats including land clearance, illegal logging, hunting and road construction.

The objective of this report is provide information on trends in forest cover from 2002 to 2010 with sufficient accuracy to inform feasibility assessments for a potential Reduced Emissions from Deforestation and Forest Degradation (REDD) project. The impact of this report on development of a REDD project will be strongly influenced by the choice of methodology under Voluntary Carbon Standard (VCS) and Climate, Community, Biodiversity Alliance (CCBA) guidelines. In particular, the choice of reference area, against which forest cover change in the CALM landscape is compared, will strongly influence how this report informs REDD project development. However, the methodology used in this report will normally be transferable to any appropriate area included in VCS and CCBA methodology in Cambodia.

During this period investment in conservation management in the CALM landscape increased. Activities to control land-grabbing and other factors influencing deforestation were implemented within the CALM landscape. This study assesses how conservation management may have controlled deforestation and compares forest cover inside the CALM landscape to areas adjacent to the landscape.

Monitoring forest cover allows assessment of management effectiveness and provides feedback to guide better management. Medium resolution satellite imagery combined with aerial photographs and existing land use data can be used to reliably estimate where forest has been recently cleared and give clues as to the main agents of change. This report also reviews the main drivers of deforestation in the Northern Plains landscape. This study does not assess forest degradation caused by factors such as logging and collection of timber for charcoal burning. Although logging is addressed by existing management activities in the CALM landscape, monitoring degradation is beyond the scope of medium-resolution remote sensing using current technology. Such an assessment is of interest for a REDD project design, but would require a separate study with different techniques.

[1] The CALM project is a partnership between the Wildlife Conservation Society (WCS), the Forestry Administration (FA) in the Ministry of Agriculture, Fisheries and Forestry (MAFF) and General Department Administration for Nature Conservation and Protection (GDANCP) in the Ministry of Environment (MoE) and other agencies and local non-governmental and civil society organisations.

METHODS

Study Area

The Northern Plains study area includes two regions (Figure 1): the first, the CALM landscape, has had substantial investment in conservation management over the whole study period, but at raised levels from 2006-2010; the second, named here the Buffer Area, has had little or no investment in conservation management.

The CALM landscape consists of four sectors. Two are conservation areas: Preah Vihear Protected Forest (PVPF) (established 2002) and the sector of Kulen Promtep Wildlife Sanctuary in Preah Vihear province (KPWS-PVH) (established 1993). Chendar Plywood is a logging concession under moratorium, which acts as a corridor between the two main protected areas of the landscape. A small area of unclassified Permanent Forest Estate lies adjacent to PVPF, and is included in this report under the name 'PVPF Extension Area'. It holds similar habitats to PVPF, is subject to similar management and has potential to be added to the Protected Forest in the future. The CALM landscape was first studied by the various partners in 1999 and has been under conservation management at varying intensities since then, particularly from 2006 onwards. GDANCP manages KPWS-PVH and the FA manages PVPF, Chendar Plywood and the PVPF Extension Area. There is a programme to develop either tenure or title for the residential and agricultural lands of most communities, which lie inside the CALM landscape.

The Buffer Area consists of two main management unit types. Firstly, the two sectors of Kulen Promtep Wildlife Sanctuary in Siem Reap and Oddar Meanchay provinces managed by GDANCP without CALM support. Here there is some conservation management, but it is less intensive than inside KPWS-PVH or other sectors of the CALM landscape due to funding constraints. Secondly, a 5 km wide buffer, surrounding the whole of PVPF, KPWS (all sectors), Chendar and the PVPF Extension Area, excluding areas in Thailand and Lao PDR. This 5 km buffer is under the management and ownership of many different entities including private individuals, military and civil government agencies and commercial businesses. Most of the 5 km buffer is notionally Permanent Forest Estate and under the Forestry Law (2002) of the Kingdom of Cambodia should have a similar level of legal protection to forest within PVPF and KPWS.

Table 1. Names and abbreviations of all sectors in the study area.

Site	Abbreviation
Chendar Plywood	Chendar
Preah Vihear Protected Forest Extension Area	PVPF Extension
Preah Vihear Protected Forest	PVPF
Kulen Promtep Wildlife Sanctuary - Preah Vihear sector	KPWS-PVH
Kulen Promtep Wildlife Sanctuary - Oddar Meanchay sector	KPWS-ODM
Kulen Promtep Wildlife Sanctuary - Siem Reap sector	KPWS-SR
5 km buffer - Preah Vihear sector	Buffer-PVH
5 km buffer - Stung Treng sector	Buffer-ST
5 km buffer - Oddar Meanchay sector	Buffer-ODM
5 km buffer - Siem Reap sector	Buffer-SR

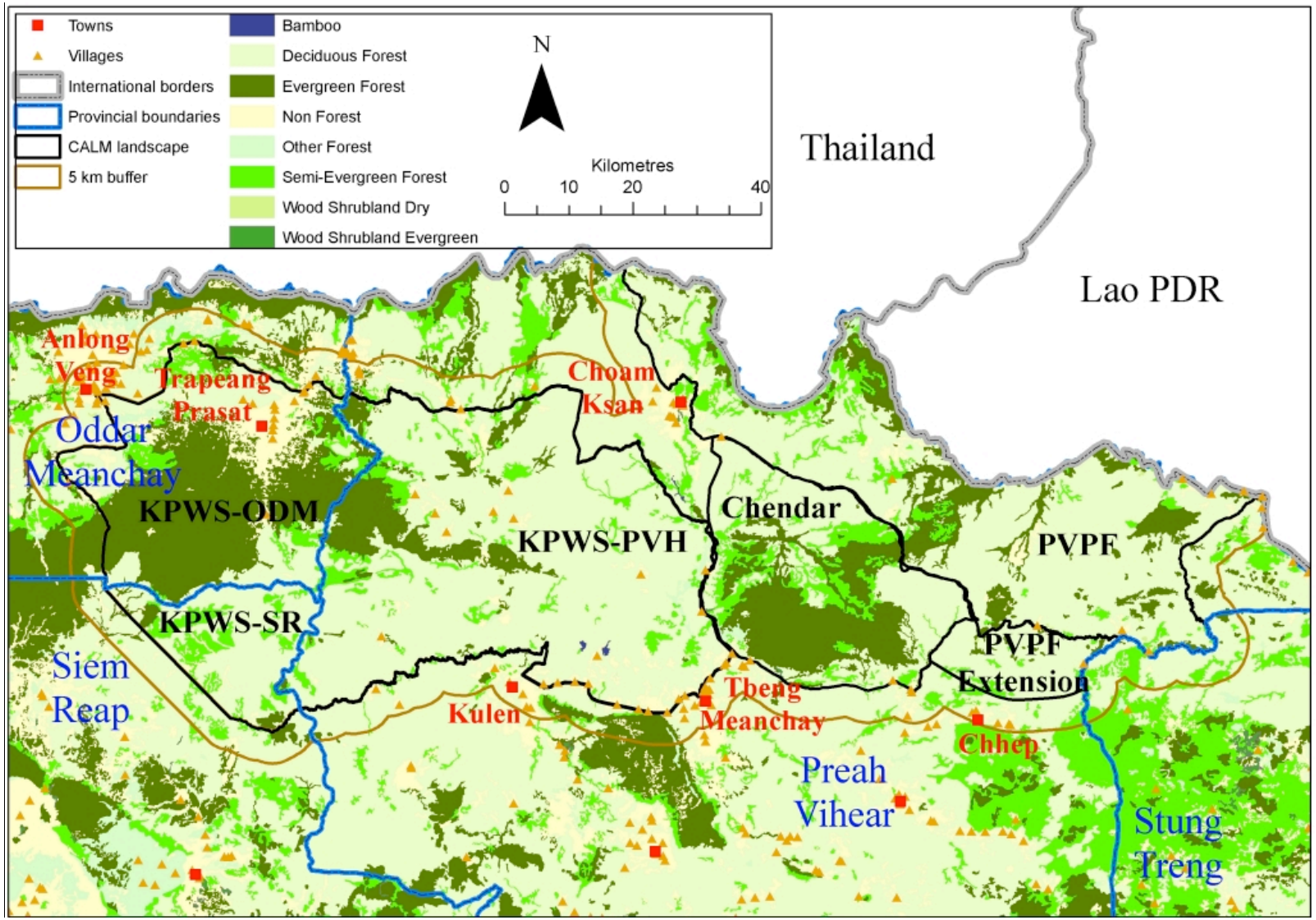

Figure 1. Map of the Northern Plains sectors including the CALM landscape, Buffer Area, land management units and the 5 km buffer area. Provinces are labelled in blue, the main Northern Plains sectors are labelled in black and the main towns are labelled in red. Towns are labelled in the study area only. New military settlements and new villages in the landscape are not mapped. Forest cover data is based on 2006 Forestry Administration data.

Remote Sensing Methodology

High spatial resolution remote sensing data have been used extensively in discriminating between agricultural land uses, but their applications are more limited in forest monitoring in tropical conservation areas because of their low temporal resolution and the high cost associated with them. An adequate alternative is the use of medium spatial resolution data; their wider area of swath and higher frequency of revisit make monitoring of forest changes potentially highly feasible over large areas. In this analysis, Landsat and Aster satellite images were used to estimate forest cover at four nominal time points: 2002, 2006, 2009 and 2010. Imagery from the Cambodian dry season (December – March) was used as this is likely to show greater contrast between forest and non-forest areas and lower cloud cover. A semi-automated technique was used to capture the boundaries of non-forest patches that were identified using a combination of techniques in the Area of Interest (AoI). The methodology has been developed by the WCS Cambodia Programme over several years of work in multiple landscapes. It has found effective in the complex mosaic of habitats prevalent in the study site. Data from three sensors (Landsat TM, Landsat ETM+ and ASTER; Table 2) were analysed in comparison to high quality ancillary datasets (Table 3) for the whole study area.

Table 2. Master images and reference dates for polygon delineation.

Dry seasons	Reference year	Master image dates	Sensor (resolution)
2001/02	2002	10 Jan 2002 with 17 Feb 2001,19 Jan 2002, 20 Feb 2002, 06 Jan 2003	Landsat 7 (30 m) ASTER (30 m)
2005/06	2006	21 Jan 2006 07 Feb 2006	ASTER (30 m) Landsat 5 (30 m)
2008/09	2009	30 Jan 2009 29 Jan 2009	Landsat 5 (30 m) Landsat 7 (30 m)
2009/10	2010	24 Dec 2009 with 09 Jan 2010* 05 Mar 2010 with 17 Feb 2010*	Landsat 7(30 m) Landsat 7(30 m)

*The second image was used to fill sensor defects in the first image.

Imagery covering the whole of the landscape in the 2002 dry season was not available, so for some sections imagery was used from a different sensor and from the 2001 and 2003 dry seasons (Table 2). For 2010, the best data were available from Landsat 7 (ETM+), which suffers from scratch lines due to a persistent sensor error. Gaps were filled with temporally adjacent images using standard techniques. The mosaic method was used to combine the various image fragments into a single image for the study area for each year. Two other types of satellite image were often available for each dry season, and these have been used as ancillary data in the visual assessments.

Interpretation delineated two vegetation classes, forest and non-forest. The national definition of forest under the Marrakech Accords[2] is an area of land covering at least 0.5 ha with at least 10% cover of trees taller than 5 m. This is a slightly lower percentage of crown cover than is used by the Forestry Administration in their assessments (20%; Brun 2009). Non-forest is all land with canopy forest cover less than this, and so includes natural grassland, bare land, water, swidden agriculture, rice paddy, other agricultural land, settlements and deforested areas. Mature tree plantations are not a feature of this landscape at present.

The image pre-processing and interpretation processing were done using the software package ERDAS IMAGINE. Subsequent data analysis was performed using ArcView 3.3 and ArcGIS 9.2; the methodological steps are shown in Table 4. Images were geomatrically corrected to an image from a reference year, which was in turn corrected to the rivers in the national hydrology dataset.

[2] As submitted to the United Nations Framework Convention on Climate Change under the Kyoto Protocol's Clean Development Mechanism

A general accuracy of +/-1 pixel was achieved. The data flow process for interpreting images to identify non-forest areas is shown in Figure 2. Note that the minimum mapping unit for forest was 1 ha, due to the limitations of medium-resolution imagery, since an area of 3x3 pixels (90 m x 90 m, 0.81 ha) is the smallest unit that can realistically be identified. This differs slightly from the 0.5 ha criterion used in national definitions but at a landscape level does not result in any bias in deforestation statistics. An accuracy assessment has not yet been carried out, but is planned for the coming months. The same methods gave overall accuracy of about 93% when applied in the Seima Protection Forest landscape in Mondulkiri, which has a similar range of habitats (Evans *et al.* 2009).

Table 3. Ancillary datasets, used for interpretation and validation, were compiled from a variety of sources.

Data	Sources	Additional Information
Aerial photographs	MLMUPC - Department of Geography	2001/2004
Satellite imagery	Landsat TM, ETM+, ASTER additional images	Various years
Administration data, including towns and villages	MLMUPC - Department of Geography (updated by WCS)	2005
Protected area boundaries	MAFF, MoE	2001
Land use	Japan International Corporation Agency (JICA)	2000
Roads	MPWT (updated by WCS)	2008
Forest cover	Forestry Administration	2002/2006
Forest cover	Existing WCS/FA unpublished analyses in PVPF, Chendar and parts of KPWS using automated techniques	various years
Agricultural parcel boundaries	WCS/FA/MoE field surveys as part of participatory land use planning work in selected villages	various years
Rivers and wetlands	MLMUPC - Department of Geography	2005

Table 4. Summary of methodological steps for image analysis.

Step	Process
1	Collection of all available comparative datasets (satellite imagery, aerial photographs, road and settlement locations, field parcel maps, etc). Selection of master and supporting images for each time point.
2	ERDAS IMAGINE used for geomatic correction, Adjustment of projection. Error gaps filled.
3	Visual identification of non-forest patches followed by capture of boundaries using a semi-automatic approach with the "Seed Tool" extension in ArcGIS 9.3. For years after 2002, the non-forest polygons of the previous time point were taken as the baseline and any observed changes were incorporated by editing, or if necessary recapturing, polygon boundaries.
4	Peer review, visualization, editing, and topology correction.
5	Application of geo-processing to finalise non-forest polygons.
6	Mapping and map production process.

Analysis

The non-forest category includes land deforested by humans and a range of natural non-forest land cover types, such as grasslands and wetlands. Historical deforestation by humans prior to 2002 cannot be separated from natural non-forest. However, all net forest loss after 2002 can be presumed to be caused by humans. This is the key information required for management planning and measurement of project success.

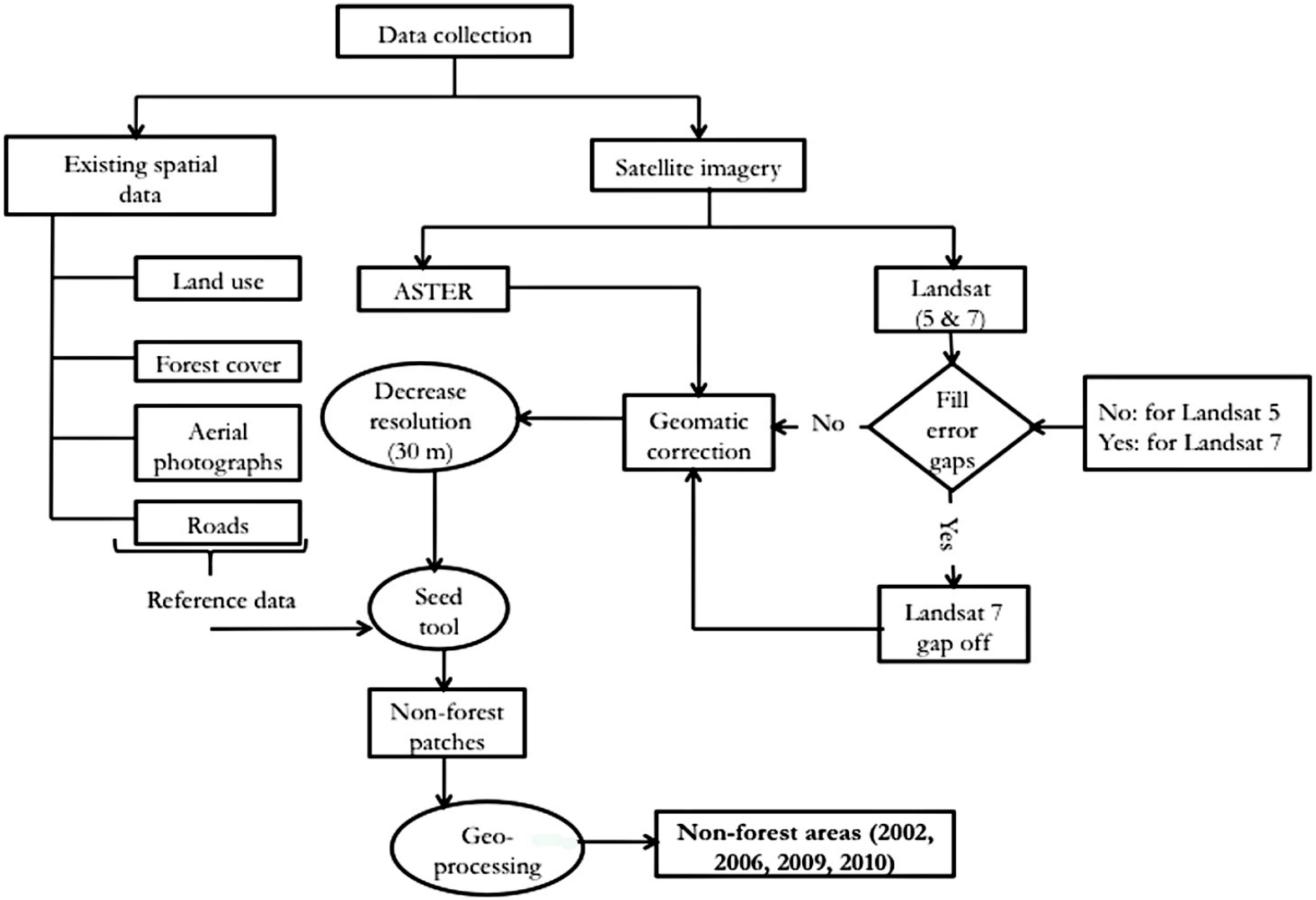

Figure 2. Flow chart summarising data processing.

RESULTS

Extent of Deforestation in the Northern Plains.

Areas of forest and non-forest calculated for each of the years with data are presented in Table 5a for each of the management units of the CALM landscape and in Table 5b for each sector of the Buffer Area. Maps of forest loss from 2002 to 2010 are presented in Figure 3. Rates of forest loss as a proportion of the initial forest area for each time period are presented in Table 6. Annualised rates of forest loss are also given to aid comparison in Table 7.

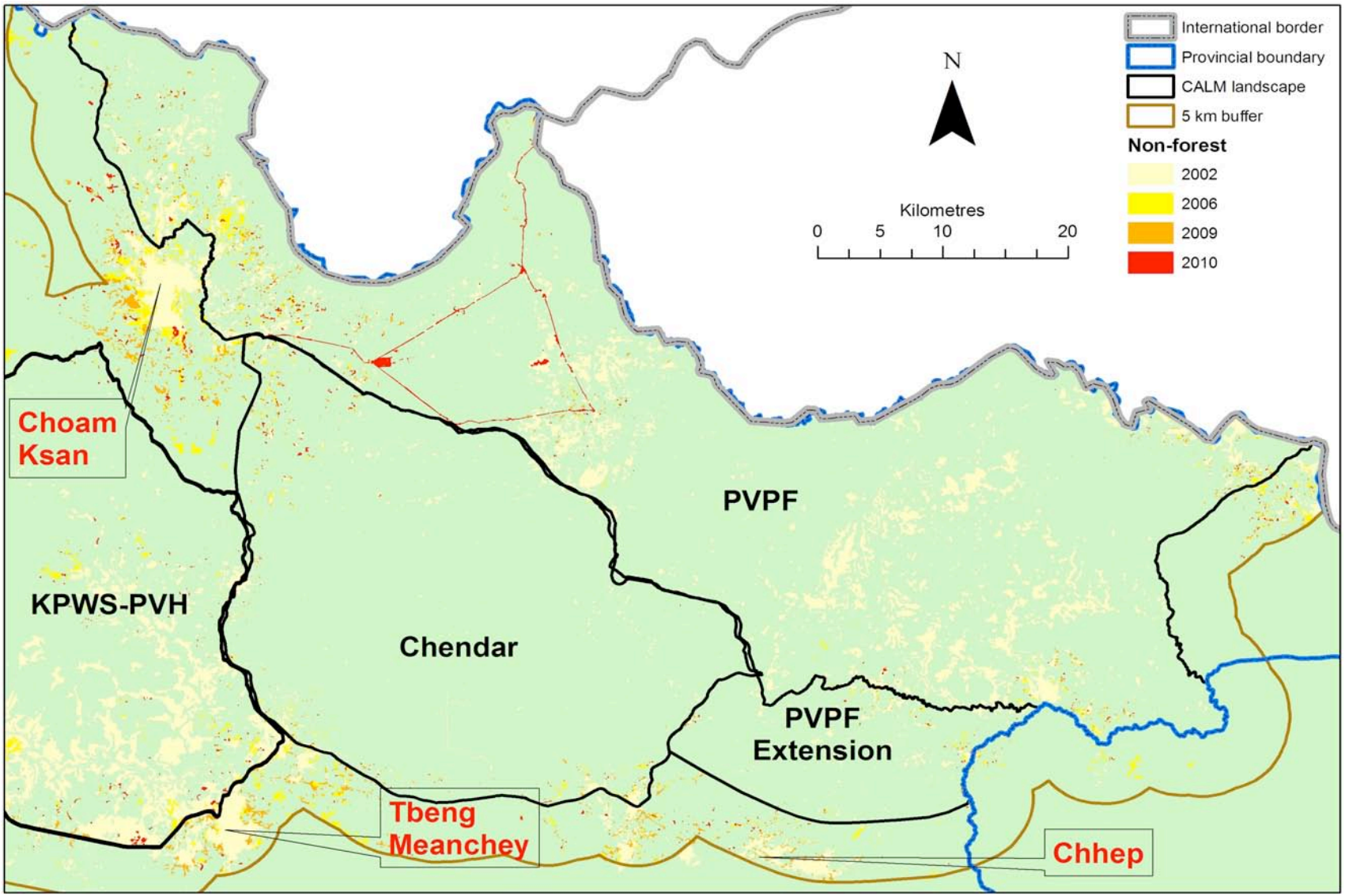

Figure 3a. Forest cover change 2002-2010 in PVPF, Chendar, PVPF extension and Buffer Area. Note large areas of natural non-forest inside PVPF indicated by non-forest in 2002. Recent anthropogenic forest clearance has been greatest in concessions in north-west PVPF and around Choam Ksan town.

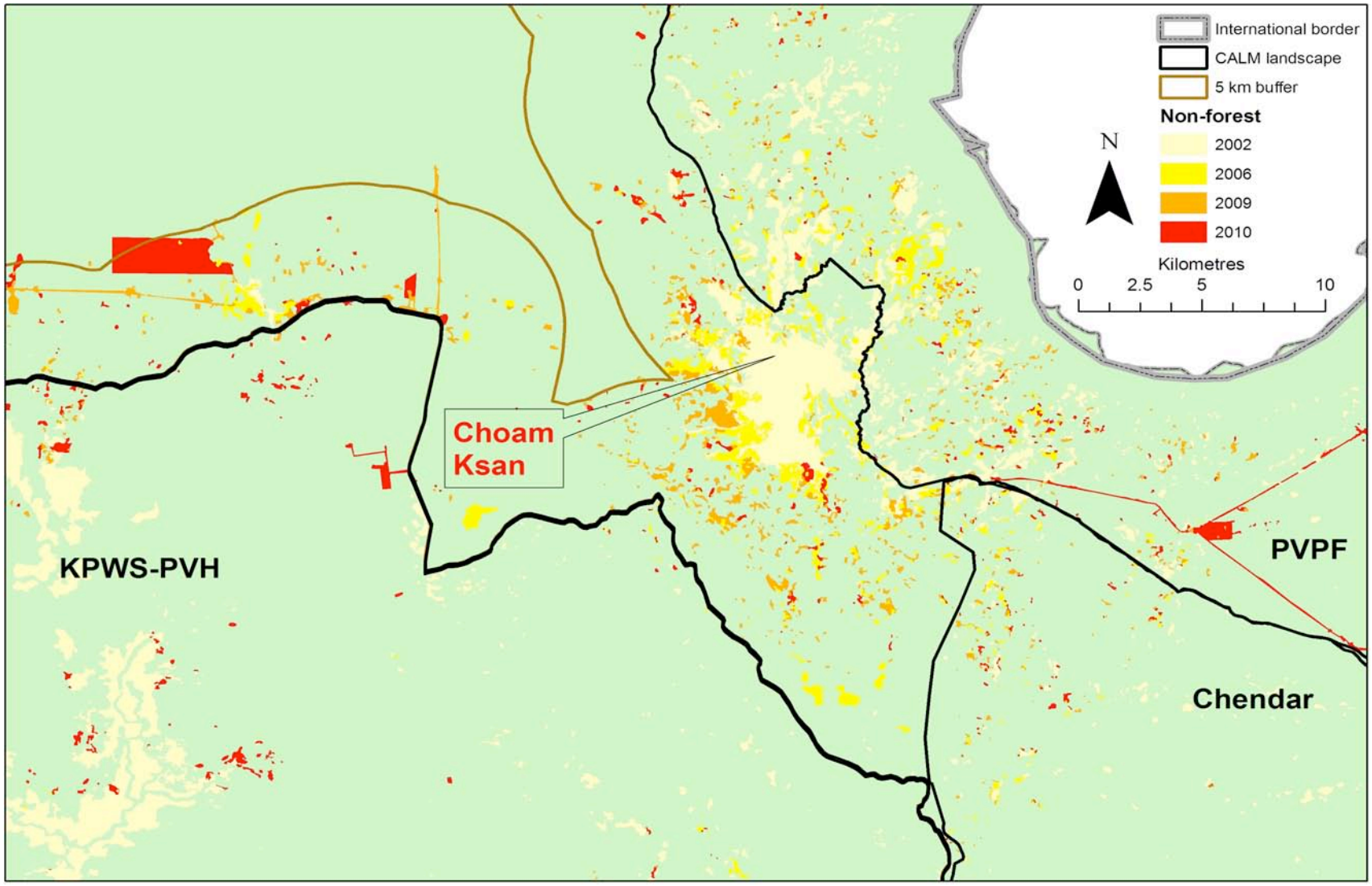

Figure 3b. Detail of deforestation in north-west PVPF, north-east KPWS and adjacent areas. Old and relatively slow deforestation around Choam Ksan town is clearly visible. Rapid deforestation from recently declared land concessions in PVPF, KPWS and Buffer Area is visible as medium-sized rectangular red areas. The largest red area in the Buffer Area is a rubber plantation concession that has been cleared of forest recently, other concessions are military bases.

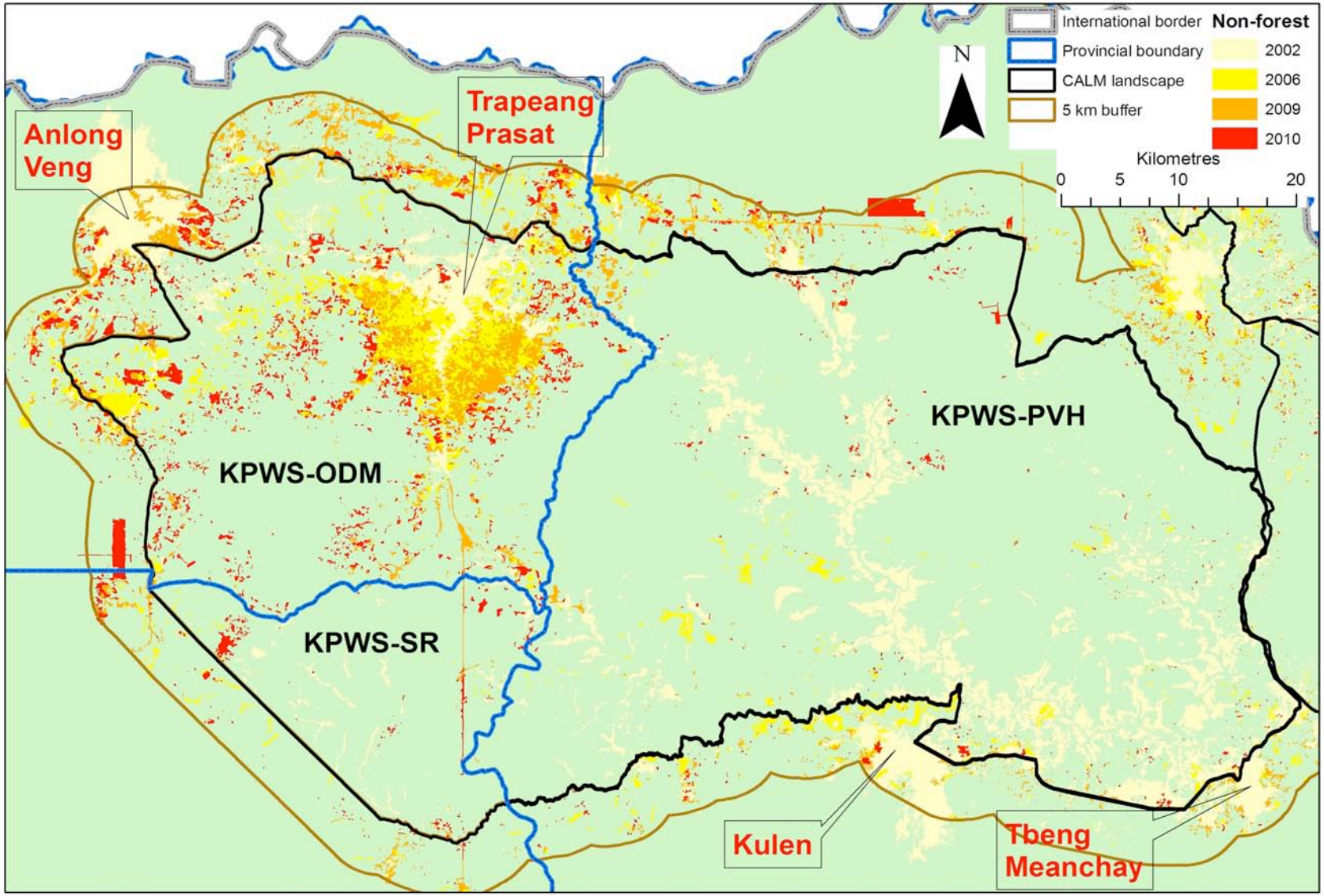

Figure 3c. Forest cover change 2002-2010 in KPWS and Buffer Area. Note rapid clearance of forest in KPWS-ODM and Buffer-ODM around Trapeang Prasat and Anlong Veng with little check since 2002. More recent forest clearance in KPWS-SR and adjacent Buffer Area lies along old and new roads (which will increase forest loss further) and in commercial concessions in the Buffer Area.

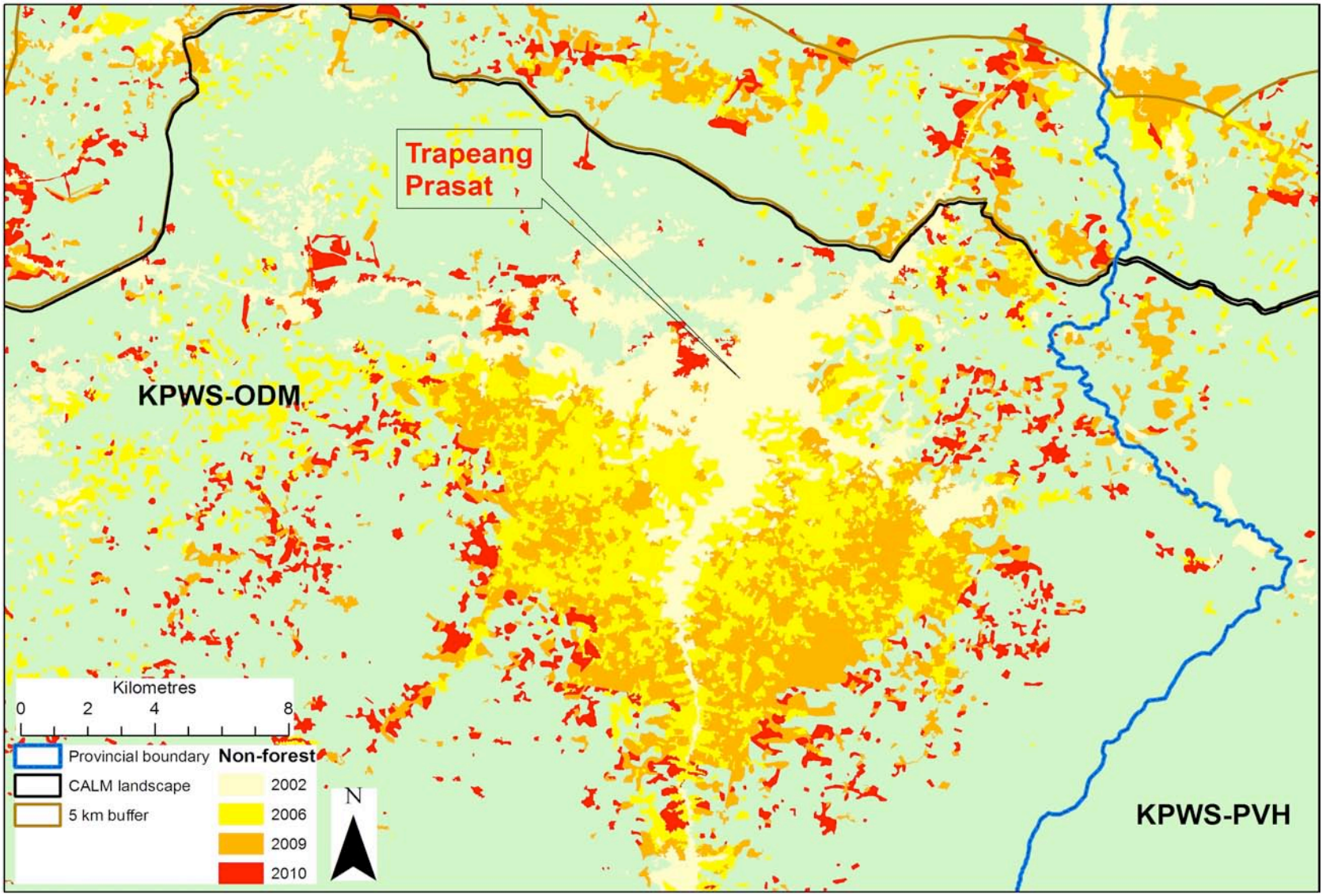

Figure 3d. Detail of deforestation around Trapeang Prasat in KPWS-ODM. The pace and scale of expansion of forest loss here is such that it has threatened forest cover in adjacent KPWS-PVH, although effective and timely intervention has controlled this for now.

Table 5a. Forest and non-forest areas in the CALM landscape 2002-2010.

Site	Total Area ha	Forest 2002		Forest 2006		Forest 2009		Forest 2010	
		ha	%	ha	%	ha	%	ha	%
Chendar	104,268	102,400	**98.21**	102,259	**98.07**	102,031	**97.85**	101,884	**97.71**
PVPF Extension	23,503	22,571	**96.03**	22,501	**95.73**	22,432	**95.44**	22,404	**95.32**
PVPF	189,986	172,297	**90.69**	171,128	**90.07**	170,246	**89.61**	169,305	**89.11**
KPWS-PVH	240,585	211,429	**87.88**	209,534	**87.09**	208,720	**86.76**	207,593	**86.29**

Site	Total Area ha	Non-Forest 2002		Non-Forest 2006		Non-Forest 2009		Non-Forest 2010	
		ha	%	ha	%	ha	%	ha	%
Chendar	104,268	1,868	**1.79**	2,009	**1.93**	2,237	**2.15**	2,384	**2.29**
PVPF Extension	23,503	933	**3.97**	1,003	**4.27**	1,071	**4.56**	1,100	**4.68**
PVPF	189,986	17,689	**9.31**	18,858	**9.93**	19,740	**10.39**	20,682	**10.89**
KPWS-PVH	240,585	29,156	**12.12**	31,051	**12.91**	31,865	**13.24**	32,992	**13.71**
Total area (forest)		508,697	**91.11**	505,422	**90.52**	503,430	**90.16**	501,185	**89.76**
Total area (non-forest)		49,646	**8.89**	52,922	**9.48**	54,913	**9.84**	57,158	**10.24**
Total area (forest and non-forest)	558,343								

Table 5b. Forest and non-forest areas in the Buffer Area 2002-2010.

Site	Total Area ha	Forest 2002		Forest 2006		Forest 2009		Forest 2010	
		ha	%	ha	%	ha	%	ha	%
KPWS-ODM	126,637	118,165	**93.31**	107,493	**84.88**	99,373	**78.47**	93,583	**73.90**
KPWS-SR	42,700	41,306	**96.73**	41,247	**96.60**	41,082	**96.21**	40,400	**94.61**
Buffer-OM	46,749	41,446	**88.66**	40,093	**85.76**	34,876	**74.60**	31,866	**68.16**
Buffer-PVH	140,764	125,456	**89.13**	122,383	**86.94**	117,531	**83.50**	115,712	**82.20**
Buffer-SR	24,012	23,629	**98.40**	23,373	**97.34**	22,729	**94.66**	22,143	**92.22**
Buffer-ST	18,862	18,677	**99.02**	18,599	**98.61**	18,574	**98.47**	18,560	**98.40**

Site	Total Area ha	Non-Forest 2002		Non-Forest 2006		Non-Forest 2009		Non-Forest 2010	
		ha	%	ha	%	ha	%	ha	%
KPWS-ODM	126,637	8,471	**6.69**	19,144	**15.12**	27,263	**21.53**	33,054	**26.10**
KPWS-SR	42,700	1,394	**3.27**	1,453	**3.40**	1,619	**3.79**	2,301	**5.39**
Buffer-OM	46,749	5,303	**11.34**	6,656	**14.24**	11,873	**25.40**	14,883	**31.84**
Buffer-PVH	140,764	15,307	**10.87**	18,380	**13.06**	23,233	**16.50**	25,052	**17.80**
Buffer-SR	24,012	383	**1.60**	639	**2.66**	1,283	**5.34**	1,868	**7.78**
Buffer-ST	18,862	185	**0.98**	263	**1.39**	288	**1.53**	302	**1.60**

Total area (forest)		368,679	**92.23**	353,188	**88.36**	334,165	**83.60**	322,263	**80.62**
Total area (non-forest)		31,044	**7.77**	46,535	**11.64**	65,559	**16.40**	77,461	**19.38**
Total area (forest and non-forest)	399,724								

Table 6. Rates of forest loss in different sectors the Northern Plains landscape as a proportion of original (2002) forest area.

	Forest loss 2002-2006 (% of 2002 forest area)	Forest loss 2006-2009 (% of 2002 forest area)	Forest loss 2009-2010 (% of 2002 forest area)
Chendar	0.14	0.22	0.14
PVPF Extension	0.31	0.30	0.13
PVPF	0.68	0.52	0.55
KPWS-PVH	0.90	0.39	0.54
KPWS-ODM	9.03	7.55	5.83
KPWS-SR	0.14	0.40	1.66
Buffer-ODM	3.26	13.01	8.63
Buffer-PVH	2.45	3.97	1.55
Buffer-SR	1.08	2.76	2.58
Buffer-ST	0.41	0.14	0.07
CALM	0.64	0.39	0.45
Buffer Area	4.20	5.39	3.56
Northern Plains	2.14	2.45	1.69

Table 7. Annualised rates of forest loss for each time period, each half of the study period and for the full eight years of the study to show general forest loss trends for each sector. Overall the CALM landscape had an annual rate of deforestation an order of magnitude less than the Buffer Area. Sectors with annual deforestation rates above the Northern Plains landscape average of 0.79% are highlighted.

	Annualised rate of deforestation 2002-2006	Annualised rate of deforestation 2006-2009	Annualised rate of deforestation 2009-2010	Annualised rate of deforestation 2006-2010	Annualised rate of deforestation 2002-2010
Chendar	0.03	0.07	0.14	0.09	0.06
PVPF Extension	0.08	0.10	0.13	0.11	0.09
PVPF	0.17	0.17	0.55	0.27	0.22
KPWS-PVH	0.22	0.13	0.54	0.23	0.23
KPWS-ODM	**2.34**	**2.58**	**5.83**	**3.41**	**2.87**
KPWS-SR	0.04	0.13	**1.66**	0.52	0.28
Buffer-ODM	**0.83**	**4.54**	**8.63**	**5.58**	**3.23**
Buffer-PVH	0.62	**1.34**	**1.55**	**1.39**	**1.01**
Buffer-SR	0.27	**0.93**	**2.58**	**1.34**	**0.81**
Buffer-ST	0.10	0.05	0.07	0.05	0.08
CALM	0.16	0.13	0.45	0.21	0.19
Buffer Area	1.07	1.83	3.56	2.26	1.67
Northern Plains	0.54	0.82	1.69	1.04	0.79

Rates of Deforestation

The Northern Plains overall lost 53,928 ha (6.15% of its original forest area) of its forest from 2002-2010 of which the Buffer Area lost more than the CALM landscape (Table 5, Figure 4). The rate of deforestation is much higher in the Buffer Area than inside the CALM landscape (Tables 5-7). The total area of forest lost as a proportion of the original forest area in 2002 in the CALM landscape was 7,511 ha (1.48% of the total area) between 2002 and 2010 (Table 6, Figure 5). The corresponding loss in the Buffer Area was 46,416 ha (12.59%). The annual rate of forest loss in the Northern Plains from 2002-2010 as a whole was 0.79%, in the CALM landscape 0.19% and in the Buffer Area 1.67% (Table 7). There is an order of magnitude difference in the annual rate of deforestation between the CALM landscape and the Buffer Area. There was already a sharp difference in the rates before the CALM project was initiated and the difference has increased since. However, deforestation rates have increased between the first and second half of the study period in all sectors of the landscape except Buffer-ST.

Deforestation is accelerating in the study area. From 2002-2006 the CALM landscape lost forest at an annual rate of 0.16% and from 2006-2010 it lost forest at an annual rate of 0.21%. In the same two periods the Buffer Area lost forest at an annual rate of 1.07% and 2.26% respectively. Further, the rate of loss in both regions of the study from 2009-2010 was much higher than in preceding years (see Tables 6 and 7).

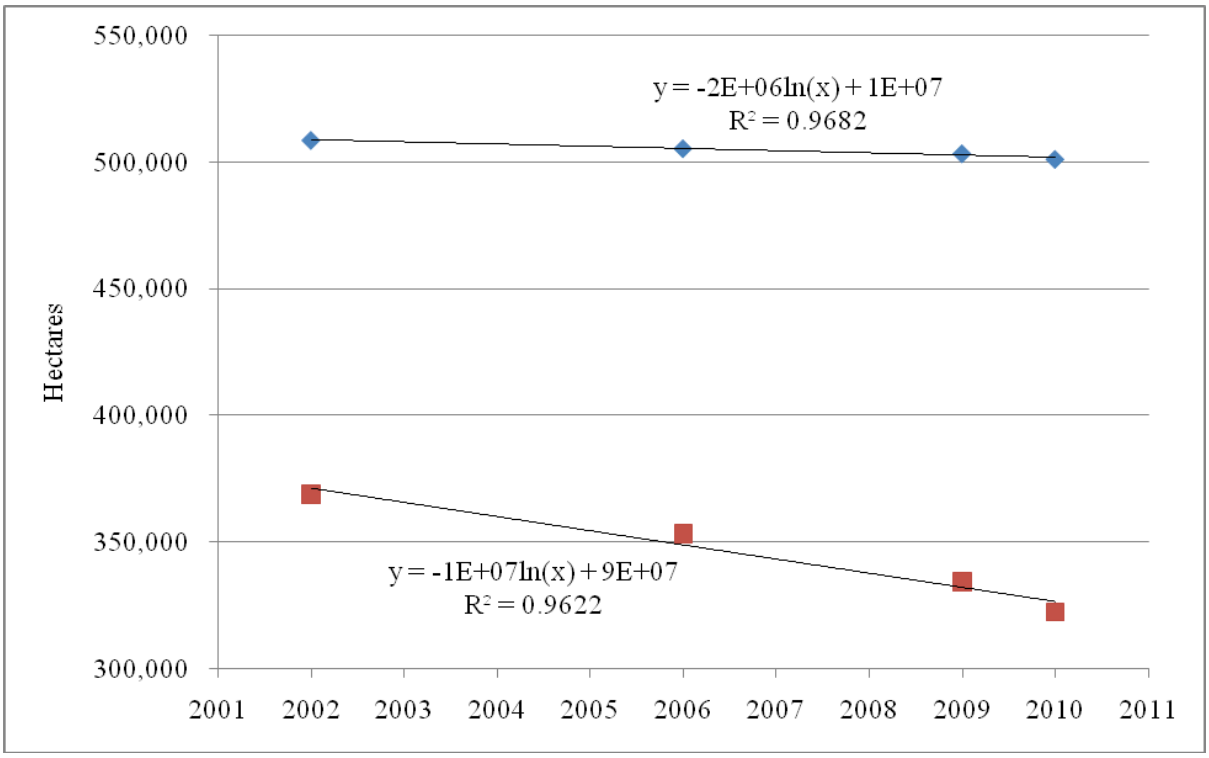

Figure 4a. Forest area 2002-2010 in the CALM landscape and Buffer Area: forest area inside the CALM landscape (blue diamonds); forest area in the Buffer Area (red squares). Logarithmic trend lines for both regions were calculated in Microsoft Excel 2007.

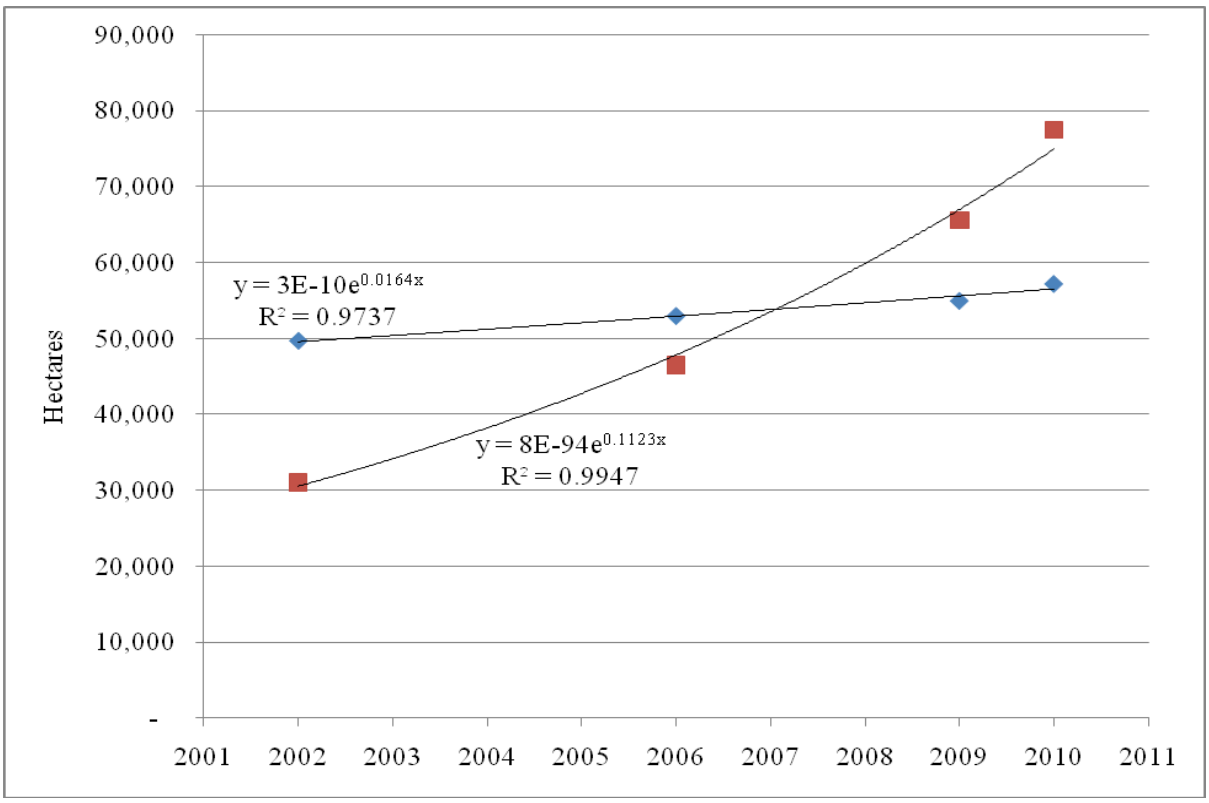

Figure 4b. Non-forest area 2002-2010 in the CALM landscape and Buffer Area: non-forest inside the CALM landscape (blue diamonds); non-forest in the Buffer Area (red squares). Exponential trend lines for both regions were calculated in Microsoft Excel 2007.

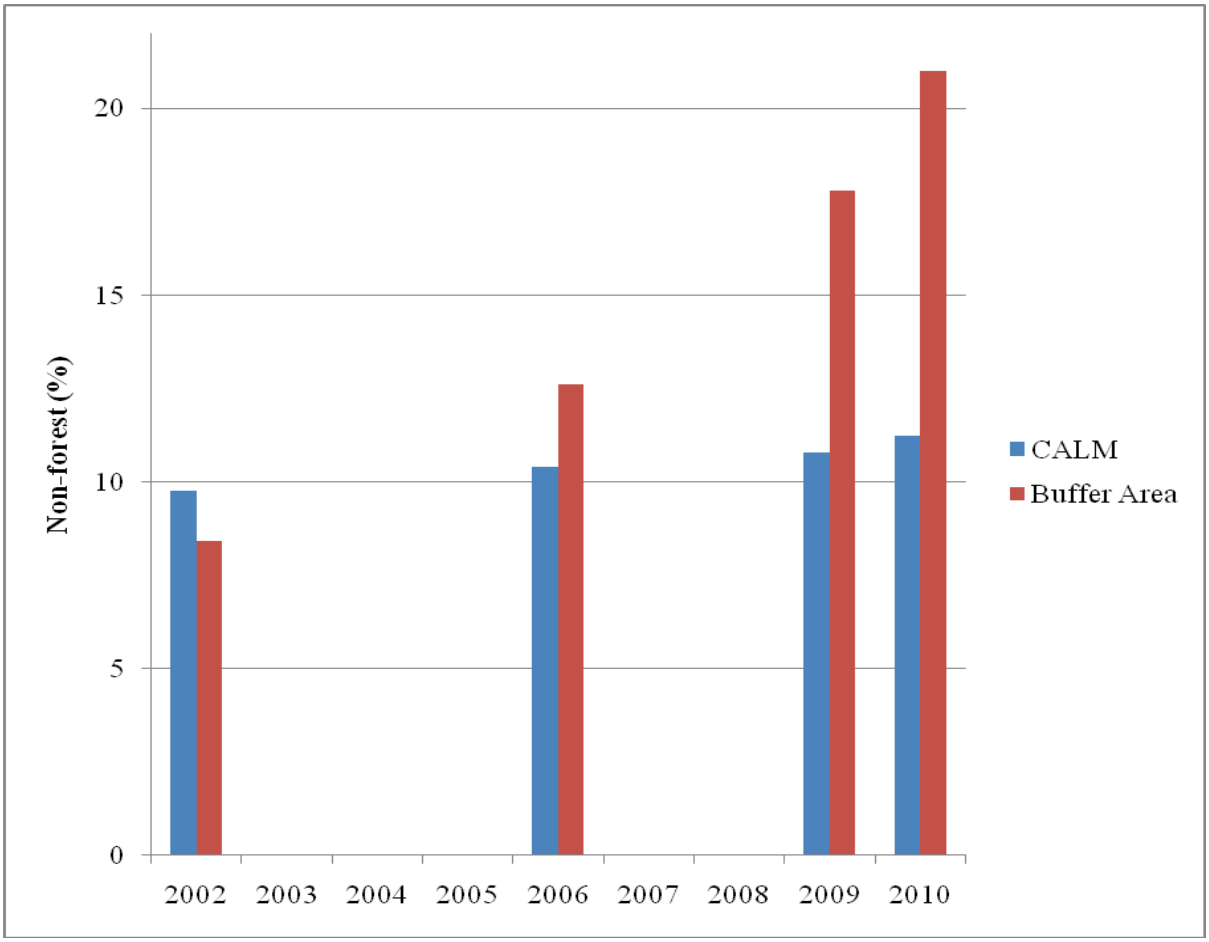

Figure 5. Percentage of non-forest in the CALM landscape and Buffer Area as a proportion of the original forest area, 2002-2010.

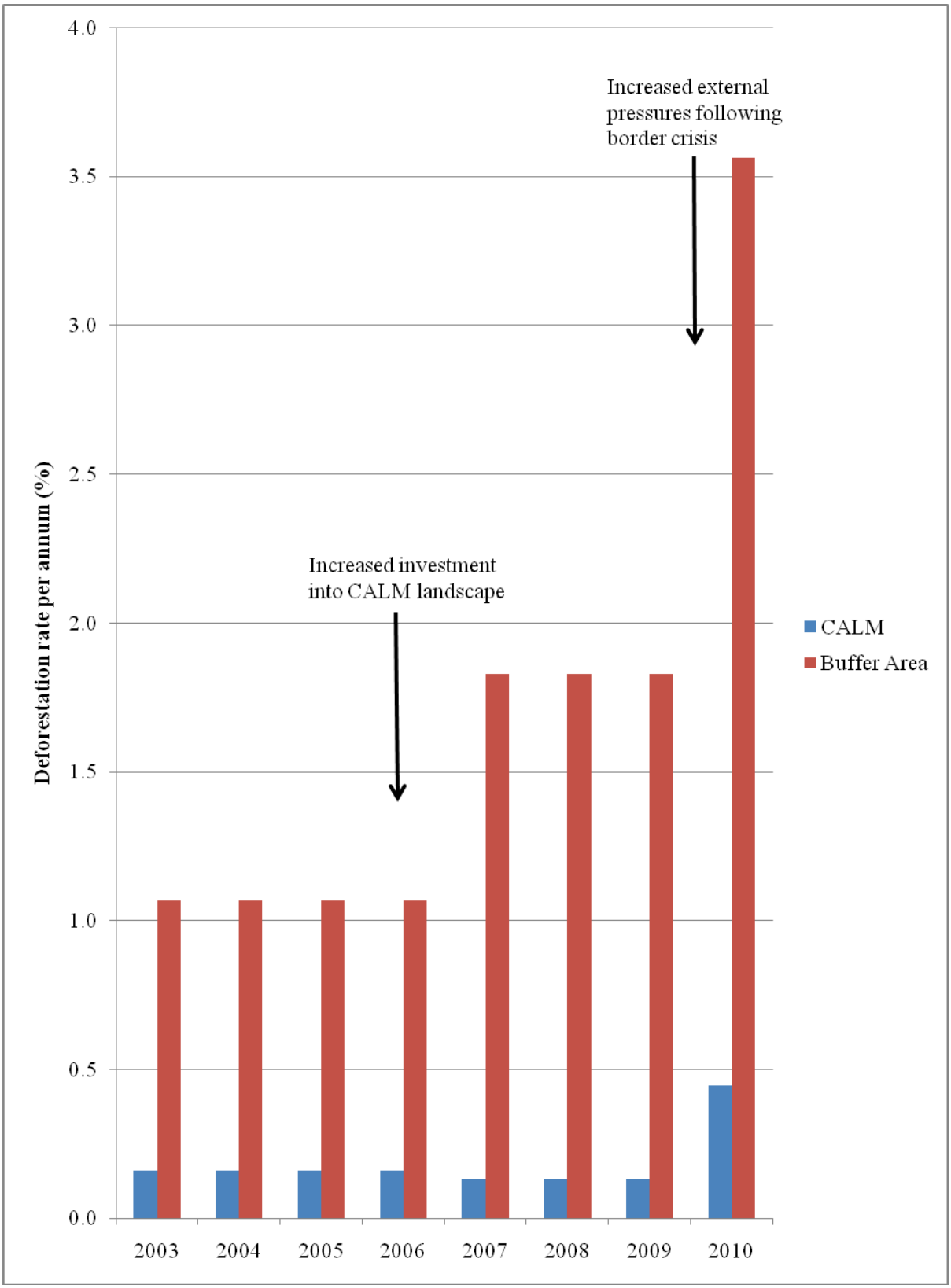

Figure 6. Annualised rates of forest loss in the CALM landscape and Buffer Area 2002-2010 based on data from Table 7. This figure is elongated vertically to enhance the visual presentation of the differences in annualised rates of forest loss in the two survey regions.

Deforestation Trends Across the Landscape

From 2006 onwards, much of the CALM landscape received increased investment in conservation management from UNDP/GEF financing. This investment was approximately an additional $300,000 per year on top of existing financing. Thus variation in rates of forest loss across the different sectors of the landscape before and after this date is of interest. Table 6 shows the rate of forest loss as a proportion of original forest area over the study period.

We compared annual rates of forest loss in each sector with the Northern Plains landscape average of 0.79% per year (Table 7). All sectors in the CALM landscape had deforestation rates below the Northern Plains landscape average throughout the study. From 2002-2006, only two sectors (KPWS-ODM and Buffer-ODM) had rates of forest loss above the Northern Plains average. From 2006-2009, there were four sectors experiencing rates of forest loss above average, increasing to five sectors from 2009-2010. All these sectors were in the Buffer Area which is why the rate of forest loss overall was much higher in the Buffer Area than in the CALM landscape. Two Buffer Area sectors experienced relatively low forest loss in the first period: Buffer-ST and KPWS-SR sector. The rate of forest loss in the latter sector increased dramatically in 2009-2010, surpassing the landscape average.

Features Associated with Deforestation

Qualitative analysis shows seven main spatial features associated with deforestation that are apparent in the study area. Some of these features are visible in Figure 3. Political features such as protected area status do not necessarily influence deforestation rate. Spatial features associated with deforestation are:

1. Towns;
2. Existing villages;
3. Land-grabbing by immigrants and associated new villages;
4. Military concessions and bases and social land concessions;
5. Roads;
6. Forest type and soils;
7. Agro-industrial concessions and commercial enterprises

CALM landscape

1. Within the CALM landscape, the three main towns which are associated with deforestation are Tbeng Meanchay, Choam Ksan and Kulen. Deforestation rates around these urban centres inside the CALM landscape was relatively high until four years ago, but have declined since then with limited recent clearance, aside from some patches close to roads.
2. Many villages have existed since before 2002 and there are varying levels of deforestation around these sites. Villages such as Tmatboey, Dang Phlet and Krala Peas have had mostly pre-2002 deforestation and Prey Veng and other villages in northern KPWS-PVH have had deforestation between 2002 and 2006. Some villages have had higher recent levels of clearance, including around Kampong Sralau, Robugn, Pou Teab, Mlu Prey and Narong. Deforestation associated with villages and towns may be caused by similar drivers.
3. Land-grabbing[3] has occurred around three newly established villages in KPWS-PVH: Tell, Chhuk and Kamprach. Recent forest clearance adjacent to the CALM landscape has facilitated access to KPWS-PVH by immigrants. This has resulted in very rapid land clearance around these villages.
4. Military concessions have been granted in two main areas: northern KPWS near Sa'aem and northern PVPF from O Chhun to Robugn and north to Mumbai. Deforestation here has been recent (2009 onwards) and extensive. There are military bases near these concessions where deforestation has been close to 100% over the final year of the study. Deforestation has generally been limited to specific concessions and along roads adjacent to

[3] Land-grabbing is a commonly practised tactic used by generally wealthy and powerful individuals to obtain land without legal land title. These individuals pay (often landless) migrants to settle in forested areas and to clear it. After several years when *de facto* tenure has been obtained, the land is sold on by the individuals.

concessions, but large areas have also cleared away from such sites.

5. The main areas of deforestation along roads inside the landscape were mostly cleared before 2002 and the situation is not dynamic. However, since 2009 new roads in northern PVPF have directly caused rapid recent deforestation as well being associated with deforestation where roads are adjacent to military concessions and bases. Improvements to the Thnal Baek to Sa'aem road in KPWS-PVH have had relatively little effect on forest cover except for minor clearance where aggregates have been quarried for road construction. The Kulen to Tbeng Meanchay has had more extensive recent clearance.
6. Forest type is heavily influenced by soil type in the Northern Plains of Cambodia and across the region (Rundel 1999). Richer soils, especially along water courses, tend to support denser, taller forest and are better for agriculture. These areas may therefore be more prone to deforestation, although this has happened in only a few areas of the CALM landscape such as at Kamprach village in north-western KPWS-PVH sector.
7. There are as yet no commercial enterprises clearing forest on a measureable scale inside the CALM landscape.

Buffer Area

1. In the Buffer Area the main towns associated with deforestation are Tbeng Meanchay, Choam Ksan, Kulen and Trapeang Prasat. Although much of this deforestation was prior to 2002, there has been continuous forest clearance at growing distances around these towns up to the present. Most noticeable is the large area of deforestation, which has continued to grow in extent around Trapeang Prasat in KPWS-ODM, Buffer-ODM and in 2009-2010 into KPWS-SR.
2. Villages have continued to expand with associated deforestation around the Buffer Area including within KPWS-SR and KPWS-ODM and this is particularly extensive in the Buffer-ODM and Buffer Area in northern Preah Vihear.
3. New villages have been created and areas have been cleared by immigrants in many areas of this zone and distinguishing them from existing villages is now somewhat difficult.
4. Military concessions have been created in areas north of Chendar and north of KPWS-PVH as well as inside KPWS-ODM and KPWS-SR.
5. Some older roads around the Buffer Area are associated with relatively old deforestation, as they are in the CALM landscape, including areas between Kulen and Tbeng Meanchay towns; along the road east of Tbeng Meanchay; and close to Choam Ksan. In addition the road between Choam Ksan and Trapeang Prasat has received high rates of relatively recent deforestation. Notably the new road south from Trapeang Prasat through KPWS-ODM and KPWS-SR has rapid associated recent deforestation.
6. Forest and soil types have heavily influenced deforestation in the Buffer Area. Most notably, the evergreen forest around Trapeang Prasat town has received very high rates of deforestation since 2002, in part because it lies on acid lithosol and grey hydromorphic soils. The combination of proximity to a rapidly growing town, newly improved roads and fertile soils are almost certainly influencing the rate of loss of forest here.
7. Agro-industrial concessions in the 5 km buffer have resulted in rapid, recent and extensive deforestation in Preah Vihear, Oddar Meanchay and Siem Reap Provinces. There have also been other commercial enterprises, which have cleared land north of KPWS-PVH although these are most closely associated with roads.

DISCUSSION

Deforestation Trends

The Northern Plains landscape overall lost 53,928 ha of forest (6.15% of its original forest area) from 2002-2010. The CALM landscape lost 7,511 ha (1.48%) and the Buffer Area lost 46,416 ha (12.59%).

Deforestation is accelerating across the Northern Plains: the overall rate of forest loss was higher in the second half of the study for both the CALM landscape and the Buffer Area. This general trend is similar to that found across Cambodia: deforestation rates have been increasing in forests across the country (RGC 2010) in recent years. Although the difference in the rate of loss of forest between the CALM landscape and the Buffer Area was large (1.01%) from 2002-2006, the difference in the rate between the two regions increased further from 2006-2009 (1.70%) and 2009-2010 (3.11%) (see Table 7, Figure 6). Indeed the annual rate of deforestation in the CALM landscape declined between the 2002-2006 and 2009-2010, whilst it rose in the Buffer Area (Table 7). Deforestation pressures across the Northern Plains increased further in 2009-2010: the annual rate of forest loss in the CALM landscape approximately tripled and the rate in the Buffer Area approximately doubled from 2006-2009 to 2009-2010. Evidently rising drivers of deforestation are still a major threat to the integrity of the CALM landscape. More investment in management would have been necessary to address these drivers adequately in this period and no doubt will be required in the future.

The areas with the lowest deforestation (i.e. that below the Northern Plains average) from 2002 to 2010 include all four of the CALM landscape sectors plus the Buffer-ST and KPWS-SR sectors. This is probably linked to high levels of investment in management in the CALM landscape as well as the remoteness of these sectors. Management activities include: participatory development of land use management structures and regulations with communities; law enforcement patrols to reduce illegal land clearance and logging; advocacy and collaboration to reduce the number of concessions granted for these sectors; monitoring of land use and illegal activities; and development of payments for environmental services programmes for local communities. The Buffer-ST sector probably benefitted from some of these activities, as it lies adjacent to the CALM landscape and, in common with the KPWS-SR sector, its remoteness with few roads or settlements will have reduced forest loss. Thus, until recently Buffer-ST and KPWS-SR have had limited deforestation pressure. It is very likely that the remoteness of much of the CALM landscape and these two Buffer Area sectors is one of the main factors contributing to limited local deforestation rates. Construction of new roads or upgrading of existing roads is likely to be a major factor facilitating deforestation by improving access and raising perceived land prices. Control of new settlements and land clearance on new roads is therefore essential for ensuring the integrity of the forest.

Both PVPF and KPWS-PVH have suffered increased rates of deforestation from 2009-2010, higher than other parts of the CALM landscape. This is because they are less remote than some sectors and have large areas adjacent to major roads where military concessions and bases have been placed. In particular, PVPF lies adjacent to the Thai border and has had very large increases in the numbers of military families resident inside its boundaries. Given the large number of military concessions and bases established in PVPF and KPWS-PVH recently and the arrival of thousands of families associated with these developments, the relatively low deforestation rate in these sites compared to much of the Buffer Area suggests that conservation management in the CALM landscape has partly controlled the impact of the military on forest loss so far.

Initially much of the Buffer Area had relatively low rates of deforestation: Buffer-ST, KPWS-SR and Buffer-SR were relatively remote until recently with low deforestation rates in the first half of the study, however, particularly since 2009, the rate of forest loss in the latter two sectors has accelerated. This is linked to development of new and improved roads and creation of agro-industrial concessions. Other sectors of the Buffer Area have existing and improved roads, towns, concessions and other characteristics, which have historically contributed to relatively high rates of deforestation and continue to do so.

It is noticeable that some large areas of both PVPF and KPWS-PVH consist of natural non-forest areas such as grasslands and wetlands, particularly along the River Sen. The large area of non-forest at the 2002 baseline in these sites is therefore substantially natural, although this does include areas around some towns and villages which were cleared prior to the study period.

Methodological Issues

We used satellite imagery from four different time periods, all during the dry season in northern Cambodia, to assess forest cover in these periods. Imagery was available for single dry seasons in all four periods, except for small areas during the first period (2002). Some imagery from this period was from the dry season in 2001 and some from the dry season in 2003 (Table 2). We believe that this has not had a significant impact on our findings and the value of this report for informing management of the forests in the Northern Plains landscape. This is because the areas using 2001 and 2003 data were relatively small. Additionally, deforestation rates were lower than in 2010 and immigration was at much lower levels. The effect on our calculations of a single year's variation in deforested area over a small part of the landscape is likely to be limited, especially as they will to some extent cancel each other out.

Although definitions of forest differ between the national definition and that used by the Forestry Administration for monitoring, these will not affect monitoring of trends in the study site as differences in classification of forest and non-forest were observed to be slight.

We did not perform an accuracy assessment for correct allocation of forest classes, but as noted earlier, the method produced high accuracy in trials in a comparable landscape in Cambodia (Evans *et al.* 2009).

Drivers of Deforestation

As detailed previously, there appear to be seven main features driving deforestation in the Northern Plains landscape:

1. Towns;
2. Existing villages;
3. Land-grabbing by immigrants and associated new villages;
4. Military concessions and bases and social land concessions;
5. Roads;
6. Forest and soil types;
7. Agro-industrial concessions and commercial enterprises.

These drivers of deforestation are similar to those identified by the Cambodian Interim REDD+ Readiness Roadmap Task Force (2010). We give a qualitative assessment below of how these features have driven deforestation in the study area and possible methods of mitigating or preventing such deforestation. A quantitative analysis of these factors will be useful in the future.

Towns (1) and existing villages (2) seem to be contributing only moderately to recent deforestation in this study area. This may be because they are relatively predictable in how they influence deforestation, as they tend to exhibit moderately low population and land use growth rates. Population size, proximity and the state of engagement of the population in conservation management appear to influence the magnitude of the effects of the feature on deforestation. Deforestation will tend to be caused by expansion of subsistence agriculture and, around towns, extension of residential land. Some short lengths of roads may be built around settlements, which may contribute to deforestation by improving access. Control of deforestation caused by these features has been achieved through appropriate land use planning and engagement with authorities to reduce agricultural and residential land expansion in conservation areas. Sectors without this investment, such as KPWS-ODM and Buffer-PVH, have suffered high levels of deforestation.

Deforestation by land-grabbing groups and associated development of new villages (3) has been relatively rapid. These groups often clear land in an attempt to obtain informal but *de facto* tenure through squatters' rights, as well as clearing forest for agriculture. Speculation on land prices, which was rife until 2008-2009, encouraged land-grabbing, but prices have since declined probably in part because of the 2008-2010 global financial crisis which has reduced money supply. Land-grabbing inside the CALM landscape has been controlled by law enforcement patrols and these have been particularly effective when deployed at early stages of settlement. Uncertain land tenure is a major contributor to this type of activity and clarification of land tenure regulations and implementation of existing regulations has helped prevent this type of deforestation. It is notable that those local communities in the CALM landscape that have been engaged in land use planning as part of conservation management, have themselves been able to

prevent land-grabbers settling in their areas. Once new villages have become established, they are hard to remove through simple law enforcement means. Indeed, two new villages, Tell and Chuuk, have been legalised into one village by the RGC as a result of their rapid land clearance and vocal lobbying over the last year. Land use planning and engagement with authorities to reduce agricultural and residential land expansion can be effective in limiting further expansion of newly settled villages.

Military concessions have been created in the Northern Plains to support military bases and are a form of social land concession providing land for soldiers and their families (4). The impact of these drivers has been greatest in areas closer to the Thai border. A number of social land concessions for non-military recipients have also been created in the study area, but only in the Buffer Area. Military concessions and bases and social land concessions result in rapid forest clearance for residential and government use and subsistence agriculture. Influencing creation of concessions is very difficult as these are often created for national strategic and political motives far beyond the normal influence of conservation management. Development of conservation finance mechanisms such as REDD may improve motivation for maintaining forest cover and minimise the risk of concessions being granted in the CALM landscape. Engagement with authorities and land users may be effective in reducing additional deforestation in areas adjacent to concessions once they have been established.

New or improved roads (5) cause some direct deforestation, but more importantly can cause increased deforestation rates as they improve access and raise land prices. These increase pressure to grab land on roads, create new concessions, clear land for agriculture and improve access for illegal logging. There has been a large increase in investment in roads in the study area since 2008. Law enforcement, engagement with authorities and land use planning may help control pressures associated with this feature.

Dense forests are often on richer soils (6) and may be selected for settlement and clearance by new immigrants to the study area and other individuals. These areas may often be more productive for agriculture and there may also be opportunities to benefit from logging larger trees in such forest types. The most obvious area of deforestation in dense evergreen forest with richer soils is around Trapeang Prasat in Buffer-ODM and some adjacent areas in KPWS-PVH. Preventing this type of forest loss can be achieved by stabilising land tenure through land use planning, engagement with authorities and appropriate law enforcement.

Agro-industrial economic land concessions and commercial enterprises (7) can cause significant deforestation as forest is cleared for creating plantations: rubber is the most significant plantation crop in Preah Vihear. Additionally, new settlements and roads are likely to develop in areas close to such concessions, which will also increase deforestation pressure. Other commercial enterprises such as quarrying and mining may cause significant deforestation, particularly if they are open cast mines. Mining activity also inevitably requires roads, which will improve access and create pressure from land-grabbers. Preventing direct deforestation by large commercial concessions is very difficult because of the large financial and political considerations. Engagement with authorities and land users may be effective in reducing additional associated deforestation in adjacent areas. Development of conservation finance mechanisms with benefits for all stakeholders may improve political motivation for maintaining forest cover and minimise the risk of concessions being granted in the CALM landscape.

We have not assessed forest degradation, which may be driven by logging, charcoal burning and other factors. Only extreme logging is likely to cause complete deforestation. Logging of many high value species was rife in the landscape until March 2010, at which point government intervention reduced this activity across the country. However, this logging was for a small number of relatively rare tree species and thus may have had relatively little impact on forest cover or carbon stocks. Only in a few small areas around military concessions was there intensive logging of lower value trees for house construction. As stated in the introduction, monitoring forest degradation would be of interest to a REDD project, but would require a separate study.

Political features such as protected area status do not appear to influence deforestation rates directly. Adequate financial support for management is necessary to ensure that those factors associated with deforestation are controlled and this apparently has much more influence than the legal status of a site.

Conclusions

This study of forest cover trends across the various Northern Plains sectors suggests a number of valuable points pertinent to management:

- Investment in management has reduced the rate of deforestation and overall forest loss in the CALM landscape relative to what would otherwise occur. Forest cover in the CALM landscape may continue to be deforested at a lower rate compared to the Buffer Area if current management investment levels are maintained. Increased investment is necessary to address recent high pressure drivers of deforestation. Any reduction in investment levels is likely to result in an increase in future deforestation rates. Protected area status is insufficient in itself to prevent high levels of deforestation.
- Forest cover is likely to continue to decline across much of the Buffer Area, almost certainly at a higher rate than in the CALM landscape as there is limited management of forests in the Buffer Area. Indeed, additional agro-industrial concessions have been granted in the Buffer-PVH in mid-2010 and the future deforestation rate may even surpass historical rates. Likewise, as access improves in KPWS-SR and Buffer-SR, the rate of forest loss there is likely to rise.
- The two sectors KPWS-SR and KPWS-ODM, which do not have CALM support, are important for conservation and an increase in investment in their management would help control the accelerating deforestation there. This would aid management in KPWS-PVH and could facilitate development of a REDD project in this sector.
- Improving the legal protected status of the PVPF Extension Area and Chendar Plywood may improve the outlook for maintaining forest cover in these sectors, although without appropriate investment this will not be sufficient.

Three characteristics influencing deforestation in the study area bear similarities to factors influencing deforestation elsewhere (Cambodian REDD+ Roadmap Committee 2010, Poffenberger 2009, Evans *et al.* 2009:

- Remoteness limits deforestation pressure. Those sectors of the study area that are relatively remote appear to have suffered low levels of deforestation until roads are built or improved, new concessions or new villages established.
- Investment in management significantly reduces deforestation. A relatively high level of management investment reduces deforestation relative to what would otherwise occur in sectors, which are exposed to such pressure by the presence of roads, concessions and villages.
- It is difficult to prevent concessions and military bases being placed within conservation areas and their associated deforestation due to the nature of concession development. Improving motivation for maintaining the intact nature of conservation areas by generating revenue from such sites may be an effective method of preventing deforestation.

As forests disappear rapidly from across northern Cambodia, it is possible that the CALM landscape may remain as one of the few large intact areas of forest in the region. The importance of this landscape for Cambodia will increase as other forests are cleared. It will be one of the few landscapes still to contain an impressive suite of highly threatened large mammals and birds. The watershed protection provided by large areas of forest will continue to support the very productive fisheries of the Stung Sen, Tonle Repou and other rivers, which are essential for the livelihoods and nutrition of people in Preah Vihear and neighbouring provinces. Safe-guarding this watershed will also ensure water supplies to proposed hydro-electric dams downstream as well as maintaining water flows into the Tonle Sap. The NTFPs, which are essential for rural life in Cambodia will be protected in the CALM landscape. Outside this landscape, in farmland, settlements and agro-industrial concessions, NTFPs will no longer be available once forest has been cleared.

Development of sustainable financing for the CALM landscape is essential if forest cover is to

be maintained at current levels; this will have both conservation and livelihood benefits. This landscape supports a very diverse assemblage of over 40 of the world's rarest and most threatened species. Thousands of families living in and around the forests rely on the forests for NTFPs, fisheries and the ecosystem benefits it provides. Strong consideration should be given to developing a REDD project to generate carbon credits from this landscape; this has the potential for conserving the forest and wildlife, maintaining and improving livelihood benefits for local communities and providing revenue to the Royal Government of Cambodia.

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APPENDIX – MAP OF VILLAGES NAMED IN THE MAIN BODY OF THE REPORT.