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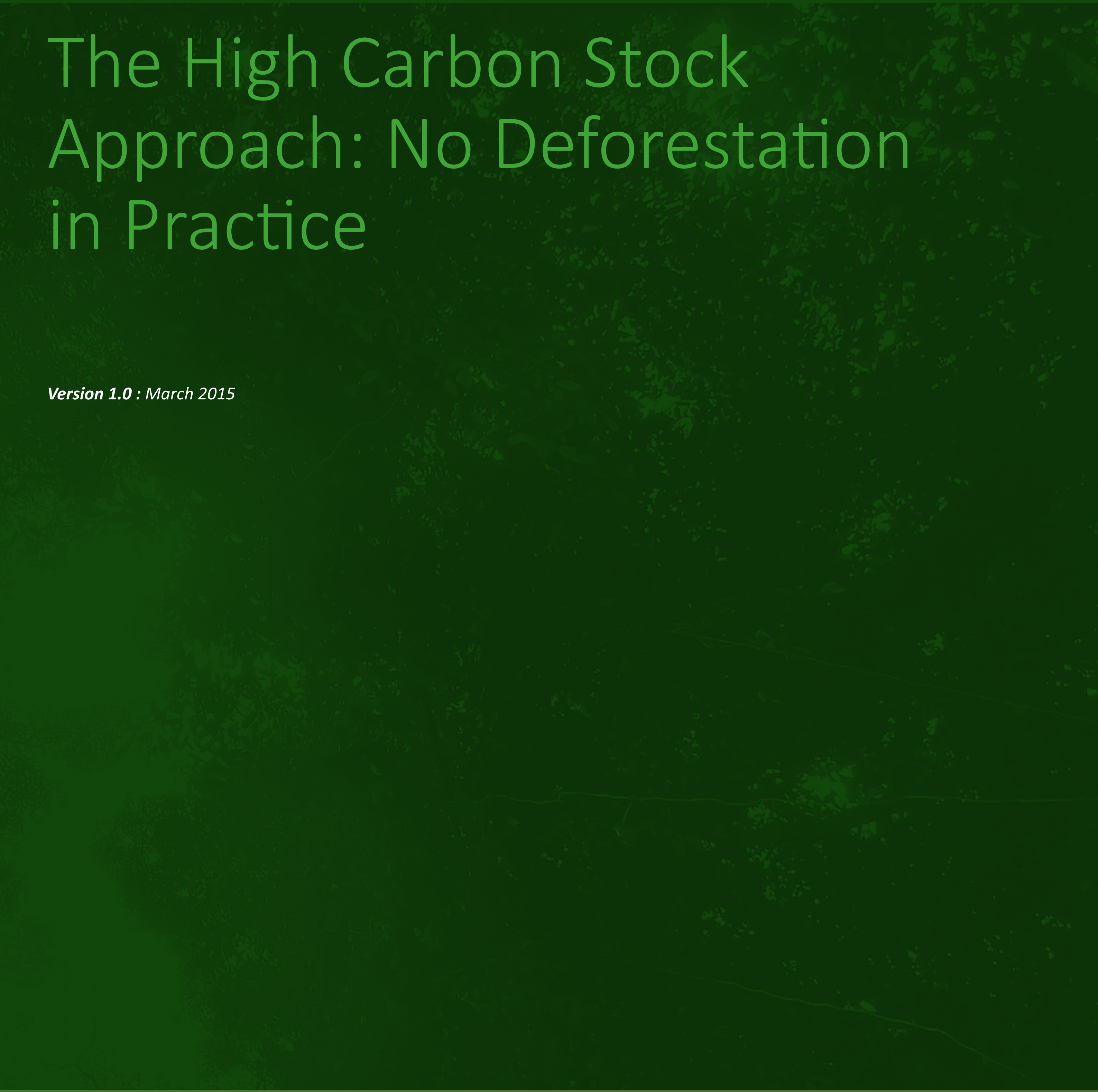
The HCS Approach Toolkit



The High Carbon Stock Approach: No Deforestation in Practice

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Cargill
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Rainforest Alliance
TFT *(Executive Committee)*
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Union of Concerned Scientists
Wilmar International Ltd. *(Executive Committee)*
WWF *(Executive Committee)*

Document overview

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Introduction

There is now broad global agreement among a wide range of companies, research institutions, conservation and environmental NGOs, many governments, and forest-dependent communities on the need to stop tropical deforestation. Tropical forests hold the greatest diversity of life on Earth and provide a range of services we all need. Without them, people, businesses and the planet will not thrive.

The question, however, is how plantation companies and farmers can ensure they are not contributing to tropical deforestation with new plantations in order to grow the food, fuel, feed and fibre we need for our growing population. How can we differentiate degraded land potentially suitable for establishing plantations and crops from forest areas that need to be protected? Current approaches such as the High Conservation Value process, greenhouse gas emissions monitoring, participatory mapping and respect for communities' rights to land and to give or withhold their Free Prior and Informed Consent (FPIC) may slow deforestation and secure peoples' livelihoods, but they have not stopped all forest clearance. These approaches remain valuable, but they do not delineate all areas of natural forest for which protection is sought, and thus do not provide sufficient guidance for implementing 'No Deforestation' policy commitments. There is also a clear need for a practical definition of 'natural forest' which can be used in concessions.

In response to this challenge and following a bold commitment to 'No Deforestation', Golden Agri-Resources (GAR) in collaboration with Greenpeace and TFT have pioneered a methodology to identify natural forest areas, called the High Carbon Stock Approach. From 2010-2014, processes to define potentially viable areas of tropical forest as well as degraded lands were trialled in Indonesia and Liberia, combining carbon storage, biodiversity conservation and local community rights and livelihoods. In August 2014, a multi-stakeholder HCS Approach Steering Group was formed to oversee the further development of the methodology and its use in the field.

To standardise and make it available to all practitioners who need it, the Steering Group has published here the HCS methodology as Version One of the HCS Approach Toolkit, to be used in further trials and for broader consultation. We will periodically issue updates to the toolkit, as well as new chapters covering how to conserve, restore and monitor HCS forests. We are very much seeking feedback on the approach, and welcome input to the Steering Group on the implementation of it across different tropical regions in order to strengthen and refine the methodology. The HCS Approach Steering Group is developing a set of 'Quality Assurance' requirements for users, and in the interim we ask HCS Approach practitioners to apply the methodology as it is laid out in the toolkit.

> *"How can we differentiate degraded land potentially suitable for establishing plantations and crops from forest areas that need to be protected?"*

To those who will be using the HCS Approach, it is important to note that identifying HCS forests is only one of several critical aspects of land use planning in forest landscapes. Lands vital to local communities, High Conservation Value (HCV) areas and peatlands must also be protected. During the HCS process and in particular the final phase of the methodology, the HCS Approach integrates with these other categories of land use. It therefore relies on high quality HCV assessments, participatory mapping, respect for customary rights and FPIC to arrive at a proposed conservation area plan.

In closing, we would like to thank the authors and reviewers who have contributed to this toolkit, and all those who share our vision of the HCS Approach and its contribution to ending deforestation.

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Aida Greenbury
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Scott Poynton
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Editorial Committee of the HCS Toolkit, on behalf of the HCS Approach Steering Group

The High Carbon Stock Approach: A practical approach to 'No Deforestation'

By Peter Heng (Golden Agri-Resources), Scott Poynton (TFT) and Grant Rosoman (Greenpeace)

"No Deforestation" is a rallying cry for concerned consumers around the world. They are fed up with images of communities being evicted from their lands and orang-utans being rescued from tiny islands of forest areas among vast open land which has been cleared for the latest industrial plantation. But to put "No Deforestation" into practice, we need to answer some complex questions:

- What exactly characterizes a forest? Most tropical forest landscapes today are not entirely covered with forests, but rather have a dynamic mix of vegetation, ranging from grassland to scrub to regenerating forests to dense forests with a high canopy. Where do we draw the line between 'forest' and 'non-forest', given the impracticality of the various international definitions of forest?
- What attributes and conditions allow a tropical forest to maintain and restore its functions as a forest? Is the size of a forest patch important to its survival?
- Can we design a healthy forest mosaic in economically active areas that maintains carbon and biodiversity, and integrates with other conservation tools? Should we 'sacrifice' smaller lower carbon and biodiversity patches to development to prioritise conservation of larger well-connected forest patches? How should we take into consideration the amount of forest remaining in the landscape?
- How are local community rights and needs addressed in the process of halting deforestation? What level of support and involvement of local communities do we need to achieve forest conservation in both the short and long term? What is the role of governments in achieving No Deforestation?

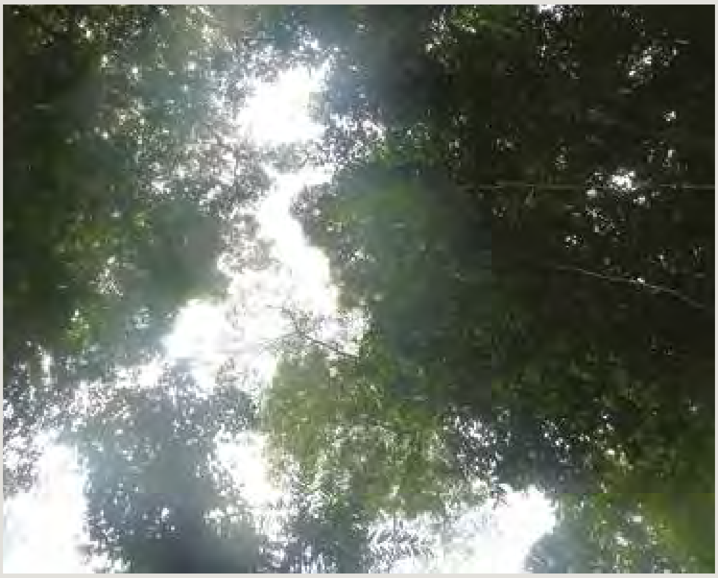
The HCS Approach is an attempt to answer these questions. It is a pragmatic land use planning tool rather than a carbon assessment, which provides a methodology for implementing the No Deforestation concept in active concessions slated for development in tropical forest countries. It aims to respect customary rights and meet community needs while at the same time considering the company's operational reality. In short, the approach offers a paradigm shift to include forest conservation as a cornerstone of any expansion of agriculture in tropical forest landscapes.

> *"The HCS Approach is already a practical tool which can be used for any product, in any country in the humid tropics, to address the need for forest protection within agricultural development"*

Development of the HCS Approach started in late 2010 by Golden Agri-Resources (GAR), TFT and Greenpeace during the development of GAR's Forest Conservation Policy. This included working through the challenges of defining 'forests' and achieving conservation of these forests in the long-term, as described above. Since then the approach has been trialled in GAR-related palm oil concessions in West Kalimantan, Indonesia and Liberia, as well as with other companies in pilot HCS studies elsewhere in Indonesia and in Papua New Guinea. The two phases of the approach have had separate expert reviews and inputs from multiple stakeholders to develop the current methodology described in this toolkit.

In 2014 dozens of companies in the palm oil and pulp and paper sectors, as well as key consumer goods companies, pledged to use the HCS Approach to implement their own No Deforestation pledges. This is encouraging, and has lent urgency to completing the first version of this toolkit for practitioners who want to responsibly develop plantations in tropical forest landscapes. While feedback from further implementation will improve the methodology, we are confident that the HCS Approach is already a practical tool which can be used for any product, in any country in the humid tropics, to address the need for forest protection within agricultural development. We look forward to learning lessons from HCS studies in new regions as we embark together on this No Deforestation journey.

All photos: Courtesy TFT ©



Acronyms and definitions

TERM	ACRONYM	DEFINITION
Diameter at Breast Height	**DBH**	Tree diameter measurement normally taken 1.3m up from ground level (*see Chapter 4*).
Environmental and Social Impact Assessment	**ESIA**	
Free, Prior and Informed Consent	**FPIC**	The principle that a community has the right to give or withhold its consent to proposed projects that may affect the lands they customarily own, occupy or otherwise use. *(Source: FPP)*
Geographic Information System	**GIS**	A computer system capable of assembling, storing, manipulating, and displaying information identified according to its location on Earth. *(From USGS)*
Global Positioning System	**GPS**	A system that uses signals from satellites to tell you where you are and to give you directions to other places. *(From Webster.com).*
High Carbon Stock	**HCS**	HCS forests are those identified through the HCS Approach as forested areas to be prioritised for protection from conversion.
High Conservation Value	**HCV**	High Conservation Values (HCVs) are biological, ecological, social or cultural values or attributes associated with natural or traditionally managed ecosystems, which are considered outstandingly significant or critically important at the national, regional or global level. HCV management areas are critical areas in a landscape which need to be managed appropriately in order to maintain or enhance one or more HCVs. Areas which possess such attributes include: HCV1: Areas containing globally, regionally or nationally significant concentrations of biodiversity values (e.g. endemism, endangered species, refugia). HCV2: Globally, regionally or nationally significant landscapes where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance. HCV3: Areas that are in or contain rare, threatened or endangered ecosystems.HCV4: Areas that provide basic ecosystem services in critical situations (e.g. watershed protection, erosion control).HCV5: Areas fundamental to meeting basic needs of local communities (e.g. subsistence, health).HCV6: Areas critical to local communities' traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities). *(Source: HCV Network)*

TERM	ACRONYM	DEFINITION
High Density Forest	**HDF**	One of the HCS vegetation classes
High forest cover landscape		A landscape with a natural forest cover greater than 80%.
International Union for the Conservation of Nature	**IUCN**	
Landscape		A geographical mosaic composed of interacting ecosystems resulting from the influence of geological, topographical, soil, climatic, biotic and human interactions in a given area. *(Source: IUCN)*.
Low Density Forest	**LDF**	One of the HCS vegetation classes
Low forest cover landscape		A landscape with a natural forest cover of less than 30%
Medium Density Forest	**MDF**	One of the HCS vegetation classes.
Medium forest cover landscape		A landscape with a natural forest cover of between 30 and 80%.
Non-timber forest product	**NTFP**	Any product or service other than timber that is produced in forests. NTFPs include fruits and nuts, vegetables, fish and game, medicinal plants, resins, essences and a range of barks and fibres such as bamboo, rattans and a host of other palms and grasses. *(Source: CIFOR)*
Reducing Emissions from Deforestation and Degradation (UN-REDD+)	**REDD+**	A framework being developed by the UN through which developing countries are rewarded financially for (a) Reducing emissions from deforestation; (b) Reducing emissions from forest degradation; (c) Conservation of forest carbon stocks; (d) Sustainable management of forests; and/or (e) Enhancement of forest carbon stocks. *(From The REDD Desk, 2015*)
Roundtable on Sustainable Palm Oil	**RSPO**	
Set-aside area, set-asides		A tract of land within a private concession or farm on which commercial crops will not be grown.
Young Regenerating Forest	**YRF**	One of the HCS vegetation classes

Chapter 1

High Carbon Stock in context and an outline of the HCS Approach Toolkit

By Charlotte Opal, TFT

CHAPTER CONTENTS

Introduction

In the past five years, dozens of leading companies in the soy, palm oil, pulp & paper, and beef industries have agreed to eliminate deforestation from their activities and supply chains. Many of them had already agreed to protect 'High Conservation Value' (HCV) areas, yet many secondary forests that provide essential carbon storage, habitat for biodiversity, and forest products for local communities are not considered HCV. Some broader definitions of 'forest' exist, but are not practical enough to be able to implement company commitments to No Deforestation in the tropics.

There is thus a clear need for a practical, scientifically robust and cost-effective methodology that can distinguish viable forest areas from degraded areas that have lower carbon and biodiversity values. The High Carbon Stock Approach represents the first practical methodology that has been tested and developed in active concessions in Asia and Africa with input from a variety of stakeholders. It is a relatively simple tool that plantation companies can use for new developments while ensuring that forests are protected from conversion.

Broadly, the HCS Approach stratifies the vegetation on an area of land into different classes. Each vegetation class is validated through calibrating it with carbon stock estimates in the above-ground tree biomass. The diagram below shows the four HCS forest classes; the threshold for potential HCS forests lies between the Young Regenerating Forest (YRF) and Scrub (S) classes.

This High Carbon Stock Approach Toolkit will take practitioners through the steps in identifying HCS forest, from initial stratification of the vegetation using satellite images and field plots, through a Decision Tree process to assess the conservation value of the HCS forest patches in the landscape and ensure communities' rights and livelihoods are respected, to making the final conservation and land use map. This chapter gives a brief overview of the HCS process and an outline of the toolkit, beginning with an overview of the HCS Approach in its broader context.

"There is a clear need for a practical, scientifically robust and cost-effective methodology that can distinguish viable forest areas from degraded areas that have lower carbon and biodiversity values"

HCS CLASSIFICATION

The HCS Approach in context

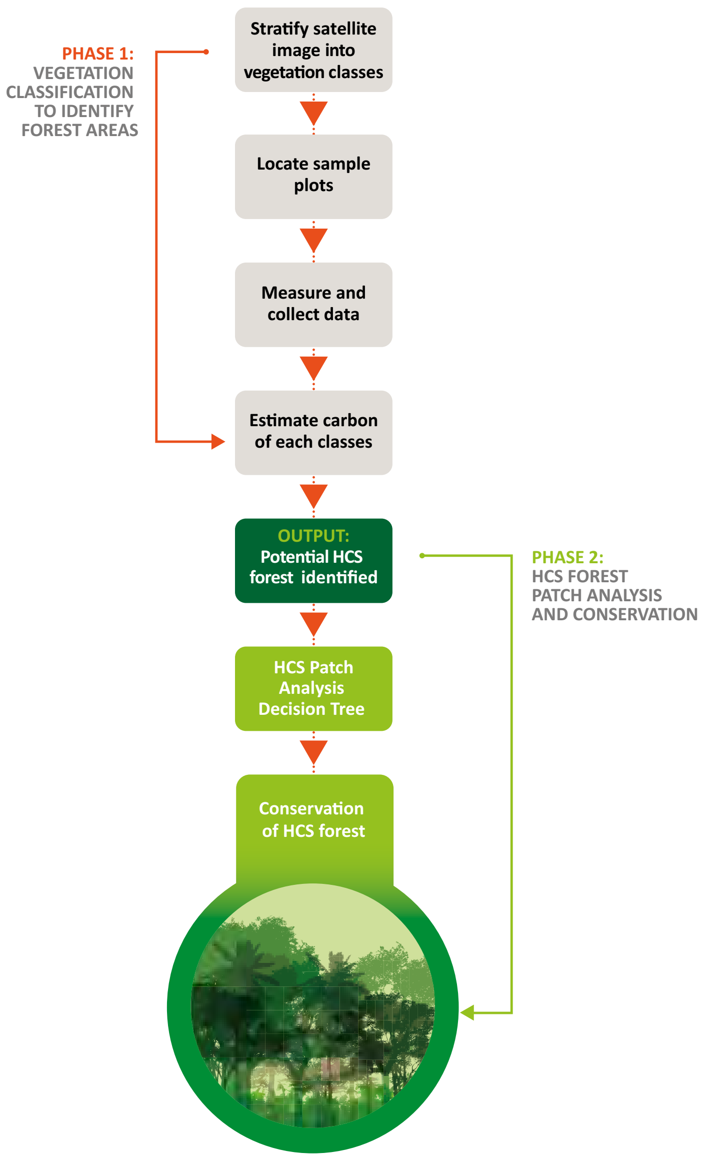
First, it is important to note that the HCS methodology is **designed for use in fragmented forest landscapes and mosaics in the humid tropics**. The methodology could eventually be adapted to other vegetation types such as tropical savannahs or temperate or boreal forests, but this first iteration was developed to identify natural forest areas in the humid tropics, and this toolkit will explain how to use it in that context.

Second, despite having the word 'carbon' in the title, the High Carbon Stock forest concept is **not intended to be used as a measure of carbon stores**, or for any type of carbon footprint or accounting. While forests are of course important stores of carbon, there are many other reasons to protect them. Estimates of carbon content of the vegetation are simply used in the HCS Approach to help distinguish different types of vegetation: generally speaking, more carbon indicates denser and more structurally complex vegetation. The HCS Approach thus uses an estimate of above-ground biomass in trees greater than or equal to 5cm DBH (diameter at breast height) only – other above-ground biomass and below ground carbon is not considered. (However, high carbon soils such as peatlands are taken into account in the approach through being added to the areas for protection and conservation in the final integrative land use planning stage).

Third, the HCS Approach is grounded in GIS and remote sensing, forestry and conservation science, but **the methodology for determining HCS forest is designed to take into account variations in the local forest types and conditions**. This means that while the methodology used to identify HCS forests is the same in every country, the results of each assessment may vary according to the context of local landscapes, even when the rules described in this toolkit are consistently applied. Average above-ground carbon values are calculated for the classes identified, but these will likely vary among countries and even within the same country.

Finally, the HCS Approach is **designed to be used in parallel and integrated with other land use and conservation strategies**. These include free prior and informed consent (FPIC) and the protection of peatlands, riparian zones, HCV areas, and areas important to local communities and indigenous people for cultural or economic reasons. Indeed, if these other aspects have not been properly assessed and mapped, the steps set out in the HCS Approach cannot be fully completed because a final integrated land use and conservation map cannot be developed.

STEPS IN THE HCS PROCESS



An overview of the HCS Approach and the HCS Approach Toolkit

This toolkit is intended for use by practitioners who seek to ensure that forests are not cleared in concessions which are designated for new planting. The HCS methodology is best implemented by a team of specialists with different skills. These skills can vary from land tenure analysis and participatory mapping to satellite imagery analysis, forest inventory, biodiversity assessments and landscape planning. The chapters that follow are therefore technical in nature, with the aim that a trained practitioner can use them in the field to implement the HCS Approach with little additional guidance.

As stated above, the HCS Approach is intended to be integrated with overall land use planning which also protects HCV areas, peatlands and lands important to communities. As those processes are well described elsewhere, this toolkit does not address them in detail; it assumes that when the HCS study begins, high-quality assessments of those other values have already occurred. Nonetheless, the authors have made best efforts to highlight those steps in the HCS methodology where these other assessments are particularly important.

The order of the chapters in the HCS Toolkit follows the steps of an HCS assessment. It takes the user through the first step of engaging local communities and stakeholders in the process, all the way through to creating a proposal for HCS forest areas which need to be conserved and areas which are suitable for development. Each step in the HCS Approach and its corresponding Toolkit chapter is outlined to the right. A short conclusions chapter highlights areas for further study.

> *"The HCS Approach is intended to be integrated with overall land use planning with also protects HCV areas, peatlands and lands important to communities"*

Putting the HCS Approach into its social context

CHAPTER 2
RESPECTING COMMUNITY RIGHTS TO THEIR LANDS AND TO FPIC IN THE HCS APPROACH

For the HCS process to be successful, and for forests to be conserved, local communities must be integrated into the process from the beginning. This chapter gives an overview of how to include communities in land use planning and integrate the HCS process with Free, Prior, and Informed Consent (FPIC): the right of local communities to give or to withhold their consent to any project affecting their lands, livelihoods and environment.

A short case study of how one company dealt with community conflict during a HCS pilot study is also presented.

Phase One: Making the first indicative HCS forest map

CHAPTER 3
INITIAL VEGETATION CLASSIFICATION THROUGH IMAGE ANALYSIS

The first step in the HCS Approach is to classify vegetation into relatively homogeneous classes on the basis of satellite imagery. The techniques of unsupervised vs. supervised vs. visual stratification are discussed alongside an overview of available image databases and tools.

The chapter includes sample satellite images from HCS studies to show how the initial classification is done.

CHAPTER 4
FOREST INVENTORY AND ESTIMATION OF CARBON STOCK

In the next step, the vegetation classes proposed in the first step are sampled in the field. This chapter explains how to select sample plots, measure vegetation, estimate above-ground biomass and refine the classification.

At the end of Phase One, an indicative map of HCS forest areas will be produced, with patches of HCS forest of varying size and connectivity identified.

Phase Two: Analysing HCS patches and creating an indicative conservation/development map

CHAPTER 5
HCS FOREST PATCH CONSERVATION: BACKGROUND AND PRINCIPLES

The map produced in Phase One will likely include some large forest areas as well as some isolated smaller patches of HCS forest. This chapter provides a review of conservation science research and literature relating to analysing forest patches in a landscape, and explains how different parameters including shape, size, configuration, and connectivity underpin decisions on the conservation of patches in the HCS Decision Tree.

CHAPTER 6
HCS FOREST PATCH ANALYSIS DECISION TREE

HCS forest patches are analysed using different parameters using a mix of GIS tools, manual analysis and field checks. This chapter describes the HCS Decision Tree, which is a relatively simple tool to address a complex set of decisions to be made about each HCS forest patch. Guidance is provided on how patches are classified at each step in the Decision Tree.

The final step in the Decision Tree integrates the HCS forests with other conservation and management areas including peatlands, HCV areas and areas important to communities to come to a development and conservation area proposal.

The future of the HCS Approach Toolkit

This first edition of the HCS Approach Toolkit aims to collate the knowledge acquired through the first wave of HCS trials and innovation. This included testing out the methodology in pilot studies, undertaken between 2011 and 2014 in palm oil and pulp and paper plantations in Indonesia, Liberia and Papua New Guinea. In publishing the methodology, the HCS Approach Steering Group expects this toolkit to be used to implement HCS assessments for agricultural expansion across tropical regions, including transparency of the decision-making processes and results.

> *"Much as the HCS Approach itself is innovative and collaborative, this HCS Toolkit will adapt and change based on the best thinking and experience of the companies, NGOs, and experts who use it"*

The HCS methodology may change slightly along with the conservation science which underpins it, and no doubt lessons will be learnt through further testing. This first edition is therefore also intended to be used for broader consultation and to gather more feedback. However, the HCS Approach Steering Group does not foresee major changes to the methodology and any fine-tuning will need to be agreed by the Steering Group. Companies committed to the HCS Approach should feel confident that the results of HCS assessments using this toolkit will be robust, relevant and accepted well into the future, even if minor methodological refinements are incorporated over time.

Finally, this first version of the toolkit takes the practitioners through to the outcome of the proposed conservation/development area map. Following this, HCS forest areas (integrated with other conservation areas) need to be conserved together with local communities and have their legal protection ensured. Innovations are also needed for financing the protection of HCS forest, and for their management and monitoring. In 2015 the HCS Approach Steering Group will be gathering experiences and leading discussions on these aspects with the aim of developing guidance and additional modules for the toolkit in order to address them.

The HCS Approach Toolkit is therefore best seen as a 'living' document which will be updated and added to over time as the methodology is refined. Much as the HCS Approach itself is innovative and collaborative, this HCS Toolkit will adapt and change based on scientific advice and research, as well as the innovations and experiences of the companies, NGOs, and experts who use it to implement their commitments to eliminate deforestation.

All photos: Courtesy TFT ©

Chapter 2

Respecting community rights to their lands and to Free, Prior and Informed Consent in the High Carbon Stock Approach

By Marcus Colchester, Patrick Anderson and Sophie Chao, Forest Peoples Programme

The chapter authors would like to thank Tint Lwin Thaung from The Center for People and Forests (RECOFTC), Janis Alcorn from the Rights and Resources Initiative, Eric Wakker from AidEnvironment, Bill Barclay and Brihannala Morgan from the Rainforest Action Network, and members of the HCS Toolkit Editorial Committee for helpful comments on previous drafts. The authors alone are responsible for any errors that remain.

CHAPTER CONTENTS

Introduction: Respecting rights and securing livelihoods in forests

Nearly all terrestrial ecosystems in the tropics are inhabited and provide livelihoods to a wide diversity of social groups, commonly referred to as indigenous peoples and local communities. Some 350 million indigenous people live in forests, while overall 1.5 billion people, including about half of the world's poorest people, depend directly on forests for their daily livelihoods (Chao, 2012). Indeed, research shows that many apparently 'virgin' tropical ecosystems have been shaped and transformed by long-term human occupation and use (Balée, 1994; Leach and Mearns, 1996; Fairhead and Leach, 1998; Posey and Balick, 2006. Notably, some customary practices actually enhance carbon stocks in vegetation and soils, such as the humus-rich *terra preta* soils in Brazil built up by centuries of indigenous cultivation as well as the forest islands created by human settlements in West African savannahs (Heckenberger, 2005). Almost any intervention that affects these ecosystems thus also affects the people who depend on them and may disrupt the ecology, implying a responsibility to respect their rights and take into consideration impacts on their livelihoods, culture and their role in shaping the environment.

> *"It is very common for people who live in forests to move around within their territory, shifting their village sites to access fresh hunting and farming areas, while allowing previously used areas to recuperate"*

These systems of land use are complex and diverse. Most forest-based communities practise mixed economies which may include, for example: hunting and gathering over extensive areas for wild game and a great diversity of fruits, wild foods, resins, drugs, medicines and constructional materials; fishing in rivers, lakes, streams, ponds, and seasonally flooded forests; farming and livestock-raising in permanent fields, pastures and on rotationally cleared forested hillsides; and tree-cropping for rattans, fruits, latexes and timbers. The products from all these activities may be used locally, bartered with neighbours or be traded regionally and globally. All these practices imply subtle local ecological knowledge embodied in practical lore, belief systems and accompanying social norms.

Corresponding to these systems of land use are equally subtle local systems for apportioning entitlements and regulating use and access, which are overseen by community, or higher level, institutions. It is common among forest peoples to find that rights to different aspects of their lands, territories and resources are held by a wide range of local institutions at the same time in ways that overlap. For example, an embracing territory may be owned collectively by a village or cluster of settlements, perhaps overseen by a council of elders. Within that area, certain hunters or groups of hunters may have their own hunting or trapping trails, specific fruit trees may belong to certain persons, farmlands and forest fallows may be owned by the specific families that first cleared them, and fishing sites may be allotted to certain groups.

Moreover, peoples' landscapes are not just important to them economically but are invested with memories, associations and ritual significance, and underpin their very identities. Sacred sites may be taboo to certain persons or in defined circumstances. Areas of forest may be reserved for religious reasons, or set aside for hunting, for farming by future generations or to allow recovery after use. Commonly, there are also well-established and locally accepted norms by which any disputes that occur can be adjudicated and conflicts resolved. These landscape designations are often invisible to outside observers and even scientists.

It is also very common for people who live in forests to move around within their territory, shifting their village sites to access fresh hunting and farming areas or trading opportunities, while allowing previously used areas to recuperate. That does not mean areas are 'abandoned', only that they are temporarily out of use or used less intensively. Studies show that these systems of settlement mobility, rotational farming and land use zoning can help ensure long term sustainability of the forested landscape[1].

The short-hand terms we use to describe these complex systems are 'customary use', 'customary rights' and 'customary law'. International human rights and environmental laws require respect for these systems. These laws include the basic human rights covenants and treaties of the United Nations, the UN Declaration on the Rights of Indigenous Peoples and the Convention on Biological Diversity. States have an obligation to protect these rights, and companies are required to respect them even where national laws or practices do not

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[1] See, for instance: http://www.agriculturesnetwork.org/magazines/global/farming-in-the-forest/intensification-of-shifting-cultivation-editorial

All photos: Courtesy TFT ©

> *"It is important to ground the HCS process within a company's obligations to respect customary use, human rights, and international laws"*

recognise them. The UN's Guiding Principles on Business and Human Rights[2] note that the responsibility of business enterprises to respect human rights exists independently of States' abilities and/or willingness to fulfil their own human rights obligations, and exists over and above compliance with national laws and regulations protecting human rights. These company obligations are also spelled out in several different sustainability standards and certification programs.

Because the High Carbon Stock Forest assessment process has been developed as a practical tool for companies to use in land use planning for forest concessions, it is important to ground the HCS process within these company obligations to respect customary use, human rights, and international laws. This chapter provides an overview of these obligations as well as the steps companies must take to integrate them into the HCS process.

Implications for company concessions and identification of High Carbon Stock forests

When companies seek to acquire forest lands by purchase or as leases ('concessions') from government agencies, they need to take steps to ensure that the rights and livelihoods of forest peoples are assured. Inevitably the commercial activities planned by plantation companies have the potential to undermine or disrupt local ecosystems and prior systems of land use. This is because *inter alia*:

- allocation of lands and resources to plantations inevitably reduces or overlaps with the lands available to local communities for other purposes;
- new infrastructures such as roads, bridges and townships open up areas to intensified and commercialised resource use, both by local people and by outsiders;
- new enterprises attract workers and other settlers to migrate into the area to get work and engage in other commercial activities, thus competing for jobs and resources with local communities;
- more obviously, if communities' lands and forests are taken over without adequate consultative planning, without respecting communities' rights or without their consent, then imposed plantations may destroy their livelihoods, trigger serious social conflicts and lead to environmental misuse.

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[2] Available at: http://www.ohchr.org/Documents/Publications/GuidingPrinciplesBusinessHR_EN.pdf

Introduction: Respecting rights and securing livelihoods in forests

The purpose of social and environmental impact assessments and land use planning tools, like those used to protect High Conservation Values or to identify High Carbon Stock forests, is to mitigate these impacts and ensure that essential social and environmental values and services are maintained or enhanced. However, if assessments are carried out without genuine participation and lands are reallocated as environmental set-asides without communities' involvement or respect for their rights and livelihoods, they may be ineffective or worse. This is because *inter alia*:

- Assessors and company managers will fail to understand: the extent of local communities' rights; how they make a livelihood; and what rights and status are attached to certain lands and forests under customary systems of land ownership and use;
- Imposed classifications may cut across local systems of land use;
- Imposed set-asides and restrictions may violate customary rights, causing resentment or disputes with local users;
- Restrictions on use will either impoverish local people or displace their land use into other areas;
- Disrupted systems of land use are likely to become more unsustainable and place greater pressure on remaining resources, including both plantations and set-asides.

These are not simply theoretical difficulties. Imposed pulp and paper and palm oil plantations and protected areas have caused widespread conflicts (Colchester, 1994 and Dowie, 2009). In Malaysia, there are hundreds of legal cases in the courts where communities are disputing the way lands have been allocated to companies without respect for their customary rights (Colchester et al., 2007). In Indonesia, where laws provide even less protection of customary rights, the government's National Land Bureau estimates that there are some 4,000 land conflicts between palm oil companies and communities. Where these disputes are unresolved they may give rise to protests, police repression, retaliatory crop theft, destruction of properties, further repression, riots, police violence, injuries and deaths. These kinds of problems sometimes paralyse plantations, cause substantial financial losses and lead to suffering by local communities.

All photos: Courtesy TFT ©

Unfortunately, detailed field studies also reveal very real problems with HCV and HCS land use planning. In numerous cases, communities deprived of lands and forests, first by land taken for plantations and then by environmental set-asides, have felt obliged to open up farms in riparian forests left uncleared to ensure environmental services under HCV 4 or impinged on areas set aside for rare, threatened and endangered species under HCV 2. The main problems stem from:

- failures by companies to recognise communities' prior rights and respect their right to give or withhold consent to operations planned on their lands;
- the use of inadequate toolkits which lack clear advice on how to set aside lands for livelihoods;
- poorly trained assessors who don't understand the complexity of customary land use systems; and
- the lack of real community participation in carrying out assessments and developing management plans to maintain conservation values.

Problems have also arisen from communities not being fully informed of how much land companies will take over for plantations and set-asides or imprudently agreeing to relinquish extensive areas of land without thinking of their future needs or because of unreal expectations about the scale of benefits they will derive from plantations and smallholdings. Where HCV and HCS zonings have (unfortunately) been carried out after lands have already been relinquished, then set-asides may be resented for squeezing communities off lands that they had expected would remain for their use for their livelihoods or for smallholdings of commercial crops.

The guidance which follows is designed to address all of these problems.

Deeper challenges

It is also important to recognise that the problems outlined in this chapter may be exacerbated by inappropriate land tenure laws and poor land governance by State agencies. All too often, statutory laws do not recognise (the full extent of) customary lands nor require communities' Free, Prior and Informed Consent (FPIC) before allocating such lands to companies. In addition, laws governing land, forestry and plantations, may hinder progressive companies from implementing management systems consistent with best practices. For example in Indonesia, pulp and paper companies cannot formally recognise and set aside areas for customary rights in designated State forests which have been allocated to them for plantations, even if they want to. Some palm oil companies operating in Indonesia which have set aside extensive areas for HCVs have found that these parts of their permitted areas have been cancelled for leaving too much 'idle land' within their concessions, contrary to the legal requirement to plant such areas with palms.

Even where pulp and paper companies reach informal agreements with communities to set aside areas for community use within their concessions, only strictly limited areas can be allocated for farming or for communities to cultivate crops of their choice like rubber, as the plantation permit has been granted to the company only for growing specified pulpwood species. Under Indonesian regulations, licenses to develop oil palm can only be issued on State land, and companies have to persuade communities to give up their rights to that land so that an oil palm license can be issued. Many communities are not informed that in releasing their lands for oil palm development, the area becomes unencumbered State land and will not revert to them at the expiry of the lease. In Malaysia, even where an RSPO member company may want to settle a land dispute with a local community, the State Government, which sometimes holds a share in the company, may refuse to settle and instead pursue litigation against the community in the courts.

In exceptional cases, such as that of Wilmar in Central Kalimantan, companies have been able to negotiate *ad hoc* agreements with local governments to allow them to maintain set-asides even where national laws proscribe this (Colchester et al., 2012), but if community rights and set-asides are to be secured and more widely adopted then legal reforms are needed.

All photos: Courtesy TFT ©

Land acquisition and Free, Prior and Informed Consent

Numerous toolkits and guides already exist on how customary rights and prior land use systems should be recognised and how lands should only be acquired for use by third parties subject to communities' free, prior and informed consent. These include guides developed:

- For certification schemes such as the Roundtable on Sustainable Palm Oil[3], Roundtable on Sustainable Biomaterials[4] and Forest Stewardship Council;[5]
- By UNDP for the UN-REDD Programme;[6]
- By the German Technical Assistance agency (GIZ) and the Centre for People and Forests for use in REDD+;[7]
- By the UN Food and Agriculture Organisation for use by governments in the governance of tenure of lands, fisheries and forests; and[8]
- By the International Labour Organisation to guide indigenous peoples in negotiations with companies[9].

Numerous reviews have also explored the requirements of international law and the practical obstacles that stand in the way of effective implementation. See, for example:

- Fergus MacKay (2004). "Indigenous Peoples' Right to Free, Prior and Informed Consent and the World Bank's Extractive Industries Review". *Sustainable Development Law and Policy*, Volume IV (2): 43-65.
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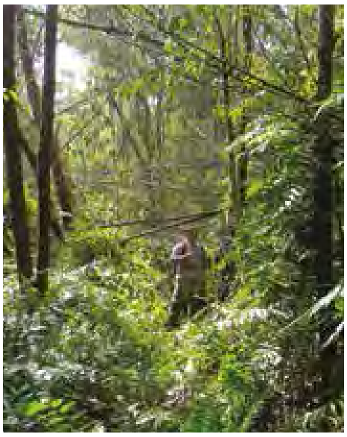

All photos: Courtesy TFT ©

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3. See: http://www.rspo.org/resources/supplementary-materials
4. See: http://rsb.org/pdfs/guidelines/12-05-02-RSB-GUI-01-012-01-RSB-Guidelines-for-Land-Rights.pdf
5. See: https://ic.fsc.org/preview.fsc-fpic-guidelines-version-1.a-1243.pdf
6. See: http://www.un-redd.org/Launch_of_FPIC_Guidlines/tabid/105976/Default.aspx
7. See: http://www.recoftc.org/basic-page/fpic
8. See: http://www.fao.org/3/a-i3496e.pdf
9. See Barsh (1995)

All photos: Courtesy TFT ©

“As each community is unique and all peoples have different cultures and norms, so each procedure towards FPIC may be different”

Acceptance by companies that, in line with international law, customary communities have rights to the lands, territories and resources that they have traditionally owned, occupied or otherwise used and have the right to give or withhold their FPIC as expressed through their own representative institutions, requires some quite fundamental changes in the way they go about land acquisition. It implies rewriting their standard operating procedures, retraining field staff and managers, and developing much more open systems of communication with local communities. Above all it means accepting that the communities involved will have a decisive voice both about whether an operation should go ahead or not and in setting out the terms and procedures by which consultations and negotiations are undertaken and agreements reached.

All the words in the expression ‘Free’, ‘Prior’ and ‘Informed’ ‘Consent’ are loaded with legal significance. They require that in any process towards an agreement, the communities feel **free** from any compulsion, coercion or duress; that concessions have not been granted and no lands taken **prior** to communities’ agreement; that communities are fully **informed** about how their rights might be affected, impacts mitigated and benefits shared; and that the procedures by which deals are negotiated and **consent** given or withheld are agreed by the communities. All the guides noted above stress that securing FPIC requires iterative engagement between operators and communities. FPIC is not a one off box-ticking procedure to be carried out by company staff, but a repeated two-way engagement and learning process for both parties. As each community is unique and all peoples have different cultures and norms, so each procedure towards FPIC may be different.

The following list sets out the key steps in any FPIC process, drawing most heavily on the RSPO Guide which should be referred to for details. More details regarding how legitimate vs. non-legitimate claims can be handled, how communities can be represented, how conflicting claims can be resolved, how consensus must be documented, and other key factors are outlined in the RSPO and other guides listed above.

Prepare

- Operators inform communities of their proposal to develop an area and explain the communities’ entitlements to FPIC and to control what happens on their lands.
- Communities decide if they want to consider the company proposal and if so, how they want to be represented in engaging with the operator, with discussions about how the interests of women, children, youth, marginalised castes, classes and land users will be taken into account.
- The procedure and steps for an iterative FPIC process of engagement between the communities and the operator is mutually agreed, taking account of all the steps noted below and the communities’ own norms and proposals. This includes clarifying how the process will be documented and validated, and the form that information will take to ensure it is accessible to communities.

Land acquisition and Free, Prior and Informed Consent

Assess and map

- A participatory land tenure and land use assessment is carried out to clarify the way customary rights are allocated and lands used by the people concerned.
- Participatory mapping is undertaken jointly to plot the full extent of customary rights and uses including farmlands, forest fallows, hunting, fishing and gathering areas, reserves, sacred sites and collective territories
- Participatory Social and Environmental Impacts and High Conservation Value Assessments are undertaken, as well as High Carbon Stock forest stratification and analysis. Together these assessments clarify which areas the company seeks to acquire for planting, which areas it is proposed be managed for conservation and which areas will remain unaffected for communities to maintain their livelihoods.
- This information will help communities assess the benefits and costs of accepting palm oil development and associated conservation zoning in their areas.

What is participatory mapping?

Participatory mapping is a tool for identifying and mapping indigenous and local community ownership of land and natural resources, as well as land use. It is a mapping method based on local knowledge which establishes local people as a key stakeholder in mapping the given areas. Communities identify the areas to which they have customary rights and which are important to them for historical, current and future livelihoods, cultural values, or ecosystem service provision. The results of the mapping can be used by the communities as a basis for negotiation with companies on land use planning. These results can also be useful to communities beyond their dialogue with companies, for instance to support village development and community-based natural resource management. They are important tools for communities carrying out land use planning to accommodate oil palm development and HCS areas into their territories.

Negotiate an agreement

- Communities choose who they want to act as their legal or other advisors and as independent observers. Funds are secured to pay for these costs and help ensure communities are adequately informed.
- Once all these elements are in place, time is given for communities to access information on alternative development options and what management of HCS forest areas for conservation means, assess all the information provided, discuss the implications among themselves and with their self-chosen advisors, and decide if they want to undertake negotiations.
- If so, negotiations then occur between the communities' representatives and the operator to clarify the terms of any relinquishment of rights. Time and scope must be given for community meetings to review interim offers and develop counter-proposals for further rounds of negotiation.
- If agreement is reached in principle then land deals can be finalised with associated provisions for land use, conservation and management, enclaving areas (from both development and conservation) for food production, benefit sharing, mitigation, grievance mechanisms, etc.
- Identify and agree on the mechanism and tools to establish and manage conservation areas such as conservation agreements and co-management, as well as fair compensation for any loss of use of conservation areas.
- Legalise or notarise agreement.

Implement, monitor, and update the agreement

- Implement agreement: this may include staged relinquishment of rights and land acquisition from specific rightsholders within the collective territory.
- Participatory monitoring of implementation.
- Activation of grievance mechanism where and when necessary.
- Adjust management system where monitoring or grievance mechanism identifies shortcoming in implementation or unexpected problems.

The ideal outcome of a good FPIC process is not just agreements that are fairly implemented but relationships of trust between communities and the operator.

All photos: Courtesy TFT ©

Accommodating rights and livelihoods in the High Carbon Stock Approach

The main purpose of the High Carbon Stock Approach is to identify viable areas of forest that should be conserved due to their value as carbon stores, for biodiversity conservation, and as areas for customary use. As described in this Toolkit, areas of vegetation in a defined area of commercial land development are screened by a combination of analysis of satellite images and field sample plots to estimate the above ground biomass of trees over 5cm in diameter to stratify the vegetation into six categories: open or cleared lands, scrub, young regenerating forest, low density forest, medium density forest and high density forest.

In pilot experiences HCS forest areas are those in the four upper categories – young regenerating, low, medium and high density forest, which are then analysed further to identify viable forest areas that are proposed for conservation. Open area, grasslands and scrub areas are determined not to be HCS areas (Greenpeace, 2013). All peatland and HCV areas are also identified and managed for conservation.

In order to accommodate the dynamic use of lands and forests by communities, forest stratification maps of the lands under consideration need to be overlaid with the participatory maps already developed to show which of these areas are subject to customary rights and use. The aim must be to ensure that HCS, HCV and FPIC processes operate together and not contradictorily. Areas of overlap then need to be checked with the participation of the rights holders to ascertain these areas' current and proposed usage whether as hunting, fishing and gathering grounds, forest reserves, sacred sites, farmlands, pastures, tree crops, rotational farming areas and future farmland reserves. This allows many of these areas, especially tree crops and farmlands, to be removed from being considered as HCS forest.

Where HCS forest areas proposed for conservation may affect either communities' rights or their current and future access and use, FPIC is then also required. Prior to this, and to ensure informed consent, discussions should be held to clarify:

- The purpose and procedures of the High Carbon Stock Approach, presented in a form and language comprehensible to the communities
- What constraints would there be on rights and resource use, including what uses would be prohibited, inside any proposed conservation areas to be managed for both HCS forest and HCV?
- What tenurial arrangements will be applied to any conservation areas: will these secure or diminish community rights?
- Who would manage and monitor the proposed conservation areas and ensure they retained their ascribed values?
- Where any relinquishment of rights or restrictions of livelihoods would ensue, what mitigations, compensation or alternatives would be offered?
- How would the costs and benefits be shared, including the impacts on current livelihoods from conservation areas and benefits foregone by limiting the areas available for smallholdings and estates?

For areas under long term cycles of rotational farming and forest fallows, and where communities expect to maintain their livelihoods from farming, ground surveys will be needed to estimate the length of forest fallows and so calculate the total areas of land needed to maintain current livelihoods from farming. This can then be taken into account in community land use planning.

Community land use planning

To help communities plan viable long-term livelihoods and ensure local food security, information must be generated from the participatory mapping and HCV and HCS zoning, to clarify the location and extent of areas:

- currently allocated to various community uses
- required by the company for proposed plantations
- to be allocated for smallholdings or other benefit-sharing developments
- to be conserved for HCV and which of these areas will restrict current uses
- proposed to be conserved for HCS forest and which of these areas will restrict current uses
- that will remain for various community uses, including the needs of future generations, if all these other allocations are acceded to.

Community participatory land use planning should then be carried out through iterative and inclusive community meetings – some with the operator, some just with chosen advisors, some without any outsiders – to assess community needs, evaluate the proposals from operators and assessors, and where necessary make counter proposals for land allocations, land uses, land management and tenure. These proposals become part of the information that feeds into FPIC negotiations (above).

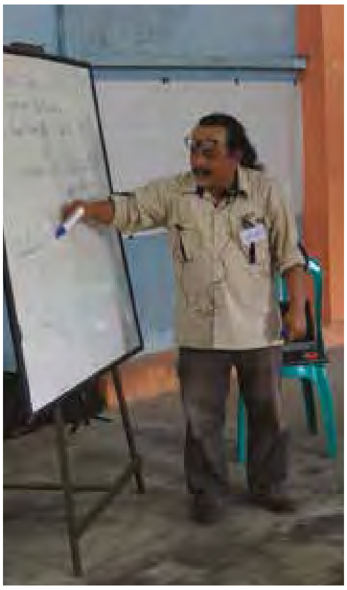
All photos: Courtesy TFT ©

Clarifying tenure and management

Clarifying tenure

Creative use of customary and statutory law should be explored to identify tenures which minimise the extent to which any proposed land allocations limit or curtail rights and land uses.

Lands need not be ceded to operators for plantations in perpetuity by sale or transfer but can instead be leased or rented for agreed terms. Community lands which are not to be ceded to the company should be excised from concessions and titled or registered as community lands. Areas to be conserved for HCV and HCS and that overlap areas of customary rights should also be secured as community lands, in compliance with relevant laws and regulations. Likewise remaining areas being retained by the communities should be secured.



> *“Areas to be conserved for HCV and HCS and that overlap areas of customary rights should also be secured as community lands”*

Management

Care must be taken to clarify which entities will have responsibility to manage which conservation areas, bearing in mind a range of options including:

- Company-managed areas within concessions
- Community-owned and -managed areas
- Government-managed areas excised from concessions
- Co-managed areas (community & government or community & company)

No proposed conservation areas which overlap communities’ lands and territories should be taken over and managed or co-managed by other parties without this being agreed through the FPIC process outlines above. Once the entities with responsibility for management have been agreed, the persons (or office holders) and institutions with those responsibilities need to be authorised, trained and budgeted to carry out their management roles. Effectively securing and protecting all HCS forest areas will usually require a mosaic of management regimes and tenures.

Since national laws are too variable to make simple recommendations, legal studies will be needed to ascertain the best options available in different countries and locales; these will need to be explored with communities and their legal advisors prior to any consent.

All photos: Courtesy TFT ©

Monitoring

Land use planning, zoning, and management are always dynamic processes, and cannot be expected to foresee every eventuality. Ensuring the effective functioning of the HCS forest and HCV systems require integrated participatory monitoring systems which combine (a) periodic remote sensing to check that extensive land clearance is only happening where agreed with (b) real time ground patrols including members of the local communities who can identify which actors are responsible for any such clearance and who can also often identify other threats or risks to agreed arrangements and land uses.

Innovative tools have already been developed for participatory monitoring of HCVs which can be adjusted to also monitor HCS conservation areas. These tools contemplate *inter alia*: the creation of local teams who regularly walk trails to check on compliance and identify threats, geo-tagged SMART reporting systems using simple software that integrate field reports in almost real time with computerised mapping, and systems for ensuring community validation of findings[10].

Feedback systems

To ensure that misunderstandings do not escalate into disputes, grievance mechanisms need to be agreed in advance with corresponding procedures to look into complaints and act on them. Procedures also need to be in place to implement recommendations coming from monitoring and grievance processes to adjust management practices, land allocations and responsibilities.
In cases of serious dissent, agreements may need to be revisited and revised.

> *"Innovative tools have already been developed for participatory monitoring of HCVs which can be adjusted to also monitor HCS conservation areas"*

All photos: Courtesy TFT ©

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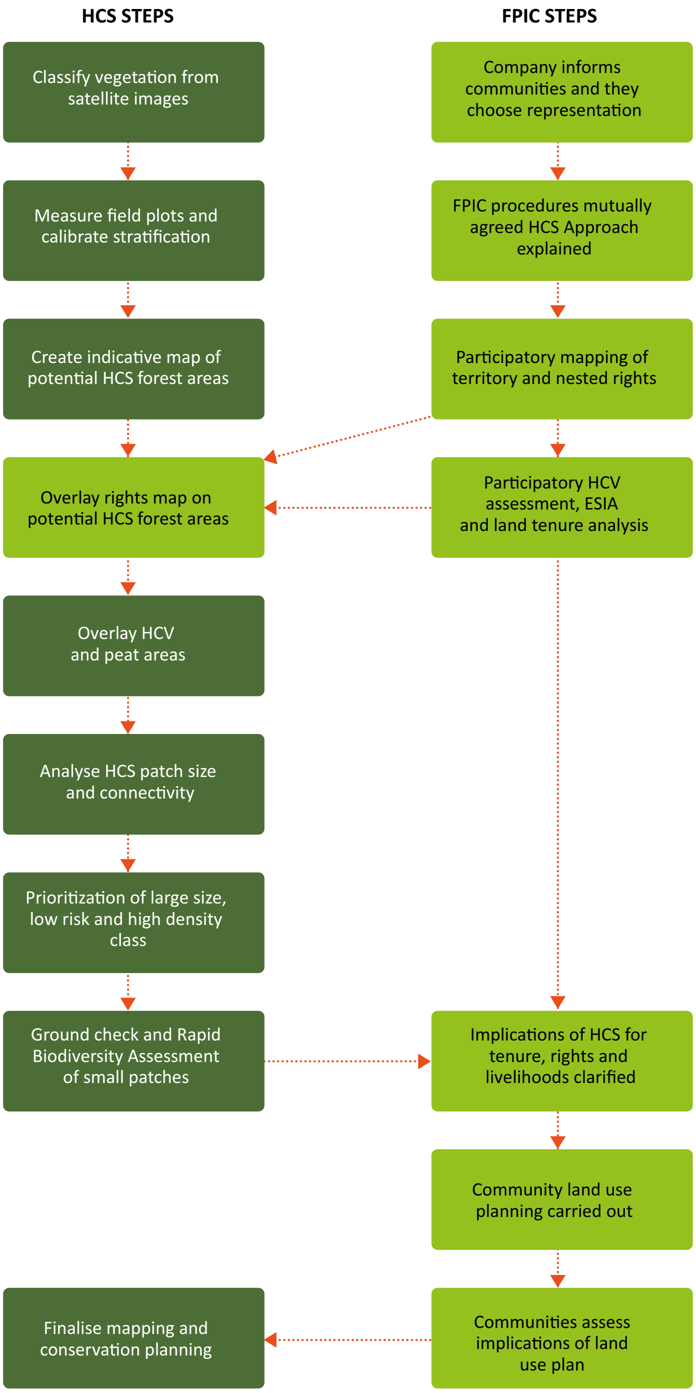
[10] **10.** See, for instance: http://www.forestpeoples.org/topics/palm-oil-rspo/publication/2013/monitoring-protocol-high-conservation-values-5-and-6-guideline

Retrofitting the HCS Approach into pre-existing negotiations

When establishing new plantations, the HCS Approach should be integrated into other processes such as HCV protection and FPIC considerations from the beginning. The main part of this chapter has proposed an integrated approach to combining HCS and FPIC processes. But where operators have already acquired lands and begun establishing plantations prior to adopting the HCS Approach, a participatory review with independent advisors needs to be carried out to assess the degree of compliance with the principles described in this chapter. In particular, because conserving HCS forest areas implies that additional areas will either not be available for development or have constraints on use, this may directly affect the amount of lands available to local people, thereby possibly reducing areas available for traditional livelihoods, new smallholdings and future generations. This may substantially reduce the benefits local people had anticipated when consenting to the presence of a developer and, for example, HCV set-asides.

Operators may therefore need to revise and redo several steps in order to achieve compliance, which may imply renegotiating agreements and management plans with communities so that new set-asides do not deprive them of benefits, lands and livelihoods or squeeze rotational farming and other land use systems onto too little land to be sustainable. The case study presented at the end of this chapter illustrates the challenges to retro-fitting the HCS process onto an existing concession where an integrated, inclusive approach was not followed from the beginning.

PART 1
INTEGRATED HCS AND FPIC APPROACH SUMMARY OF STEPS

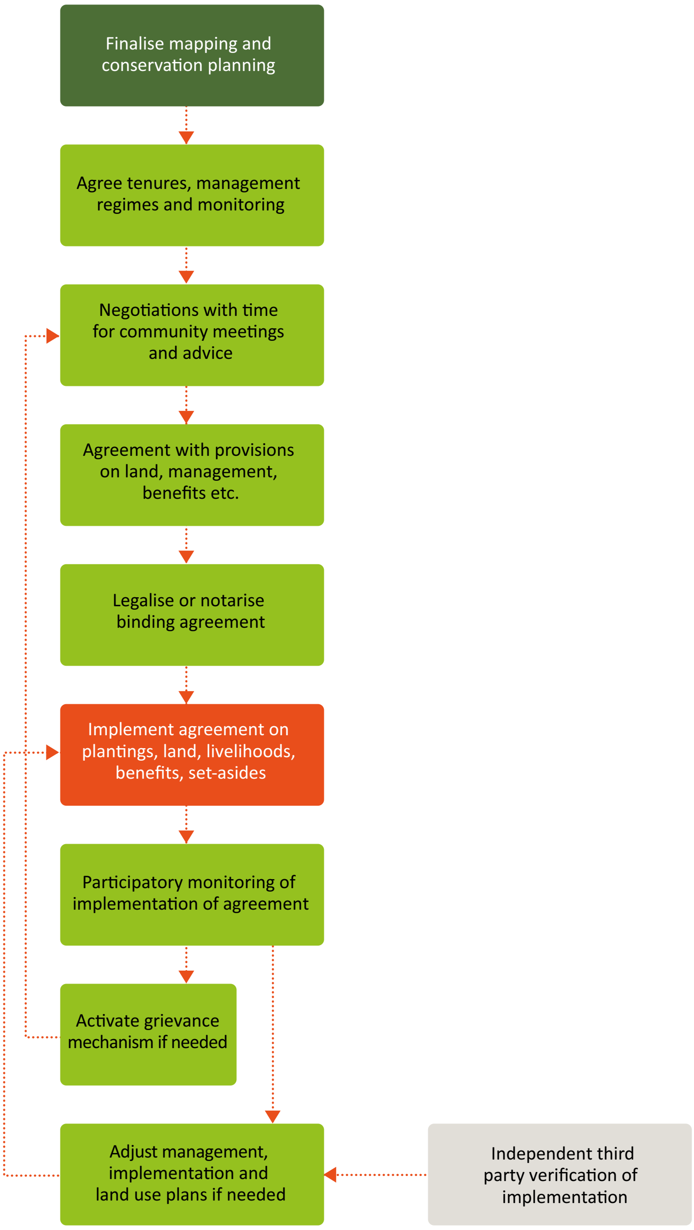


> *“When establishing new plantations, the HCS Approach should be integrated into other processes such as HCV protection and FPIC considerations from the beginning”*

Conclusions: Integrating respect for community rights to lands and FPIC into the HCS Approach

Since respecting community rights to lands and FPIC is an ongoing requirement and not a one-off exercise, elements of FPIC need to be fully integrated into the HCS Approach. The HCS Approach Steering Group is leading discussions among practitioners regarding the ideal order of each step in the HCS and FPIC processes, including how to integrate High Conservation Value Assessments. An initial view of an integrated approach is shown in the diagrams left and right. However, it is important to understand that FPIC processes will always vary from place to place and a prescribed sequence may not suit all cultures, communities or locales.

PART 2
INTEGRATED HCS AND FPIC APPROACH SUMMARY OF STEPS



Case Study

The importance of community engagement in the HCS Approach: A case study of PT KPC

By Jana Nejedlá, TFT, and Pi Li Lim,
Golden-Agri Resources

The authors would like to thank Agung Wiyono, Guntur Tua Aritonang, and Stephany Iriana Pasaribu from TFT for providing helpful background information to compile this case study.

Introduction

This case study focuses on the importance of community engagement in the HCS Approach through lessons learned in a pilot HCS project at PT Kartika Prima Cipta (PT KPC), a palm oil concession in Kapuas Hulu, West Kalimantan Province in Indonesia, a subsidiary of Golden Agri-Resources Ltd (GAR). The purpose of this pilot project is to test the implementation of GAR's Forest Conservation Policy and support the creation of a framework for the successful implementation of HCS conservation and "No Deforestation" policies for the broader oil palm plantation industry.

> *"Like the rest of West Kalimantan, there are large scale land use changes in Kapuas Hulu district due to oil palm development by private companies"*

All photos:
Images from participatory mapping activities in PT KPC. Courtesy TFT ©

Background

Kapuas Hulu district is an upland area famous for its large lakes, extensive peat swamps and productive inland fisheries. Compared to other districts, Kapuas Hulu already has large areas allocated for conservation. Like the rest of West Kalimantan, there are large scale land use changes in Kapuas Hulu district due to oil palm development by private companies. Since PT KPC started operations in the area in 2007, it has faced mixed reactions to palm oil cultivation from the local Dayak and Malay communities in some villages, both both 'for' and 'against'. More recently the company has even been handling disputes and grievances from communities who initially supported palm oil development, and surrendered their lands. These communities argue that the promised benefits of development have been slow to materialise and that planted areas for smallholder farms are not as extensive as expected.

These social issues, coupled with the communities' varied understanding of the implications of High Conservation Value (HCV) area set-asides, made it hard to explain and gain buy-in from communities for the new HCS concept. Many people feared that HCS conservation would result in additional land closed off to their use, limiting their opportunities to generate livelihoods from non-timber forest products (NTFPs) such as rubber and fisheries.

The company and TFT made an effort to share the HCS concept with key local stakeholders as early as September 2012 as part of the socialisation process. The communities had strong concerns about the HCS pilot project, including uncertainty about the loss of livelihoods if they could no longer access areas identified for HCS forest conservation, whether the company would develop plasma (palm oil smallholdings under a government-regulated scheme) for them, and whether the company would take over their customary forest. In particular, the communities feared that HCS zoning would not allow them to continue their practice of traditional shifting agriculture, a mobile system of farming which makes use of forest areas for relatively short periods, after which the lands are left to rest to allow forest regrowth and soil fertility regeneration before the cycle of clearance and use begins again.

Gaining community consent

In response to these concerns, PT KPC and TFT developed a plan to improve the relationship with the communities and gain their consent for the HCS pilot project. The first steps undertaken as part of this plan were an NTFP study and a participatory mapping process. This case study focuses on the participatory mapping process, given its importance in the HCS Approach.

Preparation is essential for ensuring that the participatory mapping process is implemented effectively. The activities that took place prior to the mapping included the following:

1. Capacity-building for PT KPC management so that they could provide guidance on the participatory mapping exercise to the public.
2. A comprehensive, multi-stakeholder socialisation in order to create awareness and to gain support for the HCS process from the communities.

Case Study

3. The technical capacity of communities engaged in the mapping process was built through training and facilitation.

The participatory mapping exercise outlined above began in three villages, namely Desa Mensusai, Desa Kerangas, and Desa Mantan, and was implemented from January through August, 2014. All villages in the PT KPC concession area were approached to take part in the participatory mapping process, but these three villages were selected as they had the resources and the willingness to collaborate with PT KPC and TFT. The village of Desa Menapar was also willing to cooperate in the participatory mapping process, and was added later to the project scope. This village started the participatory mapping process with support from PT KPC and TFT as an early success story and example to the other villages.

The Village Head of Desa Kerangas noted the following regarding the participatory mapping process:

"With participatory mapping things will get better, because the goal is to protect the next generation. Now the village boundaries are quite clear to us. For example, although the villagers have always had an understanding of the other villages that surround ours, we now know the borders to the north and to the east. Also, all village assets such as rubber plantations and sacred forest have now been identified. The impact of this process will be to protect the interests of the next generation, for a better future."

Progress to date

To prepare for the participatory mapping process, the PT KPC employees involved in the process were trained (starting in January 2014) on the participatory mapping concept and identification of NTFPs, FPIC and basic mapping competencies. TFT also conducted intensive discussions with groups of local and international NGOs active in the Kapuas Hulu area in order to gain a more comprehensive understanding about the local communities.

Interestingly, the more time-consuming and challenging socialisation processes were with local governments, including the local government of Kapuas Hulu District, the Suhaid Sub-District government and the village government (Village office and Representative Village Body/BPD). Local governments were concerned with setting aside even more land for conservation, which could affect the potential economic development in the district. The pilot project showed that engagement with local governments is a key success factor for the participatory mapping process. Participatory mapping and the consensus-building which follows are an important buy-in process.

PT KPC and TFT teams faced various challenges as they tried to gain FPIC for the HCS process from the villages and local governments due to:

- The fact that HCS is a new concept and this was the first time that participatory mapping was to be conducted in the villages; there was thus a very low level of understanding of both.
- The reservations and scepticism of villagers who had been approached by various NGOs and parties to talk about their land tenure issues in the past, and were unwilling to believe that this time it could bring them any benefits. Also, the company had continued to approach some communities that had previously withheld their consent for oil palm development.
- Communities were hesitant to cooperate with the company and provide information.

To break down these barriers, it was important for PT KPC to plan and manage interactions with the local communities with care and sensitivity. PT KPC and TFT led a series of activities, which included training for communities on the participatory mapping and HCS conservation process, and discussions with the government to provide answers and objective information to their questions or concerns. These activities started with the Suhaid Sub-District Government, who gave their permission in February 2014 to continue with the activities at sub-district level with local government and village representatives. After the socialisation at the sub-district level, the activities began in the targeted villages.

All photos:
Images from participatory mapping activities in PT KPC. Courtesy TFT ©

To explain the participatory mapping process and benefits to local communities, local languages and different types of media (such as pictures and presentations) were used to ensure that the information shared with the local communities was well-received and understood. In many cases it was important to involve special interest groups in the conversations, for instance women's groups, as opinions on palm oil and the willingness to take part in participatory mapping differed among various interest groups. Finally, it was necessary to understand the decision-making process at the level of village communities and take them into consideration in any activities undertaken.

GPS devices and training were provided to the participating communities by PT KPC and TFT, and the communities chose which members would participate. The teams for each of the four villages included village officials, members of the village with good knowledge of the village boundaries, representatives of indigenous groups, and also representatives from neighbouring villages. The mapping team also used notes from the discussions with the communities and input from community leaders who know the village borders and understand agreements with bordering villages.

Although PT KPC and TFT developed a comprehensive scope for the participatory mapping exercise, the actual outcome of the mapping activity was derived from the participation of the communities and prioritisation of information important to them. The field mapping resulted in GPS coordinates for village boundaries, roads, and settlements, as well as places important for local people's socio-cultural functions, such as cemeteries, water sources, educational facilities and local cultural sites. Areas assigned for future planting and development of the village community are also included. The mapping specialist team from TFT incorporated these data into draft maps, which were shared with the mapping teams in each village for their re-validation of the data, with photographs provided as reference material.

Mapping to date has identified village boundaries and some areas that are important to the local communities such as infrastructure and resource areas. Mapping will continue through February 2015 in the four villages to clarify community current and future land use planning. The final draft maps will be discussed with representatives from neighbouring villages and the Sub-District Government to ensure that the data given by communities matches what is already known by sub-districts.

After all the involved parties have agreed on a final version of the maps, the maps will be given to the respective villages to be signed by village government and village administrators, including representatives of indigenous groups. The final maps will indicate the boundaries of their lands and certain aspects of land use (e.g. agriculture, customary forest, housing, public facilities), as well as features important to the communities such as natural resource areas and sacred places.

Conclusions

The PT KPC case illustrates the importance of participatory mapping as a critical step in the land use planning process, and also as the basis for fulfilling local and indigenous peoples' rights to FPIC. Likewise, the rights and livelihoods of these local communities need to be embedded in the HCS methodology to ensure they are both recognised and secured. This includes the discussion of how HCS areas will be protected and managed, and the role and participation of communities in that process. An important outcome of the HCS pilot is that participatory mapping is now included in the HCS Approach.

This case study demonstrates that community relations and buy-in are crucial for HCS conservation. All stakeholders need to understand what is to be achieved and need to be engaged to help shape policies and practices on the ground. Such constructive engagement can only be built on a basis of trust and open communication. This engagement process requires stakeholders to have patience and a willingness to invest in constructive and open communication and to find solutions that benefit all stakeholders.

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http://www.goldenagri.com.sg/pdfs/News%20Releases/2014/Media%20Statement%20170114%20-%20Response%20from%20GAR%20regarding%20FPP.pdf

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> *"This case study demonstrates that community relations and buy-in are crucial for HCS conservation. Such constructive engagement can only be built on a basis of trust and open communication"*

Chapter 3

Conducting initial vegetation classification through image analysis

By Sapta Ananda Proklamasi, Greenpeace Indonesia; Moe Myint, Mapping and Natural Resources Information Integration; Ihwan Rafina, TFT; and Tri A. Sugiyanto, PT SMART/TFT.

The authors are grateful to Ario Bhriowo, TFT; Yves Laumonier, CIFOR; Arturo Sanchez-Asofeifa, University of Alberta; Chue Poh Tan, ETH-Zurich and colleagues at the World Resources Institute for helpful comments on previous versions of this chapter.

CHAPTER CONTENTS

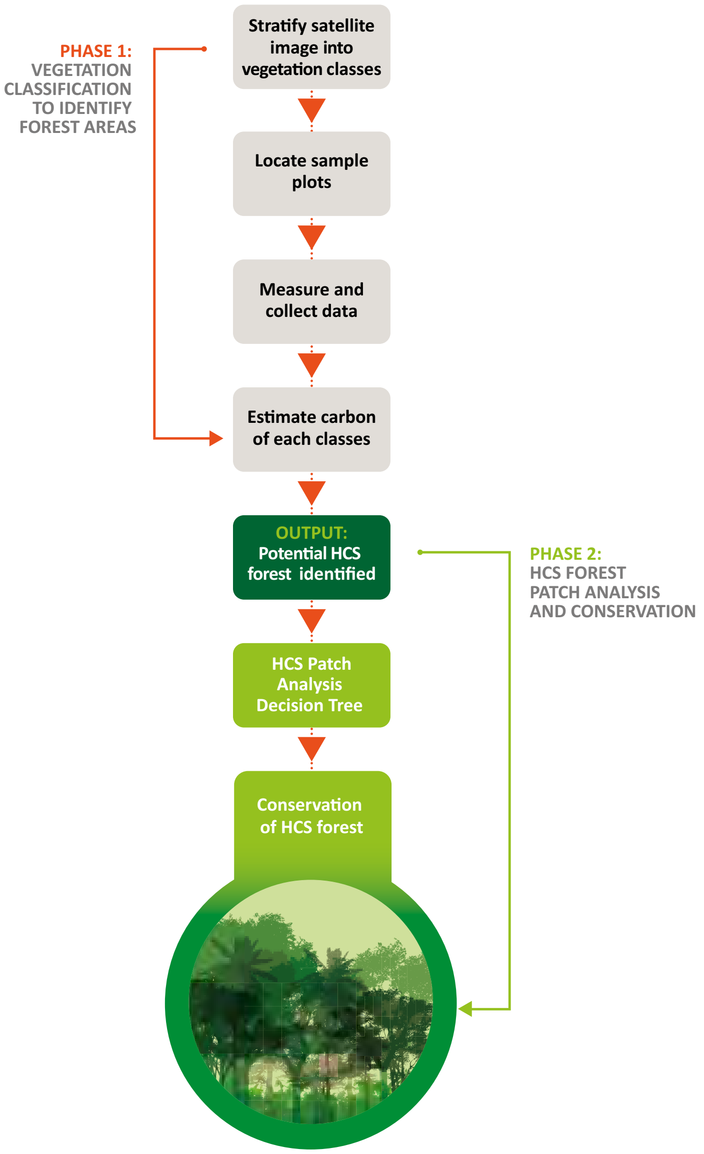
Introduction

The goal of Phase One of a HCS assessment is to create an indicative map of potential HCS forest areas in a concession and its surrounding landscape, using a combination of satellite images and field-level data. This chapter focuses on the first step in Phase One: using images and datasets to classify vegetation into uniform categories. We will take the reader through the methodology for this first step, including selecting the image database, determining the number of land cover classes and performing the classification itself.

The methodology presented in this chapter has been tested and refined through pilot tests in concession areas in Indonesia, Liberia and Papua New Guinea. The methodology is intended to be applicable to any moist tropical forest on mineral soils. Therefore we have included details of variations to the methodology. These might be necessary to address any possible issues relating to the quality of the images available and types of land use and land cover in different regions.

The intended audience for this chapter is technical experts with experience in remote sensing analysis who can use this document to guide their work and create an indicative map of potential HCS forest areas without need for further guidance. We thus assume that the reader has an advanced level of knowledge in analysis and normalisation techniques, but we have provided references to more detailed guidance where helpful.

PHASE 1: STEP DIAGRAM



> *“The methodology is intended to be applicable to any moist tropical forest on mineral soils”*

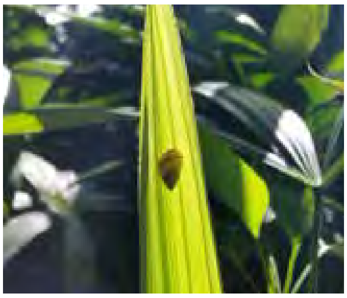
Selection of satellite images

Selection of the satellite images to be used in the vegetation classification process should ensure the images provide sufficient coverage of the assessment area, while giving preference to suitable temporal and spatial resolutions relevant to the assessment. Specifically:

- Images should be no older than 12 months and have a minimum resolution of 30 metres.
- The data must be of a quality which is sufficient for the analysis, with less than 5% cloud cover within the Area of Interest (AOI), **with no or very minimal localised** haze.
- The availability of green, red, near-infrared and mid-infrared spectral bands that assist with determining vegetation cover, healthiness of vegetation cover and vegetation density on the land should be considered.

The user will need to download and evaluate several geo-referenced quick-look images with metadata from several paths and rows of satellites. This will help to derive the strategy to spatially subset the images without clouds. To achieve these goals, users will need to source one or more satellite images and then create an **image catalogue** of multi-temporal images to obtain a good quality set of subset images for the analysis within the AOI. Acquisition of near date (within next one or two revisit periods of satellite over the same area) multi-temporal Landsat-8 images is recommended. In order to avoid influence of sun angle and atmospheric conditions of multi-date images, each subset image should be analysed and classified independently.

There are a range of satellite image types and providers that have suitable visible, infrared and microwave spectral information. A table summarising different database options and their costs and benefits, as well as emerging new tools such as unmanned aerial vehicles, is presented in Appendix A. Users should note that because the Landsat-7 satellite has had the problem of Scan Line Corrector Off since May 2003, it is **not** recommended to use Landsat 7 images from after this point for image analysis and classification because of striping. Although Landsat 7 SLC OFF strips can be filled, this should only be done to aid in visualisation and visual interpretation.



Top: Courtesy USGS ©
Left: Corozal Sustainable Future Initiative, Belize ©

After the most appropriate images are selected they are then cropped to include only the Area of Interest (AOI). In order to best classify the forest found within the concession, the AOI should include as much of the broader landscape as possible since the classification is conducted using relative amounts of canopy cover and carbon stock calculations within a landscape context. For instance, forest patches in a concession which is highly degraded with minimal presence of potential HCS will need to be compared to other larger forest landscapes outside of the concession in order to place them in context.

At a very minimum, a zone of one kilometre beyond the concession borders is necessary to ensure forest cover in the landscape is taken into consideration. Best practice would be to include even more of the surrounding landscape, for instance at the level of the water catchment area for the watershed or streams within the area of interest.

The rectangular envelope of AOI could be created and uploaded to USGS Earth Explorer to select the images for download.

Pre-processing and radiometric enhancement of satellite images

One of the major challenges in the land cover classification activity is the standardisation process, which is undertaken prior to the analysis to ensure results of adequate quality. Standardisation converts multiple source images with varying dates and atmospheric conditions into a set of images with similar image properties that can be used together; it could also be referred to as Radiometric Correction before processing the data. It should be noted that even with standardisation, some source imagery will still have limitations, for instance the striping issue with post-2003 Landsat images noted earlier.

Standardisation can include several steps of image pre-processing. Some of the standard pre-processing functions based on the Erdas Imagine Image Processing System are described below; other standard image processing system will include similar functions. It is not necessary to perform or follow all of the image pre-processing, radiometric correction or standardisation procedures described here. The analyst should evaluate the quality of image and perform the pre-processing procedure only if necessary to improve the classification.

LUT stretch:
Transform the image pixel digital number (DN) values through an existing lookup table (LUT) stretch.

Rescale:
Rescale data in any bit format as input and output. Rescaling adjusts the bit value scale to include all the data file value, preserving relative value and maintaining the same histogram shape.

Haze Reduction:
Atmospheric effects can cause imagery to have a limited dynamic range, appearing as haziness or reduced contrast. Haze reduction enables the sharpening of the image using Tasseled Cap or Point Spread Convolution. For multispectral images, this method is based on the Tasseled Cap transformation, which yields a component that correlates with haze. This component is removed and the image is transformed back into RGB space. For panchromatic images, an inverse point spread convolution is used.

> *"One of the major challenges in the land cover classification activity is the standardisation process, which is undertaken prior to the analysis to ensure results of adequate quality"*

Noise Reduction:
Reduce the amount of noise in a raster layer. This technique preserves the subtle details in an image, such as thin lines, while removing noise along edges and in flat areas.

Periodic Noise Removal:
If the periodic noise is from a non-sensor problem such as temporary atmospheric conditions, the noise can be removed from imagery by automatically enhancing the Fourier transform of the image.

The input image is first divided into overlapping 128-by-128-pixel blocks. The Fourier Transform of each block is then calculated and the log-magnitudes of each fast Fourier Transform (FFT) block are averaged. The averaging removes all frequency domain quantities except those which are present in each block (for instance any periodic interference). The average power spectrum is then used as a filter to adjust the FFT of the entire image. When the inverse Fourier Transform is performed, the result is an image which should have any periodic noise eliminated or significantly reduced. This method is partially based on the algorithms outlined in Cannon, Lehar, and Preston (1983) and Srinivasan, Cannon and White (1988).

The Minimum Affected Frequency level should be set as high as possible to achieve the best results. Lower values affect lower frequencies of the Fourier transform which represent global features of the scene such as brightness and contrast, while very high values affect frequencies representing the detail in the image.

Replace bad lines:
Remove bad lines or columns in raster imagery.

Histogram matching:
This function mathematically determines a lookup table that converts the histogram of one image to resemble the histogram of another.

Brightness conversion:
Reverse both linear and nonlinear intensity range of an image, producing images that have the opposite contrast of the original image. Dark detail becomes light and light detail becomes dark.

Histogram equalisation:
Apply a nonlinear contrast stretch that redistributes pixel values so that there are approximately the same numbers of pixels with each value within a range.

Topographic normalisation (Lambertian Reflection Model):
Use a Lambertian reflectance model to reduce topographic effect in digital imagery. Topographic effect is the difference in illumination due solely to the slope and aspect of terrain relative to the elevation and azimuth of the sun. The net result is an image with more evenly illuminated terrain. The elevation and azimuth of the sun information for topographic normalisation for each image is available when the analyst downloads the metadata of the image. The analyst should select the good quality Digital Elevation Model as the input data for topographic normalisation.

Vegetation indices

Vegetation indices are the dimensionless, radiometric measures that indicate relative abundance and activity of green vegetation. This includes leaf-area-index (LAI), percentage green cover, and chlorophyll content green biomass and absorbed photosynthetically active radiation (APAR). According to Running et al. (1994) and Huete and Justice (1999), a vegetation index should:

Vegetation indices are to be used as indicative vegetation cover, to show vegetation and non-vegetation cover where they will be used with unsupervised forest classes and non-forest land cover.

- Maximise sensitivity to plant biophysical parameters, preferably with a linear response in order that sensitivity be available for a wide range of vegetation conditions, and to facilitate validation and calibration of the index;
- Normalise on modal external effects such as sun angle, viewing angle, and atmosphere for consistent spatial and temporal comparison;
- Normalise internal effects such as canopy background variations, including topography (slope and aspect), soil variations and differences in senesced or woody vegetation (non-photosynthetic canopy components); and
- Be coupled to some specific measurable biophysical parameter such as biomass, LAI or APAR as part of the validation effort and quality control.

There are many vegetation indices that could be used in HCS analysis; this HCS Toolkit will focus on NDVI and Kauth-Thomas Tasseled Cap Transformation, which are currently the recommended indices for the HCS Approach.

> *“Vegetation indices are the dimensionless, radiometric measures that indicate relative abundance and activity of green vegetation”*

Normalised Difference Vegetation Index

The first true vegetation index was the Simple Ratio (SR), which is the ratio of red reflected radiant flux (P_{red}) to near-infrared reflectance flux (P_{nir}) as described in Birth and McVey (1968):

$$\mathbf{SR = P_{red} / P_{nir}}$$

The Simple Ratio provides valuable information about vegetation biomass or Leaf Area Index (LAI) (Schlerf et al., 2005). It is especially sensitive to biomass and/or LAI variations in high-biomass vegetation such as forests (Huete et al., 2002).

Rouse et al. (1974) developed the generic Normalised Difference Vegetation Index (NDVI) as a graphical indicator that can be used to analyse vegetation cover. NDVI is calculated as the ratio of (Near infrared - Red Band) to (Near infrared Band + Red Band):

$$\mathbf{NDVI = (P_{nir} - P_{red}) / (P_{nir} + P_{red})}$$

The result of the NDVI will be within a range between -1 to +1.

The NDVI is functionally equivalent to the Simple Ratio; it is simply a nonlinear transform for the simple ratio. There is no scatter in an SR as compared to an NDVI plot, and each SR value has a fixed NDVI value.

The NDVI is an important vegetation index because:

- Seasonal and interannual changes in vegetation growth and activity can be monitored.
- NDVI reduces many forms of multiplication noise (sun illumination differences, cloud shadows, some atmospheric attenuation, and some topographic variations) present in multi-bands of multi-date imagery.

However, there are some disadvantages to NDVI that the analyst should consider, including:

- The ratio based index is nonlinear and can be influenced by additive noise effects such as atmospheric path radiance.
- NDVI is highly correlated with LAI. However, the relationship may not be as strong during periods of maximum LAI, apparently due to the saturation of NDVI when LAI is very high (Wang et al. 2005). NDVI’s dynamic range is therefore stretched in favour of low biomass conditions and compressed in high biomass, forested regions. High density forest and medium density forest are therefore difficult to differentiate in NDVI. The opposite is true for the Simple Ratio, in which most of the dynamic range encompasses the high biomass forests with little variation reserved for the lower biomass regions (e.g. grasslands as well as semi-arid and arid-biomes).
- NDVI is very sensitive to canopy background variations, for instance if soil is visible through canopy. NDVI values are very high with darker-canopy background.

Kauth-Thomas Tasseled Cap Transformation

The Tasseled Cap (TC) transformation is a global vegetation index which disaggregates the amount of soil brightness, vegetation and moisture content in individual pixels. Under this method, each of the images is transformed using TC coefficients specific to the satellite to create a vegetation index. TC values are generated by converting the original bands of an image into a new set of bands with defined interpretations that are useful for vegetation mapping. The first TC band corresponds to the overall brightness of the image. Urbanised areas are particularly evident in the brightness image. The second TC band corresponds to "greenness" and is typically used as an index of photosynthetic active vegetation - the greater the amount of biomass, the brighter the pixel value in the greenness image.

The third TC band is often interpreted as an index of wetness (e.g. soil or surface moisture) or yellowness (e.g. amount of dead/dried vegetation). The fourth TC parameter is haze. Note that it is possible to compute the TC coefficients based on local conditions; Jackson (1983) provided the algorithm and mathematical procedures for this purpose.

The equations and coefficients necessary to derive the Brightness, Greenness and Wetness Indices from Landsat MSS, Landsat TM, Landsat 7 ETM + and Landsat 8 images are included in Appendix B.

"The Tasseled Cap (TC) transformation is a global vegetation index which disaggregates the amount of soil brightness, vegetation and moisture content in individual pixels"

All photos: Courtesy TFT ©

Principle component analysis

Principle component analysis (PCA) is another general tool to identify redundant data and generate a new set of information in which correlated data are combined. The resulting dataset of principal components is commonly smaller than the original dataset, thereby speeding up processing time. However, unlike the Tasseled Cap, the new axes formed by PCA are not specified by the analyst's prior definition of the transformation matrix, but are rather derived from the variance-covariance or correlation matrix computed from the data analyses.

Extensive interband correlation is a problem frequently encountered in the analysis of multispectral image data – in other words, images generated by digital data from various wavelength bands often appear similar and convey essentially the same information. Principle and canonical component transformation are two techniques designed to reduce such redundancy in multispectral data. These transformations may be applied either as an enhancement operation prior to visual interpretation of the data, or as a pre-processing procedure to digital classification of data. If these techniques are employed for the latter context, the transformations generally increase the computational efficiency of the classification process because of the reduction in the dimensionality of the original data set. The purpose of these procedures is to compress all of the information contained in an original n-band data set into fewer than n **new bands**. The new bands are used in lieu of the original data.

The general procedure of PCA can be divided into three steps:

1. Calculation of variance-covariance (or correlation) matrix of multiband images (e.g. in the case of a six-band image, the variance-covariance matrix has dimension of 6 by 6)
2. Extraction of the eigenvalues and eigenvectors of the matrix, and
3. Transformation of the feature space coordinates using these eigenvectors.

In short, the principle component image data values are simply linear combination of the original data values multiplied by the appropriate transformation coefficients known as eigenvectors. Therefore, a principle component image results from the linear combination of the original data and the eigenvectors on a pixel by pixel basis throughout the image.

All photos: Courtesy TFT ©

The important characteristics of the PCA component images is that the first principle component image (PC1) includes the largest percentage of the total scene variance and succeeding component images (PC2, PC3, PC4......PCn) each contain a decreasing percentage of the scene variance. Furthermore, because successive components are chosen to be orthogonal to all previous ones, the data they contain are uncorrelated.

For the Landsat MSS the first two principle components (PC1 and PC2) explain virtually all the variance in the scene. It is referred to the intrinsic dimensionality of Landsat MSS data as being effectively 2. Similarly, the first three principle components (PC1, PC2 and PC3) explain virtually all the variance in the scene and intrinsic dimensionality of Landsat TM data is 3. Therefore Landsat TM or ETM+ or Landsat 8 or similar satellites data can often be reduced to just three principle component images for classification purposes.

A detailed description of the statistical procedure used to derive principle component transformation is beyond the scope of this toolkit, but is well described from pages 60 to 65 of Brandt Tso and Paul M. Mather's *Classification Methods for Remotely Sensed Data* (2001). Finally, it is important to note that PCA should be computed from blue, green, red, near infrared, shortwave infrared I and shortwave infrared II channels or bands of similar spatial resolution (for example Landsat 8), as these bands contain similar redundant information related to vegetation and land cover.

Selection of band combination for classification

Several options of band combination can now be selected from the original bands, using various transformation results (NDVI, PCA and Tasseled Cap) to create a new dataset of bands. The analyst will choose or modify appropriate combination of channels based on the study area, characteristics of land cover and its spectral properties. For instance, a digital elevation model could be optionally included within the new dataset of bands to provide the topographic information. This may prevent misclassification as agriculture lands at the top of the mountains. Modern computer processors (multicore) can process multispectral data without the need for much additional time even if additional bands are included in the classification.

All photos: Courtesy USGS ©

The follow options provide some general ideas to analysts regarding the selection of band combinations for classification.

Option 1

Band1 = Blue Spectral Channel
Band2 = Green Spectral Channel
Band3 = Red Spectral Channel
Band4 = Near Infrared Spectral Channel
Band5 = Mid infrared I Spectral Channel
Band6 = Mid Infrared II Spectral Channel
Band7 = Brightness Tasseled Cap
Band8 = Greenness Tasseled Cap
Band9 = Wetness Tasseled Cap
Band10 = NDVI (Rescale to data bits of aforementioned channels)
Band11 = SR (Rescale to data bits of aforementioned spectral channels – optional)
Band12 = Digital Elevation Model (optional)

Option 2

Band1 = Principle Component 1 (PC1)
Band2 = Principle Component 2 (PC2)
Band3 = Principle Component 3 (PC3)
Band4 = Brightness Tasseled Cap
Band5 = Greenness Tasseled Cap
Band6 = Wetness Tasseled Cap
Band7 = NDVI (Rescale to data bits of aforementioned channels)
Band8 = SR (Rescale to data bits of aforementioned spectral channels – optional)
Band9 = Digital Elevation Model (optional)

Option 3

Microwave data such as Sentinel-1 data could be included as the additional bands in option 1 and option 2. Although option 1 and 2 data are excellent for detection based on chemical characteristics of spatial objects, microwave data could provide physical characteristics of spatial objects such as surface roughness (vegetation structure), dielectric constant (water content) and spatial orientation of the spatial objects relative to sensor look direction. Sentinel-1 data can be downloaded freely for scientific research and non-profit purposes.

Determining the number and type of classes

Once the images have been selected and standardised, the next step is to group the land cover into homogeneous classes in order to indicate potential HCS forest areas. The main purpose of the exercise is to differentiate:

- Low, medium, and high density forest (LDF, MDF, HDF);
- Young regenerating forest (YRF);
- Cleared and degraded former forest including Scrub (S) and Open Land (OL); and
- Non-HCS areas such as roads, water bodies and settlements.

As shown in the diagram below, the potential HCS forest cut-off lies between the Scrub and Young Regenerating Forest categories, where YRF, LDF, MDF, and HDF are considered potential HCS forest and S and OL are not considered HCS forest. In Phase Two of the methodology there will be adjustments to the YRF and S following analysis through the HCS Patch Analysis Decision Tree and conservation planning.

During this image-based classification exercise, other non-HCS forest areas with significant vegetation cover might be identified, for instance areas used by communities for agro-forestry which may consist of a mix of natural vegetation; fruit trees; cash crops like rubber, coffee, cocoa, or palm; and food crops. Such areas will normally already have been identified through the participatory mapping and FPIC processes outlined in Chapter 2. If such areas are indicated on the satellite images but were not included on the map of community areas, then the quality of the participatory land use mapping should be questioned, and that step may need to be re-done.

HCS CLASSIFICATION

> *“The final process of negotiating and relinquishing any community rights to using HCS forests occurs once the HCS classification process is complete”*

The land cover classes defined through this process will vary based on the landscape and the type of land cover in the concession. A description of the most commonly used classifications is included in the table on the next page. Categories included in the HCS category are indicated in green – note that the table includes qualitative factors which will only be evident after the ground survey is completed. As a reminder, HCS forests might overlap with community use areas, for instance forests used for gathering non-timber forest products or hunting. The final process of negotiating and relinquishing any community rights to using HCS forests occurs once the HCS classification process is complete.

TABLE: **GENERIC LAND COVER CATEGORIES**

VEGETATION COVER CATEGORIES	DESCRIPTION
HDF, MDF, LDF	**High Density Forest, Medium Density Forest, and Low Density Forest** Closed canopy natural forest ranging from high density to low density forest. Inventory data indicates presence of trees with diameter > 30cm and dominance of climax species.
YRF	**Young Regenerating Forest** Highly disturbed forest or forest areas regenerating to their original structure. Diameter distribution dominated by trees 10-30cm and with higher frequency of pioneer species compared to LDF. This land cover class may contain small areas of smallholder agriculture. **Note:** Abandoned plantations with less than 50% of basal area consisting of planted trees could fall in this category or above. Concentrations >50% of basal area would not be considered HCS forest but rather plantations and should be classified separately.
S	**Scrub** Land areas that were once forest but have been cleared in the recent past. Dominated by low scrub with limited canopy closure. Includes areas of tall grass and fern with scattered pioneer tree species. Occasional patches of older forest may be found within this category.
OL	**Open Land** Recently cleared land with mostly grass or crops. Few woody plants.
EXAMPLES OF OTHER NON-HCS LAND COVER CATEGORIES	
FP	**Forest Plantation** Large area of planted trees (e.g. rubber, Acacia).
AGRI	**Agriculture Estates** For instance, large scale oil palm estates overlapping with concession areas
MINE	**Mining Area** These can be further differentiated between licensed mining areas and overflow, unregulated/illegal mining areas
SH	**Smallholder Agriculture and Use** These areas can be further differentiated among mixed forest gardens/agroforestry systems which could potentially serve as wildlife corridors, swidden/rotational gardening systems for subsistence food production, etc.
(Other)	Water bodies such as rivers and lakes. Built-up areas, settlements, roads, etc.

Where single species or near-single species forests are identifiable and mappable, for instance Gelam (*Melaleuca* spp.) in Indonesia, consideration should be given as to whether the area should be treated as a separate (non – standard) vegetation cover class. If the decision is made to separate a single species area out, the usual HCS approach of stratifying the vegetation of the area into high and low carbon stock classes still applies.

It should be noted that as the Simple Ratio (SR) dynamic range is stretched in favour of high biomass conditions such as forested regions and compressed in low biomass condition, areas of natural regrowth and natural forests could be detected using this method. Moreover, Sentinel-1 Microwave data could also be included to detect the natural forest and natural regrowth regions, as the stand dynamic structure are different and could be inferred from the surface roughness.

All photos: Courtesy TFT ©

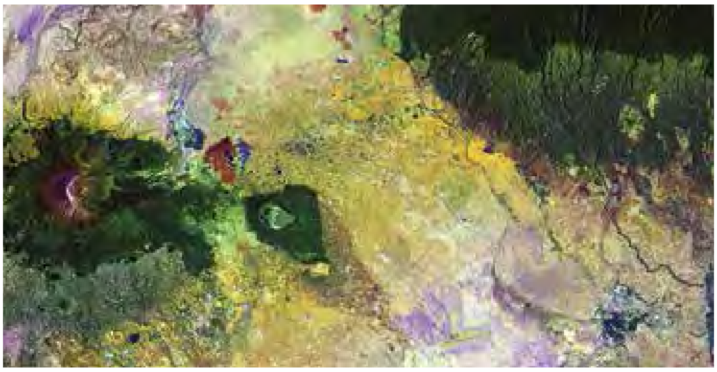
Approaches to classification

Once the images have been selected and refined, the land cover is grouped into relatively homogenous classes described above in order to delineate HCS forest from non-HCS. The process primarily consists of analysing the satellite images using Remote Sensing and Geographic Information Systems (GIS) software, which provide tools for land cover interpretation. Several software packages provide the tools to support the land cover classification, including Erdas Imagine, ENVI, ESRI Image Analysis and OpenSource software (Quantum GIS).

Land cover classification is applied for several reasons:

1. It allows the identification of different land cover classes with various forest and non-forest conditions that can be captured in image analysis (e.g. colour, canopy closure and roughness of the canopy layer).
2. The condition of the forest is often (but not always) correlated with forest carbon stock and biodiversity. For example, dense well-stocked forest is usually associated with high carbon stocks (and also commonly higher biodiversity) than degraded, low stocked forest.
3. Separating the land cover into classes allows for more efficient sample design for the ground survey (see Chapter 4), and a simpler review of the results of forest inventory and aerial survey.

All photos: Courtesy USGS ©



HCS studies generally use a combination of several methodological phases to ensure accurate representation of the land cover, namely pixel-based analysis using unsupervised and supervised methods, as well as visual methods in other phases. Regardless of the image classification techniques applied, local field knowledge of land use, land covers, forest types and its species composition, agricultural crop types, and phenology of vegetation in relation to the spectral signature of the selected dataset of images is essential.

The selection of the method used to interpret images is generally determined by the level of the interpreter's expertise and familiarity with the particular landscape and the land cover area being analysed. For example, if the interpreter has sufficient understanding of sophisticated remote sensing techniques and good knowledge of the sample area, it is recommended to use the supervised classification technique and/or hierarchical decision tree classifier using tools similar to Knowledge Engineer and Knowledge Classifier. For an area with no pre-existing land cover information the interpreter or the analyst may initiate the analysis using the unsupervised classification technique in order to see the spectrally similar and spatially contiguous spatial objects or phenomena.

In general, unsupervised classification, supervised classification techniques and hierarchical decision trees classification will be complementary to determine the classes of land cover in the study area.

> *"The selection of the method used to interpret images is generally determined by the level of the interpreter's expertise and familiarity with the particular landscape"*

Unsupervised classification

Unsupervised classification uses image processing software to group pixels by general characteristics without using any pre-determined sample class. The unsupervised classification applies K-mean image segmentation algorithm or an ISODATA (Iterative Self-Organising Data Analysis) algorithm to determine which pixels are spectrally similar to other pixels and groups them into various homogeneous classes. The user can specify which algorithm the software will use and the desired number of output classes, but otherwise does not intervene in the classification process. However, the user must have knowledge of the area being classified, as the groupings of pixels with common characteristics produced by the unsupervised classification have to be related to actual features on the ground (such as wetlands, developed areas, coniferous forests, etc.)

The classes that result from unsupervised classification are spectral classes. Because these are based solely on the natural grouping in the image values, the identity of the spectral classes will not be initially known. The analyst must compare the classified spectral classes with some form of reference data such as existing maps or field visits to determine the identity and informational value or information classes of the spectral classes.

Once the analyst has determined spectrally separable classes and defined their informational utility, the spectral classes can be aggregated into the smaller set of categories desired by the analyst. Sometimes, the analysts may find that several spectral classes relate to more than one information category. For instance, spectral class 3 could be found to correspond to Young Generation Forest in some locations and Low Density Forest in others. Likewise, Spectral class 6 could include both Medium Density Forest and High Density Forest. This means that these information categories are spectrally similar and cannot be differentiated in a given data set. In this case, the analyst might consider including additional bands to the given data set, as discussed earlier.

Overall, the quality of an unsupervised classification will depend on the analyst's understanding of the concepts behind the classifier available and knowledge about the land cover types under analysis. When using unsupervised classification in the HCS process, normally 16 classes will be enough to determine the forest and non-forest classes, which are then combined with vegetation cover, and can be a reference to locate the field plots (see Chapter 4).

All photos: Courtesy TFT ©

Supervised classification

Supervised classification is based on the concept that a user can select sample pixels in an image that are representative of specific classes and then direct the image processing software to use these training sites as references for the classification of all other pixels in the image. Training sites (also known as testing sets or input classes) are selected based on the knowledge of the user. The user also sets the bounds for how similar other pixels must be to group them together. These bounds are often set based on the spectral characteristics of the training area, plus or minus a certain increment (often based on “brightness” or strength of reflection in specific spectral bands). The user also designates the number of classes into which the image is classified.

Three basic steps are involved in a typical supervised classification procedure:

1. In the **training stage**, the analyst identifies representative training areas and develops a numerical description of the spectral attributes of each land cover type of interest in the scene.
2. In the **classification stage**, each pixel in the image data set is categorised into the land cover class it closely resembles. If the pixel is insufficiently similar to any training data set, it is usually classified or labelled unknown.
3. After the entire data set has been categorised, the results are presented in the **output stage**. The classified output becomes a GIS input.

Each of these steps is described in detail on the following pages.

> *“Supervised classification is based on the concept that a user can select sample pixels in an image that are representative of specific classes, this can then become references for the classification of all other pixels in the image”*

Training Stage

The overall objective of the training stage is to assemble a set of statistics that describes the spectral response pattern for each land cover type to be classified in an image. It is important to note that all spectral classes constituting each information class must be adequately represented in the training set statistics used to classify an image. It is uncommon to acquire data from 100 or more training areas to adequately represent the spectral variability in an image. A histogram output of each training area is particularly important when a maximum likelihood classifier is used, since it provides a visual check on the normality of the spectral response distribution. Liliesand and Kiefer’s *Remote Sensing and Image Interpretation* (Fifth Edition, 2004) provides detailed information and examples on how to identify statistically valid training areas.

The training area sample section and evaluation of training sample statistics is time consuming, but is an important step for good quality classification. The analyst should spend a good amount of time to create statistically representative and statistically separable training samples which present the information classes. A classification error matrix (described later in this chapter) can be created on the training sets of pixels and the results of supervised classification.

All photos: Courtesy TFT ©

Classification stage

While many techniques could be used for the supervised classification stage, this toolkit focuses in detail on the Gaussian Maximum Likelihood Classifier[1] and also outlines briefly the use of decision trees for hierarchical supervised classification.

The Gaussian Maximum Likelihood Classifier quantitatively evaluates both the variance and covariance of the category response patterns (from training sample statistics) when classifying an unknown pixel. An assumption is made that the distribution of the cloud points forming the category training data is Gaussian, i.e. normally distributed. Under this assumption, the distribution of a category response pattern can be completely described by the mean vector and the co-variance matrix. Given these parameters, the classifier computes the statistical probability of a given pixel value being a member of a particular land cover class or HCS classes. After evaluating the probability in each category, the pixel would be assigned to the most likely class (with the highest probability value) or be labelled 'unknown' if the probability values are all below a threshold set by the analyst.

Photo: Courtesy USGS ©

An extension of the maximum likelihood approach is the Bayesian classification, which applies two weighted factors to the probability estimate. First, the analyst determines the "a priori probability" or the anticipated likelihood of occurrence for each class in a given scene or image. Second, a weight associated with the cost of misclassification is applied to each class. Together, these factors act to minimise the cost of misclassifications, resulting in a theoretically optimum classification. In practice, most maximum likelihood classification is performed assuming equal probability of occurrence and cost of misclassification for all classes.

Maximum likelihood classification is computationally intensive to classify each pixel especially when either a large number of spectral bands are involved or a large number of spectral classes must be differentiated, but modern multi-core computer processors process the classification fairly quickly. Another means of optimising the maximum likelihood classification is to use Principle Components (PC1, PC2 and PC3) instead of original channels to perform the classification.

An alternative to Maximum Likelihood Classifier is the use of decision trees, which apply a stratified or layered classification to simplify the classification computations and maintain classification accuracy. These classifiers are applied in a series of steps, with certain classes being separated during each step in the simplest manner possible. For example, water could be separated from near infrared band by a simple threshold value. Certain classes may require the combination of two or three bands for categorisation using simpler classification algorithm such as Minimum Distance to Mean Classifier or Parallelepiped Classifier. The use of more bands or Maximum Likelihood Classifier would only be applied for those land cover categories where residual ambiguity exists between overlapping classes in the measurement space. Finally, multinomial logical regression could be applied with training sampling statistics to derive the probability of each pixel to the information classes instead of using Maximum Likelihood Classification.

Many analysts use a combination of supervised and unsupervised classification methods to develop final analyses and classifications for the indicative maps.

> *"Many analysts use a combination of supervised and unsupervised classification methods to develop final analyses and classifications for the indicative maps"*

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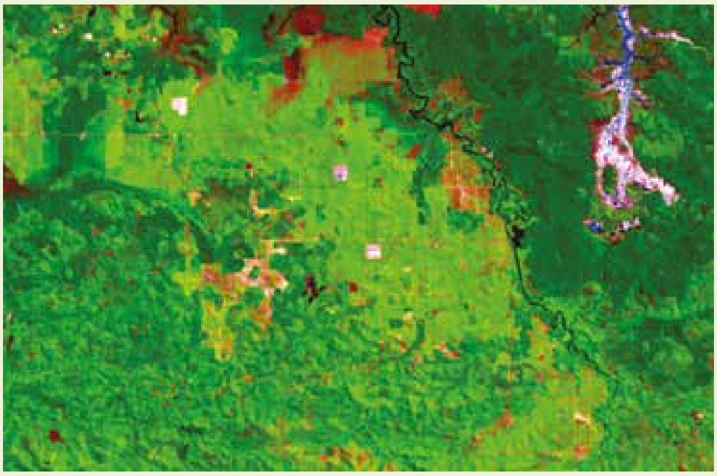
[1] Pages 271-277 of *Resource Management Information Systems: Remote Sensing, GIS and Modelling* (second edition) by Keith R. McCloy provide more details on Maximum Likelihood Classification.

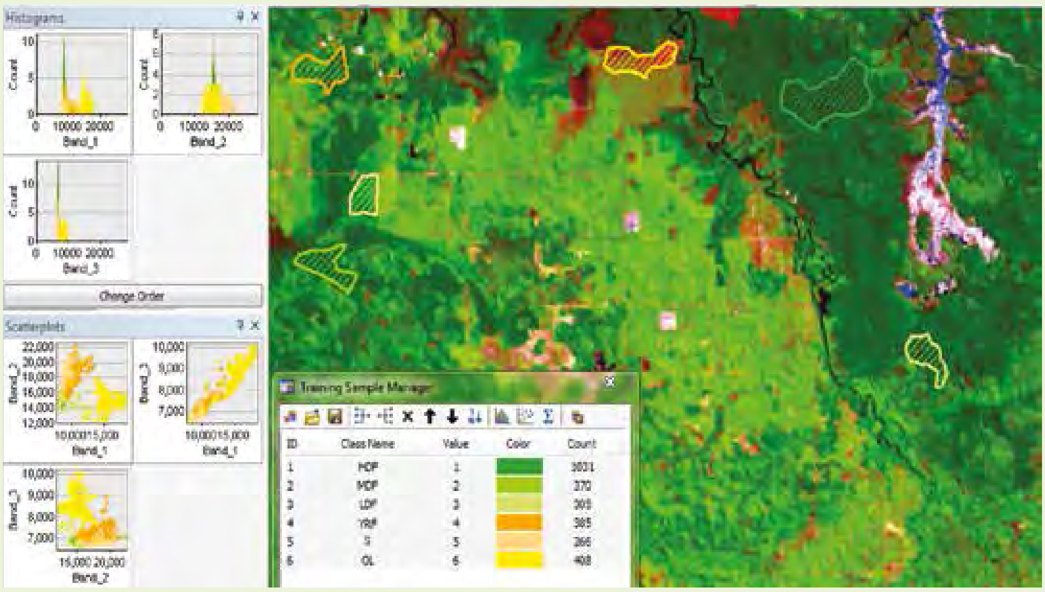
Case study: West Kalimantan

In the following case example from West Kalimantan, Indonesia, Landsat 8 satellite images processed with ArcGIS 10.1 with Images Analysis extension were used to classify the land cover. The satellite images were first pre-processed as needed to produce the image of the AOI to the right.

With the existing tools in the image processing software, six training areas were selected, representing the six HCS land cover classes as illustrated in the middle image.

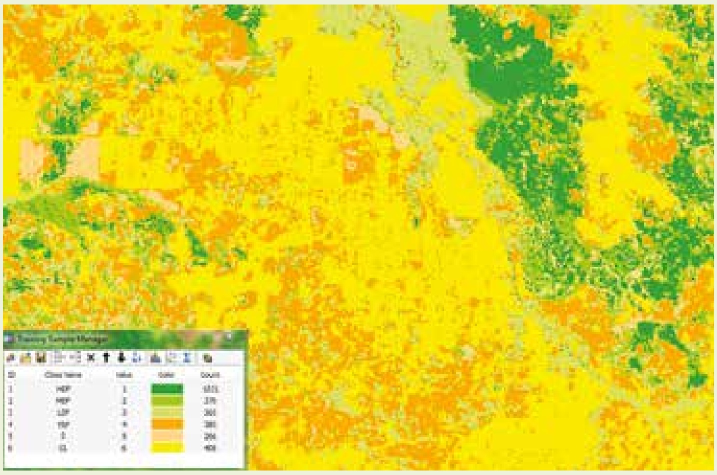
After the training samples were deemed sufficient and representative, a supervised classification using maximum likelihood classification approach was run through the processing software. The resulting interim vegetation map based on image analysis is shown in the bottom image.





Training Sample Manager

ID	Class Name	Value	Color	Count
1	HDF	1	🟩	3031
2	MDF	2	🟩	370
3	LDF	3	🟩	309
4	YRF	4	🟧	385
5	S	5	🟧	266
6	OL	6	🟨	408



Visual classification

An advanced visual classification or manual digitisation process may be carried out by an experienced analyst with excellent knowledge of the land cover conditions in the area. The analyst is able to determine each land cover class through on-screen analysis of satellite images. Images are commonly enhanced to aid identification of classes. The interpreter must have the knowledge of interpretation keys of the land cover of the study area, integrity value, professional and field experience of the study area.

Visual classification is used after the image has been calibrated and standardised where multiple images in a mosaic are being used. When used as a standalone technique, visual classification is typically the most accurate where the user knows the area well. However, this accuracy comes at a cost, as this technique requires a lot of time-consuming digitising. It can also be biased. It should therefore only be used as a stand-alone process with high-resolution image data and where the user knows the area well.

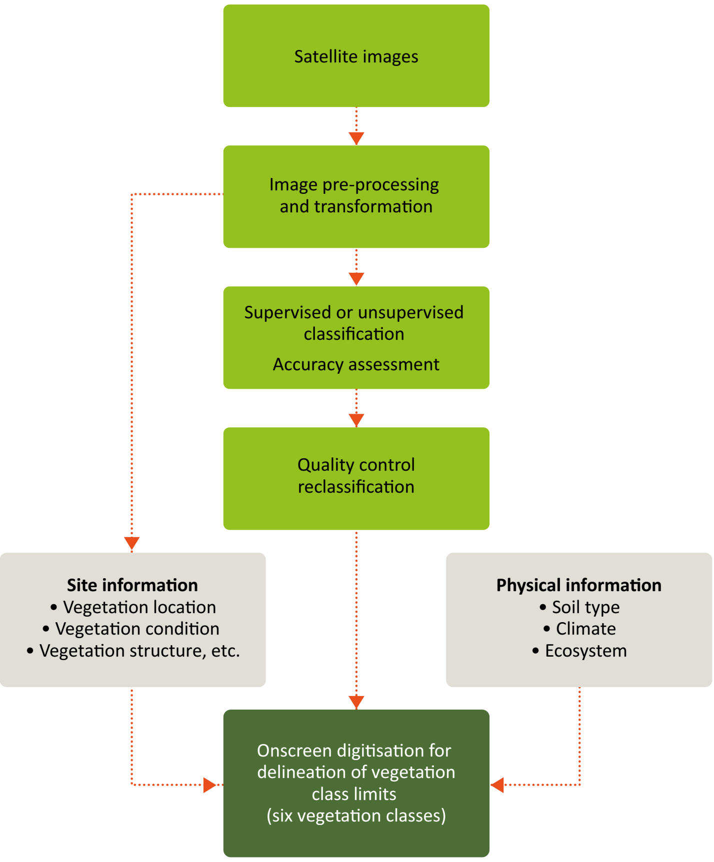
Alternatively, visual classification can also be used to complement both supervised and unsupervised processes, as these can generate an error or bias, especially in areas with inadequate image quality due to fog, smoke, topographic shadows, cloud shadows or clouds. This error or bias can be minimised through a visual quality control by the interpreter. For areas with incorrect interpretation, corrections are done to match known conditions. In this phase, unsupervised or supervised interpretation results (if applicable) are combined with other elements such as information of soil type and rainfall. An understanding of site conditions becomes the key to generating good and accurate classification. Thus the more site-specific information an interpreter has, the less the bias of error will be.

The phases of visual vegetation stratification are presented in the diagram right.

The additional numerical information such as temperature, rainfall, humidity, solar radiation, wind speed grids, digital elevation models and digital terrain models could be added as the additional bands for classification only if these data provide value-added information to separate between spectral classes. The additional categorical information such as soil types, geology, geomorphology and vegetation locations could be applied to refine the interpretation without bias.

For HCS studies, the authors recommend that visual stratification is *not* used by remote sensing practitioners until considerable experience is gained from trials of the HCS methodology using supervised or unsupervised classification in combination with the field analysis laid out in the next chapter.

THE PHASES OF VISUAL VEGETATION STRATIFICATION



> *“An understanding of site conditions becomes the key to generating good and accurate classification. Thus the more site-specific information an interpreter has, the less the bias of error will be”*

Accuracy assessment of classified image

This section outlines the accuracy assessment to be undertaken to check the classification. For further information on accuracy assessments, *Remote Sensing Thematic Accuracy Assessment: A Compendium* (1994) by ASPRS and *Assessing the Accuracy of Remotely Sensed Data: Principle and Practices* (Congalton and Green, 1999) are excellent references.

Classification error matrix based on training sample data set

Preparing a classification error matrix, confusion matrix or contingency table is a common method of expressing classification accuracy. Error matrices compare, on a category-by-category basis, the relation between known reference data (ground truth) and the corresponding results of image classification.

The table below is an example of error matrix based on training samples and classified result, from Liliesand and Kiefer (2004). It provides an example of how well a classification has categorised a representative subset of pixels used in the training process of a supervised classification. This matrix stems from classifying the sample classified into the proper land cover categories are located along the major diagonal (yellow highlighted) of the error matrix. All non-diagonal elements of the matrix represent error of omission (exclusion) or error of commission (inclusion).

The omission error corresponds to non-diagonal COLUMN elements, e.g. 16 pixels that have been classified as "S" for sand were omitted from the category. The producer's accuracies are calculated by dividing the number of correctly classified pixels in each category (on the major diagonal) by the number of training sets pixels used for that category (the column total). The producer's accuracy ranges from 51% to 100% in this case, and is a measure of omission error and indicates how well training set pixels of the given cover type are classified.

Commission errors are represented by non-diagonal row elements, for instance 38 urban (U) and 79 hay (H) pixels were improperly included in the Corn (C) category. The user accuracies are calculated by dividing the number of correctly classified pixels by the total number of pixels that were classified in that category (the row total). The user's accuracy is a measure of commissioning error and indicates the probability that a pixel classified into a given category actually represents that category on the ground. The user's accuracy in this case ranges from 72% to 99%.

Overall accuracy is calculated by dividing the total number of correctly classified pixels (the sum of elements along the major diagonal) by the total number of reference pixels. Overall accuracy in the example contingency table is 84%.

It is important to note that the example error matrix is based on training data, and such procedures only indicate how well the statistics extracted from these areas can be used to categorise the same areas. If the results are good, it means nothing more than that the training areas are homogeneous, the training classes are spectrally separable, and that the classification strategy being employed works well in the training area. It indicates little about how the classifier performs elsewhere in the scene. Training area accuracies should not be used as an indication of overall accuracy.

ERROR MATRIX BASED ON TRAINING SAMPLE DATA SET

	Training Set Data (Known Cover Types)						
	W	**S**	**F**	**U**	**C**	**H**	**Row Total**
Classification data							
W	480	0	5	0	0	0	485
S	0	52	0	20	0	0	72
F	0	0	313	40	0	0	353
U	0	16	0	126	0	0	142
C	0	0	0	38	342	79	459
H	0	0	38	246	60	359	481
Column Total	**480**	**68**	**356**	**248**	**402**	**438**	**1992**

Overall accuracy = (480 + 52 + 313 +126 + 342 +359) / 1992 = 84%

Producer's Accuracy:

W = 480/480 = 100%
S = 52/68 = 76%
F = 313/356 = 88%
U = 126/248 = 51%
C = 342/402 = 85%
H = 359/438 = 82%

User's Accuracy:

W = 480/485 = 99%
S = 52/72 = 72%
F = 313/353 = 87%
U = 126/142 = 89%
C = 342/459 = 74%
H = 359/481 = 75%

Sampling consideration of test areas

To assess the accuracies of classification for the scene, representative test areas with uniform land cover should be selected. The test areas could be selected through a random, stratified random or systematic sampling framework. Test areas could be selected during the training sample selection stage, setting aside some training samples as the test areas which will not be used as part of the training sample sets. The appropriate sampling unit might be individual pixels, clusters of pixels or polygons. Polygon sampling is the most common approach.

As a broad guideline, a minimum of 50 samples as test areas for each vegetation or land cover category should be included in the error matrix for accuracy assessment of the whole scene classification. If the area is large (e.g. more than a million acres) or the classification has a large number of vegetation or land cover land use categories (more than 12 categories) the minimum number of samples should be increased to 75 to 100 samples per category (Congalton and Green, 1999, p.18). More samples should be selected for the more important categories or more variable categories.

> *"As a broad guideline, a minimum of 50 samples as test areas for each vegetation or land cover category should be included for accuracy assessment of the whole scene classification"*

Evaluating classification error matrix based on test areas or test pixels

Once accuracy data are collected based on test areas (either in the form of pixels, cluster of pixels or polygons) and summarised in an error matrix, they are normally subject to detailed interpretation and further statistical analyses. The following error matrix was created based on randomly selected test pixels, again from Liliesand and Kiefer (2004):

Overall accuracy is only 65%. If the purpose of mapping is to locate forest (F), the producer accuracy is quite good at 84%. We may conclude that although the overall accuracy was poor (65%), it is adequate for the purpose of mapping forests. The problem with this conclusion is that the user's accuracy for forest is only 60%. That is, even though 84% of the forested areas have been correctly identified as forest, only 60% of the areas identified as forest within the classification are truly of that category.The user of this classification would find that an area identified as forest from the classification process will prove to be forest on a site visit only 60% of the time. A more careful inspection of the error matrix shows that there is significant confusion between forest and urban (U). In this example matrix, the only reliable category associated with this classification from both a producer's and a user's perspective is water (W).

ERROR MATRIX BASED ON TEST PIXELS

	Reference Data for Randomly Selected Test Pixels						
	W	**S**	**F**	**U**	**C**	**H**	**Row Total**
Classification data							
W	226	0	0	12	0	1	239
S	0	216	0	92	1	0	309
F	3	0	360	228	3	5	599
U	2	108	2	397	8	4	521
C	1	4	48	132	190	78	453
H	1	0	19	84	36	219	359
Column Total	**233**	**238**	**429**	**945**	**238**	**307**	**2480**

Overall accuracy = (226 + 216 + 360 + 397 + 190 + 219) / 2480 = 65%

Omission Error:

W = 226/233 = 97%
S = 216/328 = 66%
F = 360/429 = 84%
U = 397/945 = 42%
C = 190/238 = 80%
H = 219/307 = 71%

Commission Error:

W = 226/239 = 94%
S = 216/309 = 70%
F = 360/599 = 60%
U = 397/521 = 76%
C = 190/453 = 42%
H = 219/359 = 75%

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1. Pages 271-277 of *Resource Management Information Systems: Remote Sensing, GIS and Modelling* (second edition) by Keith R. McCloy provide more details on Maximum Likelihood Classification.

K_{hat} statistics

The K_{hat} statistic is a measure of the difference between the actual agreement between reference data and an automated classifier and the chance agreement between the reference data and a random classifier. It is conceptually defined as follows:

**K_{hat} = (observed frequency – chance agreement) /
(1 – chance agreement)**

This statistic serves as an indicator of the extent to which the percentage correct values of an error matrix are due to “true” agreement versus “chance” agreement. As the true agreement (observed) approaches to 1 and chance agreement approaches 0, K_{hat} approaches to 1. In reality, K_{hat} value ranges between 0 and 1. For example a K_{hat} value of 0.67 can be interpreted as an indication that an observed classification is that 67% better than one resulting from chance. A K_{hat} value of zero suggests that a given classification is no better than a random assignment of pixels. If the chance agreement is larger, K_{hat} could be negative values – an indication of very poor classification performance.

The K_{hat} value is computed as follows:

$$K_{hat} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} * x_{+i})}{(N^2 - \sum_{i=1}^{r}(x_{i+} * x_{+i}))}$$

Where:

r = number of rows in the error matrix

x_{ii} = number of observations in row i and column i (on the major diagonal)

x_{i+} = total of observations in row i (shown as marginal total to right of the matrix)

x_{+i} = total of observations in column i (shown as marginal total at the bottom of the matrix

N = total number of observations included in the matrix

For the error matrix shown above, the K_{hat} value is calculated as such:

$\sum_{i=1}^{r} x_{ii}$ = 226 + 216 + 360 + 397 +190 + 219 = 1608

$\sum_{i=1}^{r}(x_{i+} * x_{+i})$ = (239 * 233) + (309 * 328) + (599 * 429) + (521 * 945) + (453 * 238) + (359 * 307) = 1,124, 382

$$K_{hat} = \frac{(2480\ (1608) - 1124382)}{2480^2 - 1124382)}$$

K_{hat} = 0.57

The K_{hat} value (0.57) is lower than the overall accuracy (0.67) computed earlier. As a reminder, the overall accuracy only includes the data along the major diagonal and excludes the errors of omission and commission. K_{hat} incorporates the diagonal elements and the non-diagonal elements of the error matrix as the product of the row and column marginal. One of the advantages of computing K_{hat} statistics is the ability to use this value as the basis for determining the statistical significance of any given matrix or the differences among the matrices.

Normally it is desirable to compute and analyse both the overall accuracy and K_{hat} statistics. The analyst should provide the error matrix based on the training sample, the error matrix of test areas or test pixels, overall accuracy, producer’s accuracy, user’s accuracy and K_{hat} statistics of provided error matrices for the quality assurance of HCS classifications.

Photo top: Courtesy USGS ©
Photos bottom: Courtesy TFT ©

Quality control, finalising the initial land cover classification and next steps

The steps for finalising the initial land cover classification are described below.

Raster to vector conversion

Convert the raster image to a vector format to make editing of land cover class boundaries easier.

Elimination of small patches

Elimination of small polygons (4 pixels and smaller) is done by merging them with the closest larger polygon with similar properties; elimination of the sliver polygons (elongated polygons) is done by using the area/perimeter ratio. Minimum mapping area or units should be defined in order to remove polygon patches.

Incorporating other land use information

In finalising the initial map, information regarding current land use is incorporated into the analysis. For example, already-developed land is removed from potential HCS forest areas.

Editing the vegetation classes using composite 654 band-Landsat 8 (LDCM) image

In this step, the land cover class vector data is overlaid on a composite Landsat Image (654 band) and a visual comparison is made, with editing as required.

QC vector editing results reclassified into HCS classes

The land cover strata are reclassified into the six standard HCS vegetation classes: OL, S, YRF, LDF, MDF, and HDF.

Edge matching of vector data

If more than one Landsat image is used, the resulting classification vector data needs to be combined using the edge matching process.

Conduct aerial survey if possible

Aerial surveys should be conducted over major contiguous areas of natural forest where possible. A geo-database can then be created to enable photo viewing in GIS. This enables easy cross-checking of land cover classification.

Prepare draft land cover map

A draft land cover map, categorised by the various classes identified in the process outlined above, is then prepared for use in planning and implementation of field work, including the aerial survey and the forest inventory.

Next steps

The next stage in the HCS classification process is to test the accuracy of the interpretation results, as the accuracy will strongly influence the user's trust in the data and methods of analysis. The initial classification accuracy report of classification of satellite image for HCS vegetation stratification from the perspective of contingency table (error matrix or confusion table), producer's accuracy, user's accuracy, overall accuracy, K_{hat} statistics and interpretation of accuracy assessment report have been discussed here. The next step is to compare the results of the image interpretation with measurements taken in the field. This also allows us to calculate approximate carbon values for each class.

The next chapter will explain how to collect sample field data required to estimate the above-ground biomass and carbon stock, assign average carbon levels to each category (while noting that the purpose is not to calculate an exact carbon number but rather to differentiate types of land cover through estimated carbon values), and further refine the classification in order to create the lland cover map in which potential HCS forest areas are delineated.

> *"The next step is to compare the results of the image interpretation with measurements taken in the field, allowing us to calculate approximate carbon values for each class"*

Appendices

Appendix A: An overview of satellite image options

Satellite Name	Overview	Spatial resolution (m)	Temporal resolution	Image capture dates	Cost per scene (USD)	Available bands	Size of images	Comments
ALOS (AVNIR-2, PRISM)	http://www.alos-restec.jp/en/	10m	46 days	Jan 2006 – May 2011		1270 MHz (L-band), Polarization HH+VV		
IKONOS	http://geofuse.geoeye.com/landing/ http://glcf.umd.edu/data/	4m	14 days	2000 –	\$16-56/ Km^2	1 (Blue) 2 (Green) 3 (Red) 4 (Near-IR)	14km by 14km	
Landsat 7	US government's earth-observing satellite missions, jointly managed by NASA and the US Geological Survey. Band designations include: • Multi-spectrum Scanner (MSS) • Thematic Mapper (TM) • Enhanced Thematic Mapper Plus (ETM+) http://landsat.gsfc.nasa.gov/ http://glcf.umd.edu/data/ Since 2003, Landsat 7 image data have been affected by a stripping problem that reduces the quality of these images.	30m	16 days	April 1999 – Present	Free	8 Bands: **1.** 0.45 - 0.515 30m **2.** 0.525 - 0.605 30m **3.** 0.63 - 0.69 30m **4.** 0.75 - 0.90 30m **5.** 1.55 - 1.75 30m **6.** 10.40 - 12.5 60m **7.** 2.09 - 2.35 30m **Pan Band.** 0.52 - 0.90 15m	170km by 183km	
Landsat 8	http://landsat.usgs.gov/landsat8.php	30m	16 days	Feb 2013 – Present	Free	11 Bands: **1.** 0.433–0.453 30 m **2.** 0.450–0.515 30 m **3.** 0.525–0.600 30 m **4.** 0.630–0.680 30 m **5.** 0.845–0.885 30 m **6.** 1.560–1.660 30 m	185km by 180km	

Cont...

Appendix A: An overview of satellite image options

Satellite Name	Overview	Spatial resolution (m)	Temporal resolution	Image capture dates	Cost per scene (USD)	Available bands	Size of images	Comments
Landsat 8 Cont...						**7.** 2.100–2.300 30 m **8.** 0.500–0.680 15 m **9.** 1.360–1.390 30 m **10.** 10.6-11.2 100 m **11.** 11.5-12.5 100 m		
Quickbird	http://www.digitalglobe.com http://glcf.umd.edu/data/	2.4m	4 days	2001 – Present	$5,000 -11, 500/ scene $16-45 /km^2	Multispectral **1** = Blue **2** = Green **3** = Red **4** = NIR •Panchromatic Pan	16.5km x 16.5km	
Radarsat 2	http://www.asc-csa.gc.ca/eng/satellites/radarsat2/ Although radar data does not have infrared band, it has other important backscattering information. It is also able to penetrate through cloud cover and operate day and night. However, the data processing is more tedious as compared to optical data.	3m – 100m*	24 days	Dec 2007 - Present	$3,300 – $7,700	C Band SAR Antenna-Transmit & Receive Channel: 5405.0000 MHz (assigned bandwidth 100,540 kHz)		Radar data lacks an infrared band and therefore requires additional care to classify different vegetation classes.
RapidEye	http://www.rapideye.de/	5m	5.5 days	2009	$1.5 / km^2	**1.** 440 – 510 nm (Blue) **2.** 520 – 590 nm (Green) **3**. 630 – 685 nm (Red) **4.** 690 – 730 nm (Red Edge) **5.** 760 – 850 nm (Near IR)	25km x 25km	Radar data lacks an infrared band and therefore requires additional care to classify different vegetation classes.

Cont...

Appendices

Appendix A: An overview of satellite image options

Satellite Name	Overview	Spatial resolution (m)	Temporal resolution	Image capture dates	Cost per scene (USD)	Available bands	Size of images	Comments
SPOT-5	Satellite network run by the French Space Agency. http://www.satimagingcorp.com/satellite-sensors/other-satellite-sensors/spot-5/	2.5m to 10m	24 days	1986 - Present	$1,500 - $2,500	5 bands: Panchromatic (450 – 745 nm) Blue (450-525 nm) Green (530 – 590 nm) Red (625 - 695 nm) Near-infrared (760 – 890 nm)	60km by 60km	
Worldview-1	http://www.alos-restec.jp/en/	0.50 meter GSD at Nadir 0.55 meter GSD at 20˚ off-nadir	1.7 days at 1 meter GSD or Less 5.9 days at 20˚ off-nadir or less 0.51 meter GSD	Sept 2007 to Present		Panchromatic	17.6 km at Nadir 17.6 km X 14 km or 246,4 km^2 at Nadir	Maximum view Angle or Accessible Ground Swath 60km by 110km or 30km by 110km Stereo Image acquisition
Worldview-2	http://www.satimagingcorp.com/satellite-sensors/worldview-2/	Ground Sample Distance (GSD) Panchromatic: 0.46m GSD at Nadir, 0.52m GSD at 20° Off-Nadir Multispectral: 1.84m GSD at	1 m GSD: <1.0 day 4.5 days at 20° off-nadir or less	August 2014 to Present		Panchromatic @ 450-800nm 8 Multispectral bands @ 400 – 1040 nm 8 SWIR bands @ 1195 – 2365 nm 12 CAVIS Bands @405 – 2245 nm	At nadir: 13.1 km	Max Conti-guous Area Collected in a Single Pass (30° off-nadir angle) Mono: 66.5km x 112km (5 strips) Stereo: 26.6km x 112km (2 pairs)

Cont...

Appendix A: An overview of satellite image options

Satellite Name	Overview	Spatial resolution (m)	Temporal resolution	Image capture dates	Cost per scene (USD)	Available bands	Size of images	Comments
Worldview-2 Cont...		Nadir, 2.4m GSD at 20° Off-Nadir						
Worldview-3	http://www.satimagingcorp.com/satellite-sensors/worldview-3/	Pan. Nadir: 0.31m GSD at Nadir 0.34 m at 20° Off-Nadir Multi-spectral Nadir: 1.24m at Nadir, 1.38 m at 20° Off-Nadir SWIR Nadir: 3.70m at Nadir, 4.10m at 20° Off-Nadir CAVIS Nadir: 30.00 m	1m GSD: <1.0 day 4.5 days at 20° off-nadir or less	August 2014 – Present		Panchromatic @ 450-800nm 8 Multispectral bands @ 400 – 1040 nm 8 SWIR bands @ 1195 – 2365 nm 12 CAVIS Bands @405 – 2245 nm	At nadir: 13.1km	Max Conti-guous Area Collected in a Single Pass (30° off-nadir angle) Mono: 66.5km x 112km (5 strips) Stereo: 26.6km x 112km (2 pairs) Cont...

Appendices

Appendix A: An overview of satellite image options: **Emerging technologies**

Sensor	Website	Spatial resolution	Temporal resolution	Image capture dates	Cost of image	Available bands	Swatth
Ebee unmanned aerial vehicles (UAVs)	www.sensefly.com For mapping topography, land use, land cover and changes at very high resolution It is very good tool for monitoring changes of an area. Note that in some areas only certified pilots may use this technology. Several multirotors UAV and fixed wing drone should be explored by analysts, as the UAV technology is changing fast.	Sub meter to 5 meter	Any day and time with good weather	Any date the team selected to fly	35USD per sq.km for stereo images acquisition 700 images per single flight 10 sq.km per 45 minutes per single flight Processing time is 12 hours per 100 images @ ~800 USD per working day	Visible (blue, green and red) with visible camera Near infrared with near infrared camera	10km by 10km
LiDAR data **Airborne LiDAR**	http://www.lidarbasemaps.org/ For mapping topography, DTM Creating contours, Not for Land use or land cover mapping and detection of changes	See website 30000 points per second at 15 meter accuracy	See website Any time of good weather	See website Choice by the analysts	See website	See website	See website
Microwave or SAR - Synthetic Aperture Radar **ERS, ENVISAT (retired) and Sentinel-1, launched in April 2014**	https://earth.esa.int/web/guest/missions/esa-future-missions https://earth.esa.int/web/guest/missions/esa-future-missions/sentinel-1 https://sentinel.esa.int/web/sentinel/sentinel-data-access Old archives of ERS and ENVISATS are available through 2012	Sentinel-1: 20m resolution	Sentinel-1: 12 days revisit	Sentinel-1: Since April 2014	Sentinel-1: Free download with registration	Sentinel-1: C-Band SAR	Sentinel-1: 250 KM swath

Appendix B: Tasseled Cap transformation

Kauth and Thomas (1976) produced an orthogonal transformation of the original Landsat MSS data space to a new four dimensional feature space. It was called the Tasseled Cap or Kauth-Thomas transformation. The name 'Tasselled Cap' comes from its cap shape in Greenness (as Y) and Brightness (as X) plots. It created four new axes: the soil brightness index (B), greenness vegetation index (G), yellow stuff index (Y) and none such (N). The names attached to the new axes indicate the characteristics the indices were intended to measure.

The coefficients for Landsat MSS are (Kauth et al., 1979):

B = 0.322*MSS1 + 0.603*MSS2 + 0.675*MSS3 + 0.262*MSS4

G= - 0.283*MSS1 -0.660*MSS2 + 0.577*MSS3 + 0.388*MSS4

Y = -0.899*MSS1 + 0.428*MSS2 + 0.076*MSS3 – 0.041*MSS4

N = -0.061*MSS1 +0.131*MSS2 - 0.452 * MSS3 + 0.882 * MSS4

Crist and Kauth (1986) derived the visible, near infrared and middle infrared coefficients for transforming **Landsat Thematic Mapper** (TM) imagery into brightness (B), greenness (G) and wetness (W) variables.

B = 0.2909*TM1 + 0.2493*TM2 + 0.4806*TM3 + 0.5568*TM4 + 0.4438*TM5 + 0.1706*TM7

G = - 0.2728*TM1 – 0.2174*TM2 – 0.5508*TM3 +0.7221*TM4 + 0.0733*TM5 – 0.1648*TM7

W = 0.1446 * TM1 + 0.1761*TM2 +0.3322*TM3 +0.3396*TM4 – 0.6210*TM5 – 0.4186*TM7

Tasseled Cap coefficients for Landsat 7 Enhanced Thematic Mapper Plus (ETM+) are (Huang et al., 2002)

B = 0.3561*TM1 + 0.3972*TM2 + 0.3904*TM3 + 0.6966*TM4 + 0.2286*TM5 + 0.1596*TM7

G = -0.334*TM1 – 0.354*TM2 -0.456*TM3 + 0.6966*TM4 – 0.24*TM5 – 0.263* TM7

W = 0.2626*TM1 + 0.2141*TM2 + 0.0926*TM3 + 0.0656*TM4 – 0.763*TM5 – 0.539*TM7

Fourth = 0.0805*TM1 – 0.050*TM2 + 0.1950*TM3 – 0.133*TM4 + 0.5752*TM5 – 0.777*TM7

Fifth = -0.725*TM1 – 0.020*TM2 + 0.6683*TM3 + 0.0631*TM4 - 0.149*TM5 – 0.027*TM7

Sixth = -0.400*TM1 – 0.817*TM2 + 0.3832*TM3 + 0.0602*TM4 – 0.109*TM5 + 0.0985*TM7

Tasseled Cap coefficients for transformation of Landsat 8 imagery (Baig et al., 2014) are:

B = 0.3029*TM2 + 0.2786*TM3 + 0.4733*TM4 + 0.5599*TM5 + 0.508*TM6 + 0.1872*TM7

G = -0.2941*TM2 – 0.243*TM3 – 0.5424*TM4 + 0.7276*TM5 + 0.0713*TM6 – 0.1608*TM7

W = 0.1511*TM2 + 0.1973*TM3 + 0.3283*TM4 + 0.3407*TM5 - 0.7117*TM6 - 0.4559*TM7

Fourth = -0.8239*TM2 + 0.0849*TM3 + 0.4396*TM4 - 0.058*TM5 + 0.2013*TM6 - 0.2773*TM7

Fifth = -0.3294*TM2 + 0.0557*TM3 + 0.1056*TM4 + 0.1855*TM5 - 0.4349*TM6 + 0.8085*TM7

Sixth = 0.1079*TM2 - 0.9023*TM3 + 0.4119*TM4 + 0.0575*TM5 - 0.0259*TM6 + 0.0252*TM7

Chapter 4

Forest inventory and estimation of carbon stock

By George Kuru and Alex Thorp, Ata Marie Group Ltd.

The authors would like to thank Jaboury Ghazoul and Chue Poh Tan from ETH-Zurich; Michael Pescott and Rob McWilliam from TFT; and Yves Laumonier from CIFOR for valuable comments on previous drafts.

CHAPTER CONTENTS

Preparing for the fieldwork

As described in the previous chapter, the first step of the vegetation classification exercise in the HCS process is to use satellite imagery to assign the vegetation to the different classes and identify potential HCS forest areas.The next step of the HCS assessment is to sample these classes in the field and assign them average carbon values by measuring vegetation within sample plots. This chapter explains how to select and set up the sample plots, conduct measurements, calculate above-ground carbon and finalise the vegetation classification. The intended audience is practitioners with a good knowledge of using statistical analysis to inform sampling techniques.

Community mapping and FPIC processes

Because field sampling activities will likely lead to direct interactions with community members, local communities should already be informed about the HCS Approach and process before the forest inventory begins. Ideally this should take part during the initial engagement with communities through the early stages of the process of Free Prior and Informed Consent (FPIC) described in Chapter 2 of this toolkit. Communities will also need to give consent to any sampling activities being carried out on their lands.

Participatory mapping and community engagement should have indicated areas that communities identify as important to maintain for their current and future livelihoods and socio-cultural needs. These can include both HCS forest areas, for instance those used for gathering non-timber forest products or hunting, as well as non-HCS areas such as small farms, gardens or agroforestry plots. Note that if these non-HCS areas are identified during the image-based classification or during the field sampling, but were not identified during the participatory mapping process, this could be an indicator that the participatory mapping/FPIC process was not sufficiently completed and that it needs to be revised before the HCS process can be finalised.

All photos: Courtesy TFT ©

> *"Because field sampling activities will likely lead to direct interactions with community members, local communities should already be informed about the HCS Approach and process before the forest inventory begins"*

Preparing for the fieldwork

Determining the number and type of sample plots

Field samples for HCS assessments focus on assessing the tree biomass within potential HCS forest classes. The largest proportion of field samples are distributed in those classes defined as young regenerating forest (YRF) and low density forest (LDF). Although scrub and open land are likely to contain very low levels of carbon, the HCS assessment process does seek to field sample a limited number of plots to confirm this assumption. Other classes such as existing plantation areas (e.g. oil palm, food crops), and enclave areas including community areas, peatlands, and HCV areas are generally not assessed as it is expected these areas are separately demarcated.

The appropriate number of samples to measure in each class is difficult to predict at the beginning of the field assessment unless locally available data on variability is available. In the absence of such data, enough field time should be budgeted to increase the sample size as necessary to achieve the precision targets, recognising that it is costly to return at a later date to the site to undertake further sampling.

The recommended precision targets for the HCS assessment are:

- Forest carbon stock inventories should be planned for the purposes of attaining carbon stock estimates at a 90% confidence interval of the total carbon stocks. An adaptive process may be needed to refine the sample size to achieve the 90% level of confidence.
- Variability within one vegetation class (for instance, within the High Density Forest category) may exceed the 90% precision target, provided that in the final analysis the classes are statistically different from one another.

All photos: Courtesy TFT ©

"The largest proportion of field samples are distributed in those classes defined as young regenerating forest and low density forest"

The number of plots planned should be sufficient to meet the precision targets for each major class in each region. A simple equation for estimating the number of samples is:

$N = t^2 s^2 / E^2$

where:

N = samples to estimate mean to ± E

t = t-value from student's t-test table for 90% confidence interval

s = standard deviation estimated based on existing data sets from similar forest types. Government forestry departments often have relevant data.

E = probable error, expressed as a percentage of the estimated mean value

The resulting number should be rounded to the nearest whole number.

For example, to survey a HCS vegetation class with an estimated carbon stock level of 57 tonnes/hectare and an estimated standard deviation of 35 tonnes/ha with an allowable sample error of +/- 10% of the average carbon stock and with 90% confidence limits, the number of sample plots is calculated as follows:

$$N = t_{st\ 0.9}{}^2 * s^2 / E^2 = 1.66^2 * 35^2 / (57*10\%)^2 = 62.6$$

Rounded to N=63

Equipment needed for the field work

Plot tree measurement data will be recorded manually in field books. An example of a field book layout is shown in the Appendix, along with an equipment list for an inventory team.

All photos: Courtesy TFT ©

> *"For efficient measurement the team needs to be able to mobilise to the measuring site quickly and spend a whole day working uninterrupted"*

Selecting the survey team

A single survey team is generally made up of between 6 – 8 people as follows:

Position	No of persons	Description and role
Team Leader	**1**	**Graduate forester with inventory experience** Responsible for team organisation and performance, in particular the following: • Navigating to transect starting point • Keeping field book • Operating GPS • Tree height measurement • Capturing plot photos • Data management and handover
Measuring Assistants	**2**	**Experienced technicians** Core role is to measure diameters, label trees, and identify species. It is essential that at least one of the two assistants is familiar with local tree species names
Plot cleaner	**1**	Labourer responsible for cleaning vines and climbers off trees to be measured to enable easier diameter and height measurement
Hip chain operator	**1**	Role: Measuring transect length and location of plot center points along the transect
Compassman	**1**	Role: Ensuring transect lines are cut on the correct pre-determined compass bearing
Line cutter	**2**	Role: Clearing the transect line to enable rapid mobilisation to plot points

The number of team members required will vary depending on their skill level and the conditions in the forest. The team leader will decide the composition of the team.

For efficient measurement the team needs to be able to mobilise to the measuring site quickly and spend a whole day working uninterrupted. Therefore logistical support in terms of local guides and suitable transport for the whole team is imperative.

Where access is difficult, it may be more efficient for teams to set up a camp, in which case camping equipment will need to be supplied and a cook should be added to the team.

For most surveys, multiple teams should be employed. A logistics manager should be appointed to ensure teams receive the necessary logistical support. A data manager should be appointed to carry out data entry and general data management. Joint training exercises should be held at the start of the inventory period to ensure all team leaders understand and implement procedures the same way.

Setting up the plots

Sampling design

Plots can be located randomly or systematically within a class. Random sampling is a statistically more thorough and robust approach, but is generally slower than systematic sampling and can be more expensive. Systematic plot location is usually cheaper and easier to implement in the field, allowing a greater number of plots to be measured within a given time frame. Plots can be located along a grid formation, or completed along transect lines spaced evenly across the class without any bias. A combination of systematic and random sampling can also be used for increased accuracy.

The methods for setting up plots systematically and randomly are described below; both sampling designs are accepted in the HCS Approach.

Regardless of the sample design used, prior to the field work, a navigation plan should be established recording the sequence in which plots will be measured. The plan should describe:

- The initial access point providing easiest access to the first plot. The initial access points are normally located at convenient points along roads or other access ways.
- Co-ordinates of each plot (uploaded into GPS) in order of measurement.
- The compass bearing from one plot to the next plot
- The distance between plots

All photos: Courtesy Corozal Sustainable Future Initiative, Belize ©

Navigating and setting up systematically located plots using transects

Field team leaders should be provided with instructions for each transect including:

- Map
- Starting point co-ordinates (uploaded into GPS devices). The start points of transects are normally located at convenient points along roads, rivers, canals or other access routes.
- Transect compass bearing
- Transect length in kilometres
- Number of plots to be measured

Transects should be set up according to the following steps:

1. Team navigates to the start point of the nominated transect line using a GPS device, and saves a waypoint at the exact location of the start point. Through recent experience Garmin GPS receivers are preferred, as they are single frequency and usually have no problems operating under heavy forest canopy. They are accurate up to five metres, which is suitable for this type of survey.
2. Place a pole at the start point. Label the pole with flagging tape. Record on the flagging tape the transect number and the compass bearing of the transect.
3. Traverse the land along the planned compass bearing. The transect should be located strictly along the planned compass bearing route. If the field team meets a significant obstacle such as a cliff or waterway, the survey team should detour around the obstacle if possible, and restart the survey at the nearest possible point along the transect route. Otherwise the survey team should simply terminate the survey work on the transect.
4. Plot centre-points should be located systematically every 100 metres along the transect. For plots located on a boundary between HCS classes, the pragmatic approach is to classify the plot by its predominant type of vegetation cover, taking into account the remote sensing classification as well. In cases of extreme boundary issues, for instance where dense forest borders bare land, the plot should be noted as ‘not measured’.

Note that plot locations do not require adjustment for slope along the transect line, provided the plot locations are accurately measured by GPS. Hip chains should only be used to measure distances between plots in flat terrain.

Plots should not be moved for any reason. If a plot cannot be measured due to safety reasons, such as extreme slope, or hanging tree limbs, or if it is within a watercourse (river or stream), it should be noted as “not measured”, and the sampling should resume at the next plot centre point. The observation should also be marked on the plot map and brought to the company’s attention.

Navigating and setting up plots without transects

Random plot locations are generated using GIS software, whereas systematic plots are typically located using a grid formation. Plots should be set up according to the following steps:

1. Navigate to the initial access point using GPS.
2. Traverse the land to the plot center point using GPS to navigate.
3. Identify the actual plot location using GPS.

As stated above, plots should not be moved for any reason. If a plot cannot be measured due to safety reasons it should be noted as "not measured", and the sampling should resume at the subsequent plot centre point.

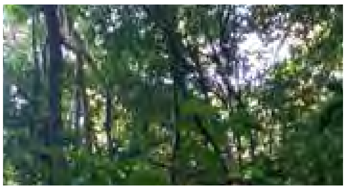
Sample plot size and shape

The same kind of plot is used for random, systematic and transect sampling. The recommended sample plot design is two concentric circles from a centre point with a total area of 500m^2 or 0.05ha. Circular plots are preferred to rectangular plots to minimise the potential error due to slope factors and physical obstacles which might skew plot boundary lines.

Plot demarcation

1. Place a pole at the centre of the plot. Label the pole with flagging tape. Record the plot ID on the flagging tape. Standing trees should not be used as plot markers.
2. Capture the GPS waypoint at the centre point of the plot and write the waypoint number in the field book. Waypoint numbers should be the running number produced by the GPS. Do not edit this number.
3. From the centre point, the first sub plot is measured by using a measurement tape or pre-measured rope that can be firmly pulled to a horizontal distance of 5.64m. A second sub plot is then established by measuring a horizontal distance of 12.61m with a firmly-pulled measurement tape or premeasured rope. Where a pre-measured rope is used, it is important that an inelastic rope is used to limit errors resulting from stretching the rope.
4. The following identification information should be recorded in the field book for all plots:

- Concession name
- Date
- Field team leader name
- Transect and plot number
- GPS waypoint number for plot centre point
- HCS class in plot based on generic definitions provided
- Soil/underfoot conditions, e.g. organic/peat soil, mineral soil, marine clay soil, standing water
- General description of the plot and surrounding area, including evidence of fire, logging, and other human activity e.g. rubber or other agriculture crops.



All photos: Courtesy TFT ©

Vegetation measurement

The focus of vegetation measurement is on large plant species which usually comprise the large majority of above ground biomass. The other forest carbon pools are not measured because they are either relatively small in size (e.g. forest understorey) or are difficult and expensive to assess (e.g. below ground biomass, deadwood, soil organic matter).

Large plant species are defined as those having a diameter at breast height (DBH) greater than or equal to 5cm. This includes both tree and non-tree species. Breast height for the DBH measurement is defined as 1.3 metres.

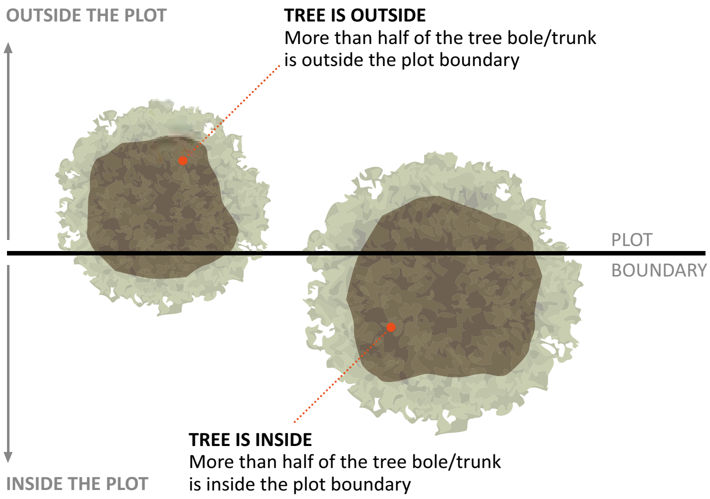
Large plant species (referred to as 'trees' for simplicity, but they may include non-tree species such as some palm species) are measured through the following steps:

1. **Identification of "In" trees:** An "in" tree is defined as a tree where the centre of the tree stem at DBH is within the boundaries of the plot. Trees on the edge of the plot will be checked using a nylon rope marked at the correct plot radii.
2. **Flagging tape:** Each tree shall be labelled with flagging tape. The label should indicate the tree number as recorded in the field book.
3. **DBH measurement:** All trees greater or equal to 15cm DBH shall be measured in the large plot. In addition to the large trees, all trees greater than or equal to 5cm and less than 15cm DBH shall be measured in the small plot.
4. **Height measurement:** Depending on the eventual allometric equation used, it may also be necessary to measure tree heights. Tree heights should be measured using clinometers in the following way:
    - Two operators measure 10 metres from the base of the tree using a clinometer.
    - At 10 metres, one measurement in percent is taken to the base of the tree. The operator at the tree can help by pushing trees and shrubs out of the sight line of the clinometer and by using a high-visibility vest to indicate the bottom of the tree.
    - Another measurement in percent is taken at the top of the merchantable height of the tree. Merchantable height is the point at which the main bole of the tree transitions into the crown, or where the first major branch occurs.
    - The sum of the two measurements (to the bottom and to the top of the merchantable bole) is divided by 10 to give the bole length in metres (e.g. 15% down plus 110% up equals 125%, for a bole height of 12.5m).

Knowing the total bole height, it is then possible to estimate the length and corresponding quality of the different sections along the bole.

> *"The focus of vegetation measurement is on large plant species which usually comprise the large majority of above ground biomass"*

FIGURE 1: **DECIDING ON BORDERLINE TREES**



Diameter at breast height is defined as follows:

TABLE: **DIAMETER MEASUREMENT METHOD**

Tree Form	Measurement Method
Well formed tree	Stem diameter is measured at 1.3m above ground from the uphill side of the tree
Tree forks below 1.3m	The diameter of each stem is measured separately at 1.3m above ground from the uphill side of the tree
Tree has large deformity at 1.3m	The stem diameter is measured at 0.5m above the point where the deformity terminates
Buttressing occurs above1.3m	The stem diameter is measured at 0.5m above the point where the buttressing terminates

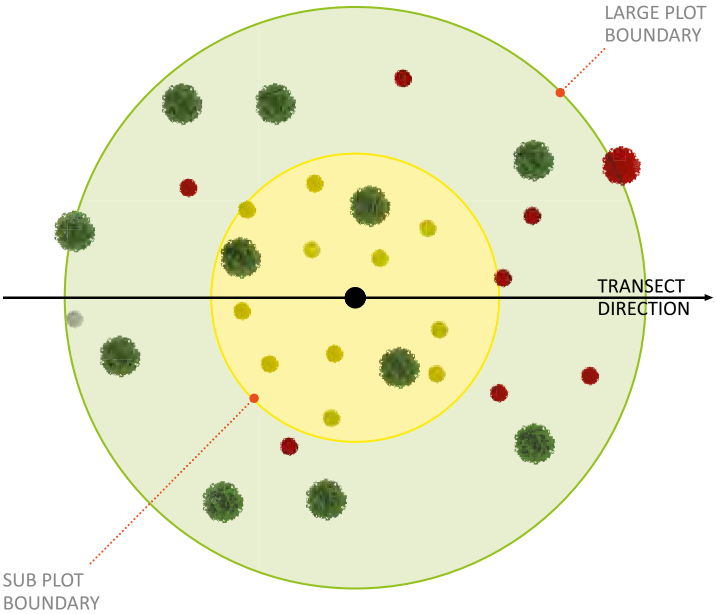
5. Species: All trees measured in the plot should be identified by their genus and preferably to their species name. This is because this information may be needed in the allometric equation, and to be able to describe forest composition and structure in a general way. As stated above, botanists or foresters with local expertise should ideally be part of the field team; local names can be noted in the field book and translated to species names later on. If certain species cannot be identified even by their local name, then photographs and botanical samples should be collected and marked so that identification can be done by experts at a later date.

The figure on the right illustrates the plot design.

> *“All trees measured in the plot should be identified by their genus and preferably to their species name”*

All photos: Courtesy TFT ©

FIGURE 2: **HCS INVENTORY PLOT LAYOUT**



PLOT	PLOT RADIUS (M)	PLOT SAMPLE AREA (M²)	TREE DBH MEASURED (CM)
SUB PLOT	5.64	100	5 – 14.9
LARGE PLOT	12.61	500	15 up

TREES DBH 5–14.9CM

🟡 MEASURED

🔴 NOT MEASURED

TREES DBH 15CM UP

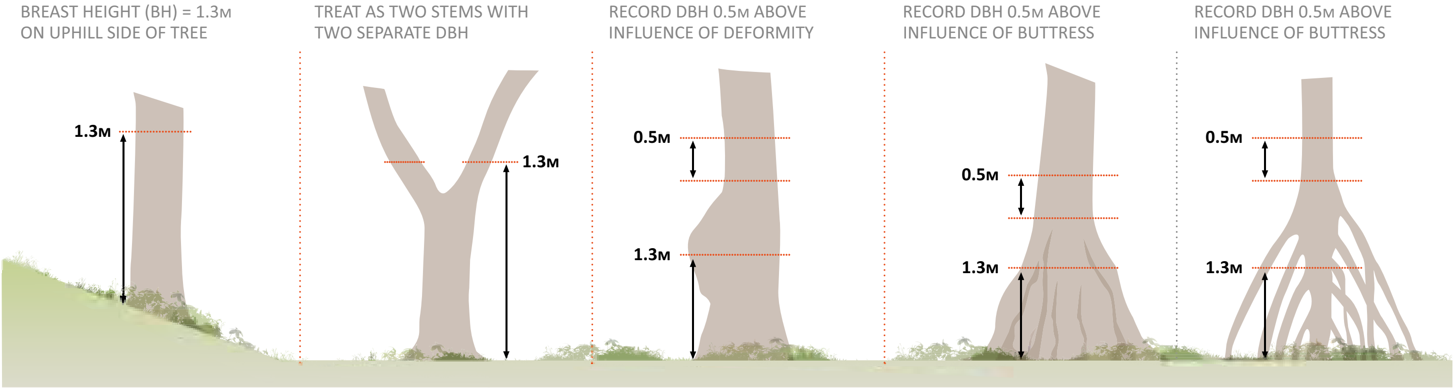
🟢 MEASURED

🔴 NOT MEASURED

● PLOT CENTRE

FIGURE 3: **DIAMETER MEASUREMENT METHOD**

Note: *Minor corrections were made to this diagram on 13.04.2015 in order to match the text*



Plot photographs

For all plots in the forest, five digital photographs should be taken at the centre of the plot. Four photos will be orientated in the north, south, east and west directions, with one photo pointing directly up to show the canopy density. The photographs should illustrate the basic structure and density of the vegetation at each plot. The GPS tracking function should be kept on at all times during field measurement to enable the photos to be geo-referenced.

The images below show how land cover ground photos compare to the pixels from the satellite images. Sky and canopy photos illustrate the density of ground cover.

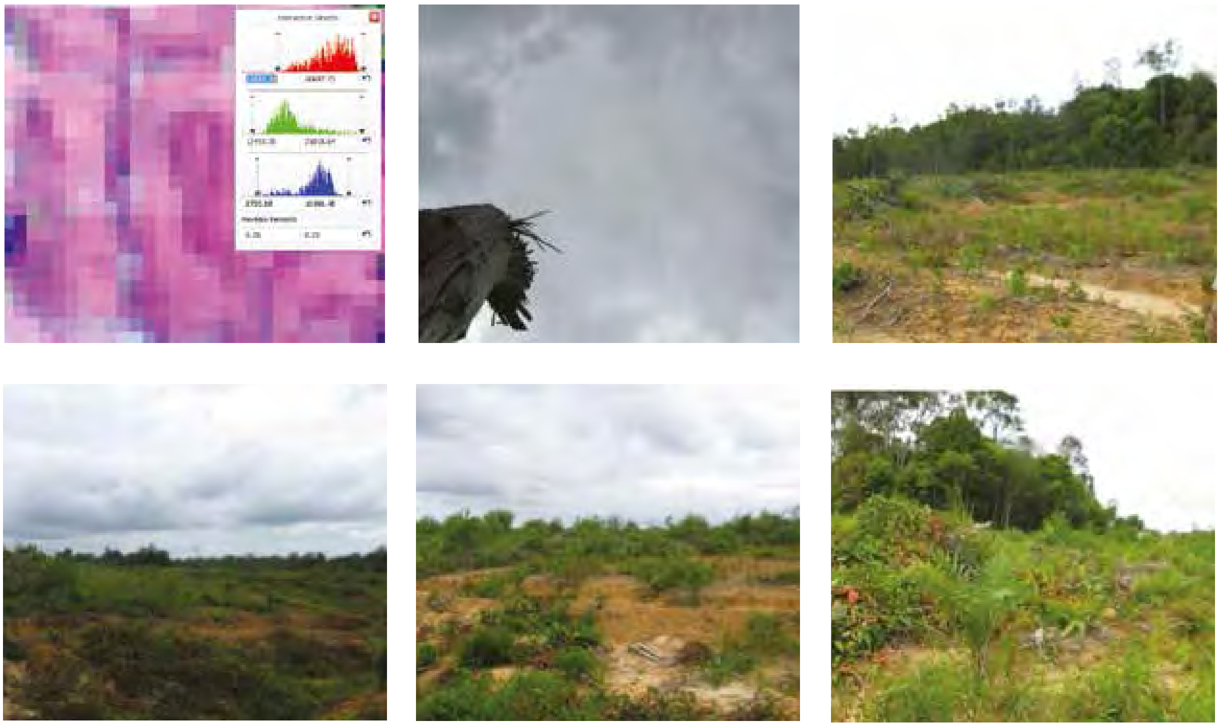
Satellite images are from Landsat 8, with an RGB combination of 6,4,2.

> *“The GPS tracking function should be kept on at all times during field measurement to enable the photos to be geo-referenced”*

FIGURE 4: **SAMPLE SATELLITE IMAGES AND CORRESPONDING FIELD PHOTOGRAPHS (CANOPY, NORTH-FACING, SOUTH-FACING, EAST-FACING, WEST-FACING)**

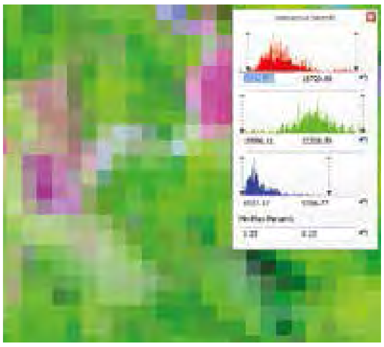
Open Land

All photos: Courtesy TFT ©



Scrub

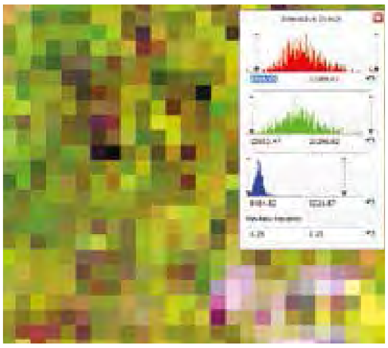
All photos: Courtesy TFT ©






Young Regenerating Forest

All photos: Courtesy TFT ©



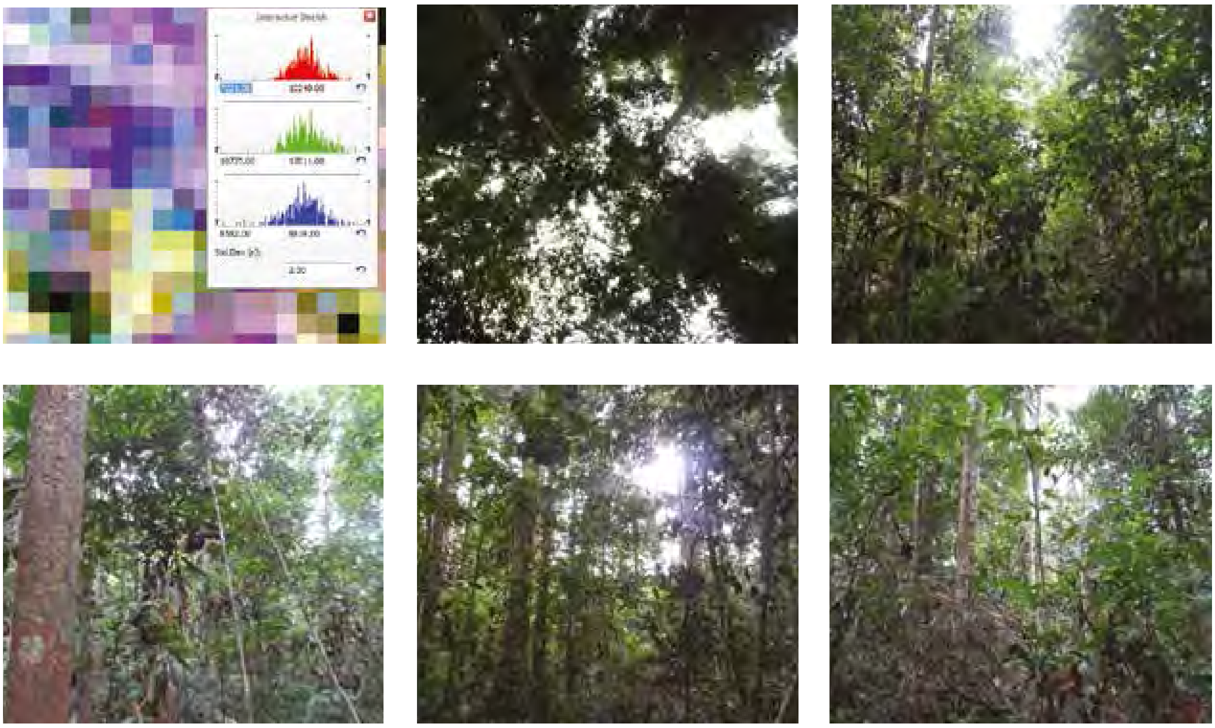



Plot photographs

FIGURE 4: **SAMPLE SATELLITE IMAGES AND CORRESPONDING FIELD PHOTOGRAPHS (CANOPY, NORTH-FACING, SOUTH-FACING, EAST-FACING, WEST-FACING)**

Low Density Forest (LDF)

All photos: Courtesy TFT ©



Data entry and management

Team leaders should download GPS track and waypoint data to personal computers in Ozi / Garmin format every evening where practical to do so. In addition to data and photographs, team leaders should write a short two to three paragraph description of forest conditions and other relevant comments for each transect.

Completed field books, GPS data, and photos should be delivered to the Inventory Data Manager who will enter the plot data into a spreadsheet and compile all information into a logical format for handover to the GIS team. Team leaders should check data entered if there is any inconsistency.

"As well as data and photographs, team leaders should write a short two to three paragraph description of forest conditions and other relevant comments"

All photos: Courtesy TFT ©

Deriving average carbon stock per vegetation class

Once the data is entered, each plot is then analysed to provide estimates of stems per hectare and carbon stocks as follows.

Stems per hectare

The average number of stems per hectare is calculated from the plot size. The equation used is:

Stems per ha = (Count of trees in the plot) / (Plot size in ha)

Carbon content

The HCS assessment process uses allometric equations to estimate biomass. Allometric equations help estimate characteristics of a tree that are difficult to measure by instead measuring correlated attributes of the same tree. For instance, diameter at breast height can be measured and then used to determine the biomass of the entire plant above ground.

Many allometric equations exist around the world; some are specific to one forest type or tree species, while others are more generic to cover a broader range of situations. Allometric equations are typically developed from large samples to improve accuracy, although it is important to recognise that the equations have usually been generated for non-degraded forests and that they might not be appropriate for degraded forests where the growing environment has been substantially altered. A useful list of allometric equations can be found at: http://www.globallometree.org/. The Scientific Advisory Committee of the HCS Approach Steering Group will advise on a list of approved allometric equations for different regions of interest, and welcomes advice and input on this topic.

> *“It is important to recognise that the equations have usually been generated for non-degraded forests and that they might not be appropriate for degraded forests where the growing environment has been substantially altered”*

It should be noted that:

- The specific gravity measures the dry density of the wood. If the species is known, the specific gravity as noted in the World Agroforestry Centre’s (WAC) Wood Density Database (http://db.worldagroforestry.org/wd) should be used, averaged to the genus level if only the genus is known. Otherwise, a default value of 0.55 ton / green m^3 for tropical tree species and 0.247 ton / green m^3 for palm species should be used, based on average values provided by Inter-governmental Panel on Climate Change (2006), Guidelines for National Greenhouse Gas Inventories, Volume 4. Agriculture, Forestry and Other Land Use and the WAC wood density database.
- The carbon conversion factor estimates the carbon component of the vegetation biomass. This can be derived for specific forest types, or the IPCC standard value of 0.47 can be used.
- The equation for estimating tree carbon mass per ha is:

  Total Carbon (ton/ha) = Σ ([Tree Carbon]) / [Plot size in ha]
- Separate calculations of volume will need to be made when estimating tree volume in sub-plots because the plot size will differ between the main and subplot.

Following completion of processing of raw data and estimation of carbon stocks per vegetation class, an ANOVA test should be applied to determine whether there are significant differences in the carbon estimates per class. This should be followed by a Scheffé pairwise multiple comparisons test to determine which groups are significantly different.

The results can be placed into the table format below.

Land cover	Number of plots	Stems per Hectare	Basal Area	Average Carbon Stocks	Standard error of the mean	Confidence limits (90%)	
						Upper	Lower
Open Land							
Scrub							
Young Regenerating Forest							
Low Density Forest							
Medium Density Forest							
High Density Forest							

Finalising the classification

Once field work is complete, field data is used to compare and revise the vegetation classification using manual "heads up" visual interpretation. In particular, the following data is used:

Aerial Survey Results:

- If an aerial survey was conducted, a database of geo-referenced aerial photos can be compiled into a *.gdb file for each region. The database is loaded into GIS, enabling photos to be viewed and compared with the results of the classification.
- Written observations collected during the aerial survey.

Forest Inventory Results:

- The forest inventory described in this chapter produces a database of inventory plot points, each with a value of carbon stock per hectare. The plot points are stratified into carbon classes as required and overlaid onto the imagery.
- The forest inventory produces a database of geo-referenced plot photos (five photos per plot) compiled into a *.gdb file for each region. The database is loaded into GIS, enabling photos to be viewed and compared with the results of the classification.
- Species mix e.g. prevalence of pioneer species such as Macaranga spp., existence of planted trees (rubber, fruit trees).
- Diameter distribution, in particular the prevalence of larger diameter trees (DBH 30cm and up).
- If height data is collected, structural indices indicating the percentage of species by height classes can be calculated.
- Description of the type and stage of development such as pioneer forest, regenerating heavily degraded forest, degraded forest, primary forest. Forest development, successional, and or maturity indices may also be calculated, which will help define conservation and management plans.
- Descriptions of plots and transects recorded by inventory teams in the field.

It must be noted that revision of vegetation class boundaries is not aimed at matching individual plot carbon figures. Revisions are only made where both of the following conditions apply:

- Inventory plots show a clear bias in classification, i.e. contiguous groups of plots with carbon values well outside the vegetation class range.
- Re-analysis of imagery justifies revision of vegetation class boundaries.

Any such revisions should be well documented and justified so that external reviewers assessing the quality of the HCS process can understand why any changes were made.

The final classification will result in a map of indicative HCS forest areas, including an average carbon value for each vegetation class, as well as a physical description of the vegetation in each class. The second half of this toolkit explains Phase Two, which involves making decisions about the importance of small isolated patches and integrating the potential HCS forest areas with High Conservation Value areas, areas important for community needs, riparian zones, peatlands, and other relevant categories of land in order to create the final development and conservation plan.

> *"Phase Two... involves integrating the potential HCS forest areas with High Conservation Value areas, areas important for community needs, riparian zones, peatlands, and other relevant categories of land in order to create the final development and conservation plan"*

All photos: Courtesy TFT ©

Appendix: Inventory Field Form and Inventory Equipment List

Field Book Layout:

Estate / concession name:		
Field Team Leader:		**Date:**
Line / Plot:		**Waypoint No:**
Land Cover:		
Tree	**DBH**	**Species or local name**
1		
2		
3		
4		
5		
6		
7		
8		
Etc		
General description of the plot and surrounding area: e.g. Evidence of fire, Mature rubber trees outside plot		

Inventory Team Recommended Equipment List:

Type	Model	No.	Comment
GPS	Garmin GPS MAP 60, 62 or 64	1	64s is recommended
Batteries	AA	1 box	Spare batteries for GPS and camera
Camera	Digital camera	1	–
Tapes	Diameter tapes – 5m	1	Coated fiberglass
	Diameter tapes – 1.8m	2	
	50m tape - TajimaYSR-50	1	Coated fiberglass
	20m tape - TajimaYSR-20	1	
	Flagging tape	20	
Hip chain	Chainman II with belt	1	
Thread	Hip Chain Thread	3 km	
Compass	SILVA® Starter Type 1-2-3	1	Suunto is an alternative
	First aid kits	1	
	Backpack	1	
	Pencils and pens	1 box	
	Waterproof permanent boardmarker	1 box	For writing on the tree label
	1 KENKO box cutter	2	For cutting tree labels
	1 ruler 30cm	1	
	Stapler and staples	2	For attaching label to tree
	Field books	4	All weather waterproof notepads
	Ziplock type plastic bags		For keeping mobiles, maps etc dry

Publication date March 2015

Chapter 5

High Carbon Stock forest patch conservation: Background and principles

By Grant Rosoman, Greenpeace

Acknowledgements: The author thanks Robert Ewers from Imperial College London, Neville Kemp from Ekologika, Rob McWilliam from TFT, Matthew Struebig from the University of Kent and Jaboury Ghazoul from ETH-Zurich, as well as colleagues from Golden Agri-Resources and Rainforest Alliance, for helpful comments on previous drafts of this chapter.

CHAPTER CONTENTS

Introduction: Integrating conservation science into HCS forest patch analysis

Most plantation development in the tropics occurs in forest landscapes that include a mixture of forested, degraded and open areas, as well as other ecosystem types such as wetlands. The image analysis and field plots undertaken in the first vegetation stratification phase of a HCS assessment therefore generally result in identifying patches of HCS forest areas varying in size, shape and quality.

The overarching goal for protecting HCS forest areas (in addition to integration with HCV areas, peatlands and areas important to communities) is to conserve ecologically viable forest areas within the production landscape that have the support of local communities as well as legal protection[1]. This meant the HCS Approach developers had to determine a way to judge the value and viability of these patches of HCS forest given that from a practical point of view not every small patch of forest can be conserved in the medium to long-term. At the same time, they had to recognise that even small forest patches can provide important habitat or connectivity to habitat as well as carbon storage, especially in landscapes with low forest cover.

As this is a science-based methodology, the HCS Approach stakeholders turned to conservation science research to inform the development of indicators of forest patch quality. Over the last 30 years there has been a relatively large amount of research into forest fragmentation and patches, particularly in relation to impacts on species and habitat[2]. In what is probably the longest-running fragmentation investigation in the Amazon, it was discovered that in heavily fragmented landscapes, protecting the remaining forest remnants is highly desirable as they are likely to be key sources for plant and animal reproduction as well as 'stepping stones' for animals to move through the landscape (Laurance et al., 2011). Unfortunately, on a global scale this research is far from conclusive, particularly in light of the huge diversity of the planet's tropical forests, and there are many confounding factors that can mask many fragmentation effects (Ewers and Didham, 2006) and that are mediated by the surrounding landscape matrix (Laurance and Vasconcelos, 2004). It remains difficult to gauge the full impact of fragmentation on populations (Ewers et al., 2010).

> *"The overarching goal for protecting HCS forest areas... is to conserve ecologically viable forest areas within the production landscape that have the support of local communities as well as legal protection"*

It is therefore not yet possible to give absolute guidance on key fragmentation and forest patch factors, such as the minimum threshold for patch size, edge effects, connectivity, shape and configuration that will ensure the long-term viability of the forest. However, one can derive general principles about the importance of particular patches in a given landscape. This chapter provides an overview of conservation science considerations used to derive the principles and the attributes to be analysed in the HCS process to determine the importance of conserving individual HCS forest patches in the landscape along with HCV, peatland, riparian zones and other areas for protection. Although they are not explored here, it should also be noted that there are a large number of GIS tools that have been developed to analyse forest patches[3].

All photos: Courtesy TFT ©

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1. See various 'No Deforestation' or 'Deforestation Free' policy commitments, for instance Golden Agri-Resources: "Ultimately, the conserved HCS forest area can revert to its natural ecological function as a forest." In Golden Agri-Resources (2012). "High Carbon Stock Forest Study Report", page 3

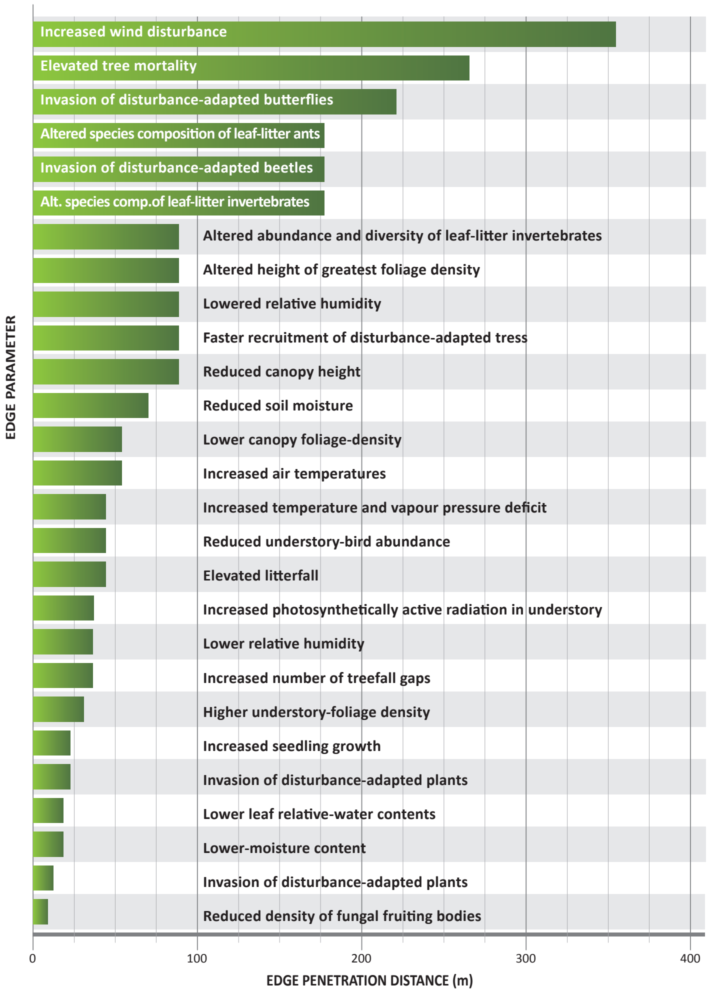
2. E.g. Laurance and Bierregaard (1997); Ewers and Didham (2006); Laurence et al. (2011) and Fahrig (2003)

3. For instance Fragstats, available at: http://www.umass.edu/landeco/research/fragstats/fragstats.html

The influence of fragmentation and edge effects on the core area of a forest patch

A patchwork of forested areas differs markedly from contiguous forest in both composition and ecology (Noss and Cooperrider, 1994; Laurance and Bierregard, 1997). Fragmentation leads to genetic isolation of plants and animal species, reducing genetic biodiversity of species. Ultimately, loss or restriction of a required habitat for a species can eventually lead to its local extinction. If this species is a 'keystone species' in ecological terms (for instance if it performs a key link in the food web or as a seed dispersal agent), then its extinction may cause a cascade of linked extinctions, altering the food web (Myers, 1993).

FIGURE 1: **RESULTS FROM A 22-YEAR INVESTIGATION INTO THE IMPACTS OF FRAGMENTATION ON THE AMAZON RAINFOREST AND BIOTA SHOWING THE PENETRATION DISTANCES OF DIFFERENT EDGE EFFECTS (FROM LAURANCE ET AL., 2002)**



Another important consequence of forest fragmentation is the increase in forest edges. Along these edges are strong microclimatic gradients leading to 'edge effects'. These are very diverse but include light, temperature, soil moisture content and wind turbulence, which impact the ecology of the fragmented forests (Thies et al., 2011). Forest edges are drier than forest interiors due to a variety of factors, including local atmospheric conditions that draw moisture away from forests. Even narrow clearings can be harmful (Laurence et al., 2011).

There are many biological impacts of edge effects, including:

- reduced species diversity, especially those of conservation importance (Fitzherbert et al. 2008);
- increased tree mortality, especially of large trees (Laurance et al. 2000);
- increasing microclimates along edges which are hostile to regeneration, impairing seed germination in rainforest fragments (Bruna, 1999);
- changes in forest structure, leaf fall and turnover in the plant community; and
- abrupt shifts in the composition of trees and other plants.

As noted by Laurance et al. (2011):

> *"Edge phenomena are remarkably diverse. They include increased desiccation stress, wind shear, and wind turbulence that sharply elevate rates of tree mortality and damage. These in turn cause wide-ranging alterations in the community composition of trees and lianas. Such stresses may also reduce germination and establishment of shade-tolerant plant species in fragments, leading to dramatic changes in the composition and abundance of tree seedlings."*

Figure 1 (left) shows the impacts that can be observed far into patches of Amazonian forest from their edges, with increased wind disturbance noted as far as 350m in from the edge. For a comprehensive literature review of fragmentation impacts on ecosystem processes, see Ellis-Cockcroft and Cotter (2014).

"Forest edges are drier than forest interiors due to a variety of factors, including local atmospheric conditions. Even narrow clearings can be harmful"

The importance of forest patch size and shape

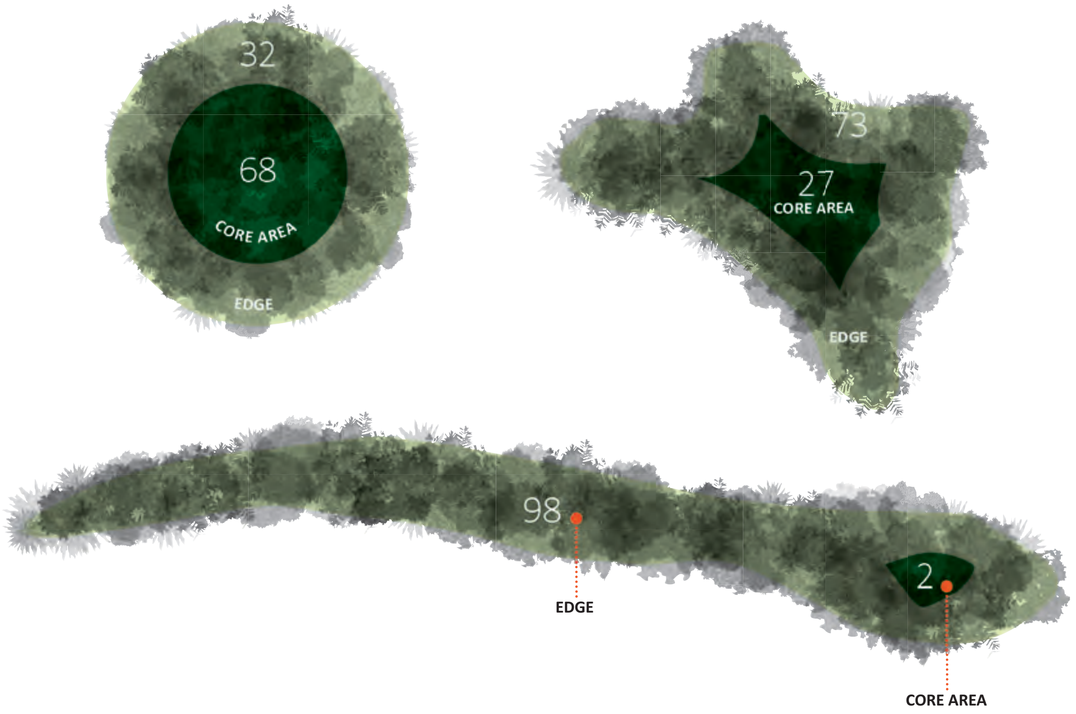
One important aspect of forest edge effects is that they increase dramatically with the degree of fragmentation. This is especially relevant in the case of patches of forest surrounded by degraded land – a typical scenario for many of the agricultural concessions for which the HCS Approach has been designed. As fragmentation increases, the percentage of the remaining total area of forest affected by fragmentation also increases because of the greater proportion of edges in each patch.

> *"The shape of each patch also influences the edge effects, with the severity of edge effects increasing with proximity to two or more edges"*

Given the general degraded nature of the forest in many concessions, mainly due to past logging, road construction and shifting cultivation, there are forest patches of varying size and degree of isolation, many with a high proportion of edges in relation to overall size. To minimise 'edge effects' on fragmented forest patches the primary factor is size of the patch. It is well documented that larger areas provide better habitat, forest carbon protection and longer-term viability than smaller or more fragmented areas. This is mostly due to reduced edge effects and a larger, relatively unaffected core area (Laurance et al., 2011; Ewers and Didham, 2006; Laurance and Yensen, 1991). This means the core area size, or the interior of a patch that is relatively unaffected by the edges, will be a key factor for analysing the importance of each individual patch in achieving forest conservation.

The shape of each patch also influences the edge effects, with the severity of edge effects increasing with proximity to two or more edges (Laurance et al., 2011). Shape complexity also has a major impact, with more compact shape patches being better than irregular or convoluted shapes as there is less colonisation and disruption to habitat and species distribution patterns[4]. Figure 2 shows how the core area (>100m from the patch edge) is affected by the shape of the patch: each patch has a total area of 100 ha, but the size of the core varies greatly depending on the shape. Using core area as a primary analysis factor would mean that forest patches with a more regular and less convoluted shape would be prioritised.

FIGURE 2: **THE INFLUENCE OF SHAPE ON THE PROPORTION OF EDGE OF A PATCH (ADAPTED FROM GOVERNMENT OF MALAYSIA, 2009)**



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[4] E.g. various references cited in Ewers and Didham, 2006.

Connectivity

Physical connectivity was chosen as the second primary factor for assessing the importance of individual patches. This is because corridors, linkages and 'stepping stone' areas are critical to allow the movement of flora and fauna through the landscape and facilitate seed dispersal, breeding, and predator/prey interaction, as well as to secure habitat for resident species (Laurance, 2004). Key corridor features that facilitate faunal movements and plant dispersal include habitat quality, corridor width, corridor length, and the degree of canopy and corridor continuity (Laurance, 2004). Even where there is no intact corridor, if species are able to move through a plantation, forest fragments can act as 'stepping stones' for dispersal and can be even more beneficial than habitat corridors (Falcy and Estades, 2007).

In considering connectivity, it is important to evaluate and consider many patches at the same time as well as links to the broader landscape to ensure decisions are not made about patches individually or in isolation from other patches or clusters of patches. While the focus of the HCS Approach is on conserving remaining forests, eventually reconnecting any isolated fragments through forest restoration will be an effective way of creating areas large enough to slow the rate of species extinction[5].

Corridors and stepping stones

A biodiversity or wildlife corridor is an area of habitat connecting wildlife populations which are separated by human activity such as agricultural development or settlements. Corridors allow an exchange of individuals between otherwise isolated populations, reducing the likelihood of inbreeding and promoting genetic diversity and therefore species resilience. They also facilitate migration by allowing wildlife to avoid the risk of having to move across roads or through settlements or farms.

Patches of habitat which are close enough together that wildlife can use them to move through a landscape are called 'stepping stones' and perform similar ecological functions as fully-connected corridors. Depending on the size of the corridor or stepping stone, it might even provide habitat for key species and not just be a transit path.

The diagram below illustrates the functionality of corridors and stepping stones in a fragmented forest landscape.

FIGURE 3. **CORRIDORS AND STEPPING STONES (ADAPTED FROM GOVERNMENT OF MALAYSIA, 2009)**

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[5] Various references cited in Laurance, 2011. See also Bentrup, G. (2008), The Woodland Trust (2000), Peres (2001), and Wearn et al. (2013)

Developing indicators and thresholds for the HCS Patch Analysis Decision Tree

Taking into account the conservation considerations outlined in this chapter, generic thresholds for patch size, quality and connectivity can be developed to create a practical tool to decide on the importance of each patch in actual concessions. The HCS process uses these thresholds in a simple Decision Tree (described in Chapter Six) to assess the value of each HCS patch, based on its value within the concession and the wider landscape.

Defining core area and prioritising HCS patches based on size

First, the HCS Decision Tree assigns priority to each patch as High, Medium, or Low, based on its core area. To determine the core area of each patch, a 'negative buffer' is used to exclude the most edge-affected area of the patch. Edge effects occur over scales of approximately 10 metres up to one kilometre from the edge and vary greatly (see above), so setting an appropriate threshold is not simple. However, for the Decision Tree and practical application, the threshold needs to be a simple round number, so 50 metres, 100 metres or 200 metres could be chosen. Based on the range of distances for different edge effects, mainly from the Brazilian Amazonia (Broadbent et al., 2008; Laurance, 2011; Ries et al., 2004), an edge effect distance and 'negative buffer' of 100m was adopted.

Once the core area has been determined, the priority of the patch can be assigned. Again, because the HCS Approach is designed for use in highly diverse forest landscapes, generic and round-number values need to be used even while noting that minimum habitat size varies considerably with type of species, species' needs, habitat quality, and the surrounding landscape matrix. Minimum habitat sizes can be as little as one ha for some vertebrates and plants, or for large far-ranging predators up to thousands of square kilometers in size are needed to ensure long-term survival (Bryant et al., 1997).

Above: Courtesy G. Rosoman, Greenpeace ©
Below: Courtesy Corozal Sustainable Future Initiative, Belize ©

> *"Minimum habitat sizes can be as little as one ha for some vertebrates and plants, or for large far-ranging predators up to thousands of square kilometers in size are needed"*

There is limited research on different core areas, but some research on total patch size. One study found that for Amazon forest fragments smaller than 25 ha (including edges) it is likely that there would be only very few species persisting [6]. Bierregaard and Dale (2006) suggested that in the Amazon, "the absolute minimum forest patch size that could be considered viable for a substantial percentage of the species ... is 100 ha". A meta-analysis of 53 studies concerning the speed that species become extinct in forest fragments found a strong extinction rate for patches up to 60 ha in size (Wearn et al., 2013). Additionally, a compilation by different species groups indicated a rough average minimum patch area of 10 ha as necessary to preserve species (Bentrup, 2008).

Given the lack of conclusive evidence on minimum patch size and the variability of forest types in which the HCS Approach will be used, a precautionary approach was taken in defining the minimum forest patch core area. While any forest patches with a 'core' have value, a 10 ha minimum core area (corresponding to roughly 25 ha of well-rounded patch including edges) was chosen for medium and high prioritisation for conservation as it was a mid-range but reasonably precautionary value for a range of different species, and was a size that has some support from research. This means that any patch with a core area of less than 10 ha is considered Low Priority, while recognising that even small and degraded fragments can hold considerable biodiversity value, especially in low forest cover landscapes, and can complement and enhance the habitat for species in larger reserves (Fitzherbert et al., 2008). The threshold for High Priority patches is defined as any patch with a core area greater than 100 ha, and patches with a core area between 10 and 100 ha are considered Medium Priority.

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6. Based on extinctions of 46 species of vertebrates, Peres et al. (2001)

Connectivity

To assess connectivity of HCS forest patches, a simple proximity to or distance between patches of 200m (corresponding to a 100m positive buffer around patches) was used, based on research in the Amazon indicating that dispersal rates dropped right off after a distance of 200m from the forest edge (Laurance, et al. 2006). Thus if the distance was less than 200m (measured edge-to-edge) it was assumed that the patches were close enough to be considered connected. If the configuration was conducive, it was also considered as a cluster of patches that could provide stepping-stones to larger patches. For instance, animals might move through a plantation if they can see a patch of natural forest up to 200m away. The threshold used to determine connectivity of a patch to an HCV area, for instance a riparian zone or protected area, is also 200m.

Defining High and Low Forest Cover Landscapes

Forest cover varies considerably across the landscapes in which the HCS Approach will be applied. It is important to take landscape-level forest cover into account because it will have an impact on the level of importance placed on small forest fragments. Research on landscape-level impacts of deforestation in the Amazon suggests that once approximately 20% of the forest cover has been removed i.e. less than 80% forest cover remains, the mean patch size rapidly reduces and the patches are more isolated (Oliveira de Filho and Metzger, 2006). Once total habitat drops below 30%, habitat fragmentation (patch size and isolation) begins to outweigh the direct effects of habitat loss (Andren, 1994). In other words, 70% of the habitat has been lost, but effectively much more has been lost because the quality of the remaining forest is much lower due to the exponential impacts of forest fragmentation.

Based on preliminary review of the research defining landscape scale it is proposed that either using a fixed area or a radius approach is acceptable. For categorising forest cover it is proposed that up to 80% forest cover in a landscape would be considered high forest cover and less than 30% would be considered low forest cover.

A landscape is defined here as "A geographical mosaic composed of interacting ecosystems resulting from the influence of geological, topographical, soil, climatic, biotic and human interactions in a given area," based on the IUCN's definition[7]. Published definitions of what is a 'landscape' vary from less than one hectare through to more than 200,000 ha (Ahmed, 2009). However, generally it is considered a larger scale land unit [8]. One option for determining the size of a landscape could be to simply take a unit size that encompasses the plantation concession and a buffer of the surrounding area e.g. 50,000 or 100,000 hectares. Alternatively, a simple and practical way to define landscape could be to use a radius from the area of interest (for instance a concession to be developed) based on maximum key dispersal distances. For example, Amazon forest birds were found to rarely disperse beyond distances of approximately five kilometres (Van Houtan et al., 2007).

> *"It is important to take landscape-level forest cover into account because it will have an impact on the level of importance placed on small forest fragments"*

Other considerations

A number of other patch physical factors as outlined in Noss (1999) were considered such as patch density, length of patch edge, and patch shape indices, but for efficiency and practicality the two critical patch factors of core size and connectivity were selected. Additional qualitative factors were also considered, including habitat quality, levels of biodiversity including rare and threatened species present, representativeness and naturalness (Ross and Cooperrider, 1994). However, because many of these factors are already considered in High Conservation Value (HCV) assessments, and because of the high cost of assessing some of them for questionable additional value, the approach was taken to assess patch quality only for the final short-list of some smaller, low/ medium priority and high-risk patches before they would normally be shortlisted for conversion to plantations. The Decision Tree requires a Rapid Biodiversity Assessment (RBA) of those patches, which allows for a precautionary check of biodiversity, as well as consideration of habitat quality and representativeness. The RBA step and methodology are described in the following chapter.

Above: Courtesy G. Rosoman, Greenpeace ©

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7. http://cmsdata.iucn.org/downloads/en_iucn__glossary_definitions.pdf

8. e.g. TELSA: A strategic planning tool for ecosystem management uses 10,000 to 200,000 ha. Available at: http://proceedings.esri.com/library/userconf/proc00/professional/papers/PAP329/p329.htm

Conclusions

While necessarily broad in order to be applicable to a wide range of tropical moist forest types, the considerations outlined in this chapter provide the preliminary conservation science basis for the analysis of the forest patches resulting from Phase One of the HCS Assessment in order to achieve a proposed conservation and land use plan. These conservation science considerations have been incorporated into a Decision Tree for deciding on the need to conserve individual patches. This represents the second phase in the HCS Approach, which is outlined in the next chapter.

Finally, it should be noted that many generalisations and approximations have been made in order to create a practical tool for identifying potentially viable forest patches that can be implemented immediately in concessions throughout the tropical world. The science behind many of the parameters and thresholds is not robust enough and requires further testing and trialling to ensure the best approach is being used to the achieve the goal. Additional research is needed to confirm the assumption that patches with larger core sizes are a proxy for higher biodiversity values. Furthermore, it is likely that additional elements may need to be incorporated. The Scientific Advisory Committee of the HCS Approach Steering Group will advise on the refinement of these parameters and thresholds for different forest ecosystems of interest, and the Steering Group welcomes advice and input from any conservation science experts to update the methodology.

> *"Additional research is needed to confirm the assumption that patches with larger core sizes are a proxy for higher biodiversity values"*

All photos:
Courtesy Corozal Sustainable Future Initiative, Belize ©

Chapter 6

HCS Forest Patch Analysis Decision Tree

By Grant Rosoman, Greenpeace and Rob McWilliam, TFT

The authors would like to acknowledge in particular Geoff Roberts (formerly) of TFT as well as Williem Cahyadi and Tara Rukmantara of PT SMART for the development of the Decision Tree over the last three years, and would like to thank Robert Ewers of Imperial College London, Matt Struebig of the University of Kent, Neville Kemp from Ekologika and Annette Olson from Conservation International for helpful feedback on an earlier version of the Decision Tree and sections of this chapter.

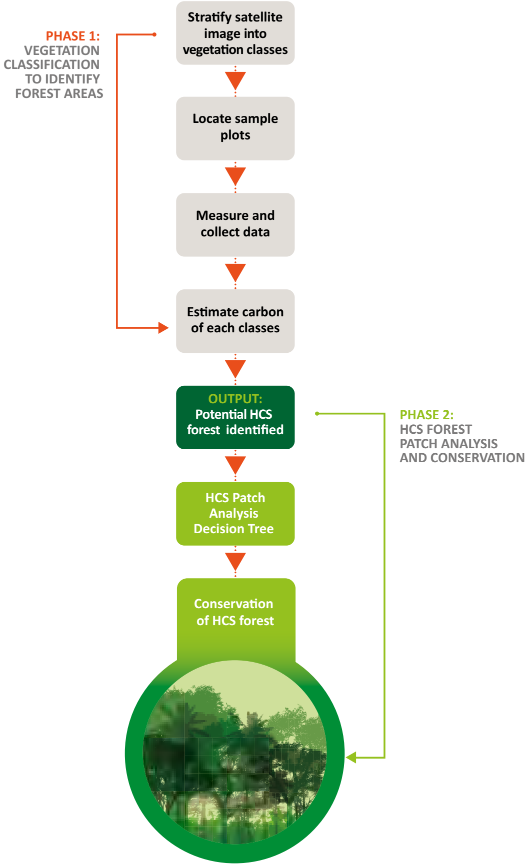
CHAPTER CONTENTS

Introduction

Phase One of the HCS Approach uses satellite imagery and field plots to develop a map of potential HCS forest areas in a particular concession. In most landscapes, the HCS forest will be present in patches of various sizes and proximity, intermingled with any existing plantations or other land-uses. The HCS Approach uses a HCS Forest Patch Analysis Decision Tree to determine the importance of each patch and whether it needs to be included in the conservation plan, given its size, shape, and connectivity to other patches, riparian zones, peat areas, or High Conservation Value (HCV) areas. The Decision Tree also makes some allowances for the degree of forest cover in the landscape.

This chapter takes the reader through the Decision Tree, which is the second and final phase of the HCS Approach to land use planning in tropical landscapes which are proposed for agricultural development.

STEPS IN THE HCS PROCESS



Principles to incorporate into the Decision Tree

The previous chapter gave an overview of some of the conservation science literature on forest fragmentation. Incorporating that into an integrated planning approach to conserving HCV areas, peatlands, and areas important for community purposes results in the following principles for analysing the value of each HCS forest patch:

1. Ensure that areas which are part of an active subsistence food production cycle to meet the food security needs of local customary communities are enclaved from consideration as HCS forest (or for plantation development).
2. Prioritise large forest patches.
3. Prioritise conservation of primary and advanced secondary forest areas.
4. Prioritise forest patch shape that maximises the ‘core area’ of a patch and thus minimises the area of forest subject to degradation on the edges.
5. Maximise connectedness between patches in order to create corridors, linkages and stepping stones in the landscape.
6. Prioritise patches located away from threats and risk factors that might lead to degradation.
7. Ensure HCS forest conservation is integrated with HCV area protection, peat land areas and riparian zone protection and considers the landscape matrix in finalising conservation plans.
8. Ensure HCS forest areas for conservation have the Free Prior and Informed Consent (FPIC) of local customary communities and that communities are active participants and co-managers in the conservation of HCS forests.
9. Ensure the HCS forest conservation plan considers practical design and management issues for plantation development, including access and minimum planted block size and shape.

Definitions of high, medium, and low forest cover landscapes

A high forest cover landscape is defined as a landscape with a natural forest cover greater than 80%. A medium forest cover landscape is defined as a landscape with a natural forest cover of between 30 and 80%. Low forest cover landscapes have less than 30% natural forest cover.

In high and medium forest cover landscapes, some additional assumptions can be made:

10. Focus on larger patches of forest (i.e. small patches are relatively less important in an area which already has relatively high forest cover).

11. The less fragmented the landscape, the less important any individual patch will be, and the more the focus moves to landscape-level forest conservation.

These principles have been incorporated preliminarily into the Decision Tree presented in this chapter. They also provide important context for creating the final land use plan for conservation and management in the concession.

Integrating information beyond HCS into the Decision Tree

As stated at the beginning of the toolkit, the HCS Approach integrates not just HCS forest but also a number of other areas for conservation. This includes the protection of HCV areas, peatlands, and areas important to communities' social and economic needs. Before the Decision Tree analysis can be completed, a mapping of data layers must be made which includes:

- Any **HCV areas**, including riparian zones within the concession and areas that are adjacent in the broader landscape, including for instance protected areas. At a minimum, an overview of HCV areas within 200 metres of the concession is necessary for using the Decision Tree, as 200metres is the standard distance used to assess connectivity of HCS forest patches to nearby conservation areas. The content of the HCV analysis, i.e. the High Conservation Values that were identified, especially HCV 1 - 4, will also be important at certain steps in the Decision Tree.
- A map of **peatlands**. As the peat soil maps that are currently available are imperfect, if peat soils are known to occur in the region then the concession management must also have a detailed identification procedure for peat of any depth, as well as converting this into spatial data (a map). While in practice some peatland forest areas may be identified as HCS forest, the current methodology is not calibrated for peatland vegetation types. The Decision Tree as it is currently formulated cannot be used to analyse peatland areas – a different set of attributes would need to be considered including hydrology. However, a peatlands map is still useful information for identifying forested peatland areas that may be potentially viable areas and that would be a high priority for protection; this information can be integrated into Step 12, conservation planning stage.
- A map of the **boundaries and customary land use of local communities**, created through a participatory exercise as outlined in Chapter 2 of this toolkit. In particular, gardens and future farm lands that are areas fundamental to meeting basic food needs[1] are completed and recorded on maps, both for communal lands and individually claimed and used areas. If these areas are located within the concession then they will be enclaved and excluded from HCS analysis and plantation development.
- Maps of any other areas that are **legally required to be protected**.

All of these areas will be enclaved and excluded from HCS analysis and plantation development, but it is nonetheless important to overlay them with the map of HCS patches in order to use the Decision Tree. If these analyses and mapping processes have not occurred, or if it is found during field visits that the participatory mapping or HCV studies were of poor quality, then the Decision Tree process will not be able to be finalised until the other processes are completed. Completion of the integrated land use plan in the Decision Tree requires all critical layers of information to be available. For example, it is necessary to ensure community garden areas are not classified as HCS forest, or that conservation planning optimises conservation area shape and connectivity.

Areas of community land that are identified as having HCS forest will be proposed for conservation as part of the integrated conservation plan for the concession. They will require FPIC negotiations and the support and participation of the communities to achieve conservation (similar to areas of HCV). Thus local communities with customary rights have the right to say no to their forest lands becoming a conservation area. However, the forest areas remain categorised as HCS forest.

Documenting the steps in the Decision Tree

Finally, each distinct step and decision taken in this process should be documented by the concession holder. The results must be transparent and available to be reviewed by external experts. The HCS Approach Steering Group is developing a quality control process to provide an expert review of the Decision Tree results. This will ensure the interpretations and decisions are in line with the full HCS process. The final conservation and land use plan must reflect the integrated planning approach which requires that habitat connectivity and the importance of each forest patch be assessed within the broader landscape.

> *"Gardens and future farmlands that are areas fundamental to meeting basic food needs….will be enclaved and excluded from HCS analysis-"*

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[1] This shall provisionally be a minimum range of 0.5 to 4 ha per person living in the community depending on the local context.

The HCS Patch Analysis Decision Tree

The full Decision Tree is presented on the following page. Broadly, the Decision Tree provides a way to analyse the conservation value of each HCS forest patch based on the conservation principles outlined above, short-listing each patch for conservation ('indicative conserve' in the diagram) or development ('indicate develop'). Some patches may change categories or boundaries in the final stages of the decision-making process.

Each step in the Decision Tree will be detailed in this chapter. To illustrate the concepts, a simple stylised concession map (below) has been created with 17 HCS forest patches of varying size and shape.

FIGURE 1: **HYPOTHETICAL PLANTATION CONCESSION (ORANGE BOUNDARY).** HCS FOREST PATCHES ARE SHOWN IN LIGHT GREEN, WITH DARKER CORES

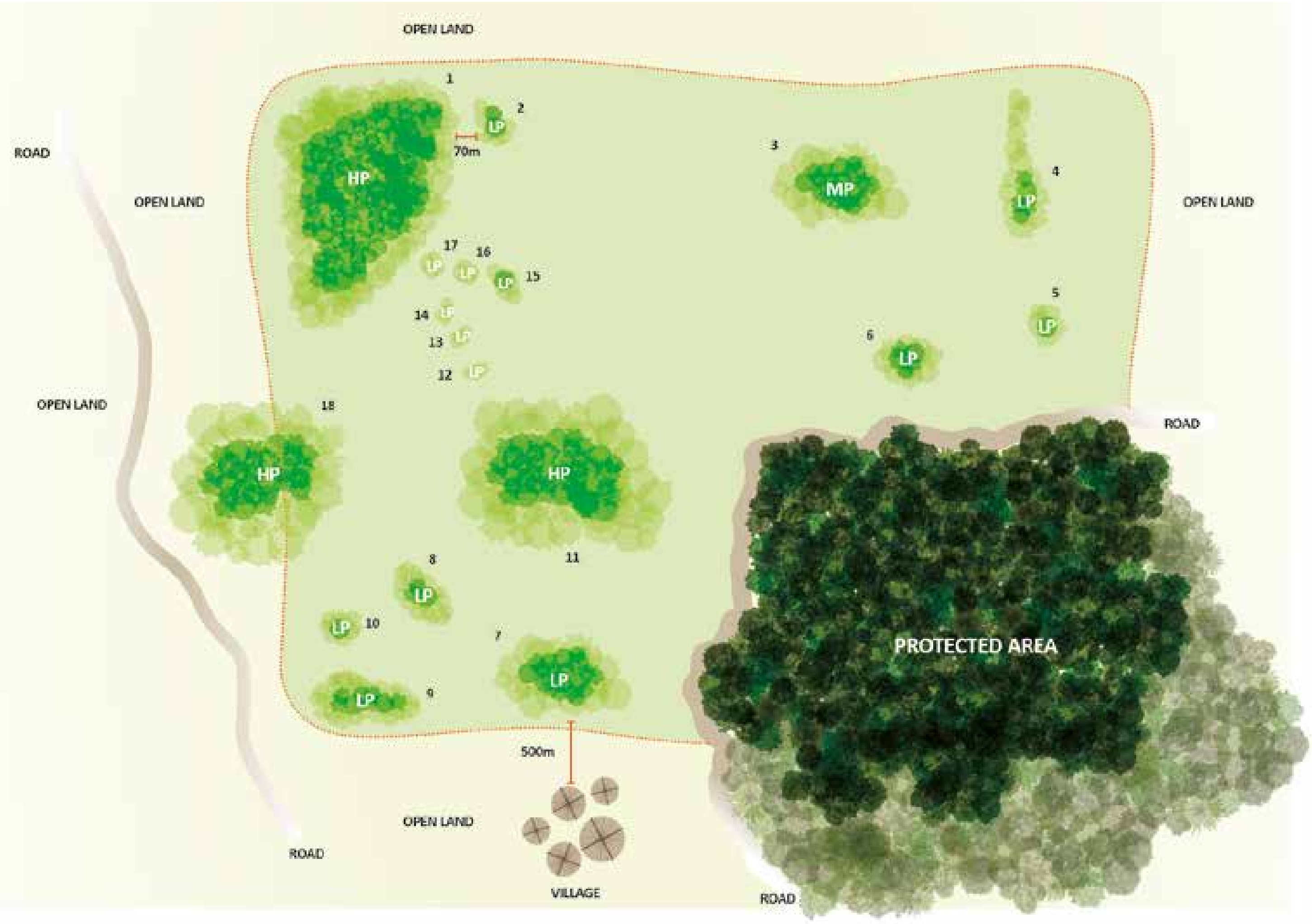
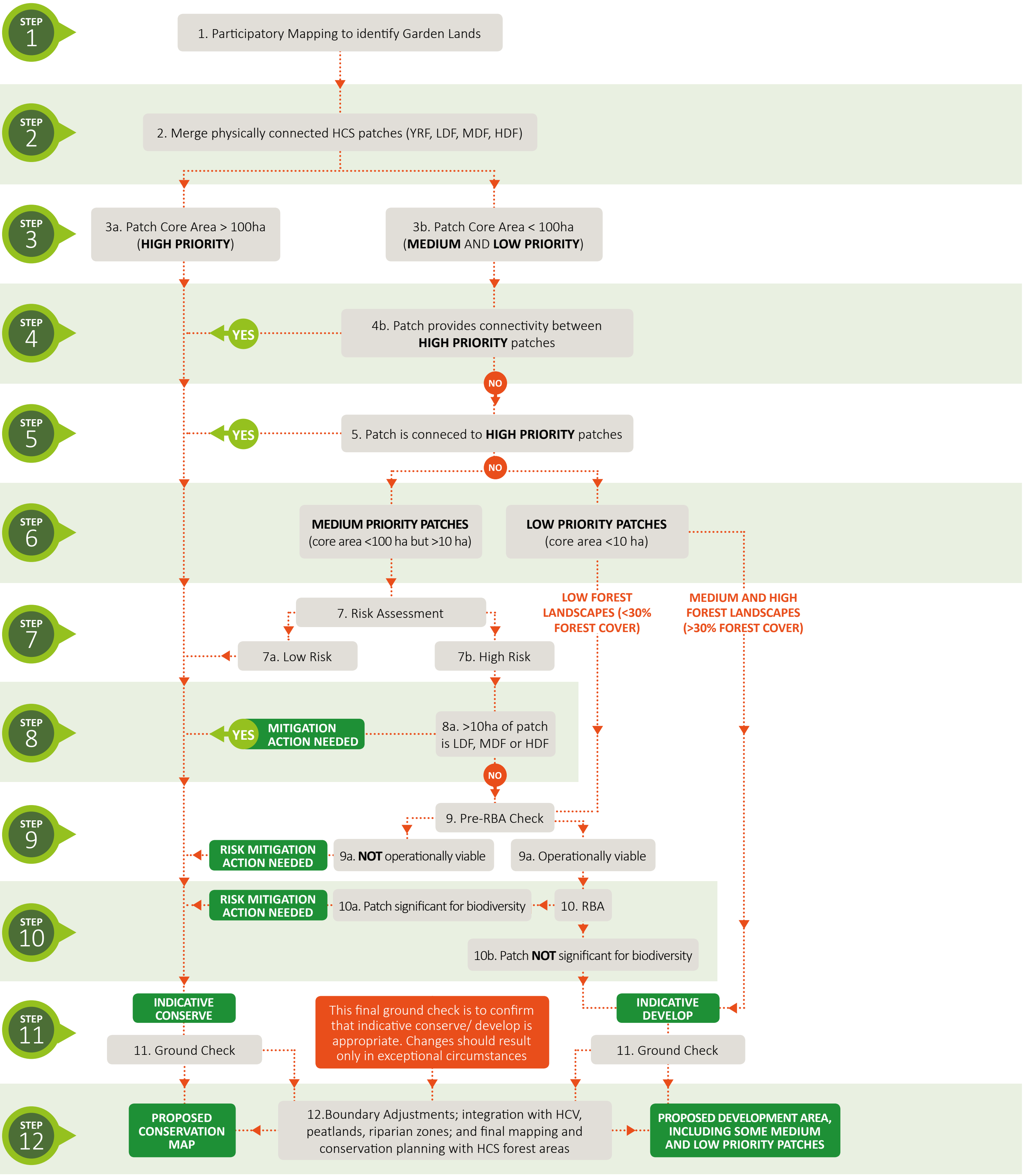


FIGURE 2: **HCS PATCH ANALYSIS DECISION TREE** (RBA = RAPID BIODIVERSITY ASSESSMENT)



The HCS Patch Analysis Decision Tree

STEP 1

Identify customary use areas, enclave community garden land and overlay HCV areas, peatlands and other areas of concern

The concession map with the potential HCS forest areas must also include other data that spatially delineates areas to be enclaved (e.g. community subsistence garden areas) or protected. This includes: community protected areas, HCV areas (separated by HCV 1-3, HCV 4 and HCV 5-6), peatlands and areas that cannot be developed due to government regulation or company commitments. The garden/farm lands and community economic use areas (such as rubber or cocoa plantations) are removed from consideration as potential HCS forest and thus not processed further via the Decision Tree. The other areas are included for information only, to show the full mosaic of already-protected/protectable areas in relation to any potential HCS forest areas. Step 12 will fully integrate HCS patches with HCV areas and other areas to be conserved.

There are also considerations to be made outside of the concession. Any large HCS forest areas indicated in satellite imagery, and any known HCV areas – for instance protected areas – that are identified within 200 metres of the concession borders are also considered in the Decision Tree process.

This allows the user to properly assess patch size and to take landscape-level connectivity opportunities into account when assessing each patch. In the sample concession, the existing Protected Area is an HCV area which borders the concession and will need to be taken into consideration in the Decision Tree process.

STEP 2

Extract all HCS forest classes and merge physically-connected patches

High Density Forest (HDF) areas through to Young Regenerating Forest (YRF) areas identified in Phase One are extracted from non-HCS classes to form one HCS layer, while maintaining the distinctions regarding type of class (HDF, MDF, LDF or YRF) for consideration later in the Decision Tree. Where HCS patches are phyically connected to each other they are merged to form one patch.

All photos: Courtesy G. Rosoman, Greenpeace ©

STEP 3

Identify patch core and prioritise patches

Each HCS patch can now be assessed according to the conservation science principles outlined in Chapter 5 of this toolkit. The HCS forest patches are first assessed for their core area, using an internal (negative) buffer of 100 metres. This is the primary filter for selecting patches for conservation, because patches with a larger core area will be more viable in the long term as they have fewer edge effects.

The larger the patch core, the higher the likelihood there is to be able to maintain or recover its ecological function as a forest, including conserving carbon and biodiversity values. Patches are therefore prioritised accordingly:

3a. A patch that contains a core of more than 100 ha of HCS forest is considered **High Priority (HP)** and will be marked for conservation. HCS forest patches that extend outside the boundaries of the concession are assessed for their full size irrespective of the concession boundary, and are also considered High Priority patches if their core area is greater than 100 ha and at least 10 ha of patch core area are within the concession.

3b. A patch that contains a core of 10 – 100 ha of HCS forest is considered **Medium Priority (MP)**, and a patch that contains a core less then 10ha of forest is considered **Low Priority (LP)**. Both will be further assessed for connectivity between High Priority patches (Step 4) and proximity to large patches (Step 5).

STEP 4

Connect High Priority patches

Connectivity is important to facilitate dispersal of fauna and flora between patches and therefore the medium to long-term viability of the forest. The first step is therefore to identify any **Low** and **Medium Priority** patches that create connectivity between **High Priority patches**.

Connectivity is defined as two patch edges within 200 metres of each other, measured from edge to edge. Any **Medium** and **Low Priority** patches which provide connectivity between **High Priority** patches are marked for conservation. Connectivity can be provided by multiple patches between High Priority patches. GIS 'aggregate' tools may be used to assist identifying connectivity.

Patches 17, 14, 13, and 12 in the sample concession are Low Priority, but also provide connectivity between High Priority patches 11 and 1. This means they are designated for conservation. Patches 15 and 16 are Low Priority and do not provide connectivity, so remain unclassified for the moment.

The figure below shows the sample concession map with the patches identified as High, Medium, or Low Priority based on the size of their core area. High priority patches and additional patches prioritized in Step 4 have been marked for conservation.

FIGURE 3: **HYPOTHETICAL PLANTATION CONCESSION FROM FIGURE 1 WITH HCS PRIORITIES MARKED ON PATCHES (AFTER STEP 4)**

7. http://cmsdata.iucn.org/downloads/en_iucn__glossary_definitions.pdf

The HCS Patch Analysis Decision Tree

STEP 5

Connect Medium and Low Priority patches to High Prority patches

In this step, the following are marked for conservation: **Medium** and **Low Priority** patches that do not provide connectivity between **High Priority** patches but are connected to **High Priority** patches, (i.e. within 200 metres measured from patch edge to patch edge), and any large HCS or HCV forest areas adjacent to the concession. In the sample concession, patches two and six fall into this category.

Medium Priority patches that do not have an immediate connectivity to **High Priority** patches, for instance patches three and seven in the sample concession, are reviewed in Step 8 (Risk Assessment). **Low Priority** patches that do not have an immediate connectivity to **High Priority** patches, for instance patches four, five, eight, nine, and ten in the sample concession, are shortlisted for development and reviewed in Step 12 (Integration and Conservation Planning).

The diagram below shows the sample concession at the end of Step Five, with most of the patches already classified.

> *“In low forest cover landscapes, small patches will have greater importance for conservation of carbon and biodiversity”*

STEP 6

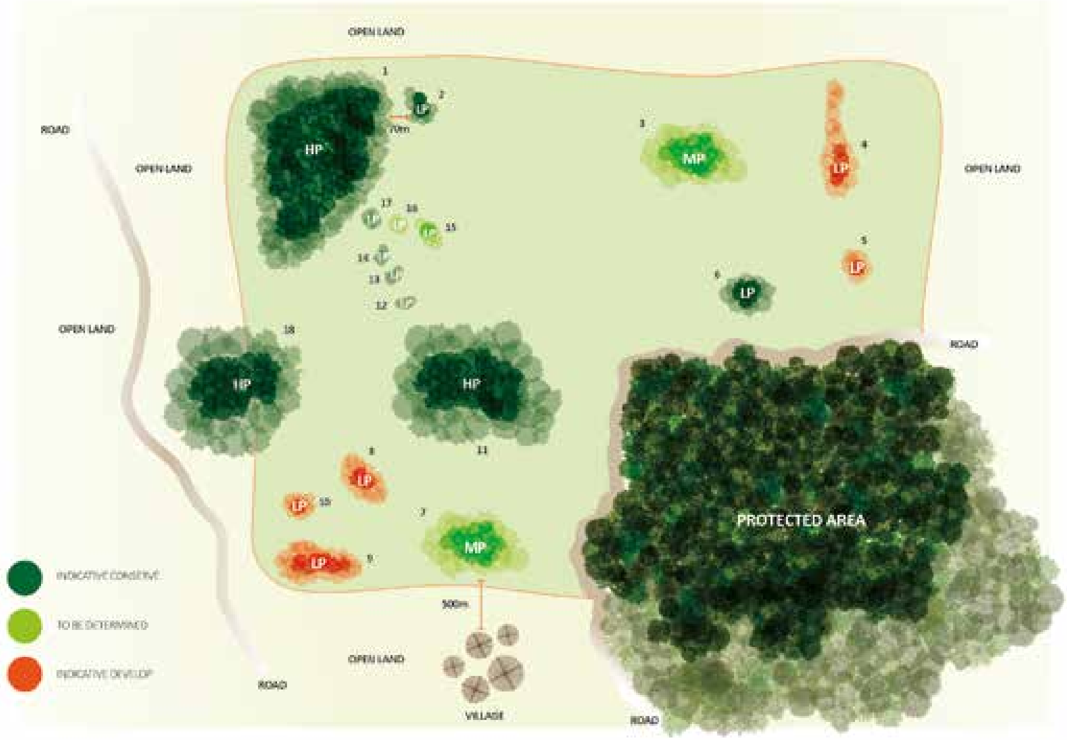
Separate Medium and Low Priority Patches

All **Medium Priority** patches (i.e. those with 10-100ha core) which have not yet been designated for conservation are subjected to a risk assessment (Step 7).

Remaining **Low Priority** patches are assessed within the context of the landscape:

- In high forest cover landscapes, Low Priority patches are not analysed further nor short-listed for conservation. They are instead classed as ‘indicative develop’ and held for consideration during the final boundary adjustment and land use planning phase.
- In low forest cover landscapes, small patches will have greater importance for conservation of carbon and biodiversity. In this case, low priority patches move to a pre-Rapid Biodiversity Assessment check (Step 9).

FIGURE 4: **RESULTS OF HCS DECISION TREE IN SAMPLE CONCESSION AFTER STEP FIVE**



STEP 7
Risk assessment

This step involves a risk assessment of Medium Priority patches which have not yet been identified for conservation. The risk assessment is based on the proximity of the forest areas to public roads, settlements, waterways used for navigation/transportation, and other anthropogenic activities such as mining, logging, or plantations. A set of buffers of two kilometres from settlements and one kilometre from other risk factors is placed in the map using GIS software to assess the indicative level of potential threat arising from human activities. We recognise that risks extend well beyond these distances, but this close proximity presents a 'high risk' of degradation or clearance. The risk classifications are:

7a. Medium Priority patches outside these high risk zones are identified as lower-risk and are marked as 'indicative conserve'.

7b. Medium Priority patches located inside these risk zones are identified as higher-risk and unlikely to be viably protected. They are further assessed in Step 8 (review of High/Medium/Low Density Forest).

Where a patch is part high risk and part low risk, the risk classification is determined by the dominant level of risk.

Patch seven in the sample concession, which lies within one kilometre of a village, is an example of a high-risk patch.

STEP 8
Review of presence of LDF, MDF or HDF in Medium Priority patches

A review of presence of LDF, MDF, or HDF is performed for any Medium Priority, high risk patches identified in step 7b. If such a patch contains more than 10 hectares of core area of LDF, MDF or HDF, in other words not YRF but rather better-quality secondary forest, it is marked for potential conservation with mitigation measures to address the threat to these forests. Mitigation measures might include co-management with the local community, employing forest guards or 'guardians', and supporting incentives that place a value on the forest such as the harvesting of non-timber forest products or conservation compensation payments.

STEP 9
Rapid Biodiversity Assessment Pre-check

The steps described up to this point will have identified many patches which will need to be conserved and some which can be short-listed for development. For the patches which remain to be classified, a Rapid Biodiversity Assessment (RBA) will need to be conducted before short-listing them for development. A brief check (Pre-RBA) is carried out prior to the full RBA, in order to quickly disqualify areas inappropriate for development and avoid the need for a full RBA.

The aim of the Pre-RBA is to identify any impediments to development and operations, for instance excessive slope, as well as easily-identifiable characteristics which would indicate a need to conserve the area, for instance the presence of streams or permanently wet areas. The methodology for the pre-RBA is included in the Appendix.

Any areas found to have impediments are moved to either conservation (e.g. for riparian areas, swamp areas, steep slopes) or enclaved from development (e.g. for gold mining areas, community garden areas).

> *"The aim of the Pre-RBA is to identify any impediments to development and operations, as well as easily-identifiable characteristics which would indicate a need to conserve the area"*

All photos: Courtesy TFT ©

The HCS Patch Analysis Decision Tree

STEP 10
Rapid Biodiversity Assessment (RBA)

The RBA is the final precautionary step for assessing Medium and Low Priority patches which have not yet been short-listed for conservation and would thus be indicated for development. The purpose of the RBA is to ensure that the patch does not contain important populations or habitat which were not identified in the HCV assessment but should nonetheless be conserved.

The RBA relies heavily on a pre-existing HCV assessment in order to know which are the relevant rare and threatened species and habitat. If an HCV assessment has not been done, it should be concluded before or during the RBA. It may be the case that the field work done during the RBA finds important HCVs which were not captured in the HCV assessment; this could trigger a review of the HCV assessment if the indication is that the original HCV was not done properly.

The purpose of the Rapid Biodiversity Assessment is to determine if any of the following elements are present in the patch:

1. Species which are:
    - **1.1.** On the IUCN Red List as Near-Threatened, Threatened, Endangered, or Critically Endangered
    - **1.2**. Listed under the CITES convention
    - **1.3.** On any national or regional list of rare, threatened or endangered species
    - **1.4**. Identified in the HCV assessment as being of concern.
2. Habitat that would normally host one of the species listed under point 1, even if the particular species was not observed during the HCV or the RBA itself;
3. Any concentrations of, or habitat of, regionally or locally rare or uncommon species, or simply representative areas that contain concentrations or combinations of local species and their habitat; and
4. Rare habitat as identified in the HCV assessment.

The RBA is not a full biodiversity assessment of all plants and animals in the patch, but rather a focused assessment of whether important species and habitat are found in the patch. The assessment should be conducted by qualified biodiversity assessors and experts, using appropriate sample techniques based on the species of concern, which may vary according to whether mammals, birds, flora, reptiles or invertebrates are relevant. There is no one prescribed methodology for the RBA; the Zoological Society of London has developed a toolkit that includes guidance on undertaking RBAs in oil palm landscapes which will be relevant for many HCS assessments[2].

If the RBA does not identify any of the values listed above, the forest patch may be developed (Step 10b of the Decision Tree in Figure One). If there are high biodiversity values present they will move to the HCV protection process if they also qualify as HCV1-3, or if non-HCV the areas are conserved unless there are fundamental viability issues (e.g. isolation, proximity to risk, small size). This latter process can be incorporated into the final conservation planning process, following advice from appropriate experts including local community representatives.

STEP 11
Ground check

Even after the satellite imagery analysis, forest sampling, and RBA, some important areas can be missed, especially if the quality of the paticipatory mapping was poor. So having already performed the previous steps, a final ground check needs to be performed to:

1. Provide an additional check of any potential HCS forest areas for conservation and exclude from HCS areas any community orchards, plantations or gardens not previously identified.
2. Check the location and boundaries of any community protected areas, and then incorporate them into final conservation plans.
3. Check other development constraints to areas marked 'develop' such as mining activities, or other situations unfavourable for plantation development, for instance riparian zones, flooded areas, steep slopes, and unsuitable soils including peatlands.

The ground check can be done using a combination of low-level fly-overs or drones, and walk-throughs in the concession.

All photos: Courtesy TFT ©

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[2] Imanuddin, S. P., D. Priatna, L. D'Arcy, L. Sadikin and M. Zrust (2013). 'A practical toolkit for identifying and monitoring biodiversity in oil palm landscapes', Zoological Society of London, available at: https://www.hcvnetwork.org/resources/folder.2006-09-29.6584228415/ZSL%20Practical%20Toolkit%20for%20identifying%20and%20monitoring%20biodiversity%20within%20oil%20palm%20landscapes.pdf, last accessed 14 December 2014.

STEP 12

Integration and conservation planning: Boundary adjustments; integration with HCV, peatland, and riparian zones; and final mapping and conservation planning with HCS forest areas

In this final step, potential conservation areas are evaluated from a landscape perspective. This ensures connectivity of patches, corridors between forest areas, (including those outside of the concession), stepping stone forest patches to provide connnectivity, and coherence of shape. The aim here is to produce a conservation plan that integrates all set-aside categories (community protected areas, HCV, HCS, riparian, peatlands, etc.) and has the highest likelihood of ecological viability. Operational concerns are also taken into account: for example, consideration of whether the conservation of a patch would fundamentally compromise the plantation operation by blocking a critical access point to a significant area of the concession, or if a patch is of a configuration and shape that makes the establishment of planting blocks impossible. General guidelines for this process are:

1. **Integration with HCV, peatlands and riparian zones:** Proposed HCS forest areas are combined and integrated with other layers of protection in the landscape. This may combine, or be carried out together, with boundary adjustments and the final connectivity decisions following consideration of the landscape matrix.
2. **Boundary adjustments:** Boundaries may be rounded to cut off small irregular points or 'fingers' of Young Regenerating Forest with no core, i.e. less than 200 metres wide, or to bridge gaps/ pockets to make a more practical plantation boundary and give a more even edge for forest conservation. This is a 'give and take' approach to rationalize the boundary for management.
3. **High-risk, Medium Priority patches with fragmented cores:** Small (<10 ha sub-cores) outlier areas of the patch may be excised and may be removed from HCS if they do not provide connectivity or do not function as stepping stone areas, or they may be expanded on to rationalise the patch, again using a 'give and take' approach.
4. **RBA findings:** These should be considered alongside the degree of different forest ecosystems conserved or protected in the landscape (representativeness), and in particular the degree to which large patches can be conserved by the company together with the community.
5. **Degree of forest cover in the landscape:** The more fragmented and the lower the amount of forest in the landscape then the greater the importance of small patches. In low forest-cover landscapes (<30% forest cover) the Decision Tree brings smaller patches into consideration, and at this final conservation planning stage additional small (non-priority) patches can also be conserved to provide some natural forest cover and improved connectivity. In landscapes with high forest cover (i.e. over 80%) the focus will move to conserving larger continuous patches.
6. **Connectivity:** Patches should be combined with riparian zones where possible and their position in relation to other patches considered in order to contribute to coherent links and corridors in the landscape. These can include 'stepping stone' patches that can act as refuge areas for weak flying birds or small animals moving through the landscape.

The final HCS conservation plan proposal should be vetted by an independent conservation science expert as well as the HCS Approach Steering Group, which is developing a quality-control procedure to ensure that the steps outlined in this chapter are properly followed. Many resources exist to help develop such a conservation plan, including:

- G. Bentrup (2008). "Conservation buffers: design guidelines for buffers, corridors, and greenways." General Technical Report SRS-109. Asheville, NC: Department of Agriculture, Forest Service, Southern Research Station. Available at: http://www.srs.fs.usda.gov/pubs/33522
- Ministry of Natural Resources and Environment of the Government of Malaysia (2009). "Managing biodiversity in the Landscape: Guidelines for planners, decision-makers and practitioners". Available at: https://www.hcvnetwork.org/resources/folder.2006-09- 29.6584228415/Guideline_Man_BioD_landscape_090519.pdf
- Zoological Society of London (2011)."A practical handbook for conserving High Conservation Value species and habitats within oil palm landscapes." Available at: https://www.hcvnetwork.org/resources/folder.2006-09-29.6584228415/ZSL%20Practical%20Handbook%20for%20Conserving%20HCV%20species%20-%20habitats%20within%20oil%20palm%20landscapes_Dec%202011.pdf

> *"The aim in this final stage is to produce a conservation plan that integrates all set-aside categories and has the highest likelihood of ecological viability"*

HCS forest conservation

After the Decision Tree is completed and the boundaries of land areas which are to be conserved or developed have been finalized, the resulting proposed conservation area must be integrated with the participatory land use map of the communities. Necessary steps must then be taken to ensure the long-term viability of the area. The HCS forest conservation areas which overlap with community lands will be most successfully targetted as IUCN category IV community conservation areas, and the finalisation of the conservation area plans will need to be carried out as a participatory process with the customary rights-holding communities. This presumes that FPIC of the customary rights-holders is respected. If FPIC is not achieved and the customary land owners do not want their lands to be part of the conservation areas, then the areas are not marked as in the conservation area. However, the areas remain as HCS forest as far as the company is concerned.

To achieve the conservation of HCS forest areas with the community, benefits and incentives will need to be addressed such as through compensatory, incentive or ecosystem service payments. This could also include negotiating co-management agreements and arrangements with local, provincial or national governments to secure the conservation status of the area. Providing further guidance on how to develop an integrated conservation plan is one of the future challenges for stakeholders involved in the HCS Approach, and will be discussed in the final conclusions of the toolkit.

> *“To achieve the conservation of HCS forest areas with the community, benefits and incentives will need to be addressed such as through compensatory, incentive or ecosystem service payments”*

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Appendix: Pre-RBA Check methodology

Introduction

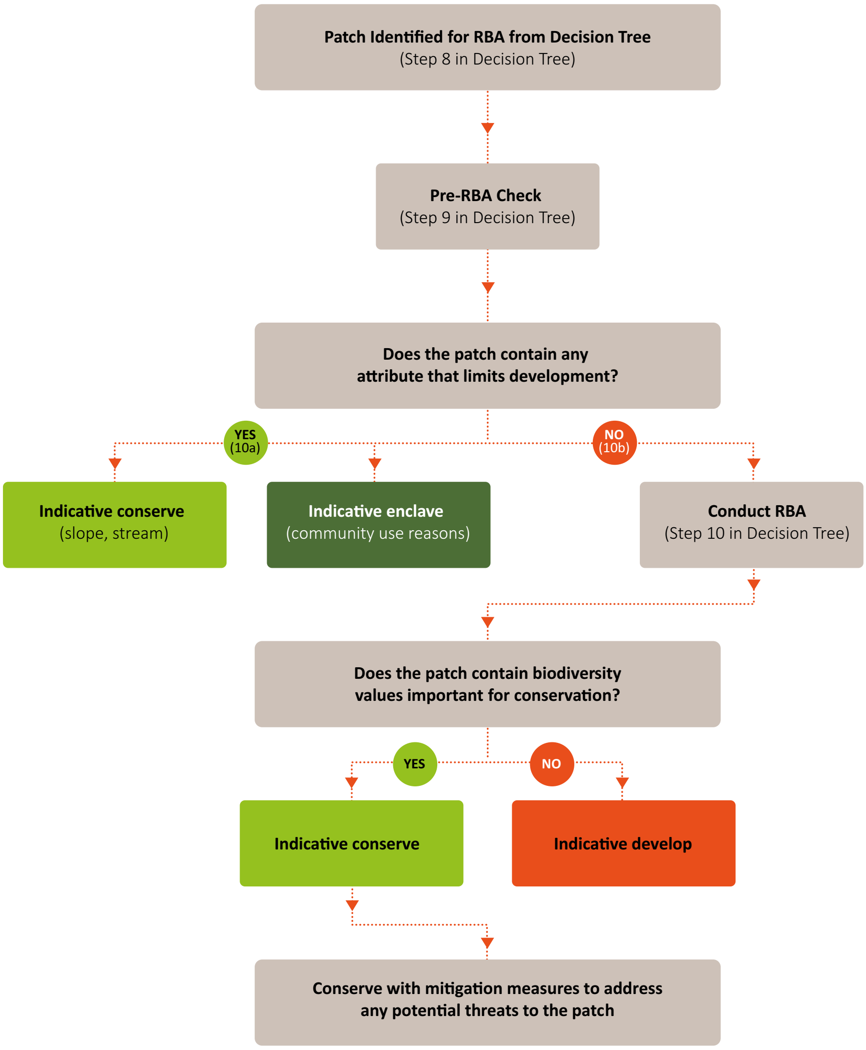
The Rapid Biodiversity Assessment described in Step 10 of the Decision Tree is designed to be precautionary towards important biodiversity values that may not have been captured in an individual patch through either the HCV Assessment or the thresholds used in the Decision Tree. The assessment aids in deciding whether smaller forest patches should be conserved or made available for development.

Because conducting a full RBA requires a certain degree of specialised resources, before undertaking an RBA it is recommended to conduct a rapid Pre-RBA to determine if there is any environmental or social constraints to developing the patch. Where such constraints exist, then the patch is short-listed for conservation and no further assessment work would be required. The core objective of the Pre-RBA check is thus to ensure that only key patches move on to the full RBA process.

An overview of how the Pre-RBA fits into the Decision Tree process is illustrated right.

> *“Because conducting a full RBA requires a certain degree of specialised resources, before undertaking an RBA it is recommended to conduct a rapid Pre-RBA”*

FIGURE 5: **THE PRE-RBA ASSESSMENT PROCESS**



Appendix: Pre-RBA Check methodology

Conducting a Pre-RBA Check

The Pre-RBA is conducted by operational staff, typically based at the site of development. The attributes selected for reviewing during the Pre-RBA are easily identified and therefore do not require experts to conduct the assessment.

The Pre-RBA is conducted via a walk-through of the patch along the axis of longest distance through the patch to increase the chance of capturing the largest variation, as shown in the figure below. The route for the walk through should be determined using GIS, with the route uploaded to a GPS for the assessor to follow.

FIGURE 6: **EXAMPLE SELECTION OF THE LONG AXIS THROUGH A PATCH**

Identifying and documenting key attributes

During the walk-through the assessor observes and documents the presence of key attributes including:

- Characteristics of the environment within the patch, including presence of water features or slope
- Evidence of recent local community activity, such as harvesting forest products
- Presence of access paths, such as roads or daily use walking paths
- Infrastructure such as housing
- Other land use, for instance semi-permanent use such as farms or gardens, and
- Accessibility issues.

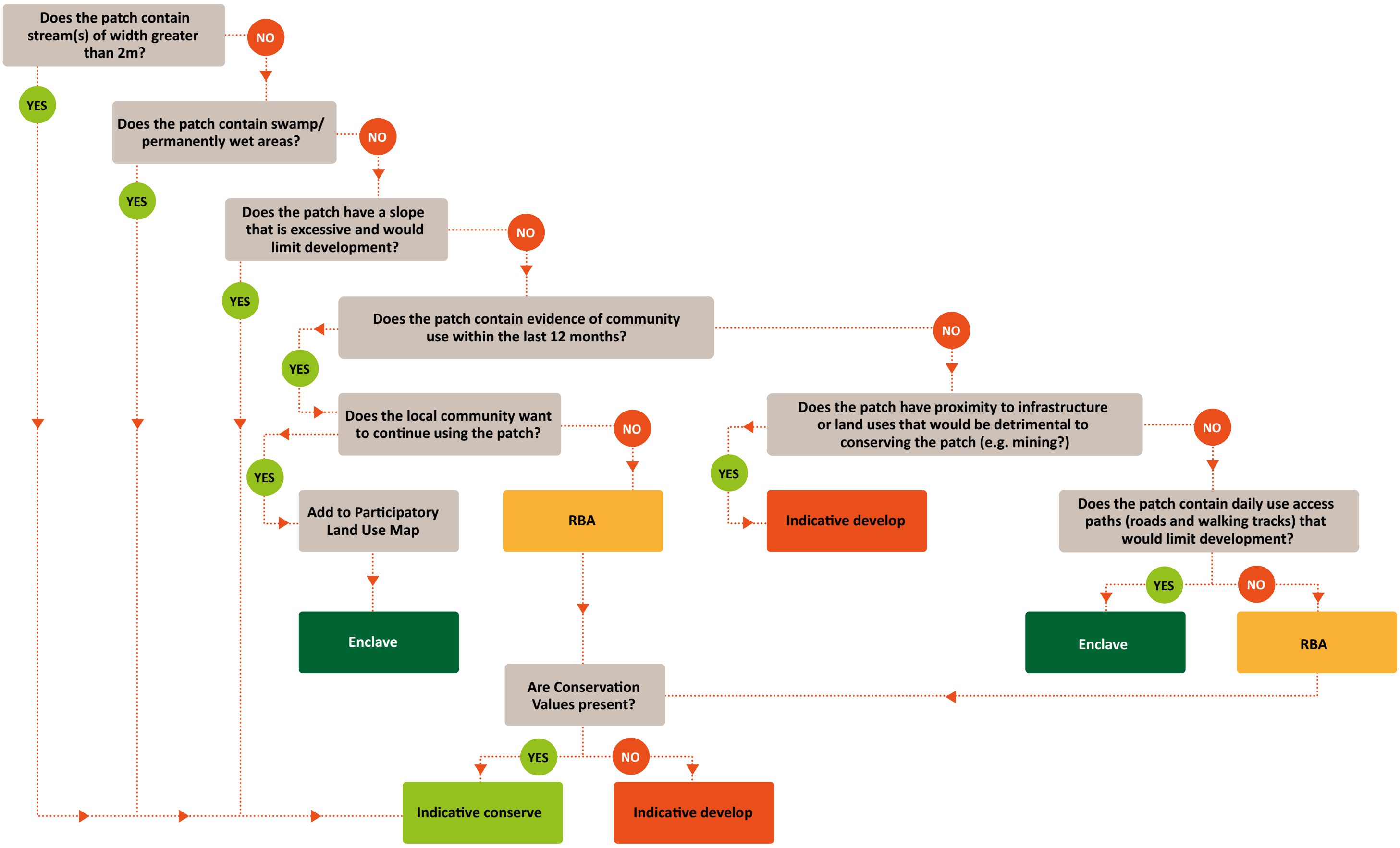
During the walk-through the assessors should photograph any key attributes and record their GPS coordinates along with any observations in the form presented at the end of this appendix.

> *"The attributes selected for reviewing during the Pre-RBA are easily identified and therefore do not require experts to conduct the assessment"*

Analysing the results of the Pre-RBA

The decision process outlined in the figure below is used to process the findings documented from the Pre-RBA. The attributes addressed at each step are ranked by importance. For example, if a patch has a stream running through the area then it is of highest importance and shall be conserved.

FIGURE 7: **PRE-RBA DECISION MAKING PROCESS**



Appendix: Pre-RBA Check methodology

Pre-RBA Check Assessment Form

Attribute	**Presence (Yes/No)**	**GPS Location**		**Photo No.**	**Comments and observations**
		Latitude	**Longitude**		
Presence of perennial stream > 2m width					A perennial stream is one which has continuous flow in parts of its stream bed for at least six months of the year
Presence of ephemeral stream > 2m width					An ephemeral stream is one which only exists for a short period following precipitation
Presence of spring					A spring is defined as any natural situation where water flows to the surface of the earth from underground
Presence of swamp or permanently water logged areas					A swamp is an area that is saturated with water, either permanently or seasonally, and surrounded by forest
Presence of excessive slope that limits development					The definition of 'excessive slope' will vary by crop and should be determined with input from the concession holder. In palm oil, the RSPO standard defines excessive slope as a gradient of 25 degrees or greater
Evidence of community use within the last 12 months					Examples include areas communities have used for gardens or collection of materials for housing
Presence of regularly-used access paths					For instance, roads or walking tracks that are used fequently for access to the area or other areas
Presence of other land use that is detrimental to either conservation or development					For instance if the patch is in the middle of a mining area
Location aspects and accessibility					If the patch is inaccessible and is thus not going to be developed, then there is no point assessing – rather just add to conservation or leave as community lands if they have identified it as such
Other observations (including wildlife and plants)					

Chapter 7

Conclusions

By Charlotte Opal, TFT

CHAPTER CONTENTS

Future development of the HCS Approach Toolkit

In 2010, a group of organisations came together to create a practical tool to decide how to draw the line between potentially viable natural forests that need to be protected, areas required for community livelihoods and degraded land that may be suitable for plantation development. The result is the High Carbon Stock Approach described here in this toolkit, which has been pilot tested in palm oil and pulp and paper concessions in Indonesia, Papua New Guinea, and Liberia and will be implemented by dozens of companies in other countries over millions of hectares in the tropics in 2015.

The toolkit has been written for experienced GIS, forest and conservation practitioners to be able to undertake their own HCS assessments with minimal guidance. With a high-quality participatory mapping process with local communities, HCV assessment, and peatlands map in hand, a small team of GIS experts, foresters, and biodiversity/conservation experts should be able to use this toolkit to oversee the implementation of the HCS Approach and create a proposal for an integrated land use plan for a plantation concession within a forest landscape. To provide additional support, in 2015 HCS Approach Steering Group members with experience doing HCS assessments will be organizing training for practitioners based on this toolkit, and the Steering Group will develop a quality assurance process including involving independent expert review of HCS assessments and transparency.

While the quality assurance and review process is being developed, companies undertaking HCS assessments should aim for transparent public reporting of their HCS assessments, including the vegetation stratification results and details on how the HCS Decision Tree and FPIC requirements were implemented for each identified HCS forest patch.

Practitioners are also invited to provide feedback on the methodology via the HCS Approach Steering Group website, www.highcarbonstock.org. Although the Steering Group does not anticipate any major directional changes in the methodology for identifying HCS forests, the toolkit will be updated as lessons continue to be learned through new HCS assessments, as further guidance is developed on how to develop an integrated conservation plan and as conservation science provides further guidance on aspects of forest patch ecological viability.

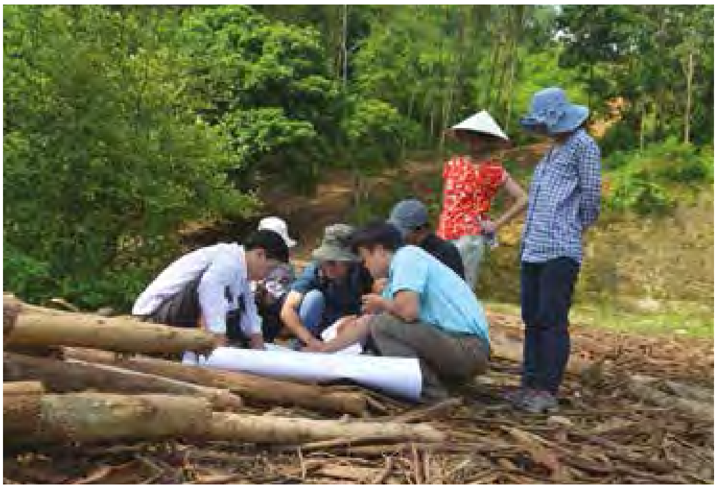
All photos: Courtesy TFT ©

Further questions for the HCS Approach

This toolkit provides a practical way for companies to develop a proposal for a responsible, integrated land use plan in a forest landscape. However, several questions remain for successful HCS Approach implementation including securing long-term protection of HCS forest areas:

1. **How can the FPIC process, HCV, and HCS assessments be better integrated?** To date, HCS assessments have largely been retro-fitted on top of existing HCV assessments and processes to ensure the right to Free, Prior, and Informed Consent, and some components of this toolkit reflect this. For new concessions, it will be both more efficient and less disruptive and confusing to local communities to integrate these assessments right from the beginning. Chapter Two of the toolkit already proposes an integrated approach to FPIC processes and HCS assessments. The integration of HCS, FPIC and HCV assessments will be further explored in 2015 through a series of technical workshops in order to develop additional guidance to include in future versions of the HCS Approach Toolkit.
2. **What is the process and what tools are available for working with local communities to achieve conservation and protection of the HCS forest areas?** The steps outlined in this toolkit allow companies to come to a proposed integrated land use plan including areas to be conserved and managed for biodiversity, ecosystem, and community needs. The identified HCS forest, HCV, and other areas will then need to achieve FPIC with local communities for their conservation as well as an agreed management plan.
3. **How can legal protection of HCS forest areas in plantation concessions be ensured?** The HCV experience has shown that in some cases where there is no legal support or framework for maintaining conservation areas within the concession, governments may revoke licenses for any set-aside areas and re-issue them to other developers who will convert the land[1]. HCS forests might face a similar fate in certain jurisdictions.

All photos: Courtesy TFT ©



> *"The steps outlined in this toolkit allow companies to create an integrated land use map including areas to be conserved and managed for biodiversity, ecosystem and community needs"*

4. **What options exist for financing protection and management of HCS forest areas?** Effective protection requires specialized resources, including 'forest guardians' and community liaison officers. Funding options for fully protecting HCS forest areas, including REDD+ mechanisms, Payments for Ecosystem Services, and lease payments need to be explored.
5. **How can smallholders and communities be compensated for forgoing the conversion of HCS forest areas?** As more companies agree to eliminate deforestation from supply chains, farmers in forest landscapes will not be able to convert land for new plantations. Forest-friendly management options need to be investigated, including land reforms and those that ensure equitable benefits to local communities, again perhaps with the support of REDD+ or other financial mechanisms.
6. **How can the protection of HCS forest areas best be monitored?** New technologies are emerging that allow for relatively low-cost and frequent monitoring of land use change in forest landscapes. There are also existing tools for monitoring HCV areas, which might have applications for HCS forests. Opportunities exist to use monitoring by local groups, crowd-sourced information and even drones.

It is clear that many complex questions remain. However, while these and other challenges will be explored by the HCS Approach Steering Group and other stakeholders over the coming months, this toolkit provides the guidance for the first few critical steps in de-linking deforestation from agricultural development, by providing a methodology tested and proven in the field. The spirit of the HCS Approach is to find practical ways forward in the face of the sometimes-conflicting goals of forest protection, community rights and livelihoods, and business growth, as well uncertainties and imperfect knowledge. While Version One of this toolkit will no doubt be updated in future years after broader implementation, trials and consultation, it is important documentation of how far we have gotten on this journey towards No Deforestation.

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[1] See, for instance, Forest Peoples Programme, SawitWatch, HuMa, and Wild Asia (2009), "HCV and the RSPO: Report of an independent investigation into the effectiveness of the application of High Conservation Value zoning in palm oil development in Indonesia," available at: http://www.forestpeoples.org/partners/publication/2010/hcv-and-rspo-report-independent-investigation-effectiveness-application-hi.

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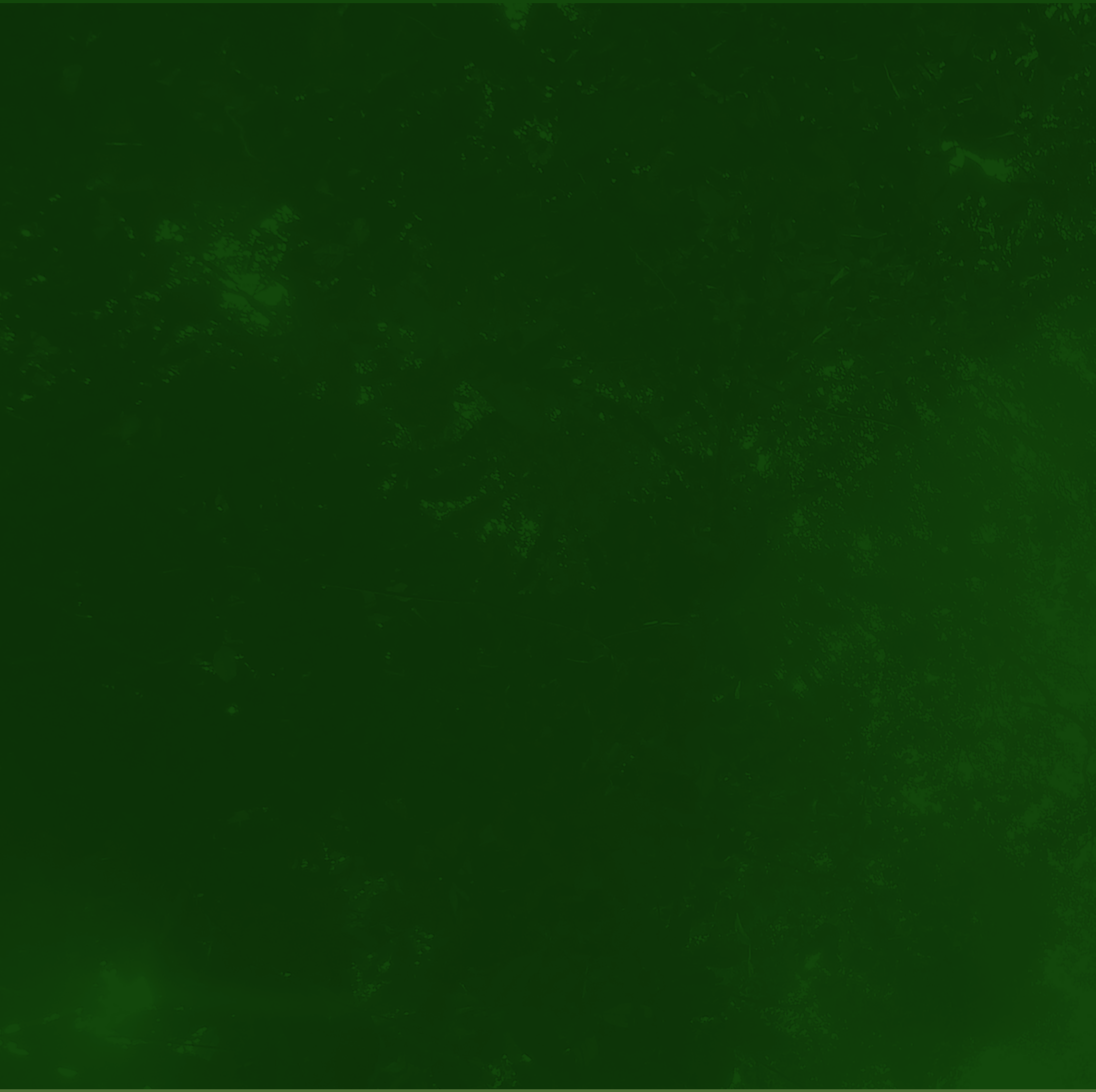

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