



# Earth Observation to Support Monitoring and Evaluation of the Green Corridor, Thua Thien-Hue Province, Viet Nam

## *Milestone 9 Report*

### Earth Observation Support for Traditional Ecological Mapping and Biodiversity Conservation in Viet Nam (EO-STEM) Project *Work Package No. 3*

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*Prepared for:*

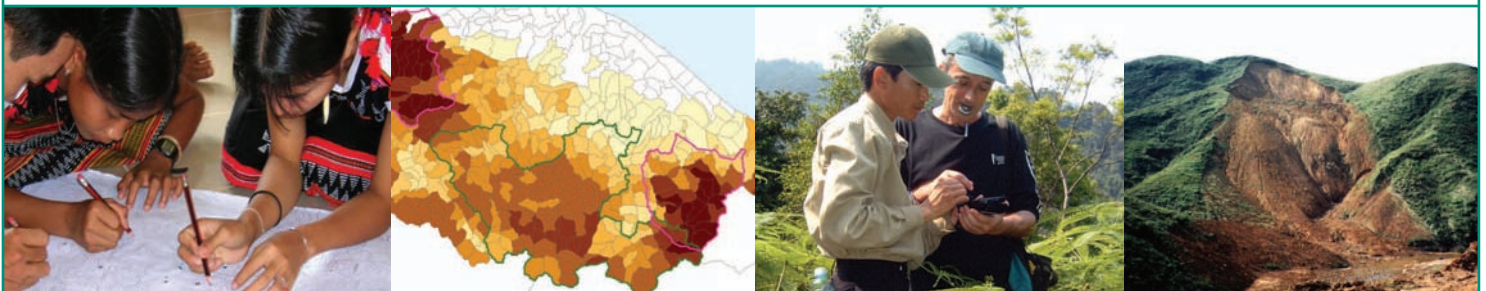
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**EARTH OBSERVATION TO SUPPORT MONITORING  
AND EVALUATION OF THE GREEN CORRIDOR,  
THUA THIEN-HUE PROVINCE, VIET NAM**

**WORK PACKAGE 3 - MILESTONE 9 REPORT:**

**EARTH OBSERVATION SUPPORT FOR TRADITIONAL  
ECOLOGICAL MAPPING AND BIODIVERSITY  
CONSERVATION IN VIET NAM (EO-STEM) PROJECT**

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## 1.0 INTRODUCTION

This report presents results from activities undertaken as part of the *Earth Observation Support for Traditional Ecological Mapping and Biodiversity Conservation in Viet Nam* (EO-STEM) Project. The main objective of the EO-STEM Project is to provide technical support to the Government of Viet Nam through the Green Corridor Project (GCP), which is being implemented in Thua-Thien Hue (TT-Hue) Province by WWF and the TT-Hue Forest Protection Department (FPD). The goals of the EO-STEM Project are directly linked with those of the Green Corridor Project, which aims to maintain and sustain the rich biodiversity of the Green Corridor area in TT-Hue Province. A key output and focus of the project is the demonstration of the application of Earth Observation data for Monitoring and Evaluation for WWF, TT-Hue Provincial authorities and other partners.

### 1.1 AIM OF THIS REPORT

The aim of this document is to review the monitoring and evaluation (M&E) system of the GCP, Viet Nam and to discuss the potential contribution of Earth Observation (EO) satellite imagery to this important activity. The M&E approach is a necessary component in most contemporary project management systems and provides a framework for measuring progress and ensuring accountability.

The GCP monitoring system has a geospatial component that includes essential monitoring activities of forestry features where it is believed that the use of EO can provide information on forest cover extent, water quality, or agricultural production. Hence, maps based on EO data can be used as to support M&E by governmental and non-governmental organizations.

A great strength of EO is the ability to obtain a time series of images and measurements over the same place on the Earth's surface at regular or pre-determined intervals that are responsive to the needs of the regulatory framework. The known repeat cycle of many satellite-based sensors in their orbits around the Earth, combined with appropriate image processing methodologies and local knowledge of an area, can provide a powerful tool for monitoring the environment in a repetitive and non-intrusive way. Indeed, there is considerable potential for this method of environmental monitoring to directly support aspects of M&E systems, and for satellite imagery to provide cost-effective and valuable information to project managers.

The contribution of EO to the M&E of the GCP are considerable, and will be reviewed and addressed as follows:

- Review the basic principles of M&E and EO;
- Review the M&E frameworks and systems in use in TT-Hue Province;

- Identify components of these systems where EO could provide valuable information; and
- Provide recommendations for ongoing use of EO to support the M&E activities of the GCP.

## 1.2 STRUCTURE OF THE DOCUMENT

Background documentation for the GCP and EO-STEM project is located in Appendix 1. Following this introduction, the main report is structured into five main sections:

- *Section 2* introduces the concept of M&E in conservation management at a landscape-level;
- *Section 3* describes current M&E activities in the Central Truong Son landscape and the Green Corridor area of TT-Hue Province, Viet Nam. This includes a discussion of the M&E Indicators that have been identified to assist in the monitoring of progress towards biodiversity conservation in the Central Truong Son;
- *Section 4* provides a background to EO, focusing on themes relevant to M&E;
- *Section 5* presents an EO-based approach to M&E, including specific examples where this approach could contribute information to M&E Indicators; and
- *Section 6* provides some recommendations and options for actions that could be implemented within the Green Corridor M&E system.

This report is supported by a set of appendices at the end of the main report.

## 2.0 PRINCIPLES OF MONITORING AND EVALUATION

Monitoring and evaluation activities, or M&E for short, usually comprise a structured framework, or set of principles, that support the assessment and measurement of project activities. This approach arose in response to the need to measure performance of projects or programs funded by governments, aid agencies, and development partners (donors) to assess the success and effectiveness of their initiatives. M&E benefits may best be summed up as follows: “Managers need information to improve their management, and donors and stakeholders need results to ensure accountability” (IUCN 2004). Therefore, the inclusion of M&E in a modern project framework has become a necessity, particularly with respect to donors and governments, due to the competition for funding in the current institutional and development landscape.

### Box 1 – Definitions of Monitoring and Evaluation

**Monitoring** can be defined as a continuing function that aims primarily to provide the management and main stakeholders of an ongoing intervention with early indications of progress, or lack thereof, in the achievement of results. An ongoing intervention might be a project, program or other kind of support to an outcome.

**Evaluation** is a selective exercise that attempts to systematically and objectively assess progress towards the achievement of an outcome. Evaluation is not a one-time event, but an exercise involving assessments of differing scope and depth carried out at several points in time in response to evolving needs for evaluative knowledge and learning during the effort to achieve an outcome. All evaluations—even project evaluations that assess relevance, performance and other criteria—need to be linked to outcomes as opposed to only implementation or immediate outputs.

(UNDP 2002)

Specifically, M&E aims to assist agencies implementing projects to:

1. Clarify what impact a project is expected to have and how it will be achieved;
2. Decide how progress and impact will be assessed;
3. Gather and analyze the information necessary for tracking progress and impact;
4. Explain the reasons for success and failure; and
5. Agree on how best to use this understanding to improve future action.

(IFAD 2006)

EO can be used to make spatial assessments of changes, and can therefore play an important role in Points 2 and 3 listed on the previous page. The most

effective way to measure progress and impact is the continuous collection and analysis of information (*monitoring*) related to a defined set of indicators. These indicators should include features of the system (in this case, conservation related activities) and of the management process (IUCN 2004). *Evaluation* includes assessment activities that occur at defined intervals to determine progress. One such assessment should be a baseline, from which progress can be measured.

Indicators need to be specific enough to ensure an accurate assessment of project activities, and holistic enough to full encompass the scope of the project. Therefore, indicators should also be:

- **Valid** – A genuine measure of progress. It is important not to confuse achievement of outputs (doing what was proposed) with indicators of having achieved proposed outcomes;
- **Key** – Reveal the most relevant information (i.e., it is more valuable to measure key indicators roughly than trivial indicators precisely);
- **Feasible to Measure** – It must be possible to gather information on the indicator; and
- **Useful** – how will the information inform management and planning? How useful will this information be to improving service delivery?

(Adapted from Connelly 2004)

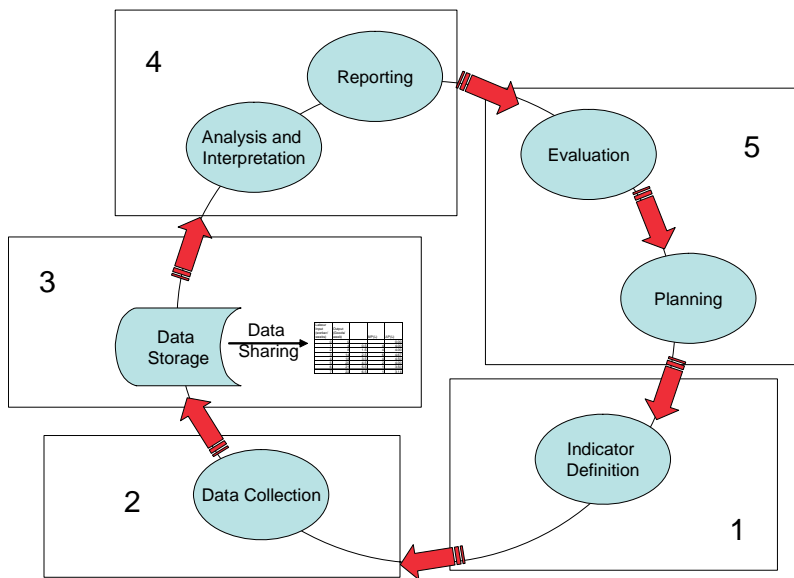
Other important aspects of indicators are that they should be: accepted by all stakeholders as a true representation of the system that is being monitored; they should be possible to track or measure; precisely described and unambiguous; and reflect the human capacity available to gather data (IUCN 2004). Figure 1 shows a typical M&E cycle.

However, perhaps the most important component of an M&E framework is **communication**. The process of setting up the framework and the definition of indicators must be transparent to all stakeholders. The technical specification of monitoring data and analysis, and the methods used to report on the outputs of monitoring exercises, must be defined at the outset.

Finally, the intervals for evaluation need to follow a clear timetable, based on institutional capacity and a realistic timeframe to measure progress, meeting the needs and expectations of stakeholders.

The responsibility for driving an M&E process often falls to a project manager, but increasingly, particularly with larger projects, a specific role is often designated for an M&E officer with a budgetary item assigned to these activities. This enables the M&E officer to adequately address the requirements of the M&E framework.

**Figure 1** Simple schematic of an M&E cycle.



(From Baker and Hoan 2006)

### 3.0 EARTH OBSERVATION FOR MONITORING & EVALUATION

Earth Observation, or EO for short, is a term that refers to the collection, analysis and communication of data captured by sensors onboard satellites orbiting the Earth. More than 70 EO satellites are currently orbiting the Earth, with over 100 missions planned for the future by governments and private sector companies. These satellites often carry more than one sensor and can provide images of different types, including optical (visible, infrared and thermal) and radar imagery.

Satellite images offer a unique perspective of the Earth, which when combined with the regular repeat cycle of their orbits, can build valuable time-series of images of the surface below. Satellite programs can provide continuity of geo-scientific measurements over long periods of time; the most well known is the NASA Landsat program, which started in 1972 with the launch of Landsat-1, and has continued to date with the launch of Landsat-7 in 1999. The Landsat program has provided data continuity for more than 30 years, and the data have been widely available to many users. However, there is now some doubt over the future of the Landsat program and its position among other competing EO activities in the United States. The Canadian RADARSAT-1 satellite was launched in 1995 and is still operating today. It features a radar imaging device and that has collected imagery that offers a different perspective on the Earth's surface features than optical imagery such as from the Landsat program. Continuity of the RADARSAT imagery for monitoring purposes will be provided through the launch of RADARSAT-2 in 2007.

EO sensors are designed with specific priorities, in terms of spatial resolution, area coverage of individual images, observation frequency, and spectral resolution (what they are designed to observe). The choice of sensor will depend on the specific application and also the resources available. There are several key issues to consider when to apply EO as part of M&E:

1. Which M&E Indicators may be assessed partially or wholly using EO-derived information?
2. What is the required frequency of the assessment (e.g., daily, weekly, monthly, annually)?
3. What is the spatial extent of the area to be assessed (e.g., a watershed, province, country)?
4. What is the required scale of the data for the assessment (e.g., map scale, image resolution) to accurately identify surface features of interest?
5. What resources are available for the assessment (e.g., data costs, computer software and hardware, and trained EO analysts)?

6. What information should be extracted from the EO imagery to assess the indicators (e.g., extent of natural forest cover classes, urban area)?
7. What analysis is required (e.g., to create a baseline or determine *change*)?

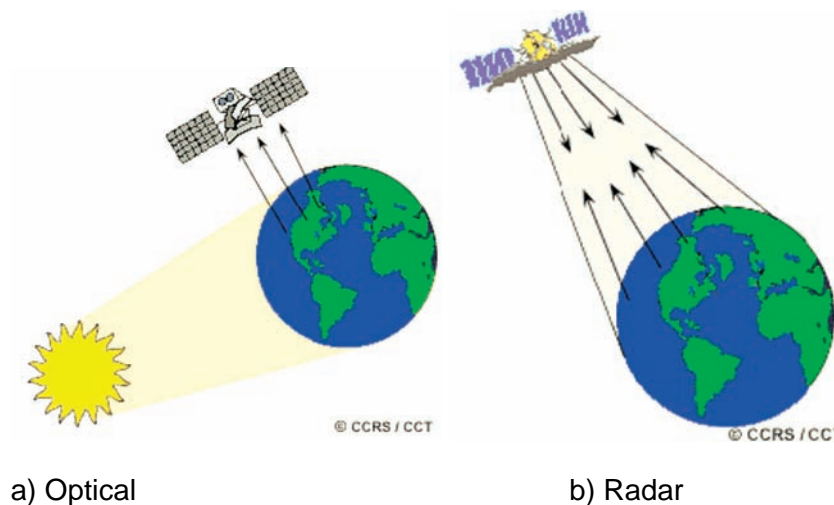
These questions are common when conducting most EO projects, but require very careful consideration for M&E, because the information and analysis will be used to judge the success/outcomes of the project. Appropriate selection of imagery and well-planned analyses can provide information to support a range of indicators, thereby improving the value of EO image acquisitions and improving efficiency of using EO for M&E purposes.

### 3.1 IMAGING METHOD

EO encompasses two main types of imaging; optical and radar (or microwave). Some satellites carry only one type of sensor, but other larger satellite platforms carry more than one sensor, sometimes both optical and radar.

*Optical* remote sensing entails a sensor capturing solar energy reflected from the surface of the Earth, often in more than one portion of the electro-magnetic spectrum (visible, infrared and thermal-infrared). The composition of the observed portion of the Earth's surface determines what light energy is reflected and how much. This concept is illustrated in Figure 2a. As optical sensors gather reflected energy in the visible range of the electromagnetic spectrum, they are susceptible to the effect of cloud cover, bad weather and illumination. Hence, capturing images in cloudy regions or during rainy seasons can be difficult and they can only be captured during daylight.

**Figure 2 How optical and radar remote sensing work.**



(Canada Centre for Remote Sensing 2006)

This approach to EO is sometimes known as *passive* remote sensing, because it is passively collecting energy reflected from the Earth's surface.

*Radar* sensors usually transmit a beam of energy to the Earth's surface, measuring what energy returns to the sensor, to characterize the surface features. This concept is illustrated in Figure 2b. As radar sensors send a beam of energy and measure the reflected energy returned to the sensor, they are often referred to as *active* sensors. The radar imaging method uses a device called a Synthetic Aperture Radar (SAR) to emit and receive energy; hence radar imagery is also often referred to as SAR data.

Radar sensors use microwave energy to image the Earth's surface, which is unaffected by the presence of moisture in the atmosphere or the presence of daylight. Hence, radar image data can be gathered in all weather conditions, day and night.

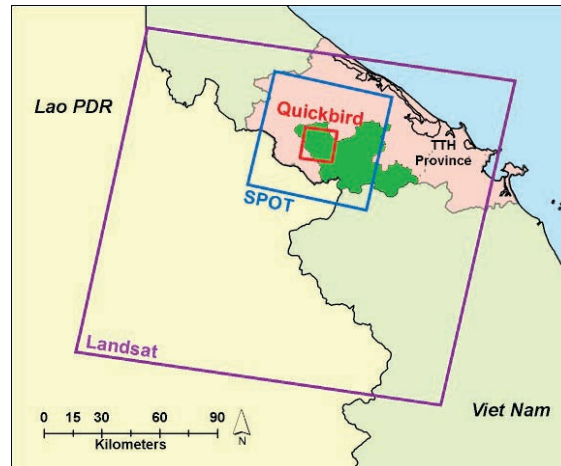
### **3.2 IMAGE EXTENT / SPATIAL RESOLUTION**

There is generally a trade-off between acquiring high spatial resolution imagery and image extent; a general rule is the higher the resolution, the smaller the image extent or swath. Therefore, a large number of high-resolution images will be required to cover a larger area; whereas images of coarser resolution tend to have a bigger "foot-print," a smaller number of them is required to cover the same area. As a result, the costs of data can be higher and image analysis can be more demanding of resources (e.g., computer storage, processing power).

Figure 3 illustrates this using an example in TT-Hue, Viet Nam, which shows the extent of a standard Landsat image (30m resolution), SPOT-5 image (10m resolution) and Ikonos image (1m resolution). There is generally a desire to have the highest possible spatial resolution; however, it is important to understand that for many applications moderate resolution data will provide suitable information for monitoring.

The spatial resolution of satellite imagery is very important, as it determines the size, or scale, of the features that can be mapped and as a result, if change can be detected. Therefore, an appropriate image source must be selected that enables the accurate and clear mapping of features. Table 1 shows typical mapping scales for various EO sensors.

**Figure 3 Demonstration of the difference between the spatial extent, or coverage, of a single Landsat, SPOT and Ikonos image.**



**Table 1 Different EO sensors, their detail, coverage, and corresponding mapping scales according to practical experience.**

Sensor	Resolution	Image Extent	Mapping Scale
MODIS	250 m (bands 1-2) 500 m (bands 3-7)	2330 km by 10 degrees of latitude (along track at nadir)	1:750,000 1:1,500,000
Landsat TM	30 m	175 x 175 km	1:100,000
SPOT-5	10 m	55 x 55 km	1:30,000
RADARSAT-1 Fine Mode	9 m	50 x 50 km	1:50,000
SPOT-5 (pan-sharpened)	2.5 m	55 x 55 km	1:10,000
RADARSAT-2 Ultra-Fine Mode	3 m	25 x 25 km	1:20,000
Ikonos (pan-sharpened)	1 m	12 x 12 km	1:5,000

Note: radar data mapping scale depends on the type features being mapped.

### 3.3 SPECTRAL RESOLUTION

The spectral resolution of optical imagery is very important, as sensors are designed for specific applications and record energy in different spectral bands. For example, SPOT-5 has 4 spectral bands covering visible-green, visible-red, and near-infrared wavelengths; this makes it suitable for vegetation and land-cover mapping applications up to a scale of 1:10,000. Some sensors provide a wider range of spectral bands that can be used for a variety of applications; for example, Landsat TM with 7 spectral bands across visible, infrared and thermal-wavelengths, that have proven excellent for a wide variety of land use analyses, albeit at a somewhat coarser spatial resolution than SPOT.

### 3.4 OBSERVATION/REVISIT FREQUENCY

Observation/revisit frequency, or temporal resolution as it is sometimes known, defines how often it is possible to capture an image over the same place on the Earth's surface. In M&E exercises, indicators are usually measured over long periods (years); however, cloud cover can seriously reduce the opportunity to obtain imagery from optical satellites such as SPOT-5 and Landsat TM. If seasonal changes in vegetation are also important, or regular monitoring is required (e.g., forest fire frequency), cloud cover and observation frequency can be important.

Some satellite images systems allow for acquisitions to be ordered and planned in advance, for example, SPOT-5, Ikonos, and RADARSAT-1. Indeed, the sensor system may not capture imagery during their continuous orbits around the Earth unless they are "switched on" according to user demand and actual product orders. In addition, the sensors can be pointed towards an area of interest, which increases the opportunity to acquire imagery when placing an order. In contrast, Landsat TM generally acquires data continuously, and it is not a possible to make an advance request or point the sensor.

### 3.5 CHANGE DETECTION METHODS

A great strength of EO technology is the access it provides to the time-series of images that is created by repeat visits over the same place, to assess *change*. For M&E, the parameter under consideration (e.g., forest extent) is the focus of the *change detection* analysis. This, therefore, provides the foundation for the application of EO within an M&E systems or framework.

There are three general methods for change detection, all requiring a baseline image (or reference set of geo-spatial data) to which subsequent images can be compared:

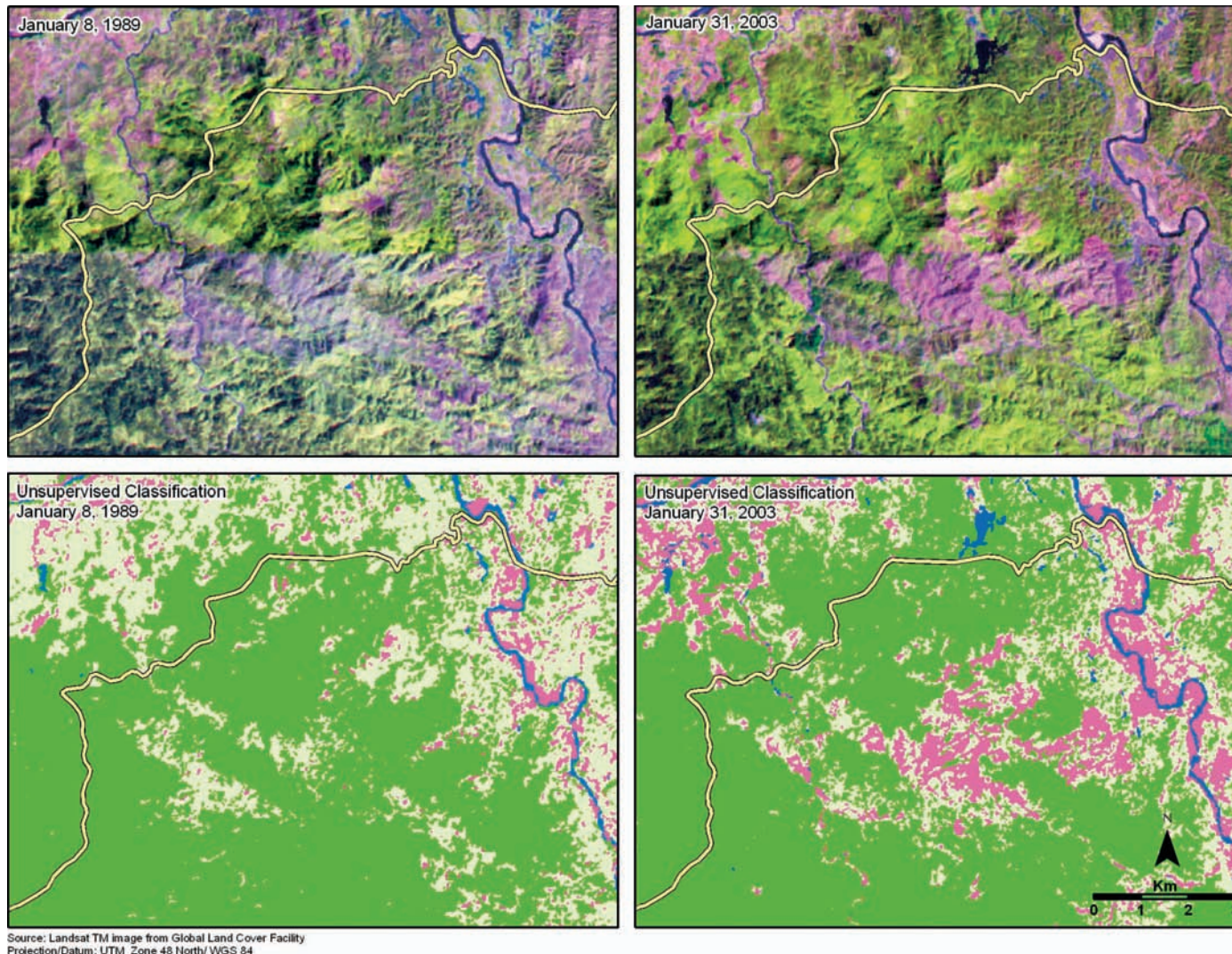
- **Manual change detection** is the simplest approach, in which an experienced EO analyst visually compares an EO image to the baseline image and identifies changes in land cover that are relevant to an M&E

indicator. A GIS may be useful to identify and digitize areas of change. This approach must be followed cautiously to ensure that the images are interpreted in a standard way, and that the analysis could be repeated.

- **Post-classification change detection** involves the comparison of classified images (e.g., land cover) between a baseline image and an image classified according to the same method at a later date. The same pre-processing, classification system, and analysis methodology is required to ensure that the results can be compared (see Figure 4). The detection of change between the classified results would normally be performed using a GIS, also allowing the integration of other data such as management units and administrative boundaries.
- **Image-to-image change detection** is a process that assesses the change in image values between a baseline image and a new image. Quantitative changes in image values are identified, and the changes in the environment are assessed and tabulated numerically by the image analyst and interpreted by an environmental practitioner, researcher or resource manager. These may be related to changes in, for example, forest cover or agricultural land (see Figure 5). The interpretation is usually supported by local knowledge and the collection of ground reference data. Care is required to ensure that seasonal changes in vegetation, atmospheric differences, and the impact of topography in highlighting or shadowing areas does not introduce errors into the interpretation.

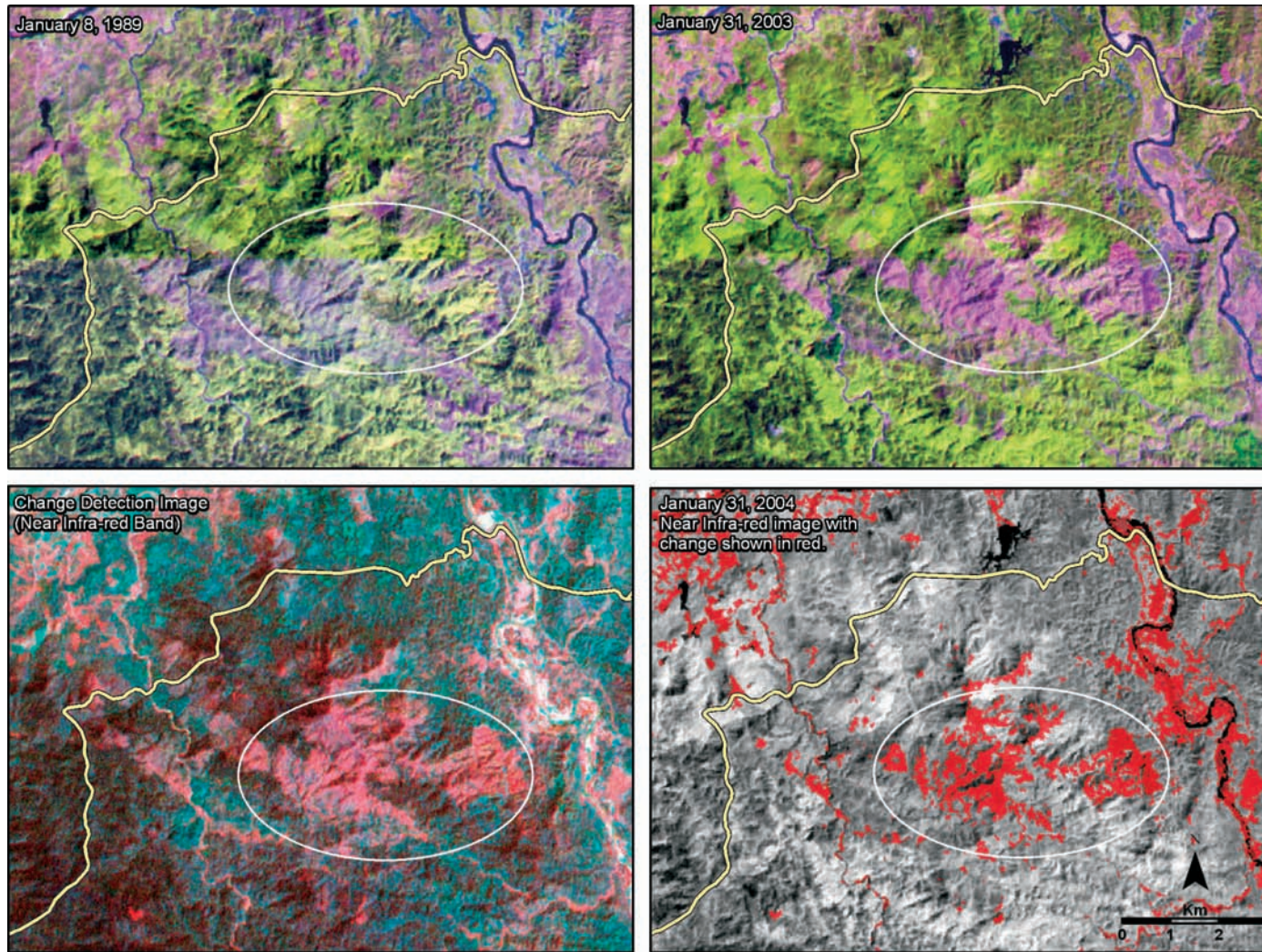
Regardless of the method used to detect change, images should be geometrically corrected and co-registered, so that they can be compared in a standard and direct way. More advanced image processing may also be required, in order to remove the bias of factors such as different solar illumination and atmospheric conditions on the dates that the satellite images were collected.

**Figure 4** An example of post-classification change detection.



The expansion of the pink colored areas in the lower right image indicates an increase in cleared land from 1989 to 2003.

**Figure 5** An example of image-to-image change detection.



Source: Landsat TM image from Global Land Cover Facility  
Projection/Datum: UTM Zone 48 North/ WGS 84

This example uses two different methods to illustrate the increase in cleared land from 1989 to 2003. The lower left image uses a false color composite where the brighter red tones illustrate greater changes. The lower right image shows the changes as a thematic layer.

### 3.6 POTENTIAL LIMITATIONS OF EO FOR M&E

Any decision to involve and utilize EO data in a project should be based on an analysis of the benefits derived from such data, and on a comparison with traditional surveying and measurement techniques, costs of imagery, processing and analysis. Hence, the following issues should be given serious consideration:

1. Image acquisition - cloud cover is major limitation that applies to the application of optical remote sensing data. The acquisition of useful optical satellite imagery depends on cloud-free conditions over the area of interest during the time of the satellite's overpass. SAR is not susceptible to cloudy conditions as it sends out its own radar energy for scene illumination; however, extracting information from SAR can more challenging than for optical imagery;
2. Accuracy - it is important to assess accuracy of individual EO products and understand any limitations in accuracy, and the implications they may have for M&E;
3. Class definition/information requirements - it is important that the sensors selected are appropriate for the application. While a sensor may have the necessary spatial resolution to accurately map a particular parameter or feature, the spectral capabilities of the satellite may not be suitable for an application, and it may not be possible to determine certain desirable land cover features;
4. Terrain, illumination and slope exposure can have a profound effect on both optical and radar imagery, albeit for different reason. The main reasons are related to differences in illumination and reflection of the sun and by the radar instrument. These are related to the steepness of the slope and its orientation to the energy source (sun or the radar), causing difference in image values on either optical imagery or radar imagery. Shadow effects are but one example; they can both enhance the rendition of terrain features, but they can also obscure other terrain and land cover. Remote sensing of very steep terrain can be a serious challenge because of distortion effects in the imagery;
5. Image processing capacity - the acquisition, processing, analysis and presentation of satellite imagery and associated image products requires skills that are greatly dependent on practical experience. In addition to technical abilities, computing infrastructure is also required; and
6. Technical jargon - EO, like many technical occupations, suffers from a wide array of acronyms, jargon and technical language. While it is important to use transparent and proven EO approaches, the extent to which technical issues and language end up in M&E documentation and procedures should be minimized. Technical jargon, when introduced in management frameworks such as M&E, is often counter-productive and can confuse matters.

## **4.0 MONITORING AND EVALUATION SYSTEMS FOR THE GREEN CORRIDOR PROJECT AND CENTRAL TRUONG SON INITIATIVE**

There are two M&E systems of interest in this review: the first is specific to the Green Corridor Project, and the second refers to the Central Truong Son Initiative. Each system is summarized in the sections below, and is followed by an assessment of the potential for EO to provide information for M&E indicators.

### **4.1 CENTRAL TRUONG SON INITIATIVE**

An M&E system has been defined for the Central Truong Son Landscape to support the Central Truong Son Initiative, which was established to address the urgent threats to biodiversity in the region. This framework involves a broad range of stakeholders from local communities to government and international organizations. The Central Truong Son Landscape includes the Green Corridor, so the framework set up for this initiative also applies to the GCP and EO-STEM project areas. The aims of the Central Truong Son M&E framework are:

- Monitor progress on the Central Truong Son Initiative Action Plan;
- Measure trends in environmental and social factors;
- Help in communicating the Initiative's achievements;
- Provide information to help with adaptive management;
- Give early warning of potential problems;
- Lead to greater understanding of what local people want from the landscape; and
- Supply data for long-term research.

(Dudley, Cu & Manh 2003)

The M&E indicators that were defined as part of this process are listed in full in Appendix 2.

### **4.2 GREEN CORRIDOR PROJECT**

The original Green Corridor Project Plan, established through the development of a Logical Framework Analysis (LFA), included an M&E framework. Subsequently, a Participatory M&E System was developed for TT-Hue Province. The M&E presented in this document adds to the original M&E plan by including considerably more detail, and by more clearly defining the objectives and the M&E indicators. While the GCP M&E system is intended to provide vital project management and progress reporting tools for the project, it is also intended to provide information to the GCP funding agency, the Global Environment Fund (GEF). Therefore, the indicators that form the backbone of the

GCP M&E approach have been developed using GEF guidelines and principles: Specific, Measurable, Achievable, Relevant and Time-bound or **SMART**.

Within M&E, two main types of monitoring are utilized, distinguishing between monitoring of project impacts and monitoring of project progress:

- Activity Based Monitoring - is designed to report on project activities specified in the project work plan; and
- Project Impact Monitoring - focuses on project elements that are direct, indirect and aggregated impacts of the project activities within three main areas: ecological and biodiversity protection; institutional impacts; and social and cultural impacts.

The GCP intends to design and implement a Landscape Information Monitoring and Evaluation System that will provide a centralized information management system to service the needs of stakeholder planning, decision-making and monitoring. In order to define the indicators, a set of positive and negative impact hypotheses were formulated for each indicator. The Ecological and Biodiversity protection impact hypotheses are listed below in Table 2. The impact indicators that were selected using this approach are based on the original log frame included in the Central Truong Son M&E framework, supplemented with additional inputs and clarifications. A full list of Ecological and Biodiversity Protection Impacts indicators are provided in Appendix 3.

**Table 2 Impact hypotheses for the Green Corridor based on the Ecological and Biodiversity Protection Impacts.**

<b>Impact Area</b>	<b>Positive Impact Hypothesis</b>	<b>Negative Impact Hypothesis</b>
Ecological & biodiversity protection impacts	Threat to project area will be reduced	Threat to project area will not be reduced
	Forest loss due to fires will be reduced.	Forest loss due to fires will be increase
	Area and quality of forest will be maintained or increased.	Forest area and quality will be reduced due to illegal logging and agricultural conversion.
	Populations of key flagship species will be maintained or increased	Populations of key flagship species will decrease
	Illegal activities will be reduced through improved enforcement activities	Illegal activities will not be reduced or increase
	Degree of forest fragmentation will be maintained or decreased.	Forest fragmentation will increase.

## 5.0 POTENTIAL CONTRIBUTION OF EO FOR M&E

The potential contribution of information derived from remote sensing satellite observations for specific M&E indicators is variable. Primarily, it depends on how well this relatively new technology is able to map landscape features or processes of interest, and how well change can be detected on an appropriate timescale. The question also arises whether or not the satellite imagery can be used for monitoring purposes throughout the entire province and on a regular (i.e., annual) basis. Crosscutting requirements are that the EO-based monitoring must provide information for the **entire province** of TT-Hue, and that information is required for reporting on an **annual** basis.

As shown in Table 3, selected Central Truong Son M&E indicators are likely to benefit from EO-derived information, in the areas of forest condition and biodiversity, forest ecosystem services, and key pressures on Truong Son. For the GCP, EO can provide objective data in support of ecological and biodiversity protection impact monitoring. On the other hand, EO is not relevant to issues, namely measurement and monitoring of institutional impacts and social impacts. For this reason further discussion of the contribution of EO to M&E in the GCP in this report will be focused exclusively on ecological and biodiversity protection impacts (see Table 4 below).

**Table 3 Central Truong Son M&E indicators where EO products may provide information.**

Issue	No.	Indicator	Reporting Frequency	Official Sources	Rating <sup>1</sup>
<b>Forest condition &amp; biodiversity</b>					
	1	Area of natural forest	5 years	FIPI & Provinces	High
	2	Forest quality	Annual	FIPI & Provinces	Medium
Forests	3	Area of plantations	5 years	FIPI & Provinces	Medium
	11	Number of forest fires	Annual	FPD	Medium
	12	Extent of forest fires	Annual	FPD	Medium
<b>Forest ecosystem services</b>					
Water	20	Catchment protection	Annual	FPD/FDD	Medium
Irrigation	21	Area of irrigation (change in area of wet rice grown)	Annual	DARD	High
<b>Key pressures on Truong Son</b>					
Enforcement	34	Number of kilometers of road	Annual	Provincial Transportation Department	Medium

<sup>1</sup> **High** suggests confidence that EO may provide valuable information to support this indicator.

**Medium** suggests a degree of uncertainty in the ability of EO to provide information, either in terms of accuracy, level of thematic or spatial detail, or that significant challenges need to be addressed to apply EO data. EO products could provide valuable supporting information to field validation or existing traditional survey and data gathering exercises.

**Table 4 GCP M&E indicators where EO products may provide information.**

Issue	Indicator	Variable	Reporting Unit	Rating <sup>1</sup>
1.1	Number and extent of forest fires	Number of forest fires	Commune	Medium
		Extent of forest fires	Forest type per Commune	Medium
1.2	Area and quality of forest	Area of forest (Government classification, including forest quality)	Sub-compartment & compartment	High
		Area of high conservation value forest	Sub-compartment & compartment	High
1.3	Degree of fragmentation	Forest Fragmentation index	Compartment	High
		Fragmentation hotspots	Compartment	High
1.4	Abundance of key indicator species	Change in long-term biological monitoring plots	Plot	Low

<sup>1</sup> **High** suggests confidence that EO may provide valuable information to support this indicator.

**Medium** suggests a degree of uncertainty in the ability of EO to provide information, either in terms of accuracy, level of thematic or spatial detail, or that significant challenges need to be addressed to apply EO data. EO products could provide valuable supporting information to field validation or existing traditional survey and data gathering exercises.

**Low** suggests EO may provide supporting data, but the required detail of information is difficult to obtain through remote sensing.

## 5.1 NUMBER OF FOREST FIRES

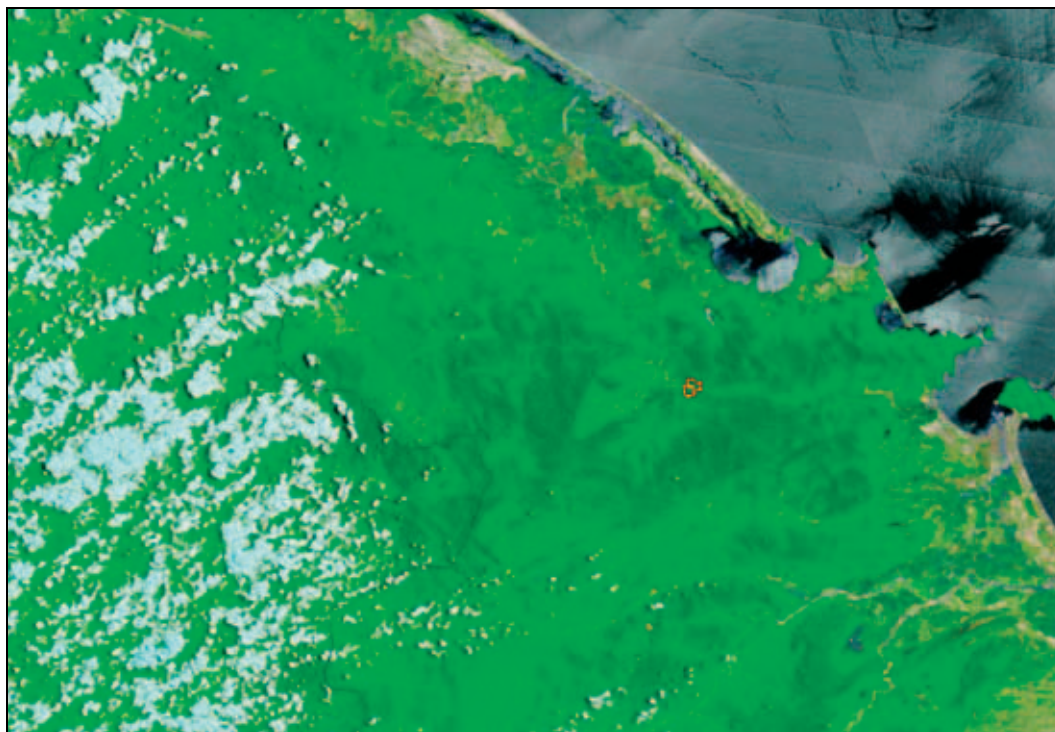
EO based detection of forest fires requires frequent (daily) observations by a sensor that is able to detect fires (i.e., have thermal spectral imaging capabilities).

The MODIS Rapid Response System provides information from the moderate resolution MODIS sensor onboard NASA Terra and Aqua satellites. The so-called Rapidfire system (<http://rapidfire.sci.gsfc.nasa.gov/>) provides web-based information on fires in near-real time, providing a method for monitoring fire occurrence (Figure 6).

Additional supporting information on fire and weather interpretation can be obtained online from the Southeast Asia Fire Danger Rating System, housed at the Malaysian Meteorological Department, in Petaling Jaya ([http://www.kjc.gov.my/english/service/climate/fdrs1\\_x.html](http://www.kjc.gov.my/english/service/climate/fdrs1_x.html)). This system provides current and archive spatial forest fire risk data.

A summary of benefits and challenges related to using EO to support fire monitoring is provided in Table 5 below. Using the information from recorded observation (coordinates of observed fires), it would be possible to sum the number of fires in each commune using GIS. Change detection in forest fire frequency would be based on simple comparison of total fires per commune; important additional information may be the number of days that successful observations were possible due to the impact of cloud cover.

**Figure 6** Example of a MODIS Rapidfire system product for Thua Thien-Hue, Viet Nam, June 2004.



(NASA 2006)

**Table 5** Benefits and challenges of EO-based fire monitoring.

Benefits	Challenges
<ul style="list-style-type: none"> <li>▪ Free access to information products;</li> <li>▪ Daily observation frequency possible; and</li> <li>▪ User may avoid requirement to download and process images.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Optical sensor and can be limited by cloud cover (no information available);</li> <li>▪ Relatively coarse resolution (pixel size for the Web Fire Mapper is 1 km, but smaller fires are detectable (e.g., 100 m<sup>2</sup>) depending on a range of factors; and</li> <li>▪ Labour intensive to check site and record fire frequency.</li> </ul>

## 5.2 EXTENT OF FOREST FIRES

Fires scars can be detected using many sensors, including optical and radar systems. Depending on the size of fires that are required to be monitored under the M&E system on an annual basis, high resolution optical data may be required (e.g., SPOT-5 or Landsat TM). A summary of benefits and challenges related to using EO to support fire mapping is provided in Table 6 below.

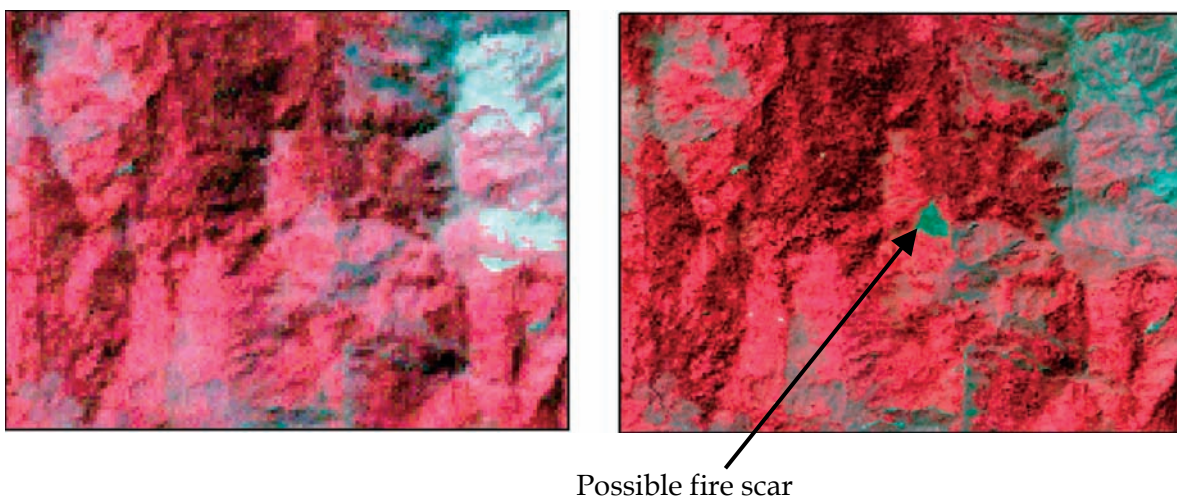
**Table 6 Benefits and challenges of using EO for fire mapping.**

Benefits	Challenges
<ul style="list-style-type: none"> <li>▪ May provide information not possible to obtain using field surveys.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Optical sensor and can be limited by cloud cover (no information available);</li> <li>▪ High resolution data required and significant time for interpretation;</li> <li>▪ Identification of fire scars may be difficult, because of topographic impacts, and fire scars may appear similar to logged areas and land cleared for agriculture; and</li> <li>▪ Technical demands of image processing.</li> </ul>

Change in the extent of forest fires could be determined using any of the change detection methods summarized in Section 3.5. Based on the requirements for fire extent to be reported for *forest type per commune*, the following approach may be required:

1. Create baseline forest map with forest classes (e.g., EO-STEM / GCP forest maps);
2. Use EO to map forest fire scars (e.g., using manual interpretation or image to image change detection techniques); and
3. Use GIS overlay to identify the type of forest lost due to forest fire and report on a commune basis.

**Figure 7 Example of fire scar extent identification using Landsat 5 TM (2003) and SPOT-5 (2005).**



### 5.3 FOREST CONDITION AND BIODIVERSITY

The GCP M&E system proposes that the area and quality of natural forest should be monitored using three variables.

- Area of **forest type** by Government classification by sub-compartment / compartment;
- Area of **forest quality** by forest management unit; and
- Area of change of **high conservation value** forest.

Monitoring is based on comparing statistics on area of forest variables for each compartment and sub-compartment. EO support for this set of M&E indicators are most appropriate with a post-classification change detection method. As described in Section 3.5, a baseline map product is created, and following the desired time period, a new or updated product is created following the same methodology. For example, the EO-STEM and GCP baseline forest mapping methodology could be repeated, and simple GIS analysis could provide an assessment of the area of forest classes by compartment and sub-compartment (forest classes are provided in Appendix 4). This process is repeatable and only dependant on the creation of compatible forest quality maps and the availability of sub-compartment/compartment boundaries in GIS format. Comparisons in forest type and/or quality between years can be made either in GIS or comparing tabular data using spreadsheets. If boundary delineations change, or data are not accurately geo-referenced, the statistics may also change.

For the monitoring of change in High Conservation Value Forest (HCVF), the EO-STEM Milestone 6 report (Hatfield, 2006) defined a methodology for assessment of HCVF based on a simple multi-criteria raster GIS model to integrate forest cover data and other ancillary spatial data. This method will be refined based on participation from GCP stakeholders. Once the model is accepted, it is possible to assess HCVF on a regular basis based on new datasets (e.g., updated forest classes). Change detection for HCVF could be based on GIS analysis.

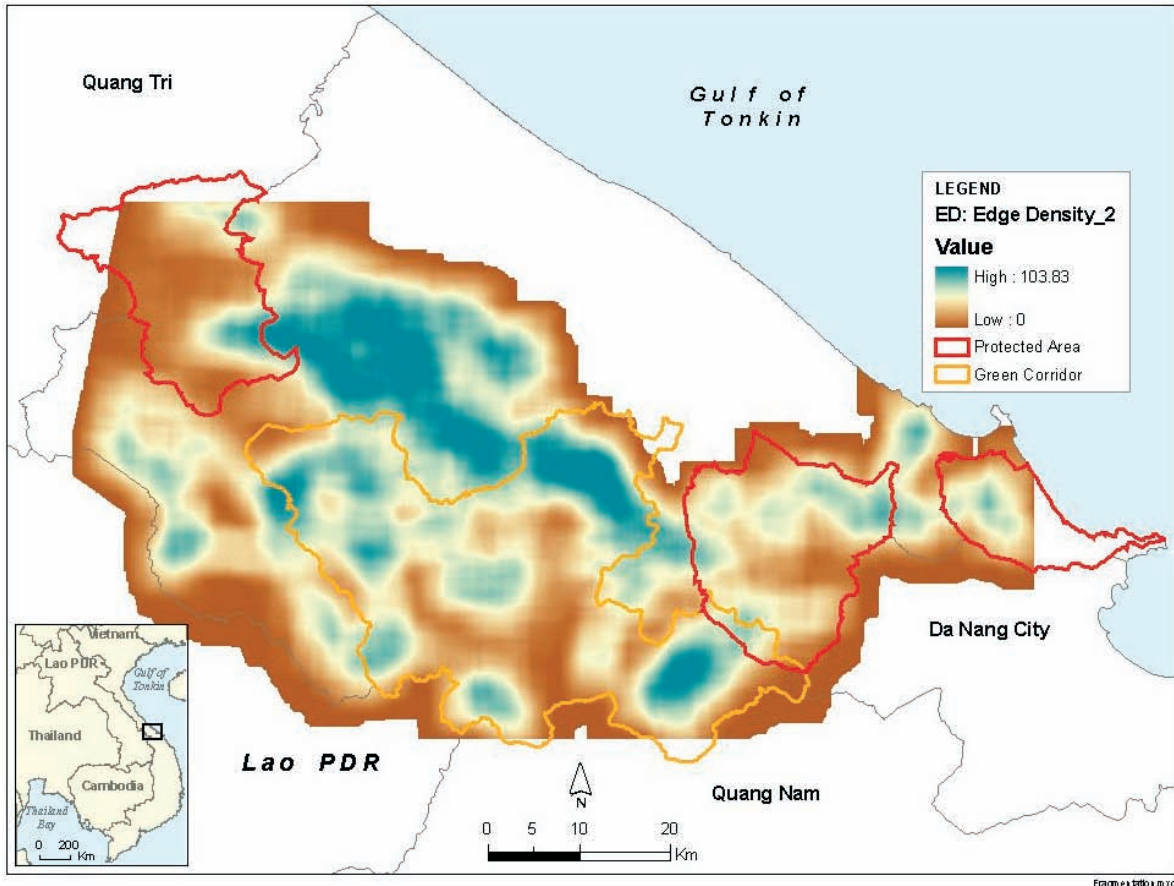
### 5.4 HABITAT FRAGMENTATION

EO support for monitoring habitat fragmentation is based on the development of maps of fragmentation metrics for the Green Corridor or TT-Hue Province. Calculation of fragmentation statistics and production of fragmentation maps requires an EO-based forest map as an input, which would be produced to support the forest condition and biodiversity indicators described above.

Specialized GIS analysis is required to assess fragmentation. This methodology is under development as part of the EO-STEM project. An example of the Edge Density metric is provided in Figure 8. Once the required fragmentation metrics

and methodology have been approved by the Province, it would be possible to create fragmentation statistics based on repeat analysis of forest cover maps. In order to be meaningful to decision-makers, it is likely that the fragmentation information would need to be summarized by forest management unit.

**Figure 8** Edge Density fragmentation metric for natural forest, Thua Thien-Hue, Viet Nam.

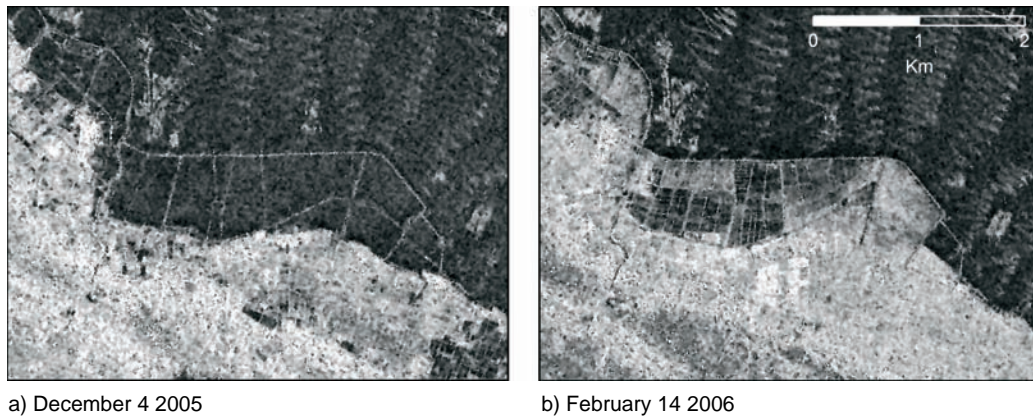


Edge density at the class level reports edge length on a per unit area basis (meters of edge per hectare). The map reveals *metres of forest edge per hectare*. Forest edge reveals areas where natural forest is adjacent to non-forest land uses, and an increase in edge density may reveal areas more likely to be threatened with fragmentation. Some areas within the protected areas and Green Corridor have high edge densities.

## 5.5 AREA OF (IRRIGATED) RICE PRODUCTION

It may be possible to develop an assessment of soil protection using measurements of area of irrigated rice derived from EO data. The following diagram (Figure 9) shows an example of an area of irrigated rice production in TT-Hue from RADARSAT-1 (Fine Mode). Using imagery such as this, it should be possible to delineate areas of irrigated rice production to develop soil protection assessments.

**Figure 9** Example of irrigated rice production in Thua Thien-Hue, using RADARSAT-1 Fine Mode imagery.



## 6.0 RECOMMENDATIONS

### 6.1 MONITORING AND EVALUATION IN 2007

#### 6.1.1 Image Selection

Based on a Needs Assessment conducted as part of the EO-STEM project, high-resolution satellite imagery was identified as a suitable source to provide geo-spatial information for the GCP project activities, either from SPOT-5 or Landsat TM.

Subsequent analysis revealed that SPOT-5 data features good spectral and spatial resolution for mapping forest cover in a complex landscape such as TT-Hue Province. The images also cover a relatively large extent (60 x 60 km). Landsat ETM+ data would also be an appropriate option for this analysis. However, due to the poorer spatial resolution of the sensor and the fact that Landsat-7 has been experiencing technical problems since 2004, the potential for continuous digital image analysis has been significantly reduced.

The EO-STEM project conducted forest type, quality and conservation value mapping using SPOT-5 imagery. The resulting mapping products can be considered as a baseline for M&E purposes. Repeat acquisitions of SPOT-5 would facilitate the provision of information for the assessment for each of the GCP M&E indicators (see Table 4), apart from forest fire frequency. The EO-STEM project did not acquire imagery of the whole Province, but two images from adjacent paths were acquired to cover the whole GCP study (Figure 10), which also represents most of the forested area of TT-Hue Province.

**Figure 10 Theoretical SPOT coverage provided by SPOT Asia.**



### 6.1.2 Cost

The costs related to continuing the application of SPOT-5 for M&E are summarized below in Table 7.

**Table 7 Summary of costs for Thua Thien-Hue monitoring activities using SPOT-5 satellite 10 m color imagery.**

	<b>Cost per scene (USD)</b>	<b>Number Required</b>	<b>Total</b>
Full scene	\$3,900	2	\$7,800
1/4 scene	2,450	2	\$4,900
<b>Total Cost</b>			<b>\$12,700</b>

Note: price quoted by SPOT Asia, November 2006.

### 6.1.3 Capacity Requirements

The production of a forest classification map requires specific skills and experience in digital classification of satellite imagery. For the successful completion of a forest classification, a technician would need to be able to confidently follow the adapted unsupervised classification procedure presented in the forest classification report. In addition, it would also be necessary to collect field data in order to validate the results of each classification map and to perform an accuracy assessment. The GIS analyses required to develop the area statistics are relatively simple and could be undertaken by a GIS technician with nominal experience.

## 6.2 FUTURE WORK

Further to the sensors outlined in this document, future EO missions scheduled for launch in the coming years should increase the applicability of satellite data in biodiversity and conservation mapping. The following radar sensors are of interest:

- RADARSAT-2 - due to be launched in 2007, RADARSAT-2 will provide polarimetric imagery, which should moderately improve forest mapping capabilities and significantly improve wetland mapping and monitoring capabilities.
- ALOS PALSAR - launched in 2006, L-band radar imagery will be operationally available from PALSAR, which will significantly improve radar forest mapping potential. The longer L-band wavelength is more likely to provide information on forest biomass than C-band radar such as RADARSAT.
- TerraSAR-X - due to be launched in 2007, TerraSAR-X has a shorter wavelength than either RADARSAT or PALSAR. This means the radar is more likely to interact in the forest canopy and may provide valuable information in combination with longer wavelength radar.

## 7.0 CONCLUSIONS

This document has presented a case for the use of EO for M&E in biodiversity and conservation management. The implicit spatial nature of many of the indicators supports this case, and the examples of forest and fire management provide proof that, if correctly defined, EO can play a significant and useful role in M&E. While the application of an EO-based approach may require significant investment at the outset (financial and institutional - training and other resource investments), the long-term benefits to the M&E framework should outweigh these costs.

In order to take full advantage of the benefits of EO and GIS for M&E, they should be integrated at the start of a project and during indicator definition. This will enable the team working on the project to define appropriate roles for these approaches and technologies in the project/M&E framework and manage the expectations of stakeholders. However, it is important of all that M&E officers are confident that EO can provide useful information for their activities.

One of the key pieces of guidance that can be take from the literature is that M&E indicators and analysis methods should be kept simple in order to reduce errors and limit uncertainties. Many EO approaches, even though they include complex equipment and technology, can actually be relatively simple and repeatable. Hence, the application of EO in this case should focus on proven EO methodologies and approaches and limit the amount of research-based analysis.

## 8.0 REFERENCES

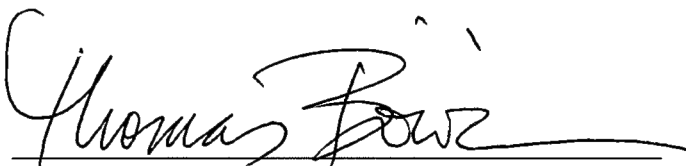
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## 9.0 CLOSURE

We trust the above information meets your requirements. If you have any questions or comments, please contact the undersigned.

### Hatfield Consultants:

Approved by:  November 30, 2006  
Andy Dean, Project Manager Date

Approved by:  November 30, 2006  
Thomas Boivin, President Date

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## **APPENDICES**

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**Appendix 1**

**Background to Green Corridor  
and EO-STEM Projects**

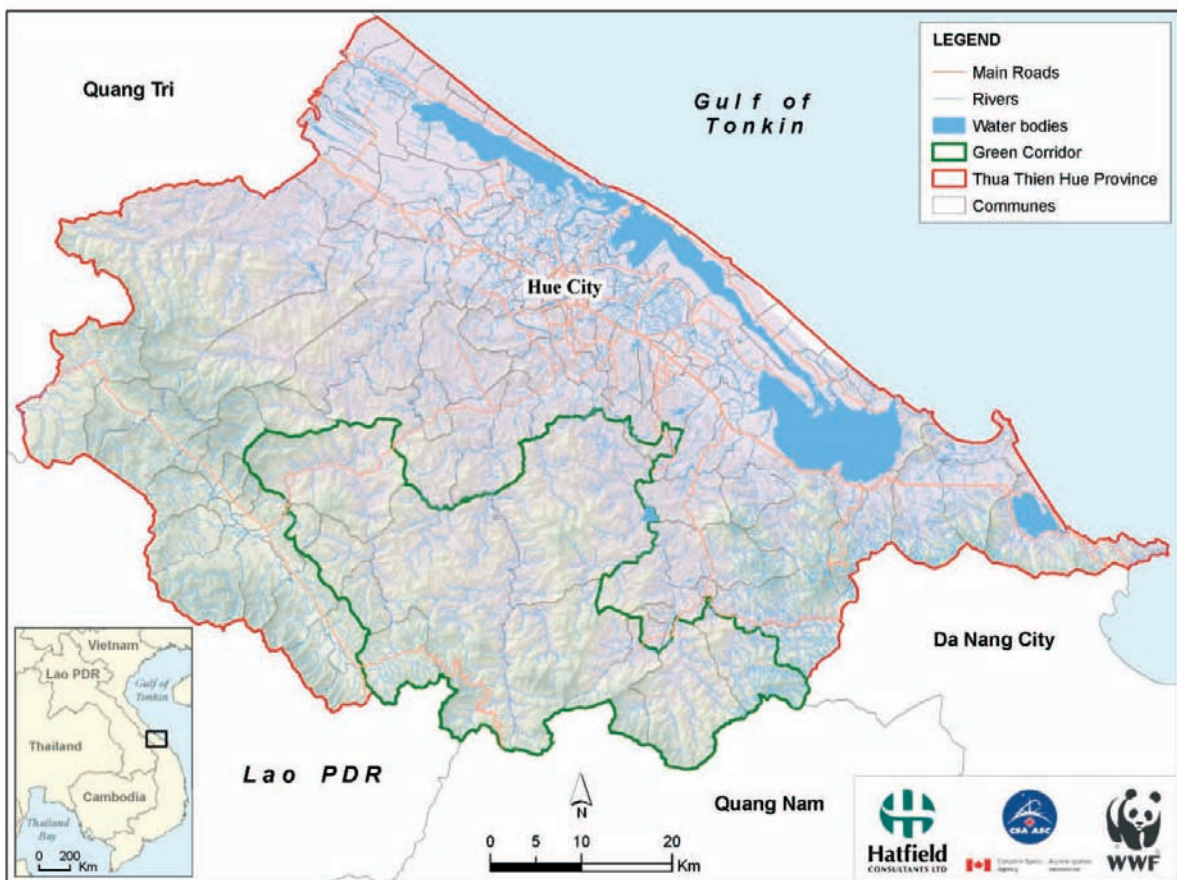
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## A1.0 GREEN CORRIDOR AND EO-STEM PROJECT BACKGROUND

### A1.1 THE GREEN CORRIDOR

The Green Corridor area has been identified through systematic conservation landscape assessments as one of the highest conservation priorities in the Central Truong Son mountain range, since it supports some of the last remaining lowland forests in Viet Nam and harbors a wide range of endemic and endangered species such as the Saola (*Pseudoryx nghetinhensis*) (Tordoff *et al.* 2003, IUCN 2006). The concept of the Green Corridor originally linked a larger area from coastal forest in TT-Hue Province to the Xe Sap Biological Conservation Area in Lao PDR; however, the Green Corridor was eventually defined as comprising eleven Communes in Nam Dong, Huong Thuy and A Luoi Districts. The Green Corridor covers an area over 135,000 hectares, stretching between Bach Ma National Park and Phong Dien Nature Reserve (Figure A1.1).

Figure A1.1 Thua Thien-Hue Province and the Green Corridor Project area.



## **A1.2 GREEN CORRIDOR PROJECT**

The GCP is a four-year initiative that started in June 2004, which is implemented by WWF Greater Mekong Program and TT-Hue Province FPD. The project receives funding from the World Bank (Global Environmental Facility), WWF, TT-Hue Provincial Peoples' Committee and SNV (Dutch International Development Agency).

The primary objective of the GCP is to protect and maintain the biodiversity rich forests of the Green Corridor forest landscape, which comprises parts of three districts of TT-Hue Province (Figure A1.1). The Green Corridor is under extreme threat from illegal logging, hunting, and the impacts of unsustainable development.

The secondary objective of the GCP is to establish a replicable model for protection and maintenance of high global conservation values in multiple-use forest landscapes of strategic importance for biodiversity conservation. The GCP develops methodologies for achieving multiple benefits from forest management in productive landscapes, and conducts urgently needed direct interventions to combat the threats to the biodiversity of the Green Corridor. To achieve this, the GCP works with forest managers, local communities and provincial government, including sectoral development planners.

The GCP takes a landscape-level approach and envisages a network of protected areas, production and protection forest, and community forests to ensure that the biodiversity unique to the area is conserved. This approach is different to a traditional protected area approach to biodiversity conservation, which aims to delineate areas for strict protection and to establish a zone around the isolated forest in which use is minimized. Through systematic assessment of landscape biodiversity value, a key output of the GCP is a conservation zonation plan and participatory conservation agreements reduce conflicting plans and strategies and will ensure that conservation goals are achievable. Ultimately, the GCP aims to develop a productive landscape in which local communities benefit from improved conservation and resource management and are not adversely impacted by inappropriate development actions at district, provincial or national level.

## **A1.3 EO-STEM PROJECT**

The EO-STEM Project is funded by the Canadian Space Agency (CSA), through the Earth Observation Application Development (EOADP) Program. Hatfield Consultants Ltd. leads the EO-STEM Project with assistance from a number of Canadian partners, including Strata360 & ÆRDE Environmental Research.

The objectives of the EO-STEM Project are:

1. Provide the WWF and the Government of Viet Nam (GoVN) with a spatial framework for efficient conservation management and planning;
2. Demonstrate proven Canadian Earth Observation (EO) technologies to produce products to support the Government of Viet Nam's and WWF's biodiversity conservation in the Green Corridor of Viet Nam through the Green Corridor Project (GCP);
3. Use participatory processes to document traditional ecological knowledge (TEK);
4. Develop a (spatial) framework for integrating EO into on-going biodiversity and forest conservation monitoring and evaluation (M&E) systems;
5. Ensure long-term sustainability of the project by providing capacity building and training in EO technologies to District, Provincial and National biodiversity conservation personnel; and
6. Produce a replicable model for integrating EO into regional biodiversity and conservation management, through the effective demonstration of EO and GIS-based biodiversity products.

This report presents findings from activities undertaken as part of the Earth Observation Support for Traditional Ecological Mapping and Biodiversity Conservation In Viet Nam (EO-STEM) Project. This report summarizes activities conducted for Work Package No. 3: *Operational Demonstration and Technology Transfer*. The report was prepared to fulfill obligations as per Hatfield Consultants Ltd's contract with the Canadian Space Agency, Contract No. 9F028-4-5007/01.

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**Appendix 2**

**Central Truong Son Landscape  
Initiative Monitoring & Evaluation  
Indicators**

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## A2.0 CENTRAL TRUONG SON LANDSCAPE INITIATIVE MONITORING & EVALUATION INDICATORS

Components	Indicators
<b>Project goal and objectives:</b>	
<b>Goal:</b> The forests and biodiversity of Vietnam and the Annamites ecoregion maintain their significant contribution to global biodiversity	Species diversity and uniqueness and natural forest cover and quality of Vietnam and the Annamites is maintained and enhanced
<b>Primary objective:</b> To protect and maintain the high global conservation value of the Green Corridor	Critical forest habitats of the Green Corridor continue to maintain populations of globally significant species such as Saola, Tiger, Edward’s Pheasant, White-cheeked Gibbon , Douc langur. Forest corridor maintained between Phong Dien, Bach Ma, Xe Sap and the forests in north Quang Nam.
<b>Secondary objective:</b> To establish a replicable model for protection management and restoration of high global conservation values in multiple use forest areas of strategic importance for biodiversity conservation	Green Corridor and key elements of the project provide effective models to achieve global conservation targets within multiple-use “productive landscapes” and are replicated. Key elements for replication include: Community commitments to conservation; Cooperation for conservation through enhanced and specific linkages between local communities and provincial authorities; Multiple use zonation plan combining conservation with sustainable use; Management for conservation as well as sustainable use in production forests; Strategic environmental framework to guide long term sustainable development; Participatory M&E system for adaptive management and landscape scale conservation.
<b>Project outcomes and activities:</b>	
<b>Result Area 1: Immediate threats to endangered species and forest habitat halted through effective control mechanisms and strengthened capacity for conservation management</b>	Number of community and provincial regulations aligned and strengthened increased. Number of skilled and motivated community and government staff committed and able to participate in effective conservation increased. Levels of natural forest cover and quality maintained or increased Number of illegal hunters and illegal loggers reduced. Number of community commitments to conservation increased. Extent of human settlements, agricultural land and roads does not increase in the high conservation priority sites within the Green Corridor. Inappropriate development interventions excluded from the Green Corridor.

Components		Indicators
<b>Component 1: Strengthen the management of the Green Corridor</b>		
<b>Activity 1.1:</b> Develop effective regulations and resource zonation based on sound scientific analysis and participatory consultation		
1.1.1	Train a team of provincial scientists from Hue University to identify landscape attributes (species, habitats and ecosystem services) of high conservation value	High conservation value thresholds identified Number of provincial scientists trained in identification of landscape attributes
1.1.2	Conduct a survey together with a team of provincial scientists and from Hue University to establish the status and distribution of species, habitats and ecosystem services that represent high conservation value	Descriptive, quantitative and mapped data of biodiversity and community resource use available and used by local decision makers. Location and extent of threats assessed and mitigation measures developed.
1.1.3	Develop a strategy to maintain and enhance the identified values	Reports on consultations with national and international experts and provincial stakeholders. Strategy for the maintenance and enhancement of identified values agreed amongst stakeholders and documented.
1.1.4	Use the strategy to develop through a process of stakeholder participation, a conservation zonation plan and set of regulations and procedures for effective management including the creation of areas for participatory management	Conservation zonation plan agreed amongst stakeholders Effective regulatory and management system developed, agreed and implemented by key stakeholders.
<b>Activity 1.2:</b> Implement activities aimed to halt the loss of individual globally threatened species from hunting, wildlife trade and illegal logging		
1.2.1	Develop a strategy to control and prevent the over-exploitation of natural resources and to eliminate illegal practices including the development of an effective penalty system	Consultations with national and provincial stakeholders documented. Strategy and action plan to curtail illegal logging and reduce the threat from hunting and wildlife trade developed and agreed amongst stakeholders and disseminated amongst enforcement officers and local communities. Strategy and action plan to curtail illegal activities implemented. Frequency of illegal hunting/wildlife capture and logging occurrences reported by local communities reduced.
1.2.2	Implement the strategy through the establishment of an appropriate grant scheme	Regulations and management system for grant scheme developed. Guidelines on purpose, eligibility and application process produced and disseminated. Training in proposal development provided. Number of grants implemented.

Components		Indicators
<b>Activity 1.3:</b> Strengthen regulations to control encroachment of forest areas and loss of forest at critical landscape areas along access routes (roads and rivers) and enforcement		
1.3.1	Identify and implement immediate actions to control further encroachment of forest areas particularly in relation to the threats originating from key access routes	Location and extent of threats known. Measures to mitigate adverse impacts from access routes identified and action plan developed and implemented.
<b>Activity 1.4:</b> Control the loss of forest through forest fires		
1.4.1	Conduct training workshop to strengthen existing forest fire control mechanisms	Guidelines for forest fire management developed. Number of stakeholders trained in application of the guidelines. Guidelines applied by forest stewards.
1.4.2	Implement a small grants scheme to build capacity for combating forest fires	Regulations and management system for grant scheme developed. Guidelines on purpose, eligibility and application process produced and disseminated. Training in proposal development provided. Number of grants implemented. Reduction in the loss of forest due to fire.
<b>Activity 1.5:</b> Promote long-term sustainable development practices in the Green Corridor that integrate biodiversity priorities into development plans		
1.5.1	Prepare a Strategic Environmental Framework that establishes thresholds for High Conservation Values	Thresholds to determine the presence of areas of High Conservation Value established. Stakeholder agreement on strategic environmental framework.
1.5.2	For any future development activity (such as eco tourism) prepare a code of practice that ensures these thresholds are not breached	Environment codes of practice developed and applied.
1.5.3	Undertake awareness raising activities to demonstrate the importance of forest conservation to sustainable development	Awareness messages, materials and methods developed and being used during training, communications and meetings.
<b>Result Area 2: Productive landscape established for the Green Corridor and maintained through locally initiated protection, management and restoration initiatives</b>		Number of forest fires reduced Fragmentation halted and connections increased. Habitat quality maintained and enhanced Area of natural forest increased. Area of forest meeting conservation targets increased. Number of communities and State Forest Enterprises actively engaged in appropriate afforestation increased. Standard of living of local communities, especially ethnic minorities is maintained or enhanced.

Components		Indicators
<b>Component 2: Improve incentives for maintaining forest cover</b>		
<b>Activity 2.1: Implement a grant scheme for conservation friendly activities</b>		
2.1.1	Implement a small grants scheme to promote innovative incentives for maintaining and restoring natural forest	Regulations and management system for grant scheme developed. Guidelines on purpose, eligibility and application process produced and disseminated. Training in proposal development provided. Number of grant funded conservation activities implemented.
<b>Activity 2.2: Promote the regeneration of degraded forest areas of key landscape importance</b>		
2.2.1	Develop best practice guidelines for forest land allocation that provide for the maintenance of natural forest cover	Experiences in forest land allocation in Vietnam reviewed. Best practices guidelines on forest land allocation developed and implemented.
2.2.2	Design and implement a strategy for regeneration of deforested areas of critical importance for landscape integrity to recover all previous high conservation values	Sites for restoration identified. Guidelines for restoration of conservation values developed and in use to improve existing and planned practices incentives for conducting restoration identified.
<b>Result Area 3: The biodiversity value of the Green Corridor is secured through development of informed policies and responsible planning measures which can be replicated at other sites.</b>		Number of effective regulatory mechanisms adopted by other institutions and agencies at provincial, national and international level. Quality of information related to habitat quality and species increased. Access to data on Green Corridor by stakeholders increased. Number of interventions which take account of lessons learnt increased. Number of stakeholders able to take positive action for biodiversity conservation increased.

Components		Indicators
<b>Component 3: Strengthen Capacity and awareness to manage at the landscape level</b>		
<b>Activity 3.1: Train the local communities and other forest stewards in conservation management practices and forest landscape management</b>		
3.1.1	Undertake an institutional capacity assessment with regard to conservation management of the stakeholders and develop a training of trainers program	Institutions and other bodies with a responsibility for managing natural resources in the project area identified. Institutional capacity assessment completed. Training needs identified and addressed Training of trainers program developed.
3.1.2	Implement the training of trainers program	Number of trainers trained in accordance with the program developed following the institutional assessment.
3.1.3	Assist trainers to develop and implement conservation training programs	Number of training sessions on conservation and forest landscape management conducted by trained trainers.
<b>Activity 3.2: Implement environmental education to increase the level of awareness and understanding of biodiversity conservation and sustainable natural resource management.</b>		
3.2.1	Develop an Environmental Education strategy for all stakeholders in the Green Corridor and those who could otherwise impact the Green Corridor	Environmental education program and materials developed and implemented.
3.2.2	Implement the strategy using appropriate institutional structures	Number of stakeholders participating in environmental education program increased.

Components		Indicators
<b>Component 4: Establish a participatory monitoring and evaluation system</b>		
<b>Activity 4.1: Develop and implement a monitoring and evaluation system</b>		
4.1.1	Implement an operational management process that integrates green corridor management with M&E	Project management and operational procedures developed and implemented. M&E system developed.
4.1.2	Identify a working group to develop and maintain an M&E system	Members identified and working group established in accordance with a documented TOR.
4.1.3	Train the working group in the role and techniques for participatory M&E	Training program developed and conducted amongst the working group members Participatory monitoring groups identified and trained.
4.1.4	Develop and implement a full M&E system including identification of criteria and indicators, data collection and storage and use of the data for adaptive management and ensuring accountability	M&E system functioning and in use by the project team and project partners. Outputs from the system are being used to improve project design and implementation.
4.1.5	Train and equip key provincial staff in the Forest Protection Department in the use of GIS to build the capacity to store and analyze spatial data related to land use and conservation planning	Training program developed and conducted amongst provincial planners, follow up training and technical support provided.
4.1.6	Establish a long-term biological research and monitoring program for the Green Corridor in collaboration with research institutions particularly focused on long-term research on flagship species such as Saola, Douc Langur and Tiger	Long-term research and monitoring program developed and in place.
4.1.7	Publish and disseminate results of the M&E semi-annually	Reports on the M&E process published and disseminated.
<b>Activity 4.2: Disseminate the progress and results of the project to district, provincial, national policy makers and practitioners</b>		
4.2.1	Design and implement a project communication plan	Communication plan developed in cooperation with the project team and implemented, Reports and other outputs of the project disseminated in accordance with communication plan. Key decision makers aware of project outputs and outcomes.
4.2.2	Establish regular meetings with provincial stakeholders to receive inputs and report on progress	Provincial stakeholders identified and actively participating in scheduled and minute meetings. Outputs of the meeting reflected in the development of provincial policies and regulations.
4.2.3	Host project workshops at mid-term and project end to receive inputs and communicate progress and results	Mid term and end of project workshops conducted and reports of proceedings and feedback documented.
4.2.4	Encourage project managers to present project at local, national, regional and international fora	Reference to, or reports on Green Corridor project included in proceedings of workshops, meetings and conferences and in policy discussion papers.

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**Appendix 3**

**Green Corridor Project Impact  
Indicators**

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## **A3.0 GCP ECOLOGICAL AND BIODIVERSITY PROTECTION IMPACT INDICATORS**

Five ecological impact indicators are identified; these are all based on the indicators that are loosely suggested in the log frame.

### **E1 - Number and extent of forest fires**

Data on forest fires is collected by the District Forest Protection Departments. The project has collected the preceding five years of data on forest fire. Constraints on data use is differences in how the data is recorded, for example, with some staff recording local names, others map coordinates and GPS. A review of this has been undertaken and training given to the District staff to improve the recording of this data.

### **E2 - Area and quality of forest**

Data on area and quality of forest exists with Provincial FIPI; however, this is updated on an irregular basis (last updating was in 2000, from data sources collected in 1998). The FIPI system also uses Landsat TM satellite data, of which there is limited data from 2003, due to a malfunction of the satellite.

The Green Corridor project and EO-STEM have undertaken a forest cover mapping of all Hues forests using SPOT 5 satellite data from 2004/5. This involved ground truthing and training of local counterparts. A forest cover map is now being produced and the efficacy of using this as a data source for forest cover mapping in Vietnam is being investigated. If this new methodology is successful the project intends to update this data in 2008 for project monitoring.

From this data, analyses can be undertaken on the types of forest (poor, medium, rich) and the change in area; in addition, analysis can be undertaken on forest loss, fragmentation, patch size, encroachment, agricultural and plantation area. A separate report will be made on this and detailed analysis of the indicators presented.

In addition, the Thua Thien Hue Forest protection Department have a project funded by the province to establish a forest cover monitoring project and it will be responsibility of FPD to collect this data and feed into the provincial information system.

### **E3 - Degree of fragmentation**

GIS Analysis of the forest cover data allows us to determine a fragmentation index, and high priority corridor areas and those vulnerable to fragmentation will be identified. Forest cover analysis in the final year of the project will be undertaken to determine changes in these areas. In addition, fixed point landscape photography will be undertaken in July 2006 for areas vulnerable

along the Ho Chi Minh highway to monitor impact of erosion and encroachment on this area. This area has been identified as a high priority and critical habitat in the WWF Central Truong Son Initiative (MARD and WWF, 2004). Preliminary baseline assessments have been undertaken along the Ho Chi Minh highway under the DANIDA funded “Mitigating the Impacts of the Ho Chi Minh highway project’ which is implemented by FPD and WWF Vietnam.

#### **E4 - Abundance of key indicator species**

A number of biodiversity surveys in taxa ranging from plants to butterflies have been undertaken in 2005. This data acquisition gives an understanding of broad biodiversity patterns and the value of the Green Corridor in a regional context. However, it neither is unlikely that this will be useful for a monitoring program nor is repeatable.

The biodiversity-monitoring program will focus on key flagship species, in particular, primates, pheasants, Saola, tiger and tiger prey. This will consist of the following:

Sketch mapping involving local communities was undertaken in 2005 to determine key populations of flagship species, assess the degree of threat and to work with local communities. This the final year of the project to determine changes in flagship species and to assess local communities change in knowledge about an area. Flagship species consisted of Edwards’s pheasant, tiger, Saola and primates.

Primate surveys have been undertaken in all the forests of Hue, under the USFWS Gibbon Conservation project. These will be repeated on an annual basis.

Four long-term monitoring plots will be undertaken in Phong Dien Nature Reserve, Bach Ma National Park and A Luoi District (A Roang Commune; also proposed Saola Nature Reserve and site of one Community Forestry pilot) and in Nam Dong District (Thung Lo / Thuong Long commune; also the proposed Bach Ma National Park; and the site of proposed community forestry pilot). The monitoring plot will consist of Douc langur and gibbon census trails, tiger and tiger prey fixed plots. Data will be collected by Forest Rangers and inserted to database.

#### **E5 - Number of Illegal Activities**

The provincial FPD regularly maintain records of the number of arrests, violations and prosecutions. This data will be fed into the information management system.

In addition, to the above indicators the project is developing an enforcement data collection system which will train rangers on patrol to collect data on human activity, including illegal logging, traps, fires etc. This data will be collected at

District level and managed on PARCMAN databases system (an Access database that can be exported to MAPINFO or other database system). These indicators will provide information for the FPS to plan and manage enforcement activities.

In addition, an undercover wildlife trade survey is to be conducted in July, which will establish a baseline on illegal traders and restaurants selling wildlife products. This will data will be collected each year under the FPD illegal activity prevention work.

#### **E6 - Threat Reduction Assessment**

To measure how well a conservation project is succeeding, Margolis (2004) propose the use of Threat Reduction Assessment to determine the degree in efficacy and impact on reducing threats to forest and wildlife resources. This will be conducted at commune level in the project communes in June 2006 and repeated in June 2008.

**List of project impact indicators, with details regarding collection method, training needed and frequency of data collection and data collected to date.**

Issue	Indicator	Variable	Source of Data	Data Collection		Methods	Training / Other	Links to Other Databases
				Existing Data	Frequency of Collection			
<b>Ecology and Biodiversity Protection</b>								
1.1	Number and extent of forest fires	Number of forest fires per commune	FPD	2000-2005	Annual	FPD data collection and ground evaluation.	Training in forest fire data collection forms undertaken (Summer 2006).	FORMIS
1.1	Number and extent of forest fires	Extent of forest fires per commune	FPD	2000-2005	Annual	FPD data collection and ground evaluation.	Training in forest fire data collection forms undertaken (Summer 2006).	FORMIS
1.1	Number and extent of forest fires	Cause of forest fires per commune	FPD	2000-2005	Annual	FPD data collection and ground evaluation.	Training in forest fire data collection forms undertaken (Summer 2006).	FORMIS
1.1	Number and extent of forest fires	Extent of forest fire by forest type per commune	FPD	2000-2005	Annual	FPD data collection and ground evaluation.	Training in forest fire data collection forms undertaken (Summer 2006).	FORMIS
1.2	Area and quality of forest	Area of forest type by Govt classification by subcompartment / compartment	FIPI (1999); Govt classification done in 1998 and 1999 using LANDSAT data	1999	Not known	Note: The satellite system used for government classification no longer exists. The Vietnamese government will have to re-evaluate how forest cover mapping is undertaken; GCP/EO-STEM propose the use of SPOT 5 data.	Collobartive project with EO-STEM/FIPI to develop improved forest mapping.	FORMIS
1.2	Area and quality of forest	Area of forest quality by subcompartment / compartment	EO-STEM/FPD/GCP (2005) data collected using SPOT 5 satellite from 2005	2005	Jun-08	EO-STEM & FIPI produce technical evaluation and review in 2006.	Training in forest mapping and classification undertaken by EO-STEM project; EO interpretation to be undertaken in late 2006.	FORMIS
1.2	Area and quality of forest	Area of change of high conservation value forest	GIS analysis	2005	Jun-08	High conservation value forest identified through GIS analysis and provincial processes in mid 2006; baseline will be established based on Forest Cover mapping.	GIS training undertaken for 20 officers in Hue; follow up for more technical aspects will be undertaken.	

Issue	Indicator	Variable	Source of Data	Data Collection		Methods	Training / Other	Links to Other Databases
				Existing Data	Frequency of Collection			
1.3	Degree of fragmentation	Fragmentation index for forest areas by compartment	GIS analysis and change in fragmentation hotspots	2005	Jun-08	Fragmentation hotspots and corridors identified through GIS analysis and provincial processes in mid 2006; baseline will be established based on Forest Cover mapping.	EO-STEM and FIPI develop methodology.	
1.3	Degree of fragmentation	Change in identified fragmentation hotspots	Fixed-point landscape photography	2006	Jun-08	Fixed-point photograph database linked to MAPINFO database.	Training on photograph monitoring and GPS location undertaken in March 2006; initial photography undertaken of hotspots sites along Ho Chi Minh highway in June 2006. Other fragmentation hotspots to be identified through GIS analysis in July.	
1.4	Abundance of key indicator species	Flagship species distribution	GCP / FPD sketch mapping and local interviews	2005	Jun-08	Community-based interviews and mapping of flagship species abundance and change; communities re-evaluated in 2008.	Training conducted in 2005 on sketch mapping, map reading, working with local communities and planning of surveys of 20 FPD Rangers.	
1.4	Abundance of key indicator species	Change in primate distribution and abundance	GCP / FPD surveys	2005	Jun-08	Baseline data established through primate census in all forest areas in TTH province in 2005.	Training conducted in survey methods and monitoring methods (2005).	
1.4	Abundance of key indicator species	Change in tiger distribution and abundance	GCP / FPD surveys	2006	Jun-08	Baseline data established through tiger census in all forest areas in TTH province in 2005.	Training conducted in survey methods and monitoring methods (2005).	
1.4	Abundance of key indicator species	Change in long-term biological monitoring plots	GCP / FPD surveys; four monitoring plots in Phong Dien Nature Reserve (Hong Ha commune); A Luoi District (A Roang commune); Nam Dong District (Thuong Long / Thuong Lo) and Bach Ma National Park (Huong Loc)	2006	Biannual	Establishing monitoring plots for tiger / tiger prey survey; gibbon and primate survey transects and listening posts.	Training conducted in monitoring and survey methods (2005 and 2006).	

Issue	Indicator	Variable	Source of Data	Data Collection		Methods	Training/ Other	Links to Other Databases
				Existing Data	Frequency of Collection			
1.5	Number of illegal activities	Number of violations per commune	FPD	2000-2005	Annual	FPD data collection.	NA	FORMIS
1.5	Number of illegal activities	Number of arrests per commune	FPD	2000-2005	Annual	FPD data collection.	NA	FORMIS
1.5	Number of illegal activities	Number of prosecutions per commune	FPD	2000-2005	Annual	FPD data collection.	NA	FORMIS
1.5	Number of illegal activities	Human and illegal activity monitoring per commune	FPD/ GCP	Jul-06	Bimonthly	Methods for enforcement patrol data collection will be implemented in July 2006, and managed on PARCMON Version II database system (ACCESS / MAPINFO).	Training in data collection methods for rangers; Training for IT team in PARCMON II database management in July-August 2006.	
1.5	Number of illegal activities	Number of enforcement patrols per Ranger Station	FPD/ GCP	Jul-06	Bimonthly	Methods for enforcement patrol data collection will be implemented in July 2006, and managed on PARCMON Version II database system (ACCESS / MAPINFO).	Training in data collection methods for rangers; Training for IT team in PARCMON II database management in July-August 2006.	FORMIS
1.6	Threat reduction assessment	Level of commune threat assessment scores	GCP / FPD	Jun-06	Annual	Threat Reduction Assessment will be conducted using methodology developed by Marguolis and Saa (2003).	Training conducted by survey team in June 2006.	

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**Appendix 4**

**MARD Forest Classification  
System**

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## A4.0 MARD FOREST CLASSIFICATION SYSTEM

The classification scheme used in this analysis to develop a forest type map followed the government of Viet Nam standard (GCP 2006), which is shown in Table A4.1 below.

**Table A4.1 Class definition for Vietnamese Classification of Evergreen Natural Wooden Forest Types.**

<b>Group I: Non-forest. Only grasses, bushes with very few trees, scattered bamboos; coverage index is under 0.3. This group has 3 sub-groups:</b>
IA: Characterized by grasses, bushes or wild bananas.
IB: Characterized by bushes, scattered wooden trees and bamboos.
IC: Characterized by high density regenerating trees. Trees taller than 1m and more than 1,000 trees/ha.
<b>Group II: Regenerating forest with pioneer species that have smaller diameter. Based on status and origin, there are 2 sub-groups:</b>
IIA: Regenerating forest after agricultural activities, characterized by pioneer species that are fast growing and prefer light. Trees are of similar age and there is only 1 story.
IIB: Regenerating forest following heavy exploitation for timber. Young community with species preferring light; diverse species composition; trees of different ages; dominance is not clear. There are maybe some big trees remaining, but the numbers are not relevant. Forest is only classified into this group if the community with the commonest diameter not more than 20cm.
<b>Group III: Impacted secondary forest. Communities have been exploited, which has changed the structure of the forest. Depending on exploitation levels and the potential products, there are two sub-group recognized:</b>
IIIA: Heavily exploited communities; present potential for exploitation is limited and the structure of the forest is significantly changed. There are 3 sub-groups:
IIIA1: Most heavily exploited forest. The upper story may have some large trees, but generally the forest is of low quality with numerous of vines, bushes, and bamboos.
IIIA2: Heavily exploited, but significant time for regeneration. Characterized by the middle story becoming dominant with majority of trees in this story having a diameter of 20-30cm. The forest has at least 2 stories; the upper story coverage is not continuous, being mostly established by the trees from the lower story before; there are maybe a few large trees.
IIIA3: Exploited forest or forest developing from IIIA2. The communities have a relatively closed coverage, having at least 2 stories. The main difference form type IIIA2 is the number of trees is higher and there are some trees with diameter more than 35cm.
IIIB: Characterized by communities that have been selectively logged, with some valuable wooden species exploited. The stable structure of the forest hasn't changed; biomass is high with a high percentage of large trees.
<b>Group IV: Pristine forest, stable forest. Pristine forest or matured secondary forest that hasn't been exploited. The forest has a stable structure, multi-story, diverse diameter sizes, but sometimes lacking lower story. There are 2 sub-groups:</b>
IVA: Pristine forest
IVB: Regenerating secondary forest.

From Ministry of Natural Resources and Environment; translated and provided to EO-STEM by GCP (2006).