KEW-ELIASCH REVIEW CONSULTATION

Report to the Office of Climate Change

Rapid forest inventory and mapping
Monitoring forest cover and land use change

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1 Executive summary

Vegetation-based carbon offset mechanisms require reliable baseline data and effective monitoring systems. The most basic information requirements include definitions of vegetation types, spatial distribution (mapping) and biomass estimates. However increasing convergence between carbon offsets, biodiversity offsets and the valuation of ecosystem services places a correspondingly greater emphasis on the integration of species-level biodiversity data and ecological factors in such evaluations.

In Section 3 of this paper, a series of rapid vegetation survey techniques is outlined, based on Kew's practical experience of survey and inventory of natural vegetation types and species assemblages across the globe. Details of the methodologies are explained, and examples of their application in a variety of contexts are given. These range from rapid, desktop studies using remote sensing imagery to measure trends in forest cover to full, multiphase, desktop and ground survey methods where data on biodiversity can be gathered in combination with information on biomass and carbon sequestration, ecosystem services, vegetation dynamics and other features.

At the rapid end of the scale, desk based survey, using satellite imagery or aerial photographs in isolation, can provide information on forest cover, vegetation dynamics and trends, but little or no information on biodiversity, ecosystem services or carbon sequestration. When this approach is combined with quantitative ground survey, however, baseline information on all of the above can be gathered, and trends can be monitored in the long term. This type of full survey enables comparisons to be made between different vegetation types and, depending on the size of the area to be surveyed, can be rapid.

In Section 4, examples are given of the application of the above methods to monitoring deforestation trends, maintenance of old growth forest and forest regeneration at a range of scales. These same methods can equally be applied to monitoring afforestation or reforestation programmes. Examples are given of the application of monitoring techniques in measuring past and present trends in vegetation cover and floristic content. In addition, the applicability of these methods to predictive mapping of vegetation responses to climate change and other threats is discussed.

Monitoring activities range in scale from landscape to single populations, and it is argued that all of these approaches are essential to monitoring, understanding the impacts and managing vegetation in future climate change contexts. Choice of technique is generally influenced by a number of factors including scale/resolution, timing, cost and available resources and data.

2 Introduction

2.1 Institutional background

The Royal Botanic Gardens, Kew is a botanical institution and an exempt charity whose mission is **to inspire and deliver science-based plant conservation worldwide, enhancing the quality of life**.

Working with its international, national and local community partners, Kew is focusing our efforts on inspiring and delivering science-based plant conservation in response to the daunting challenges of declining plant diversity and climate change. The nine core strategies that provide the framework for setting Kew's priorities include the following: engagement and learning; global conservation and sustainability; high quality, high impact research; world-class horticulture; capacity building and collaboration; world heritage; policy and advocacy; empowering staff and volunteers; and resources and infrastructure.

Kew has statutory responsibilities under the United Kingdom National Heritage Act 1983 to carry out research into plant science, care for the living and preserved collections, and share the resulting knowledge. There is a long tradition of public access for the purposes of education and enjoyment.

Since the 1770s plant specimens have been collected and despatched to Kew from around the world. This has resulted in the collation of internationally significant collections including approximately seven million herbarium specimens. Traditionally used to describe species and compile floras, these are increasingly applied to mapping global species distributions, assessing conservation status, measuring changes in flowering period through time, and more recently as a source of DNA for taxonomic research. These collections are the indispensable points of reference that underpin all Kew's programmes, and are necessary for any meaningful study of plant diversity.

2.2 Kew's developing role in forest and climate issues

Kew is actively engaged in developing systems for meeting the needs of a changing world by integrating high-quality biodiversity information and expertise with existing and novel techniques for monitoring vegetation and associated ecosystem services. This is achieved through a cross-disciplinary approach, involving the engagement of botanical specialists in system development and implementation, in parallel with integration of these techniques into standard field and data management procedures. Also, Kew is establishing data standards that will help to ensure that information collected, even where not specifically for these purposes, may subsequently be used to further understanding of long-term global vegetation trends.

In order to maximise uptake and impact, Kew is developing consultative and collaborative processes with a wide range of other practitioners, including the private sector, learning from practical experience focused on the various fields in which relationships between biodiversity and ecosystem services are crucial, and building capacity through targeted training programmes. Relevant areas of activity/interest include: in situ conservation; biodiversity action planning; seed conservation and habitat restoration; sustainable use of natural resources; developing understanding of the relationship between biological diversity and ecosystem resilience in a changing climate; and optimising shared benefits of biodiversity and carbon offsets. By integrating systematic biodiversity-focused techniques and skills with this wider range of issues, Kew is aiming to add value and maximise efficiency whilst raising the scientific integrity of the processes involved.

Table 1: Summary of methods

Approach	Contexts where used	Strengths	Limitations	Technical skills & knowledge	Biodiversity/ Carbon measure	Time (HML)	Cost (HML)	Examples Kew
Desktop: Photo interpretation	Vegetation mapping and monitoring in a wide range of contexts, including conservation/ landscape planning, baseline surveys etc. Choice of technique depends on resources, urgency, resolution requirements and desired accuracy.	Small areas can be interpreted very quickly. Does not depend on any other data.	No quality control. Data not always easily accessible.	Knowledge of area and photo-interpretation but little technical skills required.	Can be used for measuring carbon sequestration trends, e.g. maintenance of old growth forest or afforestation, PROVIDED that full baseline survey has been carried out in the past. Of limited use for measuring biodiversity trends.	L	L	Oku
Desktop: Unsupervised classification		Quick if imagery available. Mature methods that are well researched.	No quality control means validity of results can be a total unknown. Only really suited to medium-low resolution imagery (5+ metres).	Remote sensing skills required to understand results.		L/M	L	Brazil (Cristalino)
Desktop Supervised Classification		Can be quick. Has quality control. Mature methods that are well researched.	Only really suited to medium- low resolution imagery (5+ metres).	Knowledge of area required. Remote sensing skills needed to understand results.		L/M	L	Madagascar
Desktop: Statistical analysis object based classification		Can be used on all resolutions of images. Potentially fast.	Computer-intensive and technology still in its infancy. Not yet implemented into real projects	Very high skill level in remote sensing and computing.		M	M/H	
Desktop: Statistical analysis (niche modelling)	Used for future and climate modelling of vegetation (e.g. predicting viability of forests) and informing habitat restoration. Also for modelling past vegetation distribution.	Can be used in areas where satellite data hard to get or expensive, or where ground truthing impossible. Provides a better understanding of requirements of vegetation types. Can be combined with field-based data.	Relies on various unknown factors; only as good as the data and models that support it. Species-level response to predicted environmental change poorly understood. May be difficult to understand the outputs.	Requires detailed understanding of relationship between vegetation distribution and environmental factors. High level of statistical analysis.		M	L/M	Montserrat

Approach	Contexts where used	Strengths	Limitations	Technical skills & knowledge	Biodiversity/ Carbon measure	Time (HML)	Cost (HML)	Examples Kew
Field Methods: Field sketching	Generally used to supplement other mapping/sampling techniques.	Fast and simple.	No quality control.	Requires sound understanding of vegetation communities.	Adds some qualitative data about biodiversity and vegetation dynamics.	L	L	
Field Methods: Qualitative data collection	Used primarily for obtaining good understanding of vegetation distribution for planning and monitoring	Can be quick and relatively simple with the use of standard data forms. Field data may be acquired through other trips not specific to the survey.	Only useful for vegetation mapping – no quantitative data. Much travelling required to complete picture effectively over large area.	Relatively low technical skills required; some training needed.	Useful for qualitative measures of biodiversity and understanding vegetation dynamics. Adds little to carbon sequestration measures provided by satellite data.	L/M	M	Madagascar
Field Methods: Quantitative data collection (composition, structure)	Used where detailed data required for species-based decision-making, high-resolution monitoring, biomass evaluation etc.	Provides most field data needed for a full (level 4) survey. Allows full analysis of biomass, biodiversity etc.	Time consuming.	Knowledge of survey techniques and vegetation communities required. Botanical identification resources necessary if species-level data required.	Very useful in generating quantitative information about biodiversity, vegetation dynamics and carbon sequestration. Enables differentiation of biodiversity and capacity for C-sequestration between different vegetation types.	H	H/M	Guinea, Brazil (Corumbá, Cristalino), Bolivia
Field methods: Permanent transects and quadrats	Long-term monitoring of landscape and vegetation change (disturbance, vegetation composition, biomass).	Verifiable data and repeatable observations. Provides basis for high-resolution monitoring.	Time consuming to establish; and investment of effort may be lost if vegetation destroyed.	Knowledge of survey techniques and vegetation communities required. Botanical identification resources necessary if species-level data required.	Very useful in generating baseline and trend information about biodiversity, vegetation dynamics and carbon sequestration. Enables differentiation of trends between different vegetation types.	H/M	H/M	
Field methods: Photographs	Baseline vegetation surveys for future monitoring (fixed point images).	Simple and cheap; allows visualisation for non-specialists. Repeatable if georeferenced.	Long-term image storage and retrieval presents challenges.	Little specialist expertise required.	Enables coarse understanding of vegetation dynamics and, by association, biodiversity & C-sequestration	L	L	Madagascar, Guinea, Brazil

Approach	Contexts where used	Strengths	Limitations	Technical skills & knowledge	Biodiversity/ Carbon measure	Time (HML)	Cost (HML)	Examples Kew
Survey: Expert knowledge (level 1)	Vegetation mapping and monitoring in a wide range of contexts, including conservation/ landscape planning, baseline surveys etc. Choice of technique depends on resources, urgency, resolution requirements and desired accuracy.	Fast and simple. Captures local knowledge/expertise.	No quality control. Does not provide one-time 'snapshot' of situation.	Requires detailed, reliable local knowledge.	Some, limited qualitative measure of biodiversity possible	L	L	
Survey: Rapid mapping (level 2)		Fast and relatively simple.	Not ground truthed: validity of interpretation uncertain.	Requires GIS expertise and some understanding of local vegetation types and distribution.	Measure of carbon sequestration trends and vegetation dynamics possible but only if level 4 baseline survey carried out in the past.	L/M (project dependent)	L/M (project dependent)	Oku
Survey; Two-phase (level 3)		Results can be obtained and communicated reasonably fast. Can cover larger areas quickly.	Lacks the quantitative element, and often impossible to sample all vegetation types in one visit and understand seasonal change.	Requires GIS expertise and good understanding of local vegetation types.	Very useful in generating quantitative information about biodiversity, vegetation dynamics and carbon sequestration. Enables differentiation of biodiversity and capacity for C-sequestration between different vegetation types.	L/M/H (project dependent)	L/M/H (project dependent)	Madagascar, Mozambique, Zambia
Survey: Multi-phase (level 4)		Provides detailed understanding of vegetation types, species composition, biomass data as well as spatial information and specimen data.	Time consuming and relatively costly.	Combination of GIS, survey and botanical skills required. Understanding of vegetation types important for designing effective sampling strategy.	Very useful in generating baseline and trend information about biodiversity, vegetation dynamics and carbon sequestration. Enables differentiation of trends between different vegetation types.	M/H	M/H	Guinea, Zambia
Other techniques: Collections-based analysis of trends in species occurrence	Interpretation of long-term trends and conservation priorities.	Based on verifiable data already in existence and continuing to be generated by other activities.	Interpretation of results requires understanding of changing levels/foci of collecting activity. Some regions very data-poor.	Sound taxonomy and identification essential for meaningful results; statistical analysis required.	Useful for measuring population level trends in biodiversity. Enables differentiation between species and their responses to climate change or other threats.	H/M	M	Legumes of Madagascar, Sampled Red List
Other techniques: Ethno-mapping	Important where landscape and vegetation management decisions involve local communities	Captures local knowledge; results interpretable by stakeholders; promotes community engagement.	May be difficult to relate local vegetation classification to other classification systems.	May require anthropological/ linguistic skills as well as mapping and remote sensing.	Useful for augmenting survey information with ecosystem services data.	M	M	Brazil (new project), Zambia

3 Rapid forest inventory and mapping at Kew

3.1 Overview

Kew has a long history of forest inventory in the tropical and temperate zones, and its collections reflect world history and global change as well as forest richness. Vegetation mapping using remote sensing techniques is a relatively recent addition to our work, in which we are combining advanced mapping with more established knowledge of plant surveying and botanical inventory. Field survey techniques allow us to produce a picture of the structural biomass of the area, as well as calculating overall biodiversity and conservation potential and identifying priority taxa and habitats. This integrated approach enables us to scientifically underpin our mapping with first class biodiversity information.

Vegetation mapping is an important tool in determining what makes up an area and why it may be important. We apply mapping techniques to assess distribution and composition of species assemblages. In doing this we can draw up the boundaries of vegetation types and assess the factors influencing their distribution. For example, by overlaying edaphic and ecological parameters such as altitude, geology and climatic data, we can identify critical habitats and thus make evaluations in terms of conservation value and mitigation. This is particularly important in some of our mapping projects with business partners.

The process begins with assessment of satellite imagery and aerial photographs, on the basis of which vegetation is grouped into broad categories. Targeted fieldwork is then undertaken to determine whether those vegetation types hold true on the ground. Vegetation characterisation relies heavily on the collections and information recorded during the survey. Kew is developing new systems for standardising field data collections using Personal Data Assistants, thus increasing the efficiency and speed of survey without compromising quality. Structural and floristic composition can be difficult to distinguish from aerial imagery without expert knowledge of the area, so ground truthing is an essential part of the mapping process. The botanical expertise of Kew's staff and those of its overseas partner organisations is a vital component of this process, allowing rapid, science-based, verifiable evaluations.

On a project-by-project basis, the techniques employed by Kew to undertake this research are dependent on several factors. Resolution on the ground, mapping scale and resolution in the vegetation classification, for example, are all important in determining the approach which will deliver the best output. Equally significant are level of access available for ground truthing, timing or urgency of mapping results, and satellite data availability.

Kew has experience in both large- and small-scale mapping, which are incorporated into many of the projects undertaken in conjunction with conservation partners and with the private sector e.g. mining companies. There is a wealth of experience in vegetation characterisation and capacity building gained through our projects and courses, resulting in high quality vegetation inventories backed up by well-documented specimen collections.

The majority of vegetation mapping undertaken by Kew results in real conservation action on the ground, implemented by both non-governmental and governmental organisations. Kew's place on the international stage has been used to bring specialists together to map regions and gather ground control data. Kew is then able to deliver the results and data in a succinct and digestible manner, using both traditional papers and maps and, increasingly, the Internet.

3.2 Methodologies

There are a large number of methods employed in rapid vegetation mapping. Many of the surveys undertaken by Kew employ a range of these methods in combination. For the purposes of this report, these are split into field methods and desktop methods:

3.2.1 Desktop methods

- Photo interpretation
- Classification of satellite imagery
    - Supervised
    - Unsupervised
- Statistical analysis using environmental layers (i.e. rainfall, temperature, elevation and soils – similar to niche modelling)
- Herbarium specimen data collection, mapping and interpretation
- Classifying vegetation according to regional and global frameworks, and applying international standards to nomenclature.

3.2.2 Field methods

- Field sketching/mapping
- Qualitative data collection (recording what is present at given points)
- Quantitative data collection (giving numbers and values to vegetation types)
- Permanent transects and quadrats
- Photographs

Kew has standards for field data collection and the use of handheld computers in the field (also known as PDA - Personal Data Assistant).

3.3 Methodology levels

The level of detail at which a survey is carried out depends on the outcomes required as well as the time and resources available. There are four main levels, outlined below.

3.3.1 Expert knowledge (level 1)

This involves sketch mapping from expert knowledge of the region. This approach is rarely used today, but in the past some areas have only been mapped using this methodology. Unfortunately, although quick, accessible and low-cost, the method is often unreliable, being spatially inaccurate. An expert's knowledge is built up over time, so the impression one gains of the area is not necessarily representative of the current situation. Furthermore such surveys are only as good as the expert, and can only be used if there is an expert for the region. This approach is generally used for mapping eco-regions and not for vegetation at the habitat scale.

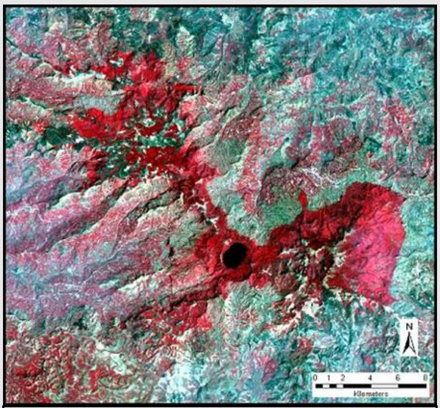
3.3.2 Rapid mapping from satellite imagery/aerial photographs (level 2)

This methodology applies a combination of expert knowledge and dated satellite imagery of the area. The approach is often used to study areas that have highly distinguishable vegetation types or where the vegetation classification is straightforward e.g. forest, grassland. The major drawback with this method is that the surveyor cannot be sure that his interpretation of the imagery truly reflects the reality on the ground, since no ground truthing is carried out. This is a quick and cheap way to map vegetation.

Kew applied this methodology to the mapping of Mount Oku in Cameroon in 2001, using expert field knowledge of the area and desktop classification of satellite imagery for conservation planning and monitoring.

CAMEROON: Mount Oku. Mapping area $800km^2$, Mapping scale 1:50,000

Project Partners: RBGKew (Lead), Birdlife international and University College London



False Colour Image (red is forest)

Overview: Mount Oku and the Ijim Ridge is the largest remaining patch of montane forest in West Africa. It has exceptional levels of flora and fauna endemism – especially amongst birds. For this reason, since 1987 an important conservation project managed by Birdlife International has been working in the area, aiming to reduce forest loss and to improve agricultural practices. This mapping project assessed on the ground effects of the conservation effort in this region. These were measured using traditional classification of remote sensing data combined with aerial photographs for the older dates. Due the rapid change in terrain and the varying nature of the imagery, all the data had to be corrected using elevation models derived from radar satellite data. The results show strong spatial patterns of deforestation between 1958 and 1988 (more than 50 % of the montane forest was lost in this period) followed by a regeneration period starting in 1988, just after the Conservation Project was created. In this last 1988-2001 period, 7.8 % of the 1988 extent of montane forest had been recovered, mainly on the eastern side of the mountain.

Outputs: Website, Data distributed to NGOS and papers.

References:

Baena S., Moat J. and Forboseh P. Monitoring vegetation cover changes in Mount Oku and the Ijim ridge (Cameroon) using satellite and aerial sensor detection. (in press) 2008

http://www.kew.org/gis/projects/oku_cameroon/index.html

3.3.3 Two phase mapping (level 3)

This technique provides detailed and rapid mapping. Using satellite imagery or possibly aerial photography to perform an unsupervised (if the region is unknown) or preliminary supervised classification, this is then followed by a single ground visit. This is a relatively rapid method that will provide better spatial and temporal information on the vegetation than using aerial imagery alone. This approach tends to use qualitative data collection methods, the aim being to obtain a quick snapshot of vegetation structure and composition and is most appropriate for large areas. The drawbacks to this approach are that it is not always possible to visit every vegetation polygon (thus, smaller species assemblages may be missed) and that the data collected do not generally allow fine scale monitoring of vegetation trends in the future.

Most recently Kew has used this method to survey montane forests in Mozambique and Malawi.

MOZAMBIQUE: Mounts Chiperone, Namuli, Mabu. MALAWI: Mounts Mulanje and Mchese. Mapping area 40,000km^2, Mapping scale 1:125,000

Survey date: satellite imagery 2002-2006; ground data 2005-2008

Survey level: Aerial survey with one ground visit. Mt Mulanje full survey

Field methods used: Qualitative data collection and expert knowledge

Purpose: The project's main purpose is to gather information and develop tools and skills to enable biodiversity management and monitoring across these montane ecosystems.

Project Partners: RBG Kew, Birdlife International, Mulanje Mountain Conservation Trust (MMCT), Forestry Research Institute of Malawi (FRIM), National Agricultural and Natural Resources Research Institute, Mozambique (IIAM)

Overview: Mozambique and Malawi is trying to identify the most significant areas for conservation and to develop the capacity and skills to manage them, before they are lost to agricultural expansion and unsustainable utilization. The national institution in Mozambique tasked with this initial conservation evaluation is the National Agricultural and Natural Resources Research Institute (IIAM) and more specifically the National Herbarium and Forestry Research departments in conjunction with the institute's GIS unit. Project activities include: (1) carrying out field surveys of plant species, vegetation and birds, (2) training a team of researchers and fieldworkers from Mozambique and Malawi to gather and utilize data for both management and monitoring, (3) developing species and habitat recovery plans, (4) developing a broad scale monitoring programme for each area, and (5) making recommendations and promoting conservation management to the appropriate national or regional authorities.

Outputs: A series of technical reports will be compiled, one for each montane area, bringing together existing information and assessments. These reports will detail the occurrence and extent of important habitats and species, and will make recommendations for their long term conservation. They will also act as a basis for conservation advocacy by IIAM.

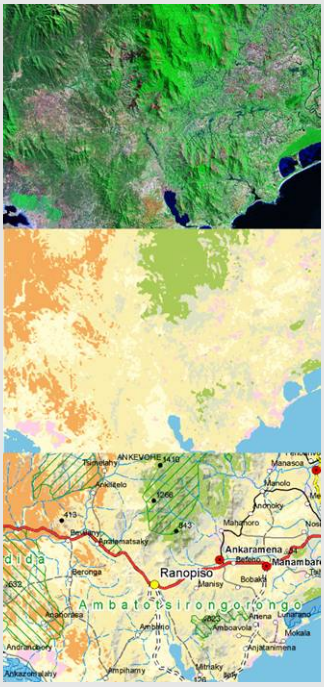
References:

http://www.kew.org/science/directory/projects/annex/ChiperoneTechReport.pdf

This approach has also been employed by Kew and its partners at the national level in Madagascar, where the Madagascar Vegetation Mapping Project produced the country's first ever vegetation atlas in 2007. This was a major milestone for biodiversity knowledge in one of the world's most significant and threatened biodiversity hotspots. The atlas is now being applied for conservation planning and prioritisation and as a baseline for monitoring programmes.

MADAGASCAR: Approximate area mapped: 590,000 km^2, Mapping Scale: 1:500,000 (final mapping scale) – 1:125,000 (working scale)

Survey date: satellite data 2000 – 2002; ground data 2003-2006



Survey level: Aerial survey with single ground visit

Field methods: Qualititative, ground point data onto field data forms.

Desktop methods: Classification of imagery and some statistical analysis

Purpose: Inform conservation planning in Madagascar, to establish a base line for Madagascar's vegetation and bring it into an international standard.

Project Partners: RBGKew (Lead), Missouri Botanic Gardens and Conservation International

Overview: The Madagascar Vegetation Mapping Project was a four year project (2003-2007), funded by the Critical Ecosystem Partnership Fund (CEPF) and managed jointly by The Royal Botanic Gardens, Kew, Missouri Botanical Garden, and Conservation International's Center for Applied Biodiversity Science. The project was innovative in a number of ways. It employed state of the art remote sensing technology and methodologies to delimit Madagascar's vegetation. It represents an all-inclusive collaboration between specialists from a wide range of botanical and conservation institutions, which resulted in the most thoroughly ground truthed vegetation map ever compiled for Madagascar. Finally, through a series of workshops, it incorporated detailed consultations with the conservation community to ensure that final products were of maximum relevance and utility to conservation planners and managers.

Outputs: Website with all data and methodology printed atlas, papers, posters (for education purposes) and CDROM for local distribution in Madagascar:

References:

Moat J. and Smith P. (Editors): *Atlas of the Vegetation of Madagascar Vegetation / Atlas de la Vegetation de Madagascar*. Kew Publishing UK 2007

http://www.vegmad.org/

http://www.kew.org/press/madagascar_atlas.htm

3.3.4 Full surveys (level 4)

Full surveys include the use of satellite imagery or aerial photography with extensive ground survey work. The ground survey component includes the collection of quantitative data such as plant biomass, species density, dominance and frequency. These surveys are scientifically robust and have quality control built into them. They are also repeatable, allowing them to be used as the basis for detailed monitoring. The downside is that they can be more expensive and time consuming.

The quantitative forest survey techniques employed in these projects include quadrats and plotless sampling techniques (e.g. point-centred quarter transects) depending on the nature of the vegetation and other determining factors. These provide standard structural data that can serve as the basis for biomass/carbon estimates.

The majority of Kew's mapping work has employed full surveys incorporating a number of different methods to produce a comprehensive scientific study. If they are to be rapid, these studies are best carried out on smaller areas. This kind of mapping has taken place in many countries for example Zambia, Botswana, Guinea (Conakry), Brazil and Montserrat.

In Zambia, for example, this method was used to map the vegetation of Mutinondo Wilderness Area (MWA), where information was needed on woody biomass and its carbon sequestration capacity. In addition, the MWA managers required an inventory of useful plants for local communities.

ZAMBIA MUTINONDO WILDERNESS AREA: Approximate area mapped: 100 km^2, Mapping Scale: 1:10,000

Survey date: satellite data 1999; ground data 2003

Survey level: Full survey

Field methods: Quantitative, ground point data onto field data forms; permanent transects.

Desktop methods: Classification of imagery and some statistical analysis

Purpose: To identify unusual habitats and plants; to map the vegetation of MWA; to assess the plant diversity of MWA; to identify useful plants; to assess the potential for carbon sequestration in MWA's miombo; and to provide training to Zambians in botanical survey techniques.

Project Partners: RBGKew, Zambian Forestry Department

Overview: During the fieldwork phase, plot-based and plotless methods were used to characterise the vegetation of MWA, and plant specimens were collected for identification. The study identified four major vegetation types in MWA. Detailed descriptions of each vegetation type were given, and for miombo woodland, plot data recording species density, biomass and frequency were analysed. These analyses suggest that MWA miombo is typical, mature plateau woodland, comparable with old growth miombo elsewhere in Zambia and the region. A preliminary vegetation map of MWA, based on Landsat ETM+ imagery, and showing the four major vegetation types was produced. The plant species recorded in MWA comprise ca. 400 species, indicating that the botanical diversity of MWA is very high. Common woody species were assessed for their utilitarian value, and of the 100 species analysed, 67 were reported in the literature as being sources of non-timber products and 39 were useful timber species. Carbon biomass in MWA was measured and the relevance of old growth miombo carbon sinks to the Clean Development Mechanism of the Kyoto Protocol was discussed. Finally, recommendations were made for the continued study, protection and management of the vegetation of MWA.

Outputs: A map of the vegetation of MWA, quantifying major habitats; Useful plants list; Plant diversity of the MWA assessed, and a checklist produced; The potential for carbon sequestration in the MWA assessed; Zambian counterparts trained in botanical survey techniques

References: Smith, P.P. (2003). A reconnaissance survey of the vegetation of Mutinondo Wilderness Area. Report for Mutinondo Wilderness Ltd. Royal Botanic Gardens, Kew.

In Botswana similar approaches have been applied to surveying the vegetation of the Orapa and Jwana Game Parks to provide a baseline against which to monitor the vegetation response to stocking levels. This work can also be used to look at other factors affecting the vegetation over time, including the effect of invasive alien plants. Transects and point plots were used to gather data and classification was developed using satellite imagery (Jwana) and aerial photography (Orapa).

BOTSWANA: Orapa Game Park (OGP). Approximate area mapped: 120 km^2, Mapping Scale: 1:10,000

Ground date: December 2001

Survey level: Full survey

Field methods used: Quantitative survey; transects and point plots.

Purpose: To map the vegetation of the Orapa Game Park as a baseline against which to measure changes to the vegetation due to stocking levels and other factors

Desktop methods: Classification of aerial photography

Project Partners: RBG Kew (lead), Botswana National Tree Seed Centre, Botswana Forestry Dept., Botswana National Herbarium

Overview: During the fieldwork phase, plot-based and plotless methods were used to characterise the vegetation of OGP, and plant specimens were collected for identification. The study identified four major vegetation types in OGP. In addition, a further two sub-types were designated, and the flora of the OGP's waterholes described. Detailed descriptions of each vegetation type and subtype were given, and for woody vegetation types, plot data recording species density, biomass and frequency were analysed. A vegetation map of OGP, based on aerial photography, and showing the major vegetation types was produced. The plant species recorded in OGP comprise ca. 175 species, indicating that the botanical diversity of OGP is moderately high. The dominant grass species present in the OGP indicate that overstocking of grazers may have occurred in the past. However, at the time of this survey (April 2005) there was an abundance of good, palatable grass, and no signs of overstocking. The OGP has excellent browsing habitats and, again, no signs of overstocking were evident. Finally, recommendations were made for the continued study, protection and management of the vegetation of OGP.

Outputs: A vegetation classification of the vegetation communities in Orapa Game Park (OGP); Detailed descriptions of vegetation types/communities; An annotated list of plant species of conservation interest in the reserve; Recommendations for monitoring and management of the plants and habitats in the OGP.

References: P. P. Smith, K. Kemoreile, D. Mafokate, K. Mathibidi, E. Mosimanyana and S. Dickson (2005). A survey of the vegetation of Orapa Game Park. A Report for Debswana Mining Company. Royal Botanic Gardens, Kew

Kew is currently carrying out two vegetation mapping projects in Guinea (Conakry), working in partnership with mining companies. The first is to develop a vegetation map for the designated concession in the Simandou Mountains. This work is aimed at identifying plant species and habitats of conservation importance so as to enable Rio Tinto to minimise the environmental damage that may occur when the mine is set up. This involves surveying mountain areas outside the concession to offset areas as part of the mitigation process. The second is looking at vegetation in a coastal area where Alcoa-RT Alcan is in the process of setting up a new refinery. This project has similar objectives with regards to identifying critical habitats, but is also concerned with the people who will be displaced as part of the development. Both projects also involve capacity building of Guinean botanists and the setting up of a National Herbarium to facilitate future work in the country.

GUINEA CONAKRY: Pic de Fon. Approximate area mapped: 250 km^2, Mapping Scale: 1:20,000

Collecting Field data onto PDAs

Survey date: 2005-present

Survey level: Full survey, with several iterations

Field methods used: Quantitative, Transects.

Desktop methods: Classification of imagery and some statistically analysis

Purpose: The work is aimed at identifying plant species and habitats of conservation importance so as to enable Rio Tinto to minimise the environmental damage that may occur when the mine is set up.

Project Partners: RBGKew (Lead), Rio Tinto Guinea

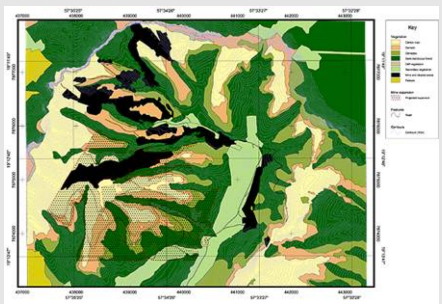
Overview: Kew's work in Guinea-Conakry is funded by a partnership with Rio Tinto, which is seeking permission to extract iron ore from the Simandou Range in Forestière Province. In 2005 we began to conduct a botanical inventory and vegetation mapping exercise in one part of the range.

Outputs: Reports and Data. First draft vegetation map for the Pic de Fon area produced in June 2006, with a botanical inventory to follow in July 2008.

Similar work has been undertaken in Brazil, on Rio Tinto Brazil's iron ore mine near Corumbá. This was a detailed, small-scale mapping project supported by extensive ground truthing, quantitative vegetation surveys and species inventory.

BRAZIL: Corumbá. Approximate area mapped: 30 km^2, Mapping Scale: 1: 10,000

Survey date: 2005



Survey level: Full survey

Field methods used: Ground truthing, collecting, plots and point-centred quarter transects

Desktop methods: Manual classification of high-resolution IKONOS imagery

Purpose: To provide baseline data to inform biodiversity action planning and biodiversity offsets

Project Partners: RBGKew (Lead), Universidade Federal de Mato Grosso do Sul, EMBRAPA

Overview: This rapid survey, undertaken over two weeks by a team of specialists with detailed knowledge of the local vegetation, is now serving as a vital reference for conservation-focused actions including habitat restoration and offsets in the context of proposed mine expansion.

Outputs: *Vegetation of the Morraria de Santa Cruz, Brazil.* Report to Rio Tinto Brazil/MCR.

Mapping of existing vegetation has also been effectively combined with predictive mapping in the Caribbean island of Montserrat. This has enabled the team to look at habitats previously existing in areas now inaccessible due to the volcanic eruption in 1997. This has enabled a more complete picture of the vegetation to emerge, helping to ensure that the Central Hills can be conserved and managed at the same time as accommodating all the needs of the island.

CARIBBEAN: Montserrat. Approximate area mapped: 100 km^2, Mapping Scale: 1:25,000

Survey date: 2007

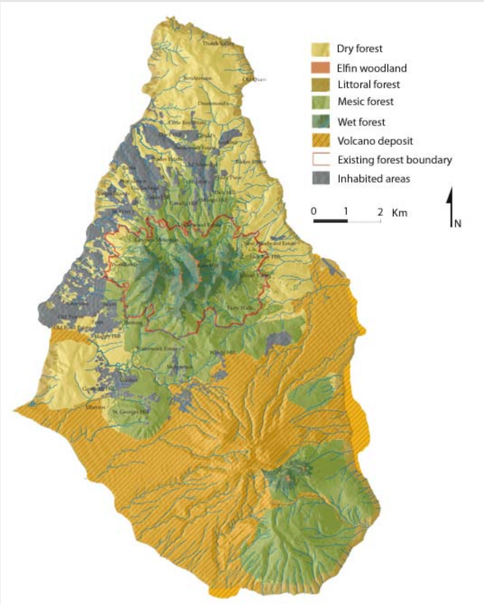
Survey level: Full surveys, with several iterations

Field methods used: Quantitative, ground point data onto field data forms, Permanent plots.

Desktop methods: Statistical methods, based on elevation and climate

Purpose: Conservation planning and demarcate reserve boundary

Project Partners: RBG Kew, Royal Society for the Protection of Birds (project lead), Department of Agriculture, Montserrat National Trust, Montserrat Tourist Board, Durrell Wildlife Conservation Trust. Supported with funds from the Darwin Initiative for the Survival of Species



Montserrat, vegetation cover

Overview: The Caribbean island of Montserrat was devastated by a huge volcanic eruption in 1997. This vegetation survey and map has been completed as part of the Darwin Initiative project 'Enabling the People of Montserrat to Conserve the Centre Hills'. As a result of extensive fieldwork undertaken during this project, planners and conservationists now have an accurate vegetation map and tool to help guide the island's recovery. Species and habitat monitoring continues to identify the most important areas for plant diversity. With wider collecting (as time allows) the aim is to produce a conservation checklist and Red List for the whole island. Permanent biodiversity assessment points were established by the project and on-going monitoring for several threatened species is helping to further GIS and general knowledge of the biodiversity of the island at a national level.

Outputs: Data and maps to Government and partners. Papers

References: http://www.kew.org/scihort/directory/projects/EnabMontserrCentreHi.html

3.4 Capacity Building

There is often an element of training in the projects that Kew is involved with. This is mostly 'on the job' training during fieldwork expeditions, but more recently it has extended to young botanists coming to Kew for internships, courses and specialised training. Over the past two years, 20 staff from different projects in the UK Overseas Territories have undergone specialised training in field data collection and use of handheld computers. Kew holds courses in tropical plant identification and vegetation survey and mapping in order to fill the gaps for field researchers. These courses are aimed primarily at capacity building for researchers in countries where Kew is working in partnership with national institutions to ensure high quality research. Many of the courses are held at Kew, allowing researchers access to the wealth of information held by staff and the collections.

4 Forest monitoring at Kew

4.1 Overview

Kew does not restrict itself to mapping and monitoring forest cover: our global focus requires that we work on a range of different vegetation types. Most of the examples given below relate to forest vegetation, but it is important to understand that vegetation types are dynamic. For example, many thicket vegetation types are derived from forest, and some have the capacity to revert to forest. Furthermore, it is very rarely the case that a single vegetation type such as forest can be managed in isolation. For example, impacts on forests are most frequently observed at their edges and it is therefore essential that the interactions between the forest and contiguous vegetation types are thoroughly understood.

Effective species/habitat management planning and habitat restoration depend on a sound understanding of vegetation distribution, relationships and trends. However, in many cases forest cover has changed so substantially from its natural state that the current situation is an unreliable indicator of past distribution. In order to help understand these issues, Kew is working to develop techniques for mapping past vegetation patterns. This has been used, for example, to interpret pre- and post-eruption vegetation on the island of Montserrat in the Lesser Antilles, helping to inform conservation and habitat restoration decisions.

Such techniques can also be applied to predict the future effects of regional climatic change on vegetation. This involves establishing a baseline against which to measure present day vegetation trends, drawing on climate models and known relationships between vegetation and environmental factors in order to map predicted change. Whereas these approaches are generally undertaken at a biome/vegetation scale, Kew is working to integrate specialist species-level information into such models, providing vital predictions for threatened taxa and indications of effective species composition for future restoration processes.

In the context of changing climate it is also essential that effective systems are put in place for long-term monitoring of vegetation and landscape change. Large-scale baseline data, such as those provided by Kew for Madagascar, are an essential point of reference for such monitoring systems. The majority of Kew's current projects involve short- or long-term monitoring to some degree. Satellite imagery is used to document changes in the landscape over the lifetime of a project, and repeated site visits for specimen collection, plant population monitoring and vegetation observations (including fixed-point digital imagery) allow us to develop a picture of vegetation trends over a period of time.

Some of our techniques for assessing change over time are desktop based. These draw on data from collections as a means of documenting change in a given area. For example, for certain taxa we see that collections cease or diminish in specific areas over time. Although in some cases this may be a reflection of decreased collecting activity, it can also indicate change in the landscape as a whole, e.g. areas of forest cleared, new settlements or human activities.

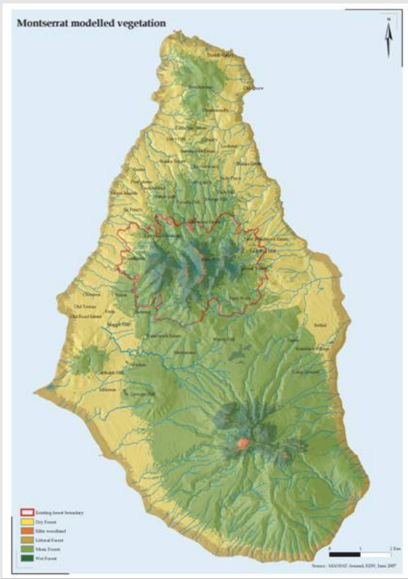
Monitoring species or population trends *in situ* requires rigorous data collection standards. Kew's Millennium Seed Bank Project (MSBP) and the Sampled Red List project (SRLI) have both developed data standards and protocols. For example, each time seeds are collected information on the precise locality, population size, ecology, threats, and phenology of the target population is also recorded, in addition to voucher specimens. By 2010, the MSBP will have recorded high quality baseline data from at least 40,000 wild populations across the globe. On re-visiting these populations in the future any changes can then be related to the relevant threatening processes. See also the Sampled Red List Index case study below.

4.2 Mapping past forest cover and landscape change

Niche modelling has been used to interpret vegetation distribution on Montserrat before 1997, when volcanic eruption destroyed half the island. Many visits were made to Montserrat during the course of the mapping exercise in order distinguish vegetation types and develop collection-based species inventories. This approach, based on establishing the relationship between vegetation types and ecological factors such as climate, soils, prevailing wind etc, allowed us to model former vegetation distribution in areas destroyed by the eruption and in parts of the eruption zone currently inaccessible due to dangers of further eruptions. In addition, we were able to develop models of the entire island's vegetation prior to colonisation. Although this Darwin Initiative-supported project has been completed the work has led to follow-up conservation projects on Montserrat — and many of the other UK Overseas Territories.

CARIBBEAN: Montserrat. Approximate area mapped: 100 km^2, Mapping Scale: 1:25,000

Ground date: 2007



Vegetation modelled pre-eruption

Survey level: Full surveys, with several iterations

Field methods used: Quantitative, ground point data onto field data forms.

Purpose: Conservation planning and demark reserve boundary

Desktop methods: statistical methods, based on elevation and climate data

Project Partners: RBG Kew, Royal Society for the Protection of Birds (Lead), Department of Agriculture, Montserrat National Trust, Montserrat Tourist Board, Durrell Wildlife Conservation Trust. Supported with funds from the Darwin Initiative for the Survival of Species

Overview: The Caribbean island of Montserrat was devastated by a huge volcanic eruption in 1997. This vegetation survey and map was completed as part of the Darwin Initiative project 'Enabling the People of Montserrat to Conserve the Centre Hills'. As a result of extensive fieldwork undertaken during this project, planners and conservationists now have an accurate vegetation map and tool to help guide the island's recovery. Species and habitat monitoring continues to identify the most important areas for plant diversity. With wider collecting (as time allows), the aim is to produce a conservation checklist and Red List for the whole island. Permanent biodiversity assessment points were established during the project and on-going monitoring for several threatened species is helping to further GIS and general knowledge of the island's biodiversity at the national level.

Outputs: Data to Government and partners. Papers and maps.

References: http://www.kew.org/scihort/directory/projects/EnabMontserrCentreHi.html

4.3 Retrospective monitoring: understanding change and trends

The Madagascar Vegetation Mapping project is the most notable example of Kew's involvement in large-scale monitoring of vegetation change. This project compared satellite imagery from the 1960s with imagery from the present day in order to map changes in vegetation cover. it has also established standards for the continual monitoring of vegetation into the future, with the creation of standard field data forms and panoramic photographs.

MADAGASCAR: Approximate area mapped: 590,000 km^2, Mapping Scale: 1:500,000 (final mapping scale) – 1:125,000 (working scale)

Survey period: satellite data: 2000 – 2002; Field data 2003-2006

Survey level: Full survey, with several iterations

Field methods: Quantitative, ground point data onto field data forms.

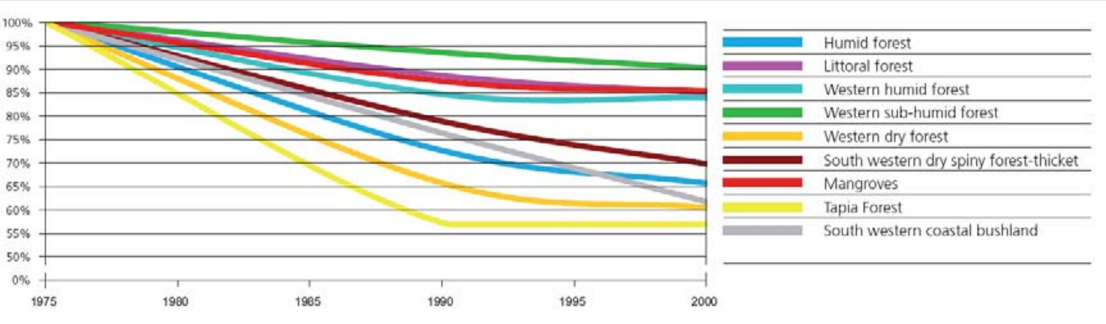
Desktop methods: Classification of imagery and some statistical analysis

Purpose: Inform conservation planning in Madagascar, to provide a sampling baseline for Madagascar's vegetation, applying international standards.

Project Partners: RBG Kew (Lead), Missouri Botanic Gardens and Conservation International

Overview: The Madagascar Vegetation Mapping Project was a four year project (2003-2007), funded by the Critical Ecosystem Partnership Fund (CEPF) and managed jointly by The Royal Botanic Gardens, Kew, Missouri Botanical Garden, and Conservation International's Center for Applied Biodiversity Science. The project was innovative in a number of ways. It employed state of the art remote sensing technology and methodologies to delimit Madagascar's vegetation.

In addition to providing the most thoroughly ground truthed vegetation map ever compiled for Madagascar — an vital baseline for future monitoring of vegetation and landscape change — the study included an analysis of past and present rates of vegetation loss for each type since the 1970s using Landsat imagery. This has helped to identify conservation priorities in a country where only about 18% of primary vegetation remains.



Percentage loss of remaining forest between 1975 and 2000

Outputs: Website with all data and methodology, printed atlas, papers, posters (for education purposes) and CDROM for local distribution in Madagascar.

References:

Moat J. and Smith P. (Editors): *Atlas of the Vegetation of Madagascar Vegetation / Atlas de la Vegetation de Madagascar*. Kew Publishing UK 2007

http://www.vegmad.org/

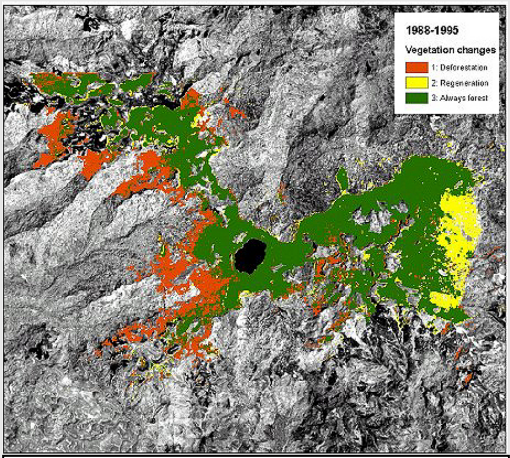
http://www.kew.org/press/madagascar_atlas.htm

A similar project is currently under way in Peru (see last case in this document), where a comparison of 1950s aerial photographs with present day satellite imagery is being used to interpret the previous extent of a highly threatened dry forest type (*Prosopis* woodland). The results will inform habitat restoration processes and conservation measures in the region.

A similar process was also used to monitor and evaluate the impacts of past conservation efforts of vegetation change on Mount Oku in Cameroon and to establish a framework for future modelling.

CAMEROON: Mount Oku. Mapping area 800km^2, Mapping scale 1:50,000

Project Partners: RBG Kew (Lead), Birdlife international and University College London



Forest change 1988-1995

Overview: Mount Oku and the Ijim Ridge is the largest remaining patch of montane forest in West Africa. It has exceptional levels of flora and fauna endemism – especially amongst birds. For this reason, an important conservation project managed by Birdlife International has been working in the area since 1987, aiming to reduce forest loss and to improve agricultural practices. This project measured on the ground effects of the conservation effort in this region. Impacts were measured using traditional classification of remote sensing data combined with aerial photographs for the older dates. Due the rapid change in terrain and the varying nature of the imagery, all data had to be corrected using elevation models derived from radar satellite data. The results show strong spatial patterns of deforestation between 1958 and 1988 (more than 50 % of the montane forest was lost in this period) followed by a regeneration period starting in 1988, just after the Conservation Project was created. In this last 1988-2001 period, 7.8 % of the 1988 extent of montane forest had been recovered, mainly on the eastern side of the mountain.

Outputs: Website, data distributed to NGOS and papers.

References:

Baena S., Moat J. and Forboseh P. Monitoring vegetation cover changes in Mount Oku and the Ijim ridge (Cameroon) using satellite and aerial sensor detection. (in press) 2008

http://www.kew.org/gis/projects/oku_cameroon/index.html

A detailed understanding of the significance of these landscape-level changes on biodiversity is predominantly achieved through data collection in the field (survey and inventory). However, desktop mapping has proven very effective in tracking the changes in vegetation over a substantial period of time. Kew's project in the Itigi Thicket in Zambia is a good example of this approach, showing change over 20 years through the use of satellite imagery. This project was able to demonstrate that the changes in the coverage of Itigi thicket were largely due to human interference and, more specifically, farming.

ZAMBIA: Itigi Thicket. Approximate area mapped: 7000 km^2, Mapping Scale: 1:125,000.

Purpose: Identify trends in Itigi dry forest cover over a 37 year period, and determine whether the Mweru Wantipa Itigi is a threatened habitat; compare trends in Itigi dry forest cover inside and outside the Mweru Wantipa National Park; pinpoint local sources of threat by determining degradation direction; predict when the Mweru Wantipa Itigi dry forest will disappear at the current rate of degradation and apply this data as a rationale for conservation.

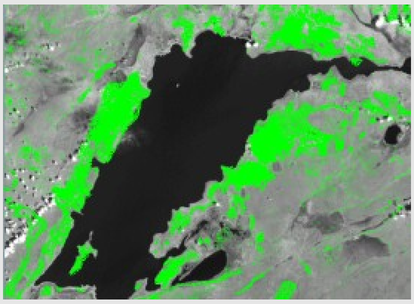
Desktop methods: Itigi thicket monitoring was carried out using three Landsat scenes (path 172, row 66) acquired during July 1984, July 1989 and October 2001, along with aerial photographs from June 1964. Using this data a time-series of images monitoring of the extent of Itigi thicket on the shores of Lake Mweru Wantipa over a 37 year period was produced.

Field methods used: Quantitative, ground point data onto field forms.

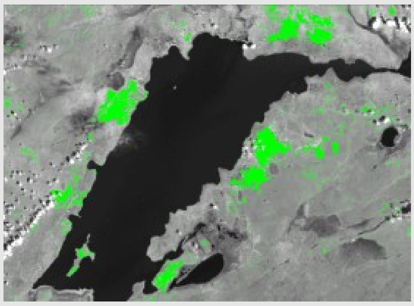
Project Partners: RBG Kew (Lead), University College London

Overview: This study showed deforestation trends in Itigi thicket over a 37 year period in the vicinity of Zambia's Lake Mweru Wantipa. Deforestation trends were quantified using satellite and aerial photography, combined with qualitative ground survey to distinguish the thicket from contiguous vegetation types. It was found that forest degradation was largely due to clearing for cassava cultivation. Itigi thicket did not appear to regenerate once it had been cleared. The novel element associated with this study was determining the extent and direction of the deforestation, indicating which villages and communities were responsible. In addition, the thicket inside and outside the national park was equally degraded, suggesting that the park authorities were unable to prevent forest clearing.

Outputs: A series of vegetation maps of current and past extents of itigi thicket around Lake Mweru Wantipa in northern Zambia; Forest degradation trends over a 37 year period, including sources and direction of degradation. An assessment of the regeneration potential of Itigi thicket, and a prediction as to when it would completely disappear.



Thicket cover (green) - 1976



Thicket cover (green) - 1999

References: http://www.kew.org/gis/projects/zambia/index.html

4.4 Ongoing monitoring

Kew's projects are also addressing current and future trends in landscape change, particularly those involved with extractive activities such as mining. Work in Pic de Fon, Guinea (Conakry) involves assessing current vegetation status, tracking changes caused by mining activity, and using the information gathered to find comparable areas outside the mining concession. Such information is not only important for evaluating impacts on vegetation in a regional context, but also helps to inform species management and biodiversity offset decisions.

Field collections are important to this process, providing valuable information on vegetation and habitats and feeding into the ground-truthing of the vegetation maps, allowing us to monitor changes in landscape use and degree of forest cover over time. A good example is one of Kew's projects in Turks and Caicos which, in addition to inventory and mapping, uses change monitoring techniques to assess the damage (possibly climate change derived) of insect attacks on an endemic variety of Caribbean Pine.

CARIBBEAN: Turks and Caicos Islands (TCI). Approximate area mapped: 430 km^{2,} Mapping Scale: 1:50,000.

Purpose: The UK Overseas Territories (UKOTs) Programme gather baseline mapping data through fieldwork providing a range of mapping opportunities. Activities started with an initial survey visit in 2005, since 2006, the Programme averages two trips per year. A range of different mapping methods have been used depending on the area and the purpose. For TCI we have used satellite and aerial photography and recorded plots (quadrats) of varying size.

Aerial Photographs for the region

Overview: The Pine Recovery Project is working to: secure an *ex-situ* collection of the TCI pine population (*Pinus caribaea* var. *bahamensis*); map the distribution of the pine population (pre-scale infestation/current/model future); map the extent of the invasive scale insect that is killing the pine tree; model/predict pine mortality using historic and current aerial and satellite imagery; create a vegetation map for TCI that is focused on pine habitats/ecotones (pre-scale infestation/current/model future). Kew is also establishing an international working group for the TCI Pine Recovery Project that will enable local capacity building, help to raise local and international awareness about the issue, and provide project steering through expert advice (e.g. fire ecosystem management).

The Plan for Biodiversity Management and Sustainable Development around the Turks and Caicos Ramsar Site aims to increase local awareness and ecotourism. The Plan has involved the Kew UKOTs Programme to undertake an initial assessment of threatened species and produce a TCI Red List. Through our fieldwork, we have been: recording species assessment data for a target list of priority species; working with local NGOs and experts to ascertain species distribution, uses, and threats; and carrying out general vegetation assessments.

Methods: This project has mapped the coverage of the pine populations in TCI in order to subsequently determine the extent and degree of the scale damage by comparing images acquired in pre and post infestation periods. The last phase of the project involves the development of monitoring procedures in order to track changes in the impact of pine scale over the life of the project (10 years) and to determine the most suitable areas for re-introduction of pine trees.

Sampled Red List Index (SRLI)

The SRLI project, which recently started at Kew, is not a strict forest/vegetation change project but was put in place to tackle Target 2 of the Convention on Biological Diversity 2010 target using methods other than ground mapping. The novel techniques it is developing can be applied at any scale, allowing long-term regional or global surveys.

The analysis carried out by the SRLI project team takes into account the temporal and spatial characteristics of species to assess their conservation status. This is a more species level biodiversity measure than habitat or landscape scale studies, and is dependent on the quality of the collections and data held in our vast herbarium collection.

GLOBAL: Red List Index for Plants (Sampled approach)

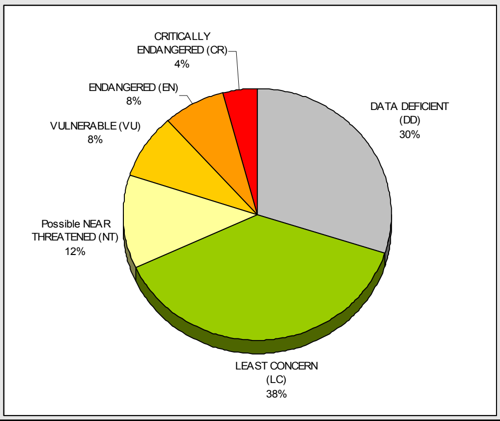
Purpose: The Red List Index (RLI) is an indicator used to monitor changes in thestatus of threatened species. It has been developed in direct response to the Convention on Biological Diversity 2010 target of 'a significant reduction in the current rate of biodiversity loss'. RBG Kew is leading the co-ordination and production of the Red List Index for plants.

Desktop methods: Species level conservation assessments using IUCN Red List categories and criteria incorporating novel GIS techniques developed at RBG Kew.

Field methods used: Extensive fieldwork to monitor RLI species planned post 2010.

Project Partners: Zoological Society of London (ZSL), Royal Botanic Garden Edinburgh (RBGE)

Overview: The RBG Kew's RLI is a truly global project aiming to monitor overall trends in the conservation status of species-level biodiversity. The project is led by ZSL who are producing the overall index for biodiversity based on 19 of the world's better known taxonomic groups. RBG Kew is co-ordinating the plant component which includes the five groups: Monocots, Dicots, Gymnosperms, Pteridophytes and Bryophytes. A random sample of 1,500 species from each group (a little less for gymnosperms as there are fewer than 1,500 species in the group) will be assessed using the IUCN Red List system. At periodic intervals the same sample of species will be assessed again to see if threat status has changed. Genuine changes between categories are then used to calculate the index. The index can also be scaled down to smaller areas, e.g. a regional Red List Index for Africa. The index can also easily be disaggregated by other components such as habitat type to see trends in threat status of habitats.



Monocot threat status – preliminary results for 588 species

Outputs: The project is set to deliver 7,000 plant conservation assessments, a representative sample of all plants by 2010 (see graph for progress up to Jan 2008) and continuing assessments post 2010 on a five yearly basis.

References:

Butchart *et al.* (2005) Using Red List Indices to measure progress towards the 2010 target and beyond. *Phil. Trans. Roy. Soc. B. 360: 255-268.*

http://www.kew.org/gis/projects/srli/index.html

4.5 Future prediction of landscape and species distribution change

Many of the projects highlighted above can be extended to the future with simple extrapolation of the results. For example, the Zambian Itigi thicket project where if current rates of deforestation continue this vegetation type will be lost by 2015-2017. Similarly, if deforestation continues unabated in Madagascar all its primary vegetation will be lost by 2067.

Most recently, Kew has been at the forefront of modelling habitat and species distributions associated with climate change models. The majority of these projects are very recent and have only just started. Three examples are given below.

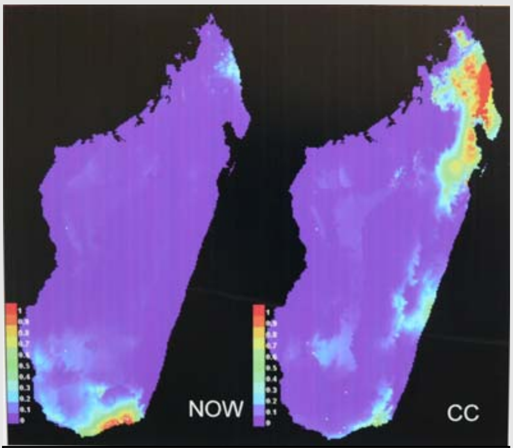
4.5.1 Species prediction

Vegetation is composed of species assemblages, and therefore understanding their relationships with ecological/environmental factors enables us to predict stress within the vegetation caused by climate change, but also its possible composition under future conditions. A recent project in Madagascar evaluates future impacts of climate change on legume species. Leguminosae is the key family of the dry forest of Madagascar, and by assessing the impacts on such a prominent taxonomic group we can gain wider insights into the consequences of predicted change.

MADAGASCAR: Climate change and its impact on endemic legumes of Madagascar

Project Partners: RBG Kew, University of St Andrews

Purpose/ Overview: This study looks at how climate change modelling of species distributions, based on herbarium specimens, can be used in conjunction with IUCN conservation assessments. In total, the impacts of climate change on 228 endemic legumes from Madagascar are being assessed using the criteria of geographical range and population reduction.



Predicted suitability for a species at present and at a future climate scenario of x2 CO_2

Methods: The endemic legumes of Madagascar are modelled using Maxent to create species distribution models for present and future climate scenarios. Additional refinement is done using the Madagascar Vegetation Atlas. Three dispersal scenarios are modelled ranging from no to full dispersal. Species distribution is measured using both area of occupancy (AOO) and extent of occurrence (EOO). Based on the current predicted distribution and any future change in predicted distribution, each species is assigned an IUCN Red List conservation category.

Outputs: The project outlines a method for using climate change modelling of species distribution in conservation assessments based on herbarium specimens. This project is part of a PhD thesis by Malin Rivers. Papers are in preparation.

4.5.2 Landscape and vegetation prediction

On the arid south coast of Peru, where the effects of climate change are already being felt, Kew is working to improve the understanding of possible future trends in dry forest distribution as part of a habitat restoration project supported by the Darwin Initiative. This project is working to increase knowledge and awareness of the biodiversity of fragmented *Prosopis* woodlands, whilst at the same time raising national and local capacity for research. Based on the extensive species- and habitat-level data the project has generated for the region, and applying new tools such as ecological niche models to determine climatic tolerance of species, we aim to generate predictive scenarios that will help to guide effective restoration and ensure that these ecosystems remain robust to future changes whilst continuing to provide livelihood value for local populations.

PERU: Habitat restoration and sustainable use of southern Peruvian dry forest

Project partners: *RBG Kew,* Universidad National Agraria, La Molina; Universidad San Luis Gonzaga de Ica, INRENA (Instituto Nacional de Recursos Naturales); Grupo Aves del Peru; Productos Ecológicos de Samaca; ANIA (Asociación para la Niñez y su Ambiente - Programa Bosques de los Niños); DarwinNET & CONAM (Consejo Nacional de Medio Ambiente); University of Cambridge

Purpose: Strengthening local/national capacity for applied biodiversity research; developing and disseminating technology for habitat restoration to protect biodiversity and combat desertification; increasing understanding of dry forest ecosystem dynamics and biodiversity; evaluating the capacity for increased production of native forest products (*Prosopis* pod flour and syrup) as sustainable economic options for forest use, and promoting wider uptake; protecting biodiversity of remaining native forest relicts by buffering with restored habitats; raising awareness of the importance of south coast dry forests and associated biodiversity, resource values, threats and management strategies; supporting the establishment of protected areas in remaining fragments of native dry forest ecosystems.

Methods: Predictive vegetation mapping based on climate predictions; retrospective vegetation mapping using aerial satellite photos and satellite imagery.

Outputs: Habitat restoration manual, protected area establishment, training and capacity building, environmental education

References: http://www.kew.org/scihort/tropamerica/peru/index.htm

Finally, in the northern region of the Brazilian Amazon, Kew is embarking on a new initiative in collaboration with the Indigenous Council of Roraima (CIR) and The Nature Conservancy (TNC) to establish long-term monitoring systems in the Raposa Serra do Sol Indigenous Reserve. This innovative approach, which involves 'ethnomapping' and assisted interpretation of satellite imagery, aims to build the capacity of local communities to monitor their natural resources independently with the help of appropriate technology and training, according to their own understanding and interpretation of vegetation classification and resource values. Indigenous reserves are extremely important for biodiversity conservation in Amazonia, and empowering communities to monitor their resources offers significant conservation gains.

5 Annex 1: Project summary tables

5.1.1 Rapid vegetation survey and mapping

Region	Area (km^2)	Scale	Dates	Survey Level(1)	Methods Field(2)	Methods desktop(3)	Comments
Madagascar	590,000	1:500,000 - 1:125,000	2000-2006	4	2b	2/3	See case study above and http://www.vegmad.org/ http://www.kew.org/press/madagascar_atlas.htm
Cameroon Mount Oku	800	1:50,000	2001	2	1	2a	See case study above and in Monitoring Forest Cover and Land Use Change Document http://www.kew.org/gis/projects/oku_cameroon/index.html
Guinea Pic de Fon	250	1:20,000	2006	4	2a	2b/3	See case study above
Guinea Coast	125	1:10,000	2007	3/4	2a	2b/3	Vegetation map of proposed refinery of the region look at the possibility of rehabilitation of secondary vegetation
MOZAMBIQUE: Chiperone, Namuli, Mabu, MALAWI: Mulanje, Mchese.	40,000	1:125,000	2002-2008	3/4	1	2	See case study above http://www.kew.org/science/directory/projects/annex/ChiperoneTechReport.pdf
PERU: South Coast Dry Forest	10,000	1:125,000	2008	3	2a	1/2/3	See Monitoring Forest Cover and Land Use Change Document for more details
Botswana Jwaneng	190	1: 10,000	2006-2007	4	2a	1/2a/2b	Main outputs: A vegetation classification and map of the vegetation communities in Jwana Game Park; Detailed descriptions of vegetation types/communities; A checklist of plant species in the reserve; Recommendations for monitoring and management of the plants and habitats in the JGP.
Botswana Orapa	120	1:10,000	2001-2005	4	2a	1/2a/2b	See case study above
Monserrat	100	1:25,000	2007	4	2b	3	See case study above and in Monitoring Forest Cover and Land Use Change Document http://www.kew.org/scihort/directory/projects/EnabMontserrCentreHi.html

Region	Area (km^2)	Scale	Dates	Survey Level(1)	Methods Field(2)	Methods desktop(3)	Comments
Turks and Caicos	430	1:50,000	2008	4	2b	2b/3	Project just started, see Monitoring Forest Cover and Land Use Change Document for more details
Zambia Itigi Thicket	7000	1:125,000	1999	2	1	2a/b	See Monitoring Forest Cover and Land Use Change Document for more details
Zambia Mutinondo	100	1:10,000	1999-2003	4	2a	1/2a/2b	See case study above
Bolivia: Central Andean Valleys	150	1:10,000		4	2a/2b	2	Vegetation mapping in small new protected area (Area Protejida Parque de las Cactáceas de Bolívia) to support development of management plan
Brazil: Corumba	30	1:10,000	2005	4	2a/2b	2a/2b	Small-scale vegetation mapping on the Morraria de Santa Cruz in advance of expansion of an iron ore mine
Brazil: Santana de Pirapama	30,000	1:100,000		3/4	2a/2b	2	Project recently started. Area of significant botanical interest with high endemism levels; objectives to trace rate of loss of cerrado vegetation, identify conservation priorities and strategies, and establish a protected area
Brazil: Cristalino	3,000	1:125,000	2006-8	4	2a/2b	2	Vegetation mapping of protected areas in the arc of deforestation of southern Amazonia for development of management plans
Indonesian: Mount Sahendaruman	400	1:125,000	1999	2/3	1	1	Small mapping project: See: **Hicks, D.M.** (2002). Vegetation map of Mount Sahendaruman. *Bird Conservation international* 12: 53 – 78.
UK Overseas Territories (Falklands, Ascension, Tristan Da Cunha, St Helena)	13,000	Various 1:100,000 – 1:10,000	2002+	3/4	2a	1	Projects in collaboration with country partners. Kew supporting with technical data and data collection with PDAs.
Borneo – Yayasan Sabah	1,460	N/A	2006		1/2	2b	Forest Survey to assess it Forest Stewardship Council status.

(1) 1 – Expert knowledge, 2 - Rapid mapping from satellite imagery/aerial photographs, 3 – Two Phase Survey, 4 – Full Survey

(2) 1 - Field sketching/mapping, 2a - Qualitative data collection (recording what is present at a point), 2b - Quantitative data collection (giving numbers and values to vegetation types), 3 Permanent transects and quadrats, 4 Photographs

(3) 1 - Photo interpretation 2 - Classification of satellite imagery (Supervised) 2b - Classification of satellite imagery (Unsupervised), 3 - Statistical analysis using environmental layers (i.e. rainfall, temperature, elevation and soils - similar to niche modelling)

5.1.2 Monitoring

Region	Area (km^2)	Scale	Change type	Dates	Comments
Madagascar	590,000	1:500,000	Past	1975, 1990, 2000,	See case study above and http://www.vegmad.org/ http://www.kew.org/press/madagascar_atlas.htm
Cameroon; Mount Oku	800	1:50,000	Past	1958, 1988, 1995, 2001	See case study above and http://www.kew.org/gis/projects/oku_cameroon/index.html
Guinea; Pic de Fon	250	1:20,000	Future	-	Project due to start at end of 2008
Peru: South Coast	10,000	1:125,000	Past and Future	1950s, 2007 + predictive scenarios	See case study above and http://www.kew.org/scihort/tropamerica/peru/index.htm
Brazil: Santana de Pirapama	30,000	1:100,000	Past	1987, 1997, 2001	Project recently started. Area of significant botanical interest with high endemism levels; objectives to trace rate of loss of cerrado vegetation, identify conservation priorities and strategies, and establish a protected area
Montserrat	100	1:25,000	Monitoring		See case study above and report on rapid for mapping
Turks and Caicos	430	1:50,000	Past and Future	2001, 2008 - future	See case study above
Zambia Itigi Thicket	7000	1:125,000	Past	1976, 1985, 1999	See case study above and See: http://vegmad.org/gis/projects/zambia/index.html
Sampled Red List Index (SRLI)	Global	Multiple	Past, Future and monitoring	Various, but every 5 years	See case study above and http://www.kew.org/gis/projects/srli/index.html
Legumes of Madagascar	590,000	1:5,000,000	Future	2100	See case study above
Seed bank field data forms	Global	Multiple	Past, Future and monitoring	2001-2010 and future	See http://www.kew.org/msbp

6 Annex 2: World map showing project sites