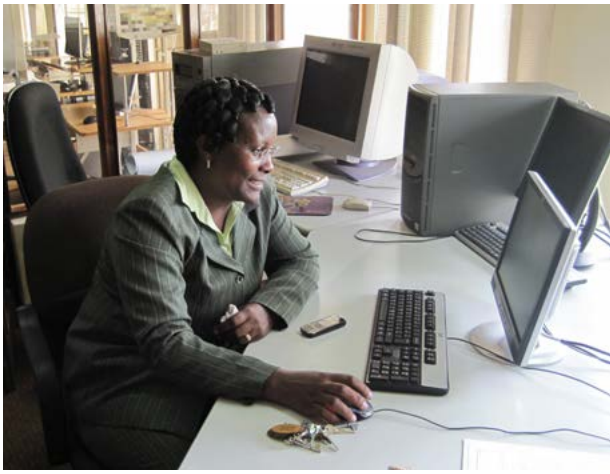
PRODUCTS AND SERVICES FOR THE AFRICAN CONTINENT

belspo

The ENDELEO, ENDELEO-OPS, MORECA, WWW, WWW2 and POPSATER projects have been financed by Stereo II, the Belgian science policy (BELSPO) research programme for Earth observation.
More information: eoedu.belspo.be > teacher's corner ; eo.belspo.be > Directory > Projects

Protecting fragile ecosystems, combating deforestation, preventing locust plagues, providing warning systems for food security or taking a census of populations... Satellite imagery allows researchers to develop operational applications that meet the priorities expressed by their African partners.

At the dawn of the third millennium, the planet's state leaders approved a global action plan in an attempt to eradicate poverty worldwide: the Millennium Development Goals.
They committed to mobilising their efforts to improve the living conditions of the most vulnerable populations and meet their needs in terms of food security, health, education and protection of the environment. As for the United Nations' major institutions and non-governmental organisations, their role is to relay local requests for support and to stimulate international cooperation in specific domains, such as food and agriculture (FAO), the environment (UNEP) or nature conservation (WWF).



Training in the use of monitoring tools by remote sensing of vegetation (Endeleo).

In support of this ambitious project, detailed, regular and near instant information provided by the Earth's observation satellites are essential tools. It is therefore crucial to ensure that the remote sensing techniques and data are within everyone's reach, in order to perfect the planet's management and monitoring systems at all levels, from local to global. For instance, to meet precise needs in the field, many African countries would like easy access to satellite data and the creation of an exchange network with countries that are more advanced in space techniques.

One of the sections of the STEREO II programme meets this desire. It is a more practical section that is devoted to the transfer of knowledge and technologies with the aim of developing pre-operational products and services. In continuous interaction with African partners and international organisations, several projects are focusing on developing mapping, analysis and assessment tools that can be used directly in the field.

A SOUND MANAGEMENT OF KENYA'S ECOSYSTEMS

East Africa's natural ecosystems have suffered considerable modifications in the last few decades. Significant demographic growth, climate changes and economic pressure are among the main factors responsible for the overexploitation of natural resources.

The resulting degradation weakens the ecosystems making them increasingly vulnerable to natural catastrophes such as the recurring drought that characterises the climate in this region. It is therefore essential to implement measures to curb the degradation of land and resources.

In Kenya, in particular, the natural ecosystems are a vital source of income for the country's most prosperous sectors such as tourism, agriculture and energy production. The public authorities are well aware that optimal management is essential if the country is to continue benefiting from all these resources in the future. Just like the environmental organisations and local managers, they want up-to-date information on the state and the evolution of the natural resources.

Satellite imagery is able to provide such a synoptic view of the state of the vegetation and changes in the ground cover over time. The **ENDELEO** and **ENDELEO-OPS** projects are working on providing simple tools that will help to improve the monitoring of the dynamics and, hence, the management of the fragile ecosystems in East Africa, and Kenya in particular. The goal is to make the information derived from the satellite images on the state of the vegetation available to the end-users, in the most accessible way possible. During the first stage, the team attempted to assess the efficiency of the conservation measures in vulnerable dry areas using image time series. An operational tool was then developed to help local managers (of rangeland ecosystems above all, but also of forests) to actively monitor the impact of their interventions.

RENDEZVOUS IN NAIROBI

In association with scientific teams from the University of Ghent and VITO, two of the project's partners are based in Nairobi: the African regional office for the United Nations Environment Programme (UNEP) and the Department of Resource Surveys and Remote Sensing, which is dependent on Kenya's Ministry of the Environment. At the beginning of the project, representatives from several NGOs, research institutes and governmental organisations attended a workshop to reconcile the various sectors' needs in terms of information with the means offered by remote sensing. Achieving this goal turned out to be a challenge in itself since, in the beginning; the users had no knowledge of the possibilities satellite imagery had to offer.

This consultation made it possible to define which quantitative indicators to provide the end-users with at regular intervals: the Normalized Difference Vegetation Index (NDVI),

which is useful for the identification of epsodes of drought; and Dry Matter Productivity (DMP), an index to estimate the production of dry biomass which is useful in the assessment of the productivity of the prairies. These two indices are derived from low- and medium- resolution data obtained from sensors such as SPOT VEGETATION and MODIS.

Their values, which are automatically updated every ten days, have been archived since 1999. These time series are essential to monitor the vegetation's dynamics. They help to show the long-term trends but also to reveal seasonal changes, by comparing the situations with a given period of the year for several consecutive years. Furthermore, to have a more concrete view of the modifications the ecosystems have undergone, Landsat, ASTER and SPOT HRVIR images, which have a higher resolution, were used to map land use changes and certain types of degradation.

BY AND FOR KENYA

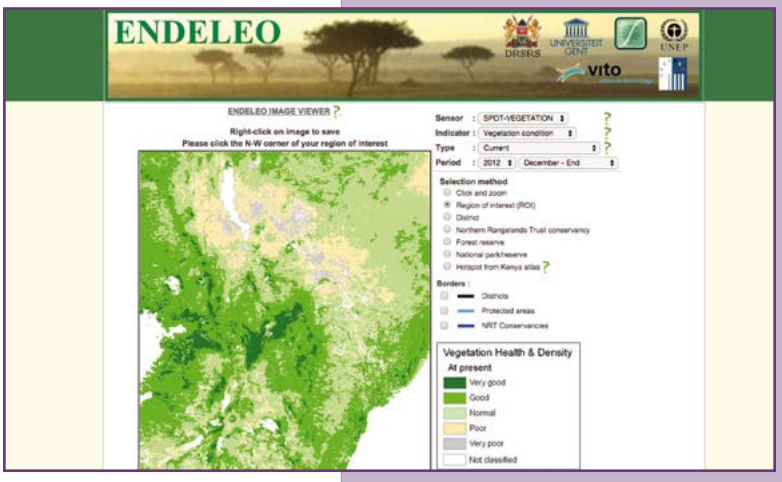
Conducted over a period of almost four years, the project involved Kenyan users at every stage. Internet tools, already designed from the outset to meet their needs, were improved according to their recommendations, in order to create a tailor-made service that better corresponded to their expectations. The project therefore led to durable interactions between the users and the **ENDELEO** team. Local organisations that had never or almost never used satellite data until this point, are now aware of the possibilities offered by remote sensing and have a precious tool in terms of environmental monitoring and support for decision-making. The users are informed several times a year, through the **ENDELEO** newsletter, of the improvements and extensions made to the tools as well as new case studies presented on the site.
The products developed have demonstrated their usefulness in daily life in the implementation

Monitoring vegetation in just a few clicks

Thanks to ENDELEO, Internet tools have been developed that allow users to visualise and analyse useful information in just a few clicks. In an effort to keep things simple, technical terms were avoided as much as possible. Substantial general documentation and a detailed user manual are nevertheless available for anyone who wishes to consult them. ENDELEO is therefore aimed at a target audience, i.e. organisations active in the protection of the environment, whose representatives have no background in terms of remote sensing, and don't have either specialised software or a significant download capacity.

The "Image viewer" tool allows the user to precisely map the state of the vegetation and study its evolution by comparing it, for instance, with the average over ten years, the previous year or the last ten days. The "Graphs" tool displays variations in the state of the vegetation during a growth season per region and per type of plant cover, in comparison with an average year. The "Tables" tool calculates the percentage of reduction or increase in the vegetation index of the year in progress compared with a reference year of choice. Finally, the "Focus Area" allows you to visualise the results obtained for certain specific cases (deforestation, fires, etc.) with the help of more detailed satellite images.

The site also includes several case studies that show, in concrete terms, the usefulness of the vegetation indices in the management of natural resources. In particular, these indices have served to study the influence of the state of the vegetation on the migration of wild animals. One study examined the behaviour of Grévy's zebra, an endangered species, and another, that of elephants. The latter can indeed cause considerable damage to natural vegetation and crops when their territory is too small.



Fires in the east of the great Mau Forest complex in 2009 and the extreme periods of drought that ravaged Kenya in 2005 and 2009 were also the subject of detailed studies. They demonstrated the usefulness of vegetation indices to assess the impact of natural catastrophes, to locate the areas most severely affected and determine the effect of environmental protection measures, such as banning grazing in certain areas of the Mau Forest. Furthermore, thanks to series of high-resolution images available since 1986, researchers have been able to map the deforested areas in several nature reserves selected by the users.

and assessment of protection processes. As a result, UNEP would like to export the concept to other countries in East Africa, such as Uganda, Ethiopia and Tanzania.

REFORESTING THE DEMOCRATIC REPUBLIC OF CONGO

Virunga National Park covers an area of 790,000 hectares in the east of the Democratic Republic of Congo, on the border with Rwanda and Uganda. It has a chain of volcanoes, two of which are active, and an amazing variety of habitats (lava plains, savannahs, steppes, tropical rainforest, lakes, marshes, etc.) that are home to exceptional diversity, represented by the emblematic mountain gorilla. Despite its inclusion on the Unesco World Heritage list, the park is subject to an alarming rate of deforestation, due to the extension of farmland and pastures, but also because of intense illegal logging (a huge amount of wood is cut down for firewood and charcoal production).

The province of North Kivu has been destabilised by wars and fighting for more than 20 years. Its capital city, Goma, has seen the arrival of countless rural families escaping the threats and its current population stands at more than a million inhabitants. Wood and charcoal (called makala) are the only easily accessible energy sources for this population. Eighty percent of these resources are extracted daily from the neighbouring national park. In 2007, the WWF, with the help of the European Union, started up the EcoMakala programme. It involves supplying the families of Goma with charcoal produced from plantations of fast-growing trees, an income-generating activity led by small farmers on land situated in the areas surrounding Virunga Park. This alternative system for the production of legal and sustainable makala offers the double benefit of improving the peasants/planters living conditions and protecting the park's forest resources. In total, more than 5,000 hectares of trees have already been replanted in all these small-sized farms (less than 5 hectares).

HOW TO BENEFIT FROM CARBON FINANCE?

Although very small, the EcoMakala plantations stock carbon, and help to reduce the deforestation of the National Park. Consequently, they are perfectly eligible for carbon finance. But proof needs to be provided that the plots meet the required criteria. Could satellite images be used for this purpose?

As regards reforestation in the DRC, the United Nations Framework Convention on Climate

© JABRUSON

Financial Incentives To Reduce Carbon Emissions

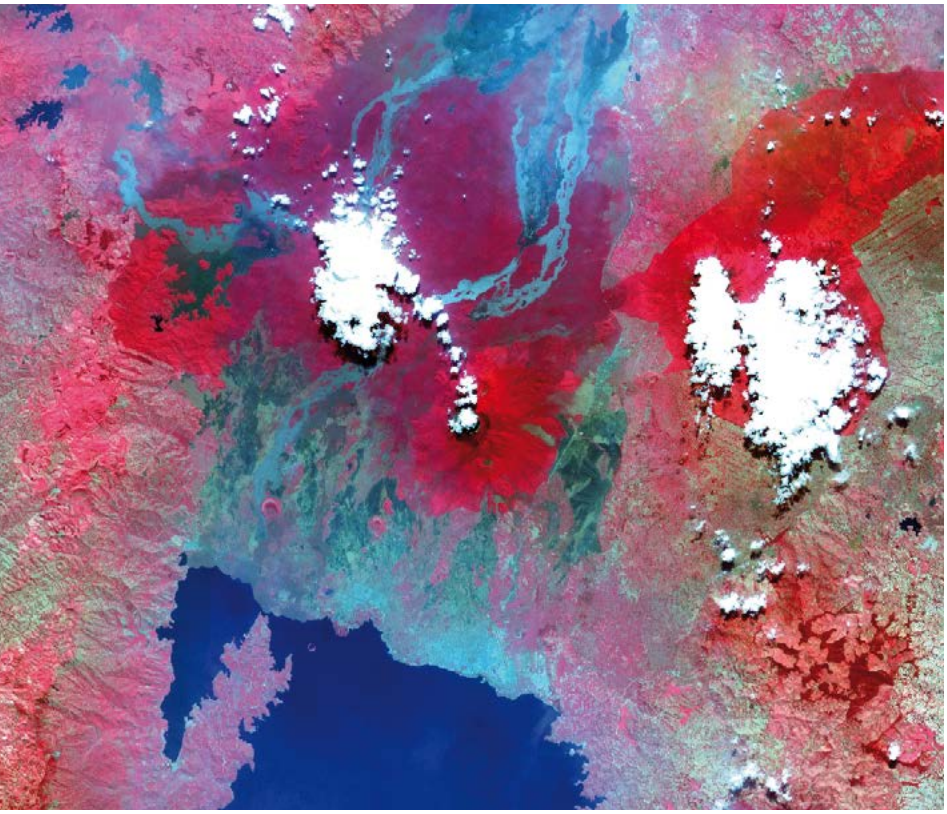
In an effort to combat global warming, international agreements have seen the light of day. At the heart of these agreements, the Kyoto Protocol aims to reduce greenhouse gas emissions, in particular by combating the deforestation responsible for 20 % of these emissions on a global level.

To protect and reinforce forest carbon stocks, the sustainable management of forests and the reforesting of plots need to be encouraged. Two types of carbon finance mechanisms have consequently been set up: the Clean Development Mechanism's Afforestation/Reforestation system, which promotes the increase of forest surface area, and REDD+ certifications (Reducing emissions from deforestation and forest degradation in developing countries) aimed at reducing deforestation. Their principle is simple: industrialised countries support projects encouraging a reduction in carbon emissions in developing countries and in return, they benefit from credits that can be included in their own emissions balance.

© K. Holt / WWF-UK

Woman at makala market, Saké, DRC.

Change (UNFCCC) defined "eligible" forest as a plot of at least 0.5 hectares that hasn't been forested since 1990, covered with a minimum of 30 % trees, with a potential height of three metres at maturity. Although remote sensing is suggested in the Kyoto agreements and can be used to monitor large plots, no study has examined as yet the feasibility of detecting 30 % tree cover in a surface area of only 0.5 hectares. To explore this question and thus support the EcoMakala programme, the WWF initiated the **MORECA** project, in collaboration with the Catholic University of Louvain and the Free University of Brussels.



SPOT HRV false color image acquired in August 1996 showing the border between DR Congo and Rwanda north of Lake Kivu. In red, dense vegetation delineates the contours of the Virunga National Park (left, with the fumes emitted by Nyiragongo) and the Volcanoes National Park (right).

A VERY USEFUL ELIGIBILITY MAP

To establish the eligibility map of the plots, different classification methods applied to the high-resolution SPOT images (20 metres) were compared. The study showed that in the case of a mountainous, fragmented landscape, as is the case in the eastern DRC, a traditional classification method based on pixels (and not objects) gives very satisfying results. Moreover, it has the advantage of being compatible with the software already used at the local branch of the WWF in Goma and at the region's head office.

The maps produced allow users to calculate the forested surface for each plot, while taking into account classification and positioning errors. The eligibility map obtained allowed the WWF branch in Goma to provide the necessary proof to grant the financing for the EcoMakala plantations. Since the method developed has proved its usefulness, it could be reproduced to support funding requests for other regions with different eligibility criteria.

The second part of the **MORECA** project studied how to follow the evolution of reforested plots in a difficult geographic and social context. The plots are indeed small and not easy to access, owing to a poorly developed road network and recurring insecurity. To elaborate this monitoring tool, very high resolution satellite images and radar images were used. GeoEye optical images with a resolution of 60 centimetres allow detailed mapping of forest cover. However, they are very expensive and their acquisition in a tropical area is often tricky owing to the extensive cloud cover. As for radar images, they can be obtained in all weather but they have a lower spatial resolution. Technological developments and increasingly competitive prices could facilitate the development of such tools in the future. The new possibilities offered by satellites such as Pleiades are very interesting in this respect.

BELGIUM PRODUCES WARNING SERVICES

The Copernicus Earth Observation Programme (formerly GMES) was initiated in conjunction with the European Space Agency and the European Union in order to provide Europe with an independent and operational monitoring capacity in terms of the environment and civil security, both on a local and global level. Belgium, which is actively involved in the programme, is using its centres of expertise in remote sensing to develop new high-performance tools. They are intended to supply reliable, up-to-date, high quality information which is precisely adjusted to the expectations expressed by the end-users. Within this framework, the overall objective of the WWW et WWW2 projects is to offer global operational services to certain specific communities of users. This is the Belgian contribution to one of the six thematic areas defined by the Copernicus programme, in this case, land monitoring.

The design and production phases of these new services are fully linked, with the Geomatics Units at the Catholic University of Louvain taking charge of scientific development, while VITO is implementing the processes in the operational processing chains. Three continuous global monitoring services, in near real time and on a continental scale, were thus proposed: "Desert Locust", "Agriculture Phenology" and "Pan Tropical Forest Watch". They have been developed in close collaboration with their future users and favour a multi-sensor approach, in order to be able to produce applications that can benefit from the most suitable available source of information.

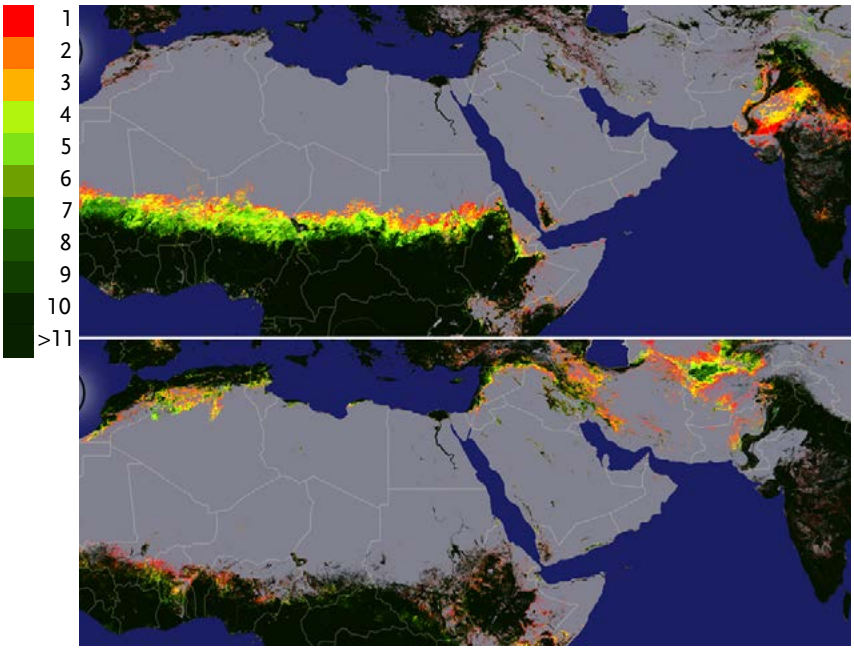
THE DESERT LOCUST, AN ANCIENT SCOURGE

The "Desert Locust" service has been set up in response to a request from the Emergency Centre for Locust Operations (ECLO) organised by the United Nations Food and Agriculture Organisation (FAO), in order to combat the devastating effect of plagues of this voracious pest. Inoffensive in its solitary form, the desert locust, under the influence of an increase in the insect population, transforms into the gregarious form which poses an extremely serious threat to agriculture. The desert locust becomes a fearsome creature owing to its voracity, the mobility of its swarms, which can cover up to 200 kilometres a day, and the vastness of the areas concerned. The areas extend over 29 million km^2, encompassing the south of Europe, the whole of Africa north of the equator, as well as the Arabian and Indo-Pakistani peninsulas.

During plagues, an adult locust can eat the equivalent of it bodyweight in fresh food a day, i.e. approximately two grams. Hence, a ton of locusts, just a small part of an average-sized swarm, can devour the same quantity of food as 2,500 people every day. Extremely polyphagous, the gregarious desert locust attacks both natural vegetation, depriving cattle of their food source, and food crops and plantations. Unfortunately, the loss of crops is considerable. If the situation continues, entire populations are threatened with famine and their survival is at stake. The great invasion of 2004-2005 in West Africa is still fresh in people's memories, with figures that speak for themselves: 26 countries affected, 6.5 million hectares destroyed, 13 million hectares treated with pesticides and crop losses estimated at USD 2.5 billion...

DYNAMIC MAPS OF THE DESERT LOCUST'S HABITAT

The WWW project has produced tools which help to improve monitoring of the vegetation and moisture conditions in arid and semi-arid areas, which are the natural habitat of the desert locust during its quiet periods of recession.



The green vegetation dynamic map from 01/09/2008 (above) and 21/09/2009 (below). The colors represent the number of 10-day periods during which the area was covered with vegetation.

It is a question of reinforcing the action of local surveillance teams to prevent the reappearance of the locusts and the formation of huge swarms. Indeed, when the rains increase and the vegetation grows, the desert locust can multiply very rapidly and their density can reach dangerous thresholds.
To optimise the early warning systems, the project's team developed a new multi-spectral and multi-temporal image analysis method to automatically detect, in near real time, the vegetation in arid and semi-arid areas. The images used are SPOT VEGETATION and Aqua/Terra MODIS time series. The originality of the method consists of combining the multi-spectral and colorimetric analyses of the spectral signal. It is based on an innovative image pre-processing technique, the simultaneous use of three channels – red, infrared and mid-infrared – and on the transformation of the common Red-Green-Blue (RGB) colorimetric system in another better adapted Hue-Saturation-Value (HSV) system.

A complete automatic processing chain was developed which generates a dynamic map of the vegetation in the whole of the desert locust's recession area, on the basis of daily observations made by the MODIS and VEGETATION sensors. Delivered every 10 days by VITO, this map with a resolution of 25 metres summarises the spatial and temporal distribution of the vegetation in a single image file. Potential locust reproduction areas can therefore be identified more precisely and ground controls can be better oriented. For the teams in this project who are in charge of locust plague warnings at the FAO, this tool is a valuable aid for the prediction of reproduction times and areas, and the migration of the desert locust. The international community therefore has a more effective and faster warning system that is continuously in operation, in near real time and on a continental scale.

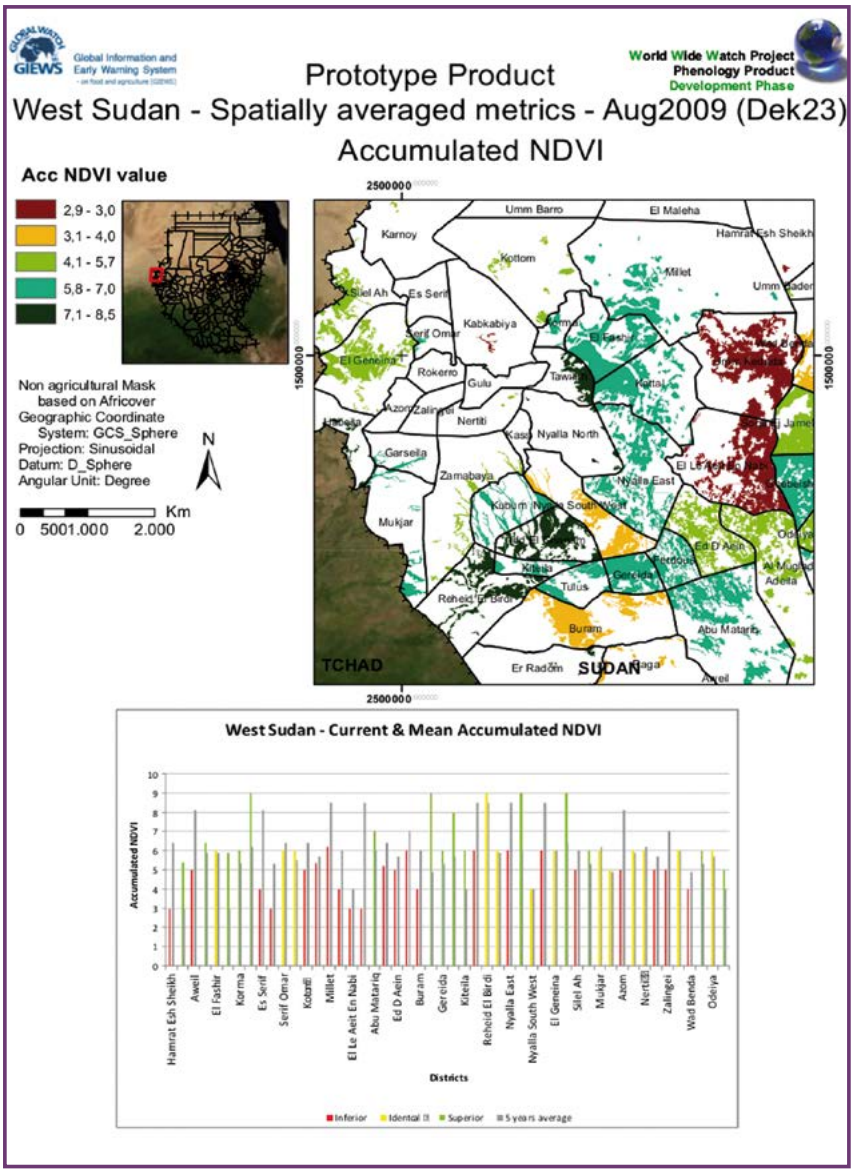
SECOND PHASE, MONITORING FORESTS AND CROPS

In the second phase of the project, **WWW2**, the "Pan Tropical Forest Watch" service was initiated in response to a request from the World Conservation Monitoring Centre, set up by the United Nations Environment Programme (UNEP-WCMC). To improve the warning systems, the service consists of automatically detecting, on a planetary scale, any changes within the tropical rainforests, especially deforested areas, fires, variations in stretches of water (overflowing and drying up), or the regeneration of the vegetation. The product is based on a series of low and medium resolution seasonal images from several sensors. The performance of a service such as this depends on the frequency of the acquisition of quality images, in the absence of clouds. In tropical areas, the cloud cover does of course make it difficult to obtain useable series. However, since the tropical rainforest is an environment with a low level of seasonality, image acquisition can be less frequent.

The "Agriculture Phenology" service was also developed in close partnership with an FAO body, the Global Information and Early Warning System (GIEWS). Dedicated to food security, GIEWS's mission is to continuously monitor the global supply and demand of farming products, and to provide early warning of food crises likely to affect certain countries.

Through this service, it is possible to monitor the interannual variability of crops, on a regional or national scale. Their phenological parameters, i.e. the observation of their seasonal development phases, are of primary importance to characterise the agro-ecological zones. This type of information is essential for knowledge of the present situation and crop prospects but also to study the fluctuations due to climate change in the longer term.

Traditionally, the phenological data is extracted from a vegetation index such as the NDVI, with a frequency of 10 days, and independently from the type of ground cover and the agro-ecological context. Based on SPOT VEGETATION and MODIS multispectral image time series, the **WWW2** teams endeavoured to provide a more specific characterisation of the phenology of the agricultural vegetation and develop a method that takes into account the types of ground cover. The suggested algorithm can be adjusted according to the type of ground cover and therefore provide end-users with more relevant data. It is composed of a series of ten major phenological indicators, including the start and end dates of the vegetative period, the date of maximum development, the rate of growth and senescence,



Phenological prototype product illustrating the NDVI values accumulated over a given period in a region of western Sudan. These map data are supplemented by comparative statistics in graph form.

the duration of growth, etc. The "Agriculture Phenology" service is in the pre-operational prototype phase and will eventually be integrated into an optimised version of the GIEWS workstation, the internet platform that manages and distributes global information relating to food security.

ESTIMATING POPULATIONS THANKS TO SATELLITE IMAGES

For the successful social and economic development of a country or region, it is essential to have precise knowledge of the state and the dynamics of its population. This information is also crucial to manage civilian displacements, caused by wars or catastrophes, in periods of crisis. Unfortunately, many countries, particularly in Africa, only have access to partial and approximate data on the real number of inhabitants and this data is all the less precise because the population is growing so quickly.

Since their emergence at the end of the 1990s, very high resolution satellite images offer a unique opportunity to observe inhabited areas in detail. While not everything can be seen from space (for instance, the number of people living in a house), these images nevertheless allow us to measure other important parameters such as the number of dwellings or the typology of neighbourhoods, which can be directly linked to the number of inhabitants.

The **POPSATER** project attempted to develop a new demographic estimation method, both in urban and rural areas, based on the combined use of high and very high resolution images completed by field surveys. It was initiated by a partnership between three Belgian entities grouping together their complementary expertise: a private company specialising in geographic information products, a research unit from the Free University of Brussels and a design office focused on the field collection and analysis of socio-demographic data.

With the very high resolution Quickbird images (60 centimetres), it is possible to distinguish dwellings and therefore count them manually or automatically if the contrast is high. To estimate the population, a direct approach can therefore

be applied, by multiplying the number of dwellings by the average number of occupants; the last piece of information being extracted from a series of field surveys.

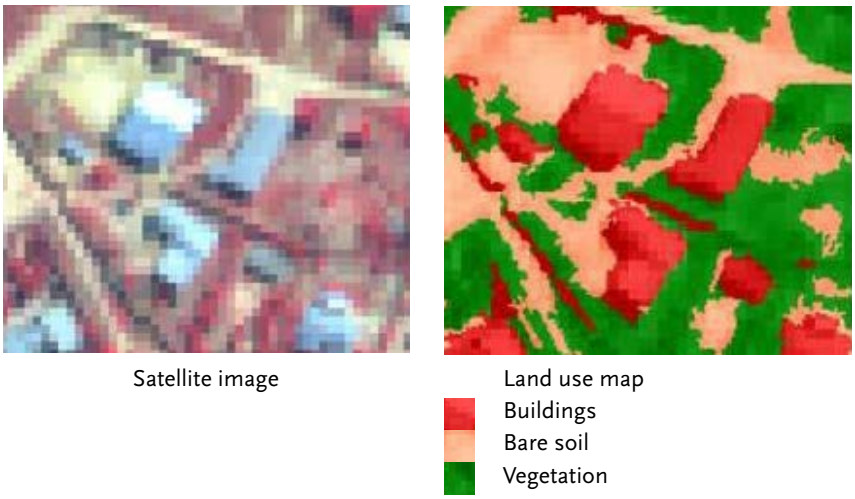
Lubumbashi, in the Democratic Republic of Congo, was selected as an urban environment test zone as there was a census available. The direct approach revealed different results between the town centre and the outskirts, where the population figures obtained were significantly closer to reality. Two factors explain this disparity: on the one hand, the small size and the density of homes in the town centre mean that it is impossible to automatically detect individual homes; on the other hand, the confusion between the roofs of homes (corrugated metal) and tarmac roads makes it difficult to extract data on developed areas. In order to solve this problem other methods were tested, in particular, on the basis of the estimation of the inhabited surface: in this case, it is no longer a question of counting the houses but the inhabited surface, i.e. the surface represented by the roofs of all the dwellings.

In this case, the estimation of the population is dependent on a zonal approach: the surface of the built-up area is measured and multiplied by the density of the sampled inhabitants in several blocks of houses. However, in Lubumbashi, it was difficult to find a unit of space where the density of occupants was constant. In the town, there is considerable diversity in the same housing block, with more wealthy homes sitting alongside slums.

In rural environments, the methods were tested on an area situated to the north of Benin. The results obtained from very high resolution images turned out to be reliable, but considering the high cost of these images, the technique isn't ideal for covering large expanses. Tests were carried out using high resolution (5 metres) SPOT 5 images, which are cheaper. With the latter, it is impossible to identify every dwelling but it is possible to estimate the built-up surface. Whilst the smallest hamlets aren't always detected, the zonal method turned out to be effective for average-sized villages because the density of occupants per dwelling is relatively stable.

Following **POPSATER**, new collaborations between the team of demographers and the remote sensing company were formed allowing them to win several bids concerning population estimations.

Automatic extraction of buildings on a very high resolution satellite image (QuickBird).



Quickbird image (60 cm resolution) of a neighborhood of Lubumbashi.
© 2009 DigitalGlobe..