Belgian science policy office (BELSPO)

ECOLOGY & LAND MANAGEMENT

BELGIAN EARTH OBSERVATION

Projects financed by the Belgian research programme for Earth observation Telsat 4 (1996-2000)

Introduction

Each organism on earth lives in a complex relationship with scores of other organisms, and its survival depends on the quality of its environment. A community of all living organisms (animals, plants and micro-organisms), interconnected with their biotic and abiotic environment, is called an ecosystem. Ecology is the science concerned with the protection of ecosystems.

In the past few decades, ecosystems have suffered increasing damage due to human interventions such as deforestation, urbanisation, extraction of raw materials, and so on. This evolution has far-reaching consequences for the earth's biodiversity: for example, if we keep on cutting down the tropical forests at the current rate, then within 30 years 5 to 10 % of all natural species will have become extinct. Human beings have a very direct interest in maintaining biodiversity : just think of the wild ancestors of cultivated crops with desired characteristics such as disease resistance, or of valuable medicinal plants yet undiscovered in the rain forest.

Scores of organisations are battling to preserve biodiversity (WWF, IUCN,…), and governments in many countries have undertaken, inter alia via ratification of the Rio Conference, to develop a sustainable development policy.

Satellite images form an important instrument for studying and protecting ecologically valuable areas such as tropical forests and river deltas.

A first step in this effort is to carefully map such areas. By monitoring them in time and space, one can identify the factors which threaten ecosystems. At the same time, models can be developed which make it possible not only to extrapolate recent evolutions into the future, but also to evaluate what the impact of specific policy options will be. Satellite images thus indirectly offer valuable information which should encourage policymakers to intervene in time and, if necessary, to actively protect specific areas.




TROPICAL DISEASES

A troublesome fly

In Africa, sleeping sickness (or trypanosomiasis) among cattle is still a major problem. This infectious disease, which is generally fatal if not treated, is transmitted by the tsetse fly (Glossina spp.). In infected zones, one sees milk and meat production fall.

Because of the high danger of infection in some areas, one is also less likely to use cattle as draught animals, even though it is precisely such animals which could raise the yield of the fields. Yet higher agricultural production is a vital necessity in order to feed the rapidly growing population. Therefore, in many African countries people are trying to learn how to control the fly or the disease itself.

The tsetse fly, Glossina spp.

When the remedy is worse than the complaint

However, combating disease among cattle can have a harmful impact on the natural environment. When one eliminates the production-restraining factor, cattle breeding and crop-growing can be allowed to expand almost without limit. This leads to vegetation loss, with possible resultant soil erosion, and even the eradication of indigenous animals. It is therefore useful, when studying methods for fighting tropical diseases in a given region, to pay close attention to the condition of the natural environment in that area.

The goal of this project is to find a method to draw up maps of the fragility of the natural environment in the various administrative units (cantons) in Togo. Once one knows the degree of fragility of the different areas, one can take this factor into consideration before beginning to fight the disease. The most fragile areas, which thus have few reserves, will be considered last for combating disease.

Methodology and Results

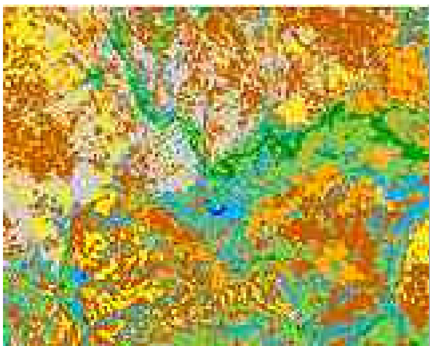
A slightly precise prediction

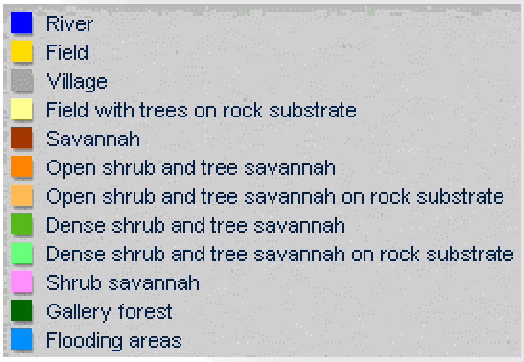
It is hard to define the natural environment's "fragility". This is mainly because nature cannot be divided up into neat little compartments. There are no straight lines within which a specific property can be captured. For example, take the question: "Is the ground dry or wet?" But what does one regard as "wet" (1) and what as "dry" (0)? The ground can also be a 'little bit' (<1 and >0) wet. The normal general logic of mathematics cannot describe this 'little bit' and so cannot take it into account.

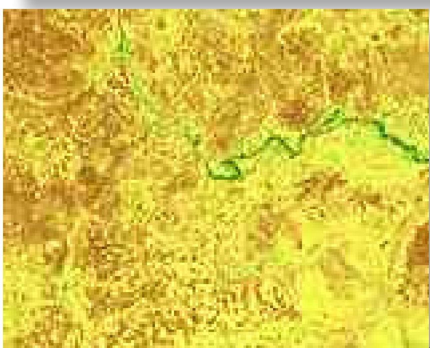
In this project, therefore, one uses fuzzy logic, which can do a good job of describing the phenomenon 'dry' or 'wet', because it allows for 'a little bit'. The answer to the question whether the ground is dry or wet lies somewhere between 'yes' and 'no'. In this case, the question is: 'Is the environment in this area less fragile because of this soil characteristic (or plant growth)?' This question is posed for a number of characteristics in each administrative canton. The answers between 'yes' (1) and 'no' (0) are collected in a database (the characteristic matrix). The closer the value lies to 0, the more fragile the environment. By mathematically processing this characteristic matrix, one can classify the cantons within a region.

Fragile Earth

Among other things, one studies the surface area of arable land and vegetation. For this, two different classification techniques were used on a Landsat TM image, as indicated in the figure : the soft classification with several fraction images as result, and the hard classification.







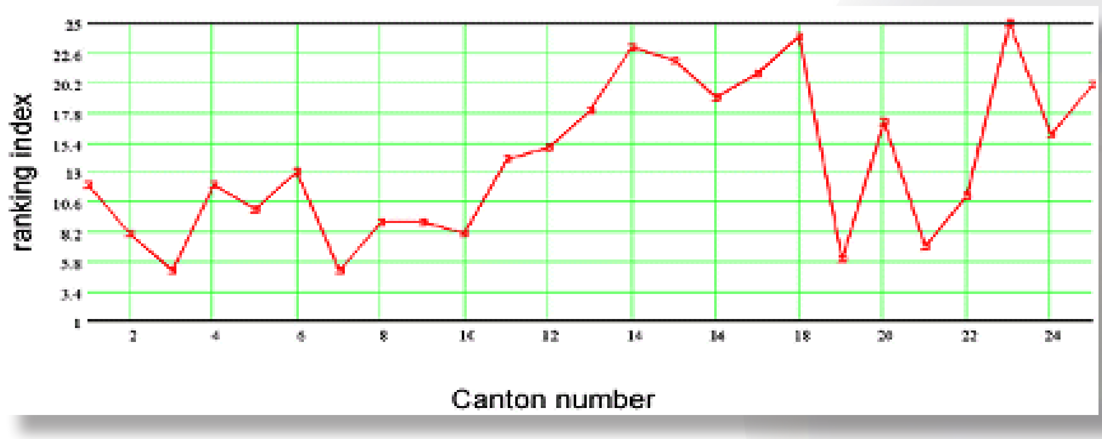
Vegetation image, based on a TM image

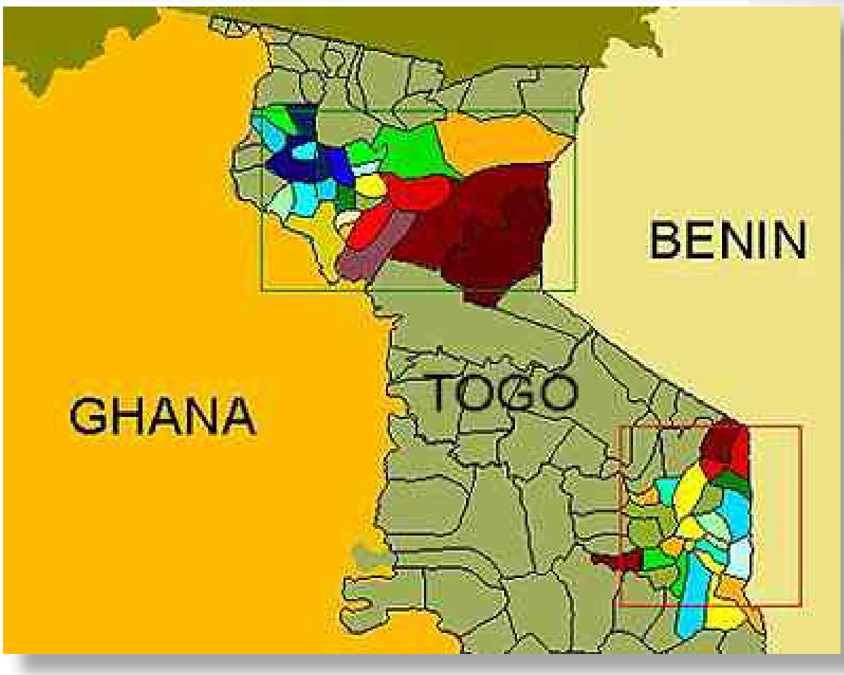
Methodology and Results

For the same area, the vegetation image (Normalised Difference Vegetation Index - NDVI) was also calculated.

The greener the image, the more green vegetation there is. Here a belt of green vegetation can be seen along the Oti River (gallery forests). Recently ploughed fields and eroded soils are coloured brown because there is no more vegetation there: only bare ground remains..

After studying a number of other characteristics, one arrives at a classification of the different cantons according to the fragility of their natural environment. The graph and the map reproduce this classification. The higher up the graph, the less fragile the corresponding canton. On the map, the most fragile cantons are reproduced in blue, and the least fragile in brown.





Savanes L'Oti

Kara

Methodology and Results

When planning how to fight against disease, it is the least fragile cantons that should be treated first. After all, for these cantons one can be pretty sure that the fight will have a permanent effect, without harming the environment. If there are enough resources, one can later set to work on the lower-priority areas as well.

An important condition for a sustainable agricultural system is that even after treatment, the maximum number of cattle per unit of surface area is not exceeded. Also, soil depletion due to the removal of organic material must be prevented.

Conclusion

By thus classifying the cantons according to fragility, one can determine where the disease has impaired agricultural production.

In this way, the anti-disease policy can be worked out in such a way that one effectively applies the available resources so as to achieve a sustainable solution, whereby one can increase agricultural production without harming the environment.
The classification is computed on the basis of physical data from the area in question. One can also use the method elsewhere and adapt the classification whenever more data about an area becomes available, or when the data change. This method is also suitable for all other diseases which can have an impact on the fragility of the natural environment.

Team

Coordinator

Robert De Wulf
Laboratory of Forest Management and Spatial Information Techniques
Universiteit Gent
Coupure Links 653
B-9000 Gent

www: https://www.ugent.be/bw/dfwm/en/research/forsit
Tel : +32 (0)9 / 264.61.10
Fax : +32 (0)9 / 264.62.40
e-mail : Robert.DeWulf@UGent.be

Partners

Nancy Van Camp (RUG)
Inge Verbiese (RUG)
Jan Biesemans (RUG)

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Info

Abstract

Diseases which are transmitted by insects (vector-transmitted diseases) to cattle (such as sleeping sickness) are still a major problem in developing countries. In regions where cattle breeding is a major economic activity, the death of cattle means a sharp loss of income for the rural population. The rapid population growth in many developing countries makes this problem even more critical.

Yet bringing such diseases under control is not a wholly positive step. Eradicating the disease can allow the cattle population to grow so much that there will no longer be enough grass and bushes to feed them all. Overgrazing leaves behind a barren landscape where wind and water sweep away the fertile top layer of the soil. The subsequent lack of food and shelter can cause the wild animals to disappear as well. To get such areas to the point where plants will grow there again or crops can be cultivated is a very slow and difficult process, sometimes requiring hundreds of years.

Such diseases must therefore be combated in a sustainable manner. With the aid of satellite images, an area is classified by its ecological fragility. Thus, one should first fight the disease where the land can tolerate an increase of the cattle population.

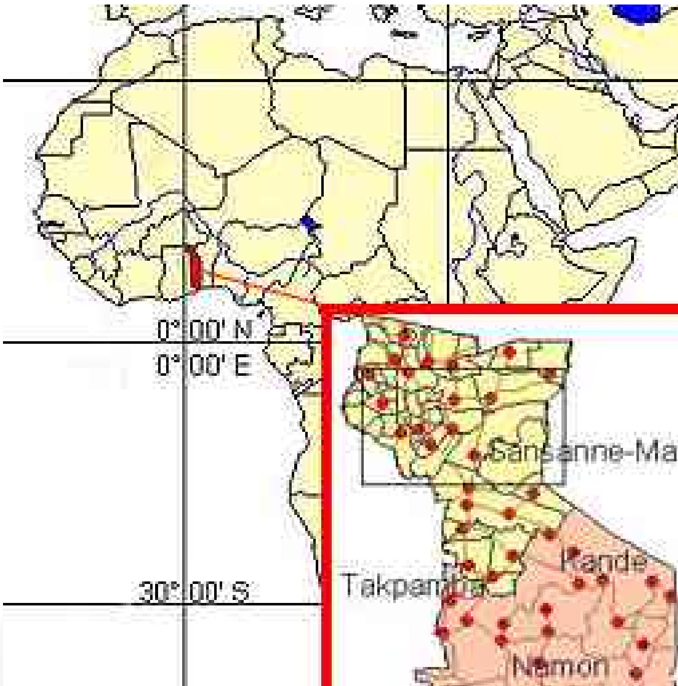
Observation area

Info

Togo in West Africa is bordered by Benin to the east and Ghana to the west. The two experimental areas are located in northern Togo. The first area is situated in the Kara region (intensive agricultural zone), and the second area is in the savanna (extensive agricultural zone) and in L'Oti (a nature reserve undergoing transformation). After consultation with the users in Togo, these two areas were deemed the most suitable as treatment units.

This region is part of the Sudanese-Guinese belt, where plant growth is characterised by tussock grass and open savanna with predominantly small trees. Both areas have a precipitation pattern with a single long dry season of 5 to 6 months (monomodal system) and an average annual temperature of 25.5°C.

Because of the major differences in geological formations, the landscape in this northern part of Togo consists of numerous small vegetation units.



Localisation map

Terrain photos Kara

Terrain photos Kara

Info

Satellite data

A study of the fragility of the natural environment requires a great deal of data about the physical characteristics of the soil, the relief, the vegetation and also the land use. The physical soil characteristics largely determine the fertility and how well the plants can take root in it. The relief of the land was derived from topographical maps and stored digitally (the digital terrain model). From this digital terrain model the topographical factor (LS) was then calculated from the "Universal Soil Loss Equation" (USLE) or universal equation for computing soil loss due to water. Along with this, the 1995 agricultural census provided information about population pressure and cattle densities. Both of these factors have a major impact on land use and the resultant fragility.

A false colour composition (bands 2, 3 and 4) of a TM image)
© ESA, distributed by Eurimage

For the Kara region, biomass data were also collected to be able to know the availability of food at the end of the dry season.

The two regions were digitised on the basis of the maps available in Togo. A Landsat TM satellite image of 1995 was used to derive the land cover and the vegetation via classification techniques and vegetation indexes. Fieldwork supported by the Global Positioning System (GPS) then allowed us to compare the classified images with reality.

WETLANDS

Water !

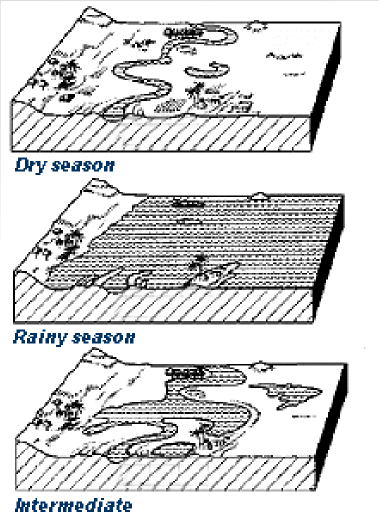
Africa boasts several of the world's largest wetlands. Some of these wetlands are located in the Sahel, an otherwise dry and hot area where rainfall is scarce and unpredictable. These flood plains are fed by rivers (Chari, Logone, Niger, etc.) carrying water from the wet South. It takes several months before the surface water flows off and is carried away via the rivers. This means that the maximum water level in the flood plains is only attained in October. By that time, the dry season has already been under way for several months. The plain dries out very gradually, and until the end of February there is still enough soil moisture in places to support lush green vegetation. Both for herdsmen and their animals and for wild animals (elephants, gazelles, antelopes, giraffes, etc.), the flood plain is indispensable to get through the long dry season.

Yet there is a problem: over the past 40 years, the human population in the area has grown substantially, and the demand for agricultural land and irrigation water is increasing. Therefore dams are being built and irrigation networks laid out.

Map of area under study:
the flood plains of the Senegal River, the inner delta and the flood plains of the Niger, Lake Chad, and the flood plains of the Hadejia-Nguru and Logone

WETLANDS

However, these completely disrupt the natural hydrology of the wetlands. At places the plain is completely dried out, with the predictable consequences for livestock and wild animals. Various organisations, such as the WWF (World Wildlife Fund) and the IUCN (International Union for the Conservation of Nature), are trying to combat this. Using refined hydrological models, the effect of each intervention (such as digging canals, cutting dikes, etc.) is forecast. The final result is evaluated with the aid of field observations and satellite images (SPOT-XS, LANDSAT-MSS, radar, etc.). Given that these wetlands are very extensive and dynamic, they can also be studied using images with low spatial and high temporal resolution, such as NOAA-AVHRR and SPOT VEGETATION. With the aid of these images, vegetation maps can be made and change processes (dehydration, etc.) can be monitored.



Methodology and Results

VEGETATION MAPS : HARD OR SOFT

Hard classification

With hard classification, each pixel is attributed to the (vegetation) class it most closely resembles. The result is a single map with a limited number of vegetation classes.

The hard classification technique is typically applied to high-resolution images, such as SPOT-XS and Landsat-TM.

SPOT XS image 30 November 1994
© CNES - Distribution Spot Image

However, when it is used to classify low-resolution images, such as SPOT VEGETATION, a problem arises. These images are built up from pixels each of which corresponds to an area of 1000 x 1000 meters (100 hectares) in the field!

Experience has shown that several vegetation types generally exist within an area of this size. For example, one pixel can consist of: an area with 20 hectares of open water, surrounded by a zone of marsh vegetation covering 30 hectares, in the middle of a vast dry area of 50 hectares (dry grass with dispersed bushes). This is called a 'mixed pixel'.

A hard classification might attribute this pixel to the class "dry grass with dispersed bushes", because that is what covers the largest part of the pixel. All the other information is simply lost. The primary purpose of a soft classification technique is precisely to retain all this information.

SPOT VEGETATION image 25 October 1998.
With the aid of these images, vegetation maps can be prepared and change processes (dehydration, etc.) monitored.
© CNES

Methodologyand Results

Soft classification

A soft classification does not make a single vegetation map, but rather a single map per vegetation type. The mixed pixel is "unmixed" into its components. Each image point on these maps has a value between 0 and 100, whereby the value 0 indicates that the vegetation type does not appear in the pixel, while the value 100 indicates that the entire pixel is covered by it.
In most cases, however, the value will lie somewhere between these extremes. These maps are called 'fraction images'.

$$r = f_1 * p_1 + \ldots + f_k * p_k + \varepsilon$$

In the literature, several methods are described to apply this unmixing. They can be based on neural networks, fuzzy logic, or statistics. This research uses the last technique.

What follows is - unavoidably - a bit of mathematics. According to the theory of the "linear mixing model", the reflectance of a pixel is equal to the sum of the reflectances of its parts (think of the open water, marsh vegetation, etc. described just a moment ago). Moreover, the reflectance of such a part is directly proportional to the surface covered (think of the 20, 30 and 50 percent in the example just given). We can put this into the formula above, where r represents the total reflectance (observed by the satellite), fi the fraction or percentage which is covered per vegetation type i and pi the pure reflectance of vegetation type i (as observed if the entire pixel were covered by this vegetation).

This equation is then converted into a system of equations by applying them to each band (for one pixel) or to each pixel (for one band). The number of unknowns is equal to the number of vegetation types to be distinguished, and thus is much smaller then the number of equations. Such systems are called "over-determined" and can be solved with multiple regression techniques. The above-mentioned fraction images are the final result.

Methodology and Results

THE SATELLITE REGISTERS CHANGES IN TIME

Two methods were evaluated for monitoring wetlands: Post-classification comparison and Multi-temporal change vector analysis. Both are capable of detecting the sometimes subtle changes, but there are important differences between them.

Post-classification comparison

Accurate, but complicated and time-consuming

For "Post-classification comparison", two sets of fraction images are necessary, one for each point in time to be evaluated. Changes can be mapped out by noting, for each vegetation type, the difference between the fraction images.
This method offers two advantages: even subtle changes are recognisable (slight shifts within the same class, not merely shifts from one class to another) and the results are a direct interpretation of the vegetation. The only disadvantage is that one must have two sets of fraction images, which costs both imaging material and computer time.

Multitemporal change vector analysis

Less accurate, but faster results

Vector analysis of changes at different points in time does not have this last disadvantage. Only two sets of low-resolution images are necessary. From them, one first derives a parameter with which the condition of the vegetation can be described, such as for example a vegetation index (NDVI).
For each pixel, a multidimensional condition vector is then defined, with each band corresponding to one dimension. Changes are mapped out by subtracting these vectors pixel by pixel. Hereby both the direction and the magnitude of the vector can be used as change indicator.

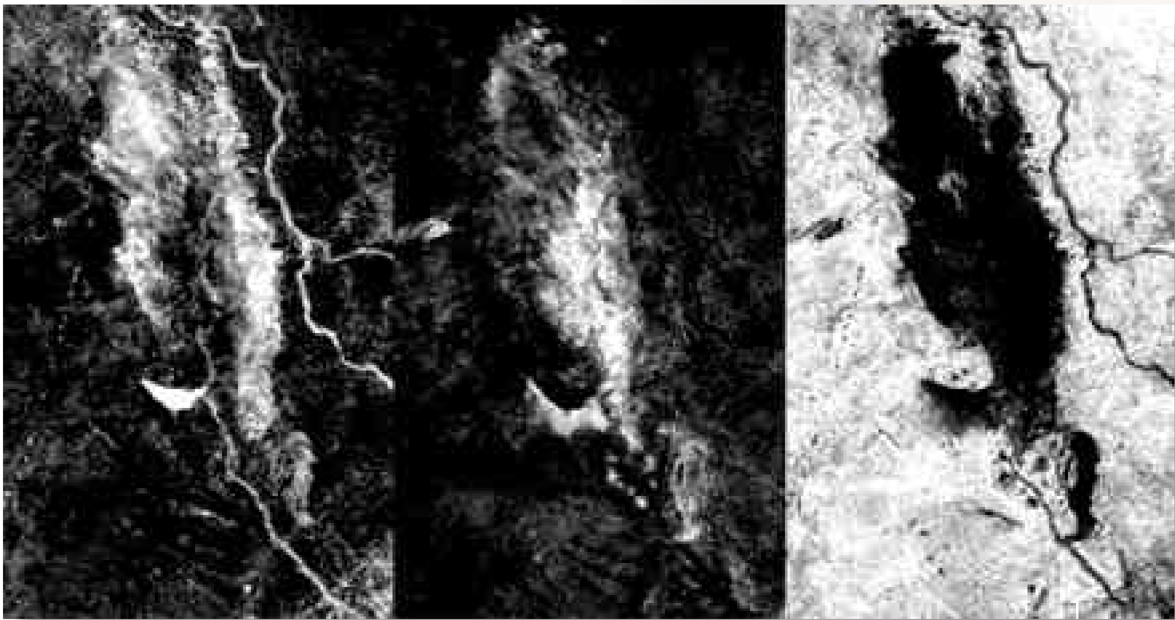
Results

VEGETATION MAPS : HARD OR SOFT

This technology was applied on a number of SPOT VEGETATION ten-day synthesis products dating from August 1998 to June 1999. A large number of combinations were looked at, varying from mono- to multi-temporal with a maximum number of bands.

The figure shows the calculated fraction images of the entire flood plain of the Logone for the three classes. The fraction images of open water, marsh vegetation and dry vegetation are shown here from left to right.

For each of the fraction images, the colour varies from black (value 0) through grey to white (value 100). The image of the dry vegetation clearly shows that the flood plain is sharply delineated (white is dry vegetation). The Logone River is also clearly visible: the white line running through the middle of the plain in the fraction image of water. On the right, moreover, you can see the Chari River. The central section of the plain, on both sides of the Logone, is dominated by marsh vegetation. This is primarily a wild type of rice which grows in deep water. At the outer edge of the plain there is primarily open water, with some marsh vegetation at points.



From the left to the right are shown fraction images of open water, marsh vegetation and arid vegetation

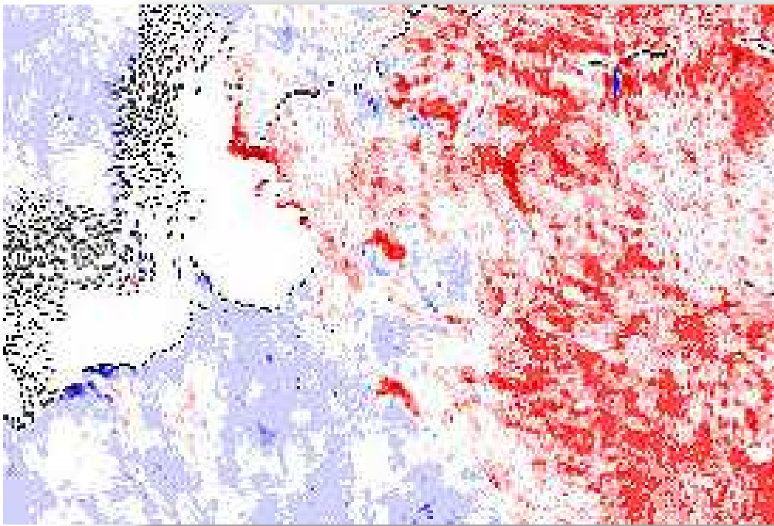
Results

THE SATELLITE REGISTERS CHANGES IN TIME

It rained there !

To assess the latter method, two NOAA-AVHRR time series were used, placed free of charge on the Internet by the Global Land 1 Km Data Set project. They date from October to January of 1993 and 1995, and thus coincide with the drying out period of the wetlands. This phase is decisive for plant growth and thus is interesting for monitoring purposes.

The figure reproduces the total NDVI-differences. It is striking that blue hues dominate in the northern half of the image, which corresponds to lower NDVI values in 1995, while in the southern part the opposite is true and red hues dominate. This indicates that in the South extra rainfall probably kept the vegetation green longer in 1995 than in 1993. This is confirmed by the blue tint of the Maga Reservoir, where the rain produced a higher water level and the NDVI values - which are negative for open water - consequently are lower than in 1993.



Differences in NDVI between 1993 and 1995. Blue hues indicate weak NDVI values in 1993, while red hues point at higher NDVI values for 1993.

This is confirmed by the blue tint of the Maga Reservoir, where the rain produced a higher water level and the NDVI values - which are negative for open water - consequently are lower than in 1993.
However, the problem with this method appears to be the interpretation of these changes on vegetation areas. For this it can be useful - along with the multidimensional approach - to incorporate the one-dimensional changes into the interpretation as well.

CONCLUSION

With the aid of remote detection, and particularly low-resolution images, vast wetlands can be mapped and their evolution monitored over time. With the results of such research, policy-makers are better able to estimate the consequences of human interventions (building dams, laying irrigation networks, etc.). They can then take these forecasts into account when making future plans, so that these ecologically and economically valuable areas are preserved.

Team

Coordinator

Prof. Dr. Robert De Wulf
Laboratory of Forest Management and Spatial Information Techniques
Universiteit Gent
Coupure Links 653
B-9000 Gent

www: https://www.ugent.be/bw/dfwm/en/research/forsit
Tel : +32 (0)9 / 264.61.10
Fax : +32 (0)9 / 264.62.40
e-mail : Robert.DeWulf@UGent.be

Partner

Jan Verhoeye (RUG)

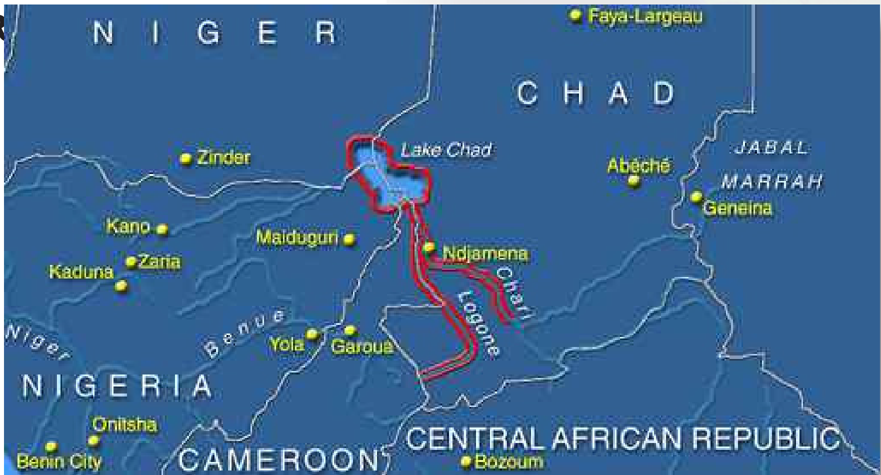
Info

ABSTRACT

Wetlands (water-rich areas) can be found all over the world. Some are fed with salt water, others (inland) with fresh water, or (in coastal areas) with a combination of both salt and fresh water. In wetlands one finds typical plants and animals, some of which live in no other ecosystem. Thus, these areas have exceptionally high ecological value.
For migratory birds wetlands constitute a major food source en route, and a suitable place to spend the winter. For human beings, they are of direct importance for fishing, and as source of food for livestock in otherwise dry areas.

On the international level, the Convention of RAMSAR was adopted in 1975 to better protect wetlands. In spite of this, these valuable areas are continuing to diminish in many places, and further efforts remain necessary. This is true in the Sahel as well.
The Sahel is known as a hot and dry area where rain is scarce and hard to forecast. Yet here is where one finds several of the world's largest water-rich areas. These wetlands have exceptional ecological and economic significance. However, their very existence is threatened by large-scale agricultural projects which entail the building of dams and irrigation networks.
On the basis of satellite images, maps can be prepared to monitor the condition of these often difficulty-accessible areas. This information can in turn form a solid basis for management aimed at their 'sustainable development', i.e. one which in the long term meets both ecological and economic needs.

OBSERVATION AR



SATELLITE DATA

Along with satellite images (SPOT XS, NOAA AVHRR and SPOT VEGETATION), data on hydrography, topography, infrastructure works, parks and protected areas, land cover, etc. were also used. During the months of February and November, field data were also collected.

Projects financed by the Belgian research programme
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GAME MANAGEMENT

THE CARRYING CAPACITY IS NOT BOUNDLESS

Wallonia's Nature and Forest Division (DNF for Division de la Nature et des Forêts) is responsible for the sustainable management of the game populations in the Walloon Region. As a result, it must set reasoned annual hunting quotas (or cull rates) for the various parts of the Walloon Region that harbour deer. Such hunting quotas are developed on the basis of two types of information, that is, the number of deer in a given area and the maximum number of deer that this area can support without endangering the forest's economic value and ecology. This is the 'carrying capacity'.

In this context, the Nature, Forest and Timber Research Centre (Centre de la Recherche de la Nature, des Forêts et du Bois) or CRNFB is studying the possibility of defining and mapping carrying capacity indices of the stands in part of Saint Hubert Forest. This index, which is based on analysis of many criteria, embraces both qualitative and quantitative parameters (e.g., dominant species, tranquillity, soil type, amount of light reaching the ground, proximity of feeding grounds and sheds, and effects of felling timber).

While some of these variables are relatively stable and can be deduced directly from existing documents (soil maps, road network, etc.), other variables related to the stands' biophysical characteristics are much more dynamic. The table recapitulates the state of our knowledge of various criteria for Saint Hubert Forest.

Code	Category	Criterion	Information source	State of knowledge
1.1	Soil	Nature	Soil map	Complete
1.2	Soil	Drainage	Soil map	Complete
2.1	Stand	Type (C, BL or dominant species)	MF: Forest plot NMF: variable	MF: complete NMF: incomplete
2.2	Stand	Age	MF: Forest plot NMF: variable	MF (C): Complete MF (BL): known or indeterminate NMF: incomplete
2.3	Light	Coverage rate	Aerial photographs (B&W)	Incomplete
3.1	Soil amelioration	Proximity of feeding grounds (grass or woody forage)	MF: Forest plot NMF: variable	MF: complete NMF: incomplete
3.2	Shelter areas	Proximity of sheds (shelter areas)	MF: Forest plot NMF: variable	MF: complete NMF: incomplete
4.1	Tranquility	Road and railway network	1/10, 000-scale map	Complete
4.2	Tranquility	Presence of humans	Users statistics and survey	Incomplete
5.1	Circulation	Presence of fences	MF: Forest plot NMF: variable	MF: complete NMF: incomplete

Table: State of knowledge of criteria required for constructing a carrying capacity index for Saint Hubert Forest
MF: forest under control of the Walloon region, NMF: forest not under control of the Walloon region,
C: conifers, BL: broad-leaved-trees

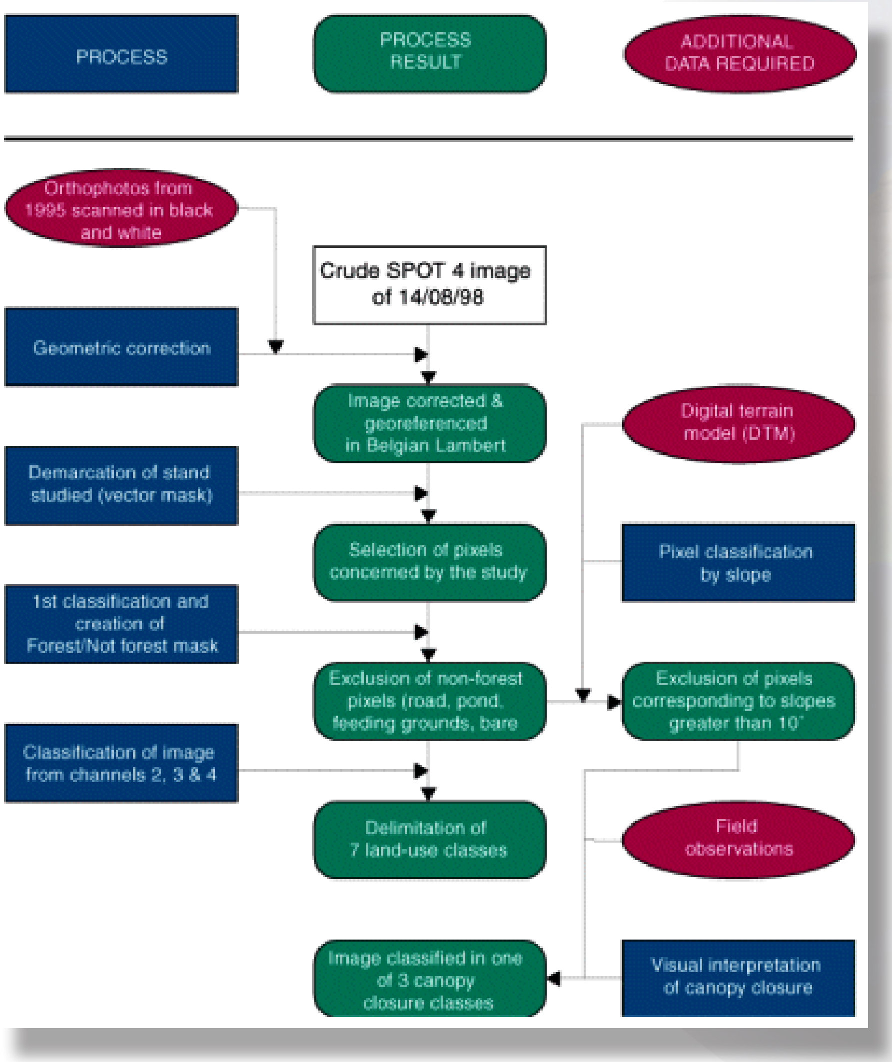
How many deer may we keep

The final goal of the CRNFB research programme is to develope a steady-state carrying capacity mapping method for managing the habitats of deer. The estimation of the canopy closure is a critical step in the model used to assess the wood's carrying capacity.

Now, a specific aim of this study is to show that remote sensing by satellites can provide accurate estimates of the types of stand in a forest and their canopy closure rates.

Methodology and Results

The diagram shows the main steps that must be followed to obtain the desired data from the crude data. This study required additional field observations to interpret the remotely-sensed signals better. An important component of this study is the analysis of the compatibility of the Game and Hunting Laboratory's requested key with the use of satellite imagery. There is also call to analysis the topography's effects on the satellite signal's quality, given the type of information being sought.



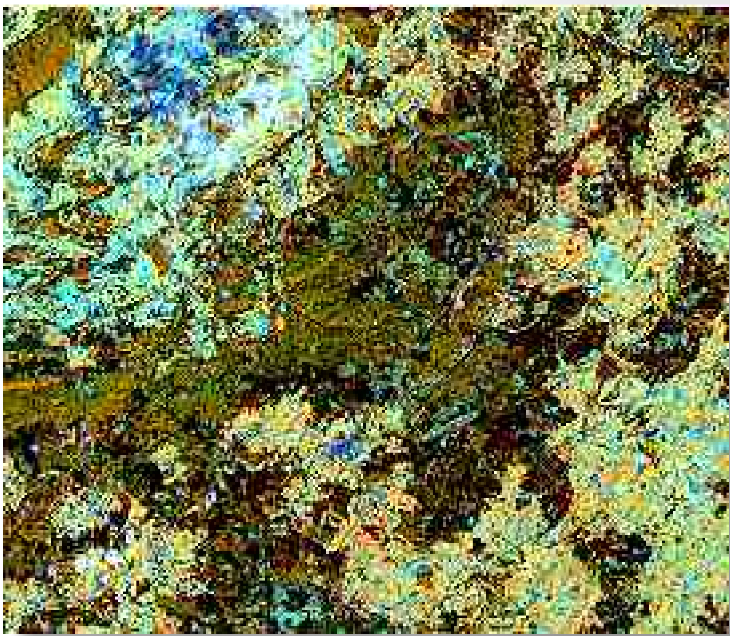
Methodology and Results

Vegetation map

Geometric correction

The first step in using a satellite image is to correct the image geometrically. The aim is to be able to make the image compatible with existing cartographic data. To do this, the ground control point (GCP) method is used. This consists in marking out easily identifiable points on the image. These points are then located on a map or orthophoto and georeferenced in a coordinate system (for example, the Lambert system in Belgium).

The SPOT image mentioned above was corrected using aerial orthophotos. The mean position errors are a 24-metre east/west shift and a 12-metre north/south shift.



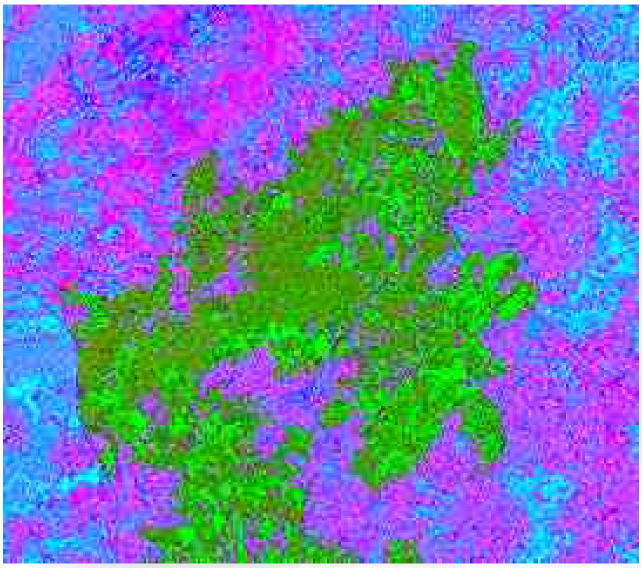
Geometrically corrected SPOT Image of Saint Hubert forest.
The conifer stands appear in black, the stands of
broad-leaved trees in dark green, the villages in dark blue
and fields and meadows in orange and light blue.
© CNES - Distribution Spot Image

Methodology and Results

A mask…

To isolate the study area from the rest of the picture we create a vector mask. This is done by digitising on the screen the outermost boundaries of the forest stands being studied. Subsequent processing is then performed only on the pixels located under this mask.

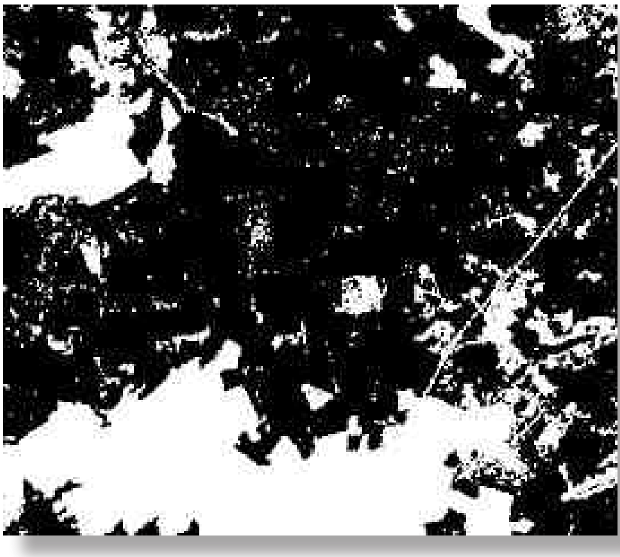
Other masks are then created inside this general vector mask in the wake of a first classification. These masks, which this time are based on the pixels' spectral values, are used to eliminate pixels that are contaminated by clouds or their shadows, for example, or to isolate broad-leaved or coniferous stands from the rest of the forest.



The Saint Hubert forest is delimited by a vector mask. Within this mask, pixels corresponding to forest (conifers in light green and broad-leaved trees in dark green) are isolated from the other pixels

Filtering

The masks that result from the multispectral classification analyses often contain stray pixels that must be filtered out to yield clear boundaries for the various types of land cover studied. The modal filter's aim is thus to reduce the spottiness created by these isolated pixels.



Crude forest/non-forest mask of a section of the Saint Hubert forest. The forest is represented in black, other landuses appear in white.

Same mask as in previous figure after modal filtering involving a 3*3 pixel mobile window.

Methodology and Results

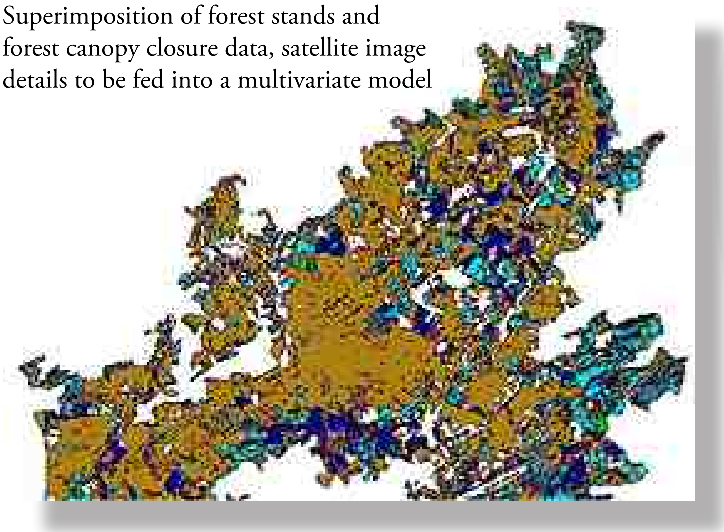
Classification

The successive classifications using appropriate masks yield a deliberately large number of classes. The next step is to recombine several classes representing the same land cover into one class. These regroupings will be dictated by the aim of the classification and map's set key. In our case, the classification enables us to determine the types of tree stands and, in the case of the spruce stands, three age classes. Some pixels that could not be put with certainty in one or the other class have been placed in a class of their own.

The forest's canopy closure is extracted by digitising the crude image on the screen. The forest areas that an image interpretation expert has identified as open areas are placed in a special class. The other forest areas are considered to have closed canopies, although the very open areas (windrow, clear cuts, very recent plantings, etc.) are generally put under the non-forest mask.

The two maps produced by this classification procedure and visual interpretation are superimposed on and crossed with each other to obtain the desired information, which is then fed into the Nature and Game Laboratory's multivariate model.

Superimposition of forest stands and forest canopy closure data, satellite image details to be fed into a multivariate model



Some examples of applications

The project shows that multispectral high-resolution images are useful for mapping forests for game management purposes. This method has comparable applications in Temperate Zone forest management.

It provides a new source of information to update existing forest databases (which were compiled from field measurements and aerial photographs) economically.

It may be used to monitor changes (acreage, state, developmental stages, composition, etc.) in large, uniform forest units.

It may be used to appraise damage caused by storms, fires, and other disasters.

Team

Coordinator

Pierre Defourny
Université Catholique de Louvain
Département des Sciences du Milieu et de l'Aménagement du Territoire
Place Croix du Sud, 2 bte 16
B-1348 Louvain-la-Neuve

www: https://uclouvain.be/en/research-institutes/eli/elie
Tel : +32 (0)10 / 47.23.74
Fax : +32 (0)10 / 47.88.98
e-mail : Pierre.Defourny@uclouvain.be

Partners

Carlos de Wasseige (UCL)
Simon de Crombrugghe (CRNFB)
Alain Licoppe (CRNFB)

Info

Abstract

Plants and animals live in a system of complex equilibria. Upsetting this balance by deforestation, for example, can lead to the disappearance of certain varieties of plants and animals and/or overpopulation by other varieties or species.

Sustainable forest management and maintaining the balance between plants and animals are musts not only for tropical forests, but at home, too. The sustainable management of the forest's game populations involves calculating the forest stand's carrying capacity. This index is compiled from several parameters, some of which vary greatly over time.

This study shows that remote sensing can be an interesting tool for characterising dynamic parameters. Remote sensing makes it possible to update geographic databases for large expanses quickly, homogeneously, and economically. These geographic databanks can then be used to estimate a wood's carrying capacity and provide foundations for sounder forest management policies. Multispectral satellite information can also be used to gauge indirectly both the value of forests and any damage that they may have sustained.

Observation area

Saint Hubert Forest covers some 16,500 hectares located in the forest holdings of Saint Hubert and Nassogne. It consists of a large forest of broad-leaved and coniferous species. The relief is hilly. Saint Hubert Forest is a game management unit. The area's carrying capacity is under investigation.

Satellite data

Sensor: SPOT 4 HRVIR

The Nature, Forest, and Timber Research Centre is currently studying a satellite image and the vector data obtained from the Walloon Region's Nature and Forestry Division and its own holdings. The satellite image was acquired on 14 August 1998 and covers a large part of the Belgian Ardennes. It comes from the SPOT 4 satellite and contains four spectral bands (green, red, near infrared, and middle infrared). The satellite imagery's spatial resolution is 20 metres.