Belgian science policy office (BELSPO)

GLOBAL MONITORING

BELGIAN EARTH OBSERVATION

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Introduction

The population continues to grow, and more and more people have to live on the same area and from the same amount of raw materials. Between now and 2025, another 3 to 4 billion people will be added to the planet's population, mainly in countries which are least able to handle the consequences of this population growth and the accompanying development. This will put the Earth under tremendous pressure - just imagine the large-scale deforestation, the loss of nature areas, environmental pollution, climate change, and so on.

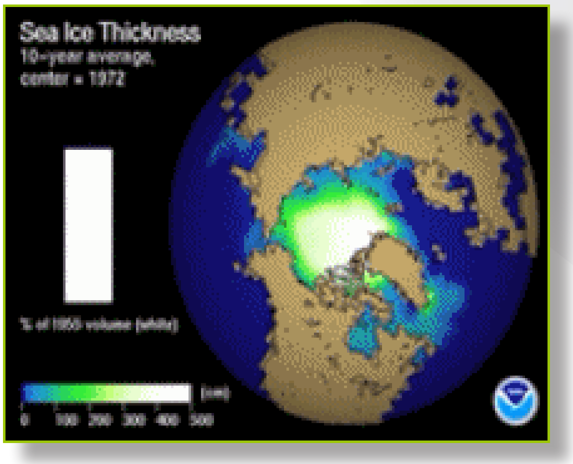
This might well have disastrous consequences - unless the economic development and management of the Earth's raw materials is placed on a sustainable basis. The past few decades have seen a growing awareness that the Earth is a single living whole, and that what happens in one place can have major consequences on the other side of the globe. El Niño and the greenhouse effect illustrate this beautifully.

Authorities throughout world are beginning to understand this, and have therefore concluded a number of international treaties and conventions, such as the Climate Treaty, the Kyoto Protocol for reducing the emission of greenhouse gasses, the Vienna Convention for protecting the ozone layer, the UN Convention on biological diversity, etc.

But it is equally striking that international financial institutions such as the World Bank and the International Monetary Fund are increasingly making financial aid to developing economies dependent on the adoption of a sustainable development policy.

Satellites are the ideal - indeed, often the only - instrument for studying world-wide processes, interactions between oceans, continents and the atmosphere, monitoring changes over vast regions, and acquiring new insights into how everything fits together. They are used to monitor vegetation, map land-use changes, measure ozone concentrations, monitor the temperature of the oceans, etc.

As such, they offer policymakers information necessary for making the right decisions for a sustainable development of our planet.

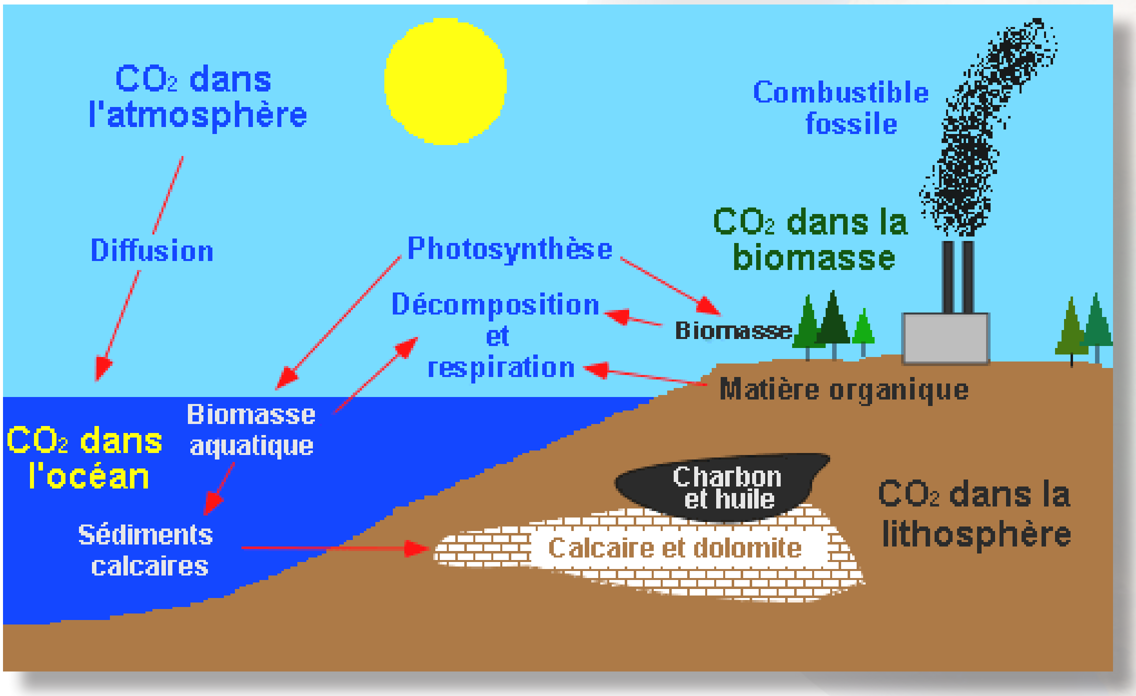


CO_2 AND PLANTS

CO_2 : We're producing too much of it

Plants absorb carbon dioxide (CO_2) from the atmosphere via photosynthesis. When plants 'exhale' and organic materials like fallen leaves and branches, etc. decompose on and in the soil, CO_2 is released once again. The equilibrium between the absorption and discharge of CO_2 is a major issue in the debate about reducing greenhouse gasses (The Framework Convention on climate changes, The Kyoto Protocol). The ever-growing greenhouse effect, after all, is partly explained by an increase in CO_2 concentrations, primarily resulting from human activities such as the combustion of fossil fuels.

The determination and prediction of changes in the carbon absorption and discharge mechanisms of plants and vegetation thus form an important aspect of this Global Change problematic.



The carbon cycle
Courtesy of "Fundamentals of Physical Geography"
http://www.physicalgeography.net/fundamentals/9r.html

CO_2 AND PLANTS

The satellite records

Ecosystem models and field measurements using measuring equipment are the traditional methods for determining the CO_2- or carbon balance in afforested areas. The carbon balance is the difference between the absorption and the discharge or emission of carbon. However, local measurements only apply for a limited area.

If we want to know the CO_2 balance for a more extensive geographical area, for example Belgium, then these measurements must be calculated or extrapolated both in time and space from various local observations. In heterogeneous areas, therefore, accuracy is highly dependent on the number of measuring points. Remote sensing provides the necessary data for applying these processes on a larger scale, so that a spatial extrapolation technique becomes unnecessary.

The computer calculates

That is why the VITO (Vlaamse Instelling voor Technologisch Onderzoek, the Flemish Institute for Technological Research) developed the C-Fix model. This is a method based on remote sensing for calculating the carbon balance of vegetation for a specific geographical area. This model not only takes afforested areas into account, it also determines the carbon balance for the whole of Belgium and maps it out for all types of vegetation.

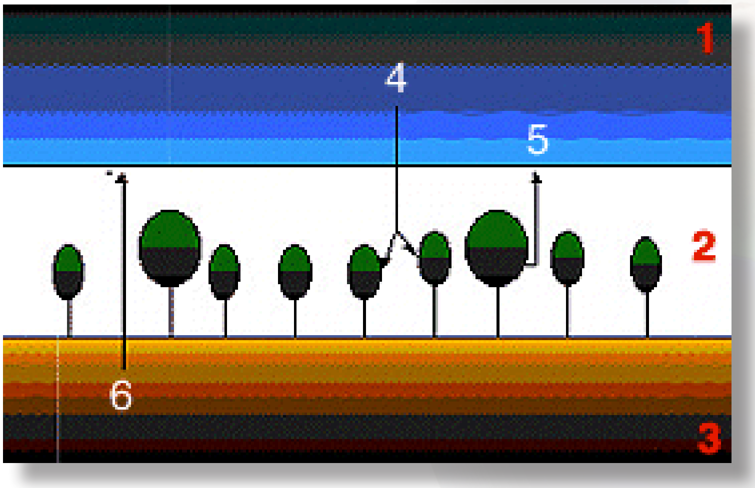
Concretely, the model is used to determine the gross primary productivity (GPP), the net primary productivity (NPP) and the net ecosystem productivity (NEP) for all types of vegetation in Belgium on a daily and/or yearly basis.

CO_2 AND PLANTS

The quantity of CO_2 which is absorbed by vegetation from the atmosphere and which is necessary for the growth of plants by means of photosynthesis is designated as the gross primary productivity (GPP). However, CO_2 is discharged once again by the same vegetation into the atmosphere through autotrophic respiration (so-called 'maintenance losses') and by decomposition of branches, leaves, etc. in the soil layer (which is referred to as 'soil respiration' or 'heterotrophic respiration'). In this context, the net primary productivity (NPP) of vegetation is expressed as the gross photosynthesis or gross primary productivity minus autotrophic respiration.

We can define the net ecosystem productivity (NEP) of vegetation as the gross productivity minus the autotrophic and the heterotrophic respiration.

The figure shows an overview of these carbon flows. The various productivities (GPP, NPP & NEP) are expressed in grams of carbon (C) absorbed per day and per square meter [g $C/m^2/d$].



An overview of the carbon flows in vegetation

1. Atmosphere
2. Vegetation
3. Soil
4. Gross Primary Productivity
5. Autotrophic respiration
6. Heterotrophic respiration

Methodology and Results

A multiplication

The Gross Primary Production (GPP) is calculated in the C-Fix model as the product of three parameters:

- climatological efficiency ec
- fAPAR
- RUE

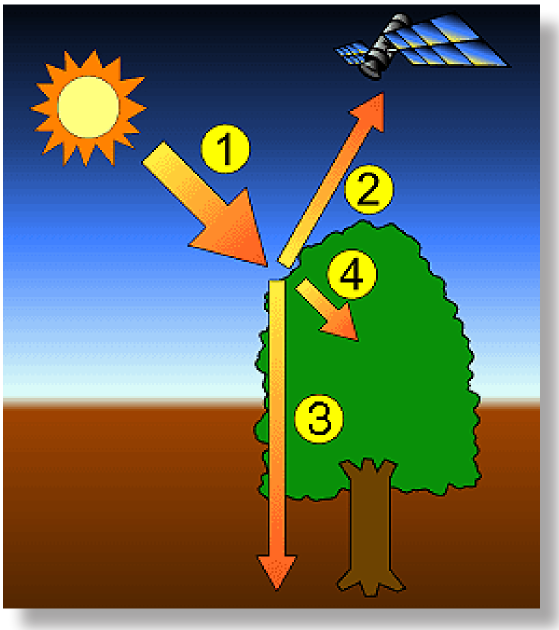
The growth of plants and thus GPP is also highly dependent on the air temperature and the amount of incident solar radiation.

The productivity losses due to autotrophic and heterotrophic respiration are calculated as a function of the air temperature, from which the NPP and NEP are then estimated:

- GPP = f(ec,fAPAR, ed, temperature, solar radiation)
- NPP = GPP - Autotrophic respiration
- NEP = GPP - Autotrophic and Heterotrophic respiration

The sun acts like a black body with a surface temperature of more than 6000°C. The sun not only radiates light, but is also a source of energy for the people, animals and plants on Earth.
Visible light, which is only a portion of the total radiated sunlight, is not only important for the visual perception of human beings and animals, but also for plant physiological processes such as photosynthesis or growth.
And that is why one frequently speaks of Photosynthetic Active Radiation (PAR). One may assume that the PAR energy at the earth's surface is around 50% of the total solar radiation.
Hereby the climatological efficiency, ec, is the share of PAR in the overall radiation.

Only a part of this incident PAR radiation is absorbed (= absorption) by vegetation; one also speaks of fAPAR, the fraction or efficiency of the absorbed PAR radiation.
The rest of the incident sunlight is either reflected (= reflection) or penetrates the foliage and reaches the ground (= transmission).
Forests have a high absorption of fAPAR and thus a low degree of reflection and transmission.
Typical fAPAR values for forests vary between 0.8 and 1.



1: Solar radiation
2: Reflection
3: Transmission
4: Absorption

Bare earth and water have a much higher degree of reflection and thus much lower fAPAR values, ranging from 0 to 0.1.

A third efficiency is the degree to which the absorbed PAR radiation is ultimately used for the conversion of CO_2 for plant growth (carbon fixation). This efficiency has also been called the Radiation Use Efficiency, ed or RUE. It indicates the efficiency with which absorbed radiation is converted in dry matter.

How many leaves ?

In the case of a specific location (for example, a field of crops or a stand of trees), the photosynthetic active radiation is measured with a PAR sensor, also called a "quantum sensor". For larger geographical areas, one uses remote sensing data, from which fAPAR can be determined. Various satellites, including NOAA, can be utilised for this. NOAA images are available daily with a spatial resolution of 1.1 km x 1.1 km.
The French SPOT satellite can also be used for this application. SPOT has a higher resolution of 20 x 20 m which is suitable for use on a plant scale. The disadvantage of SPOT, however, is its lower temporal resolution of 26 days.

The above-mentioned satellites measure the quantity of reflected solar radiation (= reflection) from the earth's surface and its covering. With the radiation measurements of a PAR sensor or with the remote sensing measurements, one can distinguish between different types of surface cover, such as water, forests, bare earth, etc.
Even more specific vegetation details can be derived on the basis of the vegetation's spectral reflection characteristics. Here we are thinking, for example, of the quantity of leaf biomass, the leaf surface area, the type and amount of leaf pigments, etc.

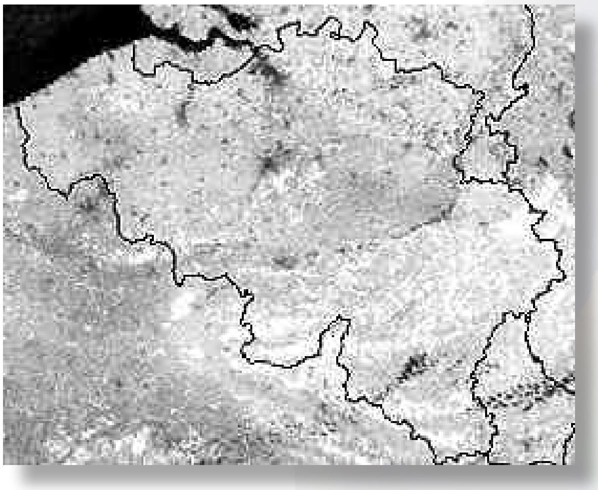
The most familiar satellite image-based parameter for deriving vegetation characteristics is the so-called NDVI (Normalised Difference Vegetation Index). The NDVI is a good criterion for the presence of green vegetation and varies between 0 and 1: low for bare earth and buildings (0.1) and high (0.9 - 1.0) for very dense vegetation, such as tropical rainforest. One can then derive the fAPAR from such NDVI images, in order finally to estimate GPP, NPP and NEP.

Methodology and Results

Results

Each day, a NOAA satellite image is taken of an area covering Belgium.

However, only cloudless images can be used for the C-Fix application. Given Belgium's notoriously overcast conditions, an average of only 40 images each year are usable.



NDVI image for Belgium

On the basis of such a NOAA AVHRR image, one can determine for all pixels (image elements) covering the Belgian territory the NDVI and finally the fAPAR. The areas in black correspond to cities (Brussels, Antwerp, Gent, etc.), while white corresponds to wooded areas.

At right you see a result of applying the C-Fix model for Belgium. The areas in Flanders, but above all in Wallonia (the Ardennes massif) with the highest NPP values, correspond to afforested areas. The major cities (Brussels, Antwerp, Gent, Liège and Charleroi), with their high degree of urbanisation, display the lowest carbon fixation level.

Agricultural areas, such as Haspengouw and the Leemstreek, show a lower NPP than the forest areas.

This is due to the shorter growing period and a lower annual radiation absorption efficiency.

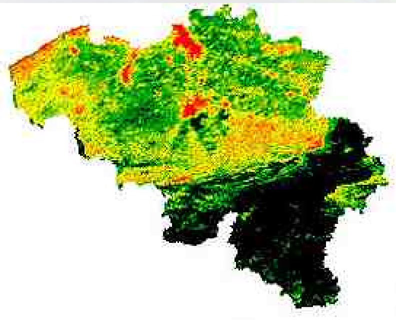
Methodology and Results

Planting trees!

Under present-day climatic conditions, with an annual average air temperature of 10°C and a CO_2 concentration of 335 ppmv, the NPP for the entire territory of Belgium amounts to around 2.38 Mton C per year.

This figure expresses the quantity of carbon which is absorbed annually by vegetation (on Belgian territory). World-wide, the total NPP quantity is equal to 75,600 Mton C per year; the share of the Belgian NPP in this total is 0.0031 %. The discharge of industry, traffic, agriculture and the residential sector (household discharge) in Belgium amounted to 30.8 Mton C in 1990. This means that only 7.7 % of these emissions were reabsorbed by vegetation. If one wanted to compensate for the just-mentioned Belgian CO_2 emissions, for example, by reafforestation, then one would have to plant trees on an area 13 times larger than the total territory of Belgium!

PPN value for Belgium for a temperature of 10°C and a CO_2 concentration of 355 ppmv

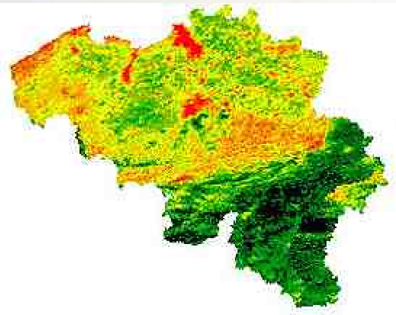


PPN value for Belgium for a temperature of 14°C and a CO_2 concentration of 355 ppmv

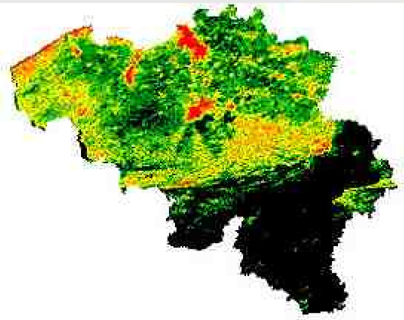
Forecasting the future's weather

C-Fix is a useful tool when making decisions relating to the greenhouse effect. The rising CO_2 concentrations in the air and the rising temperature presumably have a favourable impact on carbon fixation by vegetation. Various scenarios can be drawn up for NPP in Belgium:

- Unchanged CO_2 concentration (355 ppmv) and a temperature rise of 4° C (from 10° to 14°C).
- A rise of CO_2 from 355 ppmv to 445 ppmv and unchanged temperature (10°C).
- A rise of CO_2 from 355 ppmv to 455 ppmv and a temperature rise of 4°C (from 10° to 14°C).



PPN value for Belgium for a temperature of 10°C and a CO2 concentration of 455 ppmv



PPN value for Belgium for a temperature of 14°C and a CO2 concentration of 455 ppmv

From these figures one can derive that the quantity of absorbed carbon rises as the temperature and the CO_2 concentration increase (however, this rise of absorption of CO_2 is not directly proportional to the rise of CO_2 in the atmosphere).This simulated effect shows how vegetation can be assumed to behave in practice as the climate changes. How all of this will really come about, only future research can tell.

Methodology and Results

Conclusion

Remote sensing can be a useful tool for estimating CO_2 absorption by vegetation.

The above-mentioned figures show that the woods and forests in Belgium are not large enough to compensate our current CO_2 discharge. Even reafforestation would clearly be insufficient to fully offset emissions.

Thus the following conclusion appears inescapable: the CO_2 problematic and the related greenhouse effect and possible climate changes can only be solved by drastically reducing the discharges of CO_2 generated by industry, traffic and the residential sector. Of course, the same applies for all the other greenhouse gasses.

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Info

Abstract

The Earth's climate is determined by our planet's so-called "radiation equilibrium". A number of gasses in the atmosphere, the greenhouse gasses (CO_2, methane, ozone, etc.), have an influence on this radiation equilibrium. These gasses absorb infrared radiation which has been reflected by the Earth, thus keeping the Earth 'at the right temperature'. This is referred to as the greenhouse effect.

The greenhouse effect is a natural phenomenon which is reinforced by the discharge of CO_2 and other greenhouse gasses resulting from human activities (industry, traffic, etc.). A greater concentration of greenhouse gasses in the atmosphere means that more infrared radiation is absorbed, the greenhouse effect is increasing, and the climate is warming up.

As the temperature rises…

Because of this phenomenon, the Earth's average surface temperature is believed to have risen by around 0.5°C since the start of the 20th century. Further warming of the climate could cause the polar ice caps to melt and the sea level to rise. Such developments would have disastrous consequences.

A wide range of efforts are being made on a global scale to stop the discharge of greenhouse gasses (The Climate Change Treaty, The Kyoto Protocol) and Belgium too has committed itself to take the necessary initiatives.

... the plants refresh

Vegetation could have a favourable impact on CO_2 concentrations in the atmosphere, because plants absorb CO_2 from the atmosphere during photosynthesis.

Scientists are therefore studying precisely how the vegetation will react to an increase in the quantity of CO_2 in the atmosphere and to rising temperatures.

Satellite images are being used to provide information for the so-called C-Fix model, which can study CO_2 absorption by vegetation over wider geographical areas, such as the whole of Belgium.

The results of the research described here are giving policy makers better insight into the role vegetation could play in the CO_2 problematic, as part of a broader policy aimed at controlling the greenhouse effect.

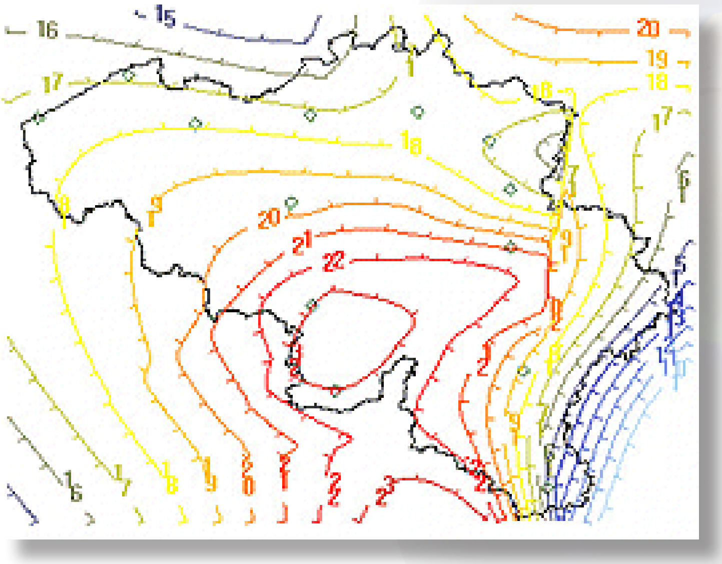
Info

Observation area

Belgium

Satellite data

The daily average air temperature and (solar) radiation, necessary as input data for the C-Fix model applied to Belgium, are calculated on the basis of meteorological data measured by the Royal Meteorological Institute.



This is done at several meteorological stations distributed throughout the country. The location of these stations with indication of the isotherms for a specific day can be found on the map.

The remote sensing data come from the AVHRR sensor on the NOAA-11 satellite platform.

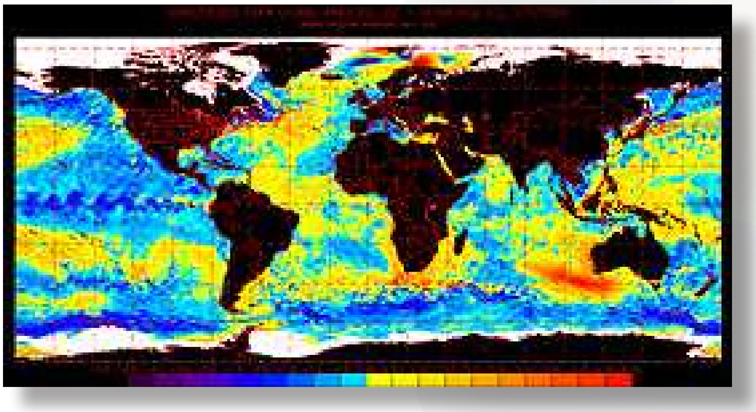
EL NIŃO TRAVELS THE WORLD

El Niño is an abnormal heating up of the waters of the Pacific Ocean in equatorial regions. El Niño means "the Christ Child", a name given to it by Peruvian fishermen when, due to this phenomenon, they saw all the fish disappear from the coast of Peru at around Christmas time every 3 to 7 years.

This heating up of the ocean waters has an impact on air pressure in certain regions. For example, it has been shown that during El Niño droughts occur in Southeast Africa and Northern Brazil, while the west coast of South America experiences excessive rainfall and flooding. The year after El Niño usually brings La Niña, with unusually cold sea temperatures and the opposite effects.

The extensive forest fires in Indonesia, the floods in China and other natural disasters are all likely to be the result of El Niño. In East Africa too, the climate seems to be influenced by El Niño/Southern Oscillation.

With the help of satellite images we are studying abnormal fluctuations in rainfall and plant growth to see whether these are always associated with the appearance of an ENSO phenomenon.



Variations in sea temperature on 1 January 2000 against average temperature. In the dark blue areas abnormally low temperatures are recorded, in the red areas abnormally high temperatures. (NOAA)

The area around Lake Tanganyika is very sensitive to climatic change. Recent fluctuations in climate are being studied by means of satellite pictures and meteorological measurements, while phenomena produced over the last 1000 years are being studied by analysing the sediments found on the lake bed.

The main aim is to understand what effect a climatic phenomenon such as El Niño/Southern Oscillation (ENSO) has on the lake and its environment. ENSO is a disturbance of the ocean and the atmosphere which occurs regularly (every 3 to 7 years) in the Pacific Ocean, but the effects of which are felt all over the world, also in East Africa.

Methodology and Results

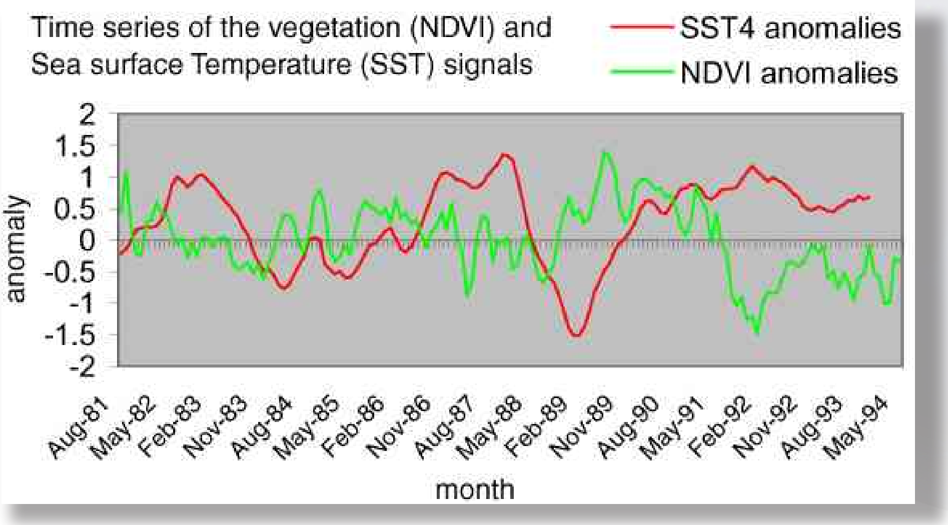
PLANTS DO NOT APPRECIATE WARM WATER

Every day, the NOAA satellite takes pictures of the entire earth's surface. These pictures are used to calculate a monthly vegetation-index (NDVI) representing the vegetation situation on the earth's surface. These monthly images have been available since 1981. This study is analysing the images for the period 1981-1994. For each pixel in each picture, the variation in the vegetation index against the average value for the month is calculated.

These variations (anomalies) are then compared with anomalies in the sea surface temperature or SST against average sea surface temperatures in the Pacific Ocean. Both anomalies are expressed over time and the researchers see whether both time series fluctuate in the same way (are major temperature fluctuations associated with major differences in vegetation?). The correlation between the two series is then calculated.

SLOW REACTION

The time series shows that the vegetation often reacts to a warming of the waters of the Pacific with a time lag. It takes an average of 6 to 7 months before the effect of the warming (or cooling) is felt in the Lake Tanganyika region. The graph shows fluctuations in the sea surface temperature (SST) and vegetation (NDVI) over time. For every month, the variation (anomaly) of the SST is given (in red) against the average SST. Positive values indicate a temperature above the monthly average; negative values a lower temperature. For every month the variation in the vegetation index against the average vegetation index is also expressed (in green). Positive values mean that the vegetation index is higher than the average vegetation index for the month; negative values indicate a lower vegetation index than the monthly average.

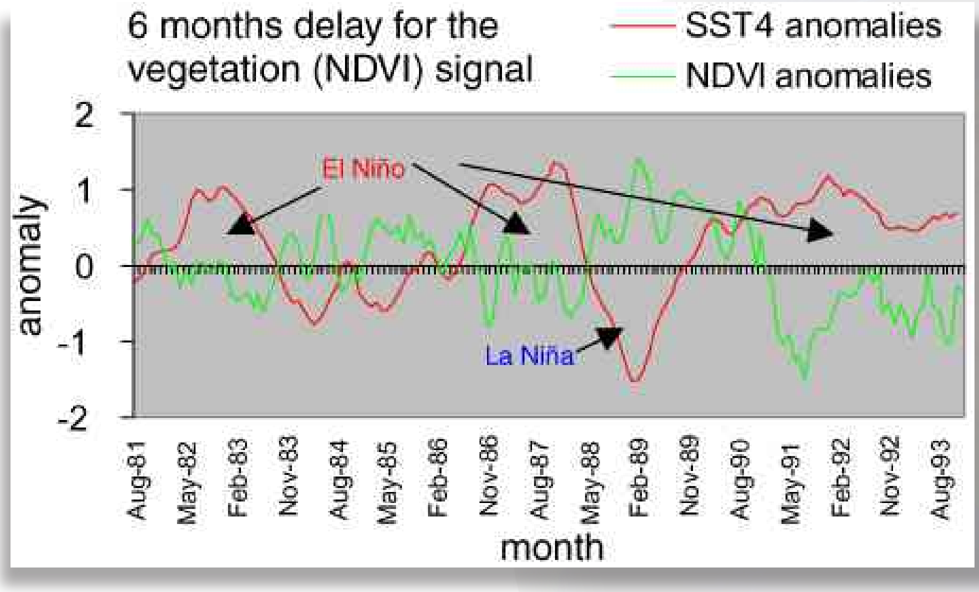


Variations in sea surface temperature (SST) and vegetation index against average values

Methodology and Results

If the time series (green curve) of the vegetation index anomaly is displaced by 6 months, the changes in vegetation are seen to coincide with changes in sea surface temperature, but in the opposite direction.

In other words, if the SST increases (El Niño), 6 months later a reduction in vegetation is observed; if the SST falls (La Niña), 6 months later more vegetation is observed.

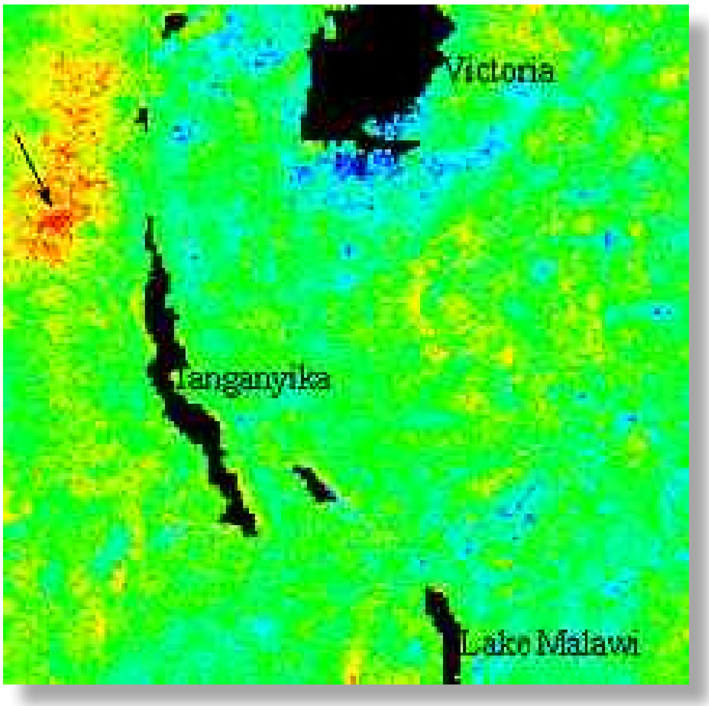


Variations in sea surface temperature (SST) and vegetation index against average values.
The curve for the variation in the vegetation index is displaced by 6 months

Methodology and Results

With a time lag of 6 to 7 months (SST positive variation, high average sea surface temperatures) El Niño causes drought in the Kivu region, with reduced plant growth (NDVI negative variation).

The map shows the zone with a strong correlation between the two anomalies (red).



El Niño (positive anomaly, high average sea surface temperatures) causes drought in the Kivu region, with reduced plant growth (NDVI negative anomaly), after a time lag of 6 to 7 months.
The map shows the affected area in red

EL NIŇO. IS IT PREDICTABLE ?

El Niño is not a new phenomenon, but something that has occurred regularly for many centuries. However, this regular pattern seems to have been disturbed since the early 1970s. This suggests that the controversial greenhouse effect could be responsible for these "upsets".

By revealing links between ENSO and climate and thus plant growth in East Africa, it will be possible, at the time of the next El Niño, not only to better forecast when the phenomenon will occur but also what regions will be affected and in what way.

Among other things, this can help harvest forecasting and ensure a more efficient aid in the event of natural disasters..

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Four institutions are contributing to the research.

The Museum for Central Africa is investigating links between recent ENSO phenomena and the climatic and fishing data recorded over the past 100 years at various measuring stations in the region. Approximately 4 months after El Niño begins in the Pacific Ocean, the temperature around Lake Tanganyika shows an abnormal increase. This has an effect on the lake and its fishing.

The Palaeontology and Palaeography Unit (UCL) is studying the layers of sediment which are deposited annually on the lake bed. Researchers are trying to discover whether layers deposited during ENSO differ from those deposited during "normal" years. This makes it possible to go back a long way into the past and thereby understand how and why climatic disturbances occur

The Laboratory for Botany (RUG) is studying the lake algae, past and present, in an attempt to determine how the algae composition varies from season to season and in the past.

The Department of Geography (UCL) is studying the most recent period of history (last 15 years).

Info

Abstract

For centuries Peruvian fishermen have watched with alarm as fish stocks suddenly shrunk every 3 to 7 years. They called this phenomenon El Niño (the Christ Child) as it always seemed to occur just after Christmas.

El Niño is an abnormal warming of the sea and is part of a wider phenomenon ENSO (El Niño/ Southern Oscillation). In addition to a warm phase, El Niño itself, that typically lasts from 8 to 10 months, ENSO often also includes a cold phase, La Niña. The whole ENSO phenomenon normally lasts from 3 to 7 years.

El Niño is changing

Over recent decades the regular ENSO pattern has changed. Although it is not yet known exactly what causes ENSO, it is suspected that the departure from the regular pattern is partly linked to the greenhouse effect. What is known with certainty is that the phenomenon does not only influence sea temperature off the Peruvian coast, but has an impact much further afield. It seems that even East Africa is affected by the ENSO phenomenon. After every El Niño drought is experienced - after a time lag - in the Kivu region, with a subsequent reduction in plant growth.

Satellite images are ideally suited to monitoring change processes. In this case they are used to identify changes in sea surface temperature and abnormal fluctuations in vegetation cover.

By revealing links between ENSO, climate and fluctuations in plant growth in East Africa, it will not only be easier to predict when the next El Niño will come, but also what areas will be affected and in what way.

Observation area

Satellite data

NOAA-AVHRR

Links

NASA Earth Observatory : https://earthobservatory.nasa.gov/Features/ElNino

OZONE

A BIT OF CHEMISTRY

Ozone (O3) is a molecule composed of three oxygen atoms. This molecule is created when ultraviolet radiation (sunlight) enters the stratosphere and smashes into oxygen molecules (O_2), breaking them down into individual oxygen atoms (O). The lone atomic oxygen quickly combines with nearby O_2 molecules to form ozone.

Although ozone is found in trace amounts throughout the atmosphere, it is not evenly distributed. Approximately 90 percent of all ozone is contained in the region of the atmosphere known as the stratosphere, which is situated between 15 and 50 km above the Earth's surface. The region below the stratosphere, known as the troposphere, is where our weather phenomena take place. The region of the stratosphere that contains higher concentrations of ozone is generally referred to as the ozone layer (approx. 24 km above the earth's surface).

The ozone layer is thinnest in the tropics and denser towards the poles, though there are large seasonal fluctuations.

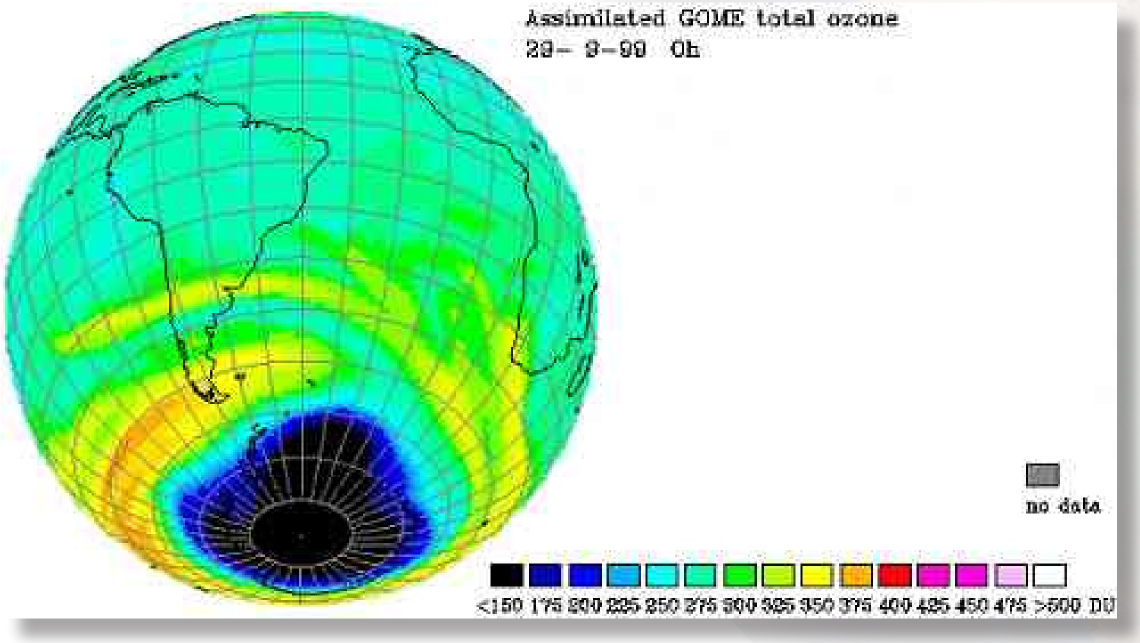
OZONE

Ozone plays a central role in both tropospheric and stratospheric chemistry: it is an important "greenhouse" gas and the ozone layer acts as a natural filter, absorbing most of the sun's biologically harmful ultraviolet (UV) radiation.

Depletion of the stratospheric ozone layer would lead to an increase in UV radiation down at the earth's surface, where it could disrupt biological processes and damage a number of materials.

In the 1970's, scientists realised that chlorofluorocarbons (CFC's), related halogen compounds, compounds containing bromine and nitrogen oxides (NOx) could all deplete the ozone layer.

CFC's are a common industrial product used in refrigeration systems, air conditioners, aerosols, solvents and in the production of some types of packaging. Nitrogen oxides are a by-product of combustion processes, e.g. aircraft emissions.



OZONE

The ozone hole

However, it was the discovery of a hole in the ozone layer which occurs each spring over Antarctica that focused world attention on the problem and the possible impact that human activities could have on life and human health, leading to unprecedented global action. Through the Vienna Convention on the Protection of the Ozone Layer in 1985, governments committed themselves to protecting the ozone layer and to co-operating with each other in scientific research to better understand atmospheric processes.

The thickness of the ozone layer has been measured for decades at a number of stations using ground-based measurements like spectrophotometers and upper-air in situ measurements with balloon sondes. Those measurements constitute a long-term database of ozone history, but the geographical coverage is incomplete since large regions like Africa and the oceans were left out.

Ozone has been measured using satellites ever since the early 1960s, but only about 15 years ago did the coverage and resolution improve to a point where satellite measurements of atmospheric ozone could become a useful tool in ozone layer studies. A major advantage of satellite measurements is the ability to gather data in remote areas.

Satellite ozone data are mainly used for monitoring the global and vertical distribution of ozone. The vertical distribution of ozone in the atmosphere is an important piece of information for climate study and climate change, while information on total ozone can help to forecast the weather.

Data and Methodology

Total ozone

The “thickness” of the ozone layer is the total amount of ozone in the atmosphere above a given location. It is measured in Dobson units (DU, 1 DU corresponds to 2,686,100 ozone molecules per m^2) – typically ~260 DU near the tropics and higher elsewhere.

Ozone profiles

Vertical distribution of ozone throughout the atmosphere. .

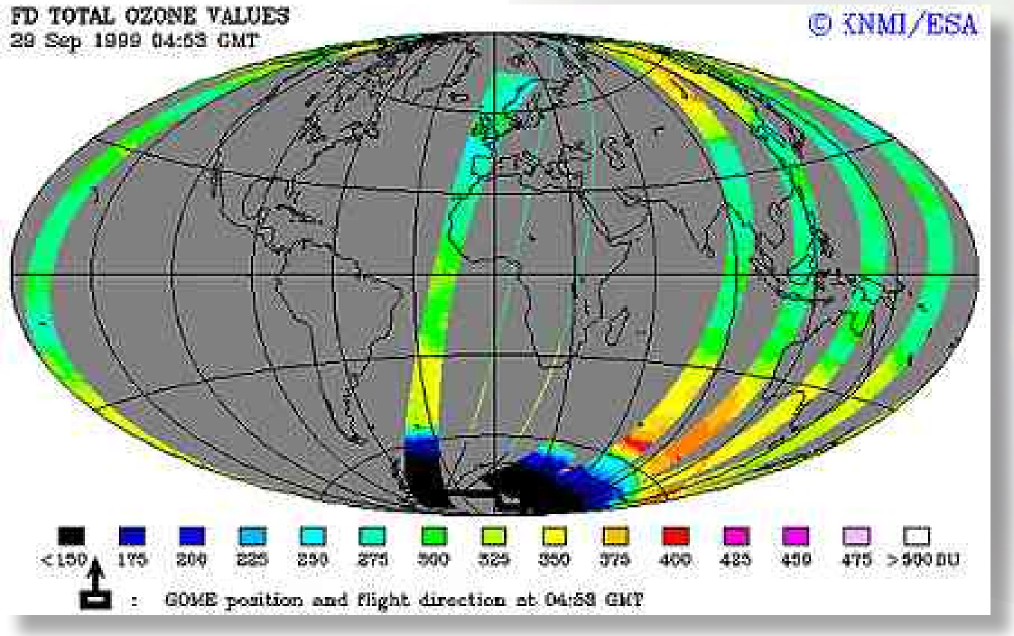
Measurement techniques

The satellites orbit at an altitude of about 700 km. From that height it is possible to measure the ozone concentrations in a number of ways. The two most commonly used are the nadir viewing and the occultation technique.

Results

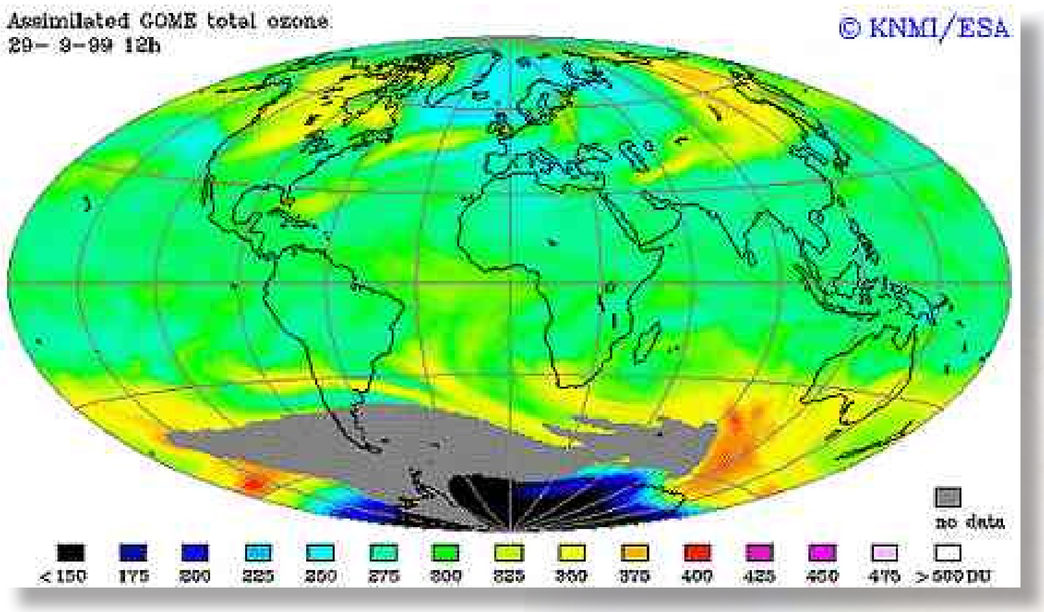
Global distribution of ozone

On a map of instantaneous raw ozone data one can see bands with ozone values as well as large areas where no data are available (coloured in grey). The “bands” correspond to regions located underneath the satellite trajectory.



Data and Methodology

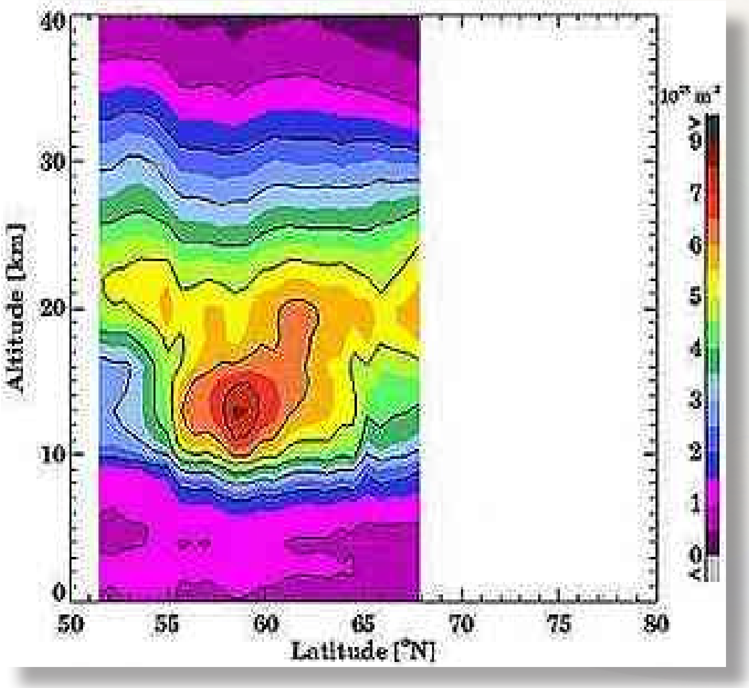
Instantaneous data can be combined to produce global maps of the ozone layer at any given time. In the image, high ozone values are coloured yellow and red, while low values are green and blue.



Vertical distribution of ozone

The vertical distribution of ozone in the atmosphere provides useful information, like the altitude at which ozone is destroyed and the possible exchanges that exist between the lower and the upper levels of the atmosphere. Conventional measurement techniques cannot provide such data.

On the map representing the vertical distribution of ozone in the atmosphere along a line oriented North to South between 52 and 67 degrees northern latitude, high ozone concentrations are coloured red and yellow while low concentrations are blue and violet. The vertical distribution of ozone varies significantly from one place to another.

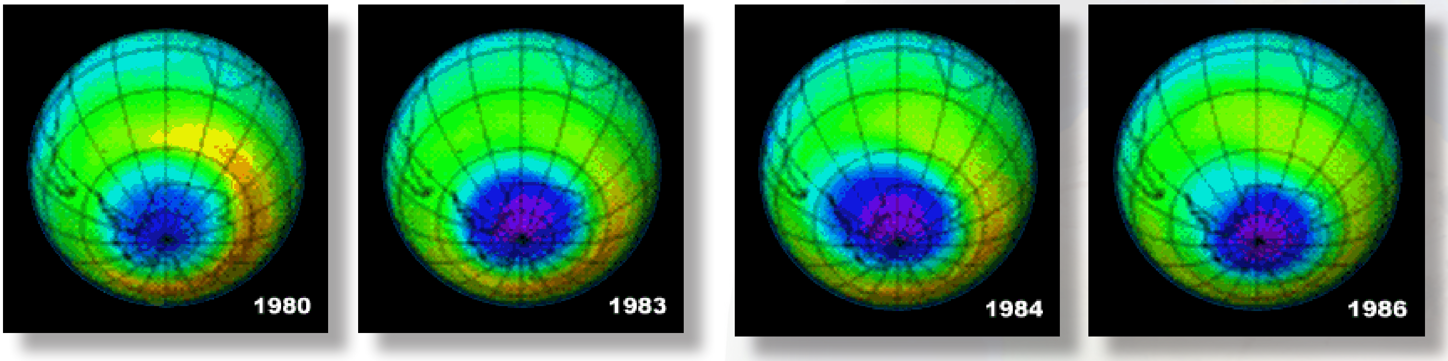


Data and Methodology

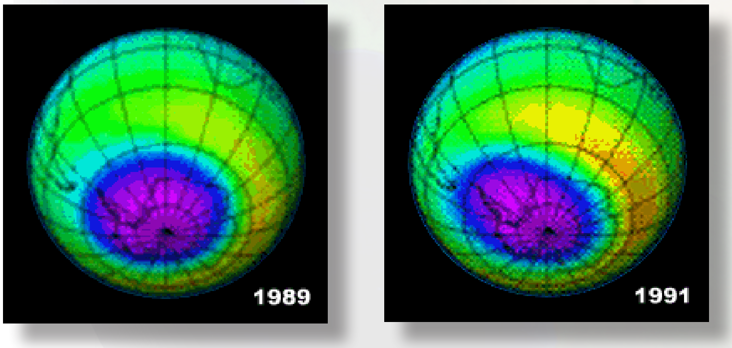
The Antarctic ozone hole

A dramatic loss of ozone in the lower stratosphere over Antarctica was first noticed in ozone sounding data during the 1970's.

At that time, the ozone hole above Antarctica was also showing up in the TOMS satellite data, but the very low values were disregarded as bad readings! Later analysis of the raw data confirmed these results and showed that the loss was rapid and large-scale, covering most of the Antarctic continent.



Evolution of the ozone layer above the South Pole as seen by the TOMS instrument for the month of October in the period 1980 to 1991. Note how the size of the ozone hole increases throughout the 1980's until it covers almost all of Antarctica.

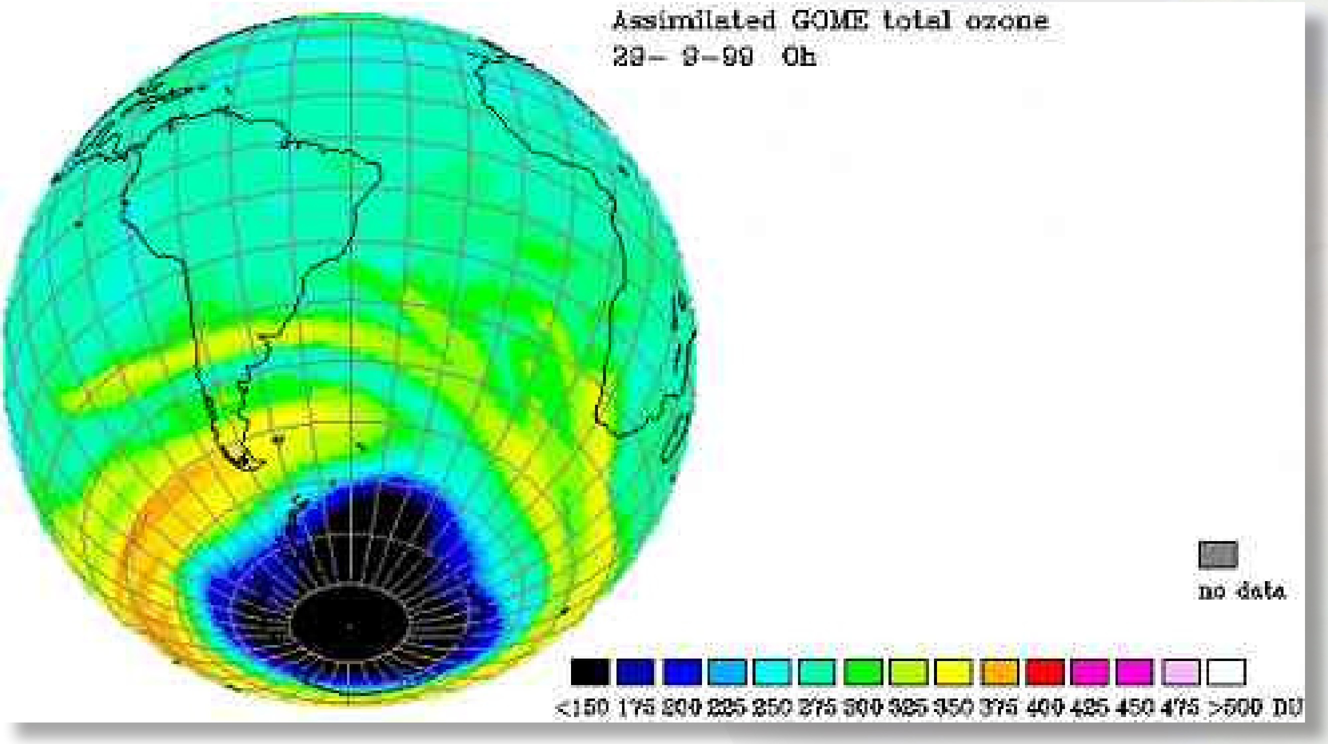


Although mid-latitude a Arctic depletion has also been observed, the loss is most dramatic in the lower stratosphere (around 15 to 20 km height) over the Antarctic continent, where nearly all the ozone is destroyed within a several km thick layer in the lower stratosphere.

Data and Methodology

TOMS satellite measurements give a global view of the ozone hole as it forms and evolves over the season, as well as the long-term evolution over the years.

More recent data obtained with the GOME instrument show the state of the ozone hole as it is appearing during the Antarctic spring of 1999.



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Info

Abstract

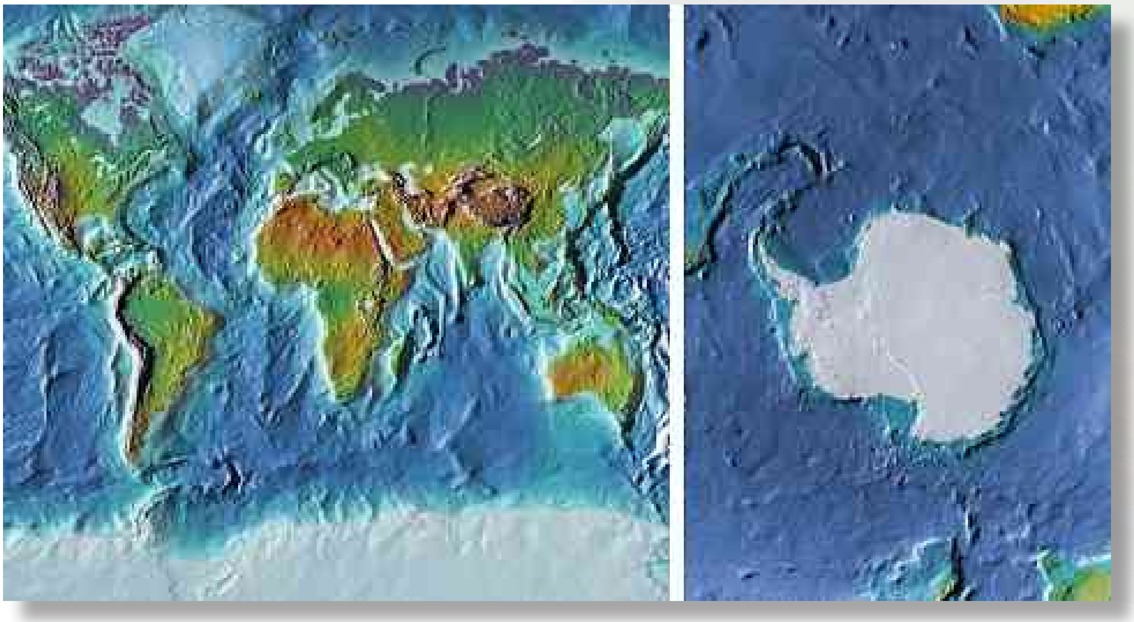
The atmosphere's ozone is concentrated in the so-called ozone layer. The atmosphere's ozone layer plays a very important role in protecting life on earth from potentially harmful UV rays, and it also helps shape the earth's climate. However, gasses resulting from human activity such as chlorofluorocarbons (CFC's) are believed to deplete the ozone layer.

The discovery of a hole in the ozone layer which occurs each spring over Antarctica focused the world's attention on the importance of the ozone layer and stirred the global community into action.

Governments committed themselves to protecting the ozone layer and better understanding atmospheric processes.

Only satellites can measure ozone on a global scale, so they are essential for ozone studies. Satellite ozone data are mainly used for monitoring the global and vertical distribution of ozone, and are a valuable tool for policy makers who need to take appropriate measures to protect the ozone layer.

Observation area



Info

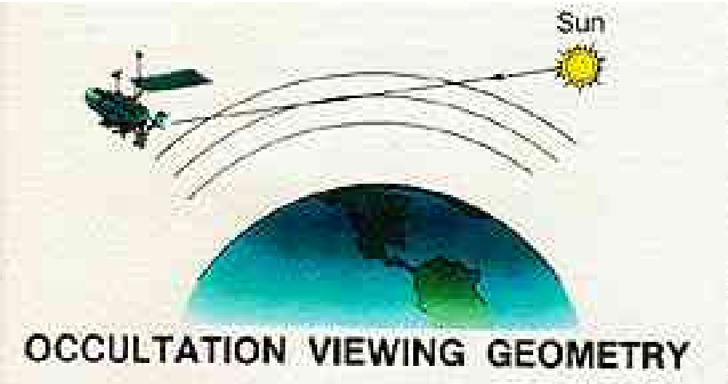
Satellite data

ERBS: SAGE II
Nimbus-7, NOAA-9, -11, -12: SBUV
Nimbus-7, Meteor-3(5), TOMS-EP-94, ADEOS-I: TOMS
ERS2 GOME

Nadir viewing instruments perform measurements looking almost vertically beneath the satellite to the surface of the earth; as the satellite moves along its orbit, the instrument scans large bands on the earth surface.

Such instruments measure the light of the sun (ultraviolet or infrared) that is reflected by the atmosphere and the earth's surface.

As light coming from the sun enters the atmosphere, it is partially absorbed and partially reflected back into space. The reflected part is analysed by the instrument on the satellite and special algorithms allow one to deduce the ozone content of the atmosphere and the vertical distribution of ozone in the stratosphere (ozone profile).



In the occultation technique, the satellite is positioned so that the earth progressively hides the light coming from the sun or a star as the satellite moves along its orbit.

As the instrument sees the sun or star through the earth's atmosphere, it can measure how the light is absorbed by the atmosphere at different altitudes.

This method allows one to retrieve ozone profiles with a higher resolution in the stratosphere and the troposphere, but it has a much lower spatial and temporal coverage.

Info

The SAGE II instrument is a seven-channel Sun photometer.

It yields 1-km vertical profiles of aerosols, ozone, nitrogen dioxide and water vapour. The focus of the measurements is on the lower and middle stratosphere, although retrieved aerosol, water vapour and ozone profiles often extend well into the troposphere under non-volcanic and cloud-free conditions.

The SBUV instrument directly measures the ultraviolet sunlight scattered by the Earth's atmosphere.

SBUV is a nadir-viewing instrument with a 200 kilometre square field of view. One measurement is made every 32 seconds along the orbital track, approximately every 1.8 degrees in latitude, from 80 degrees south to 80 degrees north. The Nimbus 7 spacecraft was in a south-to-north, sun-synchronous polar orbit so that it was always close to local noon/midnight below the spacecraft. Thus, ozone measurements were taken for the entire world every 24 hours.

The TOMS instrument measures total ozone by observing both incoming solar energy and backscattered ultraviolet (UV) radiation at six wavelengths.

TOMS is a nadir-viewing instrument and makes 35 measurements every 8 seconds, each covering an area 30 to 125 miles (50 to 200 kilometres) wide on the ground, strung along a line perpendicular to the motion of the satellite.

The GOME instrument is a nadir-scanning ultraviolet and visible spectrometer in the wavelength range 240-790 nm with a spectral resolution of 0.2 - 0.4 nm.

The satellite is on a sun-synchronous polar orbit and the instrument scans across-track with a field of view of 960 km divided into three 80x240-km pixels.

Links

On the NASA Earth Observatory: https://earthobservatory.nasa.gov/Features/Ozone

On the Belgian Institute for Space Aeronomy website: http://www.aeronomie.be/en/topics/naturalhazards/ozone.htm

RADAR AND TROPICAL FOREST

The rain forest is vitally important for the ecological stability and economic development of most tropical regions. In recent decades, however, large parts of the rain forest have been seriously affected by deforestation, undertaken either to harvest timber or to grow crops or raise cattle on the cleared land, or resulting from fires and floods.

No one knows exactly what condition the tropical rain forest is in right now. These areas are often very hard to access, and detailed maps are rare. So it is difficult to know where the forest has come under attack, or even disappeared.

People are now trying to determine the forest's condition from year to year by using satellite images. Most satellites, so-called optical satellites, take a picture of reflected sunlight, just like a photo camera or indeed our own eyes.

The problem with this method, however, is that you can't see through clouds, and for most of the year tropical areas are generally covered by a thick layer of clouds.

RADAR AND TROPICAL FOREST

A new type of camera was therefore developed, the radar or SAR, which sends out microwaves and captures their reflected signals. Microwaves and radio waves can penetrate clouds. The EcoSar project now wants to develop techniques for monitoring the evolution of the tropical rain forest with such radar images.

Landsat optical image, note the clouds to the south
© U.S. Geological Survey, Eros data Center

JERS radar image: not a cloud in the sky
© NASDA

The problem of the tropical rain forest is generally recognised, and all around the world people are seeking appropriate means to come up with a solution.

The European Commission's Joint Research Centre (JRC) is conducting a major project - called TREES - to draw maps of the rain forests throughout the entire tropical belt. These maps are being made with images from weather satellites, and are still not very detailed. With the EcoSar project, we are working together with the JRC to use radar images to get a sharper image and thus make better maps. The American space agency NASA, the Japanese NASDA and the Canadian RADARSAT worked together to test the images of several radar satellites in order to see which are best suited for studying tropical vegetation.

Methodology and Results

CAN WE SEE THE FOREST FOR THE TREES ?

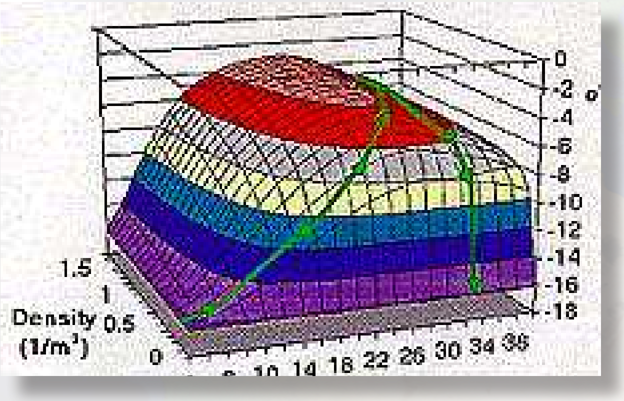
The ultimate goal of the EcoSar project is to develop a method which allows one to quickly generate good maps of the forest's condition from radar satellite images throughout the tropical areas.

To do this, computer programs must be developed which convert the images so that one can distinguish the forests which appear on them. We also want to learn as much as possible about the condition of the forest: what species of trees are still present ?, are their crowns well developed ?, does the forest manage to survive drought periods easily ?, and so on.

To derive all this information from radar images, we must clearly understand how radar signals react to the varying conditions of trees and forests.

To learn this, a mathematical program is being written which (fully in accordance with the theory of physics) calculates how a microwave is reflected by leaves, trunks, trees, forests, etc.

Together, these two groups of programs form a software package for making forest maps from raw radar satellite images.



An example of the simulation of the sensitivity
of the radar signal for the size
and the number of leaves in a forest

How ?

Radar images are like black-and-white photos: you see lighter hues where the intensity of the reflection is high, and darker ones where it is low. Often a black-and-white picture does not contain enough information for one to distinguish the various types of vegetation from each another.

However we can derive from the images several other characteristics, with which we can combine more information, and thus see the forest and its condition more clearly.

A multi-temporal image of colour combination
of radar images from different seasons
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Methodology and Results

…look again

Each month, the satellite takes a picture of the same place. When we combine these images, and we give each image a different colour, we obtain a picture like this one.

The different colours in the image thus do not reproduce the colour of the vegetation as we would normally see it, but rather the change in intensity of the reflected radar waves during the season. Because this change differs for forest, agricultural crops or savannah, it gives us further information.

…and take a good look around

Types of vegetation also differ from one another in their structure: in how large the crowns of the plants are and how far apart they stand from one another, for example. This is clearly different for grasses (savannah), bushes (coffee plantation), and trees (the forest). You can also see these differences in the texture of the radar images: is the picture at specific places mainly rough or smooth?

The texture doesn't change during the course of the season (the structure of the vegetation doesn't change), so this too gives us extra information.

With all this information, we can process the radar images and convert them into vegetation maps.

Radar satellites give highly detailed images
of the ground vegetation
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The radar images are converted
into vegetation maps

Projects financed by the Belgian research
programme for Earth observation Telsat 4 (1996-2000)
and SPSD1 Scientific support Plan for a
Sustainable Development policy(1997-2002)

Methodology and Results

Conclusions

Look around and look forwards

The EcoSar research is being conducted on an area in the Ivory Coast (West Africa) which is approximately as large as Belgium. For that region, examples are being prepared of maps which can be derived from radar images using the developed techniques.

These examples can then be used on site by foresters, but they are above all intended to demonstrate that the techniques we are developing can deliver good results. Later, these methods can be used on a large scale by international organisations and the governments of developing countries to protect and manage the remaining forests.

Our research thus stands at the service of a much greater and more important objective then merely acquiring scientific knowledge. We want to contribute to protecting nature and the environment over the long term.

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National Aeronautic and Space Administration

National Space Development Agency of Japan NASDA

Canadian Space Agency

Info

Abstract

Tropical forests, being one of the most important ecosystems on earth, not only are home for an enormous number of plant and animal species (a single tree in the rain forest along the Amazon can shelter two thousand unique animal species), they also play a major role in the absorption of carbon dioxide, a greenhouse gas, and thus help stabilise the climate

However, forests are often cut down for timber and to clear room for raising cattle, growing crops, expanding cities ... They are also threatened by forest fires, floods, acid rain, etc. Especially in tropical areas, this has enormous consequences for biodiversity.

On a global scale, many efforts are being undertaken to stop further deforestation. For example, the fight against deforestation is one of the action points of Agenda21.

Europe contributes as well: within the framework of the TREES project, the tropical forests are being mapped so as to be better able to monitor developments. Close monitoring of the changes in the tropical forest can contribute to better protection.

Satellite images make a major contribution to the mapping and monitoring of these areas which are hard to access. Given that the tropics are frequently covered by clouds, it is above all radar images which offer interesting possibilities. Here, a methodology is being developed for using radar images in mapping tropical forest.

Observation area

Satellite data

Landsat TM

JERS SAR

DEFORESTATION

When people change the land

By observing land-cover changes via remote sensing, one can study how the use of land influences land cover. Empirical, diagnostic models of land-use/cover change developed from such observations can then be used as a vital tool in sustainable regional land management.

Start in a small way

However, broad-scale, fast-track approaches to land-use change are apt to produce superficial results. To really grasp the complexity of land-use changes, small-scale land cover and socio-economic data are needed. Because collecting such data globally is a daunting task, one must focus attention on a sampling of areas to collect remote sensing and field observations. The generic trajectories and processes of change identified over these selected regions can then be carefully generalised for larger areas.

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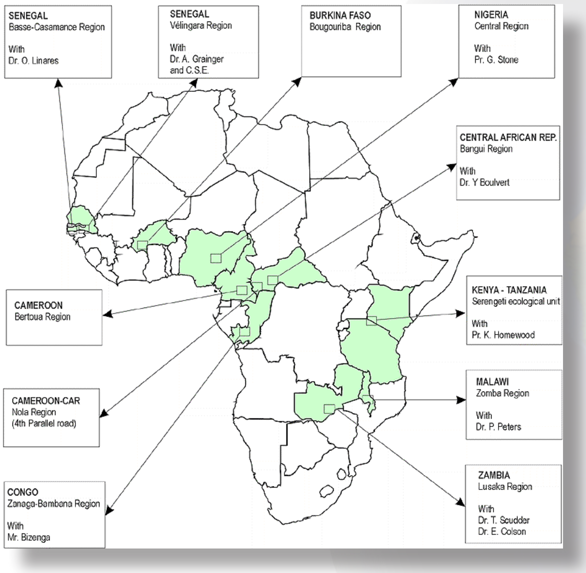
DEFORESTATION

Study the field

These selected regions must of course be truly representative, and sufficient knowledge of social and ecological processes leading to land-use changes must be available. That's why collaboration between remote sensing specialists and human ecologists conducting long-term, field-based land-use studies is so highly productive. Remote sensing scientists identify patterns of land-use changes and, using geographic information systems (GIS), relate observed patterns of change to natural and cultural landscape characteristics. Human ecologists have a deeper insight into the processes of change and the complexity of the driving forces impelling a particular land use. However, in contrast to remote sensing and GIS approaches, field-based studies rarely yield a good overview of the exact extent of land-use change processes.



Map of the areas studied

And add remote sensing

The remote sensing component is then added to the collection of African study sites where long-term, field-based studies of land-use change are being conducted. For most of these sites, a collaboration was established with leading anthropologists.

Such analysis of landscape dynamics generates spatial statistical models of land-cover change, which can be used to:

- Test hypotheses about change processes and their driving forces over an entire region;
- Suggest issues that need more investigation via field work;
- Pinpoint project areas at risk of being affected by land-cover conversion or modification in the future;
- Evaluate the likely impacts of such transformations.

The last two points are particularly important for land use planners. They not only need to measure the rates and identify the factors of land-cover changes, but also anticipate where changes are likely to occur.

Methodology and Results

Make a model

Spatial, statistical models of land-cover changes are generated by combining remote sensing, geographic information systems and multivariate mathematical models. The spatial distribution of landscape elements and changes in landscape patterns are emphasised. The location of different categories of land-cover changes is compared with maps of natural and cultural landscape variables. Maps of changes in land cover are derived from multi-temporal sequences of remotely sensed data. Changes in land cover are categorised and their spatial occurrence correlated with landscape and locational attributes.

A model is built to describe the relationship between the dependent variable - e.g. forest-cover change - and the independent landscape variables. Multivariate statistical analysis is used to determine the variables most closely associated in areas with deforestation patterns. If long-time series of remote sensing observations are available, complex trajectories of land-cover change can be identified and modelled (e.g. cycles such as “forest - agriculture - secondary growth - forest -agriculture - etc.”; or degradation paths such as “forest - smallholder agriculture - ranch - degraded land”).

Do we like what we see ?

The illustrations show some examples of interpreting land-cover change patterns measured by remote sensing:

In the Central African Republic

Road network for selective logging in the region of Nola, an area of dense, moist forest (SPOT XS from 1993).

Forests appear in red. Despite the dense network of logging roads, no major forest conversion is detectable at the spatial resolution of SPOT data (20 meters). However, a numerical analysis of the image reveals forest-cover modifications along the roads and, in particular, a decrease in tree density due to selective logging (blue/red and violet). Elsewhere in the region, migrants penetrate in the forest and cultivate along logging roads once the forest concessions have been abandoned by loggers. This process is likely to take place here in a few years.

Projects financed by the Belgian research
programme for Earth observation Telsat 4 (1996-2000)
and SPSD1 Scientific support Plan for a
Sustainable Development policy(1997-2002)

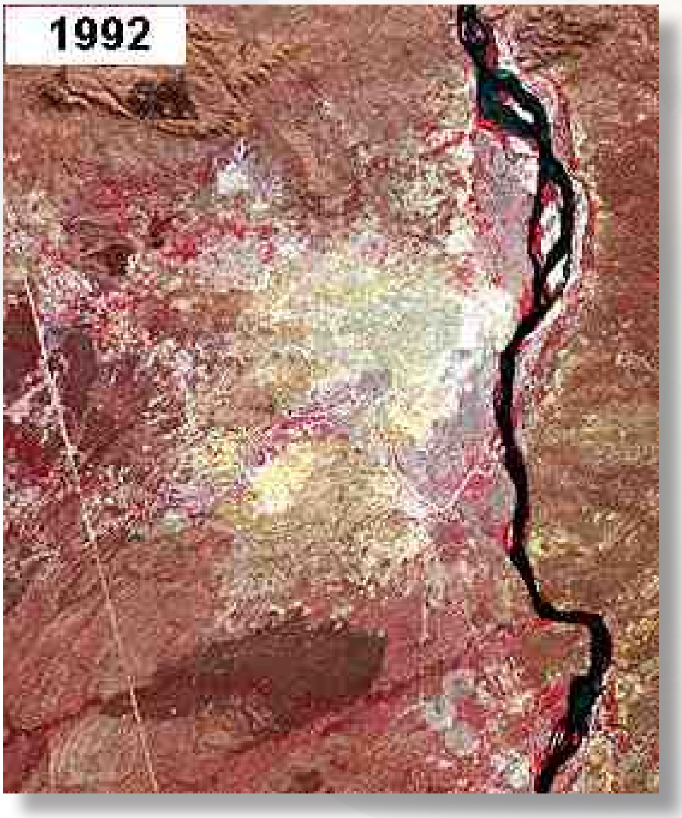
Methodology and Results

In Zambia

Resettlement of population and land degradation in the region of Lusitu, along a Zambezi tributary (SPOT XS from 1986 and 1992).

he region is dominated by savannah woodlands (brown/red). Some small patches of protected forests are visible in red. Tonga population from Gwembe (initially around 6,000 people) were resettled in this area in the late 1950's, before which there had been relatively few people there. This involuntary move followed the flooding of the reservoir of the Kariba Dam. Since then, the population has steadily increased and agriculture expanded until all available land was cleared.

An interesting aspect is that the resettlement in the late 1950's largely exceeded the carrying capacity of the land - under the people's agricultural system - at the onset. Severe land degradation has been continuously advancing since then, leading to a bare land situation (in white, yellow and grey) with a Sahelian appearance (Scudder and Colsson, personal communication). Emigration to neighbouring areas has started. In the south-eastern part of the image, new areas of pivotal irrigation can be observed on the 1992 image (three grey circles).



Methodology and Results

In Senegal

Land-cover changes in an area of rice cultivation, in the Basse-Casamance region (Senegal) (SPOT XS from 1986 and 1994).

The first image comes at the end of a long drought which affected the region.

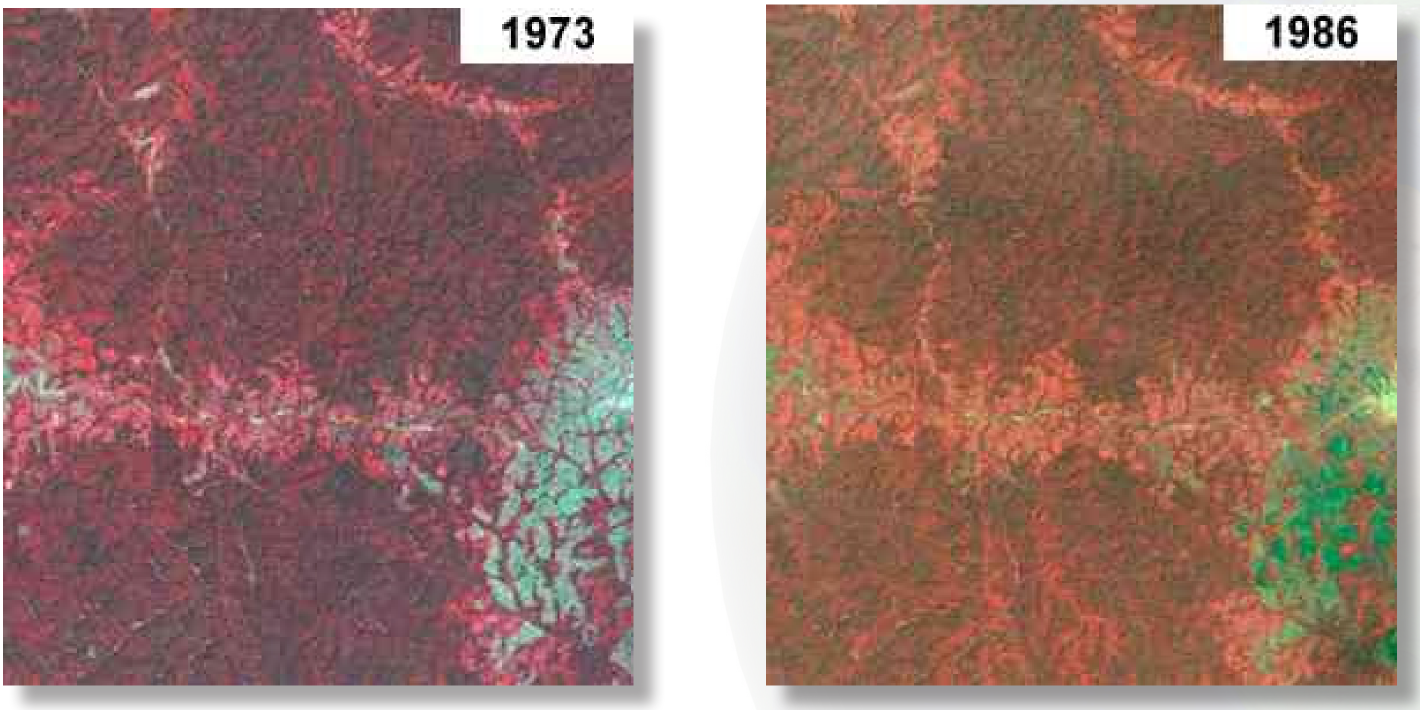
The second image comes from a much wetter year.

The 1986 image shows that several backwater channels were dried up (dark blue) with salt accumulations (stark white). Eight years later, the water level in the backwater channels has risen (blue grey and cyan). A dam was also constructed in the south-eastern branch of the channel (southern part of the image, in pale blue). This dam has brought back a substantial segment of the rice-growing area into active production over the entire length of this marigot (see patches of cultivation in grey/blue on the 1994 image). Extensive forest clearings (brown) in protected forests (bright red) can be observed in the centre and north-western parts of the image. In dry years, farmers clear the forest to grow dry, plateau crops (grey brown), while in wet years they turn back to wet rice cultivation in marigot channels and interior valley bottoms (Linares, personal communication). Around villages, several sacred forests are well preserved (bright red patches at the transition between valleys and plateaux).

Methodology and Results

Bertoua (Cameroun) will be studied more in detail here: The main land-cover change for Bertoua is agricultural expansion leading to forest-cover conversion.

Changes in land cover between 1973 and 1986 were detected on the basis of high resolution remote sensing data. A net reduction in forest cover was observed between 1973 and 1986, with an annual deforestation rate of 0.53%. The change matrix revealed that most forest clearings took place for agricultural purposes. Some forest regrowths from areas previously identified as agricultural were observed.



Cameroon: patterns of deforestation in the Bertoua region due to agricultural expansion (Landsat MSS from 1973 and 1986). The town of Bertoua and its surrounding savannahs are visible in the eastern part of the image (cyan/green). The brown/red colour corresponds to a dense forest cover. The cultivated areas (pale red) along all transportation axes and around small towns are expanding rapidly. The population of the Eastern province of Cameroon has increased in recent decades. Roads improve the accessibility of forest, which is cleared and cultivated by migrants for subsistence purposes or for local markets. A logging area is also visible in the southern part of the image (bright red).

Methodology and Results

Different factors are important

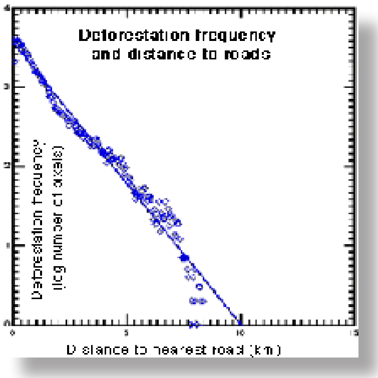
Several spatial variables were integrated into a GIS and co-registered geometrically with the forest-cover change map: land suitability, distance to the nearest road, distance to the nearest town, distance to the nearest forest edge, spatial fragmentation of the forest cover, and forest-cover density (as a proxy for clearing cost). Univariate models were built between a measure of frequency of deforestation and the above variables. The following observations were made:

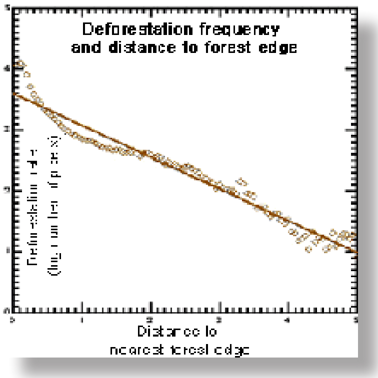
The relationship with the proximity to roads is a negative logarithmic function, with the frequency of deforestation decreasing very rapidly once one moves away from roads. 80% of total deforestation occurs within a distance of less than 2 km from roads. Beyond a distance of 7.5 km, no deforestation takes place.

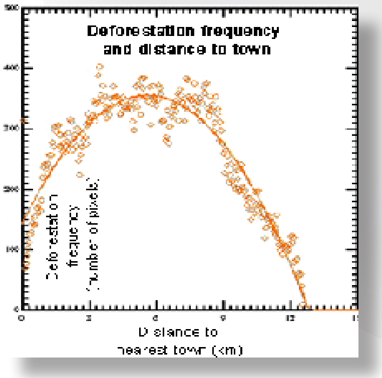
The relationship with the proximity to towns is more complex: no deforestation is measured in the immediate surroundings of towns, quite simply because there are virtually no wood resources left around them. The frequency of deforestation increases sharply at a distance from 3 to 10 km from towns (with 70% of total deforestation taking place in that interval). Beyond that distance, it decreases again. This relationship is modelled with a quadratic function.

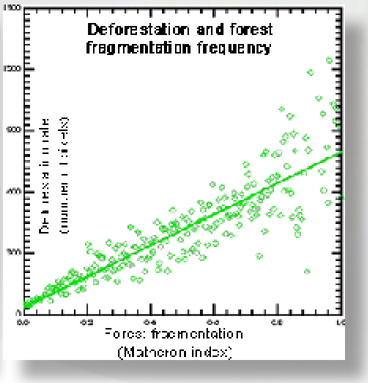
The relationship with the proximity to forest edges is also a negative logarithmic function, with a much higher occurrence of deforestation near forest/non-forest boundaries. 80% of total deforestation occurs within a distance of 1 km from forest edges.

The relationship with forest fragmentation is weaker, but grossly linear. The highest frequencies of deforestation are observed for forest covers which are already highly fragmented. This confirms that forest openings attract forest clearings. For low fragmentation values, the frequency of deforestation is uniformly low.









Methodology and Results

Why are the trees cut down ?

A multivariate model was developed to account for interaction effects between the different independent variables. It revealed that, while the distance of every location to the nearest road explained a large part of the spatial variability of deforestation, the distance to towns along the road network had a much weaker explanatory power in a multivariate model - given the information already accounted for by the other variables. This suggested that roads, as well as forest openings and forest edges, play an important role in increasing the forest accessibility to allow migrants to penetrate into the forest.

However, it was less apparent that roads increase the land rent by increasing the accessibility to town markets for the farmers , since the distance to towns did not explain the spatial variability.

These statistical results therefore suggest that the agricultural expansion leading to deforestation in this study area was mostly related to a process of human colonisation rather than to an increase in agricultural output for an expanding urban market. This must be tested through a subsequent fieldwork campaign.

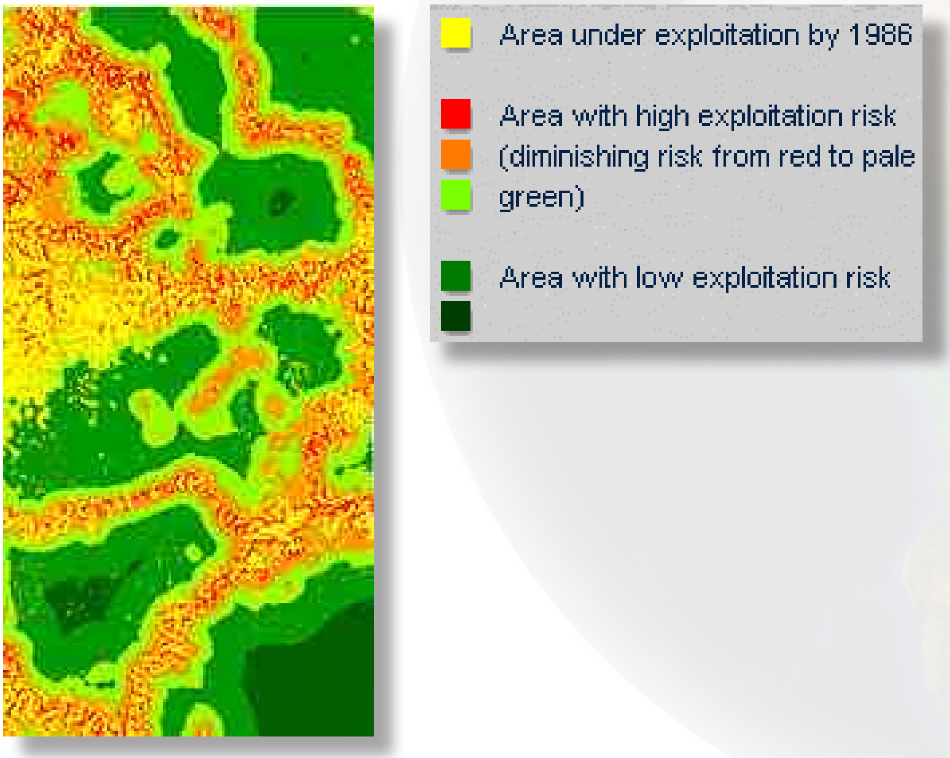
On the basis of the spatial model calibrated on past data, a projection of the areas with the highest propensity to deforestation was generated. It identifies priority areas for resource planners. Since deforestation is driven by social, economic and ecological factors that change over time, one cannot expect the rate of deforestation measured over the past period to remain constant in the future.

Methodology and Results

Conclusion

Collaboration of remote sensing specialists and human ecologists yields a good perception of land-use change processes. Remote sensing data allow identification of land-use change patterns, while human ecologists get a better understanding of the complexity of motives leading to a particular land-use.

Integration of remote sensing data in spatial, statistical models allows the projection and display on maps of future landscape patterns which would result if current land management practices (or the lack thereof) continued. Such predictive information is essential to support implementation of appropriate policies about (e.g.) land degradation, which would prevent the depletion of essential resources.



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Info

Abstract

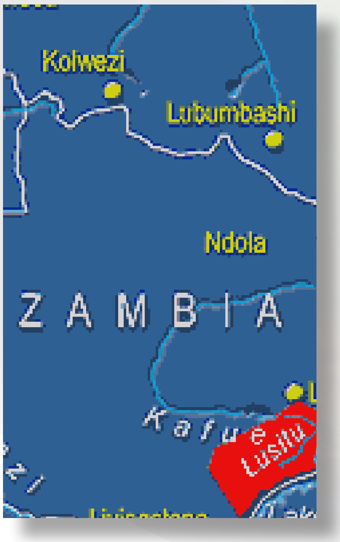
Land-use/land-cover change is central to global environmental change research. It is closely correlated to climate change, loss of biodiversity and the sustainability of human activity, and as such is either a significant cause, or a forcing function, of global change.

Land-use and land-cover changes can be analysed from three complementary angles: (i) monitoring; (ii) modelling of processes, and (iii) assessment of impacts on ecological functions. Satellite data are well-suited for studying land-cover changes. Change processes can be identified by using temporal sequences. Geographic information systems (GIS) make it possible to relate those changes to natural or cultural phenomena. Socio-economic data help to further explain causes of change processes.
Within the course of this project some examples of changes in Africa are illustrated. Deforestation in Bertoua, eastern Cameroon is studied in greater detail : different factors influencing deforestation are examined and zones at risk are mapped.

A better understanding of change processes and their causes should allow the authorities to steer their policies so as to better protect at-risk areas against further degradation.

Observation area

Processes of land-cover change are being studied for a number of African sites.
For the Bertoua area in eastern Cameroon, which is dominated by dense, semi-deciduous forests, a spatial model of deforestation has been developed.



Satellite imagery

SPOT XS
LANDSAT TM

DESERTIFICATION

According to the United Nations, around 70% of the 5.2 billion hectares of arid land devoted to agriculture are currently degraded. In other words, desertification affects practically one-quarter of the world's total surface area. These arid lands are home to around one billion inhabitants. The situation of these individuals is precarious; in fact, there are very serious concerns for more than 100 million of them. These people may well have to abandon their lands to seek their subsistence elsewhere. In terms of lost earnings, the economic costs generated by desertification in 1991 were estimated at more than 42 billion USD per year for the whole world, including 9.3 billion USD for Africa.

The causes

Multitemporal environmental studies conducted by remote detection in the Sahel all present similar results: a substantial reduction of the forests and vegetation generally, with a simultaneous significant increase in degraded soils, often indicated by soil being shifted due to wind action.

Globally, most scientists and institutions basically agree about the causes of desertification: firstly, exacerbated and constantly growing anthropic action on the environment, including exponential population growth, over-grazing, deforestation, over-cultivation of lands and deterioration of the soils and, secondly, the climatic crisis which originally revealed desertification.

Methodology and Results

Remote detection allows one to study the evolution of the vegetal coverage as well as the evolution of the environment. Comparison of airborne and satellite data over a long period (more than thirty years) makes possible a diachronic analysis of the landscape.

Thus, comparison of scanned aerial photographs and a SPOT satellite image highlights the environmental degradation in a semi-arid zone of the Sahel (department of Zinder in south-east Niger).

Landscape elements	1957-1958	1975	1987	Difference 1957-1987 (%)
Depressions and vegetation	36%	14%	8%	-78 %
Stable soil	6%	14%	23%	+283 %
Delta	0.2%	0.24%	0.56%	+180 %

Table: Evolution of some landscape elements in the Makaoratchi area(S-E Niger)

This region is characterised by an average annual rainfall on the order of 350 mm (period 1950-1990).

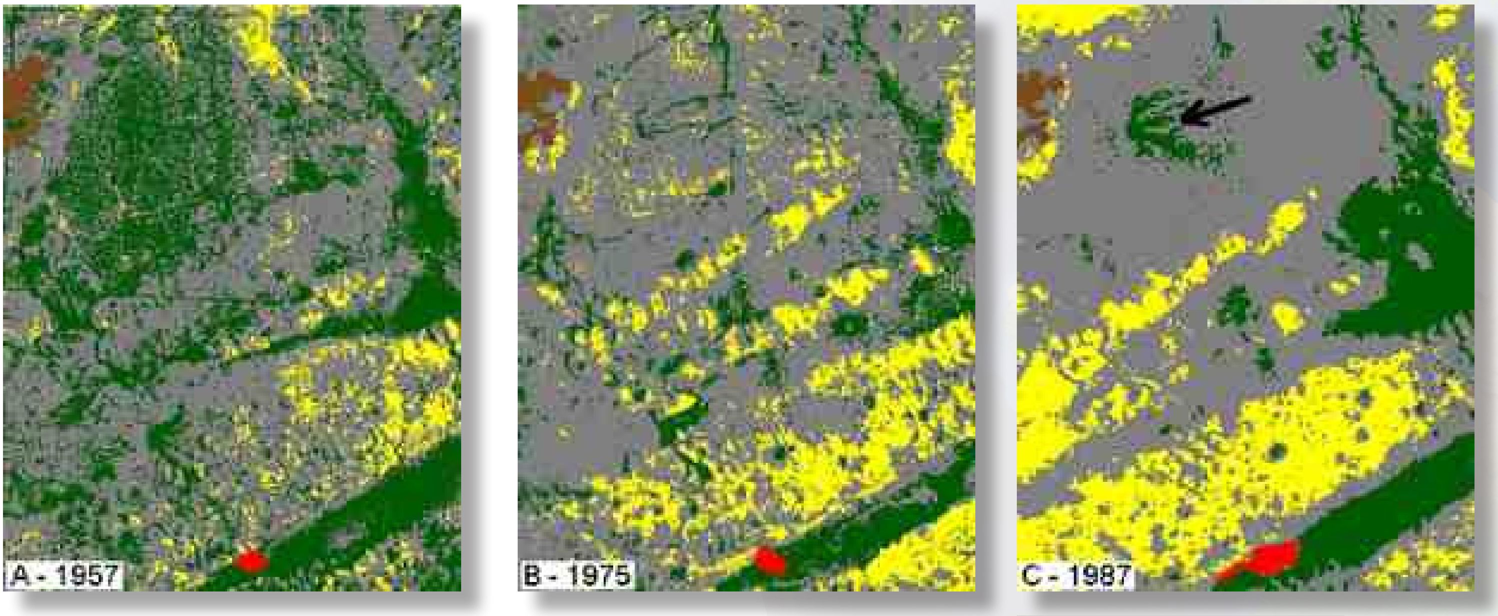
On the aerial photography of 1957-1958 the vegetation is relatively dense and wind-caused soil shifting is virtually non-existent.

The image deduced from the aerial photography of 1975, after the first great drought of 1968, reveals the disappearance of the greater part of the vegetation, which essentially remains only in the wadi beds. The now-moving sands affect ever more extensive surfaces, in particular involving the summits of the dunes and the areas surrounding the villages.

Following the terrible drought in the early 1980's (1987 SPOT image), the sector swept by deflation expanded significantly, thus reflecting the progressive environmental degradation. Vegetation has been cut to one-half that of 1975.

Methods and Results

In addition, the substantial increase in the volume of the delta (red zone) of the wadi feeding a lake located in the south of the zone under study attests to increased water erosion.
Finally, on this same image, note that the zone indicated by an arrow corresponds to the disappearance of soil, revealing a lateritic layer precisely where the soil was covered by relatively dense vegetation at the end of the 1950's.
This specific example proves that irreversible degradation can take place very quickly (in less than thirty years).



The comparison between aerial photographs and a SPOT satellite image emphasises the environmental degradation in the semi-arid area of Makaoratchi-Gayi, Zinder department, south-east Niger(period 1950-1990).

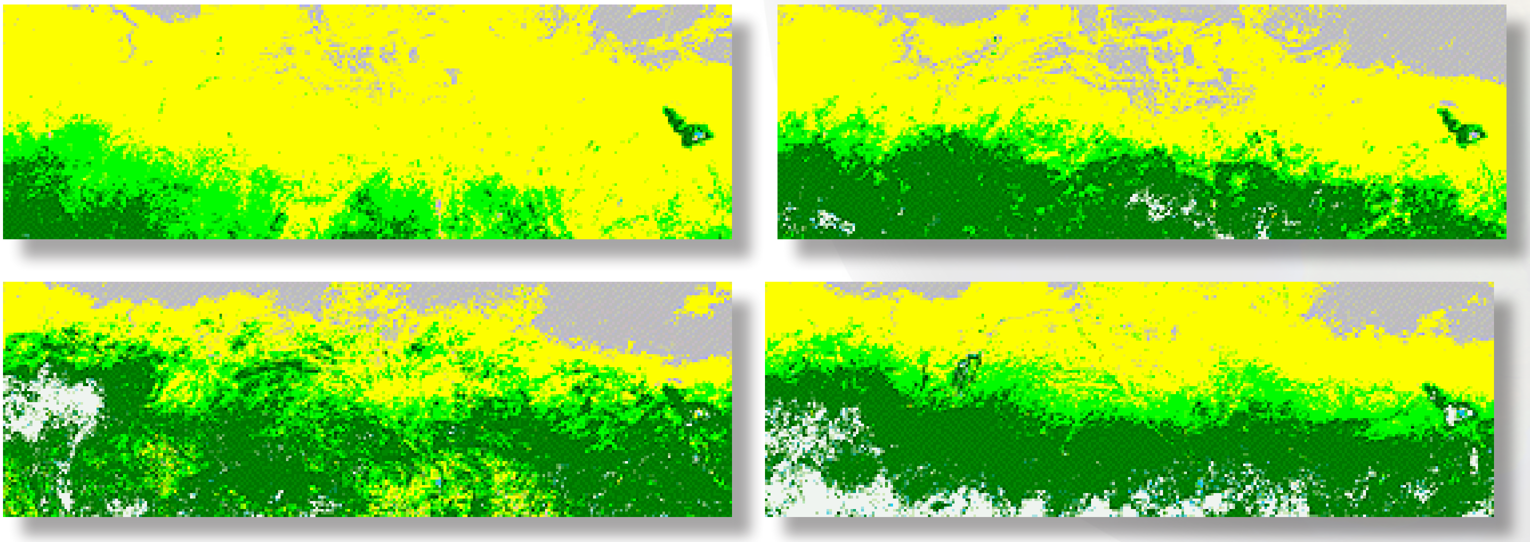
■ stable soil
🟨 deflation zone
🟩 depression and vegetation
🟫 quartzite relieves
🟥 delta

Methodology and Results

The early warning systems

In the Sahel region, agriculture is the major activity. Subject to widely varying meteorological conditions, the population is confronted with serious food problems during years with sharp rainfall deficits or when the rains are poorly distributed during the growing season. This type of situation must be foreseen well in advance in order to permit decision-makers and financial sources to react swiftly enough to prevent or limit the effects of these potential famines. Among the tools employed to forecast this type of disaster, the combination of the AVHRR low-resolution spatial sensors of NOAA and the Meteosat sensors has until now served to monitor the planet's vegetation. A new Vegetation sensor aboard of the SPOT-4 satellite has now made it possible to improve the spatial and temporal accuracy of the earlier satellite sensors, thus furnishing decision-makers with a more powerful tool within the specific framework of the food shortage rapid warning systems.

This technique makes use of satellite information furnished at ten-day intervals. It allows one to obtain accurate information (1 km2) in real time on the condition of vegetation over a very wide territory (several million km2). As an example, an animation of the Vegetation images is presented for a zone extending longitudinally from the extreme west of Mali to the extreme east of Niger. This animation shows the seasonal evolution of the vegetal coverage with, starting in June, the vegetation front's advance towards the north.



SPOT Vegetation sequence (01/04/1998 until 21/10/1998) for an area stretching from the far west of Mali to the far east of Niger. This sequence shows the seasonal evolution of the vegetation cover, with the vegetation front advancing to the north from June onward.

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Info

Abstract

Desertification has been steadily increasing not only due to human activities such as excessive husbandry over-cultivation of land, deforestation, the cutting of firewood and salinisation caused by indiscriminate irrigation, but also because of global climatic changes. Around one-third of the Earth's surface is threatened, and the subsistence of more than 100 million people is directly concerned.

The combination of aerial photos and satellite images allows one to monitor the long-term evolution of the vegetal coverage in an endangered region. However, the use of satellite images is even more important for warning systems which make possible long-term planning for the threatened zones. Thanks to the high frequency of their global images, sensors such as NOAA AVHRR, Meteosat and SPOT Vegetation permit one to follow closely changes in vegetal coverage and note in time any deviations from the normal pattern.

Observation area

Satellite data

SPOT XS
SPOT VGT