Progress report
African Great Lakes region
SarVision - IES - 2006

1. Document details

Type	: Progress report
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2. Purpose

The Institute for Environmental Security (IES) and SarVision work to advance the development and implementation of permanent monitoring of ecosystems with remote sensing technology, including innovative imaging radar.

The *purpose of this current document is to report SarVision progress* toward this overall objective in the African Great Lakes region (Congo Basin / Albertine Rift) under the 2006 IES Service Contract (162 hrs, October - December 2006). The specific objectives of the 2006 work were:

- To demonstrate initial examples of information products resulting from *systematic* ecosystem monitoring application in the programme area: recent land cover changes (deforestation), changes in hydrological patterns, agricultural crop cycles and seasonality.
- To demonstrate initial examples of the innovative use of satellite *radar* imaging for systematic monitoring.
- To deliver results in a format useful for inclusion in a *powerpoint presentation* at a proposed meeting with the Royal Netherlands Embassy in Kigali and other interested parties.

This report is written in non-technical language to be of use to project donors (e.g. the Dutch Ministry of Foreign Affairs), as well as the Royal Netherlands Embassy in Kigali, and international and local IES partners.

3. Executive summary

Ecosystems of the Congo Basin / Albertine Rift cover very large, often still inaccessible areas. This, added to the insecurity in the region, constrains the governance and sustainable management of natural resources. Illegal mining of minerals (e.g. coltan), uncontrolled deforestation, increasing population densities, agricultural expansion and food (in)security, fires, drought and flooding are reasons for major concern. Current proposals for forest sector reform in DR Congo promote industrial logging, potentially leading to environmental and social problems without proper governance and careful monitoring.

Even though initiatives on mapping and monitoring exist in the region, information on land use / cover and forest status is still not very recent. Accurate region-wide information for the year 2000 only became available in February 2007 (while information for 2003 is available for limited areas only). Hence the current forest status remains unclear.
No systematic monitoring using regular updates is implemented (yet), while the leading initiative coordinated by the University of Maryland affirms that radar is needed for this extremely cloudy area. Radar can see through clouds and smoke, enabling immediate and regular information supply. This is specific expertise that SarVision can contribute.

Many organisations and even remote sensing experts are still unfamiliar with radar remote sensing. Radar remote sensing is a relatively new technology; few operational land monitoring applications have materialised yet in tropical forest regions. The purpose of this report is to demonstrate examples of systematic monitoring and the potential use of satellite radar imaging in the Congo Basin / Albertine Rift.

Only limited time and resources were available for the development of the demonstration products. Supporting data required for proper interpretation of the radar data (accurate land use / cover maps, forest cover change maps, recent cloud free satellite imagery for reference) unfortunately became available just after 2006. Although an effort was still made to include some of this data in the report, the comprehensive classification of radar data could not (yet) be carried out.

Key achievements under the 2006 service contract between IES and SarVision are presented in this report. These achievements are:

- The preparation of new satellite datasets for the region added to a geographic information system. Both optical and radar satellite imagery for overlapping areas and timeframes (2003-2006) has been collected and pre-processed for proper comparison, improving over the best available data (2000 and older, 2003 for limited areas). This will now enable the current forest status to be assessed.
- New contacts have been made with ongoing mapping initiatives as well as local experts. Collaborations have been established with the leading groups mapping forest and land use / cover in the region at a local scale.

It was found that systematic monitoring and radar expertise in particular can greatly strengthen ongoing initiatives.

- It has been successfully demonstrated that it is possible to detect deforestation in mid altitude open canopy forest in dry tropical regions using radar. This is different from previous work in closed canopy moist tropical forests.
- New graphic information has been provided on the impact of coltan mining on forest (one of the first examples known), large scale deforestation after population displacement resulting from warfare, the impact of uncontrolled fires, and the potential of drought and flooding monitoring using satellite radar in the region.
- With these examples excellent priority areas have been identified for further data processing; proper classification of deforestation and land use / cover 2005-2006 using radar.
- Policy makers generally assume that deforestation in the Congo Basin / Albertine Rift is still very limited but, as was indicated, information is outdated and our recent examples show changes might be significant in places.

The next steps are needed in 2007 for further development and implementation of permanent monitoring:

- Build further on the datasets and collaborations established to develop map classifications using radar that are easy to grasp for policy makers and laypeople. The supporting information to make this possible has only become available early 2007. This could help answer questions such as: has the deforestation rate increased during the past 5-7 years? What is the extent and impact of coltan mining in the region? What areas are under threat from degradation due to recurrent fires?
- Strengthen collaboration with ongoing mapping initiatives. The leading initiative by the University of Maryland already indicated it would like to test the radar approach.
- Strengthen collaboration with local experts. For instance to establish the impact of coltan mining on the forest.
- In case of interest of other local partners and donors, jointly prepare further proposals for establishing a systematic monitoring system building further on existing initiatives and training of local staff on radar.

4 Monitoring and radar

About monitoring

Much of the ongoing mapping in tropical forest regions can be considered ad-hoc; maps are typically produced for a specific purpose and area and have specific thematic classes and definitions used for ‘forest’. It is not possible to compare such maps made with different methodologies over time to detect trends. In our perspective 'monitoring' implies that a time component is incorporated in a systematic methodology. The benefit of a system of permanent satellite monitoring is that maps are updated at regular intervals such as 5 weeks or 3 months using semi-automated techniques. This approach makes it possible to produce consistent time-series and more accurately identify changes and trends.
SarVision pioneers the development and implementation of such systems producing regular updates for analysing the current situation and responding to present threats.

Scale is an important issue to consider. Basically two types of systems can be considered:

- Medium resolution systems at the regional (e.g. entire Africa) or global level. Spatial resolution is 250 – 1000 m, and besides land use / cover, changes larger than 10 ha (e.g. forest clear cuts) can be detected, but no roads.
- High resolution systems at the sub-national to national level. Spatial resolution is 10 – 50 (150) m, and besides land / use cover changes up to 0.5 ha (e.g. forest clear cuts) can be detected as well as (logging) roads.

-> The current work demonstrates examples of high resolution monitoring. SarVision uses both satellite radar imagery as well optical imagery (Landsat, ASTER) whenever available (see next section).

About satellite radar remote sensing

Radar (RAdio Detection And Ranging) remote sensing is still a relatively young field in remote sensing. Many organisations and even remote sensing experts are still unfamiliar with radar remote sensing. Few operational land monitoring applications have materialised yet in tropical forest regions.

Radar imaging works entirely different from traditionally used optical imaging (e.g. Landsat or the new ASTER sensor), similar to the difference between how humans see and how bats in the dark see our world.
Radar is an active system which transmits electromagnetic pulses in a side-looking direction towards the Earth's surface, and measures the intensity, time delay and the phase of the reflected signal (‘radar backscatter’). Optical systems are passive and depend on illumination from sunlight. Other key differences are summarised in *table 1*.

Table 1. Differences between optical and radar remote sensing (adapted from Freeman, JPL)

Radar	Optical
See through clouds, haze, smoke, also at night	Can't see through clouds, haze, smoke, not at night
Provides its own illumination (“active” sensor)	Illumination from Sun (“passive” sensor)
Wavelength : large, up to 1 m	Wavelength : very small!
"Sees" how well radio waves reflect and scatter off structures	Sees how well different colours of light are reflected
Waves can penetrate a forest canopy	Sees the colour of the tops of the trees

-> **The regular detection of changes and timeliness of information supply are the key strengths of radar.**
Persistent cloud cover over equatorial areas is a notorious problem often overlooked by decision makers. Due to this problem up-to-date maps can not be made available when needed using traditional optical imagery. It can take years before acceptable, cloud free optical satellite images come available for particular regions.

Figure 1 shows an example of a major mapping exercise over the region (EU Joint Research Centre TREES Project). Clearly, due to persistent cloud cover, no information at all could be made available on the status of Virunga / Mgahinga / Volcanoes National Park from 1987 to 1995 using traditional optical satellites. In addition, the time gap between the two single dates may be too large to accurately map deforestation and degradation.

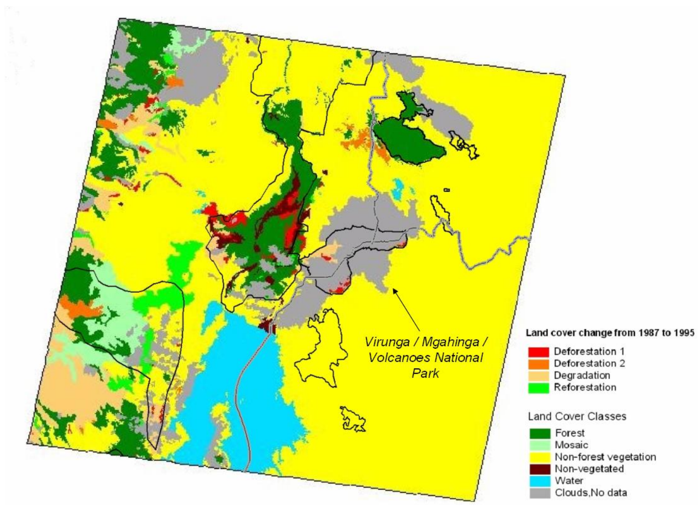


Fig. 1. Cloud cover severely constrains mapping of forest status (1987 - 1995) in DR Congo, Uganda, Rwanda using optical Landsat. Grey areas represent no data due to cloud cover. Map area 150 x 150 km (*source: EU JRC TREES Project, I-mage consult, Parks and country borders added by SarVision*).

For proper appreciation of satellite radar for land use / cover and forest monitoring, the following should be considered:

- Image acquisition programming

Satellite programming is needed as radar sensors may often be switched off and do not acquire nor store data continuously. Note this also applies to optical sensors such as ASTER.

-> The radar satellite should be programmed first to make radar information consistently available to detect changes as they happen.

-> When changes that have occurred in the past should be analysed (such as for the current report), radar imagery may not always be available as the sensor might have been turned off. Then, if images are available, the imaging modes may not be optimal. Proactively establishing monitoring systems is therefore essential.

- Image information content

Optical sensors operate in the visible and infrared region of the electromagnetic spectrum, measuring a range of small wavelengths. With radar often just one very specific, much longer wavelength is measured in the microwave region (*see figure 2*). As radar antennas generally detect how brightly features reflect this one particular wavelength, there are no other "colours" (wavelengths) to mix in. Therefore, greyscale is the only option to visualize the backscatter's intensity in single date radar images.

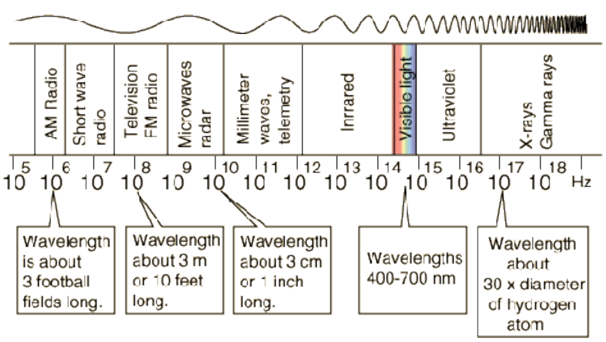


Fig. 2. Electromagnetic spectrum

Features that can visually be distinguished on single date greyscale images are often limited to rivers, settlements and roads (*figure 3, A*).

-> Buying one satellite radar image and applying visual interpretation approaches commonly used with optical imagery will <u>NOT</u> yield satisfactory results. Specific computer processing is needed.

Combining radar images of 3 different dates into a ‘multi-temporal radar composite’, does yield useful colour images emphasising changes (*figure 3, b*). However, the way radar sensors retrieve data still make it difficult for non-expert users to interpret these images. Issues like the meaning of colours in multi-temporal composites often create misunderstanding hindering the effective use of radar data in the end user community. Automated interpretation using computer algorithms yields the best results for change detection and advanced classification (*figure 3, c*). This approach extracts information from the imagery that can not be observed by visual interpretation of multi-temporal radar composites.

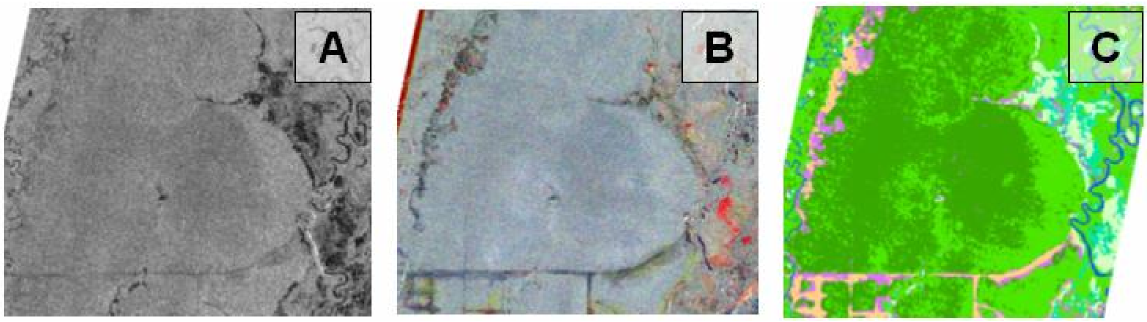


Fig. 3. A. Subset of single date radar image, B. multi-temporal radar composite (3 dates), C. radar classification of land use / cover. Example from Central Kalimantan, Indonesia.

-> Under the current 2006 service contract, multi-temporal radar composites have been developed (B). Only a rudimentary classification of deforestation (C) could be performed for a selected area (part of Virunga National park (*see figure 10*), due to time constraints and delay in delivery of supporting data.

- Geometric distortion
Due to its side-looking nature, geometric distortion occurs in particular in areas with topographic relief. This can be partly corrected for using a digital elevation model. This correction process is called ‘orthorectification’.

- Swath width and spatial resolution
Satellite sensors scan strips of the Earth’s surface. The width of this strip and therefore the size of satellite ‘scenes’ (i.e. image area) depend on the type of sensor. For example a European Envisat ASAR Image Mode (IM) image at 25m resolution has a swath width of 100 km and covers an area of 10,000 km^2, while a European Envisat ASAR Wide Swath (WS) image at 150m resolution has a swath width of 400 km and covers an area of 160,000 km^2.
-> As a rule of thumb: the higher the spatial resolution (i.e. smaller image pixel size), the smaller the swath width, and the more expensive the imagery. Obviously, the smaller the swath width, also more images are needed to cover the same area.

The following *target characteristics* have a strong impact on the information extracted from radar imagery:

Radar is particularly sensitive to surface roughness (e.g. difference between rough forest canopy and flat water surface), (soil) moisture content and metal objects. Changing moisture content can cause different backscatter levels over time for surfaces of equal roughness and material composition. Wet soils reflect more than dry soils, while healthy vegetation also reflects more than dry vegetation. This is important to consider when analyzing changes.
Metal objects (e.g. corrugated roofs) strongly reflect the radar signal back to the sensor. Hence, settlement areas can very well be detected in radar imagery, whereas this is often not the case for high resolution optical imagery (Landsat).
Although several land use / cover types can be classified from radar, in general more land use / cover and vegetation types can be distinguished on optical imagery. As noticed, this imagery is often not available when needed due to persistent cloud cover.

Radar data should be interpreted with care due to a certain amount of ambiguity about the source of radar backscatter. Good understanding of the project area, radar training and hands-on experience with image processing are essential elements required for the full appreciation of the advantages and disadvantages of radar.

5 Area of interest

The region of interest proposed for potential systematic monitoring in the Congo Basin / Albertine Rift was originally based on indications from the Royal Netherlands Embassy in Kigali and is represented in *Figure 3*. This area covers (DR) Congolese, Ugandan, Rwandan as well as Burundian territory (including many protected areas). Its size is about 1,150 x 450 kilometers: more than 500,000 km². It includes the surrounding areas of Lake Kivu, Lake Edward, the Northern part of Lake Tanganyika and the Southern half of Lake Albert.

Some of the key land use / cover types include agricultural lands, dry woodlands, savannahh and dry open canopy forest and bamboo vegetation. Moist closed canopy forest is only found in the western section of the area, representing the eastern boundary of the vast Congo Basin forest.

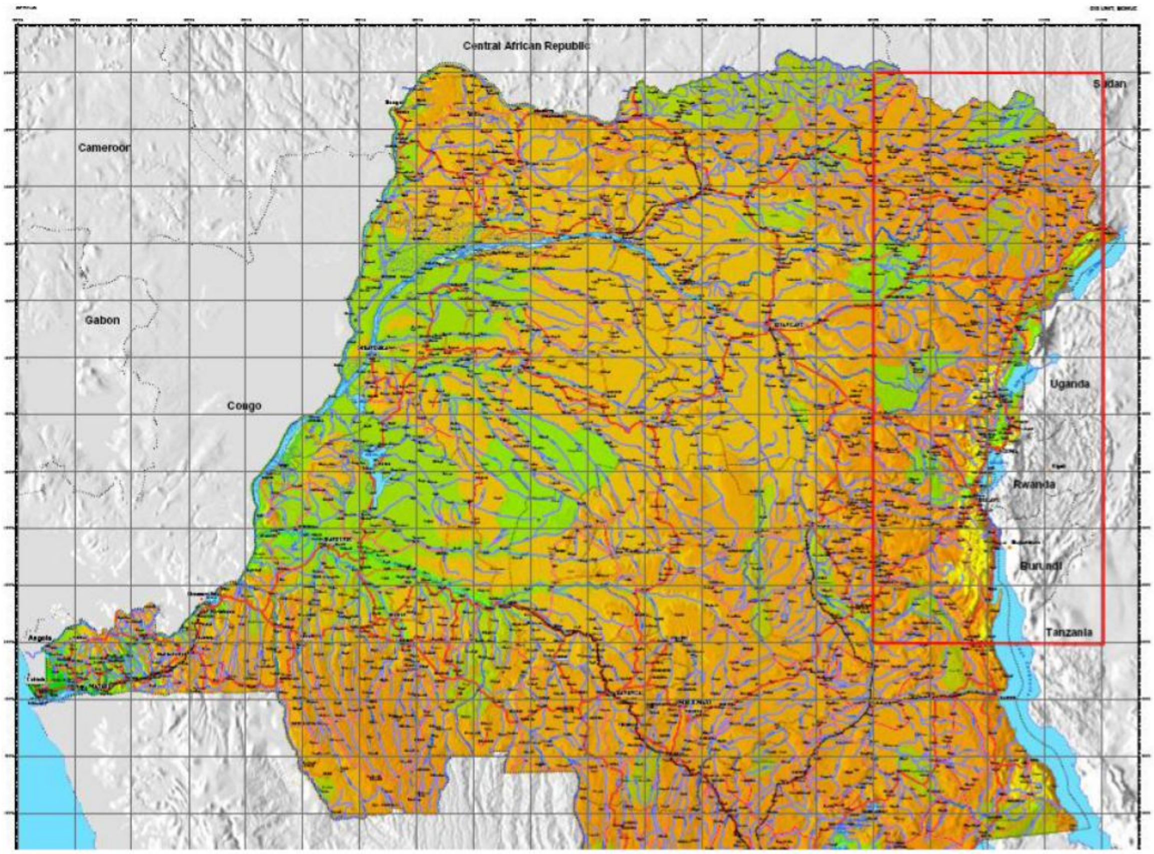


Fig. 4. Proposed area for permanent satellite monitoring (in red) Source: MONUC, 2004

For demonstration purposes, several radar images have been acquired only for part of this programme area (*see next section*), also covering part of Tanzania.

6 Methodology and data used

For this report a set of radar images from the ASAR instrument on the European ENVISAT satellite have been acquired (see annex 1): ASAR Image Mode (IM) images of 100x100 km with a spatial resolution of 25 m, and ASAR Wide Swath (WS) mode images of 400x400 km with a spatial resolution of 150 m. The ENVISAT radar sensor records a new image every 35 days over the same area, resulting in 10 images per year.

ASAR WS images are ideal for quickly getting an overview of the status of large areas. It complements the first technology because it can cover the complete North-east DR Congo region; however deforestation areas can only be detected with high confidence when they exceed a size of approximately 10 ha. Though the resolution is limited it still allows for detection of other related phenomena such as the construction of new forest roads.

ASAR IM images are ideal for high resolution (both temporal and spatial) observation of selected areas of interest. It would allow detecting small areas of deforestation (sub-hectare level) and development of new roads fast and frequent. It could be applied in areas of special interest, such as the parks and areas of known deforestation hotspots. ASAR IM radar images have been acquired for the area covering Virunga / Mgahinga / Volcanoes National Park sections and Bwindi Impenetrable Forest National Park, which is covered by 2 IM images located in the same path (*see figure 5*).

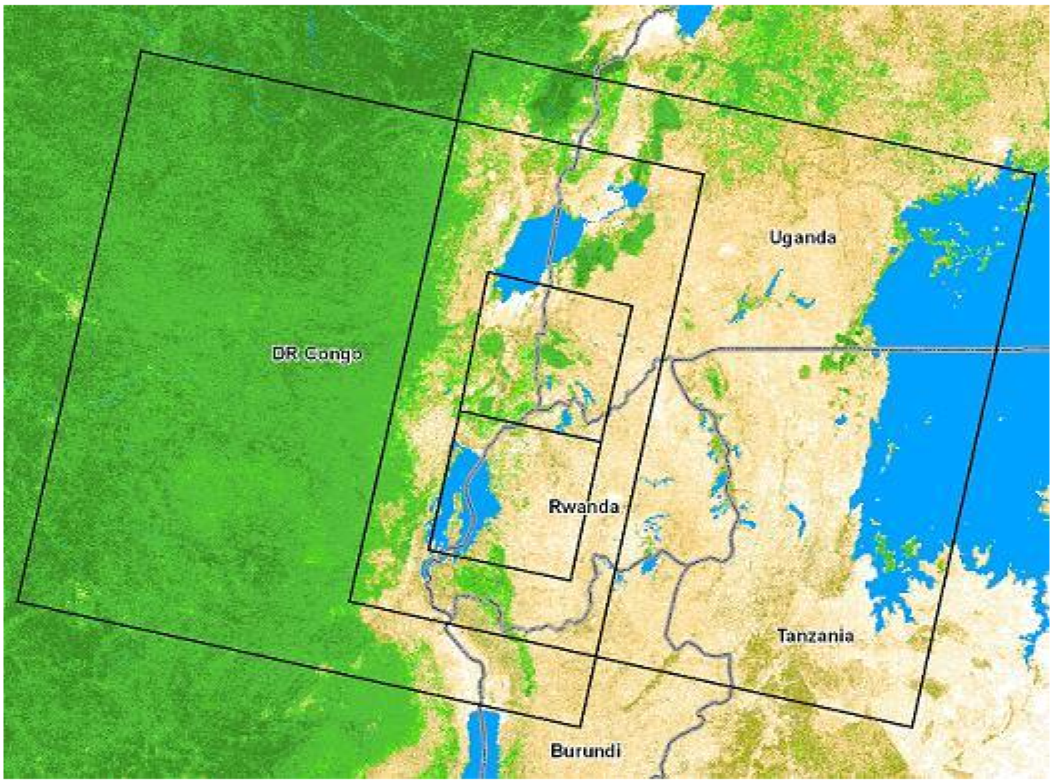


Fig. 5. Areas covered by radar satellite images obtained (large black squares: ASAR Wide Swath 400 x 400 km, small black squares: ASAR Image Mode 100 x 100 km). Background: Percent tree cover 2000, white 0% to brown 50% to dark green 100%. University of Maryland

The methodology used in this study is straightforward radar image processing. First, all images were radiometrically calibrated and geo-corrected with the Ground Control Points from the image header. Then the calibrated, geo-corrected images were visually inspected and a sub-selection of image scenes and scene locations was made. After studying the geo-correction and finding severe distortions in image mosaics it was decided to apply orthorectification to a sub-selection of images.
The orthorectified and calibrated images were then logarithmically rescaled to dBel and the IM scenes convolved with a 3x3 low pass kernel to reduce speckle levels. From these images, several multi-temporal datasets were constructed which were the basis of

this study. The following sections include (examples of) false colour composites of these datasets and a prototype change detection ratio image.

Originally the project was set up in anticipation of the use of additional data from ongoing initiatives (University of Maryland, Woods Hole Research Center, etc.) Supporting data (land cover classifications, forest change maps, recent optical satellite imagery) is required as a reference for proper radar processing. Without such basic information it remains highly unclear what one is looking at in radar images, or where to look for recent deforestation.

Unfortunately, useful supporting data have come available only just after the 2006 deadline. An effort was made to still incorporate these in the datasets to enable in-depth analysis during 2007. Preliminary examples are shown in the current report. Lack of supporting data in 2006 and time constraints considerably limited the possibilities of comparative radar data analysis. **Multi-temporal radar composites have been developed and only a rudimentary classification of deforestation could be performed for a selected area (part of Virunga National Park).**

The following datasets have come available and acquired just after the 2006 deadline:

University of Maryland – CARPE Initiative
The University of Maryland and NASA contribute to the Central African Regional Program for the Environment (CARPE). The best and most recent information covering most of the Congo Basin / Albertine Rift was released by this initiative, but only in February 2007. It describes forest cover change during 1990 – 2000.
As this represents the situation already 7 years ago, the University is now working on an update for 2005. The key obstacle is availability of useful satellite imagery due to cloud cover. Many changes have taken place in the meantime (*see examples section*).

Key data: forest cover change classifications 1980-1990, 1990-2000, Landsat imagery 2005-2006

Collaboration has started, the University of Maryland clearly acknowledge that radar is required in addition to ongoing approaches in this extremely cloudy region. Alice Altstatt of University of Maryland asserts: "We would be very interested in your [radar] data, and testing the feasibility of mapping forest cover change in this area where we know we can get optical data [to compare], so that we might be able to apply the method to cloudy areas." (*Source: email exchange SarVision - University of Maryland*)

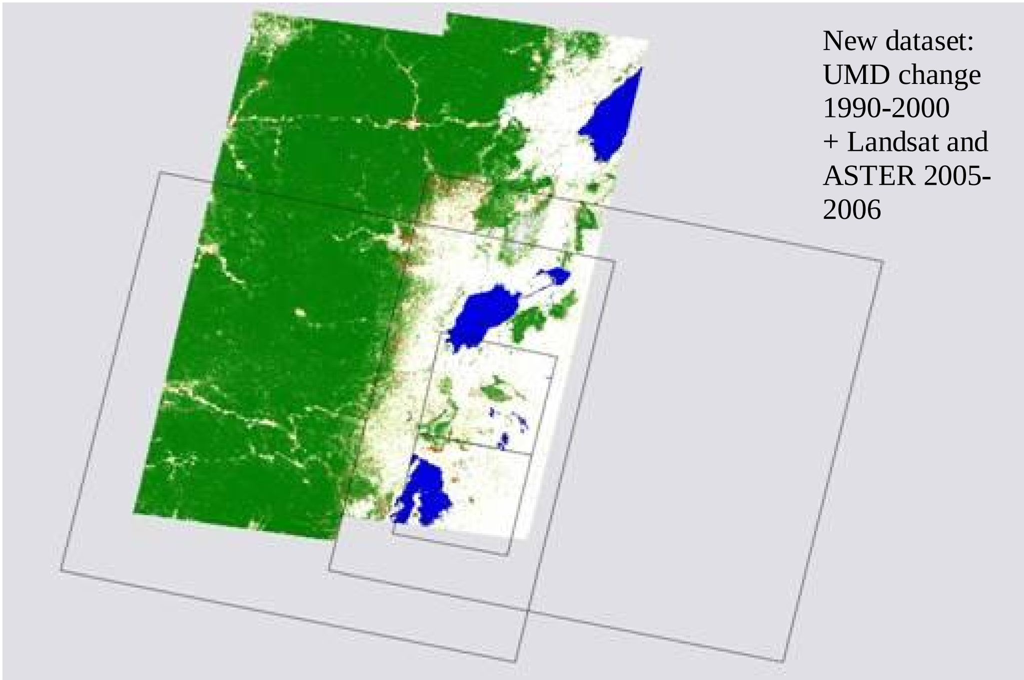


Fig. 6. Areas covered by radar satellite images obtained (large black squares: ASAR Wide Swath 400 x 400 km, small black squares: ASAR Image Mode 100 x 100 km) and the new University of Maryland forest cover change dataset (white: non-forest, green: forest, red: deforestation 1990-2000, blue: waterbodies). This dataset and selected recent Landsat imagery of 2005 – 2006 over this area has become available in February 2007.

- Sogha/Bego project of UNESCO and the European Space Agency

This project developed Digital Elevation Models, land cover and land cover change products covering part of the Albertine Rift and selected national parks. The project ended in 2003 and has not led to a follow-up. Maps are not updated, no systematic monitoring is foreseen.

Key data: land cover map 2003, change analysis 1987 – 2003. Many changes have taken place in the meantime (*see next section*).

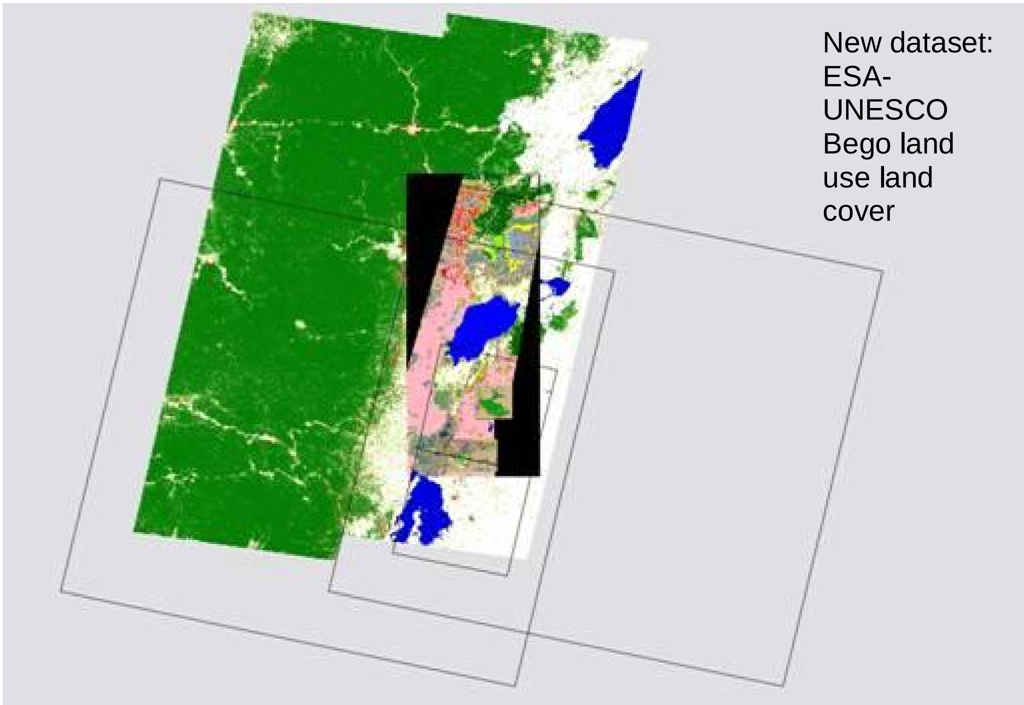


Fig. 7. Areas covered by radar satellite images obtained (large black squares: ASAR Wide Swath 400 x 400 km, small black squares: ASAR Image Mode 100 x 100 km), the University of Maryland dataset, and the Bego project land cover dataset (2003).

Example 1. Land use / cover – settlements

Trends in settlement development and agricultural expansion are relevant elements to monitor systematically. Metal objects (e.g. corrugated roofs) strongly reflect the radar signal back to the sensor. Hence, settlement areas and even single houses can very well be detected in radar imagery, whereas this is often not the case for high resolution optical imagery (Landsat).
This is demonstrated in *figure 8*, showing the border area between DR Congo and Uganda, just north of the mountain gorilla habitat of the Virunga / Mgahinga National Park sections. Remarkably, the Ugandan portion of this area is far more densely inhabited than the DR Congo part.

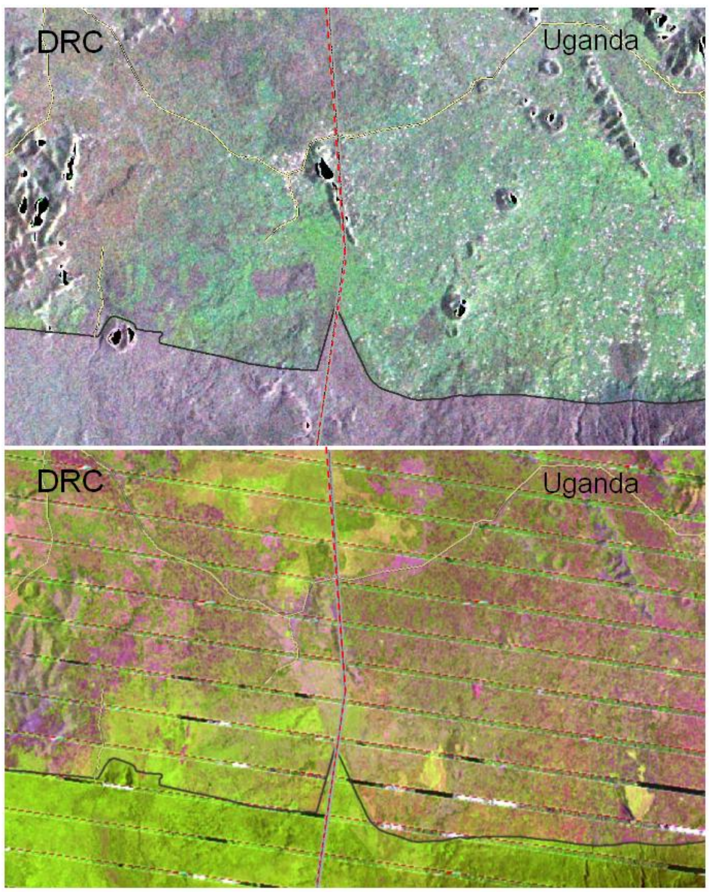


Fig. 8. Top: multi-temporal ASAR IM 25 m resolution composite (September 2006, August 2006 and June 2006). *White dots*: houses with corrugated roofs. *Blue-green*: agriculture area, *Grey*: forest and woodland vegetation. *Red dotted line*: border.
Bottom: settlements are not readily observed in this Landsat image of 25 February 2005 (note striping due to permanent satellite malfunction). *Pink, purple and green*: agriculture areas, *Green*: forest and woodland vegetation. *Red dotted line*: border.

Example 2. Land use / cover – agricultural crop extent and emergence

Agricultural crop extent can be monitored by identification of areas with strong vegetation dynamics on multi-temporal radar composites for the period considered. Changes on agricultural land that occur during the growing season due to field preparation, planting, crop growth, harvesting, etc. can be identified using radar time-series. Optical data are less useful for this purpose due to cloud cover during the growing seasons.

In addition, it is possible to monitor the date of emergence of crops in the areas considered using radar. Poor rains affect the timing of planting seasons, and can lead to poor harvests causing acute food, livelihood, and health-related problems. This type of monitoring information is crucial for food security policies. In fact such application is now slowly starting to be used by the FAO and others (see http://www.gmfs.info/).

An example for the region is provided in *figure 9*. Multi-temporal radar images are based on 3 different dates. In grey, areas are shown that are stable throughout this period (e.g. perennial vegetation, plantations, forest if not logged). Annuals such as agricultural crops however have specific growth cycles depending on seasonality. Crops may be present in only one or two of the dates (or more if a large time series throughout the year is made), producing specific image coloration. This way the onset and ending of crop growth cycles, as well as the extent of agricultural crops can be monitored using radar time-series.

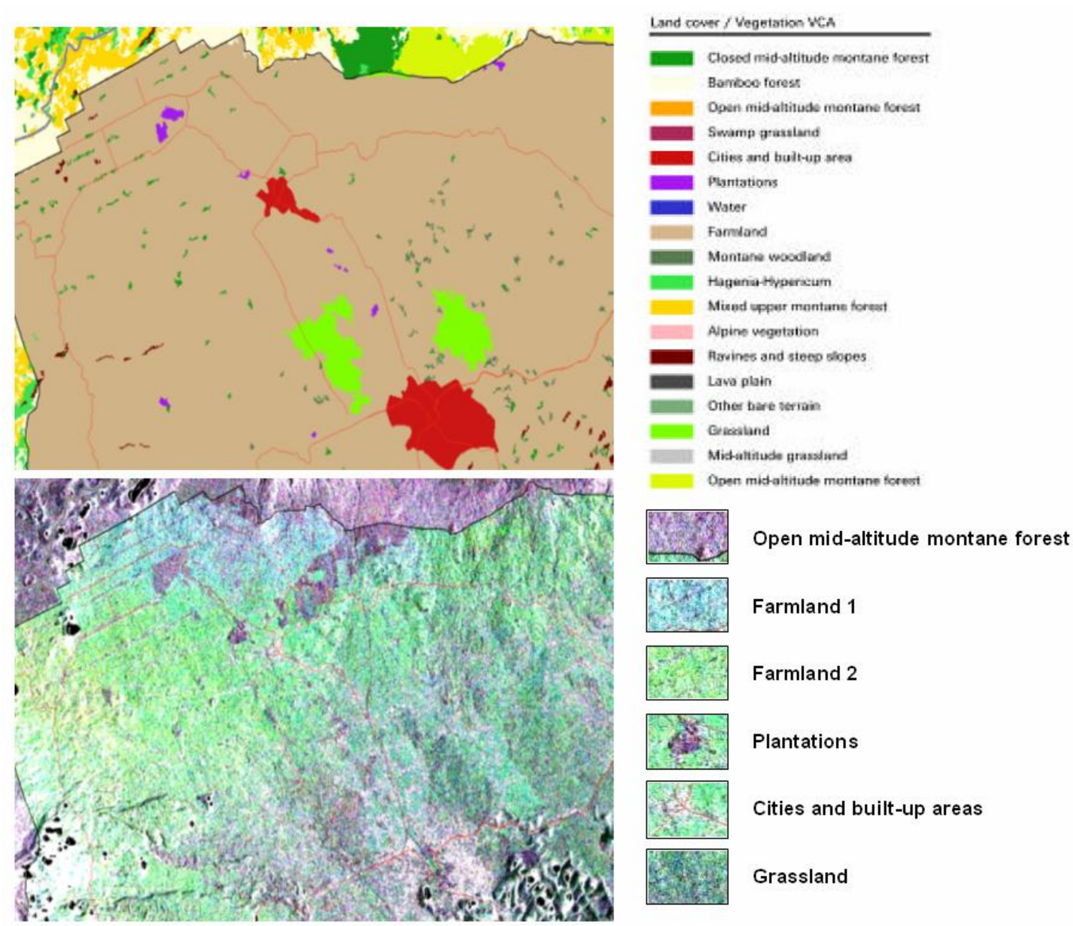
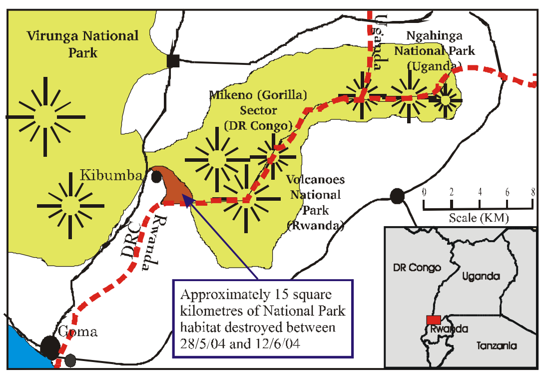


Fig. 9. Top: Land use / cover classification 2003 (Bego project). Bottom: ASAR IM multi-temporal image 2006 (dates September 2006, August 2006 and June 2006). This radar image shows a significant increase of perennial vegetation, most likely plantation, amidst agricultural crops with different cycles (blue and green). Unfortunately it remains unknown what crops are grown in the surroundings of the park, hence it is not possible to comment on crop cycles at this stage. The city of Ruhengeri is visible in whitish shades with surrounding grasslands in pale grey in the bottom right corner.

Example 3. Deforestation – gorilla habitat destruction

From mid May to June 2004, extensive habitat destruction and land conversion (deforestation, grazing and agriculture) by people accompanied by Rwandan military personnel and local authorities reportedly took place in the mountain gorilla habitat in the southern "Mikeno" sector of Virunga National Park in DR Congo. 15 square kilometer was reported to have been deforested, including a significant portion of the Mwaro corridor connecting Mikeno and Nyamulagira Sector, and important area for large mammals moving between the sectors.

Due to persistent cloud cover, optical satellite imagery is often not available when needed in support of management and policy actions. *Figures 10 and 11* demonstrate that optical satellite image may come available too late and many deforestation events may go undetected when relying on traditional optical satellites only. Radar can see through clouds and provide information every 35 days, timely enough to detect the change before vegetation grows back.



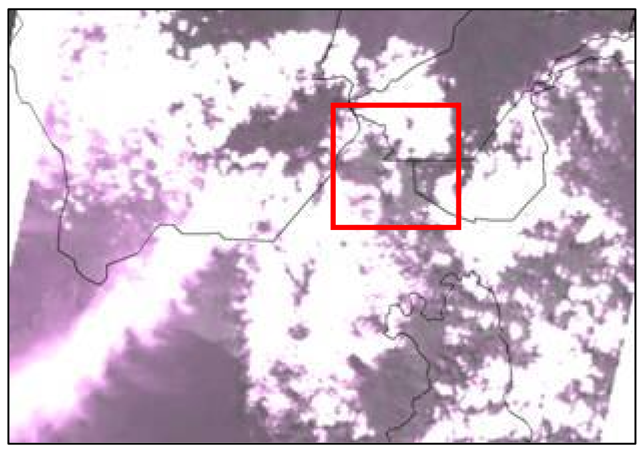


Fig. 10. Left: location of deforestation from field reports (*Source: IGCP*). Right: subset of an ASTER optical satellite image (25 May 2004) obtained during the Mikeno deforestation event. The image is useless for the area of interest (red square) due to severe cloud cover (white) and shadow.

As noted, when investigating events in the past, one has to be lucky that satellite radar sensors were turned on at the right time to take images. To make sure images are consistently available the sensor can and needs to be programmed. Fortunately, one radar image was found to have been recorded during the deforestation event.

Using this ASAR IM image from 29 July, a multi-temporal radar composite and rudimentary change classification have been developed. These successfully show that it is possible to detect deforestation in mid altitude open canopy forest in dry tropical regions using radar. This is different from previous work in closed canopy moist tropical forests.

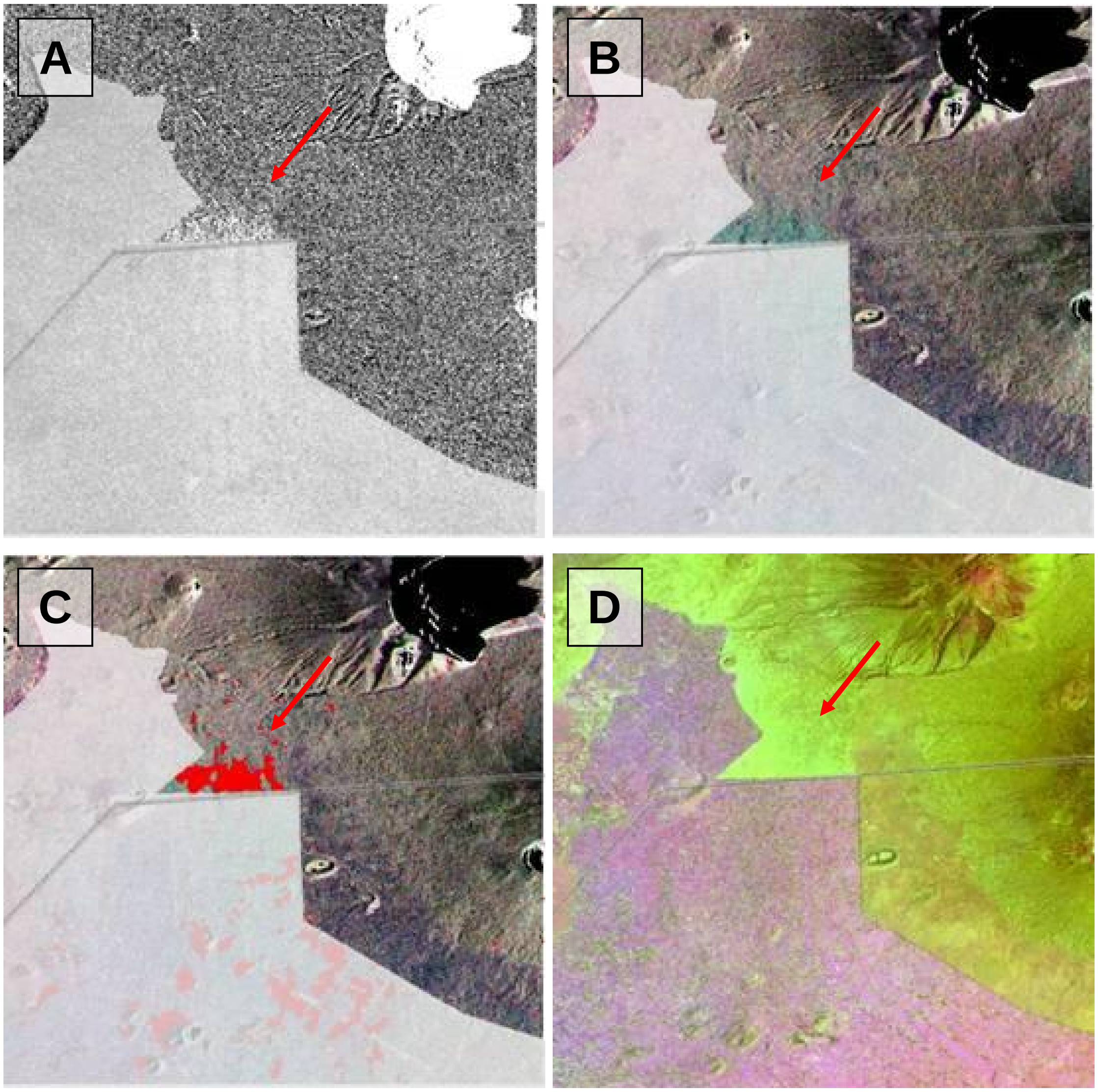


Fig. 11**. A.** The ratio between 2 raw radar satellite images before (10 July 2003) and during (29 July 2004) the deforestation shows significant change in the radar signal in white. **B**. shows a multi-temporal radar image (combining dates 29 July 2004, 10 July 2003, 1 May 2003), here the change shows up greenish, while a bamboo vegetation strip is clearly visible in dark brown. **C**. shows the result of a rudimentary automated classification of change (*red*). **D**. clearly shows that the deforestation reported from the field and timely detected by radar can not be observed anymore on the first useful cloud free optical ASTER satellite image. It became available only 7 months later (21 February 2005). Obviously, vegetation has grown back (light green) and park boundaries are as distinct as they were before the event.

Example 4. Deforestation – effects of war

Early 2003, Doctors without Borders Belgium reported that 35,000 people fled from the city of Makeke at the border of North-Kivu and Ituri province in DR Congo due to heavy artillery fire. They found a safe haven in the city of Beni, on the fringe of the northernmost section of Virunga National Park.

The Landsat satellite images of 2001 and 2006 below clearly show that Beni has expanded significantly during this period, whereas a large extent of the nearby lowland forest of the park has been deforested (deforested area approximately 6 x 10 km).

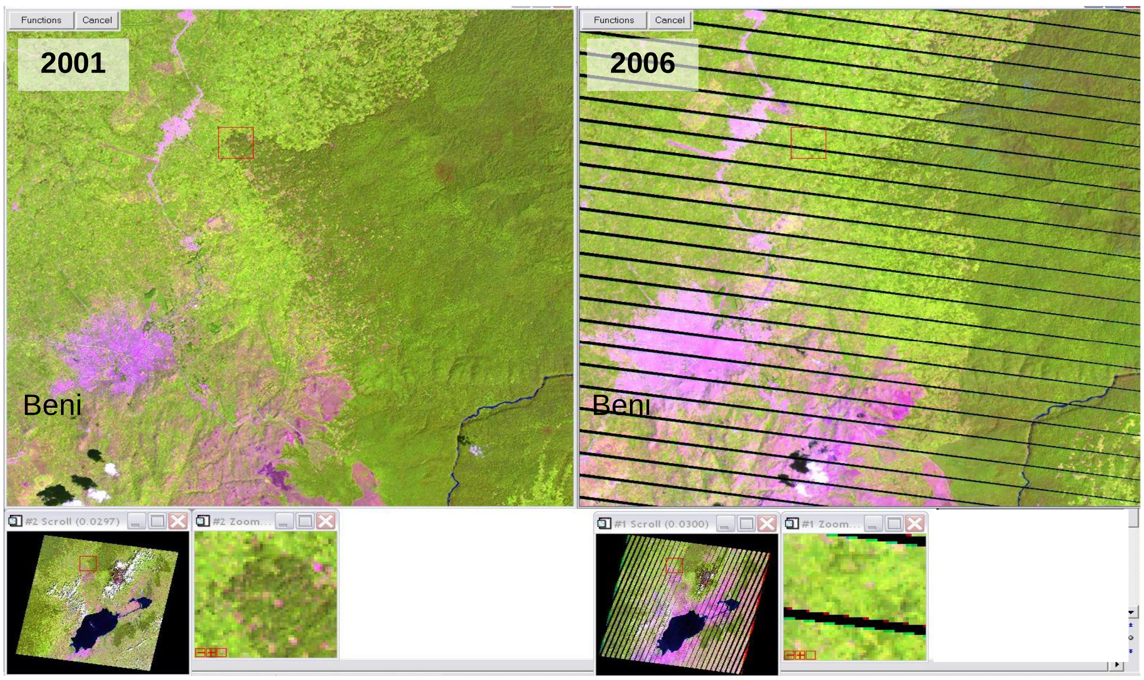


Fig. 12. *Purple/pink:* the city of Beni, *Pale green:* grasslands and mixed agriculture, *Dark green:* lowland forest, *Purple/pink:* bare areas (both clear cuts and large bare agricultural areas). Some little white clouds and their shadows are also visible. Area covered: 25 x 25 km, deforested area ~ 6 x 10 km. The smallest windows provide a closer look for the red square areas in the largest windows. Note the black striping (no information) in the 2006 image is due to permanent satellite malfunction. Original Landsat imagery courtesy Global Land Cover Facility (GLCF), USGS, NASA, University of Maryland.

Many policy makers assume that deforestation in the Congo Basin / Albertine Rift is still very limited but, as was indicated, information is outdated and our recent examples show changes might be significant. Now finally supplementary spatial information has become available to support proper radar image processing, it is proposed to demonstrate deforestation mapping in the region during the 2007 service contract using examples such as in the above.

Example 5. Deforestation – conflict coltan

Mining of minerals such as coltan (columbite-tantalite, used for the production of semiconductors in cell phones, laptop computers, etc.) is known to cause environmental damage. A great deal of the ore is mined illegally and smuggled over the country's eastern borders by militias from neighbouring Uganda, Burundi and Rwanda[1].

The example below provides the first instance of satellite imagery showing the impact coltan mining can have on forest. This area 50km north of Butembo is unsafe to visit on the ground. Consultation with a local expert and geologist revealed it is highly likely that the deforestation detected can be attributed to coltan mining activities rather than agricultural expansion. The area has known deposits (*pers. comm Dr. Patrice Yamba*).

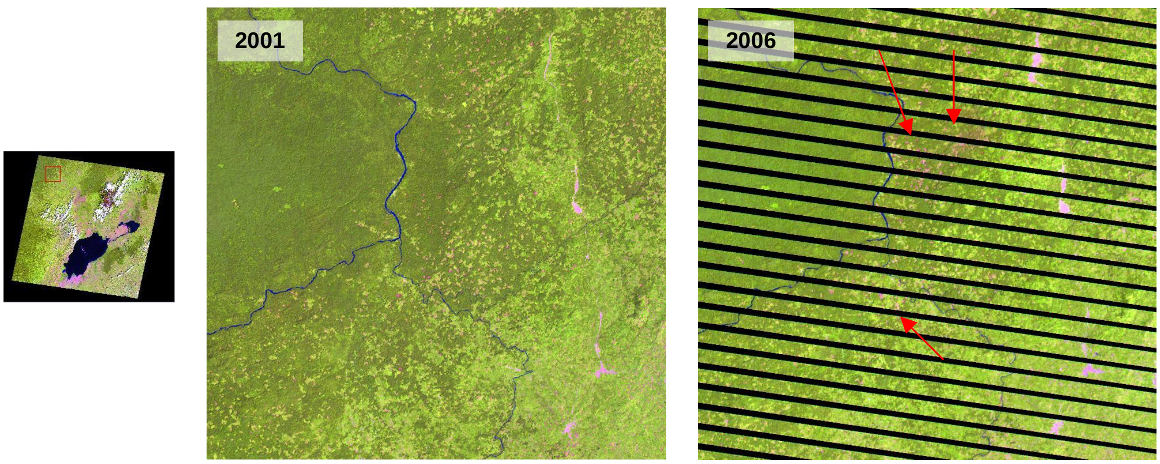


Fig. 13. *Pale green:* grasslands and mixed agriculture, *Dark green:* moist lowland forest, *Purple/pink:* bare areas (canopy damage and deforestation by clear cutting). Area covered 15 x 15 km. Arrows indicate new deforestation between 2001-2006.

Note the black striping (no information) in the 2006 image is due to permanent satellite malfunction. Original Landsat imagery courtesy Global Land Cover Facility (GLCF), USGS, NASA, University of Maryland.

Now finally supplementary spatial information has become available to support proper radar image processing, it is proposed to demonstrate coltan extraction damage in the region during the 2007 service contract using examples such as in the above. Further investigation combining geological data and new satellite data seems desirable to fully assess the impact of coltan mining.

[1] http://www.un.org/News/Press/docs/2001/sc7057.doc.htm

Example 6. Fire - active fires

Information on the location of active fires (fire hotspots) is collected by a number of satellite sensors on a daily basis, including Envisat AATSR, NOAA AVHRR, GOES, MODIS and Meteosat's MSG SEVIRI. Radar can not be used for this type of detection. SarVision works on the integration of information from these various sensors and making it available in near-realtime to users using an easy to grasp Internet interface, as a complement to land cover change information.

Figure 14 shows the location of all active fires detected by MODIS during 2003-2006, covering a large area near the borders between Rwanda, Uganda, and Tanzania. Remarkably, the large majority of fires detected is located inside National Park areas and reserves, such as the large Akagera National Park in Rwanda. Fires are still recurring every year.

The United Nations in its weekly bulletin of 3 – 9 July 2004 on Central and East Africa reported that fire had destroyed one-third of Akagera National Park.[2] The executive director of the Rwanda Wildlife Agency was quoted saying that he attributed the cause of the fires to the dry season and poachers, who, after killing wild animals, roast them within the park. The agency had sought support from local residents, the police and the army in extinguishing the fire. Army helicopters were being used to spray the burning savannahh vegetation with water.

[2] http://iys.cidi.org/humanitarian/irin/ceafrica/04b/ixl1.html

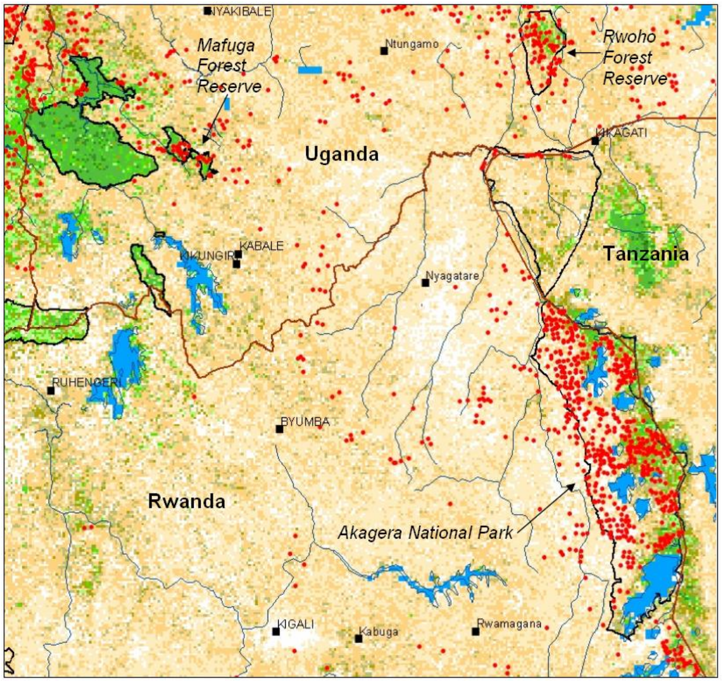


Fig. 14. MODIS active fire detections for the period 2003-2006 (red dots). Note that fire data for Tanzania has not yet been integrated, still the burning pattern is evident. The background shows percent tree cover as absent (white) to low (brown) to high (green). Original data courtesy to NASA/University of Maryland, 2002. MODIS Hotspot / Active Fire Detections. Data set. MODIS Rapid Response Project, NASA/GSFC [producer], University of Maryland, Fire Information for Resource Management System [distributors]. Available on-line [http://maps.geog.umd.edu]

Fig. 15. Photos Akagera National Park (E. van de Giessen)

Example 7. Fire - burned area extent

Apart from near-realtime detection of fire hotspots, satellite imagery can also be used to assess the area extent of fire damage. Fire affects savannahh and grassland areas annually and is part of the natural processes that have maintained this vegetation over time. Plumptre et al[3] however, identify fire as a key threat to the region: the current intensity of burning is much higher than it should be. It is probably leading to degradation of the grasslands and loss of species. Fires come from outside the parks where people burn their fields and do not control the fires, or are set deliberately within the park to drive animals towards hunters.
Figure 16 below shows that satellite imagery monitoring over time can help assess the impact of burning on ecosystems over large areas.

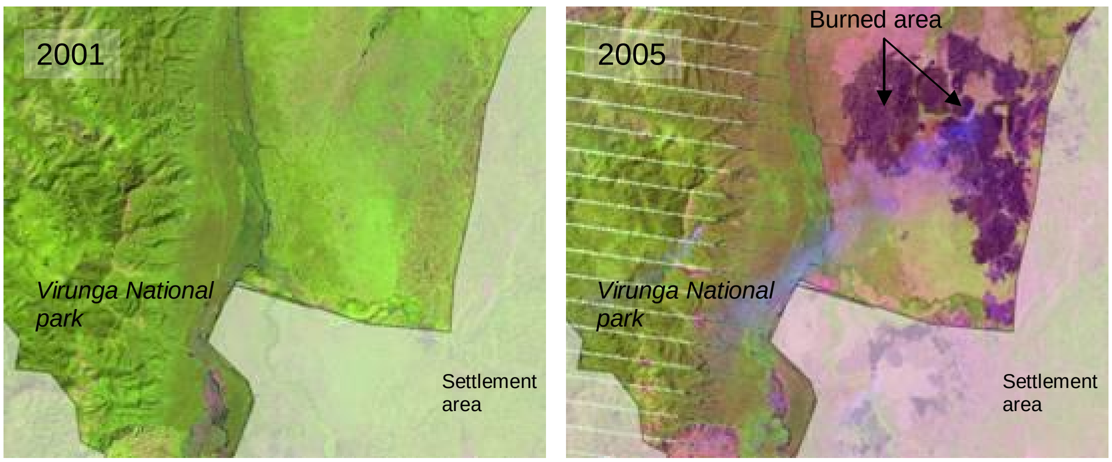


Fig. 16. Available Landsat satellite imagery of 11 December 2001 (wet season) and 25 February 2005 (dry season) showing fire damage and ongoing burning (see smoke plume) inside Virunga National Park late February 2005. The fire impacted area covers approximately 8 by 8 kilometers. Comparison with available land cover maps (Bego project) show that grassland burning has also damaged remaining savannah area. *Pink areas*: dry grasslands, *Pale green*: savannah, *Dark purple*: fire damage.

Satellite radar is well suited for the timely detection of fire damage, provided satellite data is obtained not too long before and after the actual event (i.e. change is best detected by systematic monitoring).

Now finally supplementary spatial information has become available to support proper radar image processing, it is proposed to demonstrate fire damage detection in the region during the 2007 service contract using reference areas as identified in the above.

[3] Plumptre, A.J., Behangana, M., Ndomba, E., Davenport, T., Kahindo, C., Kityo, R. Ssegawa, P., Eilu, G., Nkuutu, D. and Owiunji, I. (2003) The Biodiversity of the Albertine Rift. Albertine Rift Technical Reports No. 3, 107 pp.

Example 8. Hydrology – drought and flooding

Irrigation for agriculture poses a threat to the hydrological situation in the wider region, due to dehydration of lakes and river streams. As the Albertine Rift valley is source of both the Nile basin and the Congo Basin, this area is crucial for a very large number of people in Africa. Moreover the hydrological situation deserves close monitoring for the energy production in Uganda, Rwanda, Tanzania, and beyond. Hydro-power in Rugezi marshlands f.e. is no longer possible because the marshlands dried up. Drying out of lakes and river beds are of serious concern to many people in this region. Regular monitoring of these water bodies can provide indicators necessary for more effective water management.

ASAR WS radar covers large areas (400 x 400 km) and is particularly useful for the repetitive monitoring of (small) water bodies, as is shown in the example below. Water bodies act as a mirror bouncing the radar signal away from the sensor. The signal scattered back is not recorded and for this reason water bodies show up distinctively black on radar imagery.

A severe drought period during late December 2005 and early 2006 reportedly led to a deteriorating food security situation across a broad swath of Eastern and Central Africa. As the September to December short rainy season ended early in much of Rwanda, the season saw significant crop losses.[4] *Figure 17 and 18* show how this period of poor rains affected the water level of a lake in Tanzania and how the water level was restored after the rainy season finally set in. Distance to the shores changed over 500 m in places.

Systematic radar monitoring can clearly be very useful to detect both drought and flooding impact on a regular basis. Abnormal as well as prolonged deviations from natural hydrological dynamics can be detected in a timely manner.

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[4] Source: International Federation of Red Cross And Red Crescent Societies (IFRC) 3 March 2006 http://reliefweb.int/rw/rwb.nsf/vLCE/26A93B2A2138462449257129001B9F5A?OpenDocument&StartKey=East+Africa+Drought&ExpandView

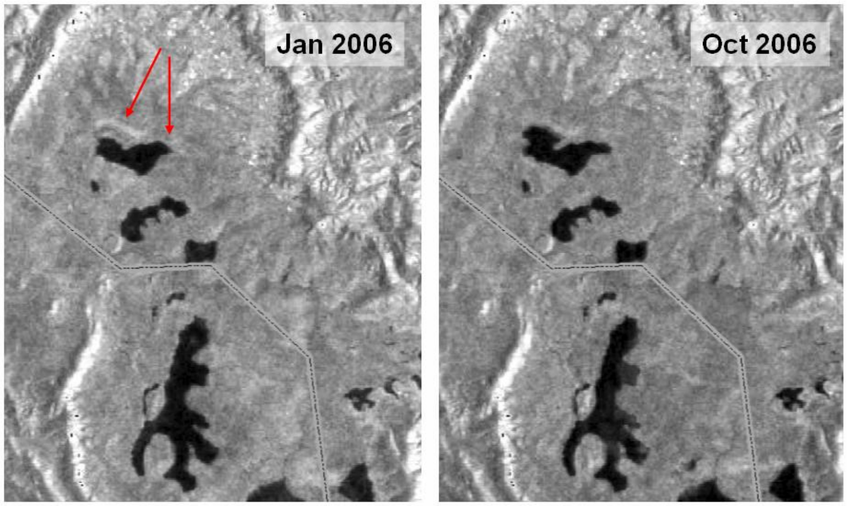

Fig. 17. Top This example shows a series of lakes in near the border of Tanzania (upper right) and Akagera National Park (bottom left corner). The nearest town in Tanzania is Karenge. The left image shows the water levels of the upper lake (black area, see red arrows) are low in January during the dry season. The right image shows that the water level had risen significantly in October, likely due to rains during the marshlands season that runs from June to September/October. Area covered 25 x 20 km.

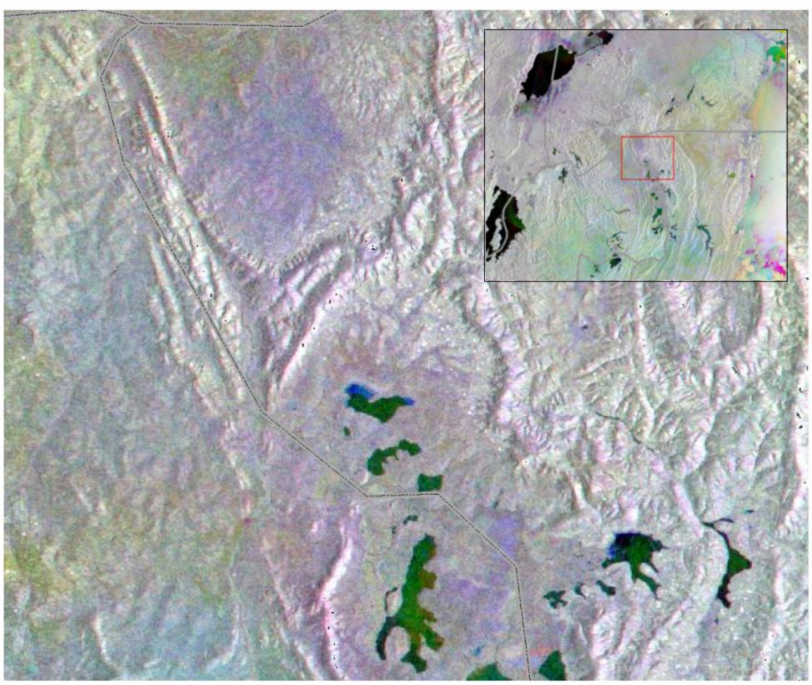

Fig. 18. Subset of ASAR WS multi-temporal image 2006 (dates October 2006, January 2006) showing the increased water level in blue.

Next steps

The next steps are needed in 2007 for further development and implementation of permanent monitoring:

- Build further on the datasets and collaborations established to develop map classifications using radar that are easy to grasp for policy makers and laypeople. The supporting information to make this possible has only become available early 2007. This could help answer questions such as: has the deforestation rate increased during the past 5-7 years? What is the extent and impact of coltan mining in the region? What areas are under threat from degradation due to recurrent fires?
- Strengthen collaboration with ongoing mapping initiatives. The leading initiative by the University of Maryland already indicated it would like to test the radar approach.
- Strengthen collaboration with local experts. For instance to establish the impact of coltan mining on the forest.
- In case of interest of other local partners and donors, jointly prepare further proposals for establishing a systematic monitoring system building further on existing initiatives and training of local staff on radar.

Annex 1. List of ASAR WS and IM radar images acquired

Mode	Path	Date
WS	035	2003-08-14
WS	035	2003-10-23
WS	035	2004-02-05
WS	035	2004-05-20
WS	221	2003-06-18
WS	221	2004-06-02
WS	221	2006-01-18
WS	221	2006-05-03
WS	221	2006-10-25
WS	264	2004-06-05
WS	264	2006-01-21
WS	264	2006-02-25
WS	264	2006-06-10
WS	264	2006-10-28
WS	493	2003-08-11
WS	493	2003-10-20
WS	493	2004-05-17
WS	493	2006-07-31
IM	035	2003-01-16
IM	035	2003-03-27
IM	035	2003-05-01
IM	035	2003-07-10
IM	035	2004-07-29
IM	035	2005-01-20
IM	035	2005-02-24
IM	035	2005-06-09
IM	035	2005-12-01
IM	035	2006-01-05
IM	035	2006-02-09
IM	035	2006-03-16
IM	035	2006-04-20
IM	035	2006-05-25
IM	035	2006-06-29
IM	035	2006-08-03
IM	035	2006-09-07
IM	228	2004-04-28
IM	228	2004-06-02
IM	228	2004-08-11