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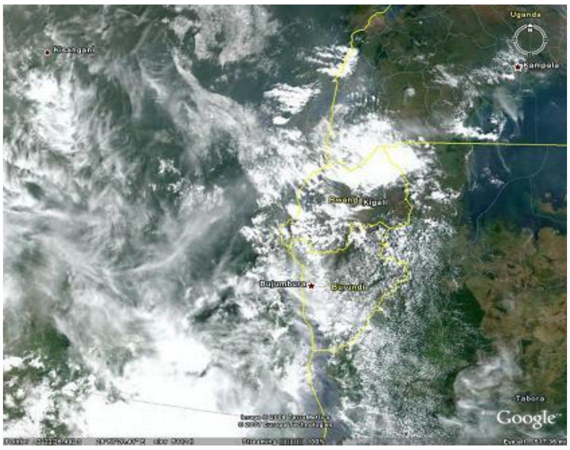
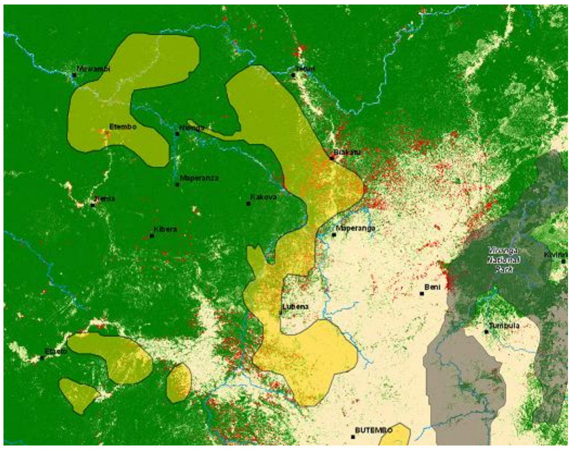
Mining, forest change and conflict in the Kivus, eastern Democratic Republic of Congo

Outcome of a short study within the IES-ESPA programme





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Institute for Environmental Security

Anna Paulownastraat 103
2518 BC The Hague, The Netherlands
Tel. +31 70 365 2299 ● Fax: +31 70 365 1948
www.envirosecurity.org

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Published and edited by:

Institute for Environmental Security
Anna Paulownastraat 103
2518 BC The Hague
The Netherlands
www.envirosecurity.org

Prepared by:

SarVision
Agro Business Park 10
6708 PW Wageningen
The Netherlands
www.sarvision.nl

With cooperation from:

WIx Wageningen International Experts
Wim Sonneveldstraat 24
6708 NB Wageningen
The Netherlands
www.wix.nl

Cover image left: Google Earth, 14 January 2008. *Due to quasi-permanent cloud cover over the Great Lakes and Congo Basin traditional satellite imagery rarely provides the useful imagery that is much needed. MODIS satellite imagery recorded 14 January 2008, uploaded in Google Earth™.*

Cover image right: see figure 5, p.15. *Overview of forest cover change and gold deposits.*

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1 Introduction

This report presents the outcome of a study carried out within the Environmental Security for Poverty Alleviation (ESPA) programme of the Institute for Environmental Security (IES). The IES works, among others, to promote and advance the development and implementation of permanent monitoring of ecosystems with satellite technology. To help achieve this overall objective in the African Great Lakes region a small preparatory study was carried out from October - December 2006 to demonstrate some initial examples of systematic monitoring using satellite data. Both optical and radar satellite imagery for overlapping areas and timeframes (2003-2006) had been collected during that study, but due to limited time and resources could not yet be interpreted.

This study was undertaken as a follow-up, in order to:

a) Demonstrate that up-to-date information on forest status can now be made available using new satellite imaging approaches; and

b) Increase understanding of the impact of mineral resource mining on forest in the eastern part of the Democratic Republic of Congo (DRC).

Satellite monitoring

It is widely acknowledged that proper law enforcement, sustainable biomass production and REDD monitoring in DRC is suffering from a lack of recent spatial forest information. 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 spanning the period 1990 – 2000 only became available in February 2007. No systematic monitoring using regular updates is implemented (yet). Hence the current status of the forest remains unclear. This lack of data, monitoring and evaluation is highlighted by several key studies (CBFP, 2007; Reed & Miranda, 2007; Maniatis, 2007). The resulting lack of transparency maintains corruption and lack of good governance in the mining and logging sectors.

The Congo Basin Forest Partnership reports that “The participants to the State of the Forest meeting, held in Kinshasa in March 2006 highlighted the lack of current remotely sensed data for ongoing forest monitoring in the region” (CBPF, 2007).

One of the main technical problems is persistent cloud cover preventing traditional satellites to take useful images for many months. Hence it is not currently possible to measure forest cover change annually at fine spatial resolutions. Experts working on satellite monitoring acknowledge that this limitation can be overcome by “daily acquisition of coarse resolution optical data or by using radar observation, that is not affected by cloud coverage” (CBPF, 2007 p. 80).

Following this suggestion, this short study assesses the use of advanced radar satellite imaging to overcome this problem and review the impact of mining and conflict on forest cover. For the current short study, SarVision has tested two types of radar data for 2006-2007 in the DRC: Envisat ASAR (European Space Agency) and ALOS PALSAR (Japanese Space Agency).

Objectives

The objectives of the current short study identified by IES were to:

- develop a map classification showing current forest status for a selected area in the Great Lakes region, building further on the datasets established during the 2006 contract
- strengthen collaboration with local experts of the Congo Forest Expert Group
- report examples of environmental damage due to mining and deforestation
- strengthen collaboration with ongoing mapping initiatives of the University of Maryland

Deliverables

The following deliverables had been determined:

- Forest change map classification (2000 – 2006) for a small selected area in the Great Lakes region, showing: 1. forest; 2. non-forest; 3. deforestation; and 4. water.
- Formal collaboration with local experts on RS/GIS established;
- Formal collaboration with ongoing mapping initiatives established;
- Brief analysis report discussing examples of environmental damage due to mining and deforestation.

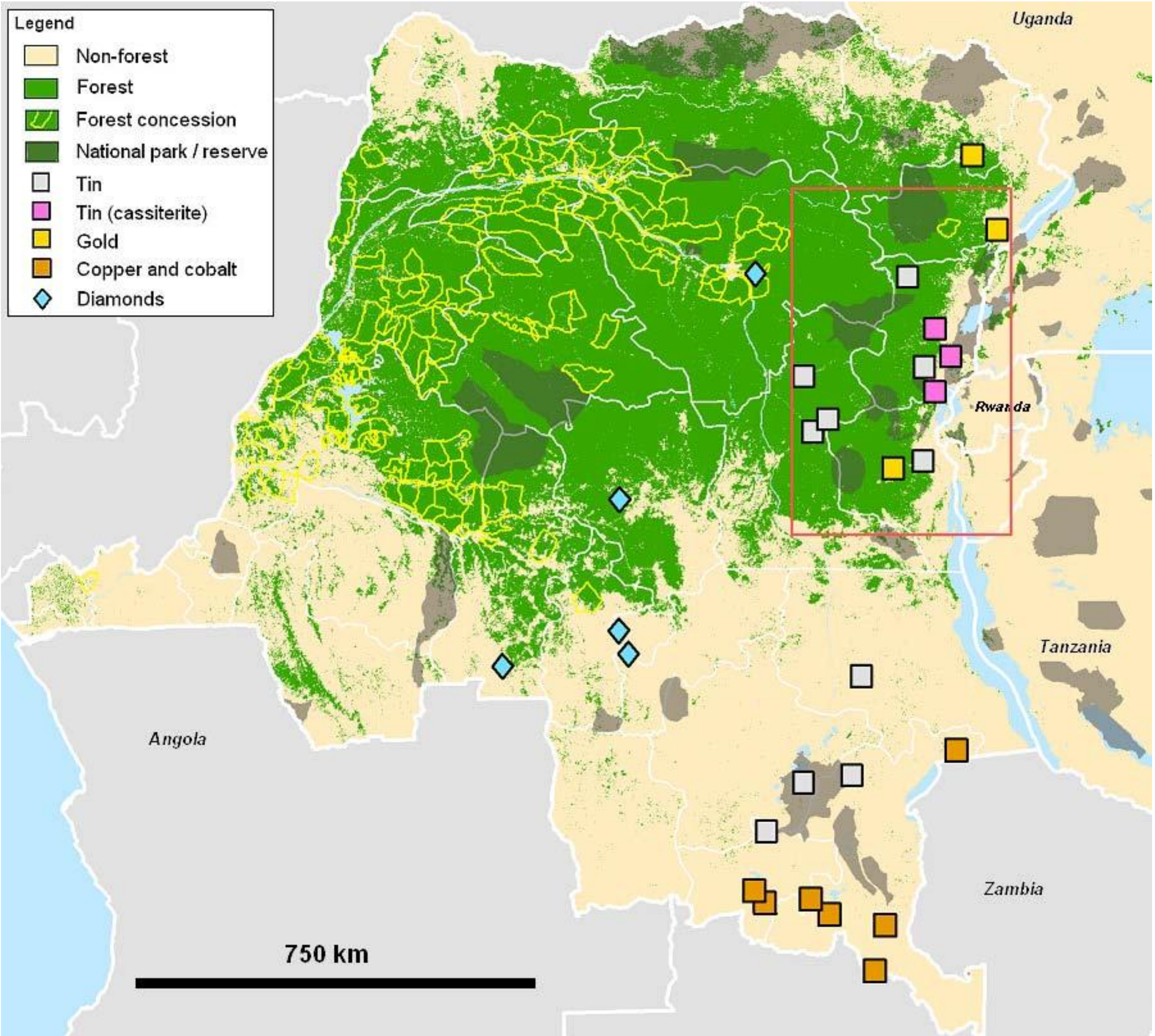
Key findings reported in the current document are the result of intensive collaboration with Dr. Patrice Yamba T. Kantu, a geologist and RS/GIS expert member of the Congo Forest Expert Group, during several days at the SarVision Wageningen office. Editorial work on mining and conflict was lead by dr. Yamba T. Kantu. The work was supported by satellite data sharing with the main mapping initiative in the region lead by the University of Maryland and South Dakota State University (CARPE).

An explicit effort was made to avoid the use of too technical or too scientific language throughout the current document. If any questions rise, however, do not hesitate to contact SarVision or the IES.

2 Study area

Pressure on the forests of the Democratic Republic of Congo (DRC) due to logging and mining is clearly differentiated in the west and east sections of the country (see *figure 1.*). The industrial logging belt (yellow concession areas) is currently still limited to the west of the country by transportation over the Congo River.

Figure 1. Forest cover, forest concessions, protected areas and mineral deposits in the DRC



This image presents forest cover, forest concessions, national parks and reserves, and a rough outline of mineral deposits in the Democratic Republic of Congo. The red rectangle presents the wider study area for geological mapping and satellite image interpretation. Source forest concessions: USAID CARPE program (Date unknown). Source parks: UNEP WDPA Parks and Protected Areas. Source mineral areas: adapted from Rekacewicz, 2005.

Mineral resources are found predominantly in the forest zone of east DRC. These forests are upland and mountain forest currently without industrial logging. Open mining of coltan and gold causes deforestation and water pollution (mercury). The mining belt in east Congo is also where most insecurity exists. Refugee camps and high population pressure due to fertile volcanic soils result in deforestation in high biodiversity value national parks for food cultivation, charcoal and fuel wood production. The forests of the east Congo mining belt are also under pressure from the densely populated neighbouring countries of Great Lakes Region.

In between the logging and the mining belt lies a relatively undisturbed forest area, the 'Okapi belt' (van Rompaey, *pers. comm.*). People living there hunt and farm at low intensity. Road construction (e.g. a road from Uganda to Kisangani) is bound to bring in industrial logging and large scale plantations (oil palm) in the coming years, which may result in large scale deforestation if this remains uncontrolled.

The present study focuses on a test area (red rectangle, figure 1) in North and South Kivu provinces, Great Lakes region. It borders Oriental Province in the north-west and Maniema to the west. To the east it borders Uganda and Rwanda. The principle cities are Goma, Butembo and Beni. The province contains Virunga National Park, a World Heritage Site home to the endangered mountain gorillas.

Biodiversity

The test site area is characterised by a complex mosaic of land cover types, belonging to the Albertine Rift Mountain eco-region. Typical tropical highland forests dominate the natural vegetation: lower montane forest – altitude: 1000 to 1600 m - and upper montane forest - altitude: >1600 m (White, 1983). It is an area of exceptional faunal and moderate floral endemism. These mountains are inhabited by mountain gorillas (*Gorilla beringei beringei*), which is one of the most charismatic flagship species in Africa, and an effective target for much of the current conservation investment in the area.

Mineral resources

This area is also very rich in other natural resources such as columbite-tantalum (otherwise known as coltan, a mineral that contains tantalum, colombium and niobium), cassiterite (tin ore), and gold. It is estimated that the DRC has 450,000 metric tons of tantalum reserves and "four fifths of the world's tantalum is found in Africa, of which 80 percent is located in the DRC's eastern region (Todd, 2006).

Conflict

Furthermore, the region is the scene of much fighting since the Second Congo War (1998–2003) also known as Africa's World War. The largest war in modern African history, one of the deadliest conflicts since World War II, directly involved eight African nations, as well as about 25 armed groups. 3.8 million people died, mostly from starvation and disease. Millions more were displaced from their homes or sought asylum in neighbouring countries. In October 2007, the United Nations High Commissioner for Refugees (UNHCR) warned of an increasing number of internally displaced people (IDP) in North Kivu related to the fighting there between the government army, the Democratic Forces for the Liberation of Rwanda (FDLR) rebels and renegade troops, including Laurent Nkunda's forces, and a build-up of military supplies and forces, including the reported recruitment of child soldiers by armed groups across North Kivu. Hundreds of thousands of people in North Kivu were displaced since December 2006, according to the UNHCR. The UN Refugee

Agency estimated in April 2008 that a total of 860,000 people in that province were internally displaced.

The combination of civil war, population displacement, ethnic tension and increasing need of natural resources (coltan and gold) for financing rebel movements in this part of the DRC is putting increasing pressure on the Congo mountain forest and its biodiversity and has led to a multitude of problems for local peoples. Problems include social group dysfunction (communities and families), mining-related illnesses, human rights violations (which include child labourers in the mining industry and abuse of women), and changes in human land and resource use which are causing great environmental damage.

In order to start the transformation toward stability and sustainability, it is essential that the links between social and environmental issues surrounding resource extraction practices are more clearly understood. The high-value natural resources of the DRC, including minerals and timber, could provide much-needed revenue for local governments; yet this will only contribute to poverty alleviation if the benefits are equitably distributed and a strong monitoring and enforcement system is in place to ensure that companies operate in an environmentally responsible manner (Reed & Miranda, 2007).

3 Materials and methods

Literature review

An extensive literature study was carried out to gather non-spatial information and reports on mining and conflict.

Spatial mining and conflict data processing

The mineral resource paper map of DRC has been scanned and georeferenced to enable incorporation in the project geographic information system (GIS). This map (Bureau de Recherches Géologiques et Minières, 1974) has a scale of 1 : 2,000,000 and covers the entire DRC. Mineral deposits data over eastern DRC was digitised on-screen and interpreted by dr. Yamba T. Kantu for the purpose of this study.

Other spatial data on mining sites and mineral deposits known from recent reports has been georeferenced and added to the project GIS as well for further analysis, including Rekacewicz (2005), and Global Witness (2006).

Spatial data on the location and degree of conflict events was generously made available by Swisspeace (Swisspeace, 2007) and included in the GIS.

Satellite image processing

For the present study, two types of radar imagery were collected over the study area, radar imagery from the Japanese ALOS PALSAR sensor and the European Envisat ASAR sensor *(table 1)*. It is important to note that the radar sensor parameters used to record the images are crucial. The radar satellite can both send and receive radar waves in two ways: in a horizontal direction (H) or a vertical direction (V). Successful detection of change improves dramatically if images with *both* information channels (e.g. HH *and* HV) are available.

Table 1. Satellite data used for the present study

Satellite sensor	Image date(s)	Information channel(s)
ALOS PALSAR	10-07-2007	HH and HV
Envisat ASAR	28-06-2005 24-01-2006 28-02-2006 13-06-2006 26-09-2006 31-10-2006	VV only (default imaging mode)
Landsat ETM+	11-12-2001	(for reference only)
Landsat ETM+	23-01-2006	(for reference only)

Two 2007 PALSAR dual polarimetric images at 12.5 m pixel size received in ground range were first radiometrically calibrated. An image composite was made using the two information channels HH, HV, and the difference HH-HV. The resulting PALSAR composite was resampled to 50 m pixel size to reduce speckle levels. The composite was co-registered to the 1990 – 2000 forest cover change map produced by University of Maryland (Hansen *et al., in press*) using 16 control points, resulting in a registration error of less than one pixel.

Unfortunately, only default ASAR imagery having only one information channel (VV) was available for the study area over 2006. In addition, if the ASAR satellite sensor has not been tasked ('turned on') to take images over specific areas only historic images of random dates are available. This limits the proper extraction of deforestation information. If the satellite is specifically tasked, two information channels (VV and VH) can become consistently available, and on a monthly basis. All ASAR images have been orthorectified to reduce the effect of topography. All images have then been co-registered to the coordinates of the 1990 – 2000 forest cover change map to ensure each pixel represents the same area on the earth's surface.

Traditional visual interpretation can not be used on radar imagery to identify forest change well. The human eye can only detect limited variations in grey levels, while computers can detect several hundreds. For the classification of forest cover change a new computer approach was used to automatically analyse the radar satellite image data, identifying groups of pixels with similar statistical properties (Hoekman *et al.* 2007, Tran *et al.* 2005, Tran 2005). A series of different maps has been produced, each with a specific radar signal threshold value defining 'change'. This was done to identify the optimal threshold for change detection.

Unfortunately, overall change map accuracy could not be assessed due to the lack of independent data for the area (i.e. aerial survey, independent map classification).
Landsat ETM+ optical imagery for reference (2006) was made available by the University of Maryland (source for this data set is the Global Land Cover Facility, www.landcover.org). This imagery has been used to compare the changes detected by radar visually, where possible.

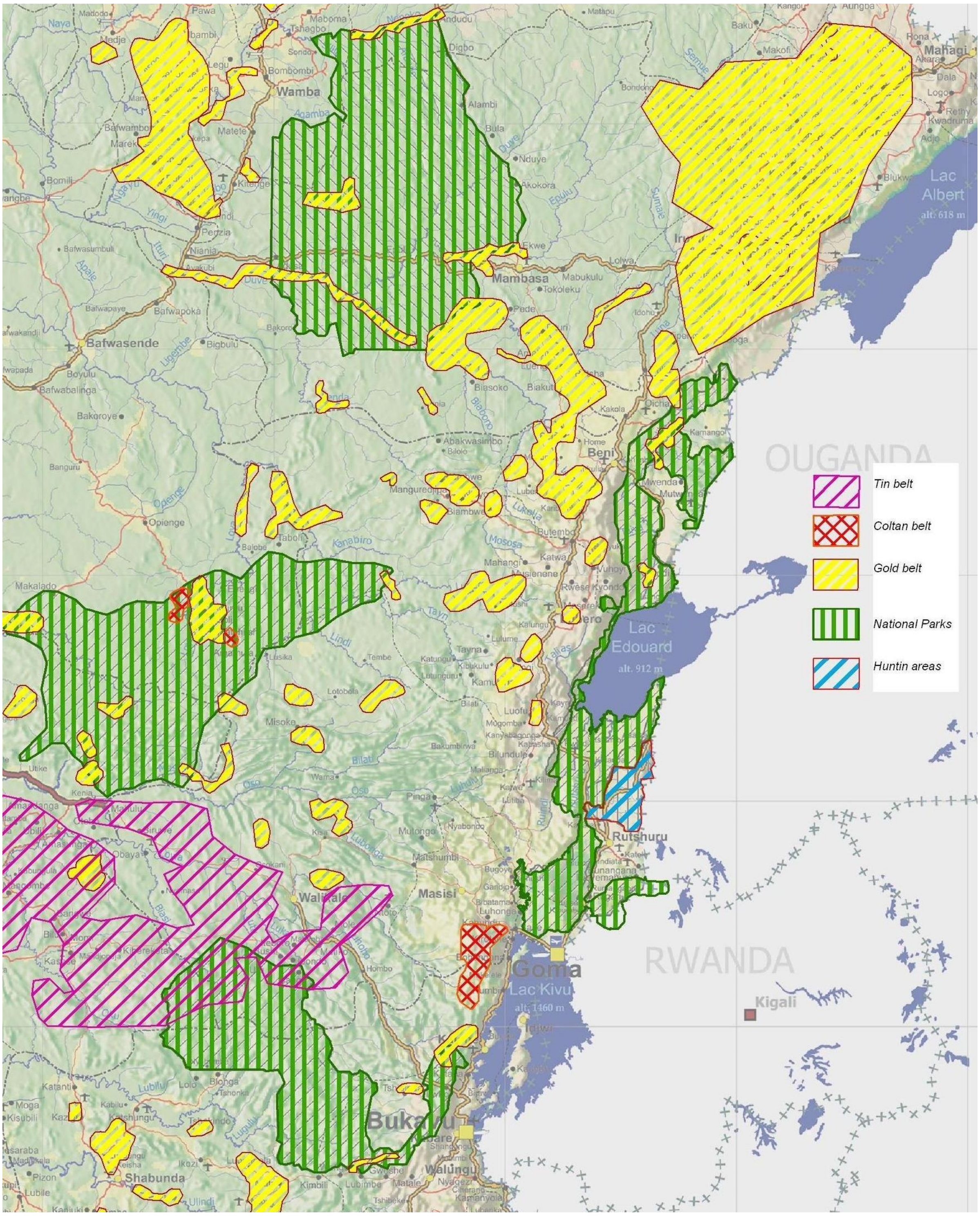
All satellite image analysis was performed using ENVI 4.3 and IDL 6.3 standard software, including IDL programs and algorithms for radar image classification developed in-house. Further GIS analysis and processing was performed using ArcGIS 8.2 and 9.2.

4 Results

Forest cover, mining and conflict maps

The digitisation of the mineral resource map has resulted in the spatial data depicted in *figure 2.*

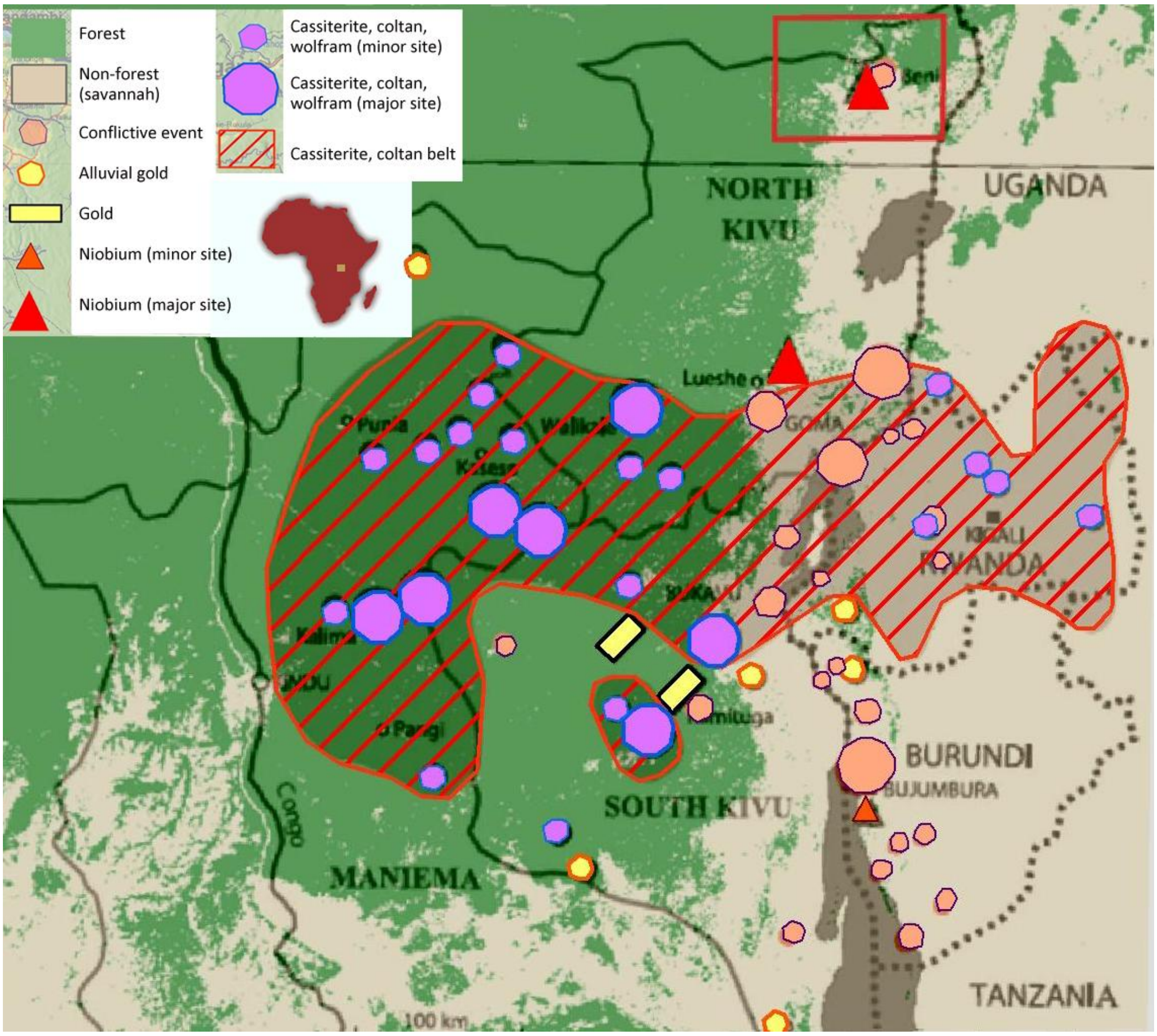
Figure 2. Mineral Resources Map



Mineral Resources Map, eastern part of DRC digitised by dr. Yamba T. Kantu.

According to a recent UN report there is "a clear geographical correlation between the activities of illicit armed actors and areas of natural resource exploitation in the Kivus and Ituri province" (United Nations Security Council 2007, p.7). Control over territory has proven to be the key factor enabling armed groups in the Democratic Republic of Congo to profit from the exploitation of natural resources. This is partly demonstrated in figure 3.

Figure 3. Geographical relation between minerals / mining and location of conflictive events



Geographical relation between mineral deposits/mining areas and location and magnitude of conflict events occurring mid-2007 (pink dots). Pink dot size corresponds to the number of conflictive events in mid-2007 and the degree of conflict of these events per district. Note that pink dots are positioned in the centres of districts, not at the exact location of the conflict!. The red rectangle locates the test area for 2000-2007 forest cover change mapping using radar in one of the key mining areas (figures 6 and 7). Source mining information: Global Witness, 2005. Source conflictive events: Swisspeace, 2007.

The extraction of coltan and recently cassiterite (tin ore) is a process that influences the environment directly through removal of forest vegetation cover and pollution. Coltan is also found in high concentration within the boundaries of protected areas such as Kahuzi-Biega National Park, home to a rich tropical forest ecosystem.

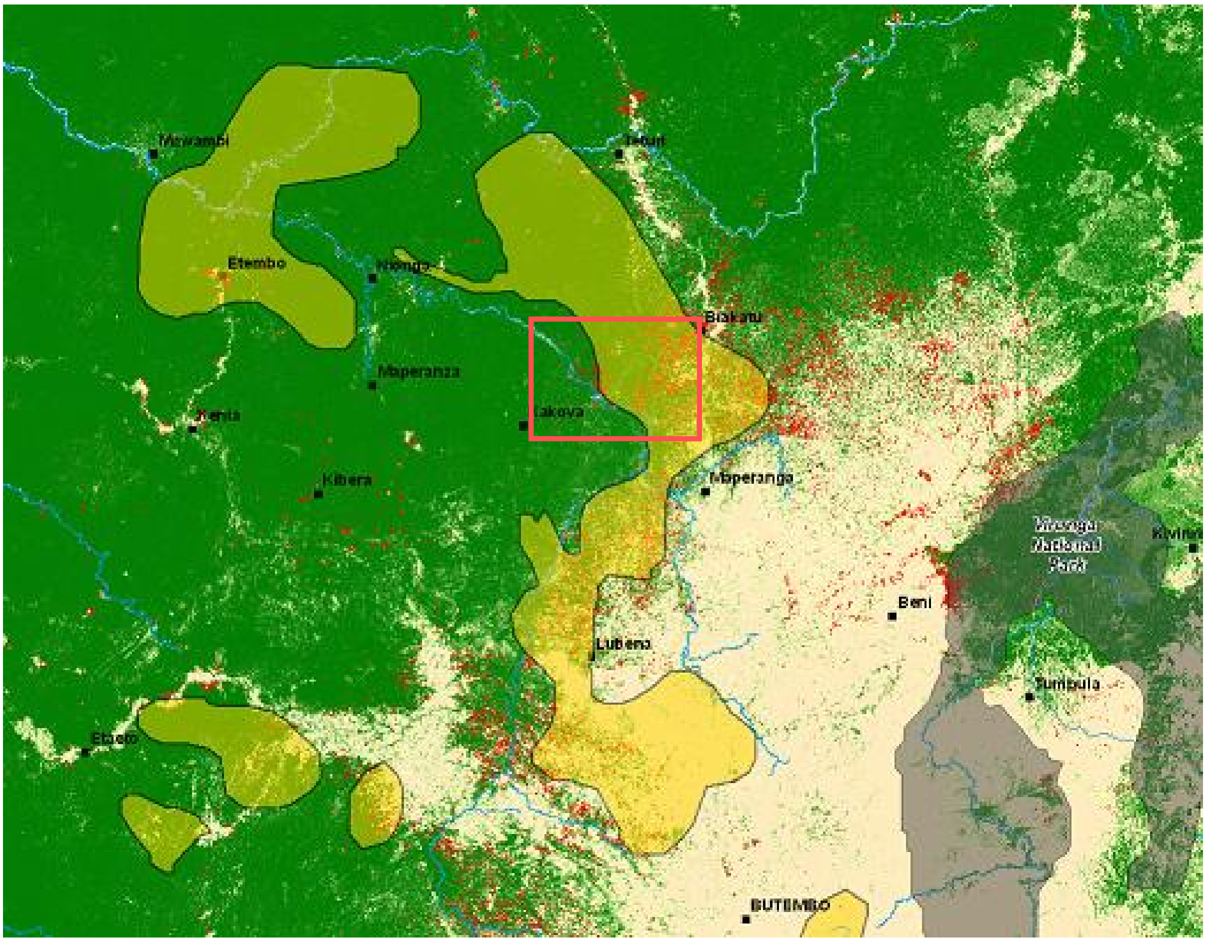
With the price of coltan now being low, and tin prices tripling in early 2004, cassiterite (tin ore) has replaced coltan as the ‘mineral of choice’ in the Kivus (Global Witness, 2005). To the north, around Butendo, Beni, the national parks of Virunga to the east and of Maiko to the west, illegal exploitation of gold occurs. This area is controlled by Mai-Mai rebel movement. None of the large profits have benefited the Congolese who live in the Kivu Provinces. The World Bank estimated that fraudulent practices caused the loss of USD 173 million in mining tax revenues in 2005 (IPIS, 2007).

Much of the fighting that is still occurring in the east of the country is driven by the desire to control natural resources.

Figure 4. Artisanal mining in the forest and inspection of coltan.

Illegal mining of coltan, cassiterite (tin ore) and gold is taking place through a large number of artisanal mining operations that take relatively little capital investment. Artisanal mining operations are unregulated and often occur in riparian zones, removing forest and vegetation cover to process the mineral soil.

Figure 5. Overview of non-forest, forest, forest cover change, gold deposits and Virunga NP



Overview of non-forest (sand), forest (green), forest cover change (red), gold deposits as digitised during the present study (yellow polygons) and Virunga National Park (grey polygon). The red rectangle locates the area shown in figures 6 and 7, for 2000 - 2007 forest cover change mapping using radar imagery.

Figure 5 zooms in to the digitized mineral resources map data shown in *figure 2* and shows that deforestation fronts coincide with mineral resources. In the centre of *figure 5*, a large area of known gold deposits has been digitised from the paper map, stretching from hills in the north via alluvial deposits to hills in the east. It seems very likely that, slightly away from large population centres, much of the deforestation is related to gold mining rather than to agricultural expansion. Reportedly, food security is threatened because agricultural production has collapsed in the Kivus as farmers have taken more lucrative employment as miners (Global Witness, 2005).

It can also be seen that deforestation very near to the large city of Beni encroaches on Virunga National Park. Very near to the city, this may more likely be the result of firewood collection and agricultural expansion to support refugees.

Forest cover change maps (2000- 2007) have been developed for this area; these will be presented in the next section. Nevertheless, confirmation on the ground is urgently needed before decisive conclusions can be drawn.

According to recent reports and studies, illegal coltan, cassiterite (tin ore) and gold mining are the principal causes of deforestation and forest degradation in the east of DRC. To open mines of coltan or gold, rebel forces have settled in the national parks of Congo. Therefore, resource extraction has many impacts on the environmental diversity of the eastern DRC; it is difficult to quantify the environmental degradation. As it remains unstable and difficult for researchers to enter and do work in North and South Kivu it is also difficult to quantify loss of biodiversity as animals are mobile and the lack of roads and navigable rivers make transportation into the wilderness areas difficult for researchers (Hart & Mwinyhali 2001; Draulans & Krunkelsven 2002).

Mining is an intensive extraction process and has had many impacts on some wilderness areas including national parks and wildlife reserves such as Kahuzi-Biega and the Okapi Wildlife Reserve which are both UNESCO World Heritage Sites. Mining in these areas are typically done through artisanal mining which is a small scale mining method that takes place in river beds it can be very environmentally damaging. Artisanal mining destroys landscapes and degrades riparian zones, creating erosion and heavy silting of the water. Moreover, the tailings are often dumped into the rivers and could be contaminated with mercury and cyanide, degrading the health of the river systems and putting the wildlife and people at risk (Sheppard 2001; UN 2002).

Miners and refugees are relocating to parks in search of minerals. A reported 10,000 people have moved into Kahuzi-Biega and 4,000 to the Okapi Wildlife Reserve (Hart & Mwinyihali 2001; Draulans & Krunkelsven 2002). Refugees from the conflicts afflicting the east of DRC and neighbouring countries are relocating to the wilderness areas, increasing the pressures on wildlife, which is collected as a primary food source, and timber that is used as fuel wood (Draulans & Krunkelsven 2002).

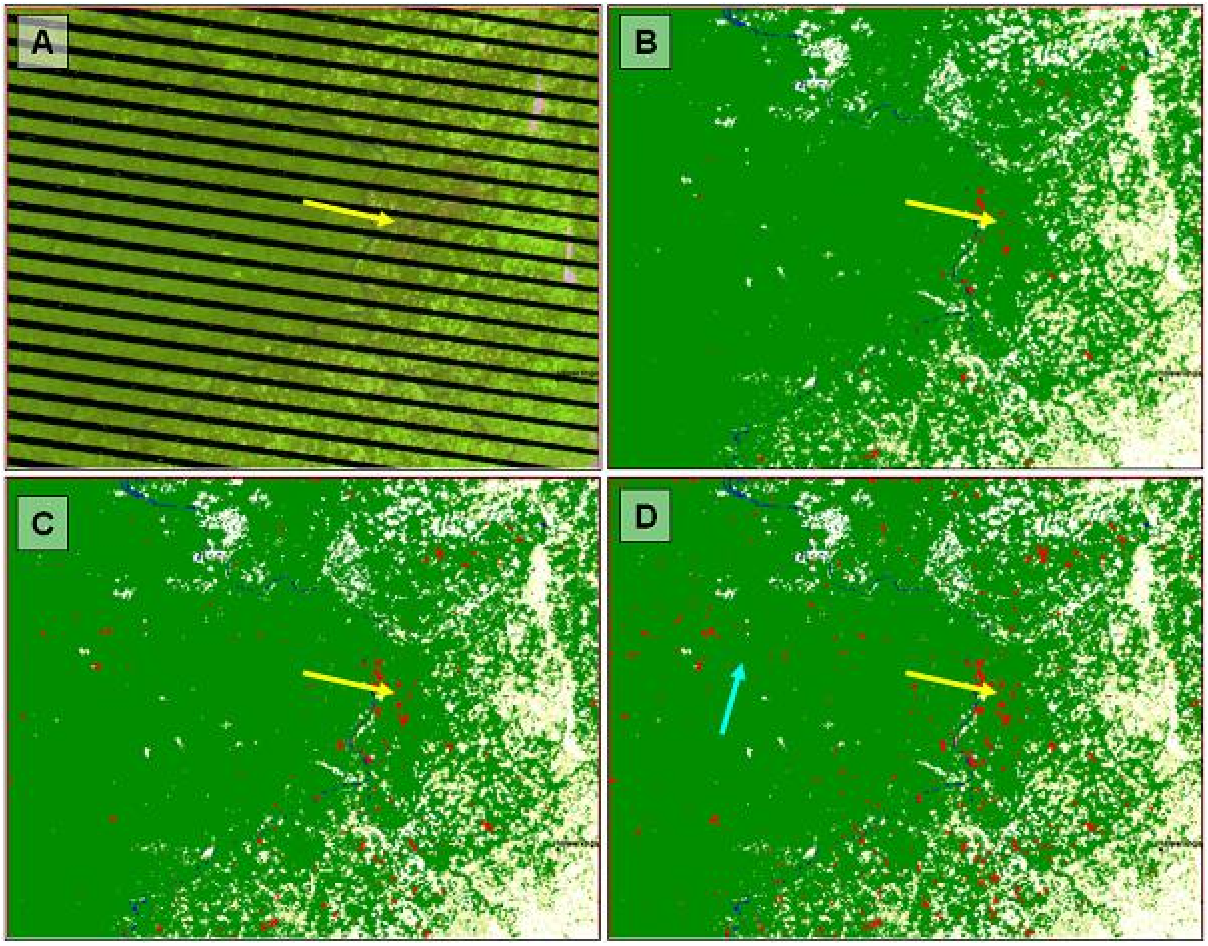
Forest cover change maps

Figure 6 shows the results of tests of ASAR radar for the detection of forest cover changes in key areas of known gold deposits (i.e. *figure 5*). It can be concluded that:

- With default imagery with only one information channel (VV), deforestation is either severely underestimated, or results suffer from too many false alarms (see blue arrow in *figure 6*).
- If ASAR imagery is only randomly available in addition, and time gaps between them are too large as a result, the quality of ASAR change detection results is seriously compromised.

Efforts must be made to ensure ASAR imagery with two information channels (VV and VH) is collected continuously in order to be able to produce convincing results.

Figure 6. Landsat 2006 reference image and ASAR 2006 forest cover change detection test results.



A. *Landsat reference image dated 11-12-2006. Although poorly visible due to the satellite's permanent scan-line malfunction and weak contrast, dark pink spots and coloration mark the location of removal of forest canopy.*

B. *ASAR test change detection 31-10-2006 at 1 dB threshold showing change in red.*

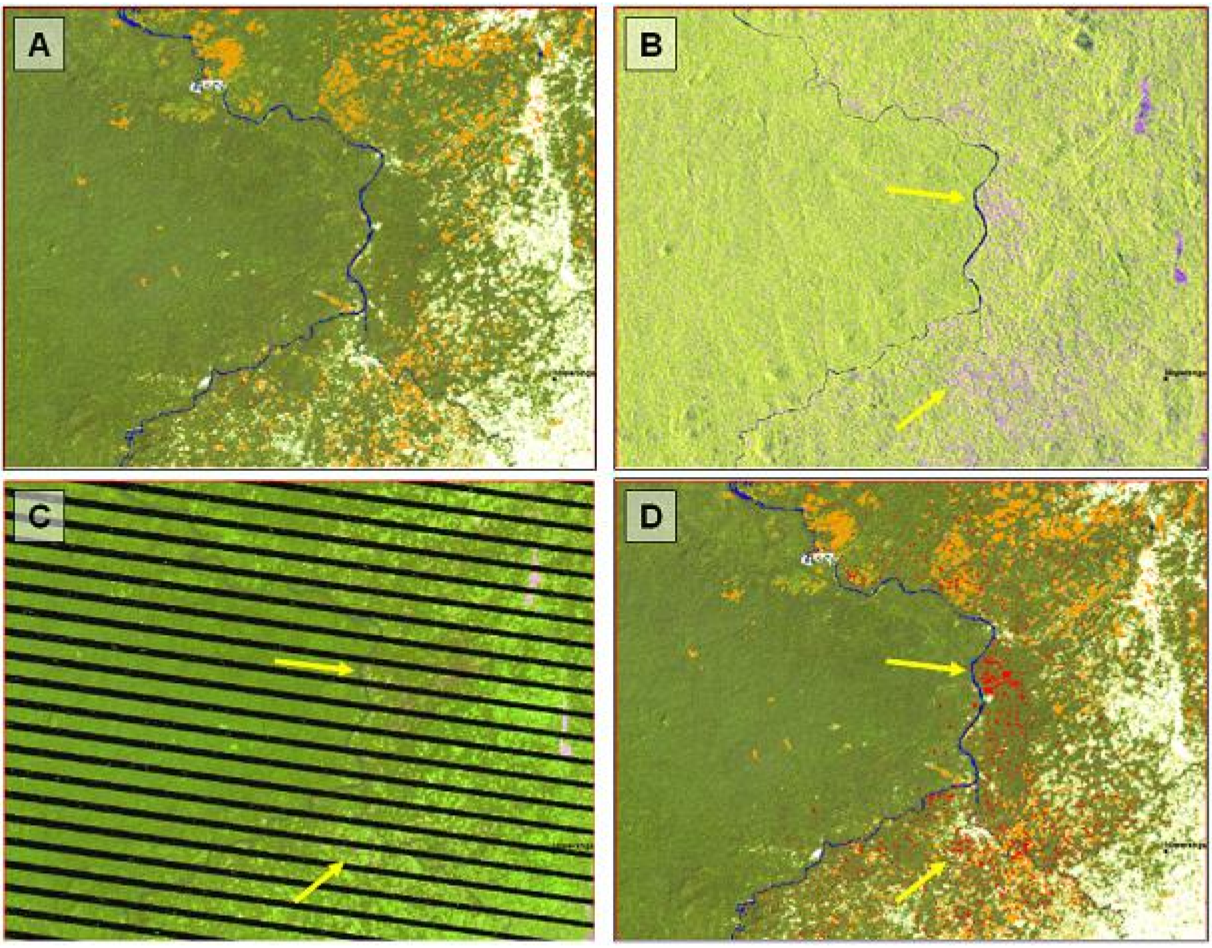
C. *ASAR test change detection 31-10-2006 at 0.7 dB threshold showing change in red.*

D. *ASAR test change detection 31-10-2006 at 0.6 dB threshold showing change in red. The blue arrow shows increased detection of removal of canopy comes at the expense of increased false alarms in areas not deforested in image A.*

Figure 7 shows the results of tests of PALSAR radar for the detection of forest cover changes in key areas of known gold deposits (i.e. *figure 5*). It can be concluded that:

- With PALSAR imagery using two information channels (HH, HV), small scale deforestation in Central Africa can be detected (see yellow arrows in *figure 7*).
- As PALSAR imagery providing two information channels is available on a yearly basis, it has now become possible to measure forest cover change annually at fine spatial resolutions, instead of the currently insufficient 5 to 10 year intervals.
- Confirmation on the ground is urgently needed before decisive conclusions can be drawn on the causes of forest cover change.

Figure 7. Landsat 2006 reference image and PALSAR 2007 forest cover change detection.



A. Landsat image dated 11-12-2001 image showing deforestation 1990 – 2000 in orange and non-forest in white (courtesy Hansen et al., in press).

B. ALOS PALSAR dual polarimetric radar image composite using information channels HH, HV, HH-HV shows recent clearings in pink (e.g. yellow arrows). Note that other non-forest areas show as green due to radar signal from shrubs and scattered trees.

C. Although poorly visible due to the satellite's permanent scan-line malfunction and weak contrast, dark pink spots and coloration mark the location of removal of forest canopy on this Landsat image of 23-01-2006. Non-forest areas show as light green.

D. The final PALSAR classification result showing forest (green); non-forest (white); deforestation 2000 – 2007 (red); deforestation 1990 – 2000 (orange); and water (blue).

5. Conclusions and Recommendations

- Satellite data from 2000 to 2007 shows that deforestation and forest degradation in eastern areas of the Democratic Republic of Congo (DRC) continues. These clearing zone spots are linked to the sites characterised by the presence of natural mineral resources, such as coltan and gold.

- Numerous rebel groups fund their occupation of eastern DRC through the exploitation of minerals, such as diamonds, gold, coltan and cassiterite (tin ore).

- The high-value natural mineral and timber resources of the DRC can only contribute to poverty alleviation if the benefits are equitably distributed and a strong monitoring and enforcement system is in place to ensure that companies operate in an environmentally responsible manner.

- Even though initiatives on mapping and monitoring exist in the region, information on land cover and forest status is not up-to-date. Moreover, one of the main problems in tropical forest areas is persistent cloud cover, preventing traditional satellites to take useful images for many months.

- With the advent of advanced radar, in particular ALOS PALSAR, it has now become possible to measure forest cover change annually at fine spatial resolutions, instead of the currently insufficient 5 to 10 year intervals.

- Many stakeholders, such as the Congolese government authorities or rangers controlling logging and mining, require specific satellite information for law enforcement. Also for the production of sustainable biomass (monitoring plantation development) the use of satellite images is indispensable. This type of monitoring is especially relevant in relation to the realisation of payment for ecosystem services contracts, for instance under the “Reducing Emissions from Deforestation and Degradation” (REDD) mechanism. This mechanism can only be effectively implemented when good baseline forest coverage data is established, and when forests are systematically and continuously being monitored.

- Therefore, it is strongly recommended to the Congolese national government, international financial institutions - in particular the World Bank -, conservation agencies as well as bi- and multilateral donors, to invest in the development of systematic satellite monitoring, using the new (radar) imaging approaches presented in this study at a larger scale. This will help to increase transparency, fight corruption and advance good governance in the mining and logging sectors of the Democratic Republic of Congo.

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Acknowledgements

This small study has been published by the Institute for Environmental Security (IES) within the framework of the Environmental Security for Poverty Alleviation (ESPA) programme supported by the Netherlands Ministry of Foreign Affairs. The IES acknowledges the authors from SarVision, Niels Wielaard and Martin Vissers, for their hard work on processing satellite images and on writing this report.

The authors would like to thank Alice Altstatt and her team at University of Maryland/South Dakota State University for making the 1990-2000 forest change map and reference satellite imagery available. The JAXA ALOS Kyoto and Carbon Initiative is acknowledged for making available PALSAR radar imagery for this study over eastern DRC. Many thanks to Dominic Senn at Swisspeace for sharing spatial conflict data for the Kivus, and to Patrice Yamba T. Kantu of the Congo Forest Expert Group for his GIS and mapping work. The authors are also grateful to Renaat van Rompaey at Wageningen International Experts (WIx) for his valuable advice and suggestions for improvement of the text.