Monitoring Tropical Rain Forests: Some Recent Developments

Gordon Petrie [1]

Currently the monitoring of the world's two largest areas of tropical rain forest — covering the basins of the River Amazon in South America and the River Congo in Central Africa — is a matter of high concern to the international community, especially with regard to the large-scale deforestation that is taking place in these two major regions of the Earth's land surface. This deforestation is caused mainly by the clearance of large areas of ground through the felling or burning of the trees for agricultural purposes — in order to grow crops or to graze cattle — or the cutting down of very large numbers of trees for sale as timber or wood pulp. The resulting deforestation can have negative or destructive effects on the soils and hydrology of the affected areas and on the plants and animals that live in the forests.

Amazon Rain Forest

The use of spaceborne imagery is the only practical method of carrying out (i) the monitoring of the huge areas that have to be covered within these basins, and (ii) the mapping of the location and extent of the deforested areas. In Brazil — the country that occupies the largest part of the Amazon Basin — until very recently, the monitoring and mapping of the forests has been carried out principally using the medium-resolution imagery that has been acquired by the U.S. Landsat and the Chinese/Brazilian CBERS satellites. Besides which, SPOT and Envisat imagery of the very northern part of the Brazilian Amazon can also be acquired via the SEAS ground station that is located at Cayenne in French Guyana. However most of the Landsat and CBERS imagery has been acquired directly within Brazil using the ground receiving station at Cuiaba, which is located in the state of Mato Grosso in West Central Brazil. Since much of the Amazon Basin is frequently cloud covered and, since each Landsat satellite can only visit a specific area every 16 days and with CBERS having a re-visit period of 26 days, it has been difficult to acquire cloud-free imagery. Furthermore, when there is a clear and cloud-free day, the satellite may not be passing overhead.

[1] *Gordon Petrie is Emeritus Professor of Topographic Science in the Dept. of Geographical & Earth Sciences of the University of Glasgow, Scotland, U.K. E-mail — Gordon.Petrie@ges.gla.ac.uk*

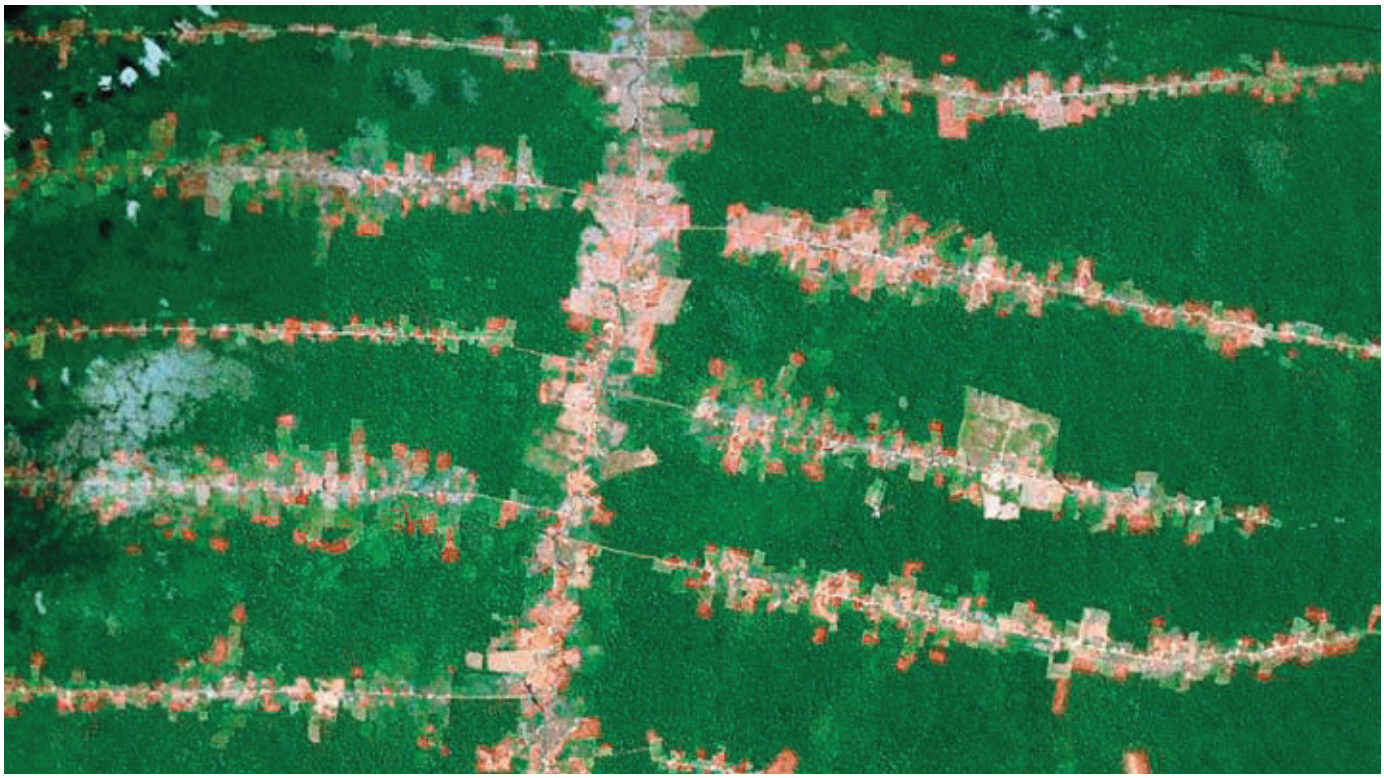

Fig. 1. Landsat TM image shows in more detail the homes that have been built and the fields that have been cleared along the parallel "fishbone" lines. (Source: NASA)

Besides which, the Landsat-7 satellite has suffered from the failure of its SLC mechanism, while the 22 year old Landsat-5 is now at the end of its operational life. Of the CBERS satellites, the CBERS-2B, launched in 2007, is still operational.

Thus, over the last four years (2005 –2008), the Brazilian National Institute for Space Research (INPE) has contracted with the international DMCII company for the supply of supplementary low-cost medium-resolution imagery that has been acquired by its constellation of DMC micro-satellites — comprising Alsat (Algeria), NigeriaSat (Nigeria), Bilsat (Turkey), Beijing-1 (China) and UK-DMC (U.K.). These have all been built in the U.K. by SSTL under knowledge and technology transfer programmes. Each of these satellites is capable of acquiring a very wide swath (450 to 650 km wide) of multi-spectral imagery of the ground with a ground resolution (32 m GSD), similar to that of the Landsat-TM scanner, but having a much wider swath. With five satellites in the constellation, the DMCII company has the capability of ensuring that a specific area can be visited every day. Thus, if an area is cloud covered, the DMC satellites can continue to image the area until it is cloud-free. Operating in this way, DMCII was able to cover the 5,000,000 sq km of the Amazon rain forest that falls within Brazil in a period of six weeks [Figure 1]. In fact, during 2007, DMCII was contracted to provide three repeat coverages for the periods June/July; July/August and September/October. The original five satellites of the DMCII constellation that were launched between 2002 and 2004 have now been reduced to four, one (Bilsat) having reached the end of its operational life. However three new satellites — UK-DMC2, NigeriaSat-2 and Deimos-1 (Spain) — are currently under construction for use in the constellation and are scheduled to be launched later this year (2009). The UK-DMC2 and Deimos satellites will generate imagery with an improved ground resolution of 22 m GSD, while NigeriaSat-2 will retain the previous 32 m GSD of the original satellites in the constellation.

Brazil is also involved in building new satellites that are designed specifically for the monitoring of the Amazon rain forest. On the one hand, it will continue to collaborate with China and, via this partnership, two new CBERS satellites (CBERS-3 and -4) will be launched that will replace the forerunners in the series. These two new satellites are presently scheduled for launch in 2009 and 2011 respectively. On the other hand, INPE is also constructing a series of micro-satellites that will utilize its own Micro-Mission Platform (MMP) that is being built in-house. The first of these satellites,

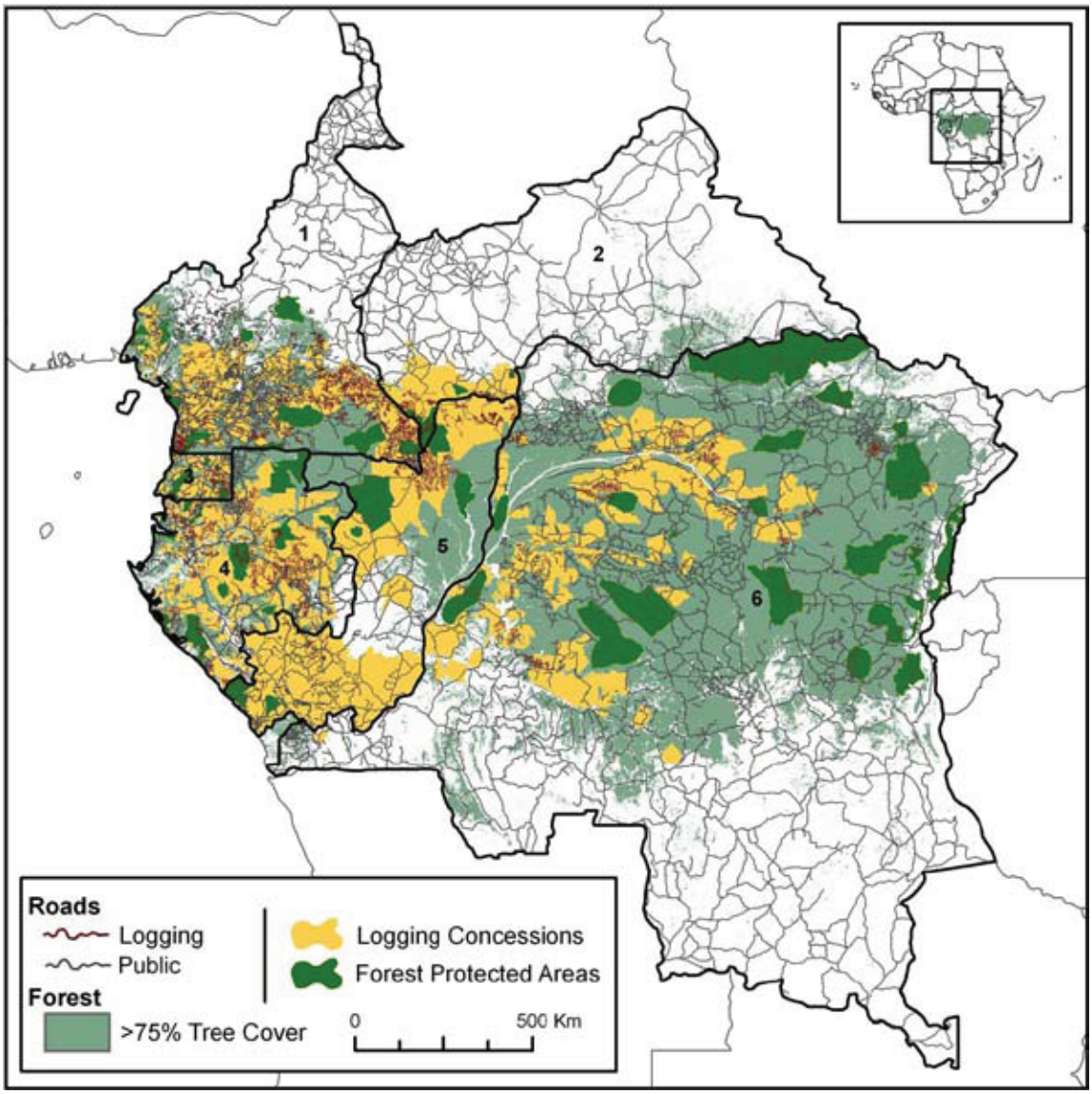

Fig. 2. Map showing the logging concessions and road distribution in the Congo Basin of Central Africa: 1 — Cameroon; 2 — Central African Republic; 3 — Equatorial Guinea; 4 — Gabon; 5 — Republic of Congo; and 6 — Democratic Republic of Congo] More than 300 Landsat images were used to map this area of 4 million sq km. (Source: Woods Hole Research Center)

called Amazonia-1, is a polar-orbiting micro-satellite (Fig. 4). It will feature a four-band multi-spectral Advanced Wide Field Imager (AFWI) that is also being constructed in Brazil. This scanner will cover an 800 km swath over the ground from the satellite altitude of 600 km, generating imagery with a 40 m GSD. The Amazonia-1 satellite will also operate a RALCam-3 pushbroom line-scanner (Fig. 5) that has been constructed by the Rutherford Appleton Laboratory (RAL) in the U.K. and is being supplied under the U.K.-Brazilian Partnership in Science & Innovation programme. The RALCam-3 scanner uses a three-lens refractive optical telescope and will generate images with a GSD value of 10 m and a ground swath width of 88 km.

The second new Brazilian satellite is called MapSAR (Multi-Application Purpose Synthetic Aperture Radar) [Figure 6]. It is also planned to be constructed utilizing the MMP micro-satellite platform. However, as the name suggests, it will have a very different type of imager in the form of a novel L-band SAR which is a joint development between INPE and the German DLR Aerospace Agency. The SAR will feature a Cassegrain-type antenna with a foldable primary reflector surface that is 7.5 x 5 m in size and is equipped with a horn-shaped feed and a very small secondary reflector surface. It is designed to be operated in any one of three modes (high, medium and low resolution) with GSD values of 3, 10 and 20 m respectively. Currently MapSAR is still in the development stage, being scheduled for launch in 2012.

In this context, it is worth noting the very successful use of long wavelength

(λ = 25 cm) L-band SAR imagers over areas of cloudy tropical rain forest by two Japanese satellite missions in the shape of (i) the JERS-1 SAR that operated between 1992 and 1998, and (ii) the PALSAR (mounted on the ALOS satellite) that has been operating since 2006. Indeed PALSAR data has begun to be used extensively by the DETER and PRODES programmes that are managed by INPE and are used to monitor deforestation in the Amazon region. The former programme (DETER) alerts government agencies with a fast response to the occurrence of illegal deforestation, while the latter programme (PRODES) provides data on the overall annual deforestation that has taken place in the Amazon region. No doubt, the success of these two Japanese satellites in monitoring and mapping both tropical and boreal forests with their L-band SARs has encouraged the Brazilian authorities to start the development of MapSAR in cooperation with DLR, which has a long history of successful development of airborne and spaceborne SAR imagers.

Another very interesting proposal for a highly specific mission to monitor Brazil's Amazon rain forest region has also been published by INPE. This would use a small (400 kg) mini-satellite that would placed in a very low (±5 degree) orbital inclination. The use of such a near-Equatorial orbit would result in the satellite passing over the Amazon region several times per day. The proposed SSR satellite would be equipped with an optical (VIS/NIR) three-line pushbroom stereoscanner, producing images with a 40 m ground pixel size (GSD), together with a second pushbroom line scanner operating in the MWIR (λ = 3.4 to 4.2 cm) region and producing images with a 500 m GSD. Within this context, it is interesting to note that Malaysia has now gone ahead with its similar RazakSat, which will have a near-Equatorial orbital inclination of ±9 degrees and is designed to pass over Malaysia in a similar manner several times per day. Razaksat is scheduled to be launched by a Falcon-X rocket from Kwajalein Island in the American Marshall Islands in the Pacific Ocean on 21st April 2009.

Congo Rain Forest

Turning next to the tropical rain forest of the Congo basin, the six countries — comprising Gabon, Equatorial Guinea, Cameroon, the Central African Republic, the Republic of Congo (Brazzaville) and the Democratic Republic of Congo (Kinshasa) — that occupy the basin simply do not possess the resources, the infrastructure and the technical and scientific capabilities of Brazil. Besides which, the DLR transportable ground receiving station that was formerly located in Libreville, Gabon, was removed some years ago. Nowadays only the very southern part of the DRC comes within the coverage of the South African ground station located near Pretoria. While only the very northern part of the basin comes within the coverage range of the SPOT ground receiving station that is located at Aswan in Egypt. So, quite apart from this limited coverage, there is a lack of any ground receiving station that can directly receive spaceborne imagery that can be used to provide the rapid access that is needed to monitor the large amount of deforestation that is taking place all across the region.

In this situation, the daunting task of monitoring deforestation in the Congo basin from satellite imagery has had to be undertaken by agencies from other countries that do not have a direct interest in the matter. Thus various American agencies and institutes have stepped in to try to plug the gap in knowledge about the situation. In particular, NASA has supported the development and operation of the Integrated Forest Monitoring System (INFORMS) for Central Africa, which is based at the Woods Hole Research Center in Massachusetts. This carries out research into forest management and conservation for the Congo basin in cooperation with the various national forest services of the countries of the region. Using Landsat imagery, mapping of the expansion of the timber extraction activities occurring across the region has been undertaken by the Center (Fig. 7). Another project, entitled the Decadal Forest Change Mapping (DCFM), has been carried out by the Central African Regional Program for the Environment (CARPE), which is based at the University of Maryland and is supported by the U.S. Agency for International Development (USAID) as well as NASA.

In June 2008, the governments of the U.K. and Norway set up the Congo Basin Forest Fund (CBFF), contributing an initial $100 million to the Fund. It is designed specifically to help the countries of the Congo basin (i) to manage their forest resources; (ii) to reduce the rate of deforestation taking place in the region; and (iii) to help local communities to find livelihoods that are consistent with the conservation of the rain forest. The U.K. government has already announced plans to carry out part of the monitoring of the Congo rain forest in cooperation with Brazil using the RALCom-3 scanner that will be mounted on the forthcoming Amazonia-1 satellite. These plans include the establishment of a ground receiving station in the Congo basin area. Brazil and China have also announced further plans to provide African nations with imagery from the CBERS satellites free of charge. These various plans and initiatives should help to overcome the many difficulties and shortcomings that are being experienced at the present time with the monitoring of the Congo rain forests.