CARTOGRAPHY AND MONITORING OF THE FIVE WORLD HERITAGE SITES OF THE DEMOCRATIC REPUBLIC OF CONGO USING SATELLITE IMAGERY

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ABSTRACT

Five parks or reserves of the Democratic Republic of Congo (DRC) are recognized as World Heritage Sites (WHS). In intense cooperation with the World Heritage Center of UNESCO and a number of conservation organizations (NGOs) and together with the Institut Congolais pour la Conservation de la Nature (ICCN), a network of Belgian research institutions has been built. The aim of the research project is to create an incorporated spatial information system of the WHS including topographic, environmental and socio-economic data and to produce up-to-date base maps of the five sites which are indispensable for managing and monitoring activities. Supplementary, zones with severe conservation problems, like the massive deforestation in the southern part of Virunga National Park in 2004, are monitored and the regeneration progress of earlier deforestation is mapped using remote sensing techniques. Another important aim is to organize capacity building activities in DRC.

1. THE CARTOGRAPHY IN THE DEMOCRATIC REPUBLIC OF CONGO

During the last thirty years cartographic production of the Democratic Republic of Congo (DRC) has quasi stagnated. On a 1 : 200 000 scale territorial maps (Carte Territoire) exist next to topographical maps per square degree (Degré Carré) (fig. 1). We distinguish two categories in the territorial maps, namely a series mainly produced before 1950, schematic and of low to very low accuracy and a later produced series equivalent to the topographical maps but delimited according to administrative boundaries instead of square degrees. The same two categories are found within the topographical maps per square degree. The series produced before the surveys by aerial photography, before the 1950’s, are lower in quality, detail and in amount of data than the maps which are produced based on aerial photos between 1950 and 1965. Other partial coverages of the country exists in different styles and quality, based on aerial photographs on a scale of 1 : 50 000, all produced before 1970.

The lack of recent and high qualitative cartography urged from new initiatives. DRC has five national parks or reserves that are part of UNESCO’s World Heritage List but sadly are also inscribed on the List of World Heritage Sites in Danger. No recent cartography of these sites exists, however this is urgently needed to ensure a sustainable management of the parks. Therefore the SYGIAP project (Système de Gestion d’Information pour les Aires Protégées) was set up for or by ICCN (Institut Congolais pour la Conservation de la Nature) in close cooperation with UNESCO. The project aims to develop a geographic information system (GIS) and to produce base maps of the five Congolese World Heritage Sites.
2. SYGIAP (SYSTEME DE GESTION D’INFORMATION POUR LES AIRES PROTEGEES)

The SYGIAP project, co-financed by Belgian Federal Science Policy, is an integral project with as global purpose the set up of a management frame of the existing cartographic information of the five Congolese World Heritage Sites (WHS) and the production of base maps which will be able to provide support for fieldwork and for the management of the sites. The project is carried out for the Congolese Institute for Nature Conservation (Institut Congolais pour la Conservation de la Nature (ICCN)), in close cooperation with the World Heritage Center of UNESCO and with the support and assistance of many partners under which several NGO’s. The five Congolese WHS that were in need of recent cartographic information are Okapi Wildlife Reserve, Garamba National Park, Virunga National Park, Kahuzi-Biega National Park and Salonga National park. The first four are located in the eastern part of the DRC and Salonga National Park is located in the centre of the country. Hereafter, a brief description of each site is given.
2.1. The five Congolese World Heritage Sites

The Okapi Wildlife Reserve has been created on Mai 2nd 1992 under the statute of ‘Total Wildlife Reserve’ (Réserve naturelle totale) and was added to the List of World Heritage in 1996 and inscribed on the List of World Heritage in Danger in 1997 because armed conflicts, poaching and illegal mining threatened the park (WHC UNESCO). The total area of almost 14,000 km² is covered by four main forest types: swamp forest, mixed forest with a crown height of 30-40m and a heterogeneous canopy with frequent emergent trees, Mbasu forest dominated by Gilbertiodendron dewevrei and secondary forest generally occurring in areas that have been deforested (Hart, T., WCMC, 1985). The altitude varies between 500m en 1200m. As the name already revealed, the Okapi Wildlife Reserve is the sanctuary for the okapi (Okapia johnstoni) (fig. 3), but houses also big mammals like elephants (Loxodonta africana cyclotis) and chimpanzees (Pan troglodytes schweinurthii), and more than three hundred bird species (Sidle and Lawson, 1986). The Ituri Forest also has one of the highest numbers of duiker species in Africa.

Garamba National Park has been instituted on March 17th 1938 under the legal statute of ‘National Park’ and was inscribed on the list of World Heritage is 1980. The inscription on the List of World Heritage in Danger took place in 1996 following the killing of three park rangers and the poaching of two white rhinoceroses (WHC UNESCO). On a surface of about 5,000 km², the park presents a vast undulating plateau broken up by inselbergs (granite formations) and large swamp depressions (WCMC). It has an abundant hydrographic network with the Aka, Dungu and Garamba as main rivers. The height varies from 710m to 1060m above sea level. The area of savannah, grassland and woodland, intermingled with gallery forests protects four large mammals: elephants, giraffes, hippopotamuses and white rhinoceroses, of which at time of writing only eight individuals remain (Davis et al., 1994 and Debonnet, G. pers. comm, 2005).

Virunga National Park was founded in 1925 by the Belgian Colonists. The park was primarily set up for scientific research, which is very exceptional in Africa. In addition to scientific research, the aim was also to protect the mountain gorilla and the hippopotamus. Because of its outstanding conservation value, the park became a World Heritage Site in 1979. Fifteen years later, the World Heritage Committee decided to add the site to the List of World Heritage Sites in Danger. This decision was taken because of several threats to the park including poaching, unsustainable harvesting and settlement from Rwandan refugees in and around the park (Verbeken, J. et al, 2004). With its area of around 8,000 km² and mountains up to 5,100 m in the Rwenzi range, the park comprises an exceptional diversity of habitats counting bamboo and equatorial forest, swamps, steppes, snowfields, lava plains and wooded savannahs. Many wild animals occur in the park: elephants, hippopotamuses, buffalos, numerous antelopes, lions, chimpanzees, many birds and of course the mountain gorilla Gorilla gorilla beringei, of which in 2005 only about 670 remain (Gray, M., pers. comm. 2005).

Kahuzi-Biega National Park is declared a national park on November 30th 1970 and inscribed on the World Heritage List in 1980. Serious apprehension that parts of the park had been deforested and that many poaching activities had been reported, as well as war and public conflicts destroying the park, allowed the World Heritage Committee to inscribe the site on the List of World Heritage in Danger in 1997 (WHC UNESCO). The park has a total area of 6,000 km² with altitudes reaching from 600 m to 3,300 m (Mount Kahuzi). Seven different vegetation types can be distinguished: equatorial rain forest, mountain rain forest, high-altitude rain forest, swamp forest, bamboo forest, sub-alpine heather and swamp and peat bog (Steinhauer-Burkart et al., 1995). Mammals living in the park include the eastern lowland gorilla Gorilla gorilla graueri (fig. 2), chimpanzees, elephants, many antelopes and duikers (Wilson and Catsis, 1990).

Fig. 2: The eastern lowland gorilla (Gorilla gorilla graueri)  
Fig. 3: The okapi (Okapia johnstoni)
Salonga National Park has been created on November 30th 1970 and was inscribed on the List of World Heritage in 1984. Because of collapse in civil order and severe poaching the site was added to the list of World Heritage in Danger in 1999 (WHC UNESCO). The park consists of two sectors of approximately equal size separated by about 45 km with a total area of 36 000 km². It is the largest tropical rainforest reserve in the world. The main vegetation type is equatorial forest with as main forest types swamps, riverine and dry-land forest. Grassland vegetation occurs in the northern sector and comprises not more than 0.5% of the total park area. Salonga National Park is the habitat of many native endangered species like the dwarf chimpanzee, the Zaire peacock and the African slender-snouted crocodile and also for the hippopotamus, leopard, duiker, okapi, buffalo and water civet (WCMC).

2.2. Existing Data

The first step of this project was to gather, analyze, assess and standardize all existing data. Primary this concerned collecting all the existing maps of the sites and assessing their quality. Territorial maps (Carte Territoire) and topographical maps per square degree (Degré Carré) were found for all the parks, but with differing accuracy and precision and all not up-to-date (see also 1. The Cartography in the Democratic Republic of Congo). Old mission reports dating mostly from the colonial period could be recuperated for some sites. For example for Virunga National Park three detailed works were used: “Overview of the Vegetation” (W. Robyns, 1937) gives general info about the physical environment and vegetation in Virunga National Park. “The Vegetation of Nyiragongo” ( J. Lebrun, 1942) gives a very detailed description of the vegetation on this volcano and “Research program about vegetation in Birunga and Kahuzi-Biega” (C. Marius,1976) resulted in two vegetation maps based on aerial photographs. Thirdly field data gathered by field and patrol missions of ICCN park guards and by NGOs were resembled. A major problem to assess these data was the lack of metadata. For lots of data, information on how, when and by whom the data was gathered is missing. Sometimes, the explanation on the georeferencing is incomplete: the projection is mentioned but the ellipsoid and/or datum is missing or is incorrect due to lack of knowledge. This makes it sometimes extremely difficult to evaluate the quality of the data. Finally, as a last but very important stage, the remote sensing data had to be collected. This includes aerial survey imagery and satellite imagery. The satellite imagery is recent and sub-recent, dating from 1980’s till now, but the aerial surveys date from about 50 years ago. The remote sensing data is, in particular for these areas, very essential because many sites or parts of the sites are always or temporary inaccessible to perform field missions. This is due to physical features, but most of the time due to unstable political situations and rebels and armed militias controlling the area.

2.3. The Geographical Information System

As a basis for all further GIS layers, georeferenced and orthorectified LANDSAT images were used. All the LANDSAT images used were downloaded from the website of Global Land Cover Facility where georeferenced satellite imagery is provided by the University of Maryland free of any charge (http://glcf.umiacs.umd.edu/index.shtml). The images georeferenced by the University of Maryland have proven to be accurate by comparing it with GPS measurements. These images were used to digitize the roads and hydrographical network. All the existing cartographic documents and mission reports were permanently used to compare with the images and to retrieve toponyms. Where possible, field work was carried out to complete features that could not be derived from satellite imagery e.g. river sources. Villages and towns were derived from existing cartographic documents in combination with waypoints coming from field work. Park limits are created by interpretation of the legal texts. Control posts and other park infrastructures are obtained merely from GPS measurements received from people on the field; the same goes for tourist infrastructure.

The same layers are used for all sites (table 1). Every layer comprises several attributes, for example for rivers, when data is available, attributes containing information about the navigability are attached (navigable yes/no, permanent/seasonable). For roads, whenever the information is available, the practicability, period of inaccessibility, inaccessible for vehicles/motorcycles/pedestrians, type of road (main road/secondary road/…) and condition of the road is mentioned. At this moment the GIS contains fourteen layers (table 1).
Table 1: SYGIAP layers

<table>
<thead>
<tr>
<th>Parc</th>
<th>Layer type</th>
<th>French file name</th>
<th>English file name</th>
</tr>
</thead>
<tbody>
<tr>
<td>png (Garamba)</td>
<td>rivers</td>
<td>png_riv</td>
<td>png_riv</td>
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<tr>
<td>pns (Salonga)</td>
<td>lake</td>
<td>png_lac</td>
<td>png_lake</td>
</tr>
<tr>
<td>pnv1 (Virunga)</td>
<td>road</td>
<td>png_route</td>
<td>png_road</td>
</tr>
<tr>
<td>pnkb (Kahuzi-Biega)</td>
<td>trail, path</td>
<td>png_sent</td>
<td>png_trail</td>
</tr>
<tr>
<td>rfo (Okapis)</td>
<td>railway</td>
<td>png_train</td>
<td>png_train</td>
</tr>
<tr>
<td>rdc (Congo)</td>
<td>administrative limits</td>
<td>png_adm</td>
<td>png_adm</td>
</tr>
<tr>
<td></td>
<td>park limits</td>
<td>png_lim</td>
<td>png_lim</td>
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<tr>
<td></td>
<td>buffer zone</td>
<td>png_tamp</td>
<td>png_buffer</td>
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<tr>
<td></td>
<td>villages and towns settlements</td>
<td>png_vil</td>
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<td></td>
<td>park infrastructure</td>
<td>png_infra</td>
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<td></td>
<td>park infrastructure of ICCN</td>
<td>png_iccn</td>
<td>png_iccn</td>
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<td></td>
<td>tourist infrastructure</td>
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<td>vegetation</td>
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</table>

During the build up of the GIS, many difficulties were encountered. First of all, a multiplicity of existing datasets for the same theme frequently occurred, many of them without metadata. It was a complicated task to eliminate the less accurate dataset(s), and even sometimes not possible at all. When no clear indication could be found that the quality of a dataset was acceptable for the desired end product, the dataset was not used.

A second problem was the difference in scale of digitizing between different WHS and even between zones of a single site, according to the available source products that could be used. The roads and rivers had to be digitized manually, which was a labour-intensive work. Only for a few big contrasting rivers automatic delineation could be made.

Of primordial importance was the fixing of the park limits in the GIS and on paper. The establishment on paper of the park limits is essential for efficient management and monitoring activities. When the borders are fixed on paper, the park managers and the authorities have a reference document they can use to grant mine concessions, to allow settlements or to delimit agricultural zones. The borders in the GIS and on the maps are created by interpreting the legal text. Some crucial points, for example a specific river source, were not visible on a satellite image, nor could be acquired through GPS field missions. So the location of these points is not accurate.

Last but not least, all old and new toponyms, as well as all the digitized roads, rivers, borders etc, have to be checked and crosschecked by people who are familiar with the terrain. Even after a thorough validation, errors will occur on the map.

Though, beside those deficiencies, the resulting document can be considered as the best available cartographic document at this moment of these WHS. The maps are produced on a scale of 1 : 200 000 and the GIS is accurate up to a scale of 1 : 100 000 to 1 : 50 000.

2.4. The Map: Example of Okapi Wildlife Reserve

The cartographic product, which is a visualisation of the underlying GIS, is produced in Mercator (Star) on a scale of 1 : 200 000. The Universal Transverse Mercator (UTM) Projection with the World Geodetic System of 1984 (WGS84) was chosen as the reference system because of its compatibility with GPS and its worldwide use. A consortium of specialists has proposed this new geographical reference system for DRC. The proposal and description can be downloaded from the SYGIAP website. Besides the UTM grid, a grid with geographical coordinates appears on the map.

The legend has eleven subcategories: planimetric legend, north arrow, sources of information, elevation model, scale, reference system, satellite interpretation and location map, a brief description of the site and the project and the logos of all collaborators.

The planimetric legend contains six categories: ways (main road, track,…), limits (park or reserve boundary, territory limit,…), hydrography (main river, secondary river,…), places (town, village,…), lettering (territory, town,…) and
La légende planimétrique est composée de diverses caractéristiques (aire de décollage avec orientation de la piste, camp,...). Le nord de l’écriture représente le vrai nord, nord cartographique (égal UTM nord) et nord magnétique. Under the north arrow, the sources of information are mentioned: satellite imagery, existing maps and field data. Extra information on the altitude of the site is given by the elevation model derived from Shuttle Radar Topography Mission (SRTM). The scale is symbolized in three ways: a bar scale, a numerical scale and a scale in words (1 cm = 2 km). For the Okapi Wildlife Reserve, five classes of land cover types are shown. The LANDSAT image is visualized in band 4, 5 and 7 (bands 1, 2 and 3 contain lots of haze). The location map shows the five sites in detail and the DRC in its entirety in an auxiliary map. Finally, the legend contains also a brief description of the relating park or reserve and some information about the SYGIAP project. The bottom right corner of the map is filled with the logos of the two Belgian universities that developed the GIS and designed the map, namely Ghent University and the University of Louvain la Neuve, and of all the collaborators dependent from site to site.

Les voies (routier avec direction et destination, tracé avec direction et destination).

La localisation des lieux (ville, village, petit village).

Les objets divers (terrain d’aviation avec orientation de la piste, affiché avec orientation de la piste, poste de patrouille, camp, carrière, terrain de pêche, territoire, clôture en forêt, etc.).

Les limites (limit de parc ou réserve, limite d’État, limite de province, limite de territoire).

Les hydrographies (cours d’eau: principales, représentées par les rives, représentées par une ligne continue, représentées par un trait unique, représentées par une ligne simple, petite rivière, small river).

Sources d’information (imagery satellite, imagery local, imagery local, LandSat 7 ETM+, Landsat 7 TM, LandSat 8 ETM+, LandSat 8 TM, Cartes 1: 200 000, 1: 20 000, 1: 5000, etc.).

**Sources of Information**

*ImageSatellite:

- Landsat 7 ETM+: p174-55, 02 mars 2000
- Landsat 7 ETM+: p174-55, 05 mai 2000
- Landsat 7 ETM+: p174-55, 07 février 2003
- Landsat 7 TM: p174-55, 02 juin 1984
- Landsat 7 ETM+: p174-55, 05 mai 2000
- Landsat 7 ETM+: p174-55, 06 mars 2002
- Landsat 7 ETM+: p174-55, 07 février 2003
- Landsat 7 TM: p174-55, 02 juin 1984

Maps 1: 200 000:

- N107: 1973
- N108: Ambaba s.d.
- N109: Mambasa a.s.
- N128: Muhumbwe 1968
- N129: Gamba 1968
- Carte de Terreiro de Mambarra 1959

**Fig. 4:** Planimetric legend, north arrow and sources of information of the base map of the Okapi Wildlife Reserve

A LANDSAT mosaic is used as a background for the map to assist in the orientation and to give an idea of the land cover. The image is plotted in such a way that the user is able to place his remarks on the base map. If possible or if desired, these comments, observations or notes can be used to update/complete the GIS and can be used for future editions of the map (fig. 5).
3. CONCLUSION

Even if GIS and the information behind it is of essential importance for direct use of the data and uncomplicated and simple updating of the information, in many cases remains the paper map an essential working document. Definitely in circumstances like in Congo where extreme weather conditions, extensive and time-consuming field work,... may cause problems on the field to work with laptops. Also for the communication with the local population to edit and complete the data, the paper map stays important.

REFERENCES


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NOTE TO THE AUTHORS’ AFFILIATION

Leen De Temmerman and Liesbeth Vansteenvoort both worked on the SYGIAP project. At this moment, Leen De Temmerman is a research assistant of the Special Research Funds (Bijzonder Onderzoeksfonds – BOF) and Liesbeth Vansteenvoort is a research assistant of the Research Foundation Flanders, both associated to the Geography Department of the Ghent University in Belgium.
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Liesbeth Vansteenvoort is a research assistant of the Research Foundation Flanders and associated to the Geography Department of the Ghent University in Belgium since 2000. Recently she is working on concepts of quality assessment of thematic maps. Her former research concerned base mapping of inaccessible regions in Eastern D.R.Congo using satellite imagery.

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