

# CARTOGRAPHY AND LAND USE CHANGE OF WORLD HERITAGE AREAS AND THE BENEFITS OF REMOTE SENSING AND GIS FOR CONSERVATION.

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Copy in color available at the website Ghent University (<http://geoweb.rug.ac.be/services/carto>)

## ABSTRACT/RESUME

Remote sensing has been widely used within various fields, with environmental applications being the most widespread. Through the joint effort of UNESCO, OSTC Belgium, Geography Dept, Ghent University and Labo SURFACES of Geomatic Dept, Liege University, a demo project to conserve five world Heritage sites was launched. The remote sensing and Geographic Information Systems (GIS) project attempted to provide basic cartography of the world heritage sites and also detect land use changes in and around the sites in the past ten years. A final contribution towards the conservation and monitoring of the world Heritage sites was made through this project. To fulfil the objectives of this project an internet site was created to provide information to a wider public audience. This raises awareness of not only the location and status of the selected Heritage sites, but also contributes to an improved information base leading to the sustainable management of these sites.

## 1 INTRODUCTION

The 30th anniversary of UNESCO coincides with the 30th anniversary of remote sensing – it has been exactly 30 years since the first satellite for earth observation purposes was launched. Rapid progress has been made in the development of research techniques and the application of remotely sensed data combined with GIS. The field of Cartography is one area that has greatly benefited with the rapid development of remote sensing, with major cuts in map production time and cost inputs of the past era. Remote sensing and GIS have led to recent advances in the production of space maps, which represent the current scenario on the ground and can even be used in emergency situations. Within the field of conservation, remote sensing and GIS can contribute significantly towards establishing the biodiversity status of different habitats on a coarse scale, thus highlighting ecosystems needing higher conservation priority. With this in mind, World Heritage sites have been identified by their respective countries as areas requiring greater conservation efforts, with some needing total preservation. Remote sensing and GIS techniques can therefore be applied to accomplish these goals leading

to the sustainable management of these sites through the provision of up-to-date terrain data.

According to the rules of the World Heritage Convention, each country shall provide, when proposing a site for nomination, precise information indicating the boundary of the site as well as the boundary of the 'buffer zone' surrounding the site. The Convention also requests that both of these areas (site-boundary and site-buffer-zone) should be protected by an appropriate legislation. Unfortunately, most developing countries do not have accurate maps available, thus site-boundary information is either missing or is of very poor quality. To provide efficient monitoring and protection of World Heritage sites, it is necessary to be able to detect changes in land cover and land use in and around the park, for example deforestation, desertification and other unsustainable practices. When negative impacts are realized, actions can be taken to protect the site.

UNESCO and OSTC (Federal Office for Scientific, Technical and Cultural Affairs) Belgium, jointly started a demo project 'Remote Sensing and GIS in Support of World Heritage Conservation'. For this demo project, funded by OSTC Belgium and in cooperation with the Geography Department of Ghent University and Labo SURFACES of Geomatic Department of Liège University, five World Heritage sites were selected and assessed.

### 1.1 Objectives of the Demo project

The objectives of this demo project are three-fold:

- To provide a basic cartography of each site and its buffer zone.
- To detect the land use changes in and around the site during the last 10 to 20 years.
- To determine the possible application of remote sensing and Geographic Information Systems (GIS) for monitoring and conservation of world Heritage sites.

## 2 SITE SELECTION

Two cultural and three natural world heritage sites were selected. These sites were selected based on the following criteria: diversity, representativeness and

availability of satellite and other data on the sites at OSTC.

The cultural world heritage sites are the historic center of Warsaw (Poland) and the Medina of Marrakesh (Morocco). The historic center of Warsaw was destroyed during World War II but is now an exceptional example of a total reconstruction of a span of history from the 13th to the 20th century. The lively medina of Marrakesh in Morocco contains an impressive number of architectural masterpieces, including the walls and the monumental gates, the Kutubiya Mosque with its 77-metre-high minaret, the Saadian tombs and characteristic old houses.

Virunga National Park (Democratic Republic of Congo), Ha long Bay (Vietnam) and Niokolo-Koba National Park (Senegal) were selected as natural world heritage sites. The natural sites represent different types of ecosystems. Virunga National Park is mainly composed of a tropical forest, swamps, steppes, snowfields, lava plains and savannas. Ha Long Bay includes some 1600 islands and islets forming a spectacular seascape of limestone pillars, while Niokolo-Koba National Park habitats are mainly composed of gallery forests and savannas.

### 2.1 Accomplishing the Objectives

In order to reach a big audience, the creation of a website was chosen as a means to meet the three main objectives. For each of the 5 World heritage sites, six items were detailed: Brief Description, Location and Cartography, Problems and Risks, Use of Remote Sensing and GIS, Change Detection and Links to other websites.

The 'Brief Description' section gives a brief explanation of the site. In 'Location and Cartography', a description of the location and other cartographic information of the site is given. A detailed map of the site can also be viewed. Some of the maps are interactive with the user simply selecting a preferred layer. The phenomenon that threatens the site of its natural or cultural value are described under 'Problems and Risks'. Under the section entitled 'Use of Remote Sensing and GIS' the applications of GIS and remote sensing for the better management and conservation of the site are illustrated. How remote sensing and GIS can also be useful in detecting changes on the site is illustrated in 'Change Detection'. Besides these 4 major sections, there is also a section entitled 'Links', where a list of interesting websites related to the subject can be found. Examples of the 5 sites can be found in the fifth section of the paper. On the web pages concerning the selected sites, specific examples of remote sensing and GIS use for the conservation and monitoring of World Heritage sites are given. More general information about the advantages of remote sensing, GIS and cartography is presented in 'Remote Sensing and GIS' and 'Cartography'.

## 3 METHODOLOGY

### 3.1 Creation of the Website

As already stated, creation of a website enables a wider audience to be reached. But how big an audience can

you reach? Technically speaking, access to the internet is possible in almost every country. The ways to get connected differ a lot. In developed countries you can have access by the normal phone network or by cable, which are relatively affordable, but in developing countries you sometimes have to use a very expensive satellite connection.

Nowadays, the worldwide internet population is estimated to be between 445.9 million (eMarketer) and 533 million (Computer Industry Almanac). Fig. 1. shows the number of internet users as a percentage of the total population for each country.

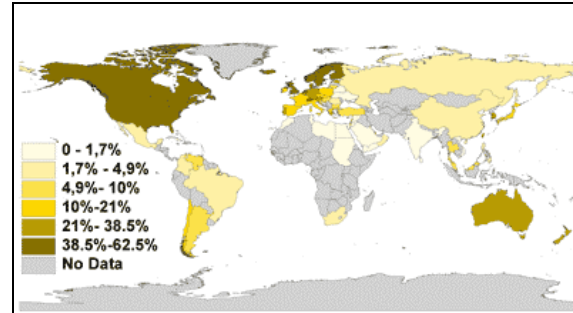


Fig. 1. The number of internet users as a percentage of the total population (source: CyberAtlas)

When creating a website for a broad audience, one has to keep a few things in mind. Not everyone has the same computer, browser, screen resolution or connection speed. To deal with different computer systems and browsers, a solution is provided through an online validation of your webpage by W3C (World Wide Web Consortium [www.w3c.org](http://www.w3c.org)). If your webpage is approved by this institute, it can possibly be viewed by any web browser (Internet Explorer, Netscape Navigator, Opera, etc) on any computer system (Windows, Unix, etc), although there can still be slight differences on how the site looks.

It is generally acceptable that one can scroll horizontally on a webpage, however vertical scrolling is not an option. To address this problem, images and tables that are not wider than the maximum screen resolution of a visitor (e.g. 640x480, 800x600, 1024x738...) have to be inserted. Adaptations of the image and table sizes can be made interactive by using script languages (JavaScript, ASP, etc)

The connection speed to the internet also varies a lot. If a webpage is over one megabyte in size, people with a slow connection (e.g. 28.800 bps) can wait over half an hour to view the webpage, while people with broadband connection can view the same page in less than a few seconds. To minimize the website size and make it more accessible, compressed image files can be used. For thematic maps and figures with few colors, the lossless GIF format is widely used. For illustration and pictures it is better to use the JPEG format. The resolution of the images should also not be bigger than 72dpi, because the computer screen does not show more than this capacity anyway.

The website project also uses mapserving technology. This has a few more advantages. All maps can become

interactive. One can zoom and pan on images. This is one way to overcome the restrictions of screen resolutions and still make sure that a visitor can see the full information given on a map. A dynamic webmap can give a lot more information than a static map by querying information on different map layers. Visitors can also assemble their own map by selecting, which information layers to see. In addition the mapserver enables that the images it produces are optimized for the web. The mapserver used for the project is MapSever. The MapServer was originally developed by the University of Minnesota (UMN) ForNet project in cooperation with NASA and the Minnesota Department of Natural Resources (MNDNR). The MNDNR and the Minnesota Land Management Information Center (LMIC) made additional enhancements. Current development is funded by the TerraSIP project, a NASA sponsored project between the UMN and consortium of land management interests.

#### 4 RESULTS AND DISCUSSION: EXAMPLES FROM THE WEBSITE

The results of the project are shown in the form of examples listed below. These are taken from the website and represent the five categories listed in section 3.1. Each subsection covers an example of one of the World Heritage sites. More information is included on the website.

##### 4.1 Location and Cartography

###### *Virunga National Park*

Virunga National Park is situated in the Democratic Republic of the Congo, 95 % is located in the region of Kivu, and 5% in the Orientale region. The park stretches from 0°55'N to 1°35'S and from 29°10' to 30°00'E and is situated along the border with Rwanda and Uganda.

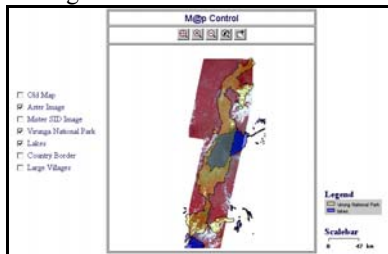


Fig. 2. Screen shot of a dynamic webmap

##### 4.2 Problems and risks

###### *Ha Long Bay*

The Halong – Hai Phong region is an important economic region in the North Vietnam. The demographic pressure leads the local authorities to build polders along the coast to enlarge the built-up areas. These zones are located on the mangrove. In the protection buffer zone, the coastal areas are very low depth, where it is easy to build a dyke and fill in with sand and dust (e.g. from coal mines). These polders are rudimentary because most of them have no drainage system nor purge system. The extensions of the built-up areas lead to a reduction of the biodiversity (suppression of the mangrove itself but also of reproduction sites of

marine animal species) and an increase of the risks of coastal erosion. At some locations, these polders start to include small limestone islands, which blacken due to the pollution. Comparison of topomaps and satellite images acquired at different times makes it easy to assess the increases in human settlement. Here is an example with a small bay at the East part of Ha Long City. This trend tends to be generalized all over of the coast (including the buffer zone). In the 1950's (topographic map, Fig. 3.), the bay was completely covered by the mangrove (in green and indicated by the red arrow on the topomap). The mangrove forest is a complex but very important ecosystem for men, offering food for men, fish breeding areas, construction materials, protection against coastal erosion and storms.



Fig. 3. Topomaps from the 1950's

In the mid 1960's (Corona space photograph taken in 1965, Fig. 4.), some polders were already built. On the satellite images, the blue line shows the coast border in 1965, while the yellow line shows the extensions built between 1965 and 2000.

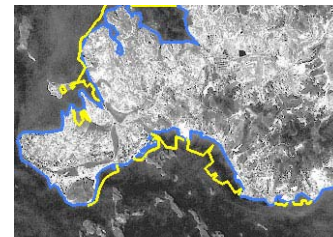


Fig. 4. Corona space photograph - 1965

In 2000 (SPOT XS satellite image, Fig. 5.), the entire bay was populated by polders or by shrimp farms. People prefer to invest in aquaculture allowing them to have high revenues within a short time frame, but underestimating the very negative impact that the disappearance of the natural mangrove ecosystem might have in the long term.



Fig. 5. SPOT XS image – 11/05/2000

Satellite images are a useful source of recent cartography (up to a scale of 1 / 20 000) and in quantifying the threat of built-up extensions in the buffer zone of the Ha Long Bay protected area. There is no recent cartography in Vietnam, the last complete survey was undertaken by the French cartographers in the 1950's.

#### 4.3 Use of Remote Sensing and GIS

##### *Virunga National Park*

The satellite image (Fig. 6.) shows three volcanoes in the southern part of the Virunga Massif. Notice the white spots, with a black border on the right side of the image. These are clouds, and the black is the cloud shadow. On this image, the abrupt change of dense vegetation (reddish brown) to sparse vegetation (blue) is clearly noticeable. This is an example of how by using remote sensing images, the boundary of the park can be detected and mapped. The green line indicates the Virunga National park boundary.

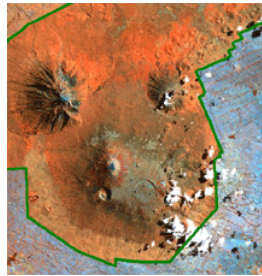


Fig. 6. Virunga National Park Boundary

The satellite image in Fig. 7 is taken by ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) in the Goma region. The image covers the Nyiragongo volcano, which is situated in Virunga National Park and is one of Africa's most active volcanoes. The town of Goma is at the bottom of the picture, visualised in blue. Blue symbolises habitation, green, vegetation and white are clouds (the black borders are the shadows of the clouds). The image is taken shortly after the eruption of the Nyiragongo volcano in January 2001. At the bottom of the image we can clearly see the stream of lava (symbolised by red), which goes straight through the city of Goma.

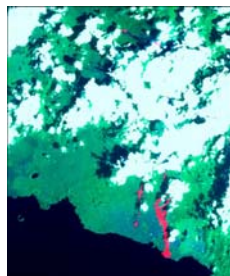


Fig. 7. Aster Image Nyiragongo volcano (source:Aster Website)

A 3D-model of the volcano can be made based on the ASTER image. These 3D models are easy to understand and interpret.

#### 4.4 Change Detection

##### *Historic Centre of Warsaw*

During the Second World War, the Historic Centre of Warsaw was completely destroyed by the German army. Aerial photographs taken in 1935 (Fig. 8), 1947 (Fig. 9) and 1990 (Fig. 10.) can be used to compare the different scenarios. In 1935, the Stare Miasto (old town) comprising the Market place with old houses (2 in Fig. 9.) and the Royal Castle (1 in Fig. 9.) are architectural heritage sites included in the ramparts of the city.



Fig. 8. Before the war (1935).

All these vestiges were destroyed in 1944 as it is clearly visible on the photograph taken in 1947. The Royal Castle, in the upper left has disappeared.



Fig. 9. After the war (1947).

Finally, on the photograph taken in 1990, the Stare Miasto is rebuilt to its original situation before the war.



Fig. 10. After reconstruction (1990).

## 5 CONCLUSION

This demo project presents a snapshot of the possible applications of remote sensing and GIS. The potential though is unlimited and sustainable management and monitoring of threatened environments and monuments can be accomplished through the combined efforts of the countries concerned working together with research organizations.