Reservoirs Inventory Mapping

Authors

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Scope: questions/ challenges the tool addresses

In most semi-arid areas of the developing world, the number, size, and location of small reservoirs is unknown. To coordinate further planning, knowledge of the existing dam inventory is imperative. Programs for reservoir rehabilitation and management depend on a knowledge of reservoir locations. This tool outlines the steps to obtain a regional reservoir inventory through remote sensing.

With optical imagery, an objective overview can be obtained of all small reservoirs in a country. Typically, such imagery is most complete when there is no cloud cover. This usually occurs in the dry season, however, when some small reservoirs are no longer full. There can be a trade-off between completeness of the imagery, and its ability to distinguish reservoirs. Once reservoir locations are identified, and their surface areas measured, storage volumes can be estimated on the basis of regional bathymetric surveys (described in a separate SRP tool).

Tool users will be able to produce country- or regional-scale reservoir inventories useful for water managers and planners. A typical user will be interested in the regional/provincial, national, or sub-continental scales.

Target group of the tool

Water resources planners, hydrologists, and technical cooperation/ development assistance agencies.

This tool is intended for use by technically schooled persons with an introductory knowledge of remote sensing. Access to remote sensing software, reasonably fast computers, and ample digital storage space are also prerequisites. On-line introductory remote sensing tutorials include:
http://ccrs.nrcan.gc.ca/resource/tutor/fundam/index_e.php
http://rst.gsfc.nasa.gov/Front/overview.html

No specialist knowledge is required beyond introductory remote sensing, but patience and perseverance is useful, especially during the interpretation of radar images. Enough information is provided below to allow technically interested persons to follow the general procedures.

Requirements for tool application

Satellite images (i.e. Landsat, ASTER, NigerSat, SPOT, Ikonos, QuickBird, etc.)
Remote sensing software (i.e. IDRISI, ILWIS (open source, free), ENVI, ERDAS, etc.)

Tool: description and application

Classification with optical satellites

In principle, any high resolution imaging satellite can be used to monitor the surface area of small reservoirs: open water can readily be identified in optical images. When reservoir surface area is known, stored volume can be estimated. Images are most useful when their resolution 30m or better. Examples of suitable optical satellites and/or sensors are Landsat, ASTER, NigerSat, SPOT, Ikonos, and QuickBird. Satellite images are built up from three to seven different bands, each band corresponding to a narrow band of wavelengths, which can be thought of as colors. Typical bands are blue (~500 nm), green (~580 nm), red (~660 nm), near-infrared (~850 nm), middle infrared (~1600 nm), and thermal infrared (~11 μm). Each band consists of a two-dimensional array for each entry, or pixel, a digital number of one or two bytes. Each pixel value maps the intensity of the reflection from the earth's surface to the satellite into a dynamic range of 0-255 or 0-65535. By assigning the visible colors red, green, and blue to three bands, one obtains a (false) color composite, as shown in Figure 1. Open water tends to be dark in all bands and, as such, can readily be distinguished from surrounding land areas.

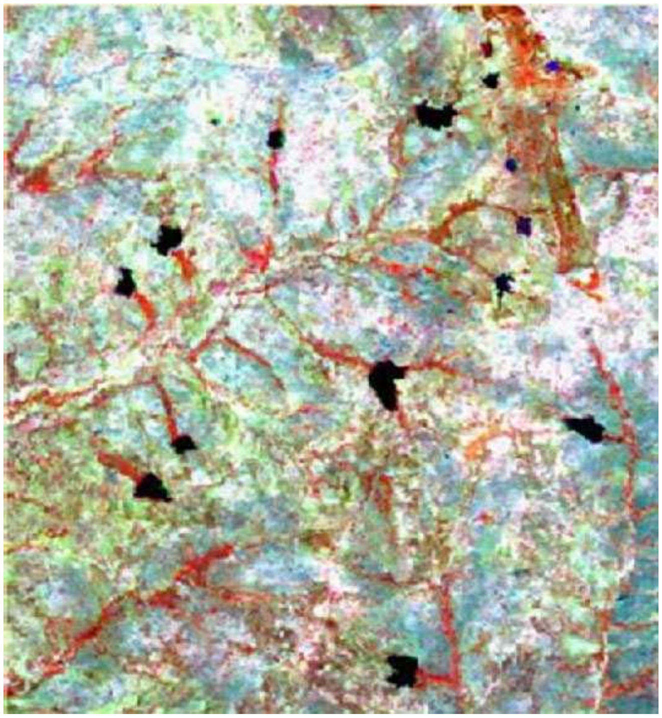


Figure 1: False color composite of Landsat bands 3, 4 and 5. Reservoirs and drainage patterns are clearly recognizable (the dark spots are the reservoirs)

Several methods are used to classify an image into land cover classes. Among the most important is a maximum likelihood classifier, which is a standard method available in remote sensing/GIS software packages such as ArcGIS, Idrisi, ILWIS, ENVI, or ERDAS Imagine. First, a (large) number of test sets is selected consisting of areas with known land cover class. The maximum-likelihood classifier then fits a multi-variate Gaussian distribution through each test set, with each band corresponding to one dimension. For each pixel, the likelihood is calculated that it belongs to any of the chosen classes. The class with the highest likelihood is assigned to each pixel.

In reality, different open water bodies tend to have different spectral characteristics due to the presence or absence of algae and sediments. When open water test sets are lumped together into one class, the resulting Gaussian is the sum of different smaller Gaussians of varying shapes. For correct classification, it is advisable to use several types of reservoirs, each one corresponding to water with different concentrations of sediment and algae. Using many non-water classes also improves the classification result. Cloud shadows and burn scars are particularly close to water in terms of spectroscopy, and should have their own test sets. Chapter 3.2.4 of Liebe 2002 describes the procedure in detail, and provides further background information.

The classification result can be filtered, for example, 5x5 median filter to eliminate single and unconnected pixels. It also eliminates pixels classified as water that are part of the river system. Remnants of river systems may have to be manually removed to obtain a map consisting only of reservoirs.

Lessons leaned

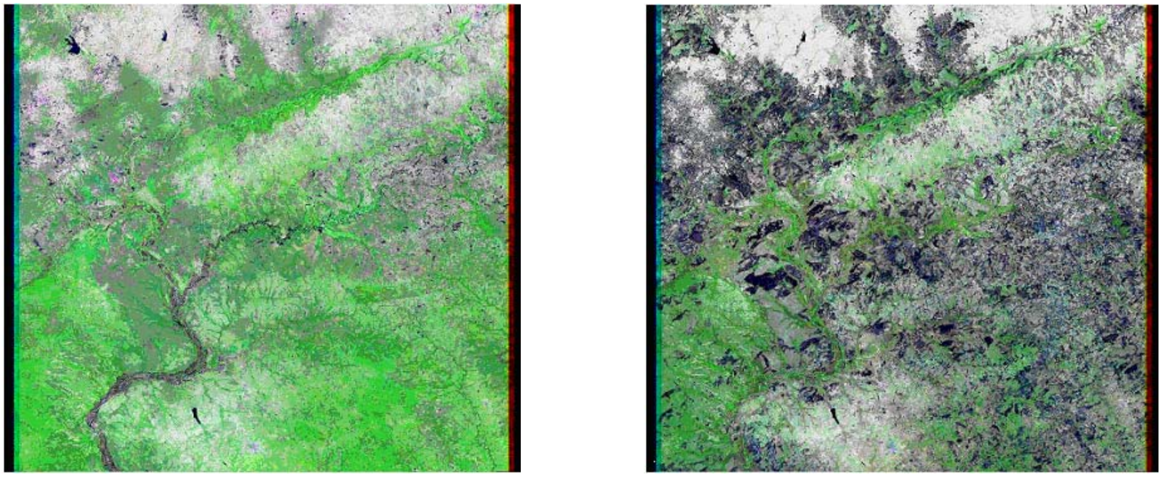
Mapping small inland water bodies is possible with optical satellite images, provided that cloud free images are available. Small reservoirs can have spectral overlap with cloud shadows and burnt areas, but the classification can be improved by using a larger number of training sets, some for the various hues observable in the water bodies, and some for cloud shadows, and burnt areas, if present. The most complete overview is often obtained through images taken at the end of/just after the rainy season.

Recommendations

Reservoir inventories are best done after the rainy season, when the reservoirs are filled to their maximum extent, and cloud coverage decreases. If satellite image acquisitions have to be scheduled, it is advisable to evaluate cloud cover data to avoid acquisition attempts in typically cloudy months (i.e. based on historical data from the CRU TS 2.1 data set).

Limitations of the tool

Cloud coverage poses a major constraint to the method, as the acquisition of optical satellite imagery depends on clear skies. With a limited number of clouds the method is still applicable, but cloud shadows might have a spectral overlap with the spectral signature from water bodies. Water bodies also have a spectral overlap with burnt areas. In case of excessive burning of the landscape, reservoir classification can become challenging (see Figure 2).



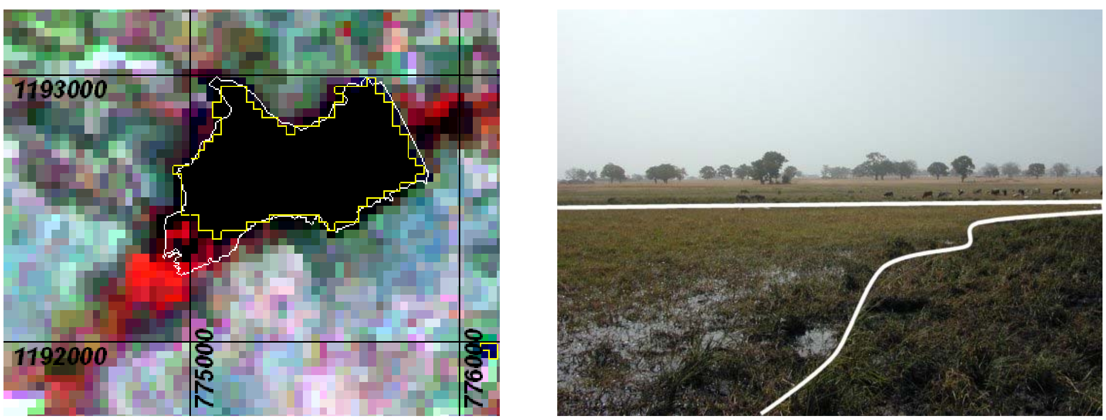
a. b.

Figure 2: The effect of fire scars on reservoir classification from optical satellite images.

a. Scene 194-053 on the 7 November 1999. The dark spots in the images are small reservoirs

b. Scene 194-053 on the 9 December 1999 with major fire scars. Reservoirs and fire scars are hard to differentiate (Source: USGS Global Visualisation Viewer)

In some cases, the presence of dense vegetation in the tail part of a reservoir can affect the measurement of its surface area (see figure 3). This does not pose a major limitation when the major interest is only in the location of reservoirs, and a rough estimate of their surface area.



a. b.

Figure 3: Herbaceous water plants in the tail part of a reservoir a.) on satellite image, b.) ground situation

The satellite image (Figure 3a) shows a large area of lush vegetation in the tail part of the reservoir. The yellow outline represents the classification result, while the white outline delimits the extent recorded during a field trip. Figure 3b shows a part of this reservoir's tail, which resembles the red shaded part on the satellite image that is within the white outline, but outside the yellow polygon. The white line in Figure 3b separates the herbaceous water plants (bottom left section), which floats on the water, from vegetated solid ground. (Satellite image referenced in UTM coordinates, Photo taken 22.01.2002)

References

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Contacts and Links

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CRU TS 2.1 data-set (http://cru.csi.cgiar.org/)

ENVI (www.ittvis.com/envi/)

ERDAS (http://gi.leica-geosystems.com/LGISub1x33x0.aspx)

IDRISI (www.idrisi.com)

ILWIS 3.4 Open. Integrated Land and Water Information System. Open Source Software (http://52north.org/index.php?option=com_projects&task=showProject&id=30&Itemid=127)