Notes on a spatial assessment of the risk of flooding in eastern Caprivi

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INTRODUCTION

RAISON was commissioned by WWF (Namibia) to produce a mapped assessment of the vulnerability of eastern Caprivi to flooding with the objective that such an assessment will improve planning. For example, much of flood damage could have been avoided and need for emergency relief measures improved if information on the risk of flooding had been available to plan the location of infrastructure and settlements. This information is particularly important as predictions are that climate change will affect flooding in this region.

Additionally, such information is needed to guide the planning of roads, clean water, sanitation, other infrastructure and emergency response actions in the region. For conservancies and their associated National Parks information on the risk and extent of flooding is particularly important as a climate mitigation measure as it will help conservancies play where to locate camp sites and lodges, and to generally improve their land use and zonation planning.

To obtain this assessment, a series of satellite images were processed to identify the presence or absence of surface water as a measure of flooding. Areas in which water was found most often in different years were classified as being more frequently flooded, and therefore vulnerable, than others. The spatial extent of flooded areas was further assessed and adjusted where necessary and possible by overlaying the flood classes on high-resolution (1 metre/pixel) aerial photographs which provided information on vegetation structure, which is a reliable indicator of flooding.

While the work done for this project was largely a desktop exercise, it followed extensive fieldwork experience in the region, which had include detailed mapping of vegetation types and an earlier assessment of the extent and risk of flooding, as reported in *An atlas and environmental profile of Caprivi*, published in 1997.

DATA PROCESSING

Three sources of Landsat imagery data were explored to acquire data: the Global Land Cover Facility (GLCF) of the University of Maryland glcfapp.glcf.umd.edu:8080/esdi/); the Global Visualisation Viewer (Glovis) (glovis.usgs.gov/) and Earth Explorer (earthexplorer.usgs.gov/) of the USGS.

Two LandSat scenes were used: 174-072 and 174-073, the first three digits being the path and the last three the row numbers. The months and years selected for this assessment depended largely on when suitable satellite images were available, which was determined by whether or not images could be found that were sufficiently clear of cloud cover.

Landsat images taken in the years 2000, 2001, 2002, 2003, 2008, 2009, 2010 and 2011 were found to be suitable, then downloaded from the above web servers and processed to identify areas with no water, shallow water or deep water. All the images were taken in the month of April, except for one taken in March 2001 and one in May 2009 and 2010, respectively. A total of 20 Landsat scenes, two for each year-month combination were therefore analysed. Landsat 7 images were used in 2000, 2001, 2002 and 2003 and Landsat 5 images for later years because of the lost data caused by 'striping' in recent Landsat 7 images.

Each scene was clipped to a buffer area extending 5 kilometres from the Namibian border around eastern Caprivi, except for floodplain areas immediately adjoining in Zambia and Botswana, which were included. ENVI image processing software was used to import three bands – 1, 4 and 7 – from each original image. All images were analyzed in their original co-ordinates: UTM zone 35 south, datum WGS84.

The three bands were stacked using the *layer stacking* tool in ENVI, stretched to remove the effect of the atmosphere on the bands and used to classify areas of inundation with the 'Maximum Likelihood (ML) with no threshold' method. The classification was based on 'training areas or Regions of Interest (ROIs)', which were areas visually identified in the images as having no water, shallow or deep water. The training ROI areas were established as polygons separately for each scene. This was necessary because the images had different angles of reflectance and were taken at different times.

The Maximum Likelihood classifications produced new images consisting of the three classes of inundation. These were exported as tif images, and then further processed and merged as grids using ArcView's Spatial Analysis extension. The two scenes for each month-year combination were therefore merged and reclassified with grid cell values of 0: water, 1: shallow water, and 2: deep water.

The resulting 10 grid files were then added up, each image being a layer so that the values – 0, 1 or 2 – could be summed for each pixel. For example, a pixel in the same place having deep water (value 2) in each of the 10 images yielded a resulting score of 20. By contrast, a pixel in the same place having shallow water (value 1) in 6 years and no water (value 0) in the other 4 images would have added to a inundation score of 6.

These summed scores for the western Kwando River area and Linyanti Swamps were inflated 1.5 times to give better comparisons with scores for the eastern floodplains associated with the Zambezi and Chobe Rivers. This was necessary because flooding generally occurs later (May-July) in the eastern Kwando-Linyanti area compared to flooding which is normally in March-April in the Zambezi-Chobe floodplains. The adjustment to inflate the scores 1.5 times would not have been necessary if enough images for the Kwando-Linyanti area had been available, which they were not.

The resulting scores for each pixel (30 by 30 metres in area) provided a measure of flood frequency. However, the 'Maximum Likelihood (ML) with no threshold' processing method resulted in certain areas being incorrectly classified as water, especially clouds and their shadows and small clusters of dense tree cover. Most of these incorrectly classified areas were manually removed from the penultimate set of flood scores by deleting the data in areas known not to be flooded. In addition, the flood scores were overlaid on high-resolution aerial photographs to identify places with dense tree cover.

DATA PRODUCTS AND THEIR APPLICATION

We believe that the maps and sets of data provide a realistic approximation of flooding in eastern Caprivi, especially at a broad scale. However, the data need to be used with caution and with appropriate interpretation, for the following reasons.

- At a fine, local scale some areas with high flooding scores (for example 15 and above, as a result of dense trees or cloud), have not been fully corrected or adjusted to lower scores. Most of these are patches of dense tree cover, particularly on islands in the Kwando-Linyanti area.

- In addition, the classifications produced average scores over boundaries between one class or flood area and another. Thus, the flood score over the border between permanent marsh and adjoining grassland is lower than over the marsh.

- Flooding occurs at different times and in different ways from month to month, year to year and in dry and 'wet' phases. For example, flood waters reach areas just south of the Zambezi River earlier than the southern areas close to the Chobe River and in the Chobe Swamps and Lake Liambezi. This lake was dry between 1985 and 2004 since when it has been flooded over a large area. The difference in pattern and extent of inundation before and after 2004 is clear in Figure 1.

It should be noted that any remote-sensing assessment of flooding in Caprivi depends on the availability of images at appropriate scales. And, as experience has shown, it is not easy to obtain a large number of images taken at different times which adequately capture the full extent of changing flood patterns. Images taken over several decades would probably be needed to achieve an overall and accurate assessment of flooding.

Vegetation, especially tree cover does, however, provide a long-term measure of flooding because the presence or absence of trees, and their density and size, reflects the suitability of any area for tree growth. Places with lots of tall trees have never been flooded for any length of time over the decades that the trees have been present. Conversely, areas lacking in trees are likely to have been flooded often and for substantial periods in recent decades. Trees therefore also provide a measure of flooding vulnerability.

As a result, it is strongly recommended that the use of these data at a local scale be combined with detailed study of vegetation structure, and mapping if necessary, using field observations and high resolution aerial photographs. Images taken in 2007 are available for the whole of eastern Caprivi, while others covering much of this area were taken in 2011. Likewise, the high resolution satellite images available in Google Earth (and can be downloaded using TerraIncognita) provide extremely good perspectives on vegetation cover.

DATA SETS

The files generated for project are listed below. All vector files are in Geographic co-ordinates (latitude-longitude) while all raster grids and images are in UTM Zone 35 South co-ordinates (i.e. Transverse Mercator, latitude of origin: 0, centra meridian 27

East, scale factor: 0.9996, false easting: 500,000, false northing: 10,000,000, units 1 metre). Projection files (.prj) for the data sets are included with the files.

Grid_files folder
Zipped file of the all grid data: all_years_grid.zip

Grid files for each month-year: 0: no water, 1: shallow water, 2: deep water
apr_2000
apr_2002
apr_2003
apr_2008
apr_2009
apr_2010
apr_2011
apr_mar_2001
may_2009
may_2010

Grid file of pixel values added for east *for each month-year*
0: no water, 20 permanent water
flood_east

Grid file of pixel values added for west *for each month-year*
0: no water, 20 permanent water
flood_west

Grid file of pixel values added for east and west for each month-year
0: no water, 20 permanent water
flood_calc

Grid file of pixel values added for east and west for each month-year and with application of majority filters, 0: no water, 10 permanent water
flood_10

Grid file of pixel values added for east and west for each month-year and with application of majority filters, 0: no water, 10 permanent water
flood_20
Info folder for all grid files
info

Vector files folder
Risk of flooding categorized into 10 classes, 0 is lowest, 10 is highest, based on the grid data: flood_10
flood risk 10 classes.dbf
flood risk 10 classes.shp
flood risk 10 classes.shx

Risk of flooding categorized into 20 classes, 0 is lowest, 20 is highest, based on the grid data: flood_20

flood risk 20 classes.dbf
flood risk 20 classes.shp
flood risk 20 classes.shx

Odd context data

Data on roads, conservancy boundaries, towns and households used in the preparation of maps in the folder ‘prepared maps’.

Tif versions folder

Tif image versions of all the grid files

Original Landsats

Zipped files of all the Landsat 7 and 7 images downloaded for this project.

Processed products of Landsats

RGB versions of the Landsats used to classify water, regions of interest (ROIs) used for classification and the masked areas used for analysis.

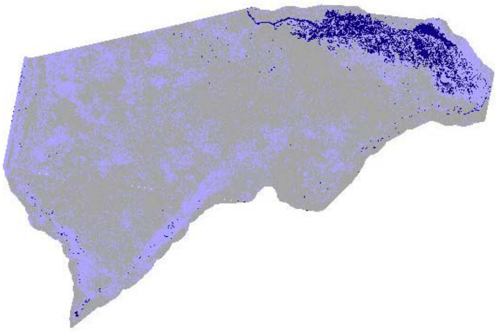
Prepared maps

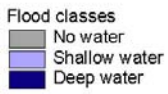
Pdf and kmz (Google Earth) files of flood risk of the whole of eastern Caprivi and flood risk maps for 12 conservancies in eastern Caprivi (Sobbe conservancy was excluded because it is far from flood areas).

Reference literature

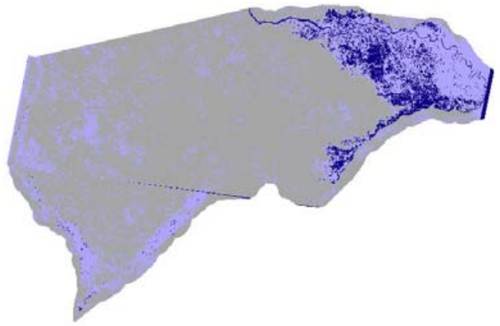
Copy of Alex Mudabeti’s thesis entitled: *A spatio-temporal analysis of floods and flood impact in eastern Caprivi, Namibia. 2011. Master of Science in Geographic Information Science and Systems***,** Centre for GeoInformatics (ZGIS) – Salzburg University

Copy of *An atlas and environmental profile of Caprivi*, published in 1997.

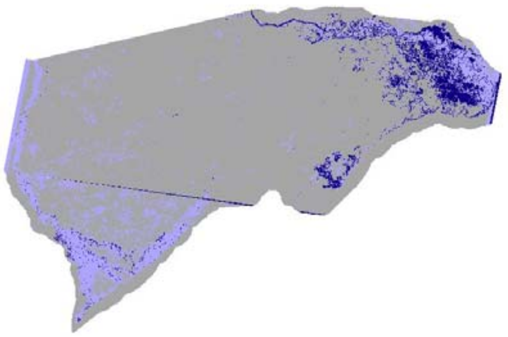




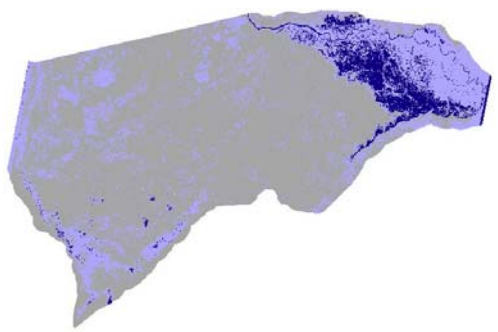
April 2000



March-April 2001



April 2002



April 2003

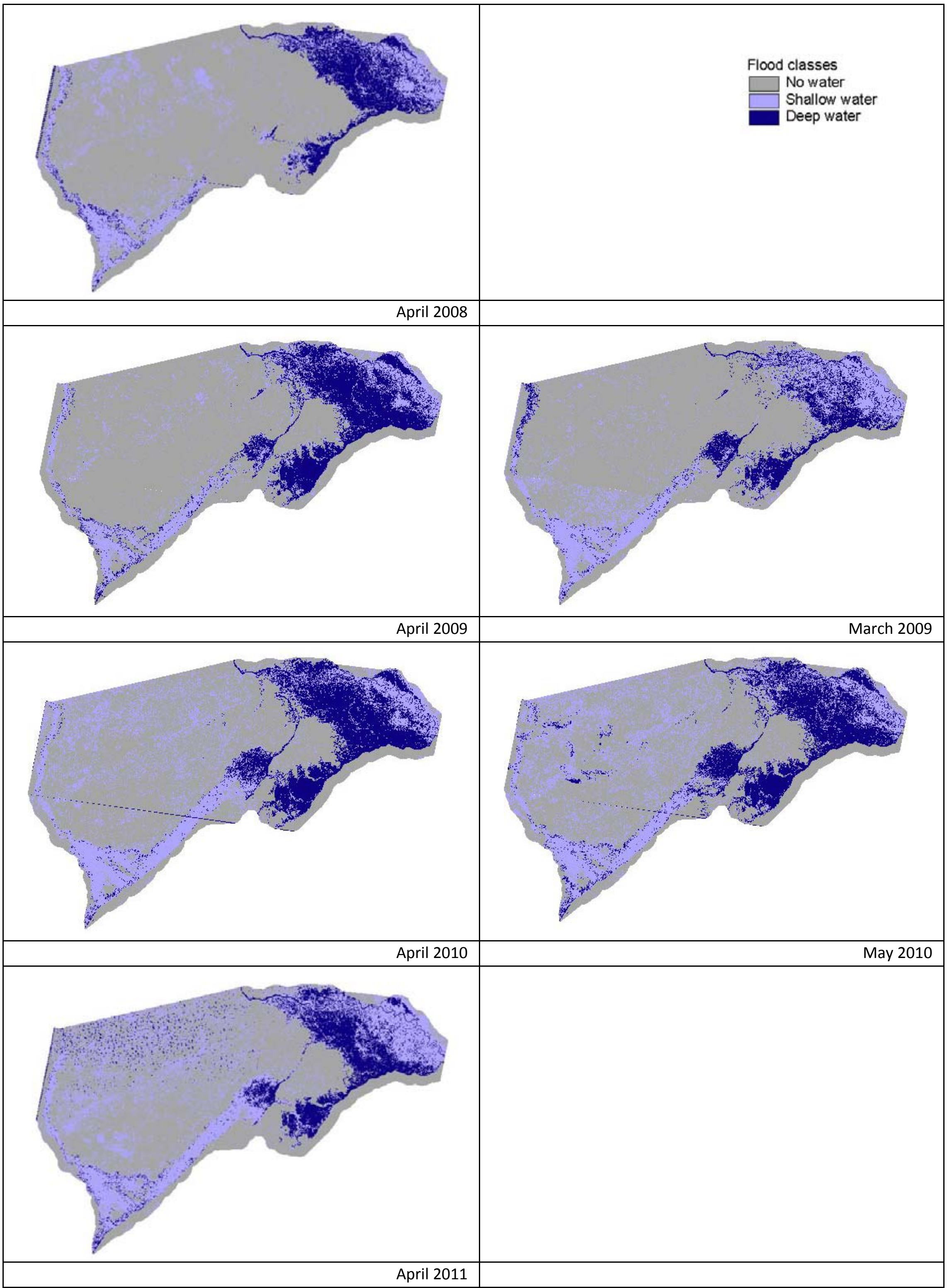


Figure 1. Areas of flooding as classified from Landsat 5 images.

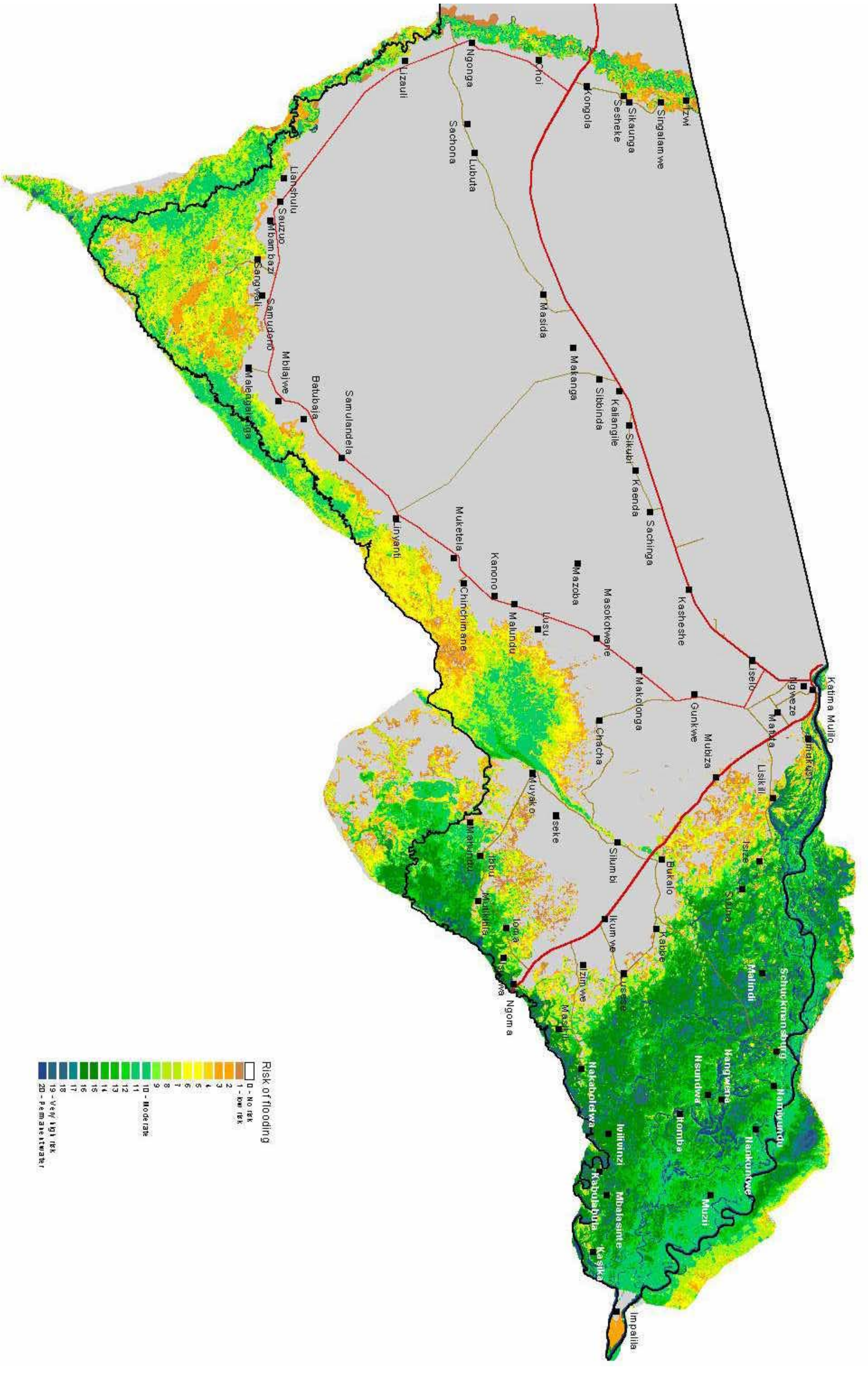


Figure 2. The risk of flooding shaded in colour along a scale from 0-20.