POSSIBILITIES OF RESEARCHING SEASONAL FLOOD DISASTERS IN THE WEST AFRICAN SAHEL WITH SPOT VÉGÉTATION DATA

Christine Wessollek, Elmar Csaplovics and Pierre Karrasch

Technische Universität Dresden, Department of Geosciences, Institute of Photogrammetry and Remote Sensing, Dresden, Germany; mail@christine-wessollek.de

ABSTRACT

The region of the West African Sahel is one of the driest areas in the world. Nevertheless in a short time the rainfall is comparatively high. Thereby the land cover changes suddenly and swayed the characteristic landscape. The most significant natural region in the West African Sahel is doubtless the Niger Inner Delta. In an area of 100 x 150 km seasonal floods influence the socioeconomic structures, the local land use and land cover.

By means of SPOT Végétation data a Seasonal Flood Disaster Monitoring was accomplished. For this purpose data of 8 points of time from December 1999 till November 2000 were evaluated. For this procedure the contents of the image were splinted into 5 common classes. Water, flooding areas, vegetation, soils and temporary clouds were in the main focus of the analysis. In addition to the conventional pixel-based classification methods threshold operations played a decisive role. Supported by land-use-indices like NVDI, NDWI or SAVI classifications results were calculated for every class named above.

In a first step the accurate determination of thresholds was custom-made by a visual interpretation by the authors for all classes and every point of time. At this point of our research work, we can conclude that it seems to be possible to create a mathematical function for the water-threshold and the flooding-area-threshold. With this threshold function it is in a second step possible to classify water and flooding areas with a modicum of effort.

INTRODUCTION

The main task of this work was to determine the annual flood in the Niger inland delta. For this data from the french satellite system SPOT VÉGÉTATION were used. The analyses to be carried out also shall check the applicability of different land-use-indices besides the classic classification approaches. The aim of this research was to proof whether a flood monitoring with vegetation data is possible. There was the task of discussing new solution trials and applying them to the existing data, if none of these methods should provide satisfactory results. Then the examined data which were available of eight different times shall be subjected to a multi-temporal evaluation. Therefore the differently greatly distinctive expanses of water were in the centre of the examination.

METHODS

Study area and Instrument

The African continent is covered by climate zones which vary from the arid to the semiarid and humid conditions respectively. In these regions the vegetation types and structures are significantly different. The characteristics of the vegetation essentially depend on the amount and periodicity of water supply. The Niger inland delta is situated in the West African Sahel, which is one of the driest areas in the world. The Sahel, for which a single rainy season during the summer months is characteristic, is part of the change humidity tropics. All weather appearances in the Sahelian room are stamped by the air pressure conditions and their resulting flow relationship. There is a comparatively high rainfall within some months due to the moving of the ITCZ.

Figure 1: The Study Area.

In September a high water-wave triggered by the summery precipitations in the headwaters, reaches the southern areas of the Niger Inland Delta. In the following time period the region becomes inundated from the south completely while filling the numerous netlike branched creeks and flat basins with water. In subject to the rains and the resulting annual flood there is a fast increase of vegetation in the flooding area. The density of vegetation decreases with dehydration of the flooded areas. In the dry winter months there are strong evaporations in the wide flood levels, whereas about 45% of the drain is steam passed on to the atmosphere. This causes the back-formation of the expanses of water as well as the desiccation of the courses of a river and flat basins. Nevertheless larger lakes in the delta remain year-roundly water filled. The regular flood and following dehydration have the consequence that the vegetation in big portions of the delta restricted to grass ways living in the water. Depending on duration of the inundation they are minted partly very differently. In areas with a long flood phase there can be giant grass formations up to four metres high. In regions with short inundation duration the grass types are of appropriate smaller.

Végétation instrument, flown on SPOT 4 and SPOT 5 is a very wide angle earth observation instrument offering a spatial resolution of 1 km and high radiometric resolution. It uses the same spectral bands as the HRVIR instruments plus an additional band as B0 for oceanographic applications and for atmospheric corrections (see table 1).

Table 1: spectral bands of SPOT Végétation.

band	wavelength
B0	0.45 – 0.52 µm
B2	0.61 – 0.68 µm
B3	0.78 – 0.89 µm
B4	1.58 – 1.75 µm

The task was to detect these annual land cover changes with Spot Végétation data. The choice of the 8 data sets from December 1999 to November 2000 was orientated to the typical seasons in the area of interest.

Evaluation process

With all classification methods the separation of the image data to the classes water, inundation areas, vegetation, soil, and depending on necessity clouds was striven. At first an unsupervised classification was used to check the separability of the designated classes, followed by a supervised classification. For the supervised classification the method maximum likelihood was used to regard the statistical properties of the classes. For all datasets the vegetation indices SAVI and NDVI were calculated.

$$NDVI = \frac{nIR - red}{nIR + red} \qquad SAVI = \frac{nIR - red}{nIR + red + L}(1 + L)$$

Because of the low vegetation density in the study area the value 1 was used for L at the calculation of the SAVI. In principle both indices are suitable for recording vegetation dynamics however the SAVI stresses more strongly the vegetation areas and has to be preferred to the NDVI. To analyse the changes of the expanses of water within the monitored period also the water index NDWI, introduced by GAO (1996), was calculated for all datasets. The SAVI and NDWI were used as added bands in the classification process.

$$NDWI = \frac{nIR - SWIR}{nIR + SWIR}$$

The unsupervised classification was performed with different numbers of classes to check the separability of the designated classes. The number of classes varied between 10 and 50. The result of this approach was the knowledge that a clean separation of this classes would get difficult also by means of a supervised classification. A rise of the number of classes in the unsupervised classification process raised merely further segmentation of the class soil; however this is not necessary for the task. Mainly the delimitation of the flooded areas, vegetation and water caused problems. Also in consideration of SAVI and NDWI as additional bands did not bring about any improvement.

The supervised classification also was carried out in several steps generating subclasses if necessary. As already expected from the result of the unsupervised classification this was primarily the case at the class soil. Finally these subclasses were summarized to soil. Like at the unsupervised classification the separation of the flooding areas was difficult because the delimitation of this class to the classes vegetation and water was problematic in the choice of the suitable training areas. Sometimes there was misclassification of these three classes to soil. In some scenes the existence of clouds also played an essential role, because there was still ground signal through the cloud cover, so the chosen training areas for the cloud cover included mixed information. Without consideration of a class clouds the pixels concerned were usually assigned to the class water. Sometimes these pixels were assigned to soil too, depending on the thickness of cloud cover and the resulting part of the ground signal of the total signal. Also at the supervised classification no improvement in the results could be achieved by the inclusion of the indices. Because of the unsatisfying results of both classification processes new approaches had to be found.

A possibility to extract free water bodies and inundated areas with the help of the introduced indices from SPOT VÉGÉTATION data was introduced by GOND (2000). To extract free water bodies three inputs are necessary: NDVI, NDWI and the SWIR band.

In a first step the difference between NDVI and NDWI is computed. Then the average value within a moving window was calculated. For this GOND used a window size of 45x45 pixels. Some tests showed this window size is also suitable for our study area. In a last step the difference between the produced average value image and the difference image is calculated. The same procedure was applied to the SWIR channel. Now thresholds for the pixel representing water bodies had to be found in both calculated images. These thresholds differed from scene to scene. Finally the two conditions were connected with an AND-function and pixels which satisfy both conditions were classified as water. To extract inundated areas with vegetation the NDVI and the NDWI were used independently and the same procedure as for the SWIR was applied to them. Just like before the thresholds varied between the datasets. Also here only pixels fitting both conditions were assigned to inundated areas with vegetation. In both calculations, extraction of free water bodies and inundated areas, the results were binary images where 1 represented water bodies or flooded areas and the rest of the image was set to 0. After the classification of this two classes the designation of vegetation was carried out with another model using the NDVI to set a suitable threshold. Like in the other

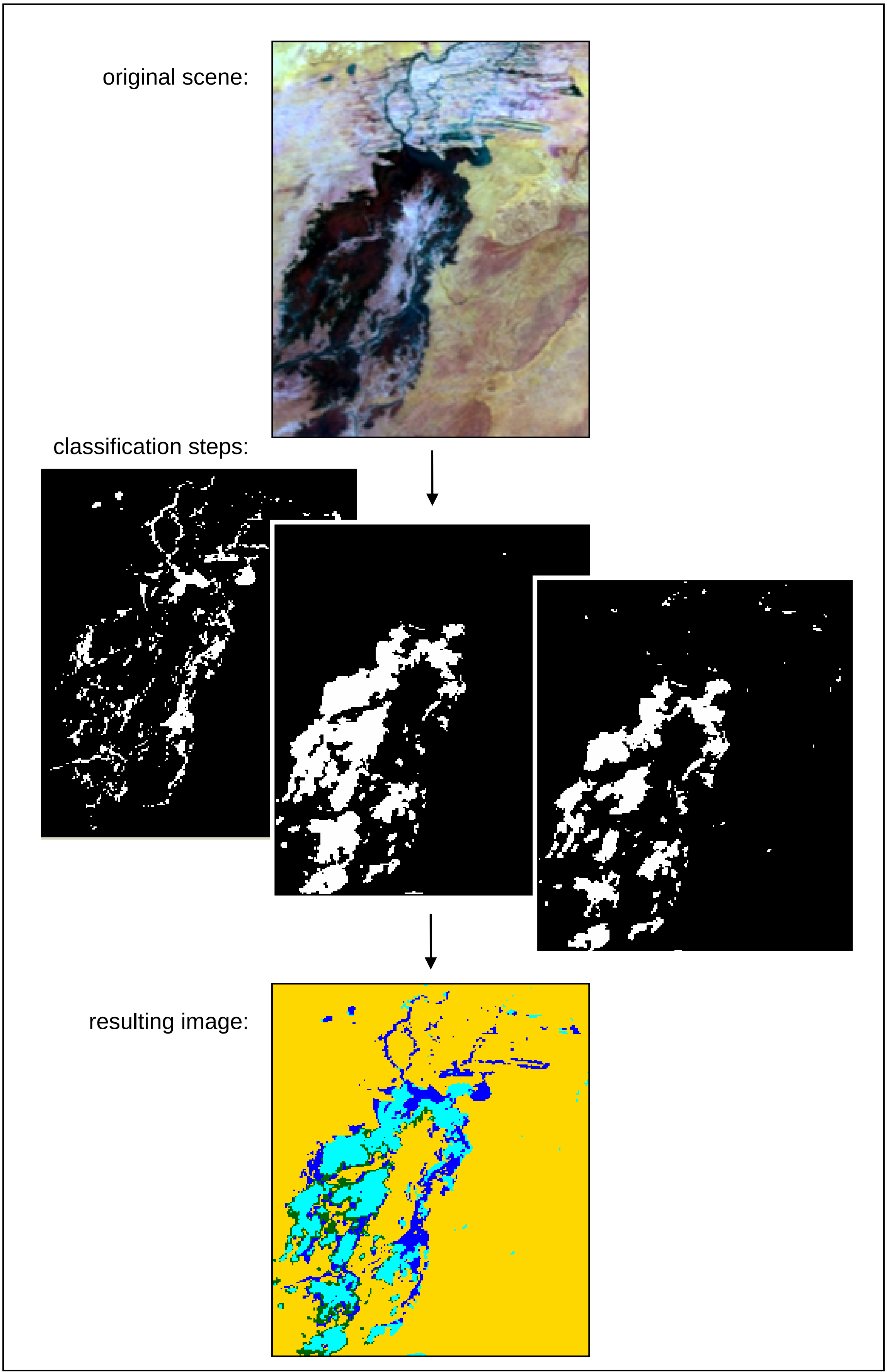

Figure 2: threshold-based classification process, example: October 2000.

models the determination of the thresholds was done by the authors. With this simple working model all vegetation pixels were detected also these pixels assigned to flooded areas with vegetation before. A separation of the two classes was not possible within this model; however it was carried out at the uniting of the individual result images. The clouds on some images were misclassified as water bodies. To avoid this problem a cloud mask had to be designed. To separate cloudy and clear pixels the blue channel and the SWIR channel were suitable. A cloud mask under consideration of these two channels was carried out by LISSENS (2000). The thresholds used in this cloud mask were not suitable in this case so that new thresholds had to be found. The values within this model are intended individually by measuring spectral profiles for every point of time.

Finally the results of the individual value operations had still to be brought together. Within this data fusion all pixels set to 0 in the classification models are summarized to soil. Despite the introduction of the class clouds some cloud pixels were assigned to the class water, so the specification of a class misclassification was necessary. This class includes all pixels which were classified by the used models as water and also as a cloud pixel.

Change Detection

The simplest method of determining the changes in land cover between the datasets is the pixel wise multiplication of two classification results. The resulting pixels then contain the products of the values of the initial images. Then these are used to derivate land cover changes. With a so called Change Map the decrease and increase of water bodies and inundated areas could be visualized quickly. The change matrix gave information about the range of all land cover changes. In this case beside the increase and decrease of water bodies and flooded areas spatial redistributions could be noticed. This can be declared by tidal wave moving from the south to the north, so that an increase of water and vegetation is recognizable in the south at first. With the movement of the tidal wave to the north the vegetation also drifts during the month. Due to the fact that in the north wider areas are affected by the flood event an increase of water bodies across the whole image can be noticed although there can be still areas with decreasing number of water pixels.

RESULTS & DISCUSSION

As seen in the previous explanation the classic classification processes didn't provide satisfying results for monitoring seasonal flood events in the study area using SPOT VÉGÉTATION data. Only the classification method using thresholds was useful because on the one hand the number of misclassification was considerably lower and on the other hand with this method it was not necessary to declare subclasses. The term misclassification is primarily marked by the process of the visual image interpretation of the authors who counts on his experience. Nevertheless the classification based on thresholds did not proceed without problems either. Here for example the courses of Niger River were detected very differently. While in some scenes the course of a river almost is closed, it shows considerable gaps into others. Among other things this has to be led back on the geometric resolution by only 1 km^2 of the VÉGÉTATION data. The different recording of the courses of a river surely can not be interpreted only as misclassification but has its causes also in actual seasonally conditional differences of the water-levels. Nevertheless an estimate of the range misclassifications is necessary since otherwise this can lead to false estimations of the change detection. Another problem at the evaluation arose by the clouds. These could be only partly detected with the help of the threshold condition. It can be said that both, the classification and the following change detection, provide plausible results because they reflect the different characteristics of the introduced seasons well.

In a first step the accurate determination of thresholds was custom-made by a visual interpretation by the author for all classes and every point of time. At this point of our research work, we can conclude that it seems to be possible to create a mathematical function for the water-threshold and the flooding-area-threshold. With this threshold function it is in a second step possible to classify water and flooding areas with a modicum of effort. Due to the different thresholds for every datasets it can be asked whether there are tendencies for these thresholds depending on the season. Therefore the values were represented graphically in the reference to the day in the year and a regression function which in the best possible way adapts to the given values was calculated (figure 3). This function is a cosine function of the form:

$$y = a + b \cdot \cos(cx + d)$$

$a = 1725{,}247$

$b = 998{,}863$ $\qquad x = \text{day of the year}$

$c = 0{,}019$ $\qquad y = \text{threshold for NDVI (16 bit)}$

$d = 1{,}003$

Dependences of the values regarding the seasons could be read from this graph: The Minimum lies, in the months March until May, where the hot dry season is, and the maximum in September, at the end of the rainy season. However, these results offer only a first clue and are not safeguarded sufficiently statistically due to the few values describing the function. Surely they represent an interesting approach which could be manifested by secondary examinations. It would be possible to continue for this study area rather and to extend by other environmental climatic regions.

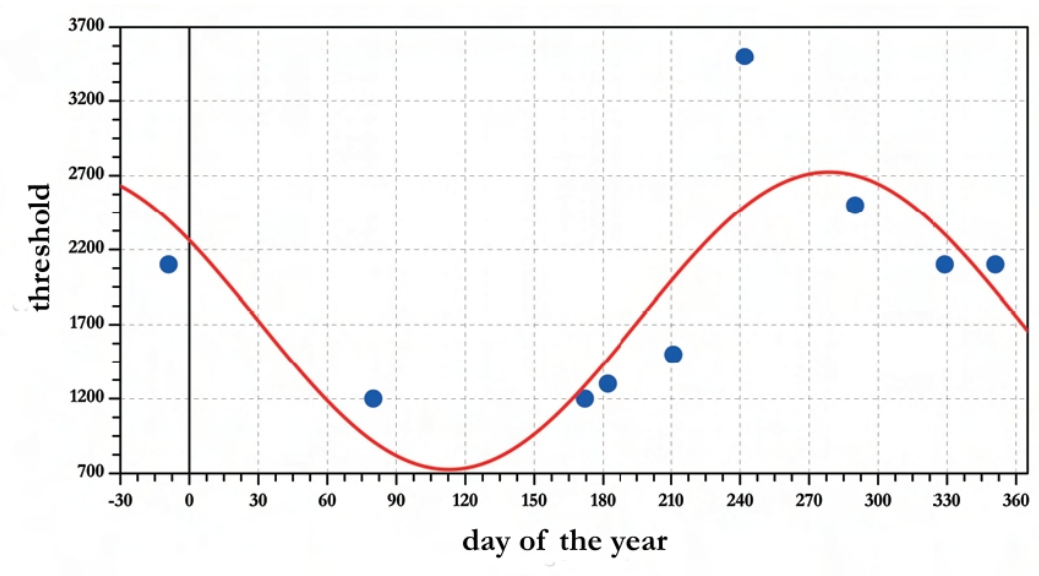

Figure 3: regression function for the threshold for the inundated areas

REFERENCES

i Wessollek C., 2005. Möglichkeiten der Untersuchung sainonaler Flutereignisse in der westafrikanischen Sahelzone mit Hilfe von SPOT-VÉGÉTATION-Daten. Diploma Thesis, Dresden University of Technology

ii Gao B.-C., 1996. NDWI – a normalized difference water index for remote sensing of vegetation liquid water from space, Remote Sensing of Environment, 58: 257-266

iii Gond V., E. Bartholomé, F. Ouattara, A. Nonguierma, L. Bado, 2000. Mapping and Monitoring small ponds in dryland with VÉGÉTATION-Instrument – application to West Africa, vegetation 2000 proceedings, Space Application Institute, JRC, Ispra, 327-333

iv Lissens, G., P. Kempeneers, F. Fierens, 2000. Development of a cloud, snow and cloud shadow mask for VÉGÉTATION-imagery, vegetation 2000 proceedings

v Spot 2005, website, http:// www.spotimage.com