The using of satellite image data from optic and microwaves data for development of a methodology for identification and extraction of flooded area

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Keywords: remote sensing, flood extent, flooded vegetation, flood evolution, ERS - 1 SAR, LANDSAT - TM

ABSTRACT

A significant number of events that are classified as natural disasters can be attributed to environmental mismanagement and degradation. Most natural disasters are localized; flooding is one of these. Investigations have been carried out in the south of Romania in some surrounding areas of Bucharest city to assess temporal and spatial surface changes of inundated areas with multispectral (LANDSAT - TM) data and multitemporal (ERS - 1 SAR) data. The Bucharest city is crossed of the rivers Dimbovita (tributary of the Danube) and Colentina. In generally the floods are caused by deforestation and soil erosion. Traditionally, optical remote sensing has been used to provide environmental information such as that required for hydrological applications; however, it is often hampered by time-of-day or weather constraints. In addition, the restricted penetration of optical wavelengths into volume, such as a vegetative canopy or soil, limits the amount of information on hydrological conditions that can be derived from an image. Because SAR is an active microwave system it can provide day and night data imaging capabilities, and the low frequencies allow for data acquisition in fog and light rain. It is particularly well suited to hydrological applications due to the sensitivity of microwave energy to the presence of water.
The purpose of this paper is to present a methodology to determine the amount of area directly affected by floodwater and it show how the combined use of ERS - 1 SAR data and LANDSAT - TM data can contribute towards a deeper knowledge of the area under consideration.
The success of flood monitoring with the optical satellite data mainly depends on the availability of cloud – free images during the flood process. The main steps in flood monitoring using optical satellite data are: identifying water bodies effectively; eliminating some cloud influences; estimating the area of the flood accurately; and, monitoring the flood process dynamically.
The mathematical approach deals with first identifying which image bands relate best toward solving the environmental hazards problem and secondly determining how mathematically to merge spectral bands into one final image from which the needed information can be obtained. Additionally multitemporal enhancement techniques for LANDSAT - TM data and also ERS - 1 SAR data were analyzed with respect to their potential to derive specific information applied to the problem. These informations are introduced into geographic information system to establish hazard maps and risk potentialities.
The results obtained from the remotely sensed data have shown a good concordance with the available " in-situ" data implying that remote sensing techniques provide a means for locating, identifying and mapping certain features and aspects of flood areas. These informations will be directed to end-users for the surveillance and the management of water resources.

1. INTRODUCTION

Bucharest city and some surrounding areas, placed at south of Romania is crossed of the rivers Dimbovita (tributary of the Danube) and Colentina. A significant number of events that are classified as natural disasters can be attributed to environmental mismanagement and degradation. Most natural disasters are localized; flooding is one of these. In addition, the connection between deforestation and floods has been known for centuries. In generally the floods are caused by deforestation and soil erosion.

In disaster prevention, risk analysis requires the compilation of a number of information extracted from satellite data: land cover mapping, digital elevation model (DEM) generation, soil moisture monitoring, wetland monitoring, snow cover mapping, mapping land-water interface, the determination of flood extent, and snow - water equivalent determinations. These informations are introduced into geographic information system to establish hazard maps and risk potentialities. Remote sensing technique is used on all stages of monitoring: before flooding, during flooding, and after flooding.

Before of flooding we observe the " smooth dynamics, the long-term trends within the ecological nonstable areas, and compile the maps of risk of ecological hazards (permanent water bodies, landscape morphology derived from DEM).

During of flooding we detect accidents and survey the areas subjected to disasters with minimal time lag (flood extent derived from 1 image and flood evolution derived from n images).

After of flooding we survey the sequences of disaster, volume of damage (destroyed areas, deposits and debris), and effects of restoration.

Identification of the surfaces occupied with water by means of mean and high resolution satellite images data is necessary for many studies concerning the surface hydrology as well as the issues of the water pollution.

2. METHODOLOGY

The purpose of this paper is to present a methodology to determine the amount of area directly affected by floodwater. This methodology employs change detection requiring a base image data set and an image during the flood period. This main task is based on the conception and development of remote sensing techniques for the study of multispectral, LANDSAT - TM data and multitemporal, ERS - 1 SAR data.

The acquisition of the cartographic data and the elaboration of digital maps concerning the landcover elements were made under ARC/INFO software environment.

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Additionally multitemporal enhancement techniques were analyzed with respect to their potential to derive specific information applied to the problem.

3. DATA

For realize this study had been used two dataset image data from optic and radar ranges: LANDSAT TM 1,2,3,4,5,7 , 1024x1024 size, 30x30 m pixel size, from 08 August 1991 and ERS -1 SAR scenes from 3 June 1992 - Bleu, 25 November 1992 - Green, and 30 December 1992 - Red (cover the representative test area, Bucharest city).

Topographical maps at 1: 10000 scales were used for locating ground checks and identifying sample areas for corresponding digital analysis. Digital data were used for digital analysis under ERDAS - PC version environment.

4. PREPROCESSING OF THE DATA

The first problem to be addressed was the creation of an integrated multisensor dataset. As the ground reference information was recorded in map form, the decision was made to rectify all imagery to that map grid, namely, a stereographic projection.

Because of the presence of significant geometric distortions due to topographic relief the airborne SAR and LANDSAT were resample to LANDSAT - TM pixel size by the nearest neighbour method and furthermore geocoded to a topographical map of 1: 10000.

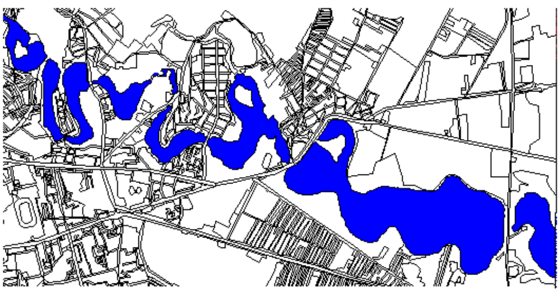

Figure 1. Topographical map, Colentina River (representative area)

The flight modelling procedure used for airborne geometric correction has two attractive features:

1) the rectified imagery is registered to the topographical map (or DEM);
2) the flight line parameters allow one to determine the three dimensional orientation of the sensor target line of sight for each corrected pixel.

Since the DEM is automatically part of the integrated data set, it was possible to incorporate information related to topography in image classification. For this purpose, elevation, slope, and aspect channels were utilised as additional features.

The NDVI derived from LANDSAT data is used to estimate different vegetation state. Since the pixels of the images may be totally or partially by clouds, which obviously triggers errors in correctly estimating the characteristics of the water surfaces, an obligatory stage of pre-processing satellite data was to identify and eliminate them. The recommended procedure in view to eliminate the cloud-contaminated pixels is based on computing the vegetation normalised difference index (NDVI), with relation:

$$NDVI = \frac{TM4 - TM3}{TM4 + TM3} \qquad (1)$$

Thus, the areas with clouds have an NDVI ranging between -1 and 0, whereas the vegetation have an NDVI as close to 1 as possible. Through eliminating these values of the NDVI index specificated for cloud contaminated pixels, water bodies might be identified easier.

In addition, during the resembling process of the geometric correction of SAR data, radiometric corrections for range attenuation and antenna pattern were included. Lee-Sigma filtering of the SAR imagery was used to substantially reduce speckle.

5. RESULTS

5.1 Futures

The purpose of this work is to show how the combined use of Landsat TM data with ERS-1 SAR data can contribute towards a deeper knowledge of the area under consideration.

1) Landsat TM

The city is star-shaped, with a historic centre in the middle from which the suburbs extend outwards. The presidential palace in the city centre can be made out, on the right of which is the main road leading to the palace and an area under construction. The national airport is to the north. The main road systems consists of three concentric circles around the historic centre in which the railway station, to the south, is easily visible. A series of roads fanning out like the spokes of a wheel connect the suburbs to the centre.

The river Dimbovita, a tributary of the Danube, which crosses the northern area of the city, shows evidence of meandrification, which has given rise to some small lakes in the eastern section of the image. Two small lakes are present in the centre and lower area of the image, while an artificial, circular-shaped humid area, is visible in the south.

Vegetation visible in the image is mainly agricultural. The fields are of different sizes and are rectangular. In the north, two larger areas are used for tree plantations.

Different band combinations (figure 2) allow examination of various features of the area shown in this image:

- Bands 3,2,1 (red, green, and blue) - this band combination allows us to show urban areas and roads, in white. The lake sited in the southern
Portion of the image shows different colour due to the sedimentation content.

- Bands 4,5,3 (near infrared, medium infrared, red) - this band combination is useful for distinguishing different types of agricultural vegetation, which appears in different shades of green, orange and ochre. This combination is also useful to obtain further information about roads, which show up in a lighter blue than urban areas;

- Bands 5,3,1 (medium infrared, red, blue) - this band combination clearly shows urban areas in pale blue on a brown background which is farmland;

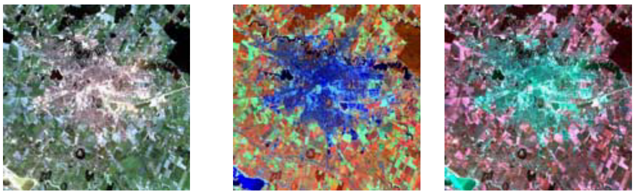

Figure 2. Examination of various features of the area with different band combinations: 3-2-1; 4-5-3; 5-3-1.

The LANDSAT - TM4 (700 - 1100nm) is useful for delimit the vegetation area of water aria because the contrast is enhanced between areas (figure 3).

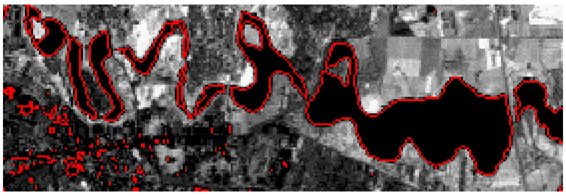

Figure 3. The accurate delimit of the water body of vegetation area

2) ERS-1 SAR

ERS - 1, the earth observation satellite of the European Space Agency (ESA) carries a C band (wavelength = 5.3 cm), VV polarisation and 23^{o} average indice angle SAR which acquires images of the earth's surface in all meteorological conditions.

In the SAR image (figure 4), the urban area is well imaged and the density of the built-up area can be assessed by the strength of the back-scattered signal. In contrast to the optical image, highways, large roads and avenues are presented as dark lines. Bridges and railways on the contrary are imaged mostly very bright due to the dielectric property of metal.

In the full-resolution subsection of the image the patchwork of the fields is well visible. The colours of the fields depend on the changes in surface roughness occurring between the acquisition dates. Data acquired in spring and summer are used to identify the crop type; a methodology similar to that applied with optical data. However it has been reported that also data acquired in the winter are of great interest, since they reveal the work performed which is often indicates the preparation of the fields for a certain crop. This permits at a very early stage in the year to assess certain crop types and estimate their extent. It is obvious that such data application must be based on good knowledge of the time and type of field preparation. Adequate ground survey needs to be available as a starting point.

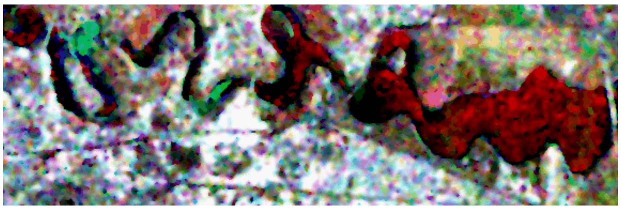

Figure 4. Representative area of ERS -1 SAR colour composite image, Colentina River, from 3 June 1992 -red, 25 November 1992 - green, 30 December 1992 - bleu

5.2 Development of a methodology for identification and extraction of flooded area from LANDSAT - TM and ERS -1 SAR images

The distinction between flooded zones and the hydrological network is done with the use of auxiliary information (topographic maps) and / or change detection approach between multitemporal ERS SAR scenes. Change detection techniques of multi - temporal ERS SAR images which are generally used are photo - interpretation (Matthews et al., 1994), colour composition (Blyth et al., 1993), ratioing (Rignot et al., 1993) and differencing (Badji et al., 1994).

The basic need of such a multitemporal approach is analysis of each temporal data set that permits accurate classification of all cover types of interest and the identification of changes of these cover types within a certain time frame. In the next step a water mask was created by image enhancement techniques from each available acquisition date. In this context, it can be stated that multispectral information concerning the extension of flooded areas can be suitable accessed and extracted by using black - and - white images of band ratios 5/1 (TM), and 1/3 (ERS-1 SAR), H.Mehl & K. Hiller. A density slice of the 5/1 image enabled a separation between permanent water and dry land surfaces. To determine the density slice ranges for these two classes, a histogram for this image was generated which showed two distinct clusters. The density slice ranges were 1-15 (permanent water), 16-255 (flooded areas), and 26-255 (dry land). Knowing the number of pixels associated with each class and the size of a pixel (30x30 m), it was possible to calculate the amount of area covered under each class.
Single band enhancement techniques don't produce satisfactory results to clearly separate water from non-water areas. Inorganic and organic suspended water as well as swampy areas show the same or similar reflectance behaviour than natural grassland or freshly ploughed fields. In a further step all the extracted water masks had to be generalised in relation to the required scale of 1: 10000.

As previously mentioned, the goal of image enhancement is to improve the visual interpretability of an image by increasing the apparent distinction between the features in the scene.
A density slice images was created from ERS -1 SAR image on 3 June 1992 and 25 November 1992 (the day with flooded areas). To determine the density slice ranges for three classes (permanent water, flooded areas and dry land) was generate a histogram, which showed three distinct clusters. The results look something like a contour map, except that the areas between boundaries are occupied by pixels displayed at the same DN. Each level can also be shown as a single colour. Results a mask, which used to segment an image into two classes (binary mask). Figure 5 a, b illustrates the application of level slicing to the " water" portion of the scene illustrated in figure 4 and the binary mask associated of each images.

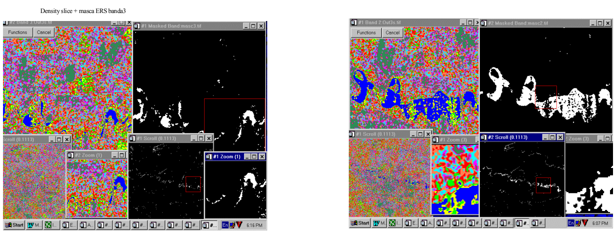

Figure 5 a, b. Density slices + binary mask operations applied to ERS - 1 SAR image data, a - mask1 image from 3 June 1992 (the day without flooded areas) and b - mask 2 image from 25 November 1992 (the day with flooded areas)

Through the subtraction operation between image mask 2 from 25 November 1992 (the day with flooded areas) and image mask1 from 3 June 1992 (the day without flooded areas) results a binary image where to can identify the flood extent areas (figure 6).

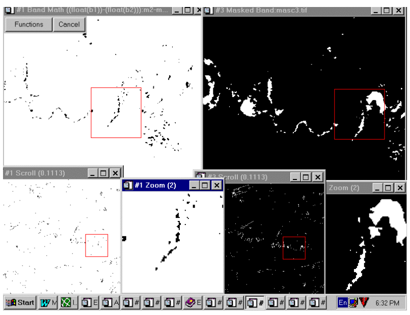

Figure 6. The flooded areas

CONCLUSION

The analysis of 3-day mode ERS - 1 SAR images allowed a flood evolution cartography with a satisfactory accuracy for a field processes analysis and enabled an accurate description of flood dynamics. The comparison between this method and conventional mapping techniques shows the usefulness of SAR data in producing a quick and effective cartography of flood evolution.

Moreover, the high radiometric resolution ERS SAR image shows that multi-temporal SAR data can also be used for precise cartography, in particular for regions where adverse meteorological conditions make the use of optical space or air borne instruments difficult. This methodology can be applied in water utilisation and management of flood like an instrument of estimation and prognosis.

Following the results presented after researcher carried out, there was worked out the methodology to delimitate by the water occupied surfaces from optical and radar satellite images.

This study has underlined important aspects that must be considered in applications of integration of ERS SAR and LANDSAT - TM data. The use of integrated optical and radar data during exceptional hydrological conditions demonstrates that operational use of this data can be envisaged in flood applications.

BIBLIOGRAPHY

H.Mehl & K. Hiller (1992): Application of multitemporal LANDSAT -MSS and -TM data for development of an inundation - risk -map, Proceedings of the Central Symposium of the " International Space Year" Conference, Held in Munich, Germany

David G. Goodenough, Bert Guidon, Philippe M. Teillet, Alain Menard, and John Zelek, The CCRS SAR / MSS Anderson River Data Set, Reprinted from IEEE Transactions in Geoscience and Remote Sensing, Vol. GE-25, No. 3, May 1987

Application to SEAST-A - Canadian Symposium on Remote Sensing, Victoria, pp. 506-515.

Curlander, J.C·, McDonough, R.N. (1991): Synthetic Aperture Radar: Systems and Signal Processing. Sous, New York.

Earth Resource Mapping (1997): ER Mapper 5.6, Reference Manual /ER Radar Manual

ESA (1992): Derivation of backscattering coefficient σ' in ERS-l. SAR PRI products, ERS-1 SAR calibration, ESA-ESRIN Technical Report, Frascati.

Guindon, B. (1985): Automated Control Point Acquisition in Radar Optical Image Registration, Canadian J, Remote Sensing, Vol.1 l, No.1, pp.103-112.

Holecz, F., et al. (1992): Classification of SAR Images in Areas with Severe Terrain Variations. Proc. IGARSS '92, Houston, pp. I 123-1125.

Lee, J.S. (1986): Speckle suppression and Analysis for Synthetic Aperture Radar, Optical Eng., Vol. 25, No. 5.

Raducanu, D. (1996): The Possibility of pattern detection and recognition using satellite imagery. Al XVIII-lea Congres Mondial al ISPRS, Viena, Austria.

Richards, J. A. (1986): Remote Sensing Digital Images Analysis, Kensington, Australia.

Rocca, F. (1987): Synthetic Aperture Radar: A New Application for Wave Equation Techniques. Report, pp. 167-189.

Schreier, G., et al. (1990): Design Aspects and Implementation of a . System for Geocoding Satellite SAR Images. ISPRS Journal of Photogrammetry and Remote Sensing, pp. I-16.

Laugier O., Fellah K., Tholey N., Meyer C. and de Fraipont P. High temporal detection and monitoring of flood zone, The 3rd ERS Symposium (ESA), 1997 Florence (Italy).