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Contribution of space technologies to flood management: the example of the MOSYM project

Th. Rabaute[1], Ph. Puyou-Lascassies[1], G. Stancalie[2], E. Savina[2] & M.-J. Adler[2]
[1]*SCOT, France*
[2]*National Institute for Meteorology and Hydrology, Romania*

Abstract

In order to improve prevention activities related to floods in Romania, a project called MOSYM has been started, aiming at developing a dedicated hydrological information system. In the frame of this project, a method for the development of risk maps will be adapted to the Romanian context and validated on a test river basin.

In order to assess the vulnerability of the considered area, this method requires among other data to get information about land use/land cover. This type of information can be generally retrieved from existing documents or collected during field trips.

This paper presents an alternative and more extensive approach which consists in deriving land use/land cover information from high resolution satellite imagery. A specific methodology is designed for this purpose in order to put the emphasis on the identification of urban areas which are of major importance for the development of risk maps.

1 Introduction

Romania is regularly undergoing severe meteorological and hydrological phenomena. In most cases, heavy and sudden rainfalls produce floods observed in several areas of the country, causing every year important physical damage on large areas and inducing human losses and economical consequences quite difficult to manage in the current Romanian context. The frequency and importance of floods in the country require therefore to follow up this type of

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risk and give the means to operate an efficient monitoring to the organisations in charge of natural hazards, such as government agencies, Civil Protection authorities or municipalities.

In order to answer this problem, the Romanian Ministry of Water, Forest and Protection of Environment has started the MOSYM project (Modernisation of the System of Measurement, Storage, Transmission and Dissemination of Hydrological Data to Various Decision Levels). This 2-year project, funded by the European Commission through the LIFE programme and by the French Foreign Office, aims at providing technical assistance to the Romanian authorities in the development of a dedicated hydrological information system combined with specialised databases to prevent and mitigate floods.

Among the different types of information to be supplied by this information system are risk maps describing the areas of the country prone to floods and which will be used by decision-makers working at the local or national level in order to improve prevention activities and reduce the impact of future floods.

2 Overall methodology

2.1 Assessment of flood risk using the Inondability method

When speaking about floods, it is now well admitted to describe risk as a combination of two separate items: hazard and vulnerability [1]. Hazard takes into account physical processes whereas vulnerability represents the sensitivity of land use to the considered hazard. Optimal risk mapping therefore implies a good knowledge of hazard - including in some cases forecast capabilities - as well as an actual ability to estimate the vulnerability of the considered areas, and mapping only hazard is not enough to assess risk in an efficient way.

The approach selected for the generation of the risk maps in the frame of the MOSYM project is based on the Inondability method [2]. The originality of this method lies in the fact that both hazard and vulnerability are expressed in the same unit, corresponding to a flood return period. In the case of hazard, the estimated return period is derived from the hydrological analysis of the studied area, whereas in the case of vulnerability, it is defined as a risk level depending on land use and expressing the importance and frequency of flood people are ready to accept.

2.2 Contribution of Earth observation to the risk mapping process

The Inondability method requires, among other information, the knowledge of the land use/land cover types in the considered areas to assess the corresponding vulnerability. However, gathering accurate information concerning these items may be difficult, more particularly in the Romanian context where maps have not been updated since several years or remain confidential and where changes occurs quite rapidly. This is particularly true for urban areas which are of particular interest in the flood risk assessment process.

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It is therefore interesting to consider satellite imagery as an alternative source of information and to design and apply a specific methodology in order to develop a land cover map which meets the requirements of the Inondability method.

These requirements are related to the knowledge of the land use/land cover at a scale compatible with the development of risk maps and the possibility to identify areas related to major man-made infrastructures and human activities (towns, industrial areas). After a preliminary analysis, a 1:25.000 scale was found acceptable for a land use map to provide a relevant basis for the generation of the risk maps.

3 Development of an Earth observation derived land use map for risk management analysis

3.1 Definition of test site

In the frame of the MOSYM project, a test site has been selected around the town of Pitesti in the Arges basin. The reasons for this choice are that Arges, one of the largest Romanian water streams, was responsible for several flood events during the last few years and that its watershed includes major towns - among which the Romanian capital, Bucharest - and important economical centres.

3.2 Description of input data

The satellite data used during this study have been acquired by the IRS sensors and are presented in Table 1. The selection has been performed according to the requirements identified for the development of the land use map as well as the characteristics of vegetation cover and agricultural practices existing in the area of interest.

Table 1. EO data used for the generation of the land use map

Satellite	Sensor	Acquisition date	Pixel size (meters)	Bands	Resolution (meters)
IRS-1C	Pan	8/04/1999	5	Pan	6
IRS-1C	LISS	8/04/1999	25	G, R, NIR	24
				SWIR	71
IRS-1D	LISS	23/09/1999	25	G, R, NIR	24
				SWIR	71

Using both sensors available on the IRS satellite family makes it possible to combine the geometric accuracy of the panchromatic data and the spectral sensitivity of the multispectral image (including green (G), red (R), near-infrared (NIR) and mid-infrared (SWIR) bands) acquired on the same date. This will be

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particularly interesting for the identification of land use features related to urban settlements.

3.3 EO data pre-processing

Operations related to EO data pre-processing aim at combining both types of available images in order to provide an enhanced result more suitable for the identification of the different land use/land cover types. An overview of the pre-processing scheme is given in Figure 1. This pre-processing is applied here to the image pair acquired on the same date.

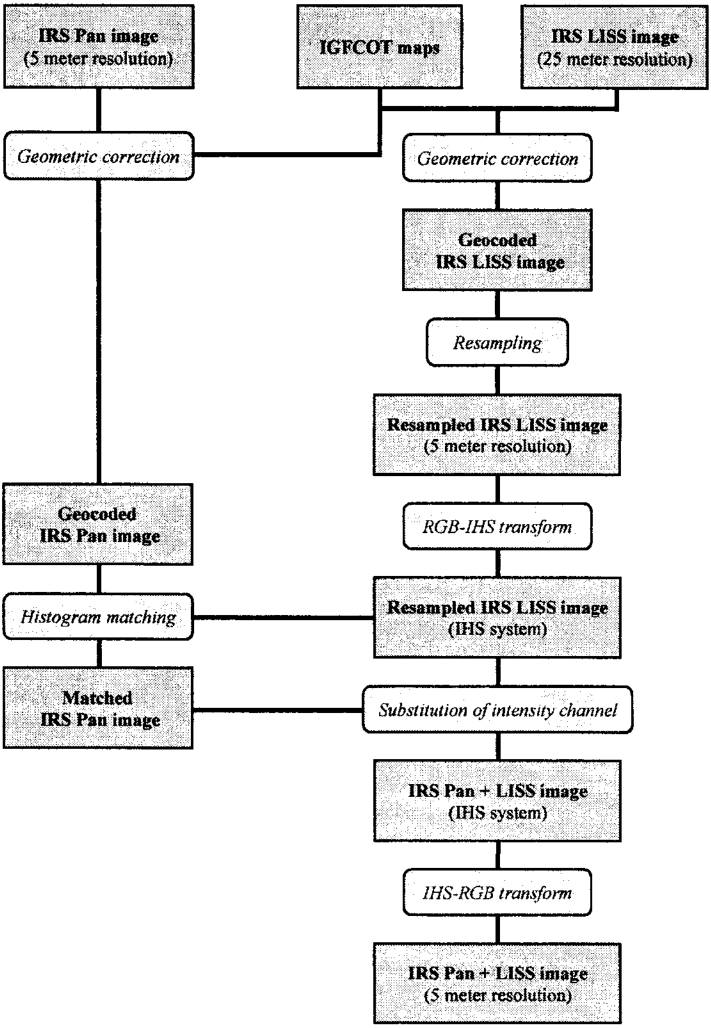

Figure 1. Overview of EO data pre-processing

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3.3.1 Geometric correction

The first pre-processing step is dedicated to geometric correction in order to get co-registered and geocoded IRS Pan and LISS data. Both types of images undergo the following geometric processing:

- Using topographic maps distributed by the Romanian National Geographic Institute (IGFCOT) as a reference, a set of ground control points (GCP) is selected on each image,
- A distortion model (2^{nd} order polynomial) is computed from the set of collected GCPs.
- The input image is resampled using a cubic convolution interpolation method.

As a result, both resulting images are in the same geographic system corresponding to the input map.

3.3.2 Radiometric enhancement

The second pre-processing step is related to data merging in order to enhance the EO data information content. The applied methodology is as follows:

- The IRS LISS image is transformed from the RGB (red, green, blue) system to the IHS (intensity, hue, saturation) one. The three bands selected for this operation among the four available are the near-infrared, red and green channels, because the initial resolution of the mid-infrared band makes it less interesting for this operation.
- The histograms of the intensity channel and the IRS Pan image are matched in order to define a lookup table to be applied to the IRS Pan image so that it becomes as similar as possible to the intensity channel.
- The intensity channel is replaced by the matched IRS Pan image and an inverse transform from IHS to RGB system is applied to get the final IRS Pan + LISS product.

Visual analysis of the resulting image shows a significant improvement of the IRS Pan image due to the introduction of multispectral information. This is particularly obvious for the discrimination of features such as urban or sealed areas.

Figure 2. Extracts of IRS Pan, LISS and Pan + LISS data

3.4 EO data processing and interpretation

Operations related to EO data processing and interpretation aim at identifying different land use/land cover types using as far as possible an automated process. The overall processing may be split in two parts: the first one is dedicated to the identification of landscape features related to vegetation, whereas the second one is specifically tailored to detect urban features. An overview of the processing scheme is given in Figure 3.

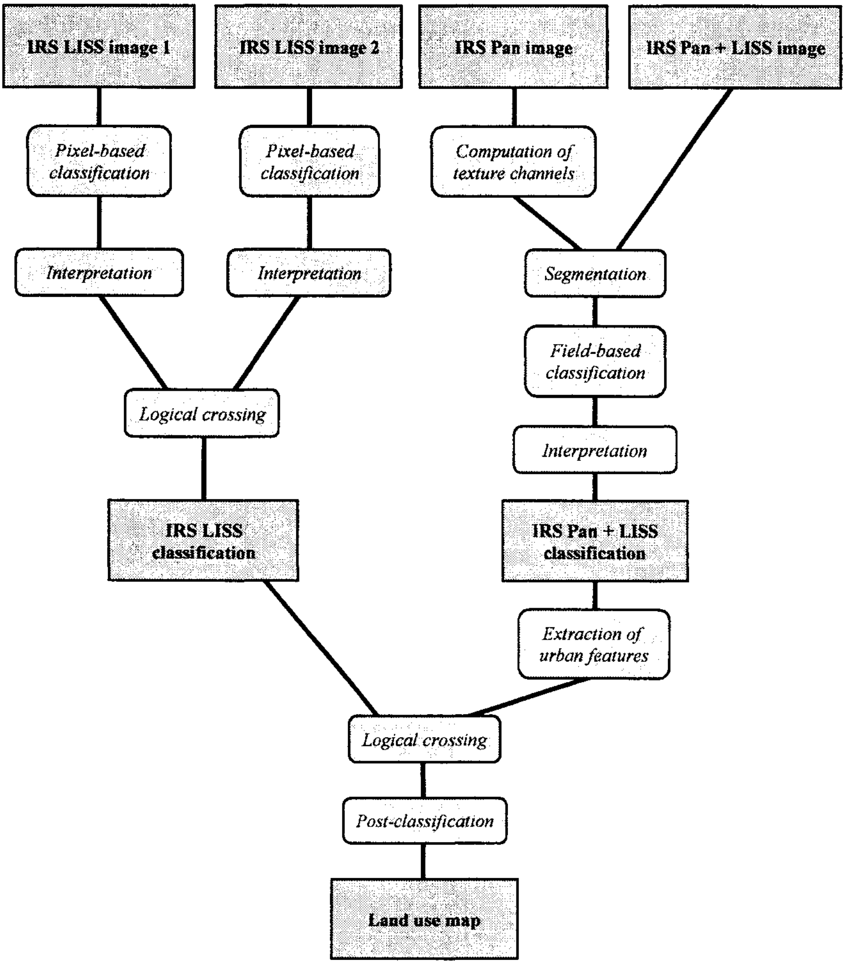

Figure 3. Overview of EO data processing and interpretation

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3.4.1 Identification of vegetation features

The identification of vegetation features is performed through a semi-automatic pixel based approach including three main steps:

- The classification of each of the two input multispectral IRS LISS images. During this step, all the available bands are taken into account, including the mid-infrared which is more adapted to separate different vegetation cover types or development stages.
- A computer-aided visual interpretation of the classification result in order to assign a preliminary land cover type to each class
- The logical crossing of both classification results to refine this interpretation and take into account the changes of the vegetation cover during the year.

At the end of this part of the process, a first version of the land cover map is available. However, the resolution of the IRS LISS sensor does not allow an optimal detection of urban features, which has to be performed through an alternative methodology.

3.4.2 Identification of urban features

The approach used to identify urban features has been already applied in other contexts [3,4] and is based upon the enhanced IRS Pan + LISS image. It is performed through a semi-automatic field based approach including two main steps:

- An image segmentation using the watershed algorithm, which aims at delineating homogeneous areas with respect to a radiometric criterion,
- The clustering of the delineated areas to spread them within a user-defined number of classes.

In order to take advantage of the geometric details provided by the merging of IRS Pan and LISS data, the process involves not only the three bands of the enhanced Pan + LISS image, but also two textural channels computed from the original Pan image:

- The first one is a texture channel resulting from a morphological computation ("top hat" filtering), allowing to enhance small, bright and high-frequency structures which are usually met in sparse or dense urban areas. The size of the kernel used for this operation (11 x 11 pixels) has been adjusted taking into account the resolution of the IRS Pan image and the size of the urban items to detect.
- The second one is a variance channel which highlights the contrast between textured, highly dynamic areas, such as sealed areas, and more homogeneous ones, such as agricultural areas. Here also, the size of the window used to estimate the variance (9 x 9 pixels) has been adjusted taking into account the resolution of the IRS Pan image and the size of the urban items to detect.

These new channels are used at two different levels during the processing:

- At the end of the segmentation process in order to suppress small areas by merging them with bigger neighbouring regions. This enables to define larger areas for which statistical information to be used during clustering is really significant. However, this merging should be handled differently depending

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on the land cover type, and textural information provided through the new channels is a good way of monitoring this part of the processing.

- During the classification in order to characterise the areas to classify. The adding of new channels enables to describe the regions not only thanks to their radiometrical properties but also through their textural ones.

The clustering of the areas delineated through the segmentation process is performed through a mobile centre algorithm using statistical parameters computed for each area. These parameters are derived from the three input image bands (average values from green, red and near-infrared bands and average deviation from near-infrared band), but also from the textural bands (average values from texture and variance).

3.4.3 Generation of the final land cover map

The first step to produce the final land cover map consists in inserting the classes identified as urban areas in the result derived from the pixel-based classification. This process is then followed by a post-classification step which aims at improving the coherence of the resulting product.

During this stage, polygons belonging to the classes identified as potential urban areas are checked and possibly assigned to another land cover/land use type depending on the values of surrounding classes.

This processing can be performed either through manual correction if the extension of urban areas is limited in the image or through automated filtering, provided that standard assignment rules can be defined.

In our case, ten different classes can be retrieved from the final land cover map:

- Bare soil
- Set aside lands
- Summer crops
- Winter crops
- Grasslands, orchards and vineyards
- Woods
- Water areas
- Urban areas dedicated to housing
- Large buildings

The generated land cover layer can then be used for modelling purposes and a level of vulnerability can be given to each class.

Figure 4. Extracts of texture and variance channels and of final land use map

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4 Conclusions

This paper presents the concrete case of the MOSYM project in the frame of which Earth observation data is directly used in a risk management analysis.

The method used to perform risk assessment has been analysed and requirements have been identified and turned into specifications necessary to generate an information product - here a land cover/land use map. A specific methodology has then been developed and applied to the selected satellite images in order to derive the required product.

Though risk management analysis must always take into account the peculiarities of the considered area - these peculiarities are essentially related to hydrological aspects -, the approach presented here can be adapted to any other area, provided that Earth observation data with relevant characteristics (resolution, spectral bands) are available. Recent and future high and very high resolution sensors should help in the development of these new concepts.

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Section Seven:

Landslides