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Procedia Engineering 161 (2016) 1949 – 1956

Procedia Engineering

www.elsevier.com/locate/procedia

World Multidisciplinary Civil Engineering-Architecture-Urban Planning Symposium 2016, WMCAUS 2016

Accuracy Assessment of Very High-Resolution Multispectral Images Derived Data for River Flow Modelling

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Abstract

The increased frequency of disaster events and the need for a rapid response for the prevention and remediation of flood disasters require realization of flood risk maps with very good precision based on high performance hydrodynamic river models using advanced hydroinformatics tools. Modelling performance, topographical data quality and quantity, hydrological and hydro meteorological surveys as well have very important for correct understanding and interpretation of all hydraulic aspects for minor and major riverbed. These are key factors in the need for new sources of data for hydrological modelling and flood risks management process. In this regard the actually development of satellite sensors, data, availability, Geographic Information System (GIS), and on the Hydroinformatics based river flow modelling techniques gives new opportunities in the analysis of the floods phenomenon. Use of the Very High Resolution remote sensing raster images to derive data useful for hydrological modelling is inviting and the answer to the question of accuracy of the data derived from remote sensing images is very important.
In the present paper is investigated the methodology for using of multispectral satellite images acquired by Worldview2, SPOT 6 and SPOT 7 sensors for deriving hydrological model data and its corresponding accuracies. A case study using multispectral images related to rivers Timiş, Bega and Timiş-Bega canal in Romania and river flow model is foreseen for the future to verify the results of the methodology.

Peer-review under responsibility of the organizing committee of WMCAUS 2016

Keywords: remote sensing; river flow modelling; multispectral imagery; hydrodynamic river modelling; vegetation indices.

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Peer-review under responsibility of the organizing committee of WMCAUS 2016
doi:10.1016/j.proeng.2016.08.785

1. Introduction

The present development of satellite sensors, data, and availability, Geographic Information System (GIS), and river flow modelling techniques gives new opportunities in the analysis of the floods phenomenon. The increased frequency of disaster events and the need for a rapid response are key factors in the need for new sources of data for flood risks management process.

The necessity to acquire data for river hydrological modelling in a short time with reasonable costs in condition of moving channel margins is born from the need to create input data for computer based modelling software like HEC-RAS or MIKE-DHI. One efficient solution is to derive data from remote sensing imagery, namely High Resolution (HR) or Very High Resolution (VHR) images.

There are many researches that investigate the use of satellite imagery in river flow modelling, the most of them based on the public available Landsat TM images. Commercial imagery, acquired by the latest satellites, such as VHR Geoeye-2 or Worldview and HR such as SPOT 6, SPOT 7, are less investigated.

Main hydrological parameters, used in river flow modelling, are:

- Q – the discharge of the river [m^3/s]
- w – river flow width [m]
- v – mean velocity [m/s]
- d – depth [m]

The most evident parameter that can be derived directly from satellite imagery is the river flow width w. Mean velocity v, depth d and discharge Q may be indirectly evaluated, using equation:

$$Q = v \cdot d \cdot w \tag{1}$$

The problem is what accuracy can be assumed for the parameter w having in mind that its measurement depends primary on the GSD of the image and secondly on the accuracy of geo-rectification of the images. The influence of the error in measurement of these parameters were recognized in the GIS based changed detection methodologies by some researchers [5] and in river discharge by using Quickbird imagery [3] while others simply ignore it.

The objective of the study is to evaluate the accuracy of estimation for river flow width w using the latest VHR and HR sensors. Joint Research Centre acquired the images used in the case study for the Control with Remote Sensing of the farmers' applications for agricultural subsidies.

2. Methods

Techniques and overall strategy

The study of the accuracy of VHR and HR multispectral images was developed using ERDAS Imagine 2011 software for rectification, spectral analysis and classification of the images, ArcGIS ArcMap 10.3 for raster - vector data conversion, Digital Terrain Model (DTM) creation, spatial analysis and HEC-RAS for river flow modelling.

The adopted methodology for the study was:

- imagery orthorectification using rational polynomial coefficients and a DTM with a 5 m Ground Sample Distance (GSD) – the adopted method is the one provided by the supplier of the images [6].
- supervised classification of the images using a signature file and unsupervised classification
- raster – vector conversion of each classified image, and getting the river water surface polygon
- intersection of the water surface polygon with the automatically generated cross sections (every 50m)

2.1. Data

VHR Multispectral images

The images that were available and were used for the case study are presented in the table below

Table 1. VHR Satellite Imagery used in the study

Image satellite sensor	Operator	GSD panchromatic	GSD multispectral	Bands	Date and local time of image dd/mm/yyyy hh:mm
SPOT-6*	Airbus Defence&Space – France	1.5 m	6 m	RGBNir	17/04/2015 12:23
Worldview-2*	DigitalGlobe – USA	0.5 m	2 m	BGRNir	09/05/2015 12:56
SPOT-7*	Airbus Defence&Space – France	1.5 m	6 m	RGBNir	08/07/2015 12:04

* Spot 6/7 © Airbus DS

** Worldview-2 © Digital Globe

Digital Terrain Model (DTM)

For images orthorectification and river flow modelling an existing DTM with a GSD of 5 m was used. This DTM was derived from aerial photogrammetry stereo pairs. DTM was produced for the use of control with remote sensing of agricultural subsidies in Romania [4]

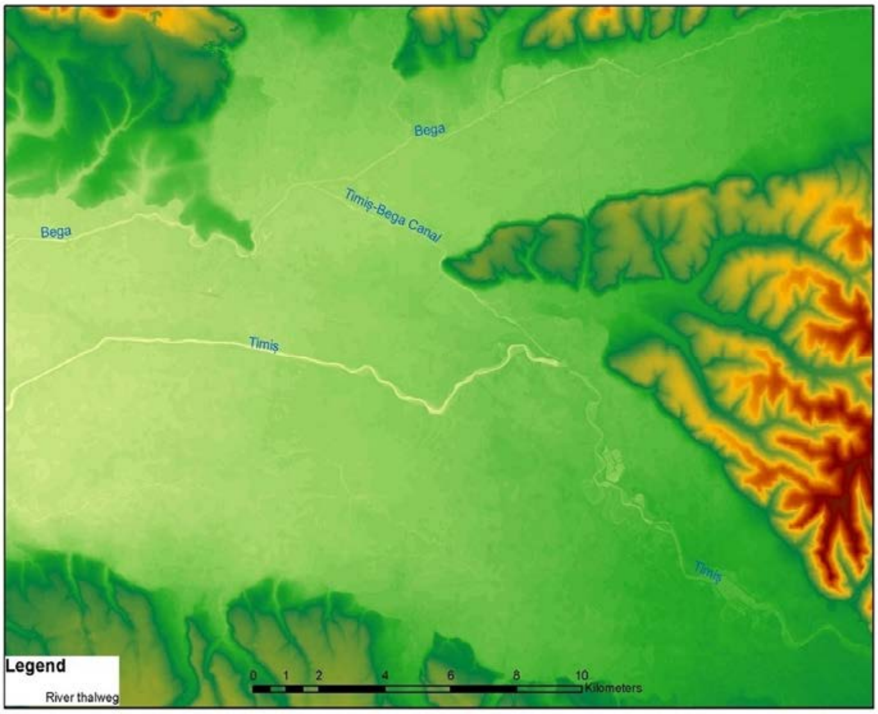

Fig. 1 Digital Terrain Model.

2.2 Hydrological data

Banat Water Basin Administration provided records for water levels and discharges every 12 hours for four hydrometric stations Lugoj (Timiş River), Coştei (Timiş Bega canal), Balinţ (Bega River) and Chizătău (Bega canal) for 5 days before and 5 days after the date of the images.

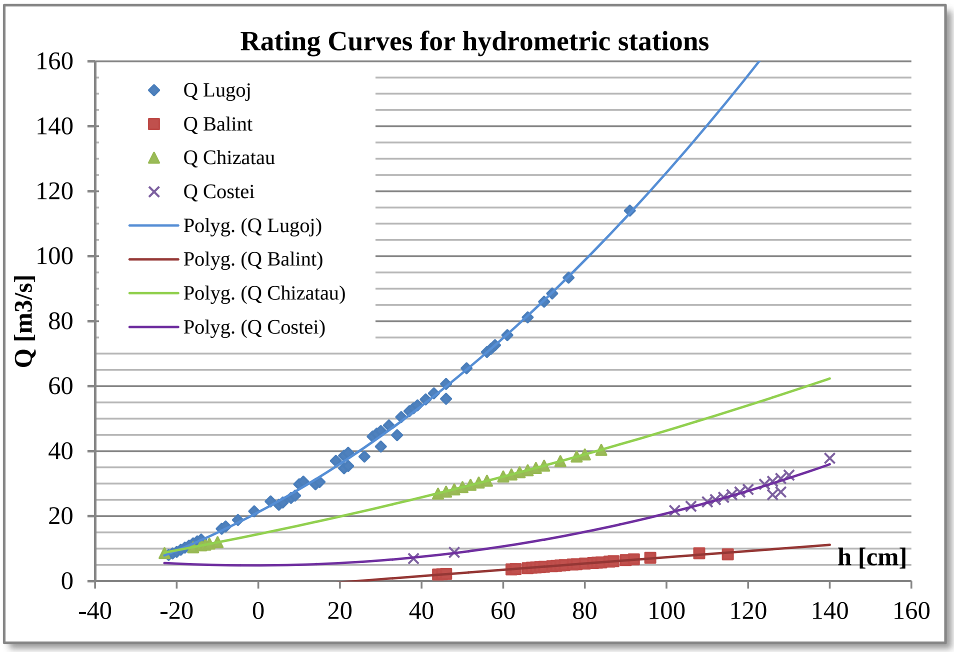

Fig. 2. Rating curves and best fit trend lines.

Rating curves best fit trendlines equations are:
Lugoj station:

$$Q = 0.0038h^2 + 0.6665h + 21.208$$
$$R^2 = 0.9969 \tag{2}$$

Chizătău station:

$$Q = 0.0006h^2 + 0.2597h + 14.447$$
$$R^2 = 1 \tag{3}$$

Coştei station:

$$Q = 0.0016h^2 + 0.0042h + 4.8292$$
$$R^2 = 0.9676 \tag{4}$$

Balinţ station:

$$Q = 0.00001h^2 + 0.098h - 2.3634$$
$$R^2 = 0.9907 \tag{5}$$

Study area

The area covered by the images is 24 km East West and 59 km North South, around city of Lugoj in Western Romania. River Timiş for 33 km and River Bega for 20 km together with the Timiş Bega Channel (10 km), that are visible on satellite images, were selected to be used in the study.

River Width Calculation

River Width Calculation Using Image Supervised Classification

Orthorectified images were classified with a user defined signature file, to detect the pixels belonging to the water surface. The classified image was transformed to vector features using raster/vector conversion. Perpendicular lines on thalweg were intersected with the water polygons. The results represent the water width.

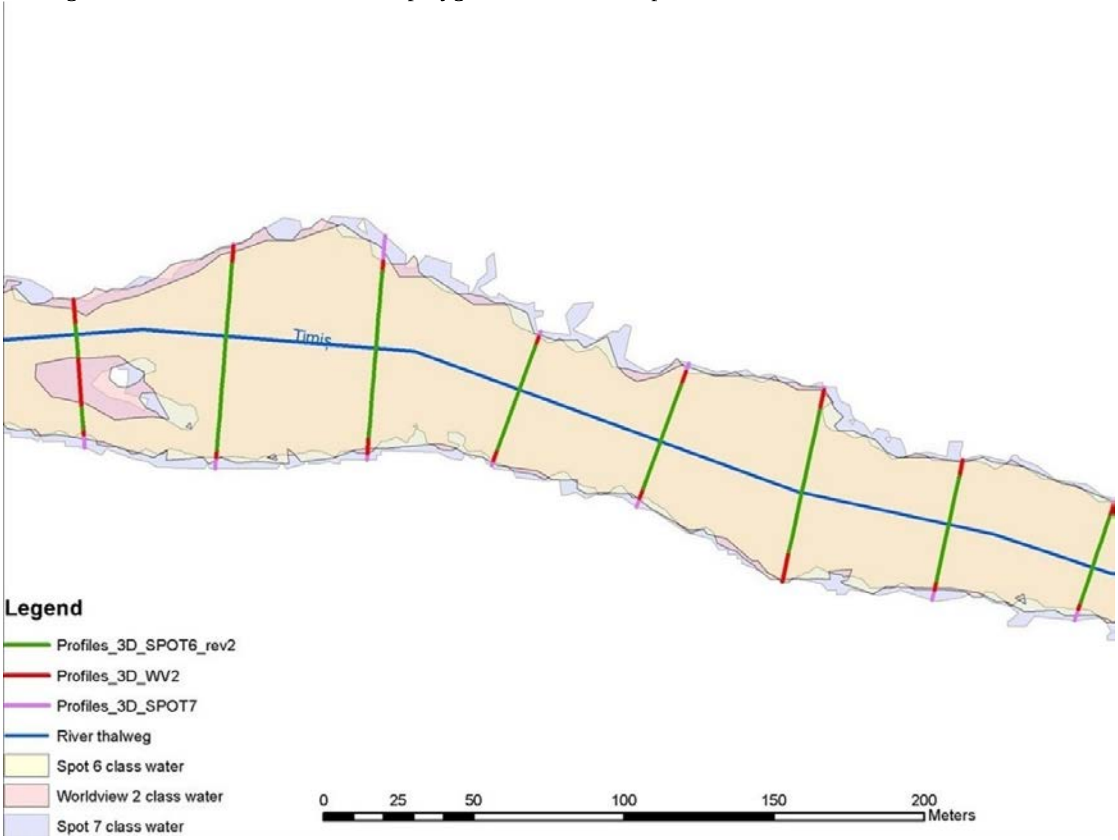

Fig. 3. Classification results after conversion to vector format.

River Width Calculation Using Normalized Difference Vegetation Index NDVI

NDVI index is widely used in land cover classification.

Red and Infrared Bands were used to calculate NDVI [7]. Although WorldView2 can provide 8 bands, out of which one is red edge and two near infrareds, it has been determined that best results for NDVI are obtained with NIR1 – 770-895 nm [2].

$$NDVI = \frac{NIR - RED}{NIR + RED} \tag{6}$$

where NIR and RED and either reflectance values or digital number. NDVI values for water bodies have a negative value, with an average of -0.257 [1].

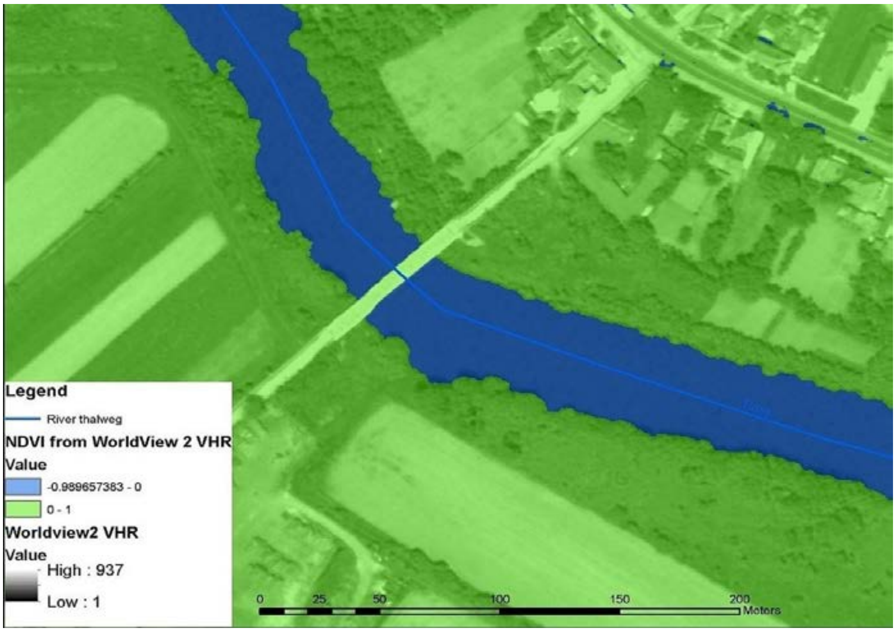

Fig. 4. Water detected derived from NDVI values calculated based on Worldview Image, with the visible panchromatic band in the background.

3. Results and Discussions

Images were ortho rectified using 13 ground control points on each image, the resulting RMSE is 0.80 m for VHR scene, 1.31 m for SPOT-6 and 0.97 m for SPOT-7. Satellite orthophotos were classified using signature files for water bodies in the first method and using NDVI value, as an intermediary step, in the second method. Raster images were converted to polygon features for the water bodies. Image supervised classification in one case and NDVI negative values in the second method yielded the water surface for the areas that are not covered by vegetation. The results for water surface in the presented methods are very similar, the differences between widths are less than 5% on average. Differences between the two methods calculated along 1012 cross sections, after eliminating the top and bottom 5% outliers are presented in the table below.

Table 2. Statistics for water widths determinations using the two methods using Worldview 2 image.

	Timiș			Bega			Timiș-Bega channel			TOTAL		
	Class	NDVI	Diff	Class	NDVI	Diff	Class	NDVI	Diff	Class	NDVI	Diff
Number of sections		512			244			167			923	
Average	32.33	31.50	0.83	19.43	18.68	0.75	12.12	11.68	0.46	25.26	24.52	0.74
Maximum	107.58	106.19	8.03	73.90	72.40	6.76	38.21	37.76	2.35	107.58	106.19	8.03
Minimum	10.27	9.87	-0.16	2.68	0.12	-0.15	1.05	-0.61	-0.12	1.05	0.12	-0.16
Standard Deviation	14.91	14.42	1.39	13.24	13.27	0.91	6.86	6.89	0.46	15.68	15.38	1.16

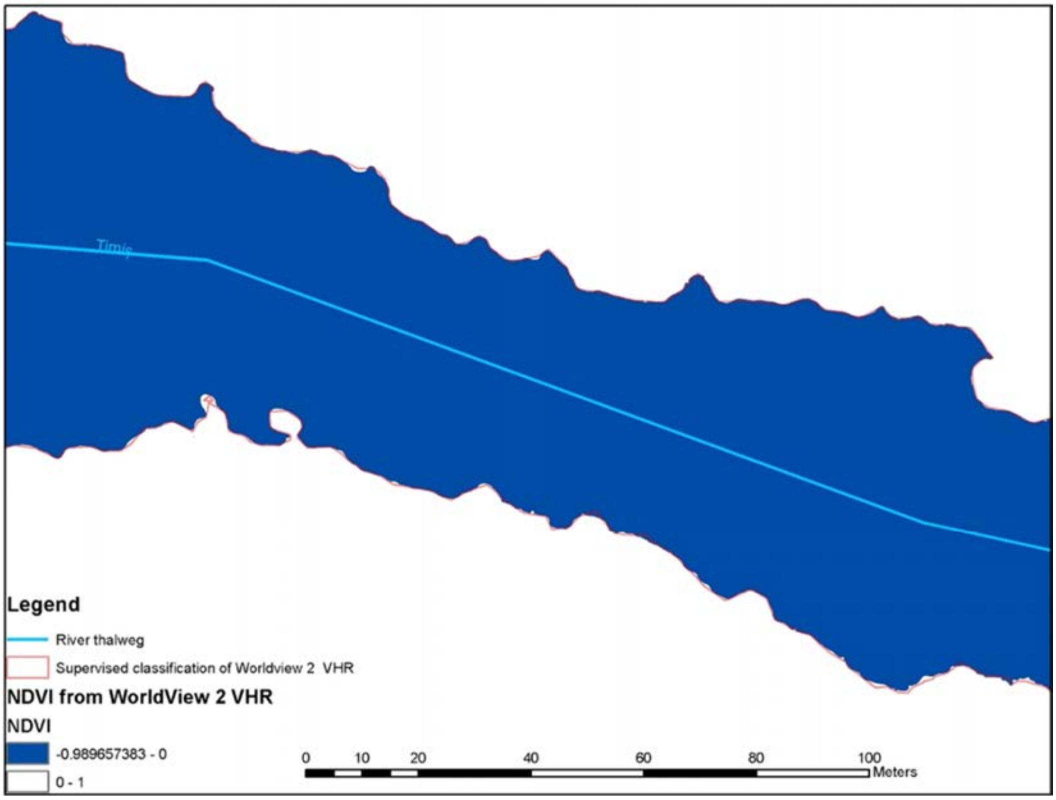

Fig. 5. Difference for water surface in the two methods using Worldview 2 image.

One limitation of both methods is given by the fact that trees near the shorelines cover the water edge and this is one limitation that needs to be overcome. Since the trees do not have seasonal growth, we can assume that an area covered by a tree on one image will be covered on all other images. Hence, in these areas there will be no significant difference between the cross section lengths. A further study is needed to automatically identify these areas.

4. Conclusions

This article presents the results of two methods investigation for automatic detection of surface water using latest satellite sensors like Spot6&7 and Worldview 2. The presented methods are applicable for surveying river widths along sections within a satellite images scene. The study area covers the midsections of two rivers in Western part of Romania.

Further work is planned to validate the remote sensing derived data with a proper river flow model using HEC-RAS software, in order to verify the measured widths on the image with the values resulting from the river flow model.

Acknowledgements

The authors express their gratitude to Gauss Srl Company for providing logistics and software tools to perform the study. Mr. Cătălin Nagy provided hydrological data for the hydrological stations from Banat Water Basin Administration, and kindly supported the study with detailed information.

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