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APPLICATION OF MULTITEMPORAL REMOTE SENSING DATA IN LARGE WATER BASINS AREA ESTIMATION

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Abstract: *Natural and artificial water basins are main source for water used by agriculture, industry and households. Traditionally the level, respectively the area, of these water bodies is monitored locally by gauging stations. In this paper the effort we put is in finding reliable procedure to obtain the mean water level from remotely sensed optical data. Topolnitsa dam was selected as test site for our study due two reasons – first, it has been used in previous research activities, and second it has serious impact on environmental state of the area where it is located. In the framework of this research we developed a method for solving the task mentioned using freely available data (multispectral and in-situ) and processing software.*

ПРИЛОЖЕНИЕ НА МНОГОСПЕКТРАЛНИ ДАННИ ОТ ДИСТАНЦИОННИ ИЗСЛЕДВАНИЯ ЗА ОЦЕНКА ПЛОЩИТЕ НА ВОДНИ ОБЕКТИ

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Ключови думи: *водни площи, модифициран нормиран спектрален индекс*

Резюме: *Естествените и изкуствени водоеми са основният източник на вода използвана в селското стопанство, промишлеността и от домакинствата. Традиционно нивото, съответно на площта на тези водни тела се наблюдава локално от измервателни станции. В рамките на това изследване основна цел бе създаването на надеждна процедура за получаване на средното ниво на водата на базата на свободнодостъпни сателитни данни в оптичния спектър и софтуер с отворен код. Две бяха причините за избора на язовир Тополница за тестов обект - първо, той е бил използван в предишни научноизследователски дейности, и второ, че оказва сериозно въздействие върху екологичното състояние на района, където се намира.*

Introduction

The amount of fresh water accumulated in lakes and reservoirs is the only source used in agriculture for irrigation, in industry, by hydropower stations, for domestic use, etc. In order to distribute fairly that amount between sectors mentioned it is of importance to have reliable information for water level at regular intervals. This data can also be used for express estimation of total volume of the water stored and used as reference point for further calculations. Normally the water level is obtained by means of in-situ gauging stations installed near river mouths, bridges, weirs and sluices. Based on this data bathymetry maps are produced and updated for major water bodies. Very often this information is considered as highly sensitive by local, national and security professionals so it is not made accessible to other institutions and to the general public.

In last decades satellites are used in solving large amount of Earth observation tasks. Important advantages when using instruments on satellites in such scenarios are the global coverage, repeatability and their relative autonomy. For monitoring the water level of lakes, dams, etc. from satellites two types of techniques are used – single point altimetry measurement performed by radar or laser, and image-based (optical or SAR) water shape retrieval, both techniques having its strengths and weaknesses. [Zheng (2013)]

In this study the authors have adopted the second approach based in freely available optical image data and other free resources accessible.

Method

In order to discriminate the water areas using only multispectral data from the rest of the land cover objects found in the image in this study we implemented pixel-based approach using spectral indices to form the raster polygons corresponding to water areas. After this procedure they were converted to shape files manually since we needed to be as much precise as possible. Next step was to use a topographic map to establish several ground control points above highest water level foreseen in dam design and of the embankment. After that we made a contour line for this highest level around the water body. This line was checked against several points taken from web site providing height data from Google maps [Daftlogic, 2014]. All water levels calculated afterwards were compared to this line in order to find the size of the water polygon created. This method is similar to this described in [Xianwei W., (2013)], but differs in the way of generating the polygons for corresponding water levels and use of indices instead of supervised classification in establishment of water areas.

Since this research was based mainly on data from multispectral satellite images it is of extreme importance to establish the typical spectral behavior for land cover class “water” in order to use it as reference. Such reference spectral curve was achieved by processing several spectral characteristics measured under laboratory conditions for pure and turbid water. The data for those characteristics were taken from spectral libraries adopted worldwide as reference standard and are being provided by USGS [Clark, (2007)] and JPL [Baldridge (2007)]. The curves we used as benchmark for comparison to those derived from the multispectral data we processed, are shown on Fig.1, and while on Fig.2 shown are the curves from real data obtained by Hydice and WorldView II instruments.

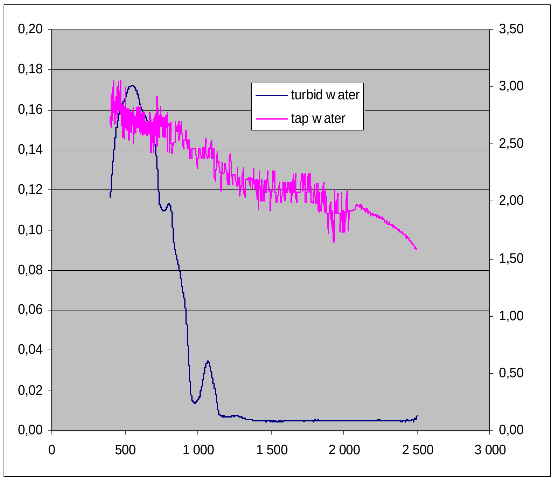

Fig. 1. Spectra for tap and turbid water from library

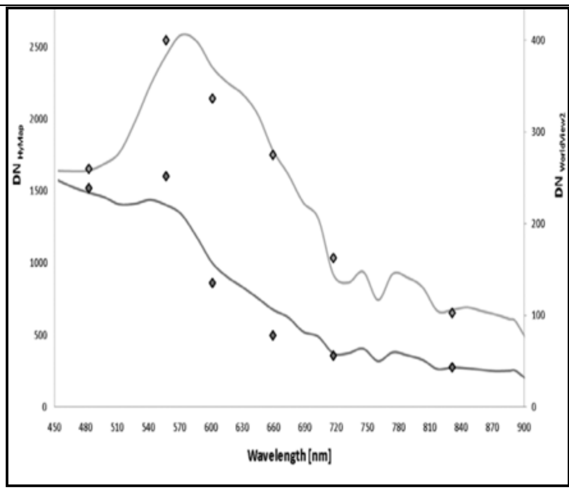

Fig. 2. Spectra from air/satellite borne instruments

The key indicator for identification of water areas in the multispectral images two indices were used – NDWI [Gao (1996), McFeeters (1996)] and MNDWI [Xu (2006)]. Although their limitations [Gudina (2014)] they are widely adopted and applied for creation of thematic layers. Both indices are defined by the following formulas:

$NDWI = \frac{(TM2 - TM4)}{(TM2 + TM4)}$	(1)
$MNDWI = \frac{(TM2 - TM5)}{(TM2 + TM5)}$	(2)

Data

During this research the main source of mulspectral images for the region we studied was the data from two instruments TM/ETM+ flying on Landsat5/7 satellites. The data from both instruments have been processed by the supplier, USGS, applying standardized procedure of Level 1 Product Generation System to equal spatial resolution of 30m, UTM projection and Cubic Convolution (CC) resampling to product level L1T. Due to malfunction of ETM+ instrument since 2003 it operates only in SLC-off mode [LSDUH, (2014)] making data from it unusable for the tasks set above and because of that for the years after 2003 we used data only from TM instrument.

All image processing and manipulation was done by Multispec remote sensing software freely distributed by Purdue University [Langrebe (2011)]. This software offers most of the functionality need for our research.

Data for the heights were obtained from a web site (Daftlogic, 2014) calculating them using information provided freely by Google Inc. The precision of those data was considered satisfactory for tasks to be solved (see Fig. 3). Output format of the data includes latitude and longitude in decimal degree, and above sea level in meters. The file produced is in CSV format which is directly used for shape file creation in GIS software.

Fig. 3. Point samples corresponding to heights

Other data used in the course of this research was those concerning water areas and volumes for certain year for the target selected (in our case Topolnitsa dam) acquired from a methodological report of the Executive environmental agency – Bulgaria. Those data were used for verification of the obtained results for the water areas.

Results

In the course of this research one image from 184 was processed and corresponding raster layers with NDWI and MNDWI were created. Based on them created were polygon layers for water area by manually digitizing on screen. During this process we faced problems with mixed pixels on the border of the polygons between water and other land cover type due to middle spatial resolution of the data used. This issue we overcome by setting a threshold for the MNDWI values at 0,6 i.e. only values higher than threshold was regarded as water (see Fig.4).

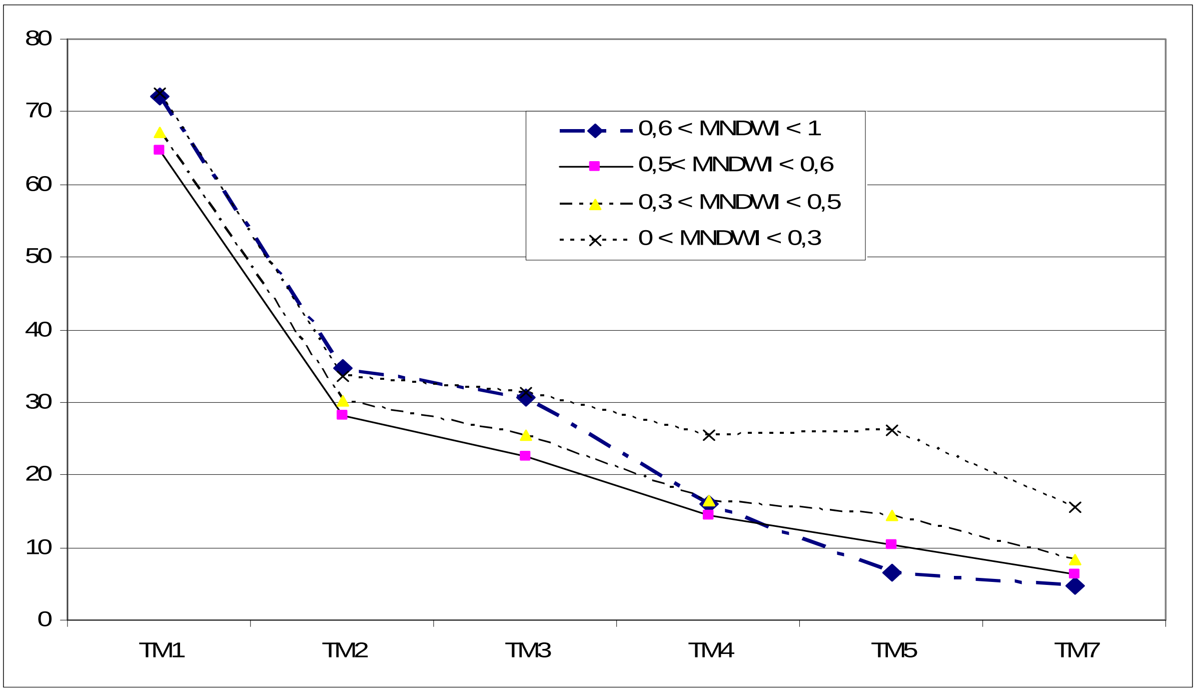

Fig. 4. Selection of threshold based on the average of MNDWI values

In order to check the correctness of the usage of MNDWI for water areas assessment we created new raster layers based on classification of raw DN values. The criterion for discrimination was again a threshold set for channels TM4-7 (due to specific absorption in these bands). Using the new raster layers polygons for the water areas were again drawn manually. Results from classification for both layers provided in Table 1 suggest that the difference of the areas between both methods could be due to the mixed pixels on the border line and the middle resolution of the sensor. Other possible cause is the peculiarity of the object selected since the area where the dam is located is relatively flat and some of the areas of the dam are shallow water or moors so a lot of vegetation is present which influences the reflectance values of initial data.

Table 1. Areas calculated by different means – threshold on raw values and MNDWI index

Year	Calculated area of the dam [ha]		Difference [ha]
	By threshold set to 18 DN for TM4-7	By MNDWI	
1984	444,33	382,68	61,65
1992	113,58	96,93	16,65
1993	258,75	239,85	18,9
2003	257,85	215,19	42,66
2007	223,83	166,59	57,24
2009	310,23	217,08	93,15
2011	196,83	149,58	47,25

Conclusion

In this research simple method for determination of the area of a water body is presented. As main discriminating feature MNDWI was used for creation of masking layers corresponding to the water areas. We found that similar results are achieved setting threshold on initial data. All results are obtained using only freely available data sources and software which sets a framework for future investigations having proven method.

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