COMPARISON OF SENTINEL WATER MASK AND OTHER INDICES FOR WATER MAPPING ON SENTINEL-2 IMAGES

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INTRODUCTION AND OBJECTIVES

Flooding is one of the most widespread of climatic hazards. It poses multiple risks to human health and economic growth. As periodic increases in water level in rivers and lakes are likely to become more common, more intense and larger in scale in many areas, it is important to monitor inland water surface using multiple data sources and methods. Remote sensing techniques are especially useful because the information about water extent can be provided in cost- and time-effective manner for large areas.

The main aim of this research was to test existing, commonly used water indices on datasets from sensor MSI onboard Sentinel-2 satellite and compare their results with a new index for water mapping – Sentinel Water Mask (SWM). The other aim was to determine if atmospheric correction is an indispensable step in the image pre-processing to obtain a satisfactory mask of water.

The use of Sentinel-2 optical images has been dictated by the fact that these data are free, have high spatial resolution (10, 20, 60 m), wide swath: 290 km and 13 spectral channels.

METHODS

Literature review and previous own research allowed to select the best three water indices: SWM, AWEInsh and MNDWI. For each of the four test areas, two datasets of Sentinel-2 imagery were prepared: before atmospheric correction (Top of Atmosphere, TOA) and after atmospheric correction (Bottom of Atmosphere, BOA).

After calculation of indices on all datasets, manual thresholding of results was carried out. Different values of thresholds have been tested and water masks were generated for each of them. The obtained waterbodies were validated using a set of 600 points distributed manually on the image, which maintained the same proportion between the classes water and non-water.

Visual and statistical analysis of water masks enabled to select the best index and threshold for all tested areas. In the end the result of statistical analysis was compared with the results obtained by other authors [1-3].

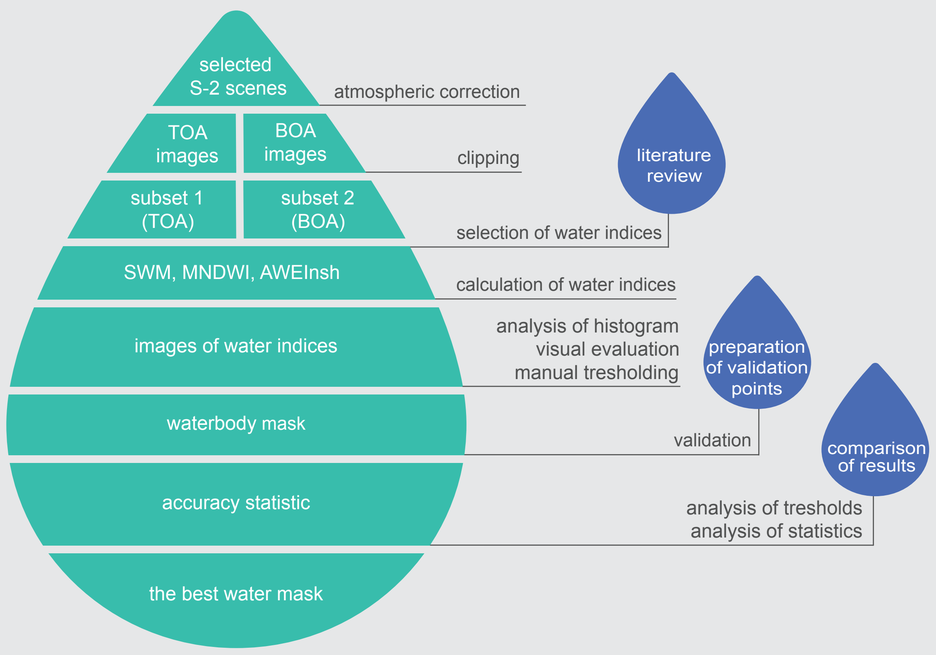


Fig.1. Methodology flow chart.

SENTINEL WATER MASK

Sentinel Water Mask is a new index [4] adapted to Sentinel-2 data before atmospheric correction. Analysis of TOA spectral reflectance curves for main land cover forms allowed for selection of spectral bands, among the ones with a spatial resolution of 10 and 20 m, those that are the most appropriate to construct the index formula (Fig. 2).

Sentinel Water Mask = (B2 + B3) / (B8 + B11)

The sum of bands with the highest water reflectance and relatively low reflectance for other land cover classes (B2, B3) was placed in the numerator of the equation. In the denominator, the sum of bands with low reflectance for water and high reflectance for other forms (B8, B11) was inserted. Such a combination of bands increases the ability to detect water by deepening the visual contrast and value separability between water and non-water areas.

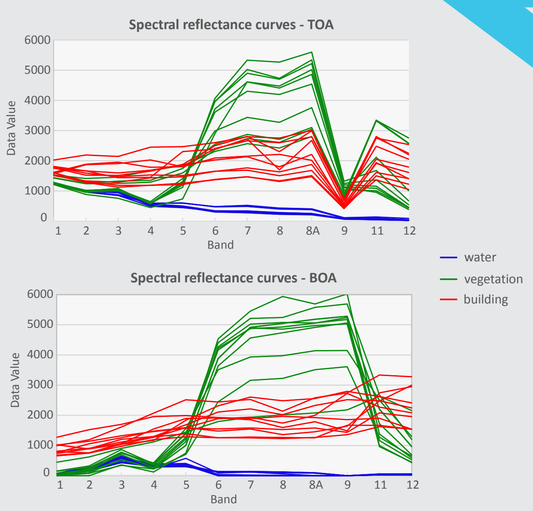
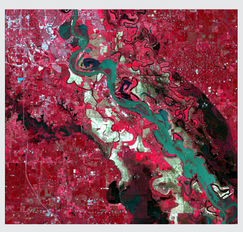


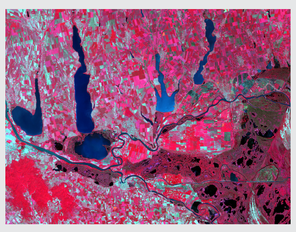
Fig.2. Spectral reflectance curves for main land cover classes.

TEST AREAS

For the needs of the study four test areas were chosen, varied in terms of location, land cover and season. The images were collected from spring to early autumn and contained rivers, lakes, flooded area as well as different land use forms: forests, farmlands, meadows, wetlands, build-up areas.



Red River, Louisiana, USA,
date: 20.03.2016,
subset extent: 31x28 km
flood area



Delta Danube, Romania/Ukraine,
date: 02.06.2017,
subset extent: 100x75 km
wetlands

Vistula Estuary, Poland,
date: 28.05.2017,
subset extent: 32x28 km
agriculture, built-up area

Dvina Estuary, Russia
date: 10.09.2017,
subset extent: 46x45 km
narrow rivers, built-up area

RESULTS AND DISCUSSION

Visual and statistical evaluation indicated that for all tested areas, water extents obtained based on the calculation of indices on images without atmospheric correction were more accurate than those computed on atmospherically corrected images. Water masks acquired from S-2 BOA images were incomplete, there were a lot of places where water was not detected. The exception was AWEInsh, which visually gave good mask both on TOA and BOA images. However, statistical analysis showed significantly better results for TOA images, even about 10-40% of Overall Accuracy.

The comparison of water indices is presented in Figure 3. Statistical analysis of results obtained using the most optimal thresholds is presented in Table 1.

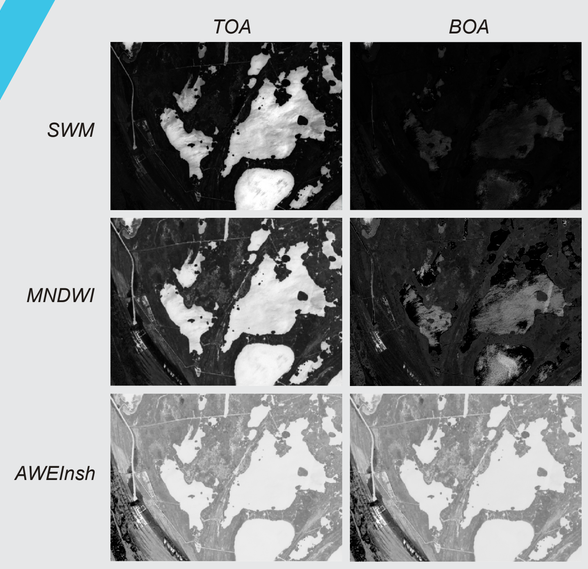


Fig.3. Comparison of water indices for TOA and BOA reflectance - Delta Dunube.

Tab.1. Accuracy assesement of indices for TOA and BOA reflectance.

		TOA			*BOA*		
Test area	***Indices***	**Thresh.**	**Over. Acc. (%)**	***Kappa Coeff.***	**Thresh.**	**Over. Acc. (%)**	***Kappa Coeff.***
1 - Red River	SWM	1.4	96.67	0.93	1.2	77.80	0.56
	MNDWI	0.3	88.67	0.77	0.30	74.46	0.49
	AWEI nsh	-500	89.83	0.80	-1000	80.63	0.61
2 - Delta Danube	SWM	1.4	99.17	0.98	1	63.67	0.27
	MNDWI	0.2	95.50	0.91	0	65.60	0.31
	AWEI nsh	0	96.50	0.93	-1500	85.00	0.70
3 - Vistula Estuary	SWM	1.4	98.67	0.97	1.2	71.48	0.43
	MNDWI	0.2	94.36	0.89	0.1	69.98	0.40
	AWEI nsh	-1000	98.18	0.96	-1500	75.29	0.51
4 - Dvina Estuary	SWM	1.6	95.83	0.92	1	52.17	0.04
	MNDWI	0.2	94.67	0.89	0.1	52.83	0.06
	AWEI nsh	0	95.50	0.91	-1500	76.50	0.53

Analysis of tested indices (SWM, MNDWI, AWEInsh) on images without atmospheric correction indicated that better results of water detection were obtained using SWM index. SWM achieved the highest Overall Accuracy and Kappa Coefficient. The range of the index values was between 0 and 12, while the optimal threshold for the tested areas was between 1,4-1,6. Moreover, SWM gave better water mask for problematic areas, such as narrow rivers, wetlands and built-up areas. The extents of water obtained with the use of MNDWI and AWEnsh tended to mix with wetland vegetation (Fig. 4).

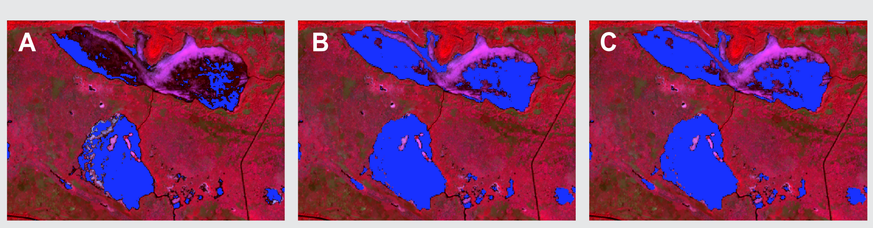


Fig.4. Comparison of water mask for TOA images - Dvina Estuary: A - SWM, B - MNDWI, C - AWEInsh.

Although AWEInsh also achieved satisfactory results, the wide range of values reaching tens of thousands made it difficult and time-consuming to determine the best threshold. The most frequently selected thresholds in this study were values -500 and 0.

The comparison of SWM index outcomes with those obtained for AWEInsh and MNDWI by other authors indicated that SWM achieved very good results. For all test areas SWM satisfied both measures of accuracy simultaneously: Overall Accuracy >= 95.00% and Kappa Coefficient >= 0.92 However, AWEInsh also met these conditions for two areas.

CONCLUSIONS

The comparison of water indices (SWM, MNDWI, AWEInsh) was made using Sentinel-2 images. The indices were calculated on satellite data before and after atmospheric correction.

In case of all tested indices, the water masks were more accurately determined on images without atmospheric correction (TOA), so this step can be omitted during pre-processing of data. Among analyzed indices the SWM ensured the best discrimination of water from other land cover classes. Good results were also obtained by AWEInsh.

SWM index achieved the overall accuracy 95.83 - 99.17%, MNDWI 88.17 - 95.5% and AWEInsh 89.83 - 98.18% (for TOA images).

The great advantage of using SWM index is its ability to detect water on images without atmospheric correction, which is a time-consuming process. This is very important in case of actions in the field of crisis management, for which the time of provision of situational information is a crucial factor in the decision-making process.

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