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How much open water do waterbirds have in the Banat Plain? The first permanent inland water bodies inventory at 10-m resolution using Sentinel-2 imagery at regional – scale

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Abstract

In the Banat Plain were recorded more than half of the number of bird species in Romania. There are eleven Nature 2000 Bird Protection Sites (SPAs) and in all of them have been registered aquatic bird species. The water surface areas were greatly reduced since the starting of the hydro-technical works 300 years ago. Nowadays, the anthropic pressure associated with the more frequent drought periods continues to threaten the water bodies, on whose existence the numerous aquatic birds depend. For the mapping and evaluation of open water surfaces in the Banat Plain, in the context of a lack of precise, consistent maps and data, the first water bodies inventory at 10-m resolution was made based on Sentinel-2 multispectral satellite images. The heterogeneous and fragmented landscape, with a great diversity of aquatic units, conducted us to develop an object-oriented approach, which allowed a multi-scale classification process. Both spectral bands and normalized differentiation water indices were used in the rule-based classification algorithm for water detection. The accuracy assessment indicated a very good overall accuracy of 96%, with a Kappa coefficient of 0.91. Also in our dataset, the small water bodies were mapped more accurately than in the other six water bodies datasets at global or European scale we compared with. The results drawn from both qualitative and quantitative assessments indicated that the water dataset developed in this study could be used as an inventory and a reference map for the permanent open water areas from the Banat Plain. It may represent the starting point for better aquatic management and elaboration of ecological strategies to support bird necessities and to counteract the increasing vulnerability and environmental threatening of waterbird species.

Keywords: *Water body inventory, Waterbirds, Sentinel-2, Object-based image analysis, the Banat Plain*

Rezumat. De câtă apă dispun păsările acvatice în Câmpia Banatului? Prima inventariere la scară regională a suprafețelor acvatice la o rezoluție spațială de 10 m utilizând imagini satelitare Sentinel-2

În Câmpia Banatului au fost consemnate peste jumătate din numărul de specii de păsări din România. Aici există unsprezece Situri de Protecție Avifaunistică (SPA) Natura 2000, în toate fiind prezente și specii de păsări acvatice. Suprafețele acvatice s-au restrâns foarte mult odată cu demararea lucrărilor hidrotehnice acum cca. 300 de ani iar în prezent intervenția antropică asociată cu perioadele secetoase tot mai frecvente continuă să amenințe suprafețele acvatice, de a căror existență depind numeroasele păsări acvatice. Pentru evaluarea suprafețelor acvatice, în lipsa unor hărți și date oficiale precise și actuale, s-a realizat prima cartare a suprafețelor ocupate de apă din Câmpia Banatului, la o rezoluție spațială de 10 m, pe baza imaginilor satelitare multispectrale Sentinel-2. Peisajul eterogen și fragmentat, cu o mare diversitate a unităților acvatice, ne-a determinat să utilizăm metoda de clasificare orientată – obiect, care a permis o abordare multi-scară. S-au utilizat atât benzile spectrale cât și indici normalizați de diferențiere a apei. S-au realizat două segmnentări ale imaginilor: prima a dus la obținerea unor obiecte ce au permis clasificarea unităților acvatice de mari dimensiuni iar cea de-a doua a avut ca rezultat generarea unor obiecte folosite penru detectarea suprafețelor acvatice mici. Clasificarea a avut o acuratețe generală foarte bună, de 96 %, cu un indice Kappa de 0.91. Setul nostru de date a fost comparat cu alte șase seturi de date ale suprafețelor acvatice la nivel global și european, observându-se o cartare mai precisă a corpurilor de apă de mici dimensiuni. Astfel, rezultatul acestui studiu reprezintă primul inventar a unităților acvatice permanente pentru Câmpia Banatului, la rezoluția de 10 m. Acesta poate fi utilizat ca suport pentru o mai bună gestiune a unităților acvatice în vederea elaborării unor strategii privind protecția păsărilor acvatice și al contracarării amenințărilor crescânde asupra habitatelor acestora.

Cuvinte-cheie: *inventarul suprafețelor acvatice, păsări acvatice, Sentinel-2, analiza imaginilor orientată – obiect, Câmpia Banatului*

Introduction

The essential role of the inland water bodies to terrestrial ecosystems, socioeconomic development, and global biogeochemical cycles is already well known (Harrison et al., 2008; Likens, 2009, 2013; Verpoorter et al., 2014). Inland waters and swamps represent the main habitat for waterbirds and play an important role for the stopover of migratory birds (Gyurácz et al., 2011). The degradation or loss of wetland stopovers has a negative influence on birds migration and survival (Merken et al., 2015). The small water bodies have also great importance for biodiversity and ecosystem services (Biggs et al., 2016) with the direct implication in waterbirds conservation or even in farmland birdlife (Davies et al., 2016). As they are belonging to the top level of the food chain, aquatic and semiaquatic birds represent biological indicators in aquatic ecosystems (Kupekar et al., 2015).

Despite this importance, for many areas of the Earth, a complete and accurate inventory of the water bodies is still missing. Thus, remote sensing data have been used often for the water bodies mapping, with different results according to the spatial resolution of the satellite images and the classification method. Most of the previous studies used Landsat imagery for water mapping, at a spatial resolution of 30 m. There were several normalized indices derived mainly from 30-m resolution Landsat imagery (Feyisa et al., 2014; Li et al., 2016; McFeeters, 2007; Shen & Li, 2010; Xu, 2007) but also from 10-m resolution SPOT multispectral bands (Lacaux et al., 2007) for better discrimination of the water from non-water areas. Some automated methods for water delineation from Landsat images were also developed, with promising results (Feyisa et al., 2014; Jiang et al., 2014; Rishikeshan & Ramesh, 2018). Since 2015, when the first Sentinel-2 satellite was launched, the European Space Agency (ESA) provides free images with a higher spatial and radiometric resolution and a shorter revisit time than Landsat, with great potential in the land cover mapping (Drusch et al., 2012). In the last five years, Sentinel–2 images had been used for water mapping based mainly on previous normalized indices, which were transferred and adapted to Sentinel-2 images, using both pixel-based and object-based image approaches (Du et al., 2016; Gordana Kaplan & Ugur Avdan, 2017; Wang et al., 2018; Yang & Chen, 2017; Yang et al., 2017). Although the majority of the previous studies were focused on smaller regions, there are some global inland water body datasets, at the medium and high spatial resolution, derived either only from remotely sensed data (Feng et al., 2015; Liao et al., 2014; Pekel et al., 2016; Verpoorter et al., 2014) or from remotely sensed data in association with other types of data and information (Lehner & Döll, 2004). There are also two datasets developed for Europe in the frame of the Copernicus Land Monitoring Service (https://land.copernicus.eu/), one of them being derived from Sentinel-1 and Sentinel-2 data (Table 3).

Study area

The Banat Plain is one of the largest plains of Romania, with an area about 7450 km2. It is located in the western part of Romania and it overlaps mostly over the Timis County and partly over Arad and Caraș – Severin Counties (Fig.1). The plain is formed by alluvial fans of the main rivers running from the Carpathians: Mureș River, in the northern part, and Timiș, Bega and Bârzava Rivers in the central and southern part (Badea et al., 2011). The mean altitude of the study area is 102 m. The maximum of 290 m is reached at the contact with the Banat Hills and the minimum altitude of 66 m is recorded in the western half part, where the entire area is subsiding. The slopes are gentle with a mean value below 2 degrees. The Mureș River, which is the most important river in the area, has a slope between 20 and 30 cm/km (Kiss et al., 2012). As a consequence, the area is distinguished by the meandering rivers, braided channels, abandoned river channels, oxbow lakes, ponds, and wetlands. In the past, the almost entire area of the subsiding plain was covered by wetlands, swamps, lakes, and low-order streams, but the hydro-technical works, started in the 18th century and continued to '70s of the 20th century, have decreased most of the water surface area and drained the majority of the swamps and wetlands (Kiss, 1999; Török-Oance & Török-Oance, 2004; Török-Oance & Török-Oance, 2005; Torok-Oance & Torok-Oance, 2005). Even so, the main rivers and the remnant small waters and swamps preserve rich biodiversity and a diverse waterbird species protected in 11 Natura 2000 Special Protection Areas (SPA) totalizing above 8% of the Banat Plain area.

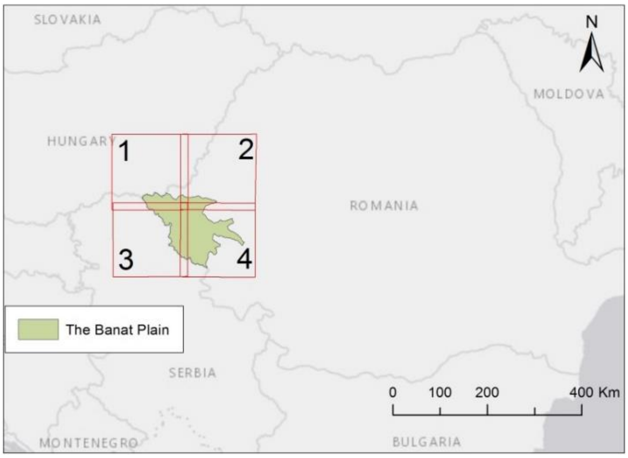

Fig. 1: Location of the Banat Plain and the swath of the Sentinel-2 images (1-4)

The objectives of this study are: (1) to realize the first permanent surface water bodies inventory of the Banatului Plain at the 10-m resolution, using Sentinel-2 multispectral data; (2) to evaluate the performance of this inventory by comparing it with similar water body datasets and statistical data; (3) to make a quantitative and qualitative analysis of the inland water bodies related to water birds life and conservation.

Materials and methods

Remote sensing data

Four clouds free Sentinel-2 scenes acquired on 12 October 2019 covering the Banatului Plain were used for the open water detection (Table 1). The Sentinel scenes were downloaded from Copernicus Open Access Hub (https://scihub.copernicus.eu/dhus/#/home).

The Sentinel-2 scenes are Level-2A products which are already orthorectified and radiometrically corrected in Bottom of Atmosphere (BOA) reflectance, provided in UTM/WGS84 projection.

Table 1. Sentinel 2 spectral bands used in this study with their radiometric characteristics and spatial resolutions

Spectral Band	Wavelength (µm)	Spatial resolution (m)
Blue (B2)	0.46–0.52	10
Green (B3)	0.54–0.58	10
Red (B4)	0.65–0.68	10
Near Infrared (B8)	0.784–0.9	10
Short Wave Infrared (B11)	1.565–1.655	20
Short Wave Infrared (B12)	2.1–2.28	20

The further pre-processing operations consist of mosaicking of all four scenes into a single one (SNAP 6 software) and the sharpening of the SWIR bands (ENVI 5.1 software). We downscaled the 20-m resolution SWIR band to 10 m based on pan-sharpening for preserving the detailed information available at the 10-m resolution in the normalized indexes computed from SWIR bands (Du et al., 2016). The SPEAR pan-sharpening algorithm implemented in ENVI software was used. Instead of the Panchromatic band, which is not provided by Sentinel-2 sensors, we used the NIR band (B8) (Du et al., 2016).

The computing of the Normalized Indexes used for water surface detection (Table 2) was done in SNAP 6 software. The Land and Water Mask (LWM) and Brightness were computed in eCognition software.

Table 2. The normalized indices derived from Sentinel-2 bands used for water surface detection.

Table 2. The normalized indices derived from Sentinel-2 bands used for water surface detection

Data	Equation/Description	Reference/data source
Normalized Difference Water Index (NDWI)	NDWI = (GREEN-NIR) / (GREEN+NIR) It detects the surface waters in wetland environments	McFeeters (2007)
Modified Normalized Difference Water Index (MNDWI)	MNDWI = (GREEN - SWIR 2) / (GREEN+SWIR 2) It enhances open water features while efficiently suppressing built-up areas, vegetation and soil noises.	Xu (2007)
Normalized Difference Ponds Index (NDPI)	NDPI = (SWIR 1 – GREEN) / (SWIR 1+ GREEN) It distinguishes small ponds and water bodies (down to 0.01 ha) and differentiates vegetation inside ponds from that in their surroundings	Lacaux et al. (2007)
Normalized Difference Vegetation Index (NDVI)	NDVI = (NIR – RED) / (NIR + RED) It distinguishes water from vegetation	(Rouse et al., 1974)
Land and Water Mask (LWM)	LWM = NIR/(Green+0.0001)*100 It distinguishes water from non-water areas	(Gilani et al., 2015)
Mean Brightness	It is calculated only for image objects, post-segmentation, using image layers with positive values (specific for eCognition software).	Reference Book eCognition Developer https://geospatial.trimble.com/products-and-solutions/ecognition

GREEN = green band ; RED = red band; NIR = near-infrared band; SWIR1= short wave infrared 1; SWIR2= short wave infrared 2

The spectral bands and normalized indexes were further used as input bands in the image classification process conducted in an object-based image environment in eCognition 9.1 software. The Multiresolution

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Segmentation algorithm (Baatz & Schape, 2000) implemented in the software eCogniton was used to subdivide the entire image and to obtain the image primitives. The algorithm relies on the scale parameter to subdivide the image into image objects. The scale parameter determines both the spectral heterogeneity and the average size of the image objects (Baatz & Schape, 2000) and also heavily impacts the classification accuracy (Gao et al., 2011). For enabling objectivity in choosing the scale parameter we used the Automated Estimation of Scale Parameter (ESP2) tool implemented in eCognition (Dragut et al., 2014). The tool estimates the appropriate scales for segmentation, based on the concept of local variance (Woodcock & Strahler, 1987) and works on multiple layers simultaneously. ESP2 was performed on the NIR band, NDWI MNDWI, and NDPI layers. We selected two values for scale parameters, 136 and 20 (shape = 0.1 and compactness= 0.5), from the local variance computed graph, related to the dimension of the water bodies. Compatibility and significance assessment of boundaries of the delineated objects was done by visual comparison.

The first segmentation, at a scale parameter of 136, had, as a result, bigger image objects used for the classification of the large water bodies. The second segmentation was computed on the unclassified pixels at scale 20 and generated smaller image objects which were used for the classification of the small water surfaces. Because of the great diversity of the water bodies and the high heterogeneity of the land cover, the delineation of the image objects in "water" and "no-water" classes, according to objects features, was made by a rule-based classification in three steps: first, we classified the well-highlighted larger and deeper water areas, like big lakes and reservoirs or large rivers sectors, based on threshold values for the NIR band and Brightness; second, we classified shallower waters based on thresholds values for NIR, MNDWI, LWM and Brightness and third, small eutrophic waters, sometimes surrounded by vegetation or included in wetlands, which were classified based on threshold values for the NDVI, NDPI, and Brightness. The few shadows areas in the proximity of the tall buildings in Timișoara misclassified as "water" were corrected using manually classification. In the final step, all three classes were merged into a single water class. The result was exported as shapefile for the integration and analysis in ArcGIS software.

Ancillary data

Ancillary GIS vector data were used for spatial analysis, zonal statistics and cartographic representation: the limits of Natura 2000 SPAs (http://www.mmediu.ro/articol/date-gis/434), the limit of the Banat Plain (Badea et al., 2011) and the map of the settlements from the study area.

Although some global water body datasets were developed, we used for the comparison only the available scale-similar inland water maps (Table 3).

Table 3. The global/continental inland water datasets and their characteristics

Water body dataset	Data used for the dataset building	SMWB (ha)	Reference/source
Global Lakes and Wetlands Database (**GLWD**) (vector dataset)	digitized inventories, archives, and remote sensing data from various sensor types	1	Lehner and Döll (2004)
GLCF global inland surface water dataset (**GLCF_GIW**) (30 m resolution)	Landsat	0.09	Feng et al. (2015)
Global Surface Water (**GSW**) (30 m resolution)	Landsat 5, 7 and 8	0.09	Pekel et al. (2016)
Water and Wetness 2015 (**WW 2015**) (20 m resolution)	Sentinel-1 and Sentinel-2	0.04	https://land.copernicus.eu/pan-european/high-resolution-layers/water-wetness
EU-Hydro* (vector dataset)	Various EO data; EU-DEM for drainage model	1	https://land.copernicus.eu/imagery-in-situ/eu-hydro
CORINE Land Cover inventory 2018 (**CLC 2018**) (vector dataset)	Various satellite data: Landsat 5, 7 and 8, SPOT 4 and 5, IRS P6 LISS III, RapidEye and Sentinel-2	25	https://land.copernicus.eu/pan-european/corine-land-cover/clc2018

SMWB = the smallest mapped water body; when this information was missing we considered that SWMB is equivalent to a one-pixel area in hectares

Ground-Truth Data and accuracy assessment

Very high resolution (VHR) Pléiades images, 0.5 m resolution color orthophoto, VHR images in GoogleEarth, GIS layers and GPS data collected in 2004 – 2016-time interval was used for the accuracy assessment. The 1500 sample points were randomly generated in a stratified random scheme, half of them in the water areas. The confusion matrix, the Kappa index and the overall accuracy (OA), producer's accuracy (PA) and user's accuracy (UA) (Congalton, 1991) were computed for the assessment of the results of the classification.

Results and discussion

A rule-based classification algorithm developed in an object-based image analysis environment was applied to Sentinel-2 Level-2A images over one of the largest plains in Romania, well known for its waterbird species richness (Kiss, 1999; Stănescu, 2005), in order to realize the first inland water bodies inventory at the 10-m resolution for this area.

The satellite images were deliberately selected at the end of the autumn season, after a long rainless time interval in an extremely droughty year, because we aimed to map the permanent water bodies. At the moment of the satellite images acquisition, after more than three months of water scarcity, the entire Banat Plain was affected by extreme agricultural and hydrological drought, according to Romanian National Meteorological Administration (http://www.meteoromania.ro), so the detected water areas represent the stable water habitat that water birds could rely on the whole year.

The inventory summarized 2396 inland water bodies (rivers, lakes, reservoirs, ponds, low-order streams, and ditches) with areas between 0.01 ha and 621 ha. The total area of detected open water surfaces is 3293.5 ha. The main rivers summarized almost 60% of the total open water area.

Qualitative analysis

Figure 2 illustrates the resulted image objects after the running of the two segmentation algorithms. Both the bigger image objects resulting after the first segmentation, using a scale parameter of 136 and the smallest ones resulting after the second segmentation, at scale parameter of 20, are significant and meaningful, their boundaries fitting well the water bodies.

A visual inspection of the classification results was first made by comparing it with VHR images and orthophotos (Fig.3). Special attention was accorded to the long-time monitoring areas where the seasonality of the water bodies was well known (Török-Oance & Török-Oance, 2016).

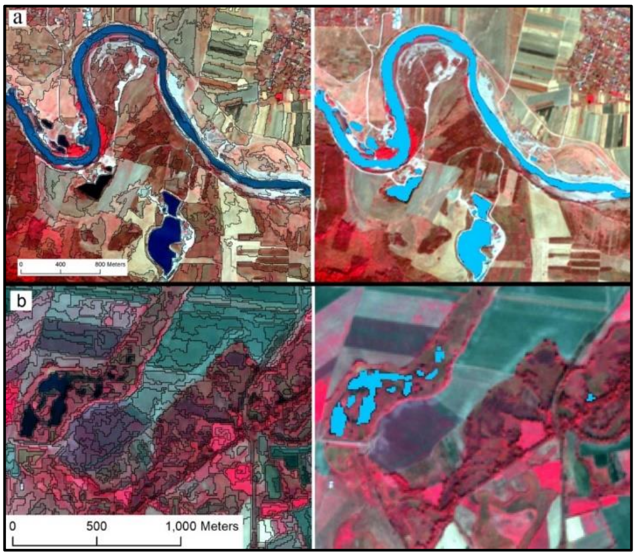

Fig. 2: Segmentation (black outlines) and classification results (light blue polygons) draped on NIR false-color image: (a) bigger image objects used for the classification of the big rivers and lakes (mixed agricultural and forest area along the Mureș River); (b) smaller image objects used for the classification of the small waters (mixed agricultural and swamps area in the Mlaștinile de la Satchinez SPA)

Fig. 3: Visual comparison of the detected water (blue polygons) with Pléiades 2-meters resolution image (Beregsăul Mare village)

We have to mention that our inventory has some limitations like any other map derived from remote sensing data. The detected water surface is slightly underestimated because the water detection was limited by the spatial resolution of the satellite images which is 10 m. All water surfaces with an area below 0.01 ha or narrower than 10 m could not be detected. Another issue was the riparian vegetation because in many cases, the trees canopy masked the water surface mainly along the small rivers and ditches (Fig 4).

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Fig. 4: Small ditches south of Bârzava River (light blue pixels) which could not be mapped because of their width smaller than a Sentinel-2 pixel

The quantitative assessment

The OA recorded an excellent value, more than 95% of the detected water areas were correctly classified from the total number of validation areas (Congalton, 1991). At the water class level, the commission error (UA) was 0.96 and the omission error (PA) was 0.94. The Kappa Index of Agreement (KIA) was 0.91. The very high level of the classification accuracy sustained that the resulting 10-m resolution dataset derived from Sentinel-2 imagery could be used as an inventory and a reference map for the Banat Plain. A similar higher accuracy of the classification was obtained using object-based image analysis methods (Blaschke, 2010; Cheţan et al., 2018; G. Kaplan & U. Avdan, 2017).

Comparison with previous global and European water datasets and national statistics

Both visual and quantitative comparison was made between our water inventory and other similar scales water datasets (Table 5). Even if the smallest mapped water body has a surface between 0.04 ha and 25 ha, none of the above-mentioned datasets were able to accurately map the inland waters from the Banat Plain (Fig. 5). In the area presented in this figure, there are many lakes with areas between 3 and 6 ha which are not present in any of the datasets. On the GLCF_GIW dataset, only a few water areas are mapped along the river, smaller than the lakes in the nearby area which are not mapped. GSW dataset mapped both river segments and some lakes located in the floodplain. Both datasets are greatly underestimating the real water surface. The WW 2015 dataset mapped well the river and many of the lakes but there are still many missed lakes, even their areas are similar to the mapped ones. On the CLC 2018 vector dataset appears only the river which is highly overestimated; the area of each of the lakes is below the minimum mapping unit which is 25 ha so they could not be mapped. The maximum width of the Timiș River in this area, measured on VHR satellite images is 101 m, but on the CLC 2018 map it is above 400 m. In the Eu-Hydro vector dataset, the river was well mapped but almost all the lakes are missing.

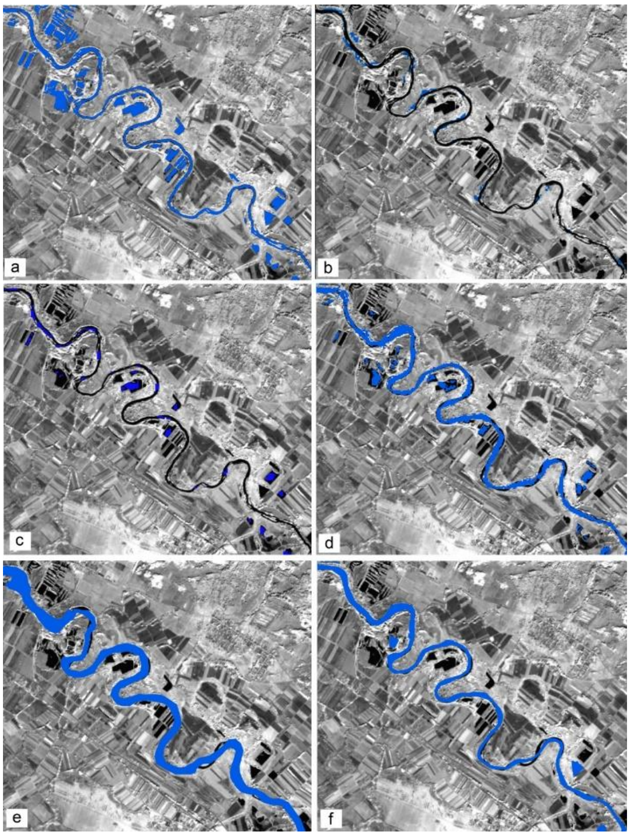

Fig. 5: The comparison of the water bodies detected in this study (a) with other global or continental water bodies datasets: (b) GLCF_GIW at 30 m resolution; (c) GSW at 30-m resolution; (d) WW 2015 at 20-m resolution; (e) CLC 2018 vector dataset; (f) EU-Hydro vector dataset. The area in the image is located along the Timiș River, south to Lugoj City.

The abbreviations are according to Table 3

There are also great differences in the total water area in hectares computed from each dataset for the study area (Table 4). The vector datasets are greatly overestimating the area of water mainly because of the dataset building methodology (https://land.copernicus.eu/pan-european/). Not a single water body was mapped in the GLWD dataset for the study area. Both 30-m resolution datasets, GLCF_GIW and GSW present lower water areas, below 2000 ha.

Table 4. The total water area in the Banat Plain computed from different water datasets

Water body dataset	Area (ha)
GLWD	0
GLCF_GIW	1935.7
GSW	1561.5
WW 2015	2750
CLC 2018	10741.4
EU-Hydro	4698.76
10-m resolution dataset derived from Sentinel-2 images	**3293.50**

The National Institute of Statistics (INS) provided through the TEMPUS Online portal (http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table) statistical data regarding the terrain land cover. Since the data are provided at an administrative unit level and not for physical-geographical units, we could only use the data for the Timiș County. This county contains more than 85% of the Banat Plain area. The total area occupied by waters in Timiș County was, for the 2014 year (the most recent year in the database) 15275 ha which represents an area 6 times larger than the one we found in this study and also larger than CLC 2018. This difference could be explained by the fact that the INS data are based on old 1992 topographical surveys and in the class "Land covered with water, ponds" are included also the wetlands, so these data could not provide useful information about open water surfaces.

The maps derived from remote sensing data, at an appropriate spatial resolution, remain the best alternative in areas with high seasonal water dynamic and an increasing anthropic impact and where the official data are inconsistent and not updated.

Waterbody inventory at SPA sites level

In these 11 SPA sites from Banat Plain, there have been recorded 26 species of waterbirds (European Environment Agency) which are included in annex 1 of the Birds DIRECTIVE 2009/147/EC. The species belong to six orders (Gaviiformes, Pelecaniformes, Ciconiiformes, Anseriformes, Gruiformes, and Charadriiformes) and are representatives of eleven families (Gaviidae, Phalacrocoracidae, Ardeidae, Ciconiidae, Threskiornithidae, Anatidae, Gruidae, Rallidae, Recurvirostridae, Scolopacidae, Sternidae). The most numerous waterbird species are recorded for Lunca Mureșului Inferior and Mlaștinile Satchinez.

Regarding conservation status, all aquatic and semiaquatic bird species reported for the 11 protected areas and included in annex 1 are classed at least concern (LC) according to the European Red List of Birds (BirdLifeInternational, 2015). In Romania though, encountered species as Phalacrocorax pygmeus, Nycticorax nycticorax, Ardeola ralloides, Ciconia nigra, Ciconia ciconia, Plegadis falcinellus, Aythya nyroca, Crex crex, Recurvirostra avosetta, are considered vulnerabile species and Ardea purpurea, Platalea leucorodia, Egretta garzetta, Himantopus himantopus are considered threatened species (Botnariuc & Tatole, 2005).

Beside these species corresponding to annex 1 of the Birds Directive, which need special conservation measures, many other present species also depend on the existence of water and contribute to existing avian biodiversity. Thus, in Mlaștinile Satchinez SPA have been identified over the years 167 bird species (Stănescu, 2005) and in the Banat Plain 114 waterbirds species (Kiss, 1999).

The present analysis reveals that, according to official data from 2007, the total area of the 11 SPA sites is 63328.40 ha, from which water occupies an area of 1669.19 ha (Table 5), which represents 2.6%. The water area detected in this study is even smaller, only 2.25%, most probably due both to the extreme drought in the summer of 2019 and the anthropic impact during the last 12 years. The most significant open water area, above 870 ha, was detected in Lunca Mureșului Inferior SPA, but it is significantly smaller than the official reported water area. The Mureș River summarize 98% of the total detected open water area in this SPA and sustained the greatest number of protected waterbird species (21 species) from all protected areas in the Banat Plain.

There are two SPA sites where we detected almost no water surfaces. In the first one, Hunedoara Timișană SPA, are reported only two waterbird species that are sustained by the existing wetlands. In the second one, Mlaștinile Satchinez, there are 66% waterbirds (21 species) from the total of protected birds in this SPA which rely on the extended wetlands included in the SPA area and mostly on the nearby open water surfaces, outside the protected area (Kiss, 1999; Stănescu, 2005; Török-Oance & Török-Oance, 2016). A special situation, most probably a data omission, is recorded in Lunca Timișului SPA, where, in the official data, are not mentioned water surfaces but 39% of the reported protected birds are waterbirds. We detected over 246 ha of open water, represented mainly by the Timiș River which is crossing the site on its entire length.

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Table 5. The Natura 2000 SPA in the Banat Plain – relevant data

Site Code	Site Name	Total area (ha)*	Area of open water (ha)*	Area of the detected open water (ha)	Number of protected birds' species**	Water-birds species (%)
ROSPA0047	Hunedoara Timișană	1537	0.00	0.00	14	14
ROSPA0069	Lunca Mureșului Inferior	17428	1391.79	873.73	46	46
ROSPA0078	Mlaștina Satchinez	268.3	0.00	0.11	32	66
ROSPA0079	Mlaștinile Murani	301.9	75.86	55.02	4	75
ROSPA0095	Pădurea Macedonia	4625.3	0.00	67.08	17	53
ROSPA0126	Livezile - Dolaț	6564.6	0.00	0.00	10	30
ROSPA0127	Lunca Bârzavei	2393.3	71.62	109.22	11	64
ROSPA0128	Lunca Timișului	13404.1	0.00	246.78	28	39
ROSPA0142	Teremia Mare - Tomnatic	6627.7	0.00	3.34	8	38
ROSPA0144	Uivar - Diniaș	10043.3	0.00	25.37	17	47
ROSPA0164	Pescaria Nadlac	134.9	129.91	71.72	11	82
TOTAL		**63328.4**	**1669.19**	**1425.37**		

** Official data from the European Environment Agency (EEA) site (https://www.eea.europa.eu/).*
*** According to Annex 1of the Birds Directive*

The total area of open water surfaces we detected for the entire protected areas is lower than in the official records. It represents the permanent water bodies that remain even after a long drought period. Open waters are used by birds for feeding, resting, and breeding. It has been suggested that between the most important environmental factors to which birds respond is the open water area and the ratio between emergent vegetation and open water (Pyrovetsi & Crivelli, 1988). Many studies showed that for the study area the open water decreased in the last 50 years and the clogging of the wetlands is the synchronous process in some areas (Kiss, 1999; Stănescu, 2005; Torok-Oance & Torok-Oance, 2005). For waterbirds, open water surfaces have great importance, both in launching to flight and landing from flight. In this regard, the reduction of open water spaces has a negative effect on waterbirds, especially geese and ducks (Stănescu, 2005). When landing on water surfaces, larger water birds need greater braking distances (Hart et al., 2013).

Water bodies are also important stopovers for wetlands migrant birds (Gyurácz et al., 2011; Pocewicz et al., 2013), so efforts for the maintaining or restoring of the water surfaces were made. It was shown that the restoration of water surface could restore migrant bird populations (Gyurácz et al., 2011) or, even when the restoration succeeded only partially, the waterbirds feeding area was extended (Török-Oance & Török-Oance, 2016). The small waters are also important, many of them could be refuges for species which have disappeared from larger, more damaged, waterbodies (Biggs et al., 2016).

Conclusion

As open water is of great importance for waterbirds, an accurate assessment of the water surface offers the information which may serve to further better protection of birds. The existing official data regarding the water bodies in the Banat Plain, where the seasonality of the water is high and the anthropic impact is increasing, are not consistent enough and are not proper to support applications for waterbirds and biodiversity conservation. In this situation, the water body maps derived from appropriate spatial resolution remote sensing data represent a suitable solution.

We produced the first permanent water body inventory at a 10-m resolution at a regional-scale, for the Banat Plain. Given the great diversity of the water bodies and the high heterogeneity of the land cover, the object-based image analysis allowed us a multiscale classification approach which led to a better result. The very good performance of the classification algorithm (overall accuracy of 95% and a Kappa coefficient of 0.91) sustained that the resulting dataset could be used as an inventory and a reference map for the open water areas from the Banat Plain. Also in our dataset, the small water bodies were mapped more accurately than in the other six water bodies datasets at global or European scale we compared with. It may represent the starting point for better aquatic management and elaboration of ecological strategies to support bird necessities and to counteract the increasing vulnerability and environmental threatening of waterbird species. Since we mapped the permanent water bodies, the dataset could be also used further as a feasible, stable, training data set for the development of machine learning classifiers for mapping complex water.

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