Development of semi-automated approach for wetland habitat mapping from multi-temporal Sentinel-2 imagery

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Abstract

Mapping and monitoring wetlands has strong societal relevance. Remote sensing offers a cost-efficient means, among which Sentinel-2 imagery with high spatial resolution and improved revisiting frequency is expected to have significant potentials. Here we present some results of pilot sites from our project GlobWetland-Africa using multi-temporal Sentinel-2 data for land cover/use mapping in and around wetlands in Africa. A supervised machine learning algorithm Random Forest was adopted, integrating various remote sensing derived vegetation and water indices, seasonality indices, textural features and topographical information. The proposed method achieved an overall accuracy over 90% for the pilot sites. The reliable mapping results suggest that this is a promising tool that has a potential to facilitate the management of local and regional wetland resources.

Introduction

Wetland is an important ecosystem that provides numerous beneficial ecosystem services and critical habitat for fish and wildlife. Accurately mapping and monitoring various wetland habitats and the surrounding land covers/uses can facilitate the understanding and management of wetlands. However, wetland habitat mapping is complex, as a dominant land cover may comprise several different habitats, without having significantly different spectral characteristics. Combination of different data types (e.g., optical and radar remote sensing, in situ environmental data and land use information) broaden the possibilities of identifying the habitats in and around the wetlands. In the GlobWetland Africa project, semi-automatic workflows are developed for wetland habitat mapping with the focus on Africa using multi-temporal Sentinel-2 data.

Objective

To provide a detailed classification of land covers/uses, in particular of the wetland habitats, in and around wetland sites.

Three pilot sites are presented: Burullus Lake (4110 km^2) in Egypt, Ichkeul Lake (522 km^2) in Tunisia and Saloum Delta (6162 km^2) in Senegal.

Methods

Data sources

- Sentinel-2 imagery: 10 bands with 10- and 20-m spatial resolution
- DEM: SRTM 1 Arc-Second Global DEM dataset
- Ground truth data: in-situ data or collected by visual interpretation of very high-resolution imagery from Google Earth (60% randomly selected for training and the remaining 40% withheld for testing).

The classification scheme (Table 1) is a hybrid and modified system based on European CORINE land cover mapping scheme and wetland typology under the Ramsar Convention [1].

Level I	Level II	Level III	Level IV
Wetland	Water bodies	Sea and ocean	Permanent shallow marine waters
			Marine subtidal aquatic beds
		Lakes	Permanent freshwater/saline lakes
			Seasonal freshwater/saline lakes
		Rivers/channels	Permanent rivers
			Seasonal/intermittent/irregular rivers
			Canals and drainage channels, ditches
		Artificial ponds	Aquaculture ponds
			Water storage areas
	Mudflats		Intertidal mud, sand or salt flats
			Seasonal/intermittent/irregular flats
	Marshes		Intertidal marshes
			Permanent freshwater/saline marshes
			Seasonal freshwater/saline marshes
	Tree/Shrub-dominated wetlands		Intertidal forested wetlands
			Freshwater tree/shrub-dominated wetlands
	Irrigated land		
Dryland	Artificial surfaces, Agricultural areas (dry), Forest, Shrubland, Grassland, Sparsely vegetated areas, Bare land		

Table 1: Classification scheme of wetland habitat mapping in GlobWetland Africa

The workflow applied in the study is shown in Figure 1. The classification method is based on Random Forest [2]. Apart from the surface reflectance, the input data included various vegetation and water indices (i.e, NDVI, mNDWI, difference between NDVI and NDWI, two red-edge NDI), seasonality indices (statistics of multi-season NDVI), Haralick's texture features and topographical information.

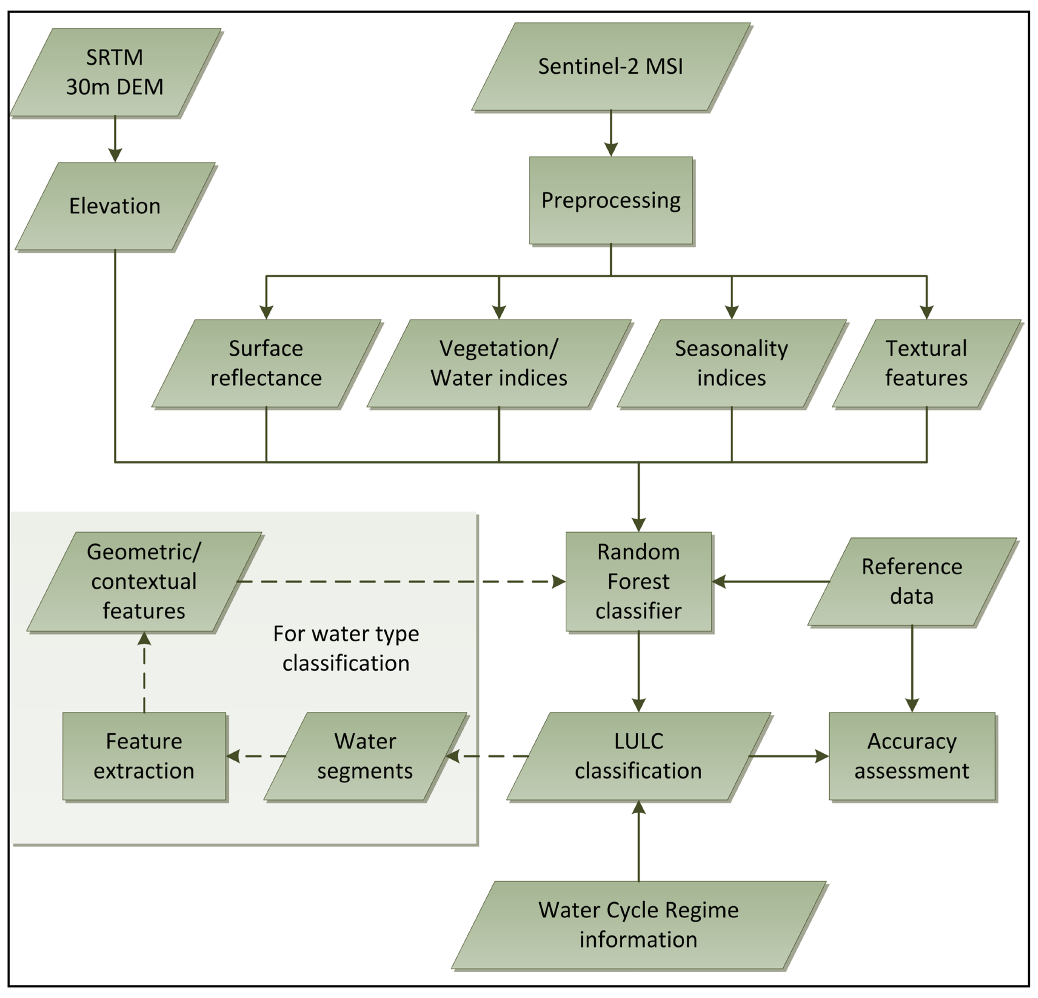

Figure 1: Workflow of the study

Results

• Burullus Lake
Map (Figure 2) produced from Sentinel-2 image of 1 May 2016 with an overall accuracy of 91.8% (kappa 0.90).

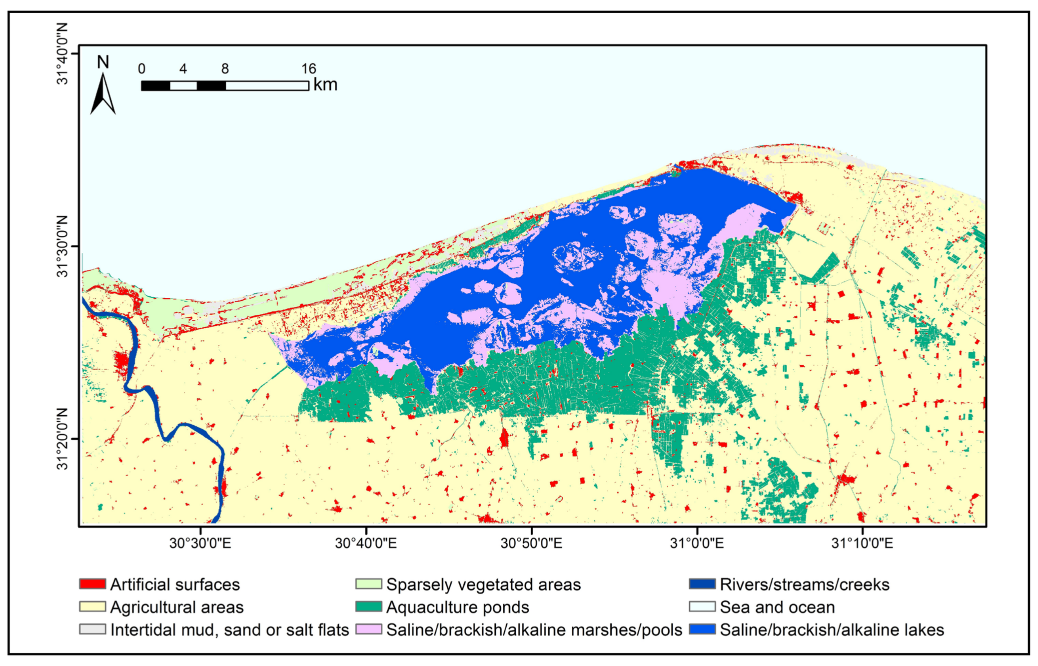

Figure 2: Wetland habitat map of Burullus Lake, Egypt

• Ichkeul Lake
Map (Figure 3) produced from Sentinel-2 images of 19 February 2016 and 27 August 2016 with an overall accuracy of 93.2% (kappa 0.91).

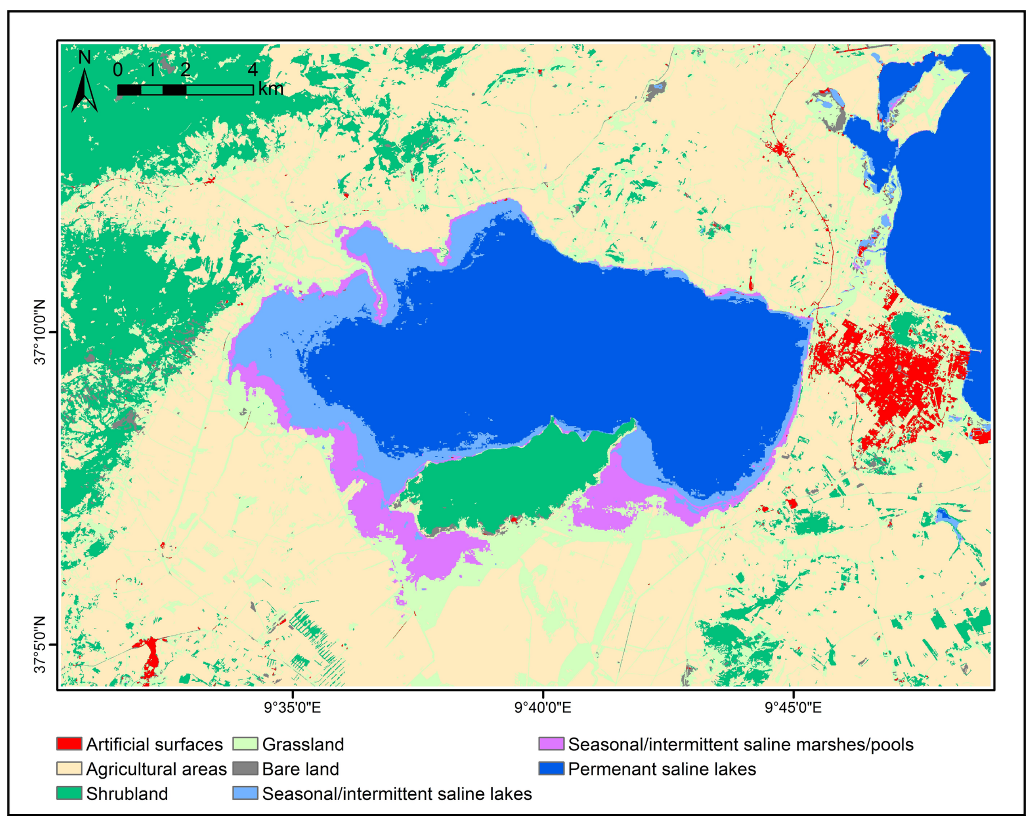

Figure 3: Wetland habitat map of Ichkeul Lake, Tunisia

Major References

[1] Ramsar Convention Secretariat. (2013). The Ramsar Convention Manual: a guide to the Convention on Wetlands (Ramsar, Iran, 1971) (6th ed.). Gland, Switzerland: Ramsar Convention Secretariat.
[2] Breiman, L. (2001). Random forests. Machine Learning, 45(1), 5-32.

• Saloum Delta
Map (Figure 4) produced from Sentinel-2 images of 4 February 2016 and 11 October 2016 with an overall accuracy of 90.5% (kappa 0.88).

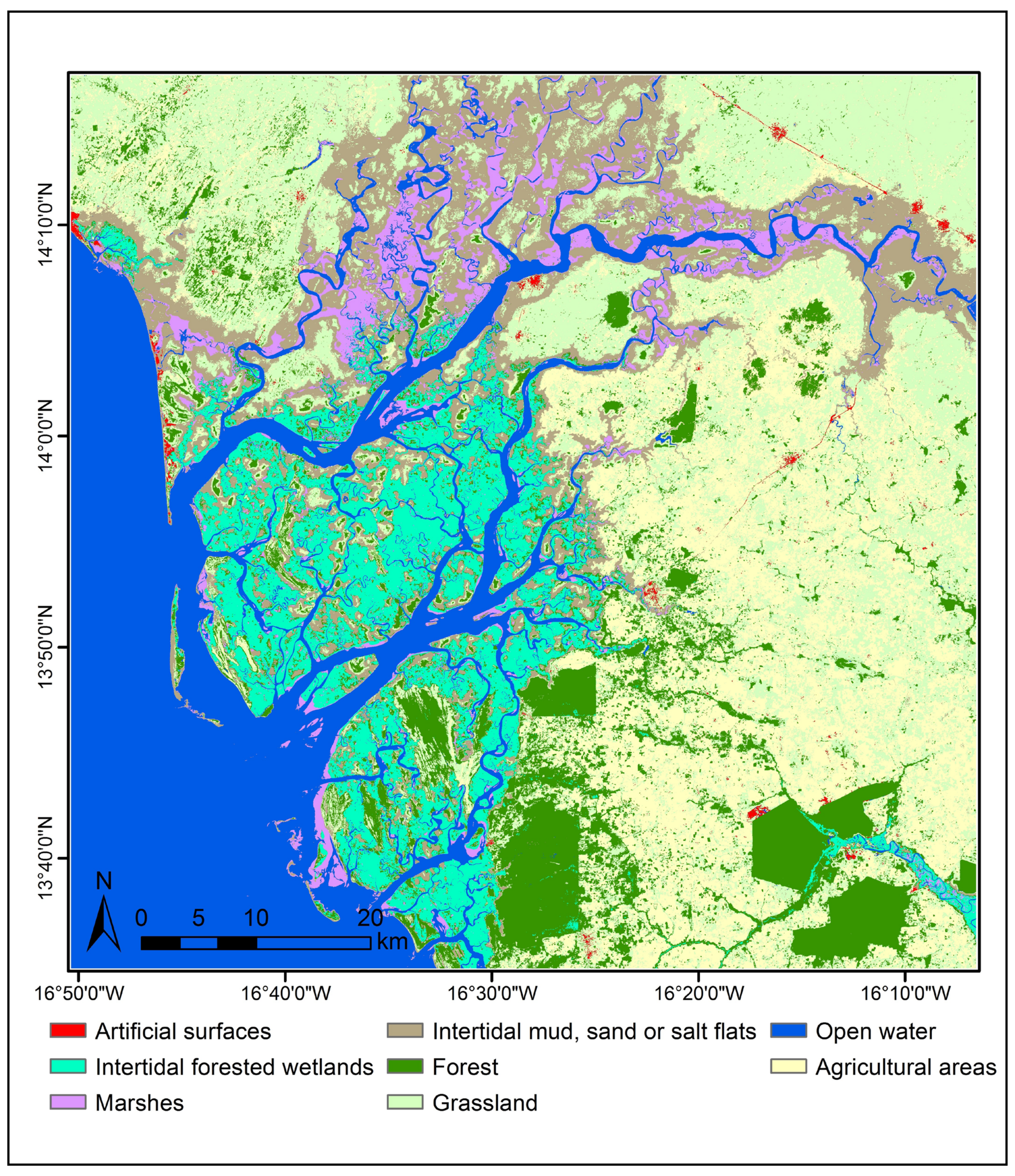

Figure 4: Wetland habitat map of Saloum Delta, Senegal

For all pilot sites, the proposed method achieved significantly higher mapping accuracy compared with classifications using only surface reflectance data based on a McNemar's test (P<0.01). The producer's and user's accuracy for each class was higher than 80% (results not shown).

Discussions

- Combining the spectral, textural and topographical features can significantly improve mapping accuracy.
- Using multi-season NDVI features may capture seasonal patterns of variation of vegetated land surfaces and improves the classification.
- Wetlands are highly dynamic so that the land covers may also change over time. Water cycle regime information could be integrated to further distinguish permanent/seasonal wetland classes.

Conclusion

This study presents an approach to map wetland types related to the Ramsar wetland classification system based on multi-temporal Sentinel-2 data. The high level of accuracy suggests the derived product can be considered as satisfactory. Future work will further improve the transferability and automation of the map production, and explore the integration of radar data into the classification for areas with extensive cloud contamination.

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