POLICY BRIEF

May 2020
The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

Remote sensing toolkits for monitoring freshwater ecosystems under global change in South Africa

Remote sensing is a valuable tool for monitoring wetland extent and other attributes at a regional scale. It provides a means of automating the mapping of the extent of inundated and palustrine wetlands, and the quantification of soil moisture, above ground biomass, nutrients, phenology and the hydrological regime. If measured at intervals using consistent methods, these values can show changes over time. The findings and data obtained during this project provide valuable information in support of the long-term inventorying of wetlands in the National Wetland Maps and the National Wetland Monitoring Programme of South Africa.

BACKGROUND

Oblique photograph taken by Mr Anton Linström of Tevredenpan in a south-westerly direction.

Freshwater ecosystems are considered to be one of the most threatened ecosystems in the world. In South Africa, the National Biodiversity Assessments (NBAs) of 2011 and 2018 have shown that wetlands are inadequately mapped, highly threatened and poorly protected. Inventorying and monitoring of these ecosystems is, therefore, a top priority, not only for NBAs but also for the National Wetland Maps of the South African National Biodiversity Institute (SANBI), and the National Wetland Monitoring Programme (NWMP) of the Department of Water and Sanitation (DWS).

For the past fifty years, remote sensing has been an important data source in mapping inundated wetlands (open waterbodies). New sensors launched since 2008 have greatly improved the capability of remote sensing for mapping of palustrine (vegetated) wetlands to species or habitat levels, in addition to quantifying above ground biomass, nutrient levels and soil moisture content at a regional scale.

Since 2014, the European Space Agency (ESA) has launched the Sentinel-1, -2 and -3 sensors and has made images freely available to the public. This presents an ideal opportunity for assessing the capabilities of these sensors in the mapping of wetlands for the National Wetland Maps and the monitoring of wetlands in South Africa.

From 2016 to 2020 the WRC funded a study, led by the Council for Scientific and Industrial Research (CSIR), which assessed the potential of new space-borne sensors such as Sentinel for the inventory and long-term monitoring of palustrine wetlands, as part of freshwater ecosystems, in the face of global change. The study has resulted in deeper understanding of the capabilities of the current, freely available, space-borne sensors, Sentinel-1 and Sentinel-2, for the detection and monitoring of wetlands.

Key facts

Previously, inundated wetlands were more easily mapped than palustrine wetlands. However, inundated wetlands constitute only one tenth (11%) of all inland wetlands in South Africa, whereas more than half of all wetlands are estimated to be vegetated. Vegetated wetlands were poorly represented in the latest National Wetland Map version 5 (NWM5) of South Africa, so accurate data on the extent of open water and palustrine wetlands are necessary for reporting. For example, vegetated and inundated wetlands are components of the United Nations Sustainable Development Goal indicator SDG 6.6.

SDG Indicator 6.6. Goal: By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.

The Sentinel optical images now contribute to a finer spatial resolution (10-20 m) of mapping and monitoring features in South Africa, compared with the 30 m resolution of Landsat images. Sentinel data have enabled improved land cover mapping in South Africa, and have contributed to operational monitoring of such diversity features as eutrophication, water bodies and fires. The sensors have three red-edge bands and two shortwave-infrared bands, which are expected to provide better mapping and monitoring of palustrine wetlands and their properties.

Photo: Anton Linström

MAIN FINDINGS

The National Wetlands Monitoring Programme (NWMP) would benefit from the inclusion of remote sensing as a tool for the continuous detection and mapping of wetlands across hydrological regimes and phenological phases. Information products include the extent of open water and palustrine wetlands and measurements soil moisture, above ground biomass, nutrients and the hydrological regime information.

Spectra from wetland vegetation were found to be highly separable from upland vegetation in the Grassland biome for two study areas, including Tevredenpan in the Mpumalanga Province and Hogsback in the Eastern Cape Province. Sentinel-2 attained high accuracies for mapping wetland vegetation communities, comparable to, or slightly less than those attained by using proprietary WorldView-3 images. Sentinel-2 can, therefore, make a valuable contribution to improved mapping and monitoring of palustrine wetlands in South Africa.

An assessment of the sizes of South African wetlands represented in NWM5 estimated that current, freely available multispectral space-borne sensors with a spatial resolution of 10 m or better would be able to detect more than 69% of the aerial extent of wetlands. Images with a spatial resolution of at least 10 m, such as Sentinel-2, should, therefore, be suitable for monitoring changes in wetlands at a regional scale. Smaller wetlands are poorly represented in NWM5, so the percentage of wetlands that could be monitored may be overestimated. Fine-scale studies show that wetlands on slopes greater than 10% will likely require images of higher spatial resolution (better than 10 m) compared to those on slopes less than 10%.

Wetland maps for the Hogsback and Tevredenpan study areas (±8 000 ha in extent) were greatly improved through the use of WorldView-3 images (1.24 m spatial resolution) and in-field visits. Wetland extent increased from 2.5% mapped in NFEPA wetlands to 15% mapped from more recent WorldView-3 satellite images for Hogsback, and from 11% to 43% for Tevredenpan.

The Sentinel sensors were able to predict above ground biomass of wetland vegetation with accuracies comparable to those of WorldView-3. This means that large changes in above ground biomass can potentially be detected and monitored at a site scale for vegetated wetlands in the Grassland biome. Above ground biomass is an important contributor to the process and health of peat wetlands. Climate change is expected to reduce the amount of above ground biomass in wetlands: seasonal monitoring of the amount and phenology will provide early warning of vegetation loss.

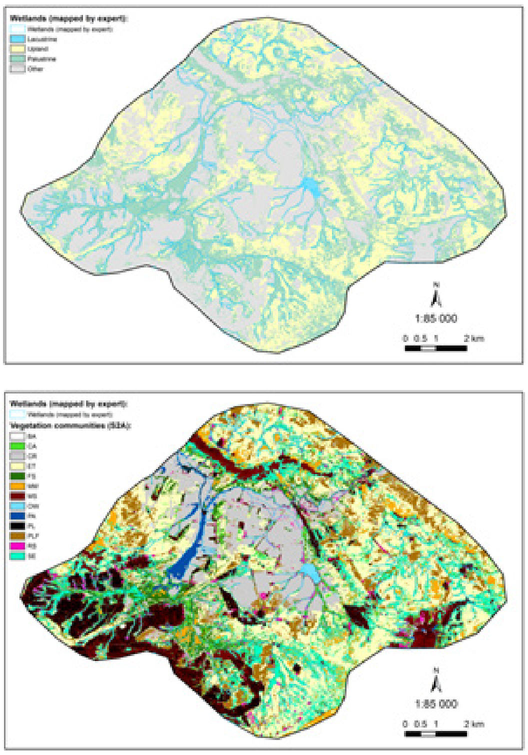
The Sentinel optical and Synthetic Aperture Radar (SAR) sensors show potential for estimating soil moisture content (SMC) across a wetland-upland gradient. The optical and the SAR sensors provided sufficient information for quantifying

SMC in a palustrine wetland of the Grassland biome (Pretoria, South Africa) and could, assist in improving the future mapping of wetland extent and hydrological regime.

The higher frequency of Sentinel-2 image capture, compared with Landsat, improves the determination of the maximum extent of inundated depressions. This is important information for SDG 6.6 reporting, and for characterising hydroperiod classes for the inventory of wetlands.

RECOMMENDATIONS

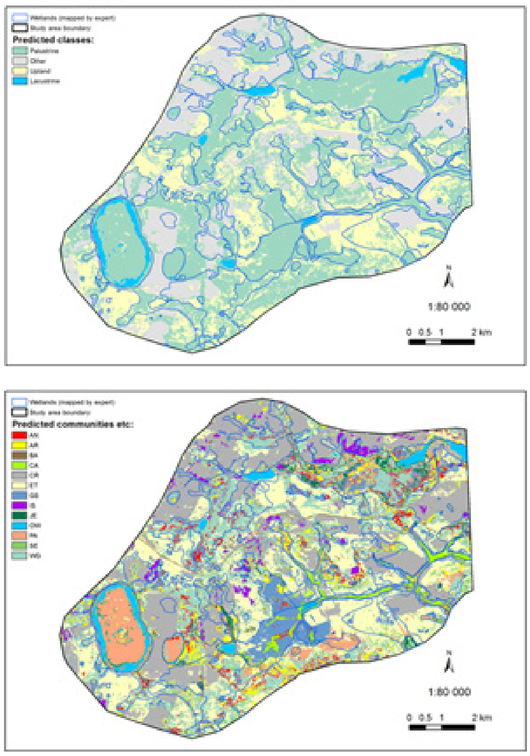
Further work will be required towards determining how remote sensing indices can be used to represent and monitor the ecological condition of wetlands over time. For example, in situ monitoring for the NWMP can be supplemented by regional and broad-scale remote sensing indicators of wetland health. However, before implementing such complementary indices for tracking wetland ecological condition, we recommend that the correspondence of such broad indicators be tested against in-field health assessments of wetlands.



Resultant map for Hogsback predicted from the Sentinel-2A image: (Top) wetland vs upland and (Bottom) vegetation communities. BA = Bare soil; CA = Carex spp; CR = cropland; ET = Eragrostis spp and Themeda spp; FS = Ficinia spp.; MM = Merxmuellera macowanii; MS = mountain slope; OW = open water; PA = Phragmites australis; PL = plantations; PLF = plantations felled; RS = Rubus spp.; SE = Sedge dominant.

The Sentinel sensors should be further investigated for the assessment of blue and teal carbon in South Africa ('blue' signifies coastal and marine systems, while 'teal' refers to inland, freshwater wetlands). Currently available Above Ground Biomass maps should be improved to better represent grasses for general monitoring at a landscape scale.

Recommended areas of research include (i) assessing whether the findings are applicable in other sites within and outside the Grassland Biome; and (ii) evaluating the use of optical and SAR data for prediction of hydrological regimes which are expected to alter with climate change.



Resultant map for Tevredenpan predicted from the Sentinel-2A image: (Top) wetland vs upland and (Bottom) vegetation communities. AN = Arundinella nepalensis; AR = Aristida spp; BA = bare soil; CA = Carex spp; CR = cropland; ET = Eragrostis spp and Themeda spp.; GS = grass-sedge communities; IS = invasive species; JE = Juncus effusus; OW = open water; PA = Phragmites australis; SE = Sedge dominant; WG = Wet-grass.

PROPOSED TOOLBOXES FOR THE NATIONAL WETLAND MAPS AND NATIONAL WETLAND MONITORING PROGRAMME (NWMP)

Remote sensing toolkit	Specific theme	Evidence or predicted effects of climate change (from Section 2.2)	Ease of implementation*	Satellite to use	Reporting to
A. Mapping wetland extent	Open water / inundated wetlands	Predicted to decline in most areas.	1	Sentinel optical and SAR sensors.	SDG 6.6; Ramsar.
	Extent of palustrine wetlands	Predicted to decline in most areas.	1	Sentinel optical and SAR sensors for broad classes, WorldView for communities.	SDG 6.6; Ramsar.
	Arid systems	Predicted to decline or disappear.	4	Sentinel optical and SAR sensors.	Not clear.
B. Biodiversity inventorying	Hydroperiod	Shifts and changes predicted.	1	Sentinel optical and SAR sensors.	DEFF, SANBI to include in SAIIAE.
C. Intervention	Subsurface burning of peatlands	Increase in number of wildfire and peatland substrate fires predicted.	N.A.	UAVs (drones). Further work may be required to assess the suitability of AFIS for early warning and prioritising areas for drone imagery.	DEFF Working on Fire (needs to be included in their response strategy).
D. Ecological condition	Species cover, AGB, invasives and nutrients	Species cover to change and potentially decline, AGB to decline, invasives to increase in cover and abundance. Nutrients unclear.	4	Preferably Sentinel and Landsat, with their free data availability. Should be tested against WorldView data to determine capabilities, accuracies and potential errors.	DEFF and SANBI for NBAs and strategic intervention planning; Ramsar.
E. Monitoring	NEMP	Evidence of increase in eutrophication noted.	3	Sentinel-3 OLCI.	DWS NEMP.
	AGB	Expected to increase at first and then decrease.	2 & 4	SAR sensors. Sentinel SAR is currently freely available, but additional SAR sensors are to be launched for public use. Further validation required for improving representation of grass AGB at landscape scale; Funding for assessing blue and teal carbon in prioritised areas.	DEFF.
	Nutrients	Not clear.	4	Priority areas and vegetation types should be identified for further research of nutrients in vegetation, while Sentinel-3 OLCI indicates nutrients indirectly, through chlorophyll a, cyanobacteria and floating macrophytes in open water.	DEFF, DWS and SANBI for NBAs and strategic intervention planning.

**1 = Can be immediately implemented with open source software at National Space Agency; 2 = requires funding to generate at a country-wide scale; 3 = Limited by intellectual property; and 4 = further research is required.*

ACCOMPANYING REPORT

Establishing remote sensing toolkits for monitoring freshwater ecosystems under global change (**WRC Report no. 2545/1/20**).

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