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Annette Froehlich *Editor*

Space Fostering African Societies

Developing the African Continent through Space, Part 1

Springer

Southern Space Studies

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Annette Froehlich
Editor

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Editor
Annette Froehlich
SpaceLab
University of Cape Town
Rondebosch, South Africa

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Dedication

Dedicated to Voortrekker—Namibia's Old Man of the Desert

I dream of our vast deserts, of our forests, of all our great wildernesses. We must never forget that it is our duty to protect this environment.
—Nelson Mandela[1]

"Voortrekker", credits: EHRA, http://www.desertelephant.org/

This publication is dedicated to the iconic Namibian desert elephant known worldwide as Voortrekker ("Pioneer"/"Leader"), who was killed by a trophy hunter in June 2019. Voortrekker's plight in many ways exemplifies the plight of African wildlife in general, and of African elephant populations in particular, which are

[1]Scott Ramsay, "Wild Mandela: conservationist and lover of the land", *News24*, January 29, 2014, https://www.news24.com/Travel/South-Africa/Wild-Mandela-conservationist-and-lover-of-the-land-20140128 (accessed July 30, 2019).

facing increasing pressure from poaching, habitat loss and human-wildlife conflict.[2] The World Wide Fund For Nature estimates that there are around 4,15,000 African elephants remaining, down from 3 to 5 million in the early twentieth century.[3] Accompanying this dramatic decline in population numbers is the loss of over 50% of the African elephant range since 1979.

Namibia is well known for its desert elephant population (one of only two such populations, the other being in Mali's Sahara Desert).[4] Voortrekker was considered to be the most important (and best-known) bull elephant of the remaining herd of 120 Namibian desert elephants.[5] He was a pioneer for this elephant population in the Ugab and Huab rivers region of Namibia and was one of the first to return to the region following the years of poaching, hunting and conflict which resulted in a decimation of the elephant population.[6] Historically, all elephants had been wiped out of the region by the early 1980s, "shot out by poachers and for sport by former apartheid-era Cabinet Ministers—and of course cattle farmers intent on driving them off their land and back into the Etosha National Park", but with Voortrekker's hopeful return to the area by the late 1980s (along with a group he led from Etosha National Park), "they had become a permanent feature and unique tourist attraction".[7]

Despite this hopeful return, the small population of Namibian desert elephants in the region (reportedly numbering 62 individuals in 2016[8]) is nevertheless declining yearly, and Voortrekker was one of only two breeding bulls left, while all nine calves born since 2014 had died within a week—a "sign of a distressed population".[9] With Voortrekker's killing, "the writing appears to be on the wall for this

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[2]World Wide Fund for Nature, "African Elephants", 2019, http://wwf.panda.org/knowledge_hub/endangered_species/elephants/african_elephants/ (accessed July 30, 2019).

[3]Ibid.

[4]Louzel Lombard Steyn, "Namibia's desert elephants back on the butcher's block", *Conservation Action Trust*, August 30, 2017, https://conservationaction.co.za/media-articles/namibias-desert-elephants-back-butchers-block/ (accessed July 30, 2019).

[5]Megan Carr, "Who killed 'Voortrekker' the dominant iconic desert elephant in Namibia", *Global March for Elephants and Rhinos*, June 30, 2019, https://www.change.org/p/us-interior-secretary-global-march-for-elephants-and-rhino-demands-ban-on-imports-of-trophies-of-endangered-species-from-africa/u/24767796?recruiter=398200968&utm_source=share_update&utm_medium=facebook&utm_campaign=facebook (accessed July 30, 2019).

[6]Jasmine Stone, "The Terrible Truth Behind The Shooting of An Iconic Namibian Elephant", *2oceansvibe*, July 1, 2019, https://www.2oceansvibe.com/2019/07/01/the-terrible-truth-behind-the-shooting-of-an-iconic-namibian-elephant/ (accessed July 30, 2019).

[7]John Grobler, "Iconic Namibian elephant 'Voortrekker' killed by trophy hunter", *IOL Independent Media*, July 1, 2019, https://www.iol.co.za/news/africa/iconic-namibian-elephant-voortrekker-killed-by-trophy-hunter-28317901 (accessed July 30, 2019).

[8]Louzel Lombard, "Namibian Tourism Ministry brushes off questionable killing of desert elephants", *Conservation Action Trust*, October 24, 2017, https://conservationaction.co.za/media-articles/namibian-tourism-ministry-brushes-off-questionable-killing-desert-elephants/ (accessed July 30, 2019).

[9]John Grobler, "Iconic Namibian elephant 'Voortrekker' killed by trophy hunter", *IOL Independent Media*, July 1, 2019, https://www.iol.co.za/news/africa/iconic-namibian-elephant-voortrekker-killed-by-trophy-hunter-28317901 (accessed July 30, 2019).

small group of hardy survivors".[10] This is especially tragic since the population cannot be replaced by savannah elephants, since they do not possess the behaviour or skills needed for desert survival (for example, storing water in a pouch in their throat, using their tusks to dig wells, or finding water where there seems to be none on the surface).[11] A 2016 study found that Namibian desert-dwelling elephants have adapted to survive in very harsh conditions by "covering their bodies with sand wetted by their urine or regurgitated water from a specialized pouch beneath their tongue that holds many gallons of water", that they "remember the location of scarce water and food resources across their home ranges, which are unusually large compared to those of other elephants", and that these elephants "play a critical role in this arid ecosystem by creating paths and digging watering holes".[12] In particular, these elephants possess "unique knowledge and survival skills", such as how to survive in the desert—knowledge which is "crucial to the survival of future generations of elephants in the arid habitat, and pressure from hunting and climate change may only increase in the coming decades".[13] The adaptations of this desert-dwelling elephant population are "not genetically transferred to the next generation, rather through the passing on of knowledge by mature individuals", while "[m]orphological differences, like the adapted elephants' thinner bodies and wider feet, also distinguish them from typical savannah elephants".[14]

Local communities of Otjimboyo, Sorris Sorris and Tsiseb conservancies voiced their concern at the killing of Voortrekker (for a hunting license cost of N $1,20,000–about 7,600 Euro or US$ 8,500), noting that:

> These elephants are our resources, and we object to them being hunted for problems caused by different populations of elephants. (…) It is our belief that the shooting of elephants does not solve the problem. In fact, this only makes it worse. We want to keep our communities safe and to do this we need to ensure that our elephants are calm and relaxed when entering villages. It is our belief that the shooting of elephants or scaring them off with gunshots, screaming or chasing them off results in aggressive animals and this cannot be tolerated.[15]

The government of Namibia had claimed that Voortrekker was a "problem elephant" causing property and infrastructure damages in the area, while others

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[10] Ibid.

[11] C. J. Carrington, "Namibia And The Sacrifice of Rare Desert Elephants", *The Dodo*, July 17, 2014, https://www.thedodo.com/namibia-and-the-sacrifice-of-r-625424514.html (accessed July 30, 2019).

[12] Carl R. Woese Institute for Genomic Biology, University of Illinois at Urbana-Champaign, "Desert elephants pass on knowledge—not mutations—to survive", *ScienceDaily*, August 3, 2016, www.sciencedaily.com/releases/2016/08/160803161607.htm (accessed July 30, 2019).

[13] Ibid.

[14] Louzel Lombard Steyn, "Questionable killing of Namibia's desert elephants", *Africa Geographic*, October 25, 2017, https://africageographic.com/blog/questionable-killing-namibias-desert-elephants/ (accessed July 30, 2019).

[15] Jasmine Stone, "The Terrible Truth Behind The Shooting of An Iconic Namibian Elephant", *2oceansvibe*, July 1, 2019, https://www.2oceansvibe.com/2019/07/01/the-terrible-truth-behind-the-shooting-of-an-iconic-namibian-elephant/ (accessed July 30, 2019).

disputed this by pointing to a “smaller herd, aggressive and frightened by farmers shooting at them, [which] may be the real cause of the Omatjete constituency’s complaints [of damages] that led to Voortrekker’s death warrant being issued”.[16] Voortrekker was remembered as an “incredibly gentle, peaceful and magnificent elephant. His presence has often calmed other inexperienced elephants around him. He was known locally as the ‘Old Man’, that was always welcome because he never caused any problems or induced fear.”[17] The Namibian government had previously issued a hunting permit for Voortrekker in 2008.[18] At that time, it took the actions of 10 dedicated women who:

> took up Voortrekker's cause, and walked 140 kilometers (about 87 miles) through the desert in order to raise the funds needed to buy the bull elephant's permit. His hunting tag was successfully purchased from the Government for a total of $12,000 USD, as a live trophy. The other five elephants had lost their lives, but Voortrekker was now a living legend.[19]

Voortrekker’s killing earlier this year (2019), despite this previous effort, elicited a heartfelt outcry, including a statement by Johannes Haasbroek, whose organisation (Elephant Human Relations Aid) is devoted to minimising human-wildlife conflict, particularly in terms of the desert-adapted elephants:

> The iconic bull “Voortrekker” has been murdered by a trophy hunter. He was the last large dominant bull amongst the 120 desert dwelling elephant left in the North West deserts of Namibia. He was targeted not for anything but his fame. We bought a license to hunt him in 2008 and for 10 years the hunting outfitters and their sick clients conspired to get this gentle giant declared a problem to justify a hunt. He never stepped out of line. I lived and fought and cried for that gentleman. I have no words anymore. Let the planet die now. With him. All that is left for me is to watch and weep. See you in a better world my friend. This one was not meant for us. I failed you. Rest in peace “Voortrekker”.[20]

Instead of allaying these concerns, the response to this outcry by the Namibian Ministry of Environment and Tourism (MET) raised further questions:

> It was shot to generate funds for the affected communities. We had the elephant hunted as a trophy and we do not entertain the naming of wild animals. That is one of the characteristics that separates wild from domestic animals. Naming animals also triggers emotional attachment to a certain or specific animal which may overshadow our judgement in wildlife conservation. It should be noted further that the MET is not here for a popularity contest.

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[16]Ibid.

[17]Johannes Haasbroek of Elephant Human Relations Aid, quoted in Africa Geographic Editorial, “Iconic desert-adapted elephant ‘Voortrekker’ killed by trophy hunter in Namibia”, African Geographic, June 30, 2019, https://africageographic.com/blog/iconic-desert-adapted-elephant-voortrekker-killed-by-trophy-hunter-in-namibia/ (accessed July 30, 2019).

[18]C. J. Carrington, “Voortrekker, Legendary Elephant, Under Threat in Namibia”, *The Dodo*, May 8, 2014, https://www.thedodo.com/living-legend-of-the-namib-voo-659043534.html (accessed July 30, 2019).

[19]Ibid.

[20]Johannes Haasbroek of Elephant Human Relations Aid, quoted in Global March for Elephants and Rhinos, “Voortrekker”, July 1, 2019, https://www.facebook.com/March4Elephants/posts/3069517189733078?comment_id=3070219739662823 (accessed July 30, 2019).

> We make decisions based on what is good for our conservation based on the existing principles, policies and legislation. It's unfortunate that the elephant was put down but we were left with no other alternative after this specific animal continued to cause damages to property in the area.[21]

Despite the MET's rejection of the naming of Voortrekker, he was an ambassador for Namibian tourism and conservation, and was beloved by tourists, as a statement issued by German tourism operators following the killing clearly echoes:

> Many people very much enjoy watching elephants in Namibia. They love elephants. Especially the desert elephants of Namibia are fascinating creatures. Elephant bulls with big tusks are not only important genetically, they are also critical for the education of younger bulls. And of course those bulls are the highlights of every photo safari. Our guests love nature and leave a lot of money in Namibia. The pictures of Voortrekker are up on many walls in Germany. We as nature lovers and tourists are shocked about the decision of MET to have Voortrekker killed. (…) We cannot bring Voortrekker back to life. But we are very much in favour of not issuing any permits for hunting of desert elephants in future. The elephants of Namibia are worth a lot more than those dollars of hunters.[22]

It remains to be seen whether Namibia's iconic desert elephants will endure, or whether photographs on walls will be the only trace left of them for the enjoyment of future generations. Nelson Mandela's words ring louder than ever before, but it is up to us whether we will conserve this great African legacy or sell it off to the highest bidder.

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[21]Ibid., Statement by MET Spokesperson Romeo Muyunda four days after the hunt of Voortrekker.

[22]Rainer Stoll, "Voortrekker", *travel-to-nature*, July, 2019, https://www.facebook.com/VoortrekkerTheDesertElephant/photos/a.433136714205248/433137520871834/?type=3&theater (accessed July 30, 2019). Translated from German.

Foreword

The publication on African Countries activities in Space demonstrates the ever-growing interest of not only State actors, but individuals of African descent in Space exploration and its con-commitment benefits. The UN Committee of the Peaceful Uses of Outer Space has provided the platform for such interests to be actualized through partnerships and collaboration with other State Parties quite advanced in knowledge about space exploration and activities. The Committee has over the years helped to enhance international corporation in the peaceful uses of Outer Space and its benefit to all members.

International cooperation in Space exploration and the use of Space technology application should be a priority to the African Continent because of its benefits in agriculture, food security, water availability, disaster management and health, which would help to advance the African Agenda 2063.

To this end, the recent establishment of the African Space Agency at the 32nd Ordinary Session of the African Union is a welcome development. Africa needs to build up its capacity in the use of Space technology applications and this publication which aims to share knowledge and best practices is a step in the right direction. It is equally important for Space actors with proven capabilities, to make available the information and know-how, through the writings in this publication for the benefit of its readers.

I commend this publication for the important role it continues to play in raising awareness on the place of Space science and technology in Africa's socio-economic development.

Vienna, Austria

Ambassador Vivian N. R. Okeke
Permanent Representative
of Nigeria to UNOOSA

Contents

Estimation of the Impact of Alien Trees in the Cape Town Water Crisis Using Satellite Data

James Wilson and Maureen Tanner

Abstract

This section investigates a proposed space-based application for South Africa: using remote sensing data to identify alien trees located in catchment areas in the Western Cape. The various satellite datasets used for the analysis are discussed and then the identification process is defined. Once a forest of alien trees is identified, calculations are performed to quantify how much water is being lost to these trees. The result of a sample calculation is that a small section of alien forest consumes approximately ten million litres a day, comparable to the amount of fresh water a medium-sized desalination plant can consume.

1 Introduction

Tall alien trees, such as pines, eucalypts and wattles can have a negative impact on the supply of water to dams when situated in catchment areas. Studies in South Africa have demonstrated that, in contrast to indigenous vegetation, such alien trees tend to reduce the annual and low-season streamflows while increasing the amount

J. Wilson (✉) · M. Tanner
University of Cape Town, Rondebosch, South Africa
e-mail: WLSJAM015@myuct.ac.za

M. Tanner
e-mail: mc.tanner@uct.ac.za

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Table 1 Water reduction estimation for eucalypts, pines and wattle

Taxon	Common names	Relative water-use	Growth rate	Growing conditions	Annual flow reduction factor (%)
Eucalyptus spp.	Eucalypts	High	Fast	Optimal	90
				Sub-optimal	72
Pinus spp.	Pines	High	Moderate	Optimal	87
				Sub-optimal	57
Wattle species	Black, silver, green wattle	High	Fast	Optimal	90

of water lost to evapotranspiration due to their high biomass.[1] Some studies have even estimated the reduction in annual run-off to be in the order of 100–300 mm per year.[2] A closer examination of the water usage rate of these alien trees reveals even more striking figures as shown in Table 1.[3]

Invasive alien tree species have high water usage needs and exhibit moderate to fast growth rates thus resulting in high annual flow reductions. For instance, a eucalypt tree has an average consumption of 15–20 L of water daily,[4] while a pine tree has an average daily consumption of 25–45 L.[5] Altogether, such invasive alien trees are estimated to use more than 28 mm^3 of water yearly (see footnote 3). On a daily basis, this amounts to 104 MLD (million litres of water per day) that is being consumed by invasive alien trees located in catchment areas. Without the presence of these trees in the catchment areas, a large portion of this water would runoff the catchment area and be collected in the dams.

The City of Cape Town has an augmentation target of 150 MLD. It is therefore argued that the identification, removal and monitoring of alien trees around catchment areas could assist the City in meeting its augmentation target and are thus viable solutions to the water crisis. This is in line with past studies that indicate that such interventions could have positive impacts on the economics of hydrological planning.[6]

[1]Dye P. and Jarmain C. (2004). Water use by black wattle (Acacia mearnsii): implications for the link between removal of invading trees and catchment streamflow response. S. Afr. J. Sci. 100, 40–44.

[2]Gorgens, A.H.M. and Van Wilgen, B.W., 2004. Invasive alien plants and water resources in South Africa: current understanding, predictive ability and research challenges: Working for Water. *South African Journal of Science*, *100*(1–2), pp. 27–33.

[3]Le Maitre, D.C., Forsyth, G.G., Dzikiti, S. and Gush, M.B., 2016. Estimates of the impacts of invasive alien plants on water flows in South Africa. *Water Sa*, *42*(4), pp. 659–672.

[4]Water Requirements for Eucalyptus Plantation, nd, Available at www.eucalyptus.com.br/eucaexpert/Pergunta%20705.doc.

[5]Forestry Facts, n.d. available at https://www.sabie.co.za/about/forestry/.

[6]Gorgens and Van Wilgen (2004).

It is therefore proposed that the use of GIS mapping of infested areas around dams and water catchment areas (focusing on Eucalypts, Pines and Wattles) could assist in the clearing of these invasive species with the aim of addressing the water crisis. Remote sensing data can be used to automate the detection, classification and density of alien trees in target areas to assist the City with removal programmes. Previous research also stated that remotely sensed imagery can be used to sense invasive plants.[7] The results can be integrated into a GIS system, which prioritises areas based on ease of access, site conditions, density of alien trees, potential water savings and other factors to develop effective and efficient removal activities. The application can also be used to ensure that tree removals are satisfactory and have indeed been done, as well as monitor the regrowth in areas where alien trees have already been removed.

2 Existing Approaches

Various solutions have been proposed in past literature to address the invasive alien trees identification issue through remote sensing. Specifically, Moderate Resolution Imaging Spectroradiometer (MODIS) and Hyperspectral Remote Sensing (Infrared) are known to be useful in this regard. In South Africa, there is growing interest in the use of remote sensing across a range of spatial scales, for operational forestry applications.[8]

MODIS offers low spatial resolution and high temporal resolution and has been found to be useful for tracking of landscape and vegetation changes over time.[9] Hyperspectral remote sensing (Infrared) has been found to be useful in the detection of invasive alien plants since it allows for differentiation between plant groups and species using high spectral resolution.[10] Invasive alien plants might also have unique structural and chemical characteristics that can be detected using hyper-spectral measurements.[11] Other approaches use statistical models based on the growth characteristics of a species to determine the likelihood of its presence in a specific area.

[7]Bradley, B.A., 2014. Remote detection of invasive plants: a review of spectral, textural and phenological approaches. *Biological invasions*, *16*(7), pp. 1411–1425.
[8]Albaugh, J.M., Dye, P.J. and King, J.S., 2013. Eucalyptus and water use in South Africa. *International Journal of Forestry Research* .
[9]Lu, L., Kuenzer, C., Wang, C., Guo, H. and Li, Q., 2015. Evaluation of three MODIS-derived vegetation index time series for dryland vegetation dynamics monitoring. *Remote Sensing*, *7*(6), pp. 7597.
[10]Schmidt, K.S. and Skidmore, A.K., 2003. Spectral discrimination of vegetation types in a coastal wetland. Remote Sens. Environ, 85, 92–108.
[11]Asner, G.P.; Martin, R.E.; Anderson, C.B.; Knapp, D.E., 2015 Quantifying forest canopy traits: Imaging spectroscopy versus field survey. Remote Sens. Environ, 158, 15–27.

3 Platform Comparison

There exist several platforms and mapping applications that could be used for this project. Remote sensing data from Landsat, Sentinel, Planet and MODIS was considered for this purpose and QGIS was used to process the various datasets. It was found that the resolution of Landsat data was too low for the given purpose and as such analysis focused on the other datasets.

Planet offer a high-end, API driven platform with extensive functionalities that could assist with the mapping and projection of alien plant species around dams and catchment areas. They offer a comprehensive suite of products that could be highly useful to the project (e.g. planet monitoring, planetbasemaps, planet imagery and archives, planet testing, planet explorer and platform).[12] However, the platform is not free of charge and would require some form of investment from the City of Cape Town, not only to obtain the data, but also to develop the software platform based on Planet's API. It is possible that the City could approach Planet to negotiate data exchange to help with the water crisis.

In contrast, QGIS is an open-source mapping application that does not require any funding. In the past, QGIS has successfully been used for the mapping of plant species[13] as well as the tracking of plant invasions.[14] The tool was therefore considered to be ideal for the project.

4 Proposed Solution

A comprehensive solution using remote sensing should include distribution mapping as well as projection of the invasive alien plants. Distribution mapping helps with early detection of new invasions, provide information to support the formulation of management strategies and the assessment of what impact these invasions might have on the environment.[15] Furthermore, the projection of future distribution of the invasive alien plants (e.g. identifying risk areas) can also assist in the management of these invasions (e.g. monitoring).[16] The proposed solution can also

[12] https://www.planet.com/.

[13] Stropp, J., Ladle, R.J., Malhado, M., Ana, C., Hortal, J., Gaffuri, J., H Temperley, W., Olav Skøien, J. and Mayaux, P., 2016. Mapping ignorance: 300 years of collecting flowering plants in Africa. *Global Ecology and Biogeography*, *25*(9), pp. 1085–1096.

[14] Hellmann, C., Werner, C. and Oldeland, J., 2016. A spatially explicit dual-isotope approach to map regions of plant-plant interaction after exotic plant invasion. *PloS one*, *11*(7), p. e0159403.

[15] Guo, Y., Graves, S., Flory, S. L., & Bohlman, S. (2018). Hyperspectral Measurement of Seasonal Variation in the Coverage and Impacts of an Invasive Grass in an Experimental Setting. *Remote Sensing*, *10*(5), 784.

[16] Garzon-Lopez, C. X., Hattab, T., Skowronek, S., Aerts, R., Ewald, M., Feilhauer, H., … & Schmidtlein, S. (2018). The DIARS toolbox: a spatially explicit approach to monitor alien plant invasions through remote sensing. *Research Ideas and Outcomes*, *4*, e25301.

be used to ensure clearances are satisfactorily performed and also to monitor regrowth post-clearance.

The method used to identify the alien species was developed in correspondence with industry experts from CSIR, SANSA and SAEON. Due to the time limits of the project, a statistical approach was ruled out. Furthermore, automated differentiation between the three separate alien species was also eliminated. The envisioned approach was to use Sentinel and Landsat data (in the visual and infrared bands), along with SAR data to identify areas with alien trees. In order to automate the identification process, the following differentiating factors were identified: tree height, leaf colour, forest age and growth rate. The forest age helps identify alien trees as natural fynbos forests reach maturity after three years and then their growth plateaus. After analysing the data, it was determined that automation of the identification process would not be possible in the time constraints. However, considerable work was done on determining forest age using MODIS data, which is discussed briefly below. The Theewaterskloof western catchment area was decided as the target area for the project after discussions with SAEON.

Fynbos tends to grow slower than most alien trees and plateaus in height at around 1–2 m off the ground, this occurs after a period of 3–5 years depending on recovery conditions.[17] This fact about fynbos allows us to easily distinguish it from alien trees which often grow much taller and much faster.[18] The primary way of identifying the approximate age of natural vegetation (not plantations) is to look at when last a fire broke out in the area. Veld fires are very much a part of the fynbos regions natural cycle, periodically burning through areas of dry older bush making way for new plants to grow in their place.[19]

In the last few years there have been more fires than would be expected, coupled with the drought conditions, fires have been wider spread and far more devastating to the landscape and the people living around it. In some of these cases there have been people arrested for arson,[20] however the presence of alien trees has also exacerbated the extent and intensity of these fires as they grow tall and suck up much of the water around them leaving dry vegetation that is not fire resistant. The natural fynbos is naturally drought resistant and there are many succulents that reduce the effects of a fire, however they do not survive under the shade and in the acid soils of the alien trees.[21] Alien tree fires are far more sever and uncontrollable than fynbos fires.

[17]Cape Nature. 2016, Field Guide to Wild Flower Harvesting.

[18]Morris, T.L. and Cramer M.D. (2011). Ecophysiological traits associated with the competitive ability of invasive alien plants. Diversity and Distributions, 17, 898–910.

[19]Kruger, F.J. and Bigalke R.C. (1984). Fire in Fynbos, Ecological effects of fire in South African ecosystems. Ecological studies, 48, 67–114. Springer Verlag, Berlin.

[20]https://www.iol.co.za/capeargus/news/suspected-arsonist-arrested-for-starting-tablemountain-fires-14217949.

[21]Mamders, P.T. and Richardson D.M. (1992). Colonization of Cape Fynbos species by Forest species. Forest Ecology and Management, 48, 277–293.

Downloading the MODIS and VIIRS data, which is freely available on NASA's Fire Information for Resource Management Systems (FIRMS) website through the Active Fire data porthole,[22] one can overlay this data onto a map of the Western Cape and its catchments and then identify areas of forest that have experienced fires in the last 3–5 years—the time frame expected for indigenous and alien vegetation to be distinguishable. This information becomes useful as the areas can then be further compared with active radar imagery and optical imagery to tell if the vegetation is fynbos or alien trees.

The active radar data will indicate the average height of the vegetation by selecting the appropriate bands and analysing the reflection off the vegetation. The optical data should substantiate the data of the SAR by indicating the density of the vegetation by its regularity and colour. Fynbos is usually a mix of greens, ranging from dark to light, whereas alien tree forests like the ones we are looking for are a dark green colour with little variation. These two analysing techniques provide conclusive evidence that the area is in fact fynbos or alien trees.

5 A Simple Approach to Identifying Alien Forests Around Catchments Areas

At present, there is a huge amount of freely available Earth observation data, however the challenge is in finding and interpreting what is useful for a given objective.

For the task of identifying alien trees, many sources were generally too challenging to use. For example, free SAR data is available from the Sentinel-1 satellites, however it was discounted as the resolution is too low to identify trees (at 15 m[23]) without coherence and polarimetric decomposition analysis requiring many hours of computing time and data time. Furthermore, foreshortening and shadows in the mountainous regions around catchments results in the complete loss of applicable data. MODIS data is useful in showing where fires have occurred and also evapotranspiration measurements but again its resolution is much too low to identify smaller clusters of trees.[24] Sample Planet data was obtained as well, with a resolution of 3 m. It is easier to identify vegetation using this data but it is again difficult to identify specific plant species without a statistical approach involving large amounts of processing, most likely involving a computer cluster.

[22]https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms/active-fire-data.

[23]Sentinel Online. 2018. User Guides—Sentinel-1 SAR—Resolution. [ONLINE] Available at: https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar/resolutions. [Accessed 13 June 2018].

[24]DAAC. 2018. Moderate Resolution Imaging Spectroradiometer (MODIS). [ONLINE] Available at: https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/modis/. [Accessed 13 June 2018].

Fig. 1 (From left to right) Planet 3 m—11 June 2018, digital globe 0.5 m—30 November 2017, Sentinel 1 SAR VH—26 May 2018

Within the time constraints of the given project, Google Earth appeared to be the only single useful way to identify trees, albeit without automation and classification. Google Earth uses multiple data sources but in this case Digital Globe 0.5 m imagery is used. Google Earth may be more out-of-date than faster updating sources such as Planet, however pine trees (one of the principle alien threats) take on average 20 years to mature fully,[25] and therefore at least for identifying existing trees, the temporal resolution of imagery is not too important. A comparison of different datasets is shown in Fig. 1, clearly showing the benefit of older yet higher resolution imagery. These images are of a pine forest on a slope just north of Theewaterskloof Dam.

5.1 Identification Procedure

The manual identification of trees using Google Earth—Digital Eye imagery is straightforward. First trees/shrubs were identified visually, thereafter, the diameters of the plants were measured using Google Earth's ruler. This is shown in Fig. 2.

The knowledge of this, combined with the fact that there is no fynbos plant of this size,[26] and that virtually no natural trees occur outside of the riparian zone (this was according to the interview with Dr. Jasper Slingsby of SAEON), means that these plants are definitively alien. They can be identified as pine trees due to the elimination of other species. They are larger and darker green than black wattles, and eucalyptus does not grow on large-gradient slopes. (Ideally, the specific species would have to be verified by field observation, but the fact that they can be identified as alien is sufficient for this objective.)

[25]Forestry. 2006. Sabie. [ONLINE] Available at: https://www.sabie.co.za/about/forestry/. [Accessed 13 June 2018].
[26]Cape Nature. 2016. Field Guide to Wild Flower Harvesting.

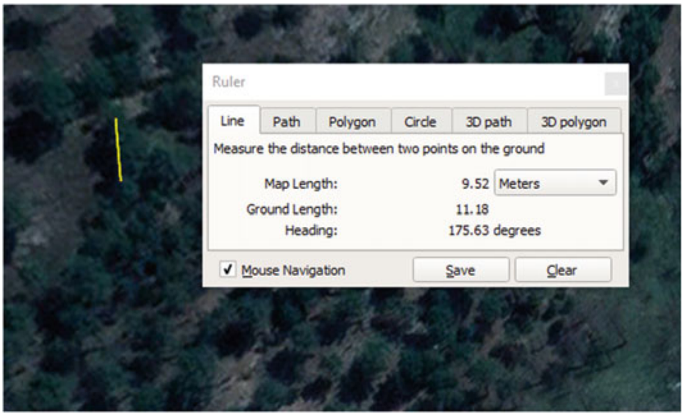

Fig. 2 Measurement of plants—image is taken from same region as Fig. 1

Fig. 3 Identified forests and affected river

Once the trees have been identified, they can be manually highlighted as vector polygons in Google Earth. Highlighted pine forests around the mountain directly north of Theewaterskloof Dam are shown in Fig. 3, along with the affected river that has had its flow reduced by these trees.

5.2 Estimation of Water Use

The water use of a forest depends on many factors, notably season, density, soil type and rainfall amount. It is difficult to be highly accurate in estimation, and therefore the method will be conservative. The forests identified in Fig. 3 will be used for these calculations. Note that this area is in a reserve and therefore is not industrial forestry.

The first step is to calculate the area of the forests. The drawn polygons were converted from KML to a shapefile and imported into QGIS (Fig. 4).

The area function in QGIS was then used to calculate the area of the forests, shown in Table 2.

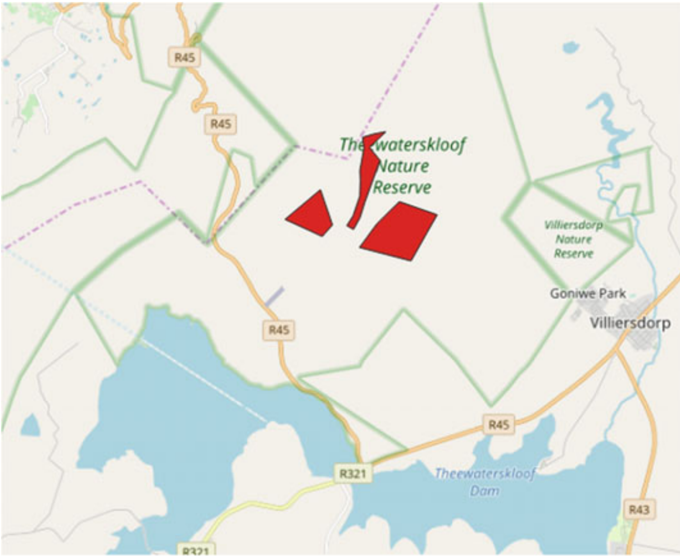

Fig. 4 Forests in QGIS over open street maps

Table 2 Area of forests

Name	Area (m^2)
Pine forest 1	767 287
Pine forest 2	815 665
Pine forest 3	1 904 249
Total	3 487 201

The density of trees then needs to be known. By visual count, the density of trees ranged from 1 per 10 m^2 to about 1 per 25 m^2 or (0.1 to 0.025 per m^2 averaged to 0.075 per m^2). A paper by the CSIR identifies two major species of pine to have a weighted total water use of 129.58 litres per year, or 35.5 litres per day.[27] Therefore, the total water use can be estimated by:

$$Water\ Use = Area \times Density\ of\ trees \times water\ use\ per\ tree$$

$$Water\ Use = 3\,487\,201 \times 0.075 \times 35.5$$

$$Water\ use = 9\,284\,673\,\text{L/day}$$

This number is staggering. A single mountain slope north of Theewaterskloof results in the use of almost 10 million litres of water a day, which constitutes a significant portion of the City's deficit.

People may argue that the transpiration of trees results in the formation of clouds which results in more rain anyway, however this argument is invalid. Again, according to the interview with Dr. Slingsby, the forests are not large enough to transpire enough moisture to form large clouds, and due to the high amount of wind in the Cape, any moisture is quickly blown to a different area. Many people do not realise the impact of pines because they look aesthetically pleasing, but it is massive, and satellite imagery helps to visualise and quantify it.

5.3 Further Work with Regards to This Identification and Estimation Method

This method of manually highlighting trees is effective, however it is slow, and does not account for deforestation measures, or the removal of forests by fire. Therefore, it is suggested that further work be done to automate this process and account for changes.

The easiest way would be to first manually identify the forests around catchment areas as done in the previous section using Google Earth. The catchment regions in the Western Cape are very small, and hardly any natural forests exist outside of the riparian zone. Once these polygons have been drawn they can be extracted to a GIS platform such as QGIS or even Google Earth Engine. Once this has been done, Planet data could be used. Planet has a fully built API with a coherence analysis (visual representation in Fig. 5). With each Planet image of the area becoming available, this coherence analysis could be automatically run within the polygons to determine if there has been pixel change, thereby deducing if the forest has grown more or been removed. This can all be fully automated once the initial polygons

[27]Gush, M.B., Dye, P.J., Geldenhuys, C.J. and Bulcock, H.H., 2011. Volumes and efficiencies of water-use within selected indigenous and introduced tree species in South Africa: Current results and potential applications. In: Proceedings of the 5th Natural Forests and Woodlands Symposium, Richards Bay, 11–14 April.

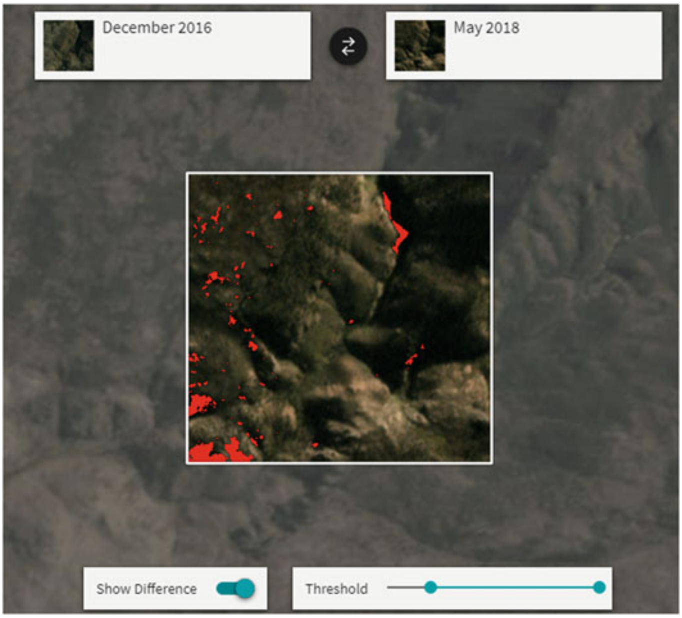

Fig. 5 Coherence analysis in planet explorer (note forest has not changed)

have been manually identified. This is useful in that removal of alien species can be accurately monitored rather than the government or NGOs spending money for removal but not being able to track progress without performing actual site visits.

James Wilson graduated from Electrical Engineering at the University of the Witwatersrand in 2017. He has a large interest in Space technology and hence pursued a Master of Philosophy in Space Science at the University of Cape Town in 2018. He is also a guitar player in an alternative rock band. He aims to work with rocketry as he completes his Master's dissertation designing a control system for a liquid rocket test stand.

A/Prof. Maureen Tanner is in charge of the Honours Programme in the Department of Information Systems of the University of Cape Town. Her research interests lie in Big Data, Space Traffic Management, Agile software development related issues, software engineering and social aspects of social engineering. She is now undertaking a M.Phil. in Space Studies at the University of Cape Town.

Olive Tree Classification and Inventory with Medium Resolution Multi-spectral Satellite Imagery

Ranya Mezzi, Mitchel Alioscha-Perez, Mohamed Allani, Fatma Guedri, Adel Zouabi, Ridha Beji, Hichem Sahli and Ali Sahli

Abstract

Remote sensing is the most widely useful tool for land use planning and decision support system. It gives the accurate information of agricultural activities such as crop identification and classification, crop area, crop growth condition monitoring and yield estimation in a concise and recurring manner for large areas and over long periods of time. This chapter presents a two-step approach for the inventory of olive tree plantations using medium-resolution optical satellite image. First, a multi-scale Conditional Random Fields (CRF) is applied for olive plantations labeling. Second, an algorithm based on a combination of three procedures, mean-sift segmentation, spectral thresholding of Red Band and NDVI and spatial thresholding is carried out to detect and count olive trees. The results of the approach are evaluated on four test sites situated in the Sbikha region, Kairouan-Tunisia and the accuracies are analyzed. Experimental results

R. Mezzi · M. Allani · F. Guedri · A. Sahli (✉)
Institut National Agronomique de Tunisie (INAT), Université de Carthage (UC), 43, Avenue Charles Nicolle, 1082 Tunis-Mahrajène, Tunisia
e-mail: sahli_inat_tn@yahoo.fr

R. Mezzi
e-mail: ranyamezzi@gmail.com

R. Mezzi · M. Alioscha-Perez · H. Sahli
Electronics and Informatics Department (ETRO), Vrije Universiteit Brussel (VUB), Pleinlaan 2, 1050 Brussels, Belgium
e-mail: maperezg@etrovub.be

H. Sahli
e-mail: hsahli@etrovub.be

A. Zouabi · R. Beji
Commissariat Régional au Développement Agricole de Kairouan (CRDA), Cité Sidi Layoun - Kairouan, 3100 El Kef, Tunisia

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show that the proposed classification and detection schemes achieve good performances with a mean total accuracy about 87%.

1 Introduction

Tunisia is the most important olive-growing country of the southern Mediterranean region. The olive (*Olea europaea* L.) is being cultivated throughout the country. Olive farms cover more than one-third of arable land (1.68 million hectares) producing 6.0% of the world's olive production and contributing 45.0% of food export income, 4.5% of total exports, and 10.0% of the total agricultural production value. The Tunisian olive is dominated by two major varieties, 'Chemlali' in the South and the Center and 'Chetoui' in the North, is rich in cultivars.[1] Olive trees number are estimated at approximately 60 million (30% in the north, 45% in the center and 25% in the south). They are mostly found in single-crop plantations, although they can also be found in combination with other fruit trees and annual crops. There are some 100 olive trees/ha in the north, 60 trees/ha in the center and 20 trees/ha in the south.[2]

Inventories on olive tree plantations are performed with the objective of providing support to the management and conservation activities in rural area or even in tree plantations. Traditional methods for obtaining information on olive tree is to use systematic or random sampling or by sampling stands, so that the final parameters for the plantations are obtained on the basis of statistical extrapolation. This renders the field survey techniques for olive tree inventories expensive, time consuming, and unsuited for large areas. In order to be able to implement agricultural policies effectively, an inventory of olive groves must be geographically known and recorded.

Remote sensing with medium spatial resolution is a cost-effective and reliable way to obtain information about trees. It may be the only practical way to insure sustainable management of olive farms with the necessary information, such as number, density, age, aboveground biomass, disease, etc. in a concise and recurring manner for large areas and over long periods of time.

This study has two fundamental objectives: olive orchards classification and individual olive tree identification. The first objective involves making use of the Conditional Random Fields (CRF) formulation to classify agricultural area at species level, from medium-resolution, single-date optical satellite image. Specifically, the main objective of this work is to explore the performance of this context-based classifier for rural agricultural areas, which has to our knowledge not been investigated in the literature with medium-resolution satellite images. The second objective

[1]Rekik, I.; Salimonti, A.; Grati Kamoun, N.; Muzzalupo, I.; Lepais, O.; Gerber, S.; Perri, E.; Rebai, A. 2008. Characterization and Identification of Tunisian Olive Tree Varieties by Microsatellite Markers. Hortscience, 43(5):1371–1376.

[2]International Olive Council, 2017. The olive sector in Tunisia, Olivae—Official Journal of the International Olive Council, 24, pp 38. International Olive Council, Madrid, Spain.

of this study is to illustrate the potential for individual tree identification and tree crown delineation using a combination of three procedures, mean-sift segmentation, spectral thresholding of Red Band and NDVI and spatial thresholding.

The rest of this chapter is organized as follows: In Sect. 2, the adopted methods and proposed algorithms are introduced and explained and in Sect. 3 the used dataset and experiments are described. Finally, in Sect. 4 some concluding remarks and future work are given.

2 Adopted Methods

2.1 Image Classification by Multi-scale Conditional Random Fields

In this section, we briefly summarize the standard Conditional Random Fields (CRF)-based labeling process. CRF is a flexible framework for contextual classification, introduced by Kumar and Hebert (2006)[3] for image classification. CRFs are undirected graphical models, consisting of nodes n and edges e. The nodes represent the image sites, e.g. pixels or segments. The edges link adjacent nodes and model statistical dependencies between class labels and data at neighbouring image sites.[4] The overall form of a general CRF model is as follows:

$$P(x|y,\theta) = \frac{1}{Z(y,\theta)} \exp\left(\sum_{c \in C} \psi_c(x_c, y, \theta)\right)$$

where Z (y, θ) is a normalization function named the partition function.

The above model is known to follow an exponential distribution, while the potentials ψ_c are functions defined over cliques $c \in C$, usually assumed to be linear and expressed as an inner product between features y and model parameters θ; x_c are the labels limited to factors of order $c \in C$.

This general CRF model can be defined on the multi-scale region-based image labeling context. This includes an appropriate potential definition and features for the energy expression, among others. For region-based image labeling, there are some other stages involved in the overall process, such as the image pre-processing (filtering), segmentation, parameter learning and classification. The general framework is illustrated in Fig. 1.

In order to avoid blurring and the delocalization of the image features, an image adaptive scale-space filtering is used. In this work, we opted for a method that guides the filtering process in such a way that intra-region smoothing is preferred

[3]Kumar, S., Hebert, M., 2006. Discriminative Random Fields. International Journal of Computer Vision 68(2):179–201.

[4]Albert, L.; Rottensteiner, F.; Heipke, C. 2014. Land use classification using conditional random fields for the verification of geospatial databases. ISPRS Annals of Photogrammetry, Remote Sensing & Spatial Information Sciences, 2(4):1–7.