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Cloud computing solution for monitoring arid rangeland dynamics: case of Moroccan highlands and southern acacia ecosystems

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Abstract

The wide availability of free satellite imagery, the recent development of cloud platforms dedicated to big spatial data (Big Data) that integrates both image archives from different providers, processing algorithms, distributed processing capabilities as well as an application programming interface (API) that facilitate scripting and automation process opened new perspectives for the use of vegetation observation time series over long timestamps and over large spatial scales (almost planetary).

This work aims at harnessing these technologies and building up an automated solution to monitor rangeland rehabilitation dynamics in arid lands and to assess the effectiveness of stakeholder's management strategies. Such solution is based on graphical user interface that facilitate the process and on the use of analysis functions relaying on analysing temporal trajectories (time series) of different spectral indices derived from satellite images (Landsat or Sentinel) at the required spatial analysis scale.

The solution is implemented using java script as scripting language using the functions offered by GEE API. The graphical user interface of the first prototype is exploitable by the means of a standard web browser and it is accessible even to people without any background in regard to programming languages or to remote sensing skills. The process was tested for two arid sites on Morocco: acacia ecosystems on the southern part of Morocco and the highlands on Moroccan eastern parts mainly on sites recently rehabilitated. It has been qualified is promising solution.

Keywords: Google earth engine; remote sensing; monitoring; arid rangelands, Big Data

Introduction

Dray Lands cover almost 90% of Moroccan territory. The water scarcity within these lands shaped very specialized species and ecosystems with very low cover, including scrublands, dry forests, and deserts, among others. These specialized ecosystems constitute a natural capital that contributes to the provision of ecosystem services necessary for human well-being. In view of their their ecological and/or biogeographical particularities and their heritage values, certain ecosystems enjoy special protection status and constitute the main income source for livelihoods of people. Within this special lands, local population have developed ingenious systems and sophisticated strategies to cope with the challenging conditions over centuries. The land use includes mainly livestock rearing, and very located rainfed and irrigated crop agriculture.

Due to societal changes, it is well established that Moroccan drylands are degraded and still facing degradation trends. Then, the ecosystems' ability to provide essential goods and services is declining making survival more difficult (Millenium Ecosystem Assessment, 2005). Overgrazing and overexploitation of dryland forests are some of the man-made causes of arid land degradation.

Even with the concern of forest managers to society's needs while guaranteeing the integrity and functioning of the ecological systems involved (Bettinger et al., 2009) and with the high prevailing man made pressures on land resources, it is often difficult to make a rigorous assessment of the trends of ecosystems due to the lack of precise and up-to-date field data, which must relate to the biophysical, climatic and social context as well as to the natural capital involved.

To compensate for the unavailability of field data, open access satellite images on the internet, mainly acquired by Landsat, MODIS and Sentinel staellites, have opened up very interesting development perspectives with well-documented case studies for vegetation monitoring using specific indices. Studies in the forestry field are numerous and relate to forest cover, primary production, plant biomass, soil degradation to fire severity, wood fuel moisture and others ... (Reeves et al. 2015, Rouse et al. 1974; Todd et al. 1998; Kawamura et al. 2005; Yu et al. 2011; Al-Bukhari et al. 2018 ...).

Although some arid lands has special conservation status such as UNESCO MAB reserve to ensure the protection of the natural capital as well as the development of the population groups that have depended on it since 1998, the impact of this designation on the dynamics of the ecosystem often remains difficult to assess rigorously. This study, by making use of the GEE platform, aims to provide managers and scientists with a tool to facilitate the monitoring of arid forest areas based on satellite images available free of charge.

Methods and Study Site

The study focused on arid lands located in the southwestern region of Morocco. The synoptic approach is dynamic and can be applied to any geographical area. It is inspired by new developments to ensure greater accessibility and portability of the GEE platform through user-friendly and easy-to-use graphical interfaces (e.g. www.globalforestwatch.org; Lagner et al., 2018). Figure 1 illustrates the operating principle of the EEM platform.

In parallel with the use of satellite imagery, the exploitation of multi-temporal series of images over large spatial areas suggests three challenges (Liu et al., 2018; Carasco et al, 2019): i- protocol for the selection of images to be taken into account for optimal coverage of the area of interest with less cloud cover, ii- establishment of a platform for efficient processing of these data which, for long time intervals and large spatial scales, are massive in nature, and iii- development of a classification method with satisfactory performance. If the third challenge is more related to the context of studies, the first two are central concerns for researchers to whom recent computer developments have been able to bring elements of solution (Soile et al, 2018); as a ready-to-use solution, Google Earth Engine (GEE, https://earthengine.google.org) is a cloud-based platform for global geospatial analyses that provides access to satellite images and greatly facilitates their use, visualization and processing by taking advantage of Google's computing power (Gorelik et al., 2017; Williamson et al. 2019).

The approach developed in the scope of this work consists of two components: the first involves the logic of processing from image acquisition to the production of the final deliverable, and the second implements an operating interface facilitating the execution of the code and the implementation of the analyses envisaged in the first component.

The first component is based on the monitoring of forest vegetation regeneration on the basis of temporal trajectories of different spectral bands and particularly derived spectral indices (NDVI, NRI, EVI, NBR, ...ect.). The operational approach, implemented in the form of a GEE script, allows the selection, pre and post-processing of image series involving the comparison between scenes and the temporal aggregation of scenes.

The processing process to be implemented can be described follows: i-Determination of the temporal ranges of analysis and the choice of the satellite imagery provider to be retained for the analyses, ii- area of interest choice corresponding to the predefined arid lands. For the choice of images, two approaches can be adopted: a- limiting the choice to images with little cloud cover, otherwise b- applying masks to apply corrections (Zhu and woodcock., 2012, Zhu et al., 2015; Langner et al., 2018); iii- calculation of composite spectral indices for each scene (NDVI, SAVI, NRI, NBR, dNBR, EVI); iv- temporal aggregation of data. The detection of the opening of the canopy can be easily detected on the basis of time series of images over a short period of time just after the occurrence of the phenomenon or operation. On the other hand, the dynamics of rehabilitation and closure of the canopy can only take place over large time ranges. This imposes to take into account different temporal windows. Thus for each derived spectral index, for each given time window, and for each pixel the maximum value of the pixel will be retained; as described by Langner et al. 2018, storing the date of obtaining this maximum value could eventually provide information on the date of occurrence of the event in question (opening or closing of the canopy for example, fire ...). v- Once the treatments have been carried out, the results can be exported and saved either on the Drive or downloaded to its own machine.

The second component of the work consists in implementing this approach in the GEE platform in JavaScript language in order to automate the process to users with no remote sensing background in such way that an implemented graphical user interface will allow defining parameters and getting results as maps, graphs and tables.

Results

The solution developed within the sope of this work simplify the processing procedure presented above. It facilitates evaluation of vegetation dynamics based on temporal dynamics of several spectral indices while considering the related seasonal and annual variation of climatic, physical and biophysical factors. The interface is structured around three pannels (Figure 1): i- parameters definition, ii-numerical results display, and iii- cartographic results from previous analyses and calculations. Through this interface, users can easily define analysis period of the dynamics of vegetation cover. Then, he can choose spectral indices of interest (Normalized Difference Vegetation Index, Enhanced Vegetation Index, Normalized Regeneration Index, Soil Adjusted Vegetation Index, Normalized Burn Rate Index) which will be used for assessing dynamics vegetation cover dynamics.

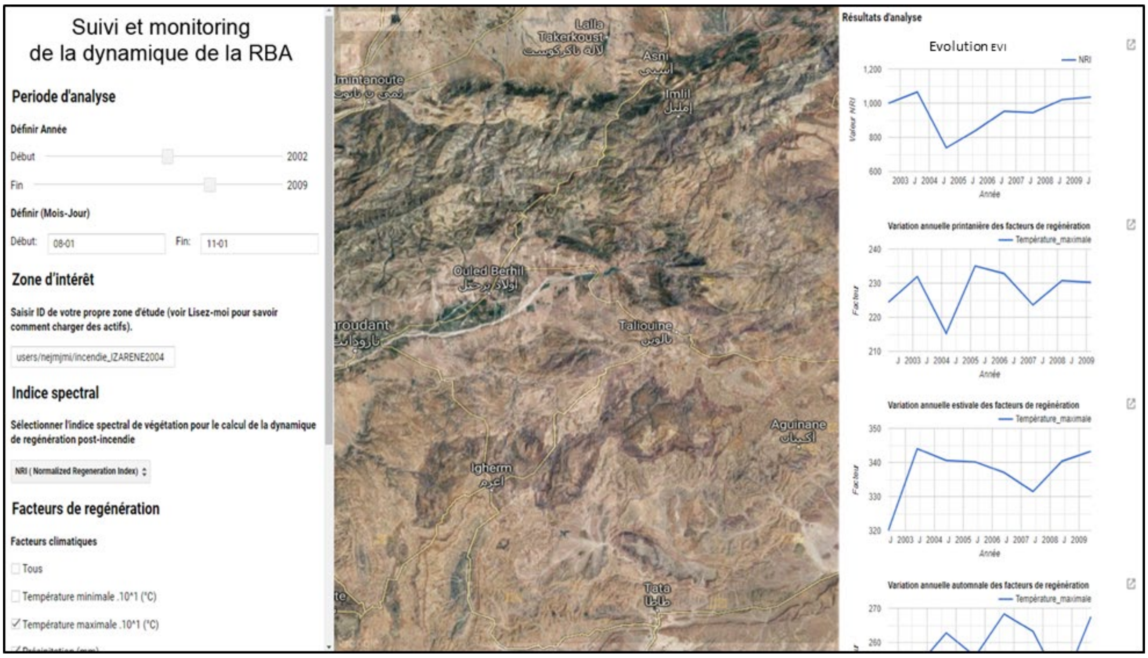

Figure 1. Main solution interface

Moreover, to understand the factors precluding temporal evolution of spectral indices, the solution offers the possibility to represent the factors underlying vegetation indices. Graphs representing variation of the spectral indices are represented at the same time as those of climatic factors. The prototype developed offers the possibility to assess vegetation dynamics in a given site, with regards to the prevailing climatic and biophysical factors. The tool is decision-support tool facilitating the assessment of ecosystem trends and then to plan conservation interventions. Furthermore, field data can greatly facilitate results validation and verify the conclusions which makes possible to compensate errors due to data sources.

Conclusion

With the increasing human pressure on natural resources and the need to adopt proactive management strategies, the use of new tools involving big spatial data analytics able to identify ecosystem trends in order to preserve ecosystem integrity remain necessary. Prototype developed facilitate monitoring tasks while overcoming field data lack. Both in terms of taking into account ground field data, optimizing processing (spatial and temporal aggregation, moving window size and shape, etc...) as well as taking into account other indices or other imagery could be proposed as amelioration perspectives.

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