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Said Moukrim
Mohammed-V University, Morocco

Said Lahssini
National School of Forest Engineer, Morocco

Mustapha Naggar
Water and Forestry Department, Morocco

K. Menzou
Water and Forestry Department, Morocco

H. Mharzi-Alaoui
Water and Forestry Department, Morocco

See next page for additional authors

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Presenter Information
Said Moukrim, Said Lahssini, Mustapha Naggar, K. Menzou, H. Mharzi-Alaoui, A. Labbaci, and L. Rhazi

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Assessing the impacts of different initiatives on the rehabilitation of pastoral and silvopastoral ecosystems: Big Data oriented approach

Moukrim S.[1,2], Lahssini S.[3], Naggar M.[2], Menzou K.[2], Mharzi-Alaoui H.[2], Labbaci A.[4], Rhazi L.[1]

[1] Mohammed V University in Rabat, Faculty of Sciences, Research center of plant and microbial biotechnologies, biodiversity and environment, Rabat, Morocco.
[2] Waters and Forests Department, Rabat, Morocco.
[3] National School of Forest Engineers, Salé, Morocco.
[4] Ibn Zohr University, Agadir. Morocco.

Abstract

Moroccan forests, through the provision of goods and ecosystem services, underpins benefits to local communities and play a crucial role for rural area development. The legal framework recognizes to people, living near public forests, the right to graze their domestic livestock. Over the years, the grazing pressure is at levels far beyond the forestland's carrying capacity throughout the country. Such pressure has been demonstrated as the main cause of forest cover loss and land degradation in Morocco and still threatening the sustainability of forests. To reduce the heavy grazing pressure on forest ecosystems and ensure their regeneration, several initiatives have been conducted such as the program of compensation for forest areas closed to grazing (CFCG), initiated by Moroccan forestry department. Socio-economic impact assessment of this mechanism was presented within several studies but its effectiveness for forest rangeland rehabilitation remains scarce and very spatially limited. To deal with this concern and to assess vegetation dynamics through various spatial and temporal scales, parcels concerned by CFCG and others within similar conditions was chosen. Time series of remotely sensed spectral indices at each parcel was used for vegetation cover dynamics assessment. Google Earth Engine platform (GEE) was used as computing plateform.

As result, the spectral indices trends shown a long-lasting degradation tendency in areas planted without compensation compared to those concerned by CFCG. Such results were also verified using aerial images covering the analyzed parcels. As conclusion, within comparable conditions, CFCG improved vegetation cover trends. The use of GEE Platform simplified the process of treatment of remote sensed imagery and made it easy to assess the state of the vegetation and will be of great use in assessing the impacts of different programs and initiatives on the restoration of pastoral and silvopastoral ecosystems.

Keywords: Forest Rangeland; Rehabilitation; Assessment; Big Data; GEE; Silvopastoral

Introduction

Moroccan rangelands, as holding diversity of species and provider of ecosystem services for communities, play a crucial role for rural area development. Indeed, provided services include supporting, provisioning, regulating and cultural services that are important for human wellbeing. Moroccan Rangelands cover about 53 million ha. Depending on land tenure status and dominant vegetation, rangelands are classified into : i- natural vegetation within forest rangeland domain that cover 9 million ha, ii- natural vegetation in common land covering 12 million ha, iii- private cropland used as rangeland after harvesting and during fallow 10 million ha, and 21 million ha of bad lands owned by the state and used as rangelands. and contribute for almost a third of the national livestock fodder (Narjisse, 2006). Wide majority of rural population relay for their income directly or indirectly to the livestock revenues.

During the past, natural rangelands in Morocco were managed in a sustainable way. Local populations developed ingenious sustainable systems of using and managing scarce natural resources. Such systems reconcile social needs and environmental requirements for the maintenance of renewable resources and biodiversity (Alkemade et al. 2013). Over the years, these rangelands knew an advanced degradation and the grazing pressure is at levels far beyond the rangeland's carrying capacity throughout the country.

To remedy degradation trends, efforts have been made to launch initiatives and pilot projects for rangelands restoration and rehabilitation and of their sustainable management. Even if socio-economic impact assessment of those initiatives was conducted within several studies, their effectiveness for rangeland rehabilitation remains scarce. This kind of assessment has traditionally been difficult and costly even spatially limited and impossible at a large-scale or at different temporal resolution.

To deal with those concerns and to assess the effectiveness and the impacts of different initiatives on pastoral and silvopastoral ecosystems through various spatial and temporal scales, we prospect within this study the use of GEE- Google Earth Engine (Bey et al. 2016), as planetary-scale cloud-based geospatial analysis platform, for processing remotely sensed images and then to derive vegetation indices which are correlated to vegetation cover dynamics and productivity and providing a measure that indicates the vigour of vegetation (Reed et al. 1994).

Methods and Study Site

Morocco is located at the northwestern corner of the African continent, between the Mediterranean Sea in the north and the Atlantic Ocean in the west. The geographical location of Morocco and its topography explain its wide diversity of ecological conditions. Natural rangelands are present in different Moroccan terrestrial ecosystems. The combination of changes in demography, climate, technology, economy, politics, and cultural or religious beliefs (Dominguez et al. 2010) has intensified a variety of natural resource crises, mainly excessive livestock grazing and frequent unsustainable use, which has become a large practice affecting the different region, and which later made livestock grazing the greatest threat to the health and sustainability of Morocco's rangelands.

To reduce the heavy grazing pressure on rangelands and ensure their sustainability, several initiatives have been conducted to rehabilitate these areas. As examples, programs of establishment of pastoral improvement perimeters and programs of compensation for forest areas closed to grazing (referred here as CFCG) was initiated by the Moroccan Forestry Department. The CFCG aims to support forest and forest rangeland rehabilitation programs by given financial incentives to the neighboring inhabitants, called users, who were organized in associations and agreed to respect grazing closure in the sites of intervention.

In this study, in order to assess the impacts of those initiatives and other on the rehabilitation of rangeland ecosystems at large scale, we evaluate the potential of medium-resolution satellite imagery for this purpose. The approach utilizes Google Earth Engine, a state-of-the-art cloud computing platform, which is a technology that is able to rapidly deliver information derived from remotely sensed imagery in near-real time. GEE were used for data collection and treatment (Bey et al. 2016). It helps to maps vegetation vigor using vegetation index, especially the Normalized Difference Vegetation Index (NDVI), which is correlated directly to vegetation productivity (Reed et *al.* 1994).

Results

NDVI changes indicating the relative trends of the health/vigor/cover of vegetation in different sample plots were analyzed within plots concerned by CFCG and compared to that of control sample plots that remain. The results are shown in Fig. 1. NDVI trends over time shows a degradation tendency in areas planted without community organizations and compensation compared to those concerned by the mechanism of compensation (Fig. 1). Photos in Fig. 2, showing the vigor and the state of vegetation before and after the implementation of the mechanism, illustrate the trends within some sample plots. NDVI change trends analysis revealed that the compensation mechanism enhanced the success of forest-rangeland rehabilitation activities. Such success is crucial and is a biological prerequisite to ensure land sustainability. Also, the field observations and discussions with key actors and forest-rangeland managers revealed that the CFCG mechanism had positive impacts on restoring plant species composition, diversity, biomass, cover and structure of both herbaceous and woody components, and improving soil nutrient status, leading to reduction in erosion. These findings agree with literature focusing on improving canopy cover in grazing exclosures (Hammi et al. 2010).

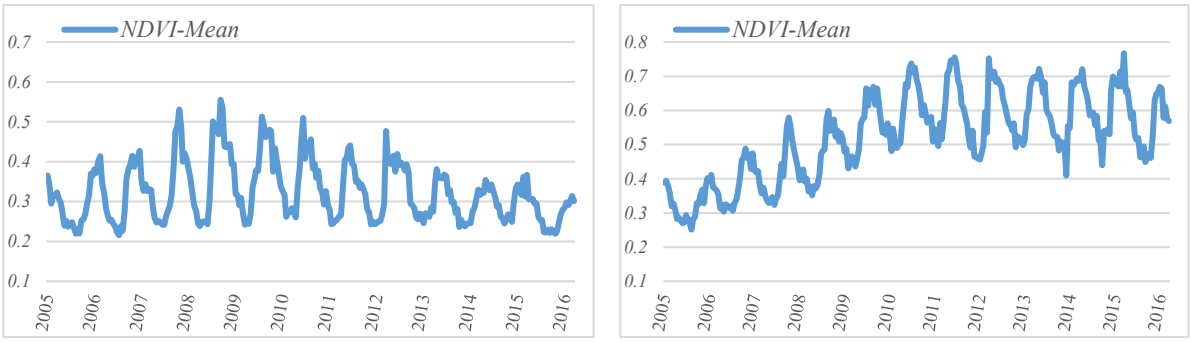

Figure 1 : Temporal evolution of NDVI after planting and grazing exclusion in various sample plots. *(a) areas managed without local population involvement; (b) areas managed with involvement of local population*.

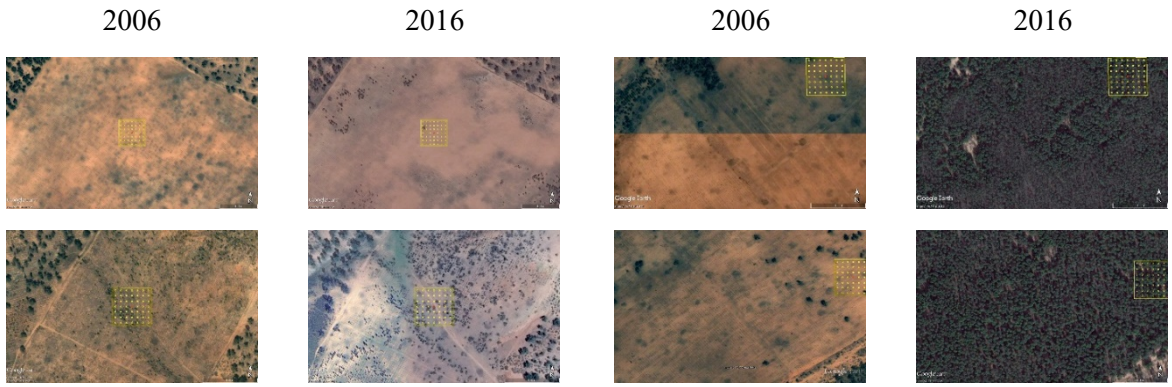

Figure 2. Photos illustrate the trends by showing the state of vegetation between 2006 and 2016. *(a) example of areas managed without local population involvement; (b) example of areas managed with involvement of local population*.

The process of geo-synchronising, visualising and the use of imagery of varying spatial and temporal resolutions from different imagery sources to produce maps and statistics for our different sample plots was facilitated and simplified by the GEE processing plateform. GEE appears as the Geo Big Data analysis platform as more functional from an operational perspective, powerful and at the same time easy to use.

Conclusions/Implications

As perspective and to overcome managers lack of technical skills or computing infrastructure capacities, we can prototype and develop a web-based application in order to automate massive amounts of remote sensing data processing by combining medium spatial resolution imagery with the computation power of Google Earth Engine. Such solution must help managers for monitoring vegetation response to rehabilitation initiatives at large scale.

The framework will be based on repeated measurements of several vegetation indexes at various times over time-period. Measurements will be taken for each time step at locations which will be concerned by a program of rehabilitation or restoration (Before and after the intervention). Also, measurements will be taken at similar other locations in regards to the ecological condition and which is not concerned by the program of rehabilitation.

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