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Assessing rangeland cover conversion in Jordan after the Arab spring using a remote sensing approach

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ABSTRACT

The influence of population growth and Syrian refugee settlements on rangeland degradation in Jordan using remotely-sensed data was assessed. Eleven cloud-free Landsat 8 Operational Land Imager (OLI) Images that cover the study area were used. Maximum likelihood classifier was applied to estimate rangeland, cropland, urban, water and forest cover percentages over the study area for the period 2013–2015. Change detection analysis of both 2013 and 2015 images revealed a dramatic expansion of urban lands and a consequent reduction in rangelands, especially in north-western Jordan. Our analysis suggests that Jordanian rangeland area decreased by 9.6%, forests by 1.5% and water by 0.6% during the study period (2013–2015). Meanwhile, urban lands increased by 11.4% and croplands by 0.2%. We attributed this change mainly to Syrian civil war and refugee settlements. This settlement process increased the demand for food and water and accelerated desertification processes in Jordanian rangelands, especially those in the north-western region. Our study underscores the value of using remotely sensed data as a viable approach to quantify degradation in Middle Eastern rangelands. Overall, we suggest initiating rigorous urban settlement regulations and land conservation control programs to mitigate land degradation in Jordanian rangelands.

1. Introduction

Rangelands are globally the single most abundant land cover type (Holechek et al., 2011) that sustain critical social economical systems worldwide (McCollum et al., 2017). Successful monitoring of rangelands is of critical importance to the food security and poverty relief of millions of people in the developing world (Al-Kofahi et al., 2017; Lund, 2007). Despite being the most extensive land cover type worldwide (occupying approximately a third of Earth's ice-free land) rangelands contribute only 11% of terrestrial net primary production (Ellis and Ramankutty, 2008). Rangeland degradation is a complex process because it is the product of interactions among environmental and socio-economic factors as well as public land use policies (Bedunah and Angerer, 2012).

Land degradation can be defined as the extreme reduction of biological or economic productivity due to unsustainable land use (Bedunah and Angerer, 2012). Rangeland degradation is a growing problem worldwide due to aridity, erodible soils and low productivity inherent to these fragile ecosystems (Reeves and Baggett, 2014). The degradation of biophysical rangeland resources negatively affects pastoral ecosystems and livestock production (Holechek, 2013) especially in developing countries. The degree of rangeland degradation in developing countries is difficult to measure due to lack of monitoring of the impacts of human population growth rate which add substantial pressure on rangeland ecosystems (Bedunah and Angerer, 2012) particularly in the developing world.

The combination of rapid population growth rates in the Middle East, which increased five-fold since 1950 (United Nations, 2002), drought, ethnic frictions, rising living expenses, and authoritarianism (a small group of society concentrate the power to rule the country) are responsible for the social turmoil that resulted in the present conflicts in the region the most notable of which is Syria (Holechek et al., 2017; Perry, 2016). The civil war in Syria (March 15, 2011-ongoing), and the related wave of refugees fleeing into Jordan, have significantly stressed the Jordanian economy, society, and environment (UNDP, 2015). Refugees face critical and prolonged problems of poverty and insecurity

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(Jacobsen, 2002). In most cases they do not have the resources to move away from the region, such that they remain internally displaced or move across borders to neighboring countries, many of which are facing their own struggles as they cope with fragile economic, environmental, and security burdens (Jacobsen, 2002). Influx of refugees can lead to pastoralist displacement and severe rangeland degradation and loss of livestock (Jacobsen, 2002).

Rangeland degradation assessment depends on the quality of information used to quantify the extent and severity of degradation (Eddy et al., 2017). Landsat sensor data provide remotely sensed imagery with extraordinary temporal and spatial resolution to map land cover (Bleyhl et al., 2017; Othman et al., 2014; Pettorelli et al., 2014). These data can be used to derive information about land cover (e.g. vegetation) commonly used to assess rangeland condition (Kong et al., 2015). Freely available time series of remotely sensed imagery coupled with ground referenced data are considered a viable approach to quantify land degradation (Reeves and Baggett, 2014; Tongway and Hindley, 2004). Change detection techniques using remotely-sensed data offer new possibilities for rangeland management research, specifically in arid and semi-arid areas (Willis, 2015). This technique consists of a process used to determine pixel variations at different times to identify areas undergoing rapid changes (Singh, 1989; Willis, 2015). This approach can enhance the conservation of natural resources and ecological monitoring through monitoring irregular, uniform, and continuous ecological dynamics of observed area (Sergeant et al., 2012; Willis, 2015).

Monitoring of rangeland degradation in remote areas of Jordan poses substantial logistical challenges because of the need for frequent assessment of ecological status over time and space. Our objective was to quantify the impact of refugee settlements and associated population growth on rangeland degradation in Jordan using remotely sensed data to detect these changes.

2. Materials and methods

2.1. Study location

The study area covers an area of 89,000 km^2 that represents Jordan land (30.5852° N, 36.2384°E located north of Red Sea (Fig. 1). During the last 5 years, human population in Jordan increased rapidly due mostly to the Syrian conflict. Jordan received a considerable number of Syrian refugees that exceeded one third of its original population. Since then, rangeland areas of Jordan have been undergone spectacular transformation due to urban and exurban development that occurred as a consequence of population growth. Rangelands in Jordan cover about 80% of the total land area, however only around 3% of the population lived on rangelands prior to the building of the largest refugee camp in the Middle East (Al-Za'atari camp) in 2012. By early 2015 the estimated population of the Al-Za'atari camp was around 83,000 people. Northern Jordan has been intensely impacted by the Syrian civil war. Since the revolution began in Syria in 2011, Jordanians have experienced the conflict of the war through the thousands of refugees that have crossed the Northern border through the towns of Jabir and Ramtha (EUI, 2015). This settlement creates significant crises in Jordan through increase the pressure on water (Müller et al., 2016) and food resources and increase land degradation in rangeland areas.

2.2. Image acquisition and processing

Landsat 8 (OLI) Imagery was used as an input source for change detection to evaluate the impact of refugee settlements and population growth on rangeland degradation in Jordan. Remote sensing provides a cost- and time-efficient method for monitoring of landscapes that are essential to the ecological and biodiversity studies (Willis, 2015). In remote sensing, spatial resolution (pixel size) for monitoring purposes usually ranges from 0.5 m to 500 m (Willis, 2015). The medium spatial resolution of Landsat image pixels (30 m) allows for spatial features to be identified at a scale suitable for monitoring vegetation structure and composition (Bleyhl et al., 2017). Landsat images are recommended for monitoring land use/land cover studies, due to their continuity and availability free of cost (Willis, 2015).

Cloud free Landsat 8 Operational Land Imager (OLI) Imagery were identified and downloaded from earth-explorer portal (http://earthexplorer.usgs.gov/). Images are available free of charge from the earth-explorer NASA portal. We used Surface Reflectance Climate Data Records datasets. Surface Reflectance Climate Data Records (CDRs) are a reliable Landsat source for land cover studies (Othman et al., 2017). These dataset (CDRs) are atmospherically corrected using the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) program.

Images were then georectified using Environment for Visualizing Images (ENVI) 5.0 (Research Systems, Boulder, Colorado, USA). Image mosaicking tool in ENVI was then used to merge the 11 images in one full scene. In image mosaicking, pixel-based coordinates were used to place images in mosaics and the feathering technique was performed to blend image boundaries.

2.3. Image classification

The classification scheme was developed by considering the research question and the problem of interest for the study area. In addition, image resolution (spatial, temporal, spectral and radiometric) of the remotely-sensed data and historical data of the study area were included and justified to be used in the current classification scheme while others were excluded. A detailed description of classification scheme is found in Table 1.

Different classifiers applied to the six original spectral bands of the 2013 image using ENVI. ISODATA was used for unsupervised classification. Parallelepiped was used for nonparametric supervised classifications. Maximum likelihood was used for parametric supervised classification. Finally, Neural Network and Support Vector Machine were used for an artificial intelligence classification.

Each map was assessed visually and compared with the rest of the classified maps. The visual evaluation of each map was in agreement with the results from the overall accuracy and Kappa coefficients of each classifier. The classifier that yielded the highest accuracy was considered and results obtained were reported. Accuracy assessment and Kappa coefficient were applied to different feature combinations (original remotely sensed bands and ancillary data) in a trial and error process in ENVI was used to determine the best approach. Finally, the best approach and classifier was used for the original six bands, applied using ENVI to produce classified maps. Change detection was computed as the difference between the proportions of each class between the two classified images.

2.4. Classification accuracy assessment and area estimation

Classification accuracy was determined by assessing the disparity between our classification results and Google Earth images. Stratified random disproportionate sampling was applied to collect the ground truth reference data due to the fact that some classes in our study site cover small areas (such as forest) and other classes are homogeneous areas (such as water). The total number of sample points used to check the classification accuracy followed the rule of thumb suggested by Jensen (2005) that is to select 10 times the number of bands per class. This resulted in 300 points in this study. A confusion (error) matrix was developed for each classified map, in order to assess the Overall accuracy, Kappa coefficient, User's and Producer's accuracies according to the method described by Congalton and Green (2009).

Due to the map classification error, the actual land cover area may differ from the areas obtained from the classification map (Olofsson et al., 2013; Stehman, 2013). Error-adjusted areas and 95% confidence intervals were calculated for each classified map, according to the

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