Land Cover/ Land Use Change and Climate Change in Dhofar Governorate, Oman

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Abstract

The study of land cover/land use dynamics under climate change conditions is of great significance for improving sustainable ecological management. Understanding the relationships between land cover and land use changes and climate change is thus very important. Understanding the interactive and cumulative effects of climate and land-use changes are a priority for urban planners and policy makers. The present investigation is based on Landsat satellite imagery to explore changes in vegetation spatial distribution between the years from 2000 to2018 The methodology is focused on vegetation indexes tracking and algebraic overlay calculation to analyzed vegetation and their spatial differentiation, land cover change pattern, and the relationships between vegetation dynamics and land cover change in Dhofar Governorate. The study results have revealed that the vegetation vigor is lower in all years compared to 2000. The scene of 2010 shows the minimum vegetation vigor, overall. Besides, the investigation shows a statistical relationship between rainfall and the status of the health of vegetation. Monsoon rainfall has an impact of the growth of vegetation. Between 2012 and 2013, the vegetation activity shows a decreasing trend. The analysis diagnoses an area affected by the worst degree of aridity situated in the southeastern of Dhofar Mountains. Climate change is the main driving factor resulted from both human activities and rainfall fluctuation.

1. Introduction

Knowledge of the current changes and dynamics of different types of vegetation in relation to climatic changes and anthropogenic activities is critical for developing adaptation strategies to address the challenges posed by climate change and human activities for ecosystems. Based on a vegetation index analysis, the study investigated the spatial and temporal characteristics and relationships between vegetation greenness and climatic factors in Dhofar governorate using the Normalized Difference Vegetation Index (NDVI) and gridded high-resolution station (land) data for the period 2000–2018. Further analysis distinguished between the effects of climatic change and those of human activities on vegetation dynamics by means of a residual analysis trend method. (Challinor, 2014 and Canty and Nielsen, 2008)

NDVI has become an important method attached with vegetation (Salinas et al., 2002 and Philippon et al., 2007) because vegetation greenness is strictly linked to climatic conditions, particularly in arid and semi-arid regions. Useful insights have also been gained for the relationship between NDVI and climate variability by analyzing temporal and spatial patterns in the NDVI and climate at local and regional scales. The foundation for using NDVI data for monitoring arid and semi-arid lands is based on a large body of research in the 1980s. Demonstrating the close relationship between NDVI and rainfall variations on seasonal to interannual time scales (Gray and Tapley, 1985, Tucker et al., 1985, Hielkema et al., 1986, Henricksen and Durkin, 1986, Justice and Hiernaux, 1986, Townshend and Justice, 1986, Rasmusson, 1988, Nicholson et al., 1990, Hutchinson, 1991, Tucker, 1979 and Tucker and Nicholson, 1999). This relationship between NDVI and rainfall provided the basis for using time series NDVI data for drought monitoring and developing early famine warning systems in regions with sparse terrestrial rainfall networks (Henricksen and Durkin, 1986, Hielkema et al., 1986, Tucker et al., 1985 and Hutchinson 1991). Numerous methodologies to explore the relationship between the NDVI and climate in semi-arid regions have been used in the past. Huete (1988) and Huete et al., (2002) Comparatively high connection has been found between precipitation accumulated over various periods and the NDVI (Hielkema et al., 1986, Tucker et al., 1991, Plessis, 1999 and Schmidt and

Karnieli, 2000). Some studies also found that this association increases if the precipitation occurring closest to the time of the NDVI image was excluded (Wang et al., 2001 and Yang et al., 1997). Residual Trends (RESTREND), i.e. negative trends in the differences between the observed ΣNDVI and the ΣNDVI predicted by the rainfall using regressions calculated for each pixel. Both these methods are based on the concept that land degradation causes reductions in vegetation production per unit rainfall as a result of soil erosion, soil degradation, changes in vegetation species composition and increased run-off of water (Pickup and Chewings, 1994 and Walker et al., 2002). The long-term trends in ΣNDVI identified in the abovementioned analyses contain a significant rainfall signal that, if removed, may allow climate trends to be distinguished from human-induced land degradation (Archer, 2004, Evans and Geerken, 2004 and Pei et al., 2013).

The study also focused attention on climate change and human activities that have negatively influenced vegetation growth. (Wu, 2014) and (Ji and Peters, 2003) While underlining the effects of human activities is not thoroughly highlighted the influence of climatic conditions basically rain fall and temperature is discussed. Despite the fact that understanding of the influence of human activities can potentially lead to consistent outcomes and hence appropriate policies that support restoration mechanisms.

2. Materials and Methods

Three scenes of Landsat imageries captured during April- May from 2000-2018 (Table 1) were utilized in the analysis of vegetation in the Al-Qara Mountain Range. The Three-georeferenced images, which were received as TOA calibrated images, were co-registered and resampled to 20m resolutions to suit the Landsat images. Precipitation data of two WMO stations were also utilized (Table 2) to test the link between precipitation and vegetation health in Al-Qara. Salalah Airport meteorological station is located in the plains of Salalah city, while the station Hagayef is located in the Al-Qara mountain range, around mid altitudes (890m). Nevertheless, the precipitation records of Hagayef are not long enough to cover the required time series from 1994-2013. Therefore, Salalah precipitation records were used to estimate the 2012 and 2013 long-term precipitations of Hagayef.

2.1 Vegetation Health Parameters

First, the vegetation changes were mapped to monitor the changes in vegetation health and the vegetation change over time. The reflectance images (Table 1) were transformed to Normalized Vegetation Index (NDVI), and the mountain range were extracted from the NDVI Images. To test if there is a link between vegetation health of Al-Qara and precipitation received, the minimum, maximum and mean of NDVI values of the Al-Qara vegetation were correlated with the precipitation parameters explained in the following section. Normalized Vegetation Index (NDVI, Tucker, 1979):

$$NDVI = (RVI - 1)/(RVI + 1)$$

Equation 1

The most commonly used vegetation indices utilize the information contained in the red and near infrared (NIR) canopy reflectance or radiances. They are combined in the form of ratios: ratio vegetation index (RVI) or normalized difference vegetation index (NDVI).

Table 1: Satellite data employed

#	Year of capture	Mission	Ground Resolution / m
1	2000	Landsat 7	80.0
2	2010	Landsat 7	80.0
3	2018	Landsat 8	30.0

Table 2: Daily precipitation records employed in the analysis

Station name	Time series bounds	Elevation (m)	Location (m) (UTM zone 40)	
			Easting	Northing
Hagayef, Dhofar	18/04/1984 – 25/03/2008 (No data: 18/04/1984 -29/03/1992)	890	184600	1907200
Salalah Airport	01/01/1980 – 31/12/2018	22	189500	1885600

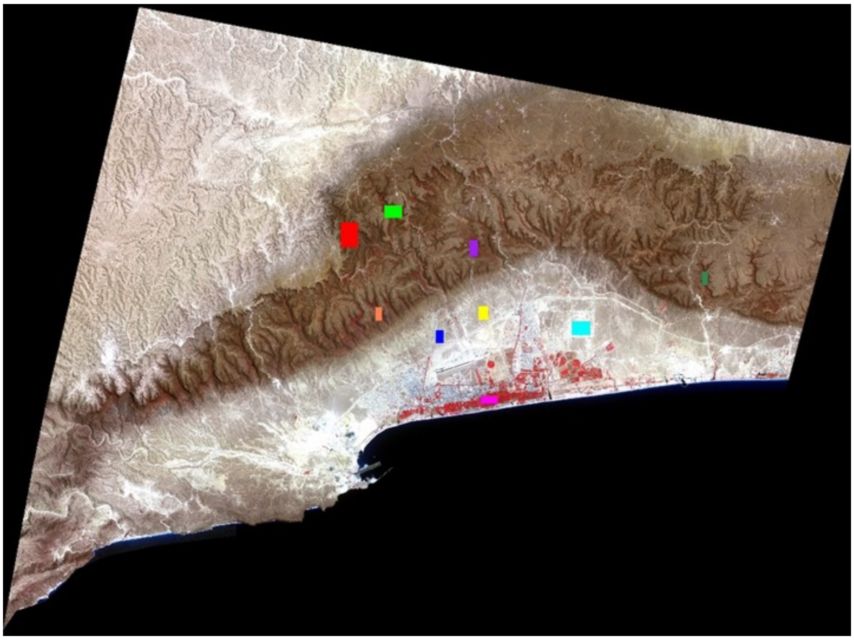

Figure 1: NDVI sampling in the Dhofar region

Table 3: The correlations between minimum, maximum and mean vegetation health (or vigor) and long-term precipitation in the Dhofar Mountain Range

Whole mountain range	Min	-0.0526	-0.0901	-0.1829	-0.1916
	Max	0.3513	0.3812	0.4861	0.4991
	Mean	0.0804	0.0525	0.0592	0.0388
Mountain vegetation_1	Min	0.0227	0.0076	-0.0718	-0.0609
	Max	0.2600	0.2821	0.3122	0.3335
	Mean	0.0949	0.0581	0.0677	0.0460
Mountain vegetation_2	Min	0.0335	0.0069	-0.0984	-0.0625
	Max	0.2431	0.2752	0.2773	0.3065
	Mean	0.1145	0.0817	0.0859	0.0753
Mountain vegetation_3	Min	0.0619	-0.0271	-0.0008	0.0165
	Max	0.1947	0.2246	0.2754	0.2815
	Mean	0.1158	0.0854	0.1103	0.0955
Mountain vegetation_4	Min	0.0270	0.0147	-0.0898	-0.0566
	Max	0.2791	0.2164	0.3093	0.3632
	Mean	0.1023	0.0617	0.0689	0.1126
Mountain vegetation_5	Min	0.0626	0.0384	-0.0329	-0.0011
	Max	0.2283	0.2173	0.2754	0.3351
	Mean	0.1263	0.1049	0.1129	0.0946

Normalized Difference Vegetation Index (NDVI) and Ratio Vegetation Index (RVI) Simplest ratio-based index is called the Simple Ratio (SR) or Ratio Vegetation Index (RVI) Vegetation health parameters were obtained for the whole Al-Qara range (Table 3), and for the five sampling areas situated within the mountain range, shown in (Figure 1).

Table 4: The long-term precipitation time series employed in the correlation analysis

Year	Annual (mm)	Total of previous year (mm)	Seasonal (mm)	July and Aug (mm)
2000	141.20	45.60	31.00	23.00
2010	86.40	214.39	36.35	29.13
2018	100.22	46.31	23.16	23.16

2.2 Precipitation Parameters

Notice: annual (January-December) precipitation, Total of previous year: total precipitation of the year (starting from March of the previous year to April of this year), Seasonal: seasonal (Monsoon season-June-October) precipitation, July and Aug: rainfall of the two months with reliable rainfall (July and August).Monthly precipitation series were extracted from both the stations and were plotted against each other. Three outliers were removed that showed over 400mm monthly rainfall at Hagayef, corresponding to 0mm at Salalah Airport station. A linear relationship was obtained to estimate the monthly time series at Hagayef station. Annual and seasonal precipitation time series were then extracted from the half-estimated Hagayef monthly time series (Table 4).

3. Results and Discussion

The change in vegetation health through the years from 2000 to 2018 is very clear in Figure 2. A classification tree was utilized with the nodal definitions shown in the legend of Figure 2. The vegetation vigor is lower in all years compared to 200 .The scene of 2000 shows the minimum vegetation vigor, overall. In 2000, the area of NDVI below 0.00 also increased in the mountain range in the region facing the city (white patches invaded the yellow area). These might indicate that the vegetation has undergone a drought. The three patches of vegetation (encircled in black) on the extreme right show exception to 2); they show decreased vegetation activity in 2013 even if compared to 2000. Between 2010 and 2018, the vegetation activity shows a decreasing trend towards 2018, with the exception of the regions marked in red. These regions were explored next by a NDVI sampling in the Al-Qara Mountain Range. Figure 3 shows how the NDVI of these sample regions (Mountain vegetation 1 through 5). The Sampling was also extended to the Salalah plain (Salalah plain 1 and 2) and to the Salalah City (Salalah City 1 and 2). Around 2000-2003, the region underwent a major drought, which is revealed by the trough seen at 2004 for all sampling regions other than the two regions in the Salalah City (Salalah City 1 and 2). Salalah City_1 shows the increased urbanization, in which the rate of urbanization seen between 2010 and 2018 is very rapid. Salalah City_2 is a fully irrigated area of vegetation grown for human recreational purposes. It shows continuous increase in vegetation health.Furthermore, the NDVI has become a significant tool together with vegetation (Salinas et al., 2002 and Philippon et al., 2007) because vegetation greenness is firmly connected to climatic conditions, mostly in arid and semi-arid regions. Valuable findings is resulting for the relationship between NDVI and climate irregularity by analyzing temporal and spatial patterns in the NDVI and climate indices. The basis for using NDVI data for monitoring arid and semi-arid lands is based on a large body of research. Research studies demonstrating the close association between NDVI and rainfall variations on seasonal scales. (Townshend and Justice, 1986, Tucker et al., 1986, Rasmusson, 1988, Nicholson et al., 1990, Hutchinson, 1991, Tucker et al., 1991 and Tucker and Nicholson, 1999). The study results indicated that vegetation cover witnessed severe degradation in southeastern parts of Dhofar Mountains. The vegetation cover is denser in the Southern west of the study area. However, it decreased to the southern parts of in the 2000–20108. In NDVI image of the period between 2000– 2018 (Figure 2), there was an average change in the vegetation value (highest was 0.26, lowest was −0.54) and overall trend values appeared to degrade towards the southern part, increased in Southwestern part. The negative value signifies a decrease in intensity and the positive value means an increase in intensity. Thus, the average change in the intensity of vegetation varied during the years (2000–2018 (Table 5). Generally, the course of land cover change in Dhofar Mountains is not uniform.

3.1 Correlation Analysis Of Vegetation Health And Precipitation

Only Mountain vegetation 1 and 2 reveal a significant (<0.1 and <0.05 respectively) positive correlations between mean vegetation health and seasonal and July-August precipitation, implying these are the only areas with direct involvement of climate to the vegetation health, or in turn land degradation. Vegetation health analysis above shows (Figure 2) clear degrading trends that are confirmed by the correlation analysis.

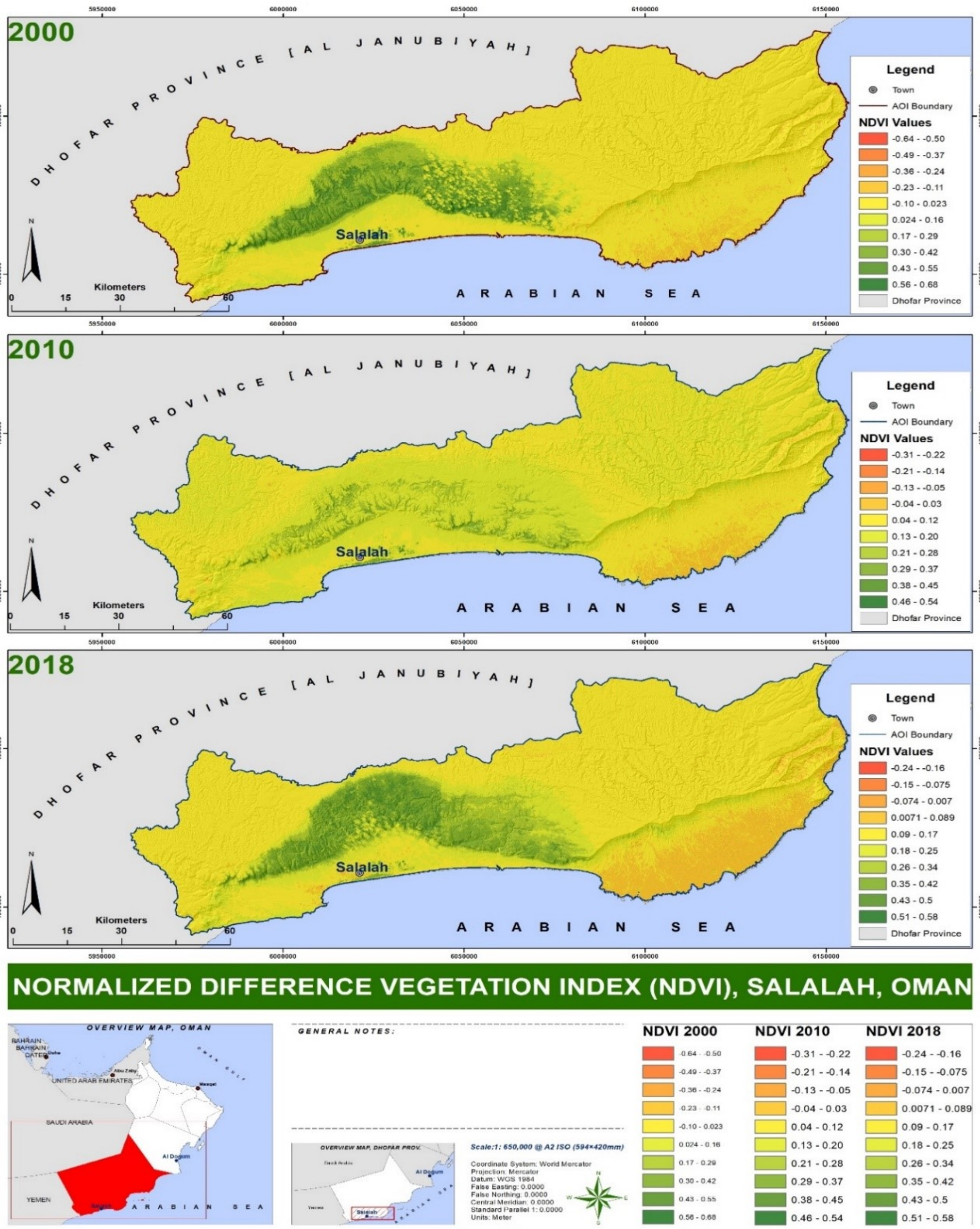

Figure 2: NDVI results in the Dhofar region

Human dimensions (grazing, clearing, burning etc.) of degradation might be minimal in these regions, because of the proximity to the arid areas on the landward slopes of Al-Qara Mountain Range. The average vegetation health of the whole mountain region, parameterized by the mean NDVI of the region is positively and significantly (<0.1) correlated with the seasonal precipitation, although local vegetation conditions differ from this overall picture. However, it should be noted that minimum vegetation health is positively correlated to all precipitation parameters in all regions although not significant at the level require to be acknowledged to causality. Further, the mean vegetation health is positively correlated with seasonal and July-August Monsoon precipitation, although not significant. It could be concluded that in regions other than Mountain vegetation 1 and 2 the degradation seen (Figure 2 and Figure 3) were caused by a combination of factors, of which one cause might be climate. However, this requires further investigation.

Table 5: The correlations between minimum, maximum and mean vegetation health (or vigor) and long-term precipitation in the Dhofar Mountain Range

Region		Annual rainfall	Season rainfall		July-Aug rainfall	
Whole mountain range	Min	0.5461	0.7524		0.7236	
	Max	-0.5863	-0.7135		-0.6818	
	Mean	-0.1216	0.9150	*	0.8921	
Mountain vegetation_1	Min	0.6511	0.6713		0.6458	
	Max	-0.4204	-0.7892		-0.7541	
	Mean	-0.1776	0.9414	*	0.9239	*
Mountain vegetation_2	Min	0.6312	0.6768		0.6603	
	Max	-0.0875	-0.8783		-0.8472	
	Mean	-0.1394	0.9878	**	0.9782	**
Mountain vegetation_3	Min	-0.4773	0.8508		0.8806	
	Max	-0.4841	-0.7989		-0.7722	
	Mean	-0.7553	0.7077		0.7161	
Mountain vegetation_4	Min	0.6977	0.6122		0.5929	
	Max	-0.7869	-0.1842		-0.1290	
	Mean	-0.4050	0.3500		0.4066	
Mountain vegetation_5	Min	0.5882	0.6969		0.6859	
	Max	-0.5853	-0.4939		-0.4418	
	Mean	-0.1880	0.8785		0.8544	

4. Conclusions

The above investigations were based on landsat satellite imagery. Results, clearly shows sharp changes in vegetation presence through the years from 2000 to 2018. The vegetation vigor is lower in all years compared to 2000. The scene of 2010 shows the minimum vegetation vigor, overall. Besides, the investigation shows a statistical relationship between rainfall and the status of the health of vegetation. Monsoon rainfall has an impact of the growth of vegetation. The region experienced a major drought condition between 2010 and 2018; the vegetation activity shows a decreasing trend towards 2010. The analysis diagnoses an area affected by the worst degree of aridity. This area is situated in the southeastern of Dhofar Mountains (encircled with black in the Figure 2). In this area, the process of land degradation is very active, with tremendous decreased in vegetation activity in 2018 even if compared to 2010. Fortunately, the analysis identifies two areas, situated in the Southern west of the study area, where vegetation has increased in vigor and density. Overall, the process of land cover change in Dhofar Mountains is not homogenous. The areas preserved from this process is usually inaccessible and far from human activities.

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