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Research Paper

Assessment of desertification trends in Sistan Plain, Iran using Rs and GIS

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Abstract: Desertification is land degradation and loss of biological productivity in arid, semi-arid and dry sub-humid areas due to climatic variations and destructive human activities. Since the vegetative mass is the major biological production of dry lands, one can consider the deterioration of plant cover as the main indicator of desertification process. Sistan plain is an arid region in south-eastern Iran that suffers from severe types of desertification and land degradation. To assess the trend of vegetation cover changes that was occurred during 1990-2006 periods we conducted a two-year study in the region. The basic tools that employed in this study were in-field sampled data, TM and ETM+ images plus with RS software. All needed processes were done including geometric and radiometric corrections, mosaicing, clipping, PCA and Tasseled cap. Field sampling was carried out in 26 sites with nine plots in each site. To determine the best vegetation index (VI), we evaluated 83 VIs, among them WDVI, $TSAVI_2$, $MSAVI_1$ and $NDVI_{ab}$ proved to be the best for separating and discriminating the plant cover on the images with correlation coefficients of 0.89, 0.86, 0.84 and 0.70, respectively. Then by applying an appropriate threshold, the images were classified in two categories: vegetation and non-vegetation. Kappa coefficients of resulted classification maps for four selected indices calculated using confusion matrix, suggesting that WDVI map is the most accurate map. Finally, change detection map was obtained by subtracting images, showing that 11.37% (95288.9 ha) of the study area experienced changes in vegetation cover from year 1990 to 2006. Of all changed area 89.23% belongs to Decertified class while just 10.77% of changed area indicates the Restoration.

Keywords: desertification, trend, vegetation indices, WDVI, Sistan, vegetation cover

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Introduction

Desertification is defined as land degradation in arid, semi-arid and dry sub humid areas (generally called dry lands which cover 41% of global land surface) due to climate variations and human activities. More than 900 million people in hundred countries in all continents except South Pole, suffer from desertification [17]. Today use of satellite imagery for studying natural processes becomes a common task because that they provide real-time, frequent and cost-effective data with a wide coverage and good spectral and spatial resolution [20]. For those reasons, many researchers have used this technique to study different aspects of natural resources. Amini et al (2008) investigated the changes of Zagros forests area. They found that in a 47-years period, (1955 – 2002), 4853 ha of these forests were destroyed and just 953 ha was reforested or afforestated. A research by Darvish and Faour (2008) in Lebanon clarified that agricultural lands increased from 932 to 4878 ha an rangelands decreased from 29581 to 25000. Qui (2008) also found that in china from 1995 to 2001, 426.9 km^2 of lands were desertified and 478.1 were restored. Sistan region is located in south-eastern Iran and suffering from severe types of desertification. Desertification in Sistan causes serious problems such as habitat destruction, migration, biodiversity losses, lack of food security, increased rate of diseases, etc. in this study we tried to assess the trend of desertification based on understanding the changes occurred in vegetation cover obtained from field samplings and multi-temporal images. Because that must processes of dertification are trying to degrade vegetation cover, so it can assumed that vegetation changes are a good or even the best indicator of desertification over time. The main questions are as follow: how was the trend of changes in vegetation cover of Sistan during the 16-years period? Which vegetation index (VI) is the best for distinguishing sparse plant cover of Sistan on satellite images? In this research it was tried to using ground surveys and satellite data, the best vegetation index is selected and changes of vegetation cover is mapped.

Materials and methods

The study area

Sistan region is a highly populated region in south-eastern Iran (figure 1). Mean annual rainfall is 53mm and mean annual temperature reaches 22°C. Based on De Marten index, Sistan considered as hyper-Arid region. Elevation varies between 450 to 530m above the sea level and general slope is about 0.6 percent. From geological point of view, the formations are mainly quaternary with the exception of mount Khajeh that is a pliestocene basaltic rock. Soils of the region are Entisol and Aridisol. In this study 837097.1 ha of Sistan was investigated which includes central, Shahraki and Naruii, Shib Ab, Poshtab stricts.

Currently, population of Sistan riches 400,000 people. Their main activity is agriculture [3]. When Hamoun lakes (that surrounded Sistan) are filled with water, fishing, reed harvesting, and bird catching are also sources of income. Sistan falls compeletely in administrative unit of Zabol Shahrestan which encompasses 934 villages. In 1973 an agreement between Iran and Afghanistan was adopted which force Afghanistan to deliver a minimum of 26 m^3/s flow of water through Hirmand river to Iran. However the agreement never completely came into force. In addition to 1950 drought, the Sistan region frequently experienced other droughts among them 1998-2005 drought was the most severe one, at least in the past 600 years. This 7-years drought ended with a flood in April 2005. The area that we assessed in this study includes all Bakhshes(sub-provincial administrative unit) except some parts of Bakhsh-e-Poshtab to represent the Sistan status (figure 2).

The following materials and methods were employed:

- four frames of TM sensor, path 157, rows38 and 39 (the study area was so big that falls in two frames) taken at 25 April 1990 and 15 April 1998
- Four frames of ETM+ sensor, path and rows are as same as those for TM. Acquisition dates were 18 April 2002 and 29 April 2006.
- Geological map of the study area,
- a GPS, Etrex model for recording the geographical coordinates of the sampling points and tracking,

- Climatic data records,
- Land use map,
- Software including ENVI 4.2, spss 13.

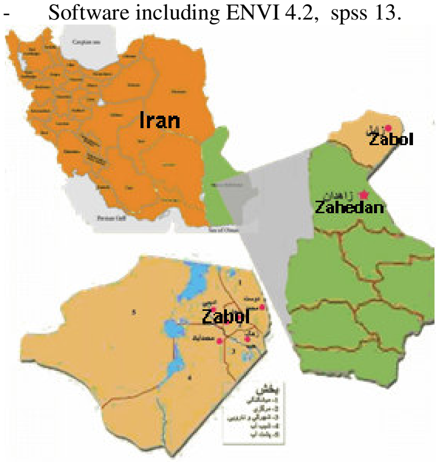


Figure 1: Sistan region

Figure 2: The study area

Image processing

In the first step, the images were Georeferenced according to MrSID files with RMSe of 0.40 to 0.65. Then atmospheric and radiometric corrections were applied on the images and DN values converted to reflectance values [10]. After that, because the study area had been falled in two rows, the images of 157-38 and 157-39 both for TM and ETM+ were mosaiced and were bond together. Then according to boundary vector file, the mosaiced images were cliped and pixels outside of the boundary masked with a background value of zero. The area of interest was 838097.1 hectares and the perimeter was 594.2 km. processing such as PCA, Tasseled cap and VIs were done [9]. In this study we employed 83 VIs to select the best index for evaluating the sparse plant cover of Sistan (Annex A) [4,6,7,9,14,15,16,19]. It is important to note that because some indexes needed slope and/or offset of soil line, we calculated it by correlating band 3 and 4 at sites that no plant cover was presented-bare soil (figure 3) [2].

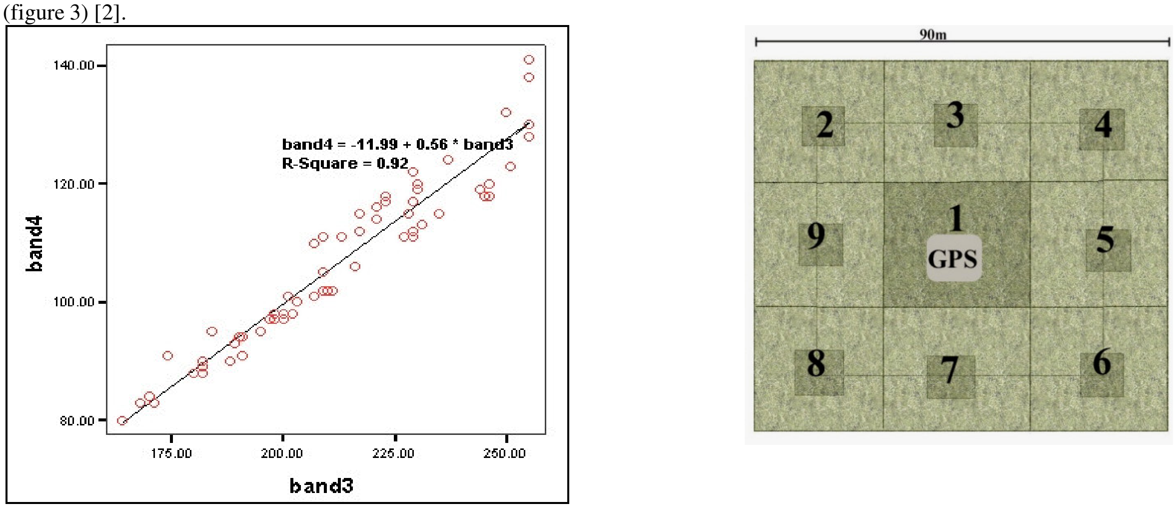


Figure 3: The conventional soil line for year 2006 (left) and plots Arrangement (right)

Gathering field samples of plant cover

In late April 2006, the field surveys was started and lasted for two weeks. first using landuse and roads map, we determined the sampling sites with good distribution, considering that each sampling site cover at least 8100 square meter (3×3 pixels). Systematic random method was selected for sampling. On the field, in each point, geographic coordination was recorded using GPS and consider as center for a virtual 90×90 rectangle which later 10×10 plots established around it. A total of 26 points were sampled [13].
In addition to field sampling, we used QuickBird satellite images of 4th may 2006.

At first, 90×90 Parcells were clipped from images, then using unsupervised classification the green area separated from others. Pixels of green area divided to the total number of pixels to obtain vegetation cover percentage (figure 4). This method couldn't be applied for all sampling sites because of limits in obtaining images, however, it is appear be good for sampling Woodlands and forest plantations where field sampling and estimation is not easy.

Selection of the optimum index

To correlate the field data and satellite image values, firstly the average of 9 plots were calculated for each site and considered as plant cover percentage for that 8100 m^2 site. Then a point vector of all 26 points was created and was converted to raster file. In the satellite image, average values of 9 corresponding pixels were calculated. Then simple and multiple regressions were applied on the two series of data.

Classification and accuracy estimation

After selecting the optimum VI, a presice treshold of plant presence was determined using vertical and horizontal profile tools and based on the treshold, the maps of above ground plant cover were produced. Finally ground truth data were gathered and error matrix as well as Kappa coeficient was calculated.

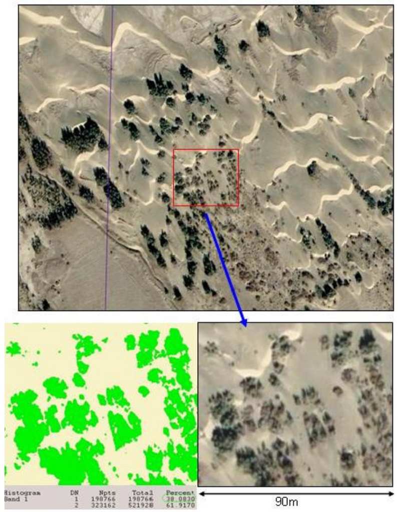


Figure 4: plant cover estimation on Quickbird imagery

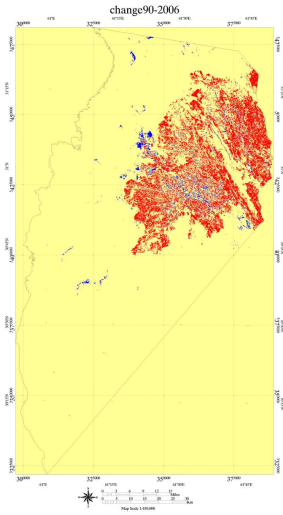


Figure 5: 1990-2006 changes in plant cover of Sistan

Change detection

Because that the main objective of this study is to identify vegetation cover changes over time, it was necessary to compute difference map [11,12]. For this aim, the final state image subtracted from initial state image to clarify the changes. Finally change map was obtained in 3 classes: Desertified, Restored and Unchanged [1]. It is important to note that there were some individual isolated pixels (haze) for each class which eliminated by a median 3×3 filters.

Results

Having the highest correlation coefficients, WDVI showed to be the best VI for assessing the sparse vegetation cover of Sistan. Other few indices including $TSAVI_2$, $NDVI_{ab}$ and $MSAVI_1$ were also promising and noteworthy (table 1).

Table 1- correlation of the best VIs with Sitan vegetation cover

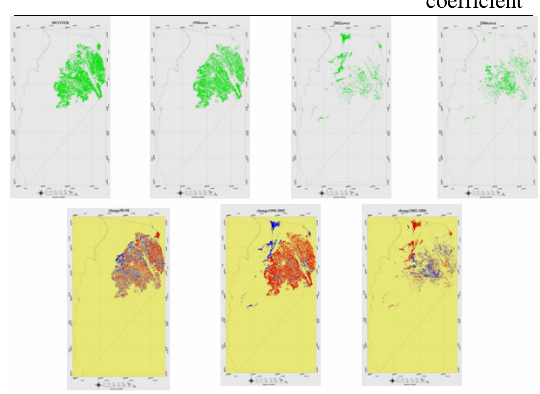
Confidence level	Correlation line	R	index
0.99	Y=41.39+0.58X	0.89	WDVI[1]
0.99	Y=-10.86+0.61X	0.86	NDVIab[2]
0.99	Y=44.70+105.44X	0.80	TSAVI2[3]
0.99	Y=59.02-1.35X	0.70	MSAVI1[4]

Table 2- Kappa coefficients and overall accuracy for the VI-derived classified maps

WDVI	TSAVI	$NDVI_{ab}$	MSAVI	-
83.27	68.78	71.93	60	Overall accuracy(٪)
0.64	0.49	0.56	39	kappa coefficient

Table 3- desertification in Sistan with special emphasis on plant cover

year	Plant cover (ha)	
1990	101247.8	
1998	91159.2	
2002	25830	
2006	26475.57	
	Change(ha)	
period	Restored	Desertified
1990-1998	42782.85	32694.21
1998-2002	83949.75	18620.55
2002-2006	19775.43	20421.00



Annex A – from left to right, plant cover of Sistan in 1990, 1998, 2002 and 2006 (upper row) and its changes during 1990-2006 (lower row).

1-weighted difference vegetation index, 2- Normalized difference vegetation index, 3- transformed soil adjusted vegetation index, 4- modified soil adjusted vegetation index

The images were classified using the four above indexes. Error matrix was calculated based on gathered ground truth data, revealed that WDVI is the optimum VI for Sistan region (table 2).

Having WDVI the best index, plant cover maps for 1990, 1998, 2002 and 2006 were developed. Then, the changes were detected by subtracting the images. Results showed that for 1990 to 2006 period, 11.3% of the study area was changed from which 89.23% (85031.5 ha) was negative or desertified while just 10.77% (10258.3 ha) of changes was positive or restored (table 3, figure 5).

Discussion

Although Rouse et al (1974) and Darvish and Faraou (2008) consider NDVI as the most common and general VI and many researchers have used this index in their studies (Reed et al., 1994 ؛Morisette et al., 2006 ؛Anderson et al., 2006 ؛Washington-Allen et al., 2008 ؛Huang et al., 2009), the results of this study propose WDVI as the most appropriate index for assessing Sistan's vegetation cover. Using this index it was clarified that from year 1990 to 2006, vegetation cover of Sistan decreased from 101.267 to 24.457. Literature reviews and commiunications with local people and experts revealed that A considerable proportion of such negative change is due to hydrological drought (not climatical) that arise from Hirmand river depletion. Most of the restorations are observed in Chahnimeh tree plantations at the western parts and Lurg-Bagh enclosured rangelands at the eastern parts. Ghorghori area and Niatak region also showed some positive changes. The main factor of desertification during this period is drought, drying up of Hamouns, devastation of reed beds and lack of alternative water resources such as underground water or rainfall. Regarding that Hamoun lakes fed from Hirmand River, construction of Kajaki dam and other reservoirs in Afghanistan reduced Hirmand flow and therefore threatened depleting the aquatic ecosystem of the lakes and their dependents. Moreover, annual evaporation in Sistan reaches 5000 mm while mean annual rinfall is just 50mm (it was 109.9mm for year 1990 and 39.6mm for 2006). Having shallow water of the lakes, persistent winds and intense solar radiation and interuptions in Hirman flow, the lakes completely dried out in 2001[17]. 2002 is the driest year which the drought reach the hieghst point [5]and vegetation cover decreased dramatically to 25830 ha . In that year total precipitation was 37.5mm, wind speed average was 12.9 knots, number of days with 2 km or less visibility reaches 88, number of cloudy days was just 13 and flow of Hirmand River met zero during some parts of that year. Following Hamouns depletion, plant cover of Sistan including reed beds, shrubs and rangelands were deteriorated and agricultural farms were abandoned. 120-days winds also intensify land degradation and soil erosion and causes abration of plants which reduces yield and seed production. Furthermore, existed seeds already have been died because that embryos had dried or that buried deeply in soil or placed in a bad place to germinate. So, it is hard to expect full rapid recovery in plant cover.

A comparison between the two images suggest that about 90 percent of degradations in plant cover belongs to abandoned farms and the remain back to deterioration of rangelands, riparian zones and reed beds. With focusing on the resulted change map, we observed that despite of such severe drought, some parts of the studied area experienced restoration. Those include a) forests and tree plantations around Chahnimeh reservoirs, b) Niatak artificial forests which irrigated from sub surface water of Niatak river bed, c) Lurg Bagh enclosured ranges which located in Hamoun's dry bed and d) Ghorghori natural forests which are near to Iran-Afghanistan border and in dry years enjoy from water of the neighboring country. This region experienced the least damage during drought years.

Now, with regard to environmental conditions of Sistan which highly depends on situation of upstream areas in Afghanistan and considering economical and social aspects of Sistan and the conditions that emerged after the drought, it is clear that the best choices for solving the problem should be sleeked into inter governmental negotiations, global discussions along with initiatives of international organizations and cooperation of local authorities and communities so that with a general consensus on the transboundry issues, integrated sustainable planning achieve based on long-term view and immediate actions. More important, due to declines in water resources in coming decades, it is unavoidable to manage the resource accurately in all sectors including generation, storage, transfer, distribution, consumptions either in urban, rural, industrial or agricultural sectors. Lastly, it is predictable that by new innovative techniques and cost effective measures together with bilateral and multilateral agreements and with modifications in water consumption patterns, this negative trend will become softer in future.

Conclusion

Generally, we can conclude that by using Landsat images and appropriate vegetation index it is feasible to detect even poor vegetation cover and calculate its changes over time.

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