

Spatiotemporal Impact of Precipitation Trend on LULC Using Satellite Remote Sensing Technique in Khirthar National Park, Sindh Pakistan

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Abstract: Water footprint techniques are extensively used for essential life chores. It also maintains the natural ecosystem. The variations in climatic spell are not only important to investigate the past and current scenarios, but it is also useful to develop the water resource projects. The current study explored the spatial-temporal climatic variation of dry and wet periods (between 1998 and 2010) using the digital image processing technique of ENVI (Environment for Visualizing Images) classics, satellite remote sensing (SRS), and GIS. The results are organized for the reported period i.e. between 1998 and 2010, showing the change detection of the hydrological effect in the dry and wet years. It shows a significant change in the land use land cover (LULC) of vegetation, water, settlement, and ephemeral rivers followed by 91%, 97.45%, 94.40%, and 62.94 % respectively through the wet year of 2010, in association with the dry period of 1998. For more authentications, the Normalized Difference Vegetative Index (NDVI) image difference of the wet and dry period has also been evaluated, which has shown vegetation in large areas with more water potential in the wet year 2010. The water potential can be used by diverting it to the natural depressions, ditches, and ponds for storage purposes and to increase recharge of groundwater by increasing its quality and quantity. The stored water could be utilized in the drought-prone days for sustainable agriculture activities, to reduce the migration rate of the community, and to improve the socio-economic conditions in the study area of Khirthar National Park.

Keywords: Climate change, image processing, NDVI, remote sensing, land use land cover.

Introduction

Precipitation is a highly important climatic variable which has a direct impact on the occurrence of drought, which occurs with spatial temporal variation in frequency, severity, and duration (Azam et al., 2018a; Azam et al., 2018b; Azam et al., 2018c; Maeng et al., 2018). Implications of rising precipitation extremes are more severe in arid regions, particularly the ones having a diverse topography due to subtle hydrological cycles and ecological processes to climate variability (Alamgir et al., 2020; Khan et al., 2020). The gradually increasing pressure on natural resources and its consequent threats for human beings have drawn global attention to the issue (Soomro et al., 2020, Memon et al., 2020a). The study focusing spatial temporal variation of LULC can be used to monitor and maintain the ecological phenomenon (Soomro et al., 2020; Soomro et al., 2019). Ecosystem and life activities can easily be monitored by using remote sensing methods (Ambreen et al., 2021). However, some data remain constant or change slightly over the period (Kit and Ludeke, 2013). Currently, spatial techniques have been applied to examine the LULC change by the environment variables and human activities. Environmental characteristics can be measured using remote sensing techniques like indices, spectral and spatial enhancement techniques.

Water is the main source of economic activity. It is the basic commodity to sustain livelihood chores on the earth's surface and maintain the environmental

ecosystem. Remote sensing is used for the monitoring and exploring the water resources (Memon et al., 2020b). Nowadays, investigation of the variation in two climatic spells is quite easy through advanced technologies of remote sensing and GIS. The prolonged or short period may be examined accurately using the authentic dataset. Careful expertise is obligatory to investigate the required goals, depending on the nature of investigation for the issue. The successive change detection plans are depending on the temporal multiple imageries, which reflect the real ecosystem (Tri Dev et al., 2016; Yang et al., 2015).

The Landsat dataset has been extensively utilized to investigate the water potential and the variation in the LULC (Tri Dev et al., 2016; Rover et al., 2012; Alsdorf et al., 2007; Rokni et al., 2014; Du et al., 2012; McFeeters 1996; Yang et al., 2015). The documentation is useful to detect water resources (Rover et al., 2012; Alsdorf et al., 2007), delineation of flooded areas (Soomro et al., 2020; Jain et al., 2005; Chignell et al., 2015; Wang et al., 2011), and variations of LULC (Memon et al., 2020a; Rokni et al., 2014; Du et al., 2012; Xu 2006). The present study conducted for the spatial-temporal change detection of LULC for the dry and wet climatic periods through digital image processing technique using Geo-informatics software ENVI classics, Erdas imagine, and Arc Map in Khirthar National Park (KNP). The study covers an area of around 20,301 km² (Fig. 1), at latitudes between North 24° 58' 7.7" to North 26° 6' 59.36", and East 67° 16'

16.49". It is located in the Kohistan region, foothills of Khirthar mountains, Sindh (Fig. 1).

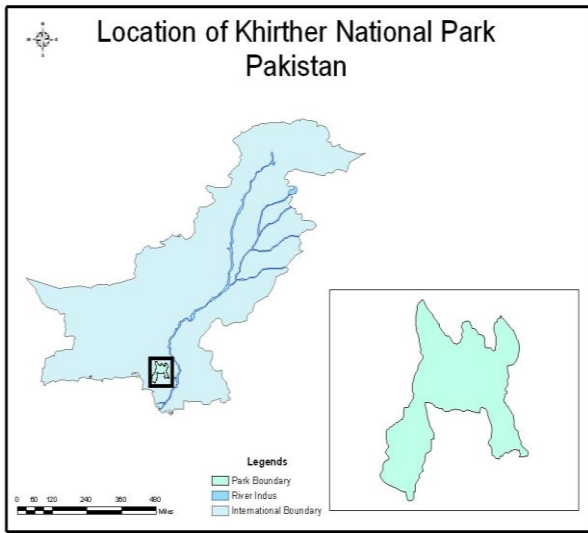


Fig. 1 Location map of Study Area (Khirthar National Park).

The harsh weather and prolonged drought confronts intense pressures on natural resources (Memon *et al.*, 2019). While people struggle hard to earn their living and make only small earnings through agriculture including grazing and browsing of herded livestock, with nomadic and semi-nomadic traditional style in the heights of hills.

Material and Methods

The Landsat 7 data images, August 18, 1998, and August 19, 2010, were downloaded through the United States Geological Survey (USGS) website. Separate bands have been downloaded from each data set and a composite image of each set has been developed. These are Thematic Mapper (TM), 30-meter resolution with seven bands. The image was used to detect water potential, and land covers (U.S. Geological Survey 2015). In Landsat 7, bands 5 and 4 are used for near-infra-red and red bands, respectively. Color Composite Image (CCI) with Red Green Blue (RGB) color combination, using 3, 4, 5 bands for both images have been developed to study the driest and the wettest years during that period. Histogram Equalization Technique was applied to the images.

A supervised classification method has been employed to classify the image because it gives accurate results. Supervised classification was performed on each data set, with a maximum likelihood classifier to find the exact result-oriented bottom-level class (Andrefouet et al., 2003). The maximum likelihood algorithm assumes the training data set with their statistical regulation and fits it approximately into the sample size and pixel counts. Moreover, ground truthing data, using the Global Positioning System (GPS) has been used to verify the ground objects.. All the data of classified maps have been converted into shape file in the Arc

Map. The area of each classified map, from the images of 1998 and 2010, was calculated to get the difference.

Normalized difference vegetative index (NDVI) for agriculture was used for both images as mentioned in the equation below:

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

Where; NIR characterizes the Near Infra-Red

Present work is aimed at the observation of study area; ground-truthing of the required object and getting control points of different benchmarks for the accuracy of images with spatial referencing and help of GPS.

Results and Discussion

Figure 2-A shows the data/image of the year 1998, while Figure 2-B gives the data/image of the year 2010. The drought spell was prolonged from 1996 to 2001 in the study area, a severe drought in the history of Pakistan. In 2001, a baseline study was conducted on the KNP.

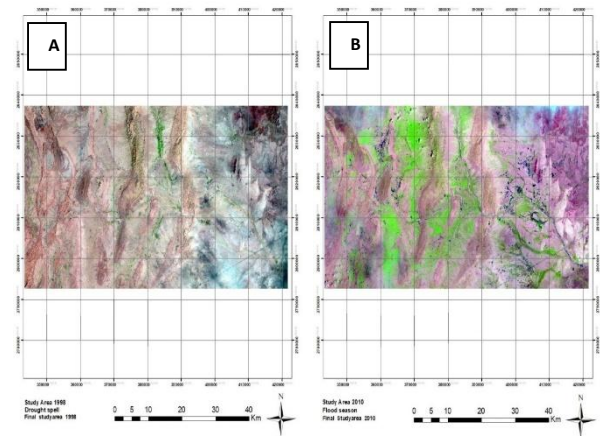


Fig. 2 Two CCI of contrast periods with a spectral combination of 3, 4, and 5, showing the impact of the wet and dry seasons. A: The image taken in August 1998. B: This image was taken in August 2010.

During field work the environmental impact of prolonged drought conditions was visible from vegetation, agriculture, rangelands, and even from the socioeconomic condition of the people. The grazing and browsing of animals were the only survival factors observed. The satellite image 1998 also shows the same condition as found exactly on the ground. The image-2010 was used, because it was the flood season where the contrast could be observed from satellite data along with its impact on the ground realities. It was a good year in terms of precipitation as the region near the foothills of the plateau and mountains was also affected. Thus, both scenarios were chosen to understand the dry and wet spells for a comparative study in the region. The floods of 2010 created a catastrophic condition in the KNP. Most of the mature crops like rice, wheat, and onion, lying in the open air swept away by massive hazardous floods of the year 2010.

The images of the years 1998 and 2010 show the drought and wet conditions respectively. The image of period 1998 explains the drought spell (Fig. 3-A), while the image of period 2010 indicates the floods (Fig. 3-B). The composite image with the combination of RGB color palette has been given the band combination of 3, 4, and 5 (Fig. 2). This combination has brightly shown the vegetation in a good year with red color because band 3 is useful for this purpose, while band 4 has delineated the boundary between the vegetation and rock. Whereas, band 5 is used for surface rock and barren land exposure. This combination has accurately explored both the images of different contrast periods. In 1998, drought season is visible, while in 2010 lush vegetation exposure shows the dominance of wet and rainy seasons (Fig. 2). Further investigation for accurate assessment was conducted by applying the spectral enhancement. Histogram equalization technique, with the false-color composite band combination of 4, 3, and 2, has been applied in this image (Fig. 3). In this process, the red color has enhanced the vegetation over the study area (Fig. 3B). Similarly, rock exposure was also more visible from Figure 3(A), using the histogram

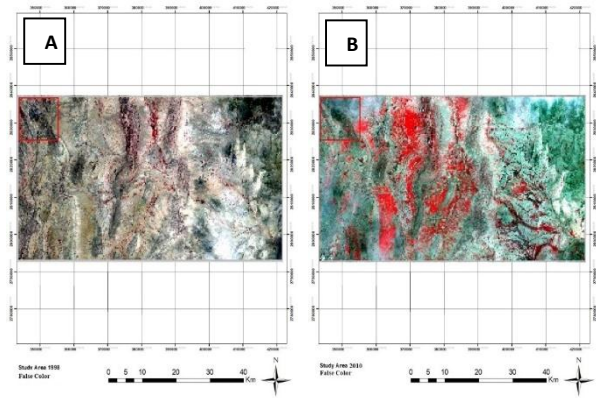


Fig. 3 The false-color composite of contrast period to expose the vegetation cover using the 4, 3 and 2 spectral combinations. Image 'A' for the dry year -1998 and 'B' for the wet year -2010.

between +1 and -1. Lush green vegetation and water bodies are the most enhanced ones and are made darker with values greater than +0.5. Sparse vegetation like grassland is visible between the values +0.2 and +0.5. The barren rock, sand, and land under stress show low

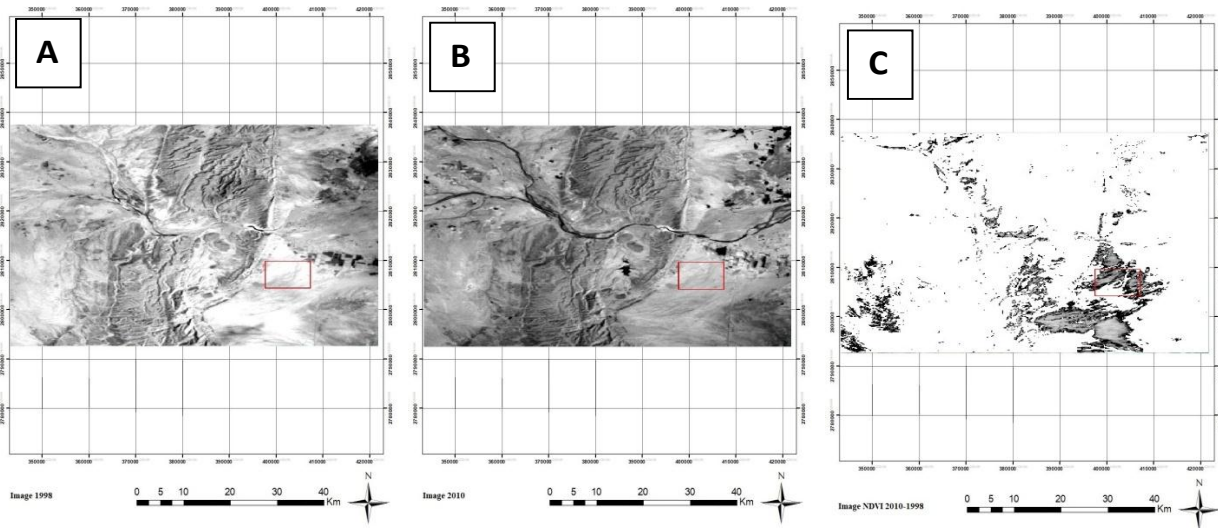


Fig. 4 NDVI from both the images of 1998 and 2010. A: shows the data/image of 1998. B: shows the data/image of 2010. C; this figures the difference between the two images.

equalization technique with the band combination of 5, 4, and 3. This image is more enhanced to expose the barren land, rock, and sporadically spread vegetation over the study area.

NDVI is used to enhance the vegetation (or stress on vegetation) under drought conditions or arid environments. The difference is visible through infrared exposes where the vegetation is shown in bands 4 & 3 in Landsat 7 and band 5 & 4 in Landsat 8. It ranges

NDVI values. NDVI with the gray level of both the periods, i.e., 1998 and 2010, have been extracted.

The image of NDVI shows discloses the variation between the years 1998 and 2010. NDVI showed additional flora differences. Low NDVI value with light gray color shows low vegetation (Fig. 4A) and high NDVI value with darker gray color shows lush vegetation (Fig. 4B). Extracted NDVI from the image 1998 visibly exposes the drought condition where just

Table 1 Change detection statistics (%) (Initial State: Max. Likelihood 2010, Final State: Max. Likelihood 1998).

	Rock (Red) 52041 points	Vegetation (Green) 30015 points	Water (Blue) 1743 points	Settlement (Yellow) 896 points	Ephemeral rivers (Cyan) 21204 Points	Row Total	Class Total
Rock (Red) 72166 points	57.79	22.42	29.66	21.42	17.17	100.00	100.00
Vegetation (green) 2515 points	2.27	8.00	8.29	9.78	5.92	100.00	100.00
Water (Blue) 219 points	2.83	0.50	2.55	1.25	1.38	100.00	100.00
Sattlement (Yellow) 471	1.61	3.20	8.09	5.60	2.30	100.00	100.00
Ephemeral rivers(Cyan) 29153 points	14.48	17.90	30.83	31.72	37.06	100.00	100.00
Rainfed land Potential (Magenta) 20529 points	21.02	47.98	20.59	30.23	36.17	100.00	100.00
Class Total	100.00	100.00	100.00	100.00	100.00		
Class Changes	42.21	92.00	97.45	94.40	62.94		
Image Difference	8.55	-80.46	-73.06	-22.42	-24.08		

small spots of vegetation are visible, and even the water courses are found dry. Plain areas with a blanket of sand and hills are uncovered in this image (Fig. 4A). Extracted NDVI from the image 2010 shows the wetness in the image. The courses and small lakes are found waterfilled . However, the plain or hilly area of KNP is covered with vegetation. The NDVI from these images proves that this contrast is most useful to compare the images of the drought period and wet period (Fig. 4C). These places were found covered by vegetation only in the wet period in 2010.

Classified data of different features found in the study area were also obtained. The main features were rock, waterbody, vegetation, settlement, and natural stream. The difference of covered area has also been calculated in percentage (Table 1). Vegetation cover was main focus of this study and the difference in both the images was also the most visible. Another table is also based on the

classified data in which the difference of area in kilometers is mentioned. (Table 2).

Table 1 discloses moderately varied detection for the significance of years, wet 2010 and dry 1998 in the study area. The outcomes display; a noteworthy variation of 91% in the vegetation index, 97.45% in water, 94.40% in the settlement area, and 62.94% in ephemeral rivers, which were extended throughout the wet year 2010, in comparison to the drought year of 1998. However, the image difference is shown as - 80.45%, -73.05%, -22.42%, and -24.07%, followed by vegetation, water, settlement, and natural runoff, which are shrunk in the drought years.

Table 2 reveals the area occupied by various classes in a square meter, which is converted into km². Based on the significant changes during the year 1998 and 2010 for dry and wet climate variation respectively, the class

Table 2 Change Detection Statistics (Km²) (Initial State: Max. Likelihood 2010, Final State: Max. Likelihood 1998).

	Rock (Red) 52041 points	Vegetation (Green) 30015 points	Water (Blue) 1743 points	Settlement (Yellow) 896 points	Ephemeral rivers(Cyan) 21204 Points	Row Total	Class Total
Rock (Red) 72166 points	585.25	231.81	61.94	27.43	192.91	1099.34	1099.34
Vegetation (green) 2515 points	23.02	82.74	17.31	12.53	66.50	202.11	202.11
Water (Blue) 219 points	28.68	5.15	5.33	1.60	15.51	56.27	56.27
Settlement (Yellow) 471	16.29	33.13	16.89	7.18	25.89	99.39	99.39
Ephemeral rivers(Cyan) 29153 points	146.62	185.08	64.38	40.64	416.38	853.10	853.10
Rainfed land Potential (Magenta) 20529 points	212.84	496.17	43.00	38.73	406.44	1197.71	1197.71
Class Total	101.27	1034.08	208.86	128.12	1123.36		
Class Changes	427.46	951.34	203.53	120.94	707.25		
Image Difference	86.63	-83.20	-152.58	-287.29	-270.52		

change of rock occupied 427.45 km², Vegetation 951.34 km², Water 203.53 km², Settlement 120.94 km², and Ephemeral rivers covered 707.25 km², respectively during the wet climatic period of 2010, as compared to the dry climatic period of 1998.

The results of this study are in line with results of similar studies by Soomro et al., 2020., Memon et al., 2019 in the same region, by selecting a wide range of study areas. While in the current results, the methodology and period of the climatic situations are different as they were worked out using the latest technology of ENVI Classic remote sensing and ArcGIS. However, the limited geographical study area was selected for the present study.

Conclusion

The study was conducted on KNP to compare the driest and wettest periods, using the Landsat images. It was a prolonged drought condition till 2001. In 2010, flooded conditions were observed in the KNP. The contrast periods have shown a vast difference between vegetation and water found in those images. The study concluded that a noteworthy increase in many landscape features was observed. About 91%, 97.45%, 94.40%, and 62.94 % increase in vegetation, water, settlement, and ephemeral rivers, respectively in the wet year (2010) against the drought year (1998) has been calculated. The fact and figures indicate increased area under the coverage of natural resources i.e., vegetation and potential water resources in the study area.

It is also concluded that small reservoirs may be remotely accessed and developed on a needed basis to store the water for groundwater recharge and efficient irrigation systems using alternative sources of energy. These reservoirs enhance the local agricultural system for improving the socio-economic conditions of the people and reducing the migration rate.

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