SindhUniv. Res. Jour. (Sci. Ser.) Vol. 52 (04) 341-352 (2020)
http://doi.org/10.26692/sujo/2020.12.52
SINDHUNIVERSITYRESEARCHJOURNAL(SCIENCE SERIES)

Integrated Remote Sensing and GIS Based Approach for Sustainable Development of Khirthar National Park

A. H. CHUGHTAI, H.U. ABBASI, M. A. JISKANI, H. ISLAM

Centre for Environmental Sciences, Faculty of Natural Sciences, University of Sindh, Jamshoro, Pakistan

Received 18th April 2020 and Revised 29th October 2020

Abstract: The sustainable management and planning for the conservation of National Park is extremely important and to assess the changes in National Park's biodiversity, natural eco-system and ground surface features by gathering larger area information through integrated remote sensing and GIS techniques. Multi-Spectral remotely sensed satellite data has been implemented in this study to assess change in Khirthar National Park where human influence is slowly increasing due to which agriculture is also expanding and will ultimately restrict the accommodations of wildlife and remove the rare natural vegetation species in National Park. This research study carried filed survey, analyzes the vegetation change using NIR and RED band of Land sat imagery to calculate the Normalized Difference Vegetation Index (NDVI)and extracted the Land Surface Temperature (LST) using thermal band to define variations in climate at Khirthar National Park (KNP). NDVI and LST was calculated to assess decadal change at KNP by acquiring satellite images of Land sat 5 TM (1992, 2000 and 2010) and Lands at 8 OLI&TIRS (2018).The results of this research study and field survey revealed that NDVI and LST has been increased during study period, the high NDVI values of 1992, 2001, 2010 and 2018 results were 0.31, 0.38, 0.42 and 0.45. The high temperature during the study time span results of 1992, 2001, 2010 and 2018 were 49^{o}C, 47.5^{o}C, 51^{o}C and 56^{o}C. This increase of vegetation is not just because of the natural vegetation but it is mainly due to increase of agriculture. Therefore the sustainable management is highly recommended for such natural heritage to prevent further loss of biodiversity and natural eco-system.

Keywords: Remote Sensing; NDVI; LST; National Park; Biodiversity; Sustainable Management.

1. INTRODUCTION

The increasing anthropogenic activities worldwide are affecting the ecology of natural ecosystems. These activities are significantly the main driving forces (Vitousek 1994) that contribute environmental changes and hindering sustainable development of natural resources (Zewdie and Csaplovies 2017). To prevent from such hindering towards the sustainable development of National Parks, the biological diversity of these protected areas are considered as important to conserve. Almost 7000 protected areas(Mc Neely 1992) have been established around the world to minimize and restrict the human meddling. The increasing anthropogenic activities are affecting the biomes originality and ecosystem, which is also a great challenge to conserve the national park by reducing the anthropogenic activities. Khirthar National Park is the one among those parks where human influence is continuously accommodating the land of National Park. Assessment of these long-term anthropogenic activities impacts on such protected areas is difficult while it is important to monitor the land cover change since the short-term variations may not yield better understanding (Lambin and Strahlers 1994; Lunetta, Knight . 2006) of such protected areas. The satellite based remote sensing and GIS data has made it possible to assess and monitor not only present but also provide satellite data to assess past scenarios and predict future losses. Remote sensing data can monitor larger areas with low cost-effective and can be applied in many applications (for example: deforestation, agriculture monitoring, monitoring temperature regime, modeling biodiversity and ecosystem and land use land cover change).Satellite images having low resolution from 250 m to 1000 m and medium resolution from 10 m to 30 m cover larger area of earth surface provide very useful information to detect long-term changes and land use land cover mapping especially seasonal or annual vegetation cover change dynamics at regional and global scale (John and Nellis 1991; Jakubauskas, Legates . 2001; Pettorelli, 2005; Lunetta, . 2006; Reed 2006). Repeatedly, changing of these land cover classes to land use for multi-purposes especially for development is to boost or increase the economy of developing country by extracting natural resources, agriculture expansion, urbanization and industrialization (Hansen, 2004; Mustard, 2004).The intensification growth of land use due to human activities are taking place at alarming stage which generate the drastic outcomes in developing countries as a result faces threat to wildlife and their ecosystem, natural vegetation, forest resources and change in morphology of natural landscape only and

Email: ah_chughtai18@yahoo.com, habibullah.abbasi@usindh.edu.pk jiskanimnsr@gmail.com hamzihyd@gmail.com

only because of urbanization (Lambin, 2001; Defries . 2004). In order to evaluate useful in formation from satellite imagery a lot of change detection techniques have been implemented to detect changes at particular landscape area using different classification techniques along with discrete boundaries (Pearson 2002; Southworth, Munroe . 2004). These classification techniques and change detection algorithm has been reviewed by (Coppin, 2004; Mausel 2004) and are very much useful to assess, monitor and detect land cover changes and vegetation dynamics because of natural and anthropogenic activities. The advantage of long term multi-temporal satellite data (for example: vegetation indices) with acceptable accuracy of can provide totally changed perspective of land cover classes (Southworth, Munroe . 2004) and can be used for the assessment for forestation and other vegetated LULC classes (Singh 1986).

The main objective of this paper is to justify the long-term changes in vegetation and LST in Khirthar National Park using remotely sensed multi-temporal and multi-spectral Land sat satellite data because of freely available in comparison to other high resolution satellite data which have less than 5m spatial resolution and are much more expensive to pay for individual researcher or for academic purpose. The importance of sustainable monitoring for the assessment of National Parks encourages the researchers to estimate the changes whether due to anthropogenic or natural activities.

Study Area

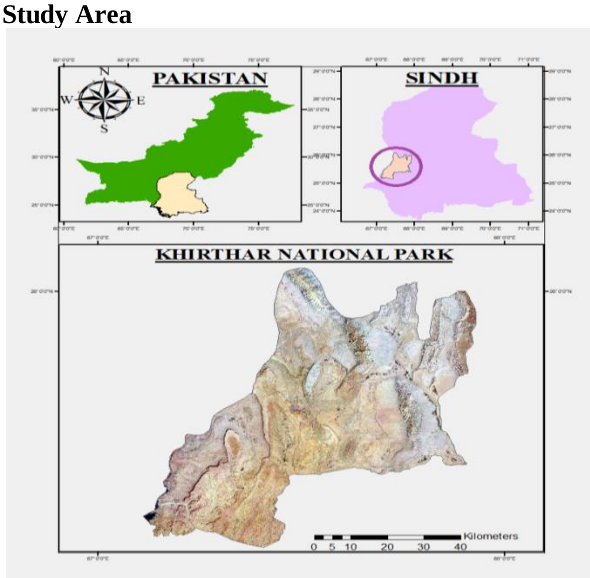


Fig. 1. Map of Khirthar National Park, Sindh, Pakistan

Khirthar National Park covers an area about 3,087 square kilometers located in Jamshoro district at 25°42′N 67°35′E geographical location and is the second biggest National Park of Pakistan established in 1974 and the first National Park of Pakistan was enlisted in UN's list of National Park around the world. International Union for Conservation and Nature (IUCN) has listed Khirthar National Park as category type II of protected areas which is being supervised/managed by Sindh Wildlife Department. Khirthar National Park is a dry arid land area of outstanding beauty and cultural heritage having countless landscapes such as desert with rugged lines, hilly terrain and stony hills and valleys which provides important habitat for biodiversity including 34 mammals, 58 birds and 10 reptiles, among which some rare species such as Indus Ibex (Enright 2001). The National park is surroundedby two wildlife sanctuaries (Mahal Kohistan and Hub Dam Wildlife Sanctuary), game reservoirs (Surjan, Sumbak, Eri and Hothiano Game Reserve), RaniKot Fort and the Great Wall of Sindh, villages (Goth Hafiz Muhammad Ibrahim Gugo, Goth Abdul Karim Burro and Goth Haji Nabi Bux Burro) and rivers (HUB River and BARAN River). The annual precipitation rate of Khirthar National Park is around 150 to 200 mm and mostly occurs in monsoon (Pakistan). The human population at Khirthar National park is increasing as reported by Pakistan Bureau of Statistics was 103,826 in 1998 and 145,450 in 2017 and this rapid change is responsible in Khirthar National Park.

2. MATERIALS AND METHODS

The geometric corrected Lands at satellite imagery having TM and OLI & TIRS sensor data of years 1992, 2001, 2010 and 2019weredownloaded from Earth Explorer USGS website(USGS) with cloud free and clear atmospheric conditions of same path but having two different rows (path:152/row:042 and path:152/row:043) which were later mosaic on the basis of Nearest Neighbor Algorithm to extract study area and finally radiometric/atmospheric correction was performed in ARCGIS software. This satellite data was used for the assessment of land use/land cover change during study time period and to justify these changes at study area, Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) maps were generated. The details of satellite imagery applied in the study area are showed in **(Table 1).**

Satellite & Sensor	Date of acquisition	Path	Row	Band	Source
Landsat TM	27-04-1992	152	042	3, 4 and 6	USGS website
Landsat TM	27-04-1992	152	043	3, 4 and 6	USGS website
Landsat TM	22-05-2001	152	042	3, 4 and 6	USGS website
Landsat TM	22-05-2001	152	043	3, 4 and 6	USGS website
Landsat TM	29-04-2010	152	042	3, 4 and 6	USGS website
Landsat TM	29-04-2010	152	043	3, 4 and 6	USGS website
Landsat OLI & TIRS	09-06-2019	152	042	4, 5 and 10	USGS website
Landsat OLI & TIRS	09-06-2019	152	042	4, 5 and 10	USGS website

Normalized Difference Vegetation Index: In remotely sensed data a variety of enhancement technique are possible (Nagler, 2009) to get useful information from spectral data. A number of enhancement techniques have been developed to calculate indices such as vegetation, water, soil, built-up indices etc, and these enhancement techniques only extract the present spectral data information rather than creating or extracting new information from satellite images. Vegetation Indices highlights a particular property of vegetation by combining surface reflectance of multiple wavelengths among NDVI is most commonly used(Tucker 1979)because of its direct relation to the capacity of photosynthesis and energy absorbed by plants canopy (Xue and Su 2017). NDVI quantifies the amount of vegetation which strongly absorbs the visible light due to chlorophyll and on the other hand leaves cell structure strongly reflects near-Infrared light. Thus NDVI uses NIR and RED band of satellite images to calculate the difference between these both and mathematically can be represented as:

$$\boldsymbol{NDVI} = \frac{(\mathbf{NIR-RED})}{(\mathbf{NIR+RED})}$$

NDVI results obtained always ranges between -1 to +1. Where -1 to 0 index values show no vegetation while above zero show vegetation but 0.6 to +1 show dense and healthy vegetation.

Land Surface Temperature (LST): Land Surface Temperature is the radiometric temperature extracted from land surface through thermal infrared band of the sensor (Norman and Becker 1995; Srivastava, Majumdar . 2010) and has been widely used in various field including climate modeling and change, hydrological cycle, agricultural monitoring, urban climate, vegetation monitoring and change detection studies(Bastiaanssen, Menenti . 1998; Kogan 2001; Su 2002; Arnfield 2003; Voogt and Oke 2003; Kalma, McVicar . 2008; Wang and Liang 2009; Jr, Ruedy . 2010; Wang, Tang . 2010; Feizizadeh and Blaschke 2012; Ghobadi, Pradhan . 2013) which provides better understanding of environmental studies (Mallick, 2012; Biro, 2013; Pradhan . 2013; Jebur, 2014; Tehrany, 2014; Yusuf, 2014). Various LST methodologies and algorithm has been developed since past few decades to retrieve LST such as Radiative transfer equation by (Berk, Bernstein . 1989), Mono-window algorithm by (Qin, 2001), multi-angle algorithm (Dash, Göttsche . 2002), generalized single channel proposed by(Jiménez-Muñoz and Sobrino 2003)and split window by (Kharraz. 2003). The equation for retrieving LST based on Planck's formula derived by(Weng, Lu . 2004) to study urban heat islands which is also being mostly used in recent research studies and has been implemented in this research study. This research article is going to retrieve LST from Lands at 8 OLI&TIRS and Land at 5 TM by following steps below:

1. Converting digital numbers into Top of Atmospheric (TOA) reflectance

For Landsat 8:

$$\boldsymbol{TOA = M_L * Q_{cal} + A_L}$$

Where:

M_L= RADIANCE_MULT_BAND of corresponding band number.

Q_{cal} = Corresponding Band of the image.

A_L = RADIANCE_ADD_BAND of corresponding band number.

For Landsat 5:

$$\boldsymbol{\left(\frac{L_{max} - L_{min}}{Qcal_{max} - Qcal_{min}}\right) * (Qcal - Qcal_{min}) + L_{min}}$$

Where:

L_{max}, L_{min}, $Qcal_{max}$ and $Qcal_{min}$ values are available in metadata.

Q_{cal} is the corresponding thermal band.

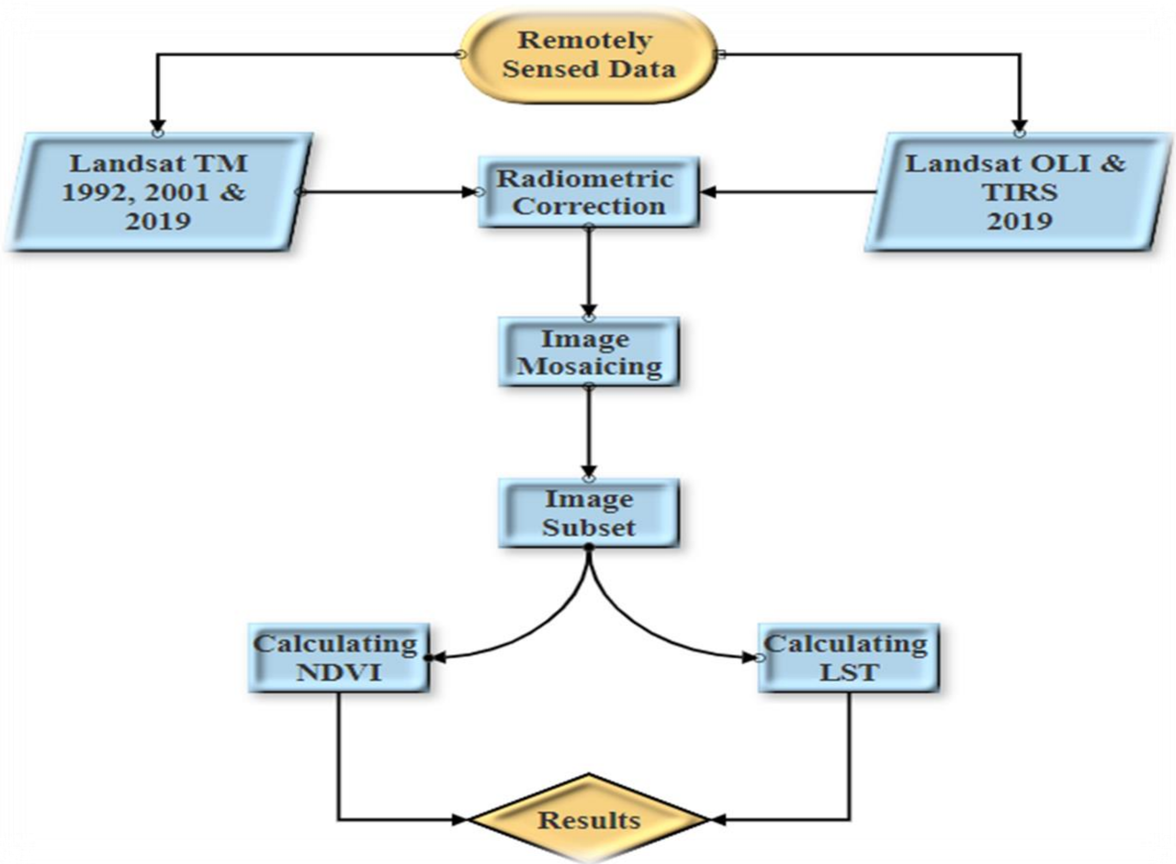
2. Calculating LST

$$LST = \left(\frac{K_2}{\left(ln\left(\frac{K_1}{TOA}\right)+1\right)}\right) - 273.15$$

K_1 and K_2 are the band specific thermal constant.
Where:

LST is the radiant temperature in Kelvin For Lands at 8 $\mathbf{K_1}$ and $\mathbf{K_2}$ are band specific thermal co-efficient constant whose values for Lands at 8 OLI & TIRS are **774.89** and **1321.08** while for Lands at 5 TM $\mathbf{K_1}$ and $\mathbf{K_2}$ values are **607.76** and **1260.56**.
LST results always in Kelvin unit, therefore to get results in degree Celsius the temperature is adjusted by adding absolute zero value which is approximately "-273.15 ºC".

In this research study, to assess change at study area NDVI and LST results were generated in ArcGIS software during the study time period using above mentioned algorithms and the results will be discussed in the third section of this paper.



3. <u>RESULTS AND DISCUSSION</u>

The generated maps of Khirthar National Park from remotely sensed satellite data of 1992, 2001, 2010 and 2019 by calculating vegetation index using NDVI and surface temperature using LST in ArcGIS software which clearly showed increasing trend in both NDVI which is mainly due to anthropogenic activities such as agriculture and LST. The extracted NDVI value of Khirthar National Park of 1992 ranges between -0.43 to 0.31, 2001 ranges between -0.13 to 0.38, while the results of 2010 and 2019 ranges between -0.57 to 0.42 and -0.18 to 0.45 respectively.

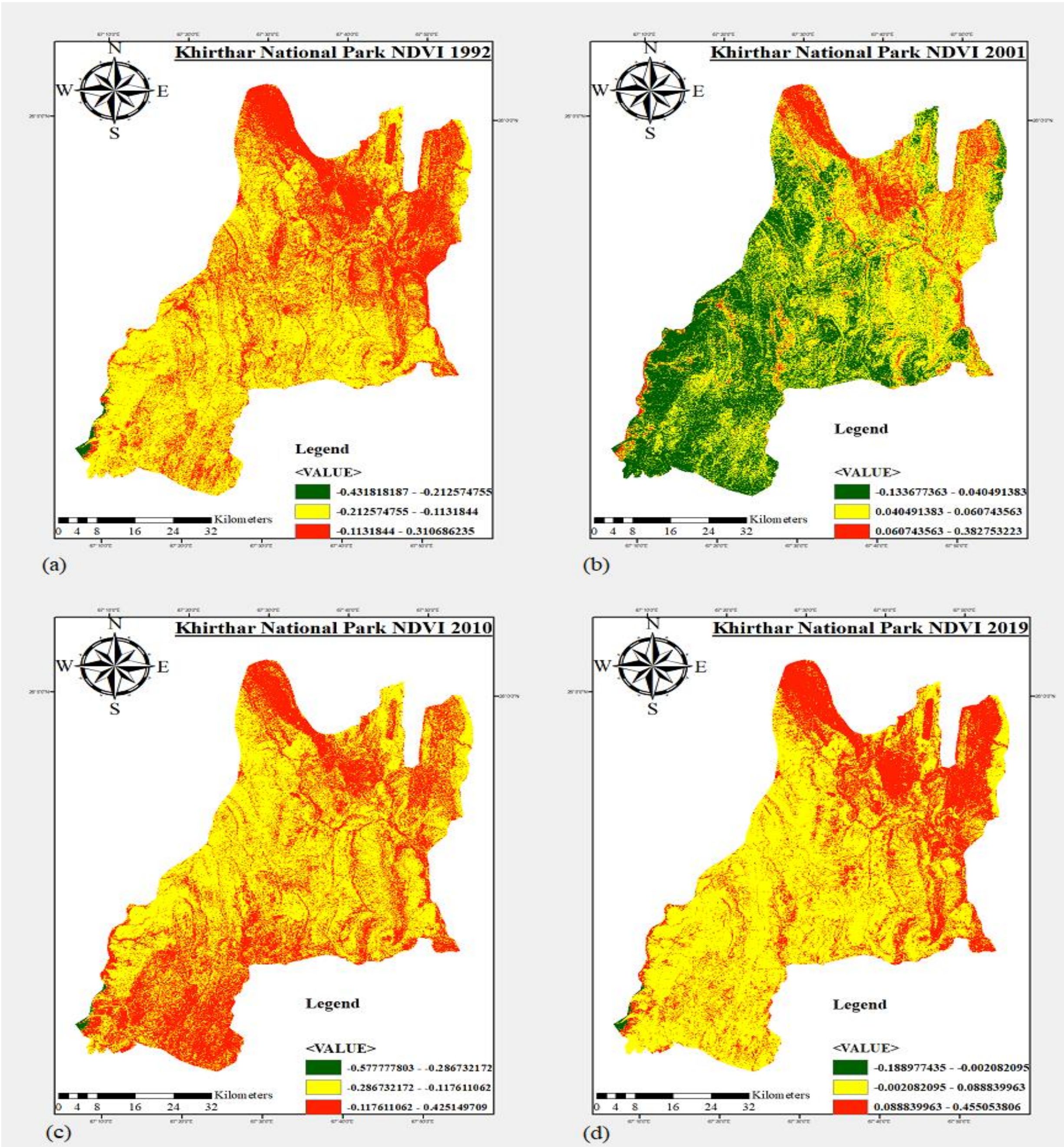


Fig. 4: The spatial distribution of NDVI at Khirthar National Park during 1992 (a), 2001 (b) and 2010 (c) using Lands at TM and 2019 (d) using Lands at OLI & TIRS.

In the case of LST, the low and high temperature values of 1992, 2001, 2010 and 2019 ranges between 25 ºC to 49 ºC, 24 ºC to 47.5 ºC, 25 ºC to 51 ºC and 30 ºC to 56 ºC respectively.

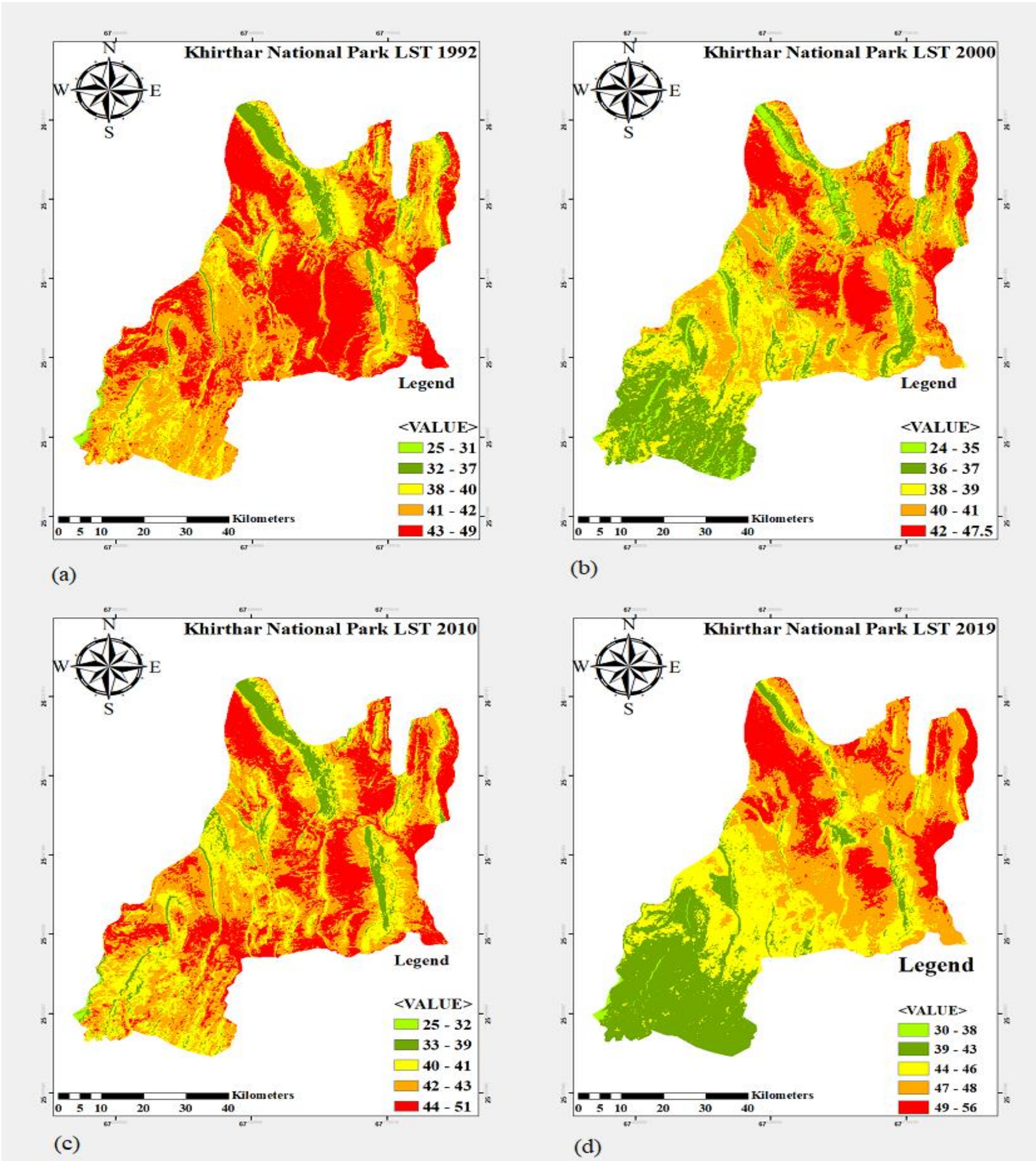
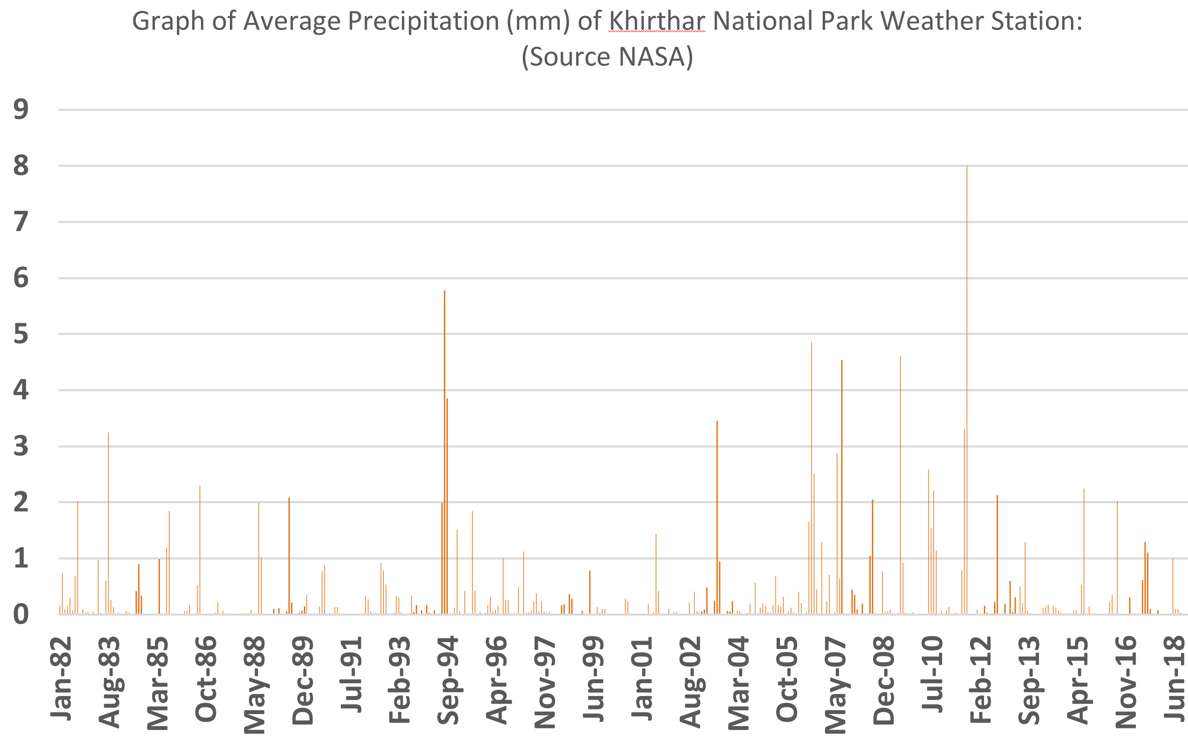
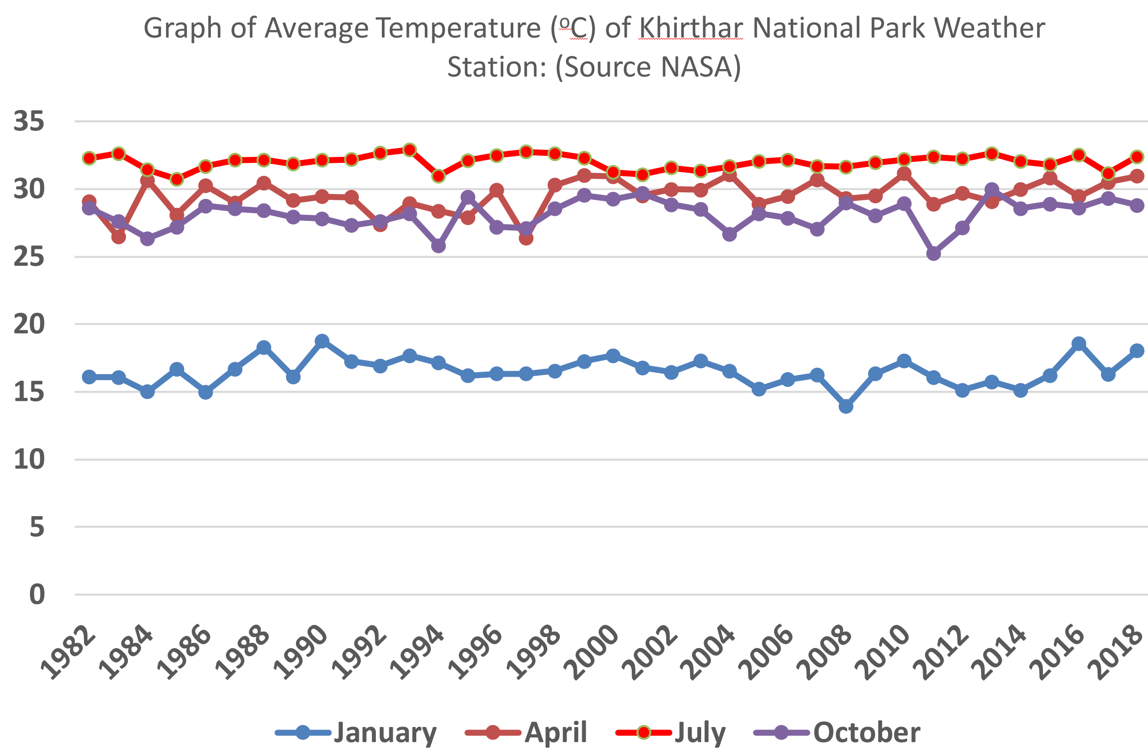


Fig. 5: The temperature distribution of LST at Khirthar National Park during 1992 (a), 2001 (b) and 2010 (c) using Lands at TM and 2019 (d) using Lands at OLI & TIRS.

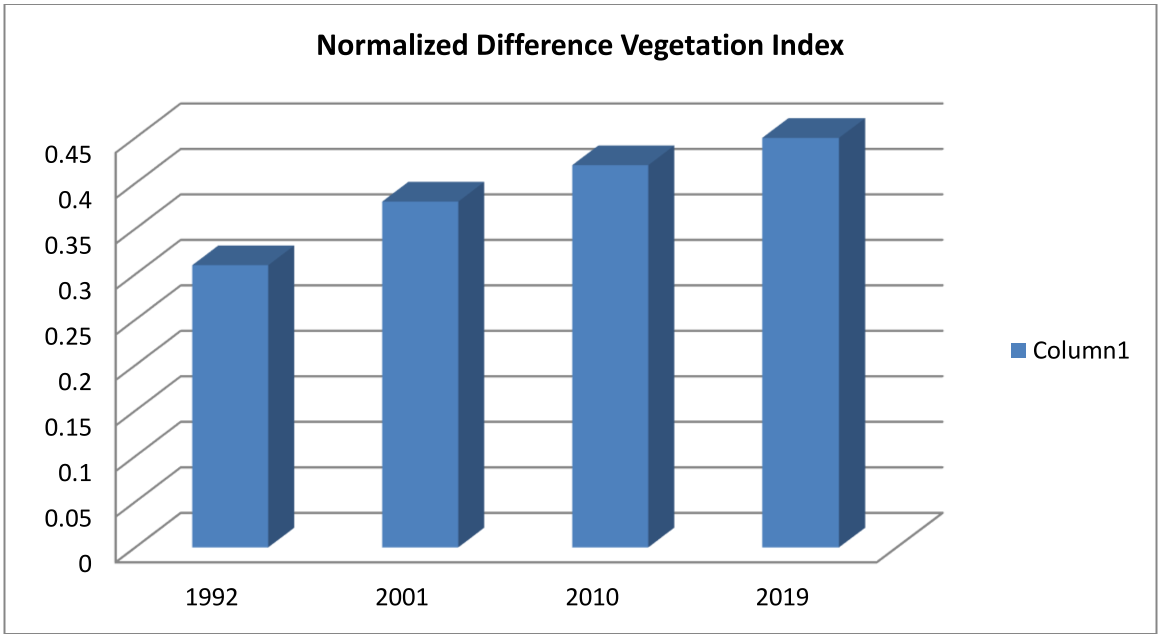
The average temperature and precipitation data were collected from NASA Agro climatology to acknowledge the precipitation rate at study area from 1982 to 2018 which is almost low due to arid environment and only occurs in monsoon while the temperature was collected of selected months according to four seasons.



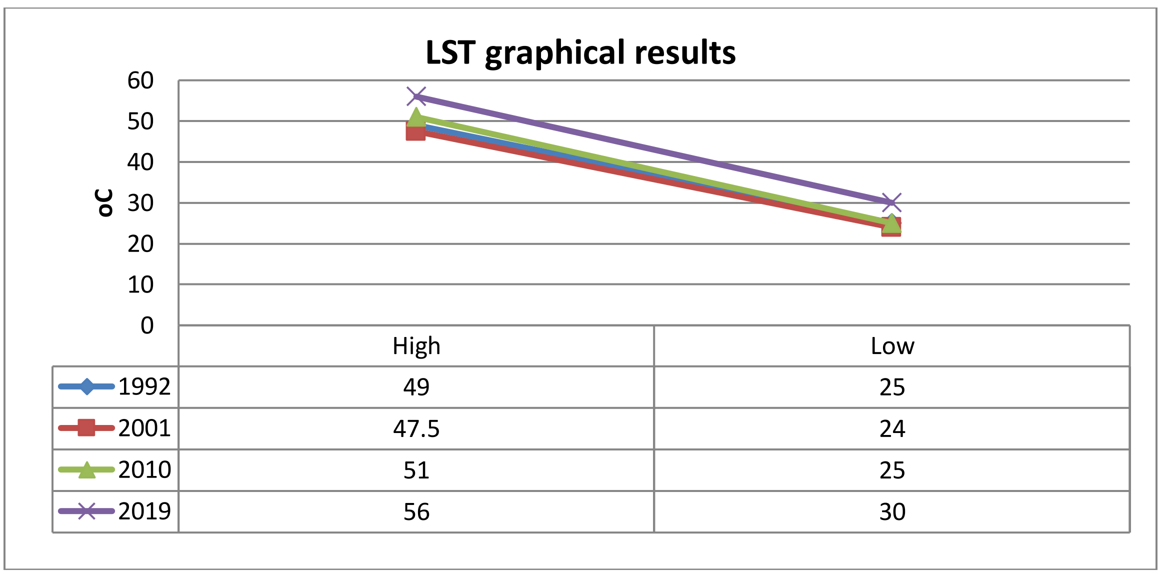
Graph of Average Precipitation (mm) of Khirthar National Park Weather Station: (Source NASA)
9
8
7
6
5
4
3
2
1
0
Jan-82
Aug-83
Mar-85
Oct-86
May-88
Dec-89
Jul-91
Feb-93
Sep-94
Apr-96
Nov-97
Jun-99
Jan-01
Aug-02
Mar-04
Oct-05
May-07
Dec-08
Jul-10
Feb-12
Sep-13
Apr-15
Nov-16
Jun-18



Graph of Average Temperature (ºC) of Khirthar National Park Weather Station: (Source NASA)
35
30
25
20
15
10
5
0
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
January
April
July
October



The graphical representation of NDVI of 1992, 2001, 2010 and 2019



The graphical representation of Land Surface Temperature during the study period

Years	NDVI	LST
1992	**High: 0.31** **Low: -0.43**	**High: 49** **Low: 25**
2001	**High: 0.38** **Low: -0.13**	**High: 47.5** **Low: 24**
2010	**High: 0.42** **Low: -0.57**	**High: 51** **Low: 25**
2019	**High: 0.55** **Low: -0.18**	**High: 56** **Low: 30**

The statistical result of NDVI and LST of 1992, 2001, 2010 and 2018

4. CONCLUSION

The appropriate planning and development of protected areas are considered to be much important for sustainable development and understanding the dynamics of land cover pattern by integrating remotely sensed data. The remotely sensed satellite data is widely used in environmental assessment of the globe since many decades and has proposed a lot of change detection methods and algorithms for land use/land cover change but unfortunately none of the single change detection algorithm is applicable in all cases that is why the selection of appropriate change detection method is much important in the assessment of remotely sensed data which is still remains a challenge and new researches are continuously developing advance change detection algorithm to reduce time and less cost effective for betterment of image processing. The remotely sensed satellite data used in this research to assess environment of Khirthar National Park, Sindh, Pakistan has revealed a much richer biodiversity and ecology which is being currently in threat due to increasing anthropogenic activities, specifically the strong correlation of the variety of vegetation and animal species to their sustainable physical environment.

This research study made an attempt to assess and justify environmental change at Khirthar National Park using Landsat 5 TM sensor data of year 1992, 2001 and 2010 and Lands at 8 OLI & TIRS sensor data of year 2019 to detect changes. The change were assessed by generating NDVI maps and retrieving LST and the results showed increasing trend in vegetation which is mainly due to agricultural activities near the flow of streams and the increasing trend in LST showed high temperature at hills and rough terrain while low at streams and agricultural areas. These environmental changes not only affect the ecology of National Park but also disturb the biodiversity of the National Park.

As far as this research study is concern, the GIS based analysis of NDVI and LST has revealed and exhibited the clear change in National Park with help of remotely sensed data and the main reason behind this is increasing human population and their influence which transform the National parks beautiful landscapes to unplanned agricultural practices by ignoring the value of ecological services and biophysical limitations. Furthermore the author recommended that comprehensive research study should be conducted to prevent further ecological and biodiversitical losses which will ultimately help stakeholders in proper policies making and geared towards sustainable development of natural resources.

REFERENCES:

Arnfield, A. J. (2003). "Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island." International Journal of Climatology: a Journal of the Royal Meteorological Society 23(1): 1-26.

Bastiaanssen, W. G. M. and M. Menenti, . (1998). "A remote sensing surface energy balance algorithm for land (SEBAL). 1. Formulation." Journal of Hydrology 212-213: 198-212.

Berk, A. and L. Bernstein, (1989). "MODTRAN: A moderate resolution model for LOWTRAN 7, technical report GL-TR-89–0122. Geophysics, Lab, Bedford, MA."

Biro, K., and B. Pradhan, (2013). "Land Use/Land Cover Change Analysis And Its Impact On Soil Properties In The Northern Part Of Gadarif Region, Sudan." Land Degradation & Development 24(1): 90-102.

Coppin, P. and I. Jonckheere, (2004). "Review ArticleDigital change detection methods in ecosystem monitoring: a review." International Journal of Remote Sensing25(9): 1565-1596.

Dash, P. and F. M. Göttsche, (2002). "Land surface temperature and emissivity estimation from passive sensor data: Theory and practice-current trends." International Journal of Remote Sensing 23(13): 2563-2594.

Enright, N. J. (2001). "Kirthar National Park Baseline Environmental Study. University of Melbourne/Sindh Wildlife Department, unpublished report.".

Feizizadeh, B. and T. Blaschke (2012). Thermal remote sensing for land surface temperature monitoring: Maraqeh County, Iran. 2012 IEEE International Geoscience and Remote Sensing Symposium.

Ghobadi, Y., and B. Pradhan, . (2013). "Assessment of spatial relationship between land surface temperature and landuse/cover retrieval from multi-temporal remote sensing data in South Karkheh Sub-basin, Iran." Arabian Journal of Geosciences8(1): 525-537.

Hansen, J. A. and R. Defries, . (2004). "Land use change and biodiversity: A synthesis of rates and consequences during the period of satellite imagery. In G. Gutman & C. Justice (Eds.), Land change science: Observing, monitoring, and understanding trajectories of change on the Earth's surface." New York, NY:Springer.: 277-299.

Jakubauskas, M. E. and D. R. Legates, (2001). "Harmonic analysis of time-series AVHRR NDVI data." Photogrammetric Engineering and Remote Sensing 67(4): 461-470.

Jebur, M. N., and H. Z. M. Shafri, (2014). "Per-pixel and object-oriented classification methods for mapping urban land cover extraction using SPOT 5 imagery." Geocarto International29(7): 792-806.

Jiménez-Muñoz, J. C. and J. A. Sobrino (2003). "A generalized single-channel method for retrieving land surface temperature from remote sensing data." Journal of Geophysical Research: Atmospheres108(D22).

John, M. B. and M. D. Nellis (1991). "Seasonal variation of heterogeneity in tallgrass prairie: a quantitative measure using remote sensing." Photogrammetric Engineering and Remote Sensing57(4): 407-411.

Jr, H., and R. Ruedy, (2010). "Global Surface Temperature Change." Reviews of Geophysics48: RG4004.

Kalma, J., and T. McVicar, (2008). "Estimating Land Surface Evaporation: A Review of Methods Using Remotely Sensed Surface Temperature Data." Surveys in Geophysics29: 421-469.

Kogan, F. N. (2001). "Operational Space Technology for Global Vegetation Assessment." Bulletin of the American Meteorological Society82(9): 1949-1964.

Lambin, E. F. and A. H. Strahlers (1994). "Change-vector analysis in multitemporal space: A tool to detect and categorize land-cover change processes using high temporal-resolution satellite data." Remote Sensing of Environment48(2): 231-244.

Lambin, E. F., and B. Turner, (2001). The causes of land-use and land-cover change: Moving beyond the myths.

Lu, D., and P. Mausel, (2004). "Change detection techniques." International Journal of Remote Sensing25(12): 2365-2401.

Lunetta, R. S., and J. F. Knight, (2006). "Land-cover change detection using multi-temporal MODIS NDVI data." Remote Sensing of Environment105(2): 142-154.

Mallick, J., and C. K. Singh, . (2012). "Land surface emissivity retrieval based on moisture index from LANDSAT TM satellite data over heterogeneous surfaces of Delhi city." International Journal of Applied Earth Observation and Geoinformation19: 348-358.

McNeely, J. A. (1992). The contribution of protected areas in sustaining society. Opening address to the IV World Cong., Caracas, Venezuala, Feb., UNDP and UNEP.

Mustard, J., and R. Defries, (2004). Land-Use and Land-Cover Change Pathways and Impacts. 6: 411-429.

Nagler, P. L., and E. P. Glenn, (2009). "Synthesis of ground and remote sensing data for monitoring ecosystem functions in the Colorado River Delta, Mexico." Remote Sensing of Environment113(7): 1473-1485.

Norman, J. M. and F. Becker (1995). "Terminology in thermal infrared remote sensing of natural surfaces." Agricultural and Forest Meteorology77(3): 153-166.

Pakistan, E. (2000) "Emerging Pakistan Travel Website."

Pearson, D. M. (2002). "The application of local measures of spatial autocorrelation for describing pattern in north Australian landscapes." Journal of Environmental Management64(1): 85-95.

Pettorelli, N., and J. O. Vik, (2005). "Using the satellite-derived NDVI to assess ecological responses to environmental change." Trends in ecology & evolution20(9): 503-510.

Qin, Z., and A. Karnieli, (2001). "A mono-window algorithm for retrieving land surface temperature from Landsat TM data and its application to the Israel-Egypt border region." International Journal of Remote Sensing22(18): 3719-3746.

Reed, B. C. (2006). "Trend Analysis of Time-Series Phenology of North America Derived from Satellite Data." GIScience & Remote Sensing43(1): 24-38.

Singh, A. (1986). "Change detection in the tropical forest environment of northeastern India using Landsat." Remote sensing and tropical land management: 237- 254.

Sobrino, J. A., and J. El Kharraz, . (2003). "Surface temperature and water vapour retrieval from MODIS data." International Journal of Remote Sensing24(24): 5161-5182.

Southworth, J., and D. Munroe, . (2004). "Land cover change and landscape fragmentation—comparing the utility of continuous and discrete analyses for a western Honduras region." Agriculture, Ecosystems & Environment101(2): 185-205.

Srivastava, P., and T. Majumdar, (2010). "Study of land surface temperature and spectral emissivity using multi-sensor satellite data." Journal of earth system science119(1): 67-74.

Su, Z. (2002). "The Surface Energy Balance System (SEBS) for estimation of turbulent heat fluxes." Hydrol. Earth Syst. Sci.6(1): 85-100.

Tehrany, M. S., and B. Pradhan, (2013). "Remote Sensing Data Reveals Eco-Environmental Changes in Urban Areas of Klang Valley, Malaysia: Contribution from Object Based Analysis." Journal of the Indian Society of Remote Sensing41(4): 981-991.

Tehrany, M. S., and B. Pradhan, (2013). "Spatial prediction of flood susceptible areas using rule based decision tree (DT) and a novel ensemble bivariate and multivariate statistical models in GIS." Journal of Hydrology504: 69-79.

Tehrany, M. S., and B. Pradhan, (2014). "A comparative assessment between object and pixel-based classification approaches for land use/land cover mapping using SPOT 5 imagery." Geocarto International29(4): 351-369.

Tucker, C. J. (1979). "Red and photographic infrared linear combinations for monitoring vegetation." Remote Sensing of Environment8(2): 127-150.

USGS "United States Geological Survey."

Vitousek, P. M. (1994). "Beyond Global Warming: Ecology and Global Change." 75(7): 1861-1876.

Voogt, J. A. and T. R. Oke (2003). "Thermal remote sensing of urban climates." Remote Sensing of Environment86(3): 370-384.

Wang, K. and S. Liang (2009). "Evaluation of ASTER and MODIS land surface temperature and emissivity products using long-term surface longwave radiation observations at SURFRAD sites." Remote Sensing of Environment113(7): 1556-1565.

Wang, N., and B. H. Tang, . (2010). A generalized neural network for simultaneous retrieval of atmospheric profiles and surface temperature from hyperspectral thermal infrared data. 2010 IEEE International Geoscience.

Weng, Q., and D. Lu, (2004). "Estimation of land surface temperature–vegetation abundance relationship for urban heat island studies." Remote Sensing of Environment89(4): 467-483.

Xue, J. and B. Su (2017). "Significant remote sensing vegetation indices: A review of developments and applications." Journal of Sensors2017: 17.

Yusuf, Y. A., and B. Pradhan, (2014). "Spatio-temporal Assessment of Urban Heat Island Effects in Kuala Lumpur Metropolitan City Using Landsat Images." Journal of the Indian Society of Remote Sensing 42 (4): 829-837.

Zewdie, W. and E. Csaplovies (2017). "Remote Sensing based multi-temporal land cover classification and change detection in northwestern Ethiopia." European Journal of Remote Sensing48(1): 121-139.