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EVALUATION OF RELATIONSHIP OF VEGETATION DYNAMICS WITH SEASONAL CLIMATE EVOLUTION IN SHEIKH BADIN NATIONAL PARK, PAKISTAN

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Abstract

Climate change and other biotic factors are causing desertification and degradation of the range resources at an alarming rate especially in the arid and semiarid regions worldwide. The mountainous region of Sheikh Badin National Park (SBNP) –famous for its floristic composition and biodiversity, is facing serious consequences of climate and anthropogenic effects in Pakistan. The influential role of extreme climate changes needs to be explored to mitigate growing risk of degradation of natural vegetation and biological resource in this mountainous region. In the present study, relationship of the NDVI (Normalized Difference Vegetation Index) was investigated with the seasonal LST (Land Surface Temperature), and TRMM (Tropical Rainfall Measurement Mission rainfall) rainfall data of 2000-2018 period in the SBNP of Khyber Pakhtunkhwa province, Pakistan for sustaining the ecosystem health. The findings of the study revealed increasing trends in the NDVI during the winter, spring, summer and autumn seasons with corresponding increase in the rainfall in the study area. The correlation coefficient R value between the NDVI and the LST was found -0.37 for winter, -0.72 for spring, -0.002 for summer and -012 for autumn (significant at $p<0.05$). The correlation between the NDVI and the rainfall data revealed R values 0.41, 0.79, 0.64 and 0.7 for the winter, spring, summer and autumn seasons (significant at $p<0.05$), respectively. The rainfall appears to be a major determinant of vegetation health and consequent ecosystem sustainability in the study area. However, the seasonal changes in climate and their implications necessitate adoption of integrated management of ecosystem to conserve biological resources on sustainable basis in this region in future.

Keywords: climate change, MODIS, rangeland, vegetation index, Khyber Pakhtunkhwa

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INTRODUCTION

National parks play a key role in in preserving natural resources and sustaining healthy ecosystems worldwide (Allendorf and Yang, 2013; Aastrup et al., 2021). They provide protection to wildlife habitats, conservation of natural resources, healthy environment, i.e., clean air and water for current and future generations (Becken et al., 2014; Loomis et al., 2024). However, climate change coupled with unplanned utilization of rangeland resources has given rise to approximately 20% desertification/degradation of rangelands worldwide (Wehrden et al., 2012; Rehman et al., 2015). The degradation and fragmentation of natural habitat are still happening resulting in loss of healthy ecosystem and biological resource in many areas (Steffen et al., 2015). As a result of such changes, some species of plant and animal are experiencing succession or completely disappearing from different regions (Noss, 2001). The rangeland vegetation in Sheikh Badin National Park (SBNP) is exposed to extensive degradation due to natural and human factors (Marwat et al., 2012) resulting in gradual decline of several plant species such as *Monothica*, *Pinnus* and *Tamarixaphylla* in the area (Attaullah et al., 2015). The studies on Karakoram National Park in Gilgit-Baltistan and Machiara Park in Kashmir revealed that >70% of the pastures and rangelands are affected by the anthropogenic and extreme climatic conditions (Alam, 2010; Zahoor, 2010; Khan, 2013).

Application of geographic information system (GIS) and remote sensing data products like MODIS (Moderate-Resolution Imaging Spectro-radiometer) derived NDVI (Normalized difference vegetation index), LST (Land surface temperature) and TRMM (Tropical Rainfall Measurement Mission) are very effective tools to monitor changes in natural resource, vegetation growth, productivity and ecosystem health (Roohi et al., 2004; Martínez and Gilabert, 2009). The MODIS data products updated by NASA Administration are free of charge and have improved spatial and spectral resolutions, cloud screening, and atmospheric correction (Friedl et al., 2002; Justice et al., 2002). Therefore, they are widely applied for remote sensing based monitoring, such as of rangeland production (Reeves et al. 2006; Xu et al., 2007; Yu et al., 2010), land use/land cover and evolving conditions (Tang and Zhang, 2002; Haque and Basak, 2017). Cheng (2006) studied the validation of the derived MODIS-NDVI and enhanced vegetation index products for a rice-planting region in southern China. NDVI is mainly used for monitoring the vegetation health and growth useful for estimation of biomass and flora production (Ding et al., 2007; Ashraf et al., 2016; Yang et al., 2019). It offers a substantial source to evaluate seasonal and inter-annual changes and effectively monitor the vegetation in the arid foothills rangeland (Paudel and Andersen, 2010). Monitoring natural vegetation health is crucial in wake of dynamic changes in climate and global warming. Although relationship of vegetation dynamics and climate factors like temperature and rainfall has been studied in different regions of the world (Yang et al., 2019; Garai et al., 2022; Usoltsev et al., 2022; Thanabalan et al., 2023), but seasonal climate impact on protected mountain ecosystem like SBNP in the semi-arid region has not been studied before. It is hypothesized that rapid changes in climate may have influential role in impacting natural vegetation health in the SBNP and risk assessment of climate influence is necessary for effective restoration of the ecosystem health in future.

In the present study, an effort has been made to investigate trends of the NDVI, LST and rainfall data and their cross relationship in Sheikh Badin National Park of Khyber Pakhtunkhwa (KPK) province, Pakistan, for 2000-2018 period. The understanding of relationships between these factors has advantages, for example, for improving rangeland management, planning afforestation interventions and sustaining ecosystem health in this mountainous region in future.

Description of the study area

The study area of Sheikh Badin National Park is located near Darra Pezu towards North of Dera Ismail Khan (D.I.Khan) and west of Lakki Marwat district in the KPK province of Pakistan (Figure 1). It was declared national park in 1993 by the government to preserve local flora and fauna, and is ranked 16th largest among 26 national parks in the country (Zahoor, 2010). The park is a part of the Marwat mountain range where elevation reaches upto 1376 m and occasional snowfall occurs during months of January and February. The mountainous region of Sheikh Badin has significance due to its rich biological resources. The park is accessed via a link road from Indus highway running between D.I.Khan and Laki Marwat districts. The area is scarce of water resource and locals have to depend on rainwater which they store in ponds for their survival. Annual rainfall in D.I.Khan is generally below 500 mm, majority of which occur during the monsoon period, i.e., from mid of June to end of September. The mean minimum and maximum temperatures are 25°C and 30°C during summers, and 4.2°C and 20.3°C during winters, respectively.

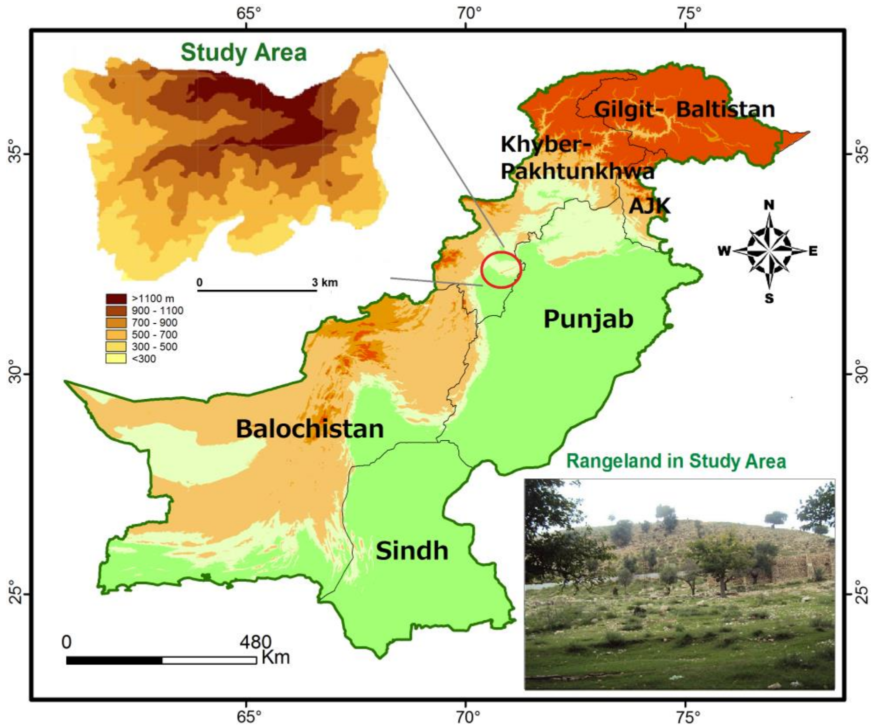

Figure 1 Location of Sheikh Badin study area in Khyber Pakhtunkhwa province of Pakistan.

MATERIALS AND METHODS

Data used

The base map of SBNP was acquired from wildlife department of the KPK province for delineating boundary of the study area. The satellite image of Landsat-8 OLI/TIRS (Path-Row: 151-38) of year 2018 was downloaded from Earth Explorer website (earthexplorer.usgs.gov) for land cover analysis. The MODIS data products, e.g. NDVI and LST, and TRMM data were acquired to study seasonal trends and relationship of the NDVI, LST and rainfall in the study area. A good portion of the MODIS data is provided in the form of readily processed data products (NDVI and LST). We used Terra-MODIS satellite imagery downloaded from Earth Resources Observation and Science (EROS) Center (http://earthexplorer.usgs.gov/) taken at 16-day interval and 250 m spatial resolution provided in a standard product (MOD13Q1, Level 3 Product) for NDVI analysis. MOD13Q1 product is very effective for analyzing the changing trend in the vegetation (Coppin et al., 2004) and the Terra MODIS 250 m resolution imagery for examining the rangeland conditions over relatively large areas (Yu et al., 2010). The LST data was acquired from a standard product MODIS (MOD11A2 images taken at 8-day interval) and rainfall data from TRMM data product (3B43) to analyze seasonal climate and its relationship with the NDVI of the study area. LST gives an effective method for separating light warmth transitions and in this way, surface temperature can be viewed as a statement of changing surface soil moisture and vegetation cover (Weng et al., 2004). The monthly precipitation product of TRMM 3B43 with spatial resolution of 0.25° is preferred for its better accuracy in different areas (Adeyewa and Nakamura, 2003; Chiu et al., 2006; Fleming et al., 2011; Zeng, 2011; Erazo et al., 2018).

Image processing and analysis

The boundary of SBNP and the image data were georectified using Universal Transverse Mercator (UTM) coordinate system (Zone 42 North) for integration and overlay analysis in ArcGIS software. The Landsat-8 image data was used to map and assess spatial variability of different land cover types in the study area through visual and digital interpretation techniques. The former interpretation was performed for qualitative and the later for quantitative analysis of the land cover in the study area. Image classification was performed using supervised method following maximum likelihood rule for which training samples were collected from representative land cover types such as forest, rangeland, bare soil in the study area. The classification results were verified through visual analysis of respective Google earth imageries and pictures of the study area. The NDVI data was initially used to study trends of four seasons, i.e., winter (December-February), spring (March-May), summer (June-August) and autumn (September-November) for 2000-2018 period. Pearson correlation R was used to determine the direction of relationship between two variables (Wessa, 2017). Generally, healthy vegetation reflects more near-infrared energy than stressed vegetation. The index is measured using near-infrared (*NIR*) and red (*R*) band values via Equation 1 as given below.

$$NDVI = \frac{NIR - R}{NIR + R} \quad (1)$$

The NDVI values range between –1 and +1, the closer to positive one values indicate higher greenness of vegetation cover or better level of photosynthetic activity, while closer to negative one values represent stressed vegetation or non-vegetated area. The LST or the emissivity corrected land surface temperature is computed using Equation 2 (Stathopoulou and Cartalis, 2007).

$$T_s = \frac{\mathrm{BT}}{\{1 + [(\lambda BT/\rho)]\mathrm{In}\ \varepsilon_\lambda]\}} \quad (2)$$

Where T_s is the LST in Celsius (ºC), BT is at-sensor BT (ºC), λ is the wavelength of emitted radiance (for which the peak response and the average of the limiting wavelength λ =10.895), ε_λ is the emissivity as computed in Barsi et al. (2014).

$$\rho = h\frac{c}{\sigma} = 1.438 \times 10^{-2}\ m\ K \quad (3)$$

Where σ is the Boltzmann constant (1.38 × 10−23 J/K), h is Planck's constant (6.626 × 10−34 J s), and c is the velocity of light (2.998 × 108 m/s) (Weng et al., 2004). A mean drift of 2ºC in the seasonal LST data was found from the observed data. Later, relationship of the NDVI was studied with the LST and rainfall data of the four seasons for 2000-2018 period using the linear regression model (Garai et al., 2022). The flowchart of main steps of methodology followed in this study is shown in Figure 2. Chen et al. (2020) evaluated the applicability of TRMM products at different time scales (1998-2016 period) for drought monitoring in the middle and lower reaches of the Yangtze River Basin in China.

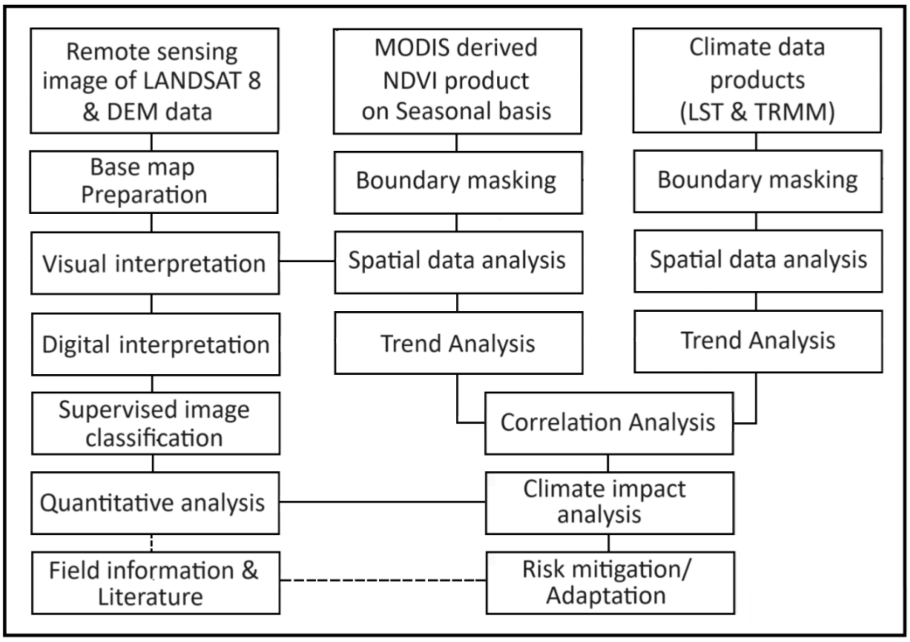

Figure 2 Flowchart of methodology followed in the present study.

RESULTS AND DISCUSSION

Land cover and NDVI analysis

Major land cover types identified through image analysis of the study area were rangeland over 61.8% area, forest over 20.2% area and bare soil over 18% area during the 2018 period (Figure 3). Attaullah et al. (2015) has recognized a total of 107 plant species in the park area, among which 26 belong to trees, 20 to shrubs, 53 to herbs and 8 to grasses. The rangeland consists of shrubs like *Agave sisalana, Cotoneaster nummularia, Datura metel, Dodonaea viscosa, Echinops echinatus, Ehretia obtusifolia,* herbs including *Aerva javanica, Alhagi maurorum, Allium griffithianum, Aloe vera, Amaranthus viridis, Asparagus capitatus, Cyprus rotundus, Erodium cicutarium,* and grasses like *Aristida adscensionis, Bromus japonicas, Cechrus ciliaris, Cymbopogon distance, Cymbopogon jawarncusa, Cynodon dactylon and Eragrostis minor*. The dominant tree species include *Acacia modesta, Acacia nilotica, Ailanthus altissima, Calotropis procera, Capparis decidua, Cordia myxa, Dalbergia sissoo and Eucalyptus lanceolatus.* During 2018, mean NDVI was observed 0.19 in the winter, 0.17 in the spring, 0.2 in the summer and 0.21 in the autumn. Relatively higher NDVI values observed during the summer and autumn seasons are likely because of favorable rainfall and temperature conditions prevailed at the highland areas. The >0.3 NDVI values concentrated in the northeastern elevated parts are associated with thick vegetation cover of the forest class found in the SBNK (Figure 4). According to Wang et al. (2011), high NDVI values exhibiting better plant vigor are generally found over mid and elevated areas in a region. The <0.2 NDVI values dominated in the southern and eastern fringes represents bare soil and sparse vegetation likely because of less favorable climatic conditions and/or anthropogenic effects in the study area. According to Zeleke and Hurni (2001), if the area of one land use class decreases, the area of other class will increase, i.e., deforestation leads to grassland and grassland converts to sparse vegetation which may further transform into bare soil.

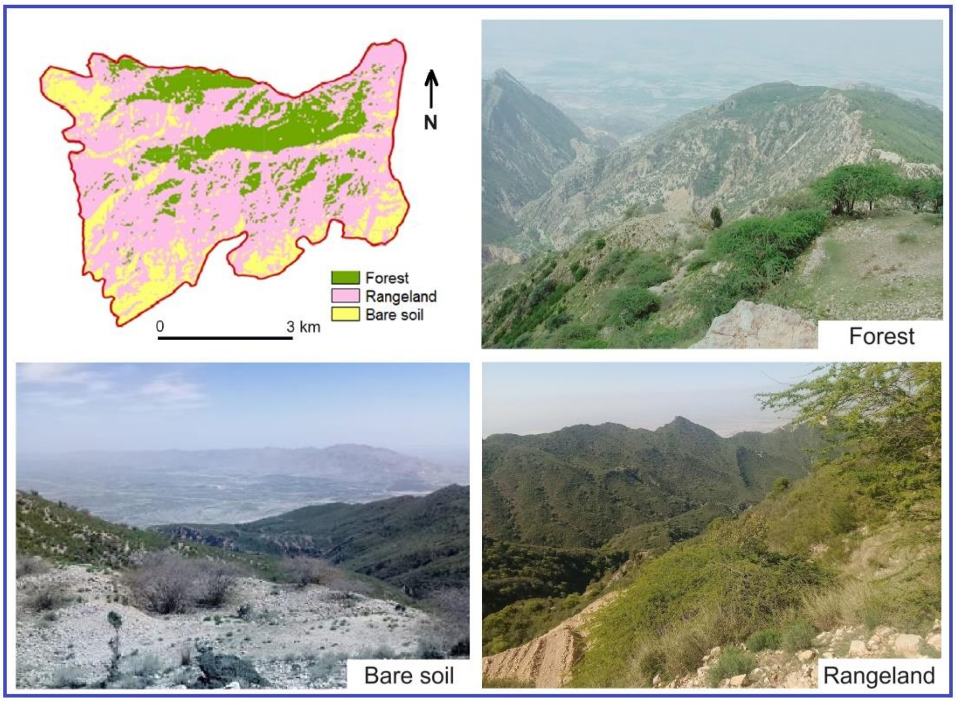

Figure 3 Major land cover types in the SBNP area

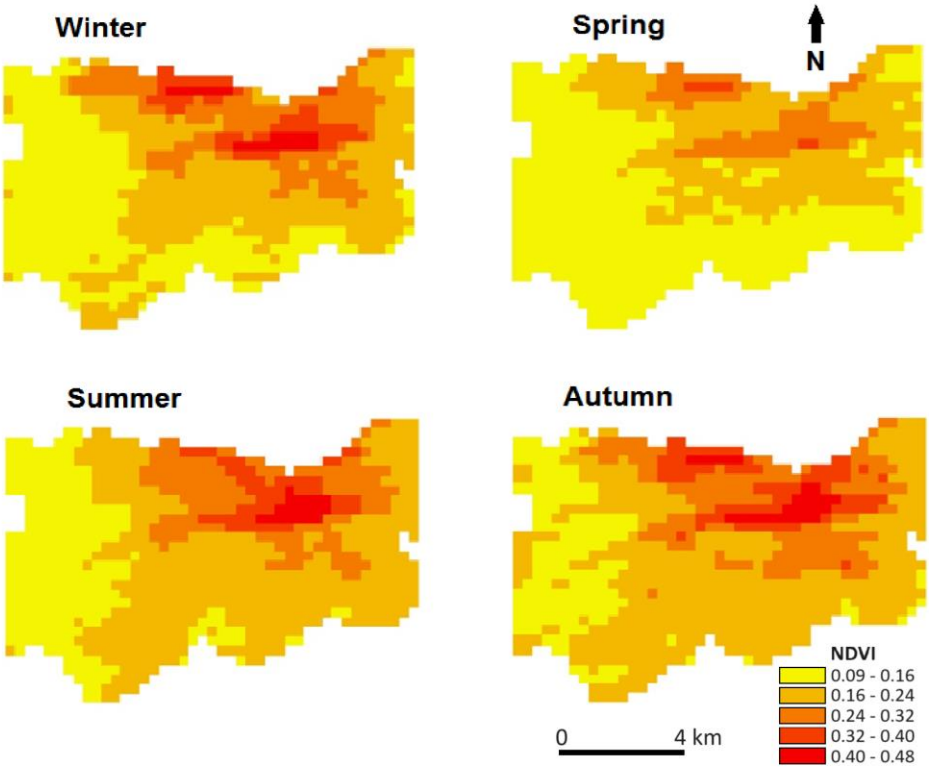

Figure 4 Seasonal distribution of NDVI in the study area (2018)

Trend analysis of the NDVI, LST and Rainfall

The time-series data of the NDVI, LST and rainfall indicated variable trends in different seasons during the 18-year period (Figure 5). The NDVI values were observed within range of 0.15 - 0.26 during winters of 2000-2018 period (the lowest in year 2000 and the highest in 2016), which exhibited a positive trend with R value of 0.55 (Table 1). The LST values ranged within 17 - 24.4°C (the lowest in year 2005 and the highest in 2001) and rainfall within 22 - 127 mm (the lowest in year 2000 and the highest in 2009) during the winter season of 18-year period. The former indicated a positive trend with R=0.12 and the later arising trend with R=0.48. During the spring season of 2000-2018, the NDVI values were observed between 0.15 and 0.26 (the lowest in 2001 and the highest in 2014), which exhibited a positive trend with R=0.48. The spring LST ranging within 30.9-36.8°C (the lowest in year 2014 and the highest in 2010) exhibited a negative trend (R=-0.15) and the spring rainfall ranging within 7-265 mm (the lowest in year 2000 and the highest in 2014) indicated a rising trend (R=0.56) during the 2000-2018 period (Figure 5). The summer NDVI was observed between 0.16 and 0.27 (the lowest in 2002 and the highest in 2015) during the 18-year period, which exhibited a positive trend with R=0.48 (Table 1). The summer LST ranging within 31.1-37.1°C (the lowest in year 2008 and the highest in 2009) exhibited a positive trend (R=0.1) and the summer rainfall ranging within 111-339 mm (the lowest in year 2002 and the highest in 2015) indicated a rising trend (R=0.22) during the 2000-2018 period (Table 1 and Figure 5). The low rainfall value received during summer 2002 is likely due to prevalence of an extreme drought during 1998-2003, while the high rainfall of 2015 may be attributed to the high flooding condition prevailed during 2014-2015 period in this region (Ahmad et al., 2016).

The NDVI of autumn (2000-2018) was found between 0.18 and 0.32 (the lowest in year 2000 and the highest in 2011), which exhibited a positive trend with R=0.38. The LST of autumn ranging within 29.1-33.5°C (the lowest in year 2010 and the highest in 2013) exhibited a slightly positive trend (R=0.06). The autumn rainfall was found within range of 22-167 mm (the lowest in year 2007 and the highest in 2015), which indicated a rising trend (R=0.13) during the 2000-2018 period (Table 1). Overall low values of the NDVI observed during 2000-2002 may be attributed to last major drought occurred during 1998-2003 in this region (Ashraf et al., 2011). According to Thenkabail et al. (2004), that major drought had affected more than 100 million people in parts of Pakistan, western India, eastern Iran and Afghanistan.

Figure 5 Seasonal trends of the NDVI, LST and rainfall in the SBNP

Table 1. Summary of the seasonal NDVI, LST and rainfall data of the study area (2000-2018)

Season	Parameter	Minimum	Maximum	Mean	Trend
Winter	NDVI	0.15	0.26	0.2	Increasing
	LST (°C)	17	24.4	19.8	Increasing
	Rain (mm)	22	127	67.3	Increasing
Spring	NDVI	0.15	0.26	0.2	Increasing
	LST (°C)	30.9	36.8	34.1	Decreasing
	Rain (mm)	7	265	111.6	Increasing
Summer	NDVI	0.16	0.27	0.2	Increasing
	LST (°C)	31.1	37.1	34.6	Increasing
	Rain (mm)	111	339	223.6	Increasing
Autumn	NDVI	0.18	0.32	0.2	increasing
	LST (°C)	29.1	33.5	30.1	Increasing
	Rain (mm)	22	167	73.2	Increasing

Correlation between the NDVI and climatic parameters

The NDVI had shown an inverse relationship with seasonal LST exhibiting coefficient of determination R^2 value of 0.32 for winter, 0.49 for spring, 0.06 for summer and 0.05 for autumn season during the 2000-2018 period (Figure 6). The correlation coefficient R between the NDVI and LST was found -0.37 for winter, -0.72 for spring, -0.002 for summer and -012 for autumn (significant at $p<0.05$). The higher warm temperatures generally affect photosynthesis and respiration processes of plants (Usoltsev et al., 2022; Qasimi et al., 2023). On the other hand, a linear relationship was observed between the NDVI and seasonal rainfall data with R^2 value of 0.17 for winter, 0.63 for spring, 0.41 for summer and 0.48 for autumn season during the 2000-2018 period (Figure 6). The correlation between the NDVI and rainfall data revealed R values 0.41, 0.79, 0.64 and 0.7 for the winter, spring, summer and autumn seasons (significant at $p<0.05$), respectively. According to several studies, the NDVI had shown a positive correlation with rainfall in different arid and semi-arid regions (Guo et al., 2006; Gessner et al., 2013; Yang et al., 2019). The study of Abbas et al. (2105) exhibited a positive correlation between vegetation cover and winter rainfall in the Upper Indus Basin of Pakistan. According to Usoltsev et al. (2022), the decrease in vegetation occurred during particular years may be attributed to insufficient rains received in the area.

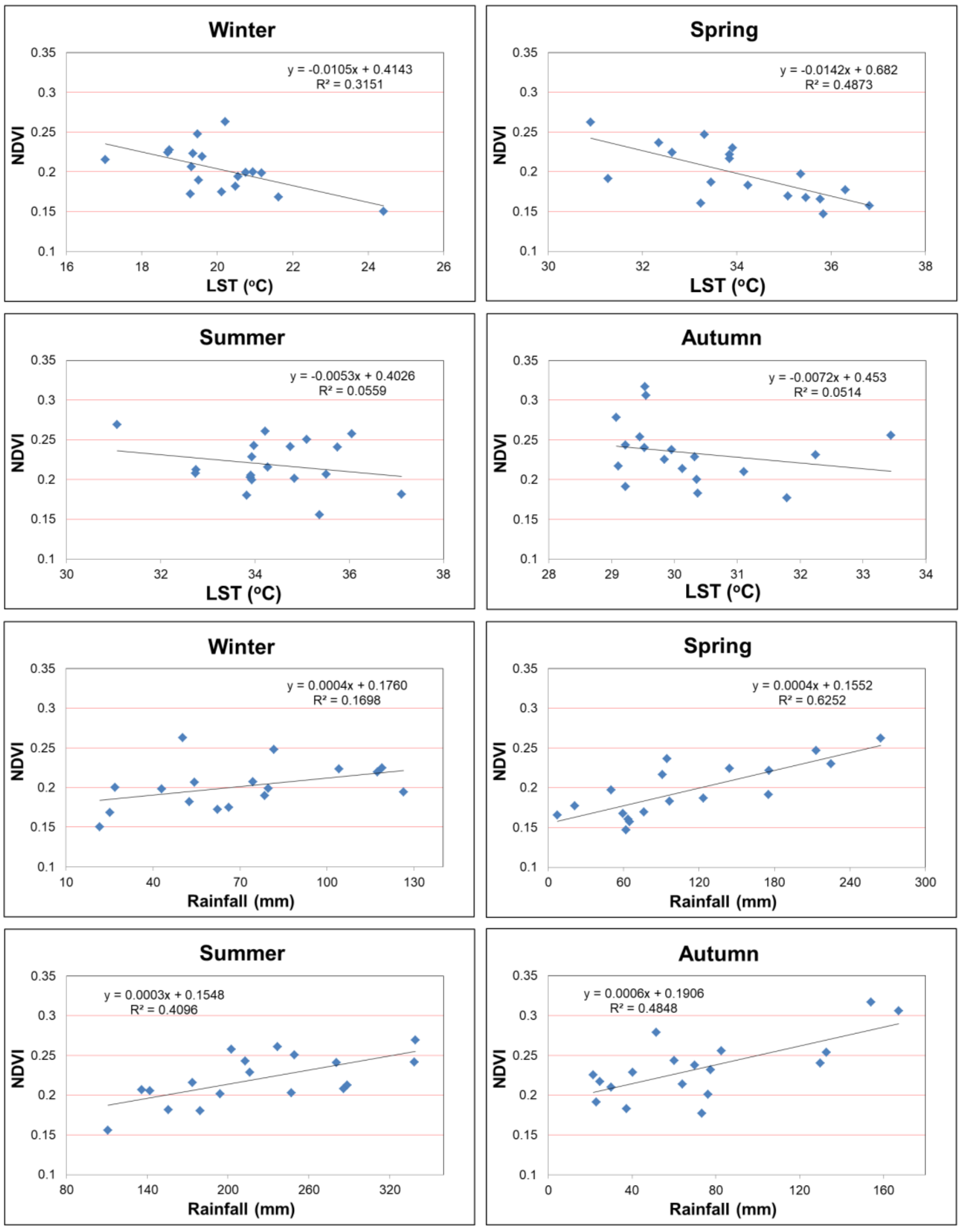

Figure 6 Relationship of the NDVI with seasonal LST and rainfall (2000-2018)

CONCLUSIONS

In the present study, relationship of the NDVI was investigated with the seasonal LST and rainfall data of 2000-2018 period for improving ecosystem health in Sheikh Badin National Park of Pakistan. The results of the study revealed increasing trends in the NDVI during the winter (R=0.55), spring (R=0.48), summer (R=0.48) and autumn seasons (R=0.38) in the SBNP with corresponding increase in the rainfall of winter, spring, summer and autumn seasons of 2000-2018 period. The NDVI had shown an inverse relationship with seasonal LST exhibiting R^2 value of 0.32 for the winter, 0.49 for spring, 0.06 for summer and 0.05 for autumn season. In contrast, a linear relationship was observed between the NDVI and seasonal rainfall data with R^2 values of 0.17, 0.63, 0.41 and 0.48 for the winter, spring, summer and autumn during the

2000-2018 period, respectively. The higher NDVI values observed in the SBNP may be attributed to favorable climatic conditions (temperature & rainfall) prevailed at the elevated areas. The increasing trends in seasonal rainfall may support in sustaining dense vegetation and promoting healthy ecosystem in the SBNP area. Future research should be focused on application of high resolution image data coupled with ground information to explore changes in species compositions; plant penology and increase in intrusion/intensity of invasive species in the region. As it is difficult to isolate climate related changes from impacts of factors like slope, aspect, elevation, vegetation types, soil degradation and land management practices, therefore, an integrated ecosystem management approach would be beneficial for effective conservation of the biological resources in this region in future.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

AUTHORS CONTRIBUTION STATEMENT

NF: Database development, Image processing, Visualization, Writing original draft; RK: Conceptualization, Supervision, Management; AA: Methodology, Analysis, Visualization, Review & editing; MA & RN: Data curation, Resources, Investigation; IZ: Administration, Management, Project support

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REFERENCES

Aastrup, M.L., Sponarski, C.C., Bath, A.J., & Frenette, A., 2021. A national park in the making: Local perceptions and equity implications around a proposed National Park in Romania. Society & Natural Resources, 34(10), 1358–1374. DOI: 10.1080/08941920.2021.1955170

Abbas, S., Qamer, F.M., Murthy, M.S., Tripathi, N.K., Ning, W., Sharma, E., et al., 2015. Grassland growth in response to climate variability in the Upper Indus Basin, Pakistan. Climate, 3(3), 697–714. DOI: 10.3390/cli3030697

Adeyewa, Z.D., & Nakamura, K., 2003. Validation of TRMM radar rainfall data over major climatic regions in Africa. Journal of Applied Meteorology, 42(2), 331–347. DOI: 10.1175/1520-0450(2003)042<0331:VOTRRD>2.0.CO;2

Ahmad, B., Rana, A.S., Abuzar, K., Kiran, R., Mansoor, R., & Kubra, S., 2016. Diagnostic study of heavy downpour in 2015 flash floods over Chitral area, Northern Pakistan. Pakistan Journal of Meteorology, 12(24), 79–93.

Alam, J., 2010. Endemic flora of Gilgit and Baltistan and conservation strategies for threatened endemic taxa. Department of Botany, Karachi University, Karachi, Pakistan, pp. 278.

Allendorf, T.D., & Yang, J., 2013. The role of ecosystem services in park–people relationships: The case of Gaoligongshan Nature Reserve in southwest China. Biological Conservation, 167, 187–193. DOI: 10.1016/j.biocon.2013.08.013

Ashraf, A., Hussain, I., Ahmad, M.M., Iqbal, M.B., Ali, M., & Hussain, Q., 2016. Crop growth monitoring using Green seeker technology - A case of NARC field station in Pothwar region. Proceedings of the Pakistan Academy of Sciences, 53 (3), 195–205.

Ashraf, A., Nazi, R., & Mustafa, N., 2011. Evaluating drought impact on vegetation cover of Rarkan Rod-Kohi area, Balochistan using Remote sensing technique. Proceedings of the Pakistan Academy of Sciences, 48 (3), 143–150.

Attaullah, Khan, N., & Muhammad, Z., 2015. Diversity of life form and leaf size classes at Sheikh Buddin National Park, Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan. South Asian Journal of Life Sciences, 3 (1), 6–13. DOI: 10.14737/journal.sajls/2015/3.1.6.13

Barsi, J.A., Schott, J.R., Hook, S.J., Raqueno, N.G., Markham, B.L., & Radocinski, R.G., 2014. Landsat-8 thermal infrared sensor (TIRS) vicarious radiometric calibration. Remote Sensing, 6, 11607–11626.

Becken, S., & Job, H., 2014. Protected areas in an era of global–local change. Journal of Sustainable Tourism, 22(4), 507–527. DOI: 10.1080/09669582.2013.877913

Chen, S., Zhang, L., Zhang,Y., et al., 2020. Evaluation of Tropical Rainfall Measuring Mission (TRMM) satellite precipitation products for drought monitoring over the middle and lower reaches of the

Yangtze River Basin, China. Journal of Geographical Sciences, 30, 53–67. DOI: 10.1007/s11442-020-1714-y

Cheng, Q., 2006. Multisensor comparisons for validation of MODIS vegetation indices. Pedosphere, 16(3), 362–370. DOI: 10.1016/S1002-0160(06)60064-7

Chiu, L.S., Liu, Z., Vongsaard, J., Morain, S., Budge, A., Pand, N., & Bales, C., 2006. Comparison of TRMM and water district rain rates over New Mexico. Advances in Atmospheric Sciences, 23(1), 1–13. DOI: 10.1007/s00376-006-0001-x

Coppin, P., Jonckheere, I., Nackaerts, K., Muys, B., & Lambin, E., 2004. Digital change detection methods in ecosystem monitoring: a review. International Journal of Remote Sensing, 25(9), 1565–1596. DOI: 10.1080/0143116031000101675

Ding, M., Zhang, Y., Liu, L., Zhang, W., Wang, Z., & Bai, W., 2007. The relationship between NDVI and precipitation on the Tibetan Plateau. Journal of Geographical Sciences, 17(3), 259–268. DOI: 10.1007/s11442-007-0259-7

Erazo, B., Bourrel, L., Frappart, F., et al., 2018. Validation of satellite estimates (Tropical Rainfall Measuring Mission, TRMM) for rainfall variability over the Pacific slope and coast of Ecuador. Water, 10(2), 213. DOI: 10.3390/w10020213

Fleming, K., Awange, J.L., Kuhn, M., & Featherstone, W., 2011. Evaluating the TRMM 3B43 monthly precipitation product using gridded raingauge data over Australia. Australian Meteorological and Oceanographic Journal, 61, 171–184. DOI: 10.22499/2.6103.003

Friedl, M.A., McIver, D.K., Hodges, J.C.F., Zhang, X.Y., Muchoney, D., Strahler, A.H., et al., 2002. Global land cover mapping from MODIS: algorithms and early results. Remote Sensing of Environment, 83(1), 287–302. DOI: 10.1016/S0034-4257(02)00078-0

Garai, S., Khatun, M., Singh, R., Sharma, J., Pradhan, M., Ranjan, A., et al., 2022. Assessing correlation between rainfall, normalized difference vegetation index (NDVI) and land surface temperature (LST) in Eastern India. Safety in Extreme Environments. 4, 119–127. DOI: 10.1007/s42797-022-00056-2

Gessner, U., Naeimi, V., Klein, I., Kuenzer, C., Klein, D., & Dech, S., 2013. The relationship between precipitation anomalies and satellite-derived vegetation activity in Central Asia. Global and Planetary Change, 110, 74–87. DOI: 10.1016/j.gloplacha.2012.09.007

Guo, L., Wu, S., Zhao, D., Yin, Y., Leng, G., & Zhang, Q., 2014. NDVI based vegetation change in inner Mongolia from 1982 to 2006 and its relationship to climate at the biome scale. Advances in Meteorology. DOI: 10.1155/2014/692068

Haque, M., & Basak, R., 2017. Land cover change detection using GIS and remote sensing techniques: A spatio-temporal study on Tanguar Haor, Sunamganj, Bangladesh. The Egyptian Journal of Remote Sensing and Space Science, 20(2), 251–263. DOI: 10.1016/j.ejrs.2016.12.003

Justice, C.O., Townshend, J.R.G., Vermote, E.F., Masuoka, E., Wolfe, R.E., Saleous, N., et al., 2002. An overview of MODIS Land data processing and product status. Remote Sensing of Environment, 83(1-2), 3–15. DOI: 10.1016/S0034-4257(02)00084-6

Khan, B., 2013. Rangelands of Gilgit-Baltistan and Azad Jammu & Kashmir, Pakistan – Current status, values and challenges. Food and Agriculture Organization of United Nations, Country Office, Islamabad, Pakistan, pp. 43.

Loomis, J., Richardson, L., Dara, P.K., Mueller, J., et al., 2024. Ecosystem service values provided by national parks to residential property owners. Ecological Economics, 220, 108175. DOI: 10.1016/j.ecolecon.2024.108175

Martínez, B., & Gilabert, M.A., 2009. Vegetation dynamics from NDVI time series analysis using the wavelet transform. Remote Sensing and Environment, 113(9), 1823–1842. DOI: 10.1016/j.rse.2009.04.016

Marwat, S.K., Khan, M.A., Ahmad, M., Zafar, M., & Usman, K., 2012. Floristic account of the asclepiadaceous species from the flora of Dera Ismail Khan District, KPK, Pakistan. American Journal of Plant Sciences, 3(1), 141–149. DOI: 10.4236/ajps.2012.31016

Noss, R.F., 2001. Beyond Kyoto: Forest management in a time of rapid climate change. Conservation Biology, 15(3), 578–590. DOI: 10.1046/j.1523-1739.2001.015003578.x

Paudel, K.P., & Andersen, P., 2010. Assessing rangeland degradation using multi temporal satellite images and Grazing pressure surface model in Upper Mustang, Trans Himalaya, Nepal. Remote Sensing of Environment, 114(8), 1845–1855. DOI: 10.1016/j.rse.2010.03.011

Qasimi, A. B., Isazade, V., Kaplan, G., & Nadry, Z., 2023. Spatiotemporal and multi-sensor analysis of surface temperature, NDVI, and precipitation using Google earth engine cloud computing platform. Russian Journal of Earth Sciences, 22(6). DOI: 10.2205/2022ES000812

Reeves, M.C., Zhao, M., & Running, S.W., 2006. Applying improved estimates of MODIS productivity to characterize grassland vegetation dynamics. Rangeland Ecology & Management, 59(1), 1–10. DOI: 10.2111/1551-5028(2006)59[001:AIEOMP]2.0.CO;2

Rehman, Z., Kazmi, J., Khanum, F., & Samoon, Z., 2015. Analysis of land surface temperature and NDVI using geo-spatial technique: A case study of Keti Bunder, Sindh, Pakistan. Journal of Basic & Applied Sciences, 11, 514–527. DOI: 10.6000/1927-5129.2015.11.69

Roohi, R., Ashraf, A., & Ahmed, S., 2004. Identification of land use and vegetation types in Fatehjang area, using Landsat-TM data. Journal of COMSATS- Science Vision, 9(1&2), 81–88.

Stathopoulou, M., & Cartalis, C., 2007. Daytime urban heat islands from Landsat ETM+ and Corine land cover data: an application to major cities in Greece. Solar Energy, 81, 358–368.

Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., et al., 2015. Planetary boundaries: Guiding human development on a changing planet. Science, 347(6223), 736. DOI: 10.1126/science.1259855

Tang, J.M., & Zhang, S.W., 2002. Application research of MODIS data in monitoring land use change. Remote Sens.Technol. Appl. (in Chinese), 17(2), 104–107.

Thanabalan, P., Vidhya, R., Kankara, R.S., & Manonmani, R., 2023. Time-series analysis of MODIS (LST and NDVI) and TRMM rainfall for drought assessment over India. Applied Geomatics, 2, 383–405. DOI: 10.1007/s12518-023-00505-y

Thenkabail, P.S., Gamage, M.S.D.N., & Smakhtin, V.U., 2004. The use of remote sensing data for drought assessment and monitoring in Southwest Asia. Research Report 85. Colombo, Sri Lanka: International Water Management Institute, p.34.

Usoltsev, V.A., Lin, H.1, Shobairi, S.O.R., Tsepordey, I.S., Ye, Z., & Anees, S.A., 2022. The principle of space-for-time substitution in predicting Betula spp. biomass change related to climate shifts. Applied Ecology Environmental Research, 20(4), 3683–3698. DOI: 10.15666/aeer/2004_36833698

Wang, J., Ye, B., Liu, F., Li, J., & Yang, G., 2011. Variations of NDVI over elevational zones during the past two decades and climatic controls in the Qilian Mountains, Northwestern China. Arctic, Antarctic, and Alpine Research, 43(1), 127–136. DOI: 10.1657/1938-4246-43.1.127

Wehrden, H.V., Hanspach, J., Kaczensky, P., Fischer, J., & Wesche, K., 2012. Global assessment of the non-equilibrium concept in rangelands. Ecological Applications, 22, 393–399.

Weng, Q., Lu, D., & Schubring, J., 2004. Estimation of land surface temperature, vegetation abundance relationship for urban heat island studies. Remote Sensing of Environment, 89, 467–483. DOI: 10.1890/11-0802.1

Weng, Q.H., Lu, D.S., & Schubring, J., 2004. Estimation of land surface temperature-vegetation abundance relationship for urban heat island studies. Remote Sensing of Environment, 89(4), 467–483.

Wessa, P., 2017. Pearson Correlation (v1.0.13) in Free Statistics Software (v1.2.1), Office for Research Development and Education, URL https://www.wessa.net/rwasp_correlation.wasp/ (Accessed 10 June 2024)

Xu, B., Yang, X.C., Tao, W.G., Qin, Z.H., & Liu, H.Q., 2007. Remote sensing monitoring upon the grass production in China. Acta Ecologica Sinica, 27(2), 405–413. DOI: 10.1016/S1872-2032(07)60012-2

Yang, J., Wan, Z., Borjigin, S., Zhang, D., Yan, Y., Chen, Y., et al., 2019. Changing trends of NDVI and their responses to climatic variation in different types of grassland in inner Mongolia from 1982 to 2011. Sustainability, 11(12), 1–12. DOI: 10.3390/su11123256

Yu, L., Zhou, L., Liu, W., & Zhou, H., 2010. Using Remote sensing and GIS technologies to estimate grass yield and livestock carrying capacity of Alpine grasslands in Golog Prefecture, China. Pedosphere, 20(3), 342–351. DOI: 10.1016/S1002-0160(10)60023-9

Zahoor, M., 2010. Ethno botanical studies of some plants from Sheikh Baddin Hill and derra-ePezu, District Lakki Marwat, Khyber Pakhtunkhwa, Pakistan. M.Phil. Thesis, University of Science and Technology, Bannu.

Zeleke, G., & Hurni, H., 2001. Implications of land use and land cover dynamics for mountain resource degradation in the northwestern Ethiopian highlands. Mountain Research and Development, 21(2), 184–191. DOI: 10.1659/0276-4741(2001)021[0184:IOLUAL]2.0.CO;2

Zeng, H.W., & Li, L.J., 2011. Accuracy validation of TRMM 3B43 data in Lancang River Basin. Acta Geographica Sinica, 66 (7), 994–1004.