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GEOSPATIAL SURVEILLANCE OF URBAN INFLUENCE ON THE GREEN GOLD OF FEDERAL CAPITAL OF PAKISTAN USING CONTEMPORARY ORDINATION AND REMOTE SENSING-BASED APPROACHES

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Abstract

Understanding the consequences of urban influence on urban green gold is of paramount significance yet very complicated. The amalgamation of remote sensing and ordination techniques in the present research made it possible to appraise the extent of risk urban influence posed on these ecological amenities over the past two decades (1998-2018). The research outcomes highlighted that the urban expansion in the federal capital was mostly at the expense of vegetation where the urban green gold covered areas of Islamabad shrunk from 70% in 1998 to 60.7% by 2018 with significant losses observed in the vicinity of Margalla hills and Rawal watershed. This landscape change had a severely negative connotation on the species distribution primarily in the planned and rudimentary developments where environmental stresses introduced due to massive construction activities favored dominance of species instead of diversity. The progressive decline in biomass of the local vegetation over the years, as determined by all the indices, is an indication of a very unsustainable future in the absence of strong policy interventions.

Key words: Redundancy analysis; Normalized difference water index; Enhanced vegetation index; Soil adjusted vegetation index; Tasseled cap indices.

Introduction

Built environment includes not only the buildings but the physical outcome of various environmental and socio-economic processes which pertain strongly to the societal needs and standards. Thereby, the built environment can also be referred to as urban influence whether that influence is on physical activity; local vegetation; public health; transportation; climate, or any other physical feature or process of life (Dovjak & Kukec, 2019; Santamouris, 2013).

Vegetation in all its shapes and forms (trees, herbs, shrubs, grasses, etc.) is a significant part of any environment and is also an important indicator of urban influence. Lower or higher vegetation, as well as urban green spaces (that frequent the built environments), are all beneficial for the urban population on many levels. Urban green areas especially hold significance because they provide a 'novel ecosystem' that helps preserve and protect many plants and animals (Dylewski *et al.*, 2020).

Pakistan along with other developing countries of Southeast Asia has experienced rapid urbanization over the past decades. This level of urbanization has been greatly accredited to population migration from rural areas to metropolitan cities like Islamabad (Federal Capital). Such an expansion of population in the big cities has caused many unprecedented pressures on the local ecology of built areas (Chen *et al.*, 2011). Studies reveal that rapid development of the built environment has significantly negative connotations on vegetation coverage since to accommodate the growing population, vegetative lands are lost to construction and conversion of green spaces to impermeable ones (Byomkesh *et al.*, 2012). Therefore, the principal objective of the present research was to determine the extent of risk urban influence posed to the Urban Green Gold of the Federal capital of Pakistan.

Materials and Methods

The general methodology followed to determine the extent of the risk posed by urban influence on the distribution and health of urban green gold of Islamabad constituted of the following steps: study area zonation, soil and vegetation sampling and analyses, multivariate analysis (RDA), remote sensing-based analyses (vegetation indices).

Study area zonation and analyses: The study area was divided into four distinct zones including planned developments, rudimentary developments, green spaces, and roadside green belts for soil and vegetation sampling. The zonation was done by in-depth appraisal of topographic sheets of the study area to ensure fair representation from different parts of the city. A total of 120 quadrates of 1m x 1m were laid in the study area (6 in each zone) and 40 soil samples were collected for the assessment of disparity in vegetation distribution pattern via random sampling (for sampling points refer to Fig. 1). The vegetation cover in each zone was recorded as per DOMIN scale (Bashir *et al.* 2016) whereas the soil samples were collected at the depth of 5cm. The Electrical Conductivity (EC), soil pH, Organic Matter (OM), Total soil Nitrogen (TN), Extractable Phosphorus (EP), heavy metals, and potassium were analyzed by employing the methodology provided by Ryan *et al.*, (2017), Allen method (Allen *et al.*, 1974), Nikolsky method (Nikolsky, 1963), and Li *et al.*, (2008) method respectively.

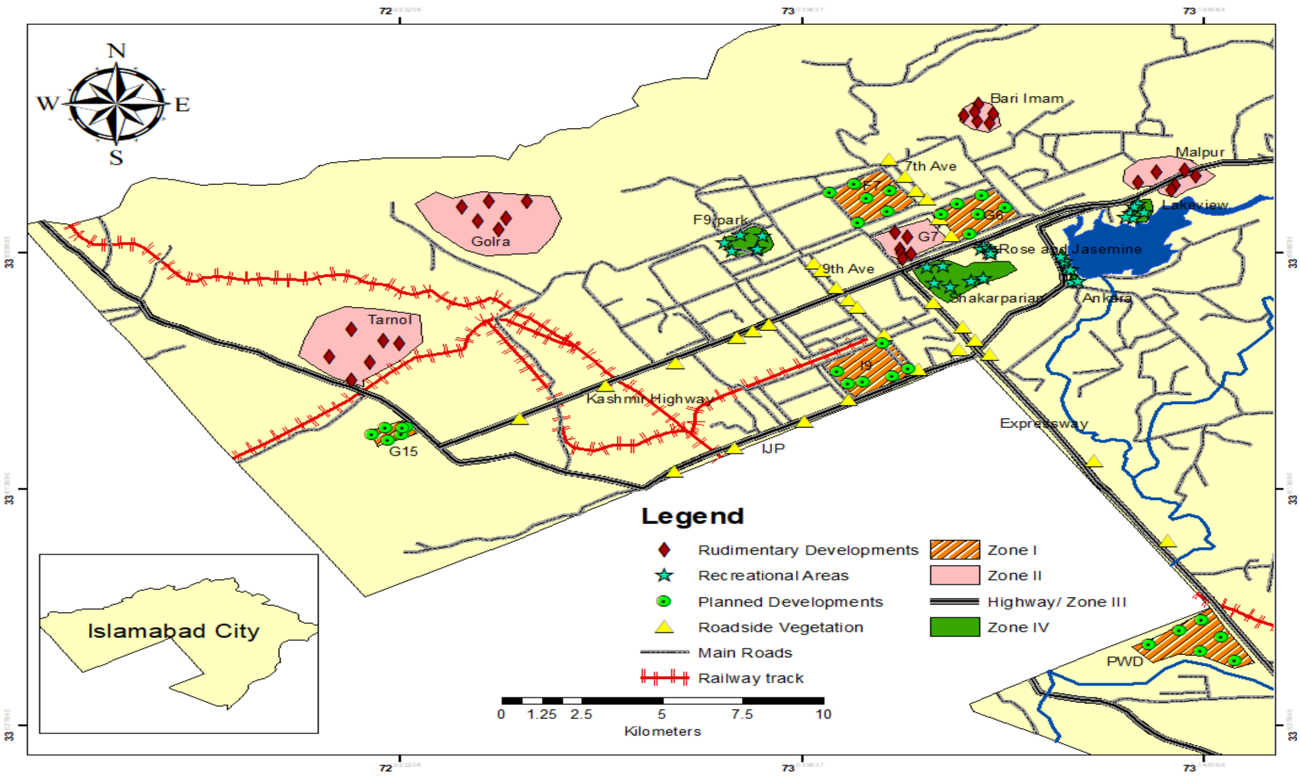

Fig. 1. Study area map of Islamabad city showing the sampling sites from all four of the study zones.

The assessment of biotic exchange between the vegetation species and environmental parameters was quantified by Redundancy analysis which is a constrained ordination method that assumes one set of variables to be dependent on the other set and summarizes the disparity in response variables with help of the explanatory variables (Leps & Smilauer, 2003). For present research, the effect of environmental variables (explanatory variables) was appraised on the spatial distribution of vegetation (dependent or response variables) in the study area.

Spatio-temporal surveillance of biomass health: For this study, spatio-temporal surveillance of biomass health was assessed by utilizing various remote sensing-based indices namely Enhanced Vegetation Index (EVI), Soil Adjusted Vegetation Index (SAVI), Normalized Difference Water Index (NDWI), and Tasseled cap indices. These indices were applied on the satellite imagery acquired from USGS earth explorer and consisted on Landsat 4-5 TM data for the years 1998 and 2008 and Landsat 8 Oli data for the year 2018.

EVI was evaluated by employing the methods followed by Garroutte *et al.*, (2016) using the formula EVI = 2.5 * ((Band 4 - Band 3) / (Band 4 + 6 * Band 3 - 7.5 * Band 1 + 1)) for Landsat 4-5 data. In Landsat 8 however, EVI = 2.5 * ((Band 5 – Band 4) / (Band 5 + 6 * Band 4 – 7.5 * Band 2 + 1)) was used. Whereas SAVI was calculated using the methodology of Vani & Mandla (2017) using the formula SAVI = ((Band 4 – Band 3) / (Band 4 + Band 3 + 0.5)) * (1.5) whereas Band 5 and 4 were utilized to assess the data of 2018. Tasseled cap indices were calculated using the methods given by Samarawickrama *et al.*, (2017) that used six of the seven Landsat TM bands (all but Band 6) for the algorithm, generating three levels of information and NDWI by the methods of Ahmed & Akter (2017) which employed the following formula: NDWI = (NIR – SWIR) / (NIR + SWIR).

Results and Discussion

Urbanization pattern is different for different parts of the cities and so is the effect it has on species distribution. For instance, the results indicated that the urban soils were more alkaline due primarily to the exposure to construction material like concrete and plaster. This affected solubility and thus the availability of hazardous ions or micronutrients in the soil. Since the pH of the soil was high, the availability of nutrients was low due to a decrease in solubility (Mickelbart *et al.*, 2012). Rudimentary developments on the other hand receive less attention and faced more environmental pressures than planned developments due to improperly planned anthropogenic activities. For instance, extensive agricultural practices in these areas added harmful chemicals to the soil in addition to the massive construction activities that were targeted towards these areas. Because of that, the species in both these zones had to tolerate different types of pressures and thus responded to them in different ways. Species like *Cynodon dactylon* and *Cannabis sativa* handled external environmental pressures well and thus were dominant in most of the zones of the city while others didn't. Similar findings were reported by Ahmad *et al.*, (2014) for Korang River, Islamabad and Malik & Husain (2006) for Lohibehr, Rawalpindi.

Thereby, the number of species present in each zone, their grouping pattern as well as response to environmental variables exhibited significant disparity among all four zones. RDA biplots (like the ones shown in Fig. 2) superimposed species and environmental axes such that the angle between each axis and arrow reflected the degree of correlation of the variable with that axis (Farrag, 2012). If a plant species (represented by blue triangles) is close to an explanatory variable in the plot (red arrowheads), then it is likely to be affected by the said variable the most. Furthermore, the longer is the arrow of any explanatory variable, the higher is its effect on nearby species and vice versa. The distance between the species symbols showed a degree of similarity among them within a quadrat.

Figure 2 indicated that in Zone I of Islamabad, the arrows of both Phosphorus and Nitrogen were long, and thus was their influence on determining the abundance of *Malvestrum coromendelanum, Hierachleu odorate,* and *Rumex dentatus* whereas Potassium affected *Euphorbia helioscopia*. In Zone II, heavy metals showed a strong influence on the species distribution such as Nickel that strongly affected *Silybum marianum, Oxalis corniculata, Tagetas patula,* and *Plumeria rubra.* Cadmium on the other hand showed a strong influence on *Cynodon dactylon, Taraxacum officinale, Poa pratensis*, and *Malvastrum coromandelianum* while Electrical conductivity influenced the distribution of *Cannabis sativa* along the gradient.

Zone III showed a slightly different influential pattern of environmental variables where pH slightly affected *Conzya candensis* and *Chionochloa rubra* while Potassium affected the distribution of several species (however, not very strongly as indicated by the size of the arrow) such as *Oxalis corniculate, Cynodon dactylon, Euphorbia helioscopia, Parthenium hysterophus, Malvestrum coromendelanum, Bougainvillea spectabilis, Conyza canadensis,* and *Eucalyptus staigeriana.* Nickel also influenced some species distribution in this zone including *Ricinus communis*, *Cannabis sativa*, and *Phoenix dactylifera*.

Zone IV of Islamabad was a designated green area, where Cadmium displayed a very weak association with *Elymus repens* and *Cupressus sempervirens,* and similarly Lead showed a weak association with *Malva parviflora, Callistemon lanceolatus,* and *Morus alba.* Chromium conversely showed mild association with *Chenopodium album* and *Broussonetia papyrifera.*

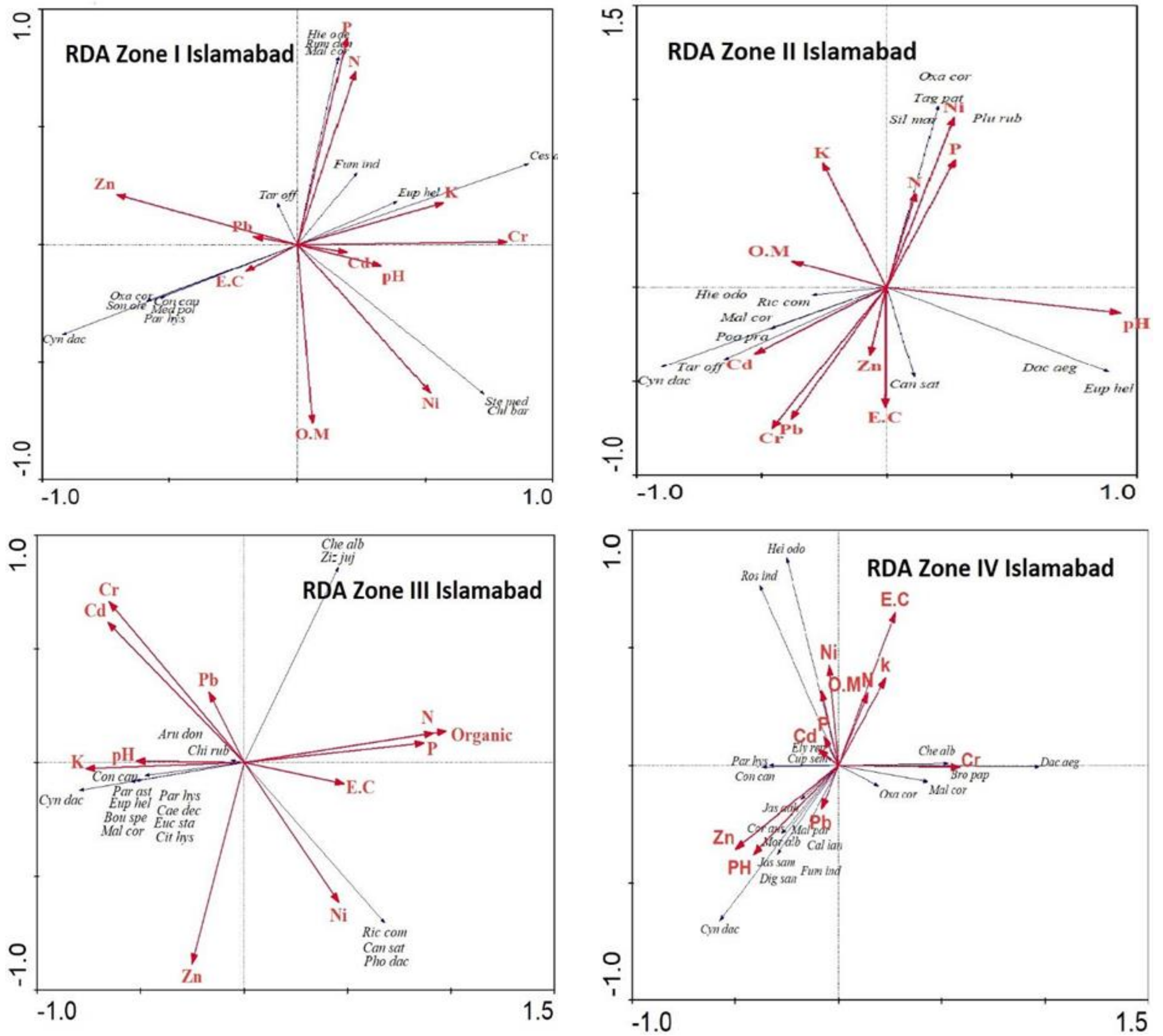

Fig. 2. Redundancy biplot exhibiting relationship of Islamabad's response variables with the explanatory variables.

All these species make up the urban green gold and contribute to the wellbeing of the urban population in a multitude of ways. Among others, one of the benefits of having green spaces is high albedo which is requisite for lowering the land surface temperature. Additionally, these land features enhance the functioning of the urban ecology, play a vital role in flood control, air pollution prevention and control as well as preventing soil erosion (Manes *et al.*, 2014). Moreover, vegetation biomass plays a key role in the carbon cycle as it sequesters carbon (via photosynthesis process) that is produced by anthropogenic activities and thus maintains climatic balance. Besides, the spatial distribution of vegetation biomass influences the radiation budget by decreasing surface albedo. Therefore, assessing vegetation biomass is of paramount significance for monitoring the landscape of any built environment. Nonetheless, monitoring vegetation biomass is a dynamic and complex process if done by traditional methods. Vegetation Indices based on remotely sensed data, on the contrary, provide an image enhancement method with great information extraction potential (Ojoyi *et al.,* 2016). These indices when corroborated with the results attained by ordination inferred that the environmental degradation in zones I and II of the city was far more prominent than the other zones.

In the present research, several different indices were used in conjunction because of vicissitude in the accuracy of the vegetation cover classification by each of them. Some classified sparse vegetation better while others were sensitive to soil disturbances and yet others were sensitive to atmospheric influences. For instance, NDWI was best fitted to determine the areas with vegetation under water stress (Ding *et al.,* 2017). SAVI on the other hand, was best suited for areas with sparse vegetation and agricultural areas whereas EVI represented dense canopies well.

As indicated by the ranges given in (Fig. 3) all the indices indicated an overall decline in the vegetative biomass's health throughout the study duration where the vegetation indices all had a range from -1 to 1, and the closer the value is to 1, the healthier the vegetation cover.

The basic vegetation classification based on these indices revealed that the urban green gold of the federal capital (incorporating higher and lower vegetation as well as crops) occupied approximately 70% of the area in 1998 (53% vegetation area 17% agricultural land). This shrunk slightly to 69% in the year 2008 where although the area covered by vegetation reduced to 48%, the agricultural land increased such that it covered 21% of the study area. By the year 2018, the total percentage of the land occupied by vegetation reduced to 60.77% in the city where the vegetation covered 35.7% of the land and agricultural land took up 25.07% of the area. Da Silva *et al*., (2020) also employed a combination of all these indices to provide a comprehensive overview of vegetation biomass in Santa Catarina, Brazil.

Figure 4 however, shows comparative outcomes of EVI and SAVI for deliberating the spatiotemporal differences observed in Islamabad city over the past two decades as EVI was effective in removing the atmospheric and background influences from areas with dense vegetation cover such as Margalla hills. Whereas, SAVI was effective in reducing the influence of soil brightness especially for the areas where vegetation cover was low.

It was evident from the data presented in Figures 3 and 4 that the vegetation biomass of the city reduced over the years due to rapid urban expansion which is generally at the cost of ecologically significant land parcels such as forests, shrubs, rangelands, and green gold of the city. These findings were in line with those obtained by Hemati *et al.* (2020) in the research conducted on the Karaj district of Alborz Province, Iran. Their research also elucidated an expansion of cultivated land in each scenario along with urban expansion due primarily to the increment in the demand for natural resources.

The expansion of built-up surfaces caused dramatic changes to occur in the city's landscape between 1998 and 2018 that not only impacted the green gold but also influenced the waterways, surface albedo, and in turn land surface temperature. However, urban sprawl is problematic for developed and developing countries alike for a multitude of reasons. China, for example, faces concerns about being unable to sufficiently sustain the food source in the future. Correspondingly, Canada is concerned about the expansion of urban areas putting undue pressure on governments to continue providing infrastructure and services to all the citizens (Stan & Sanchez-Azofeifa, 2017).

Since vegetation in all forms is crucial to the sustainability of the city environment, steps should be taken to protect vegetation biomass, diversity, and distribution. Furthermore, if the present practices continue to persist, the future will hold more and more areas covered with impervious surfaces, high surface temperatures, fewer amenities (like infrastructure, natural land, water, and gas) because of population intensification. This would reduce the well-being to a much greater extent unless there is some intervention by the government. Thereby, city planners can use the findings of the present research to minimize the negative impacts of ever-intensifying trends of urban expansion and agglomeration in Islamabad.

Study limitations: Present research only considered anthropogenic and biogeophysical variables and could not consider economy-related (landscape valuation) and policy-related variables (i.e. land-use zoning, infrastructure policy) due to quantification and data availability issues.

Therefore, it is recommended that future studies may include these factors as they can significantly alter the rate of urban expansion and thus are crucial to study in reference with vegetation. It is further endorsed that such policies be adopted that have worked in other parts of the world to stem the unchecked city growths and preserve the natural land.

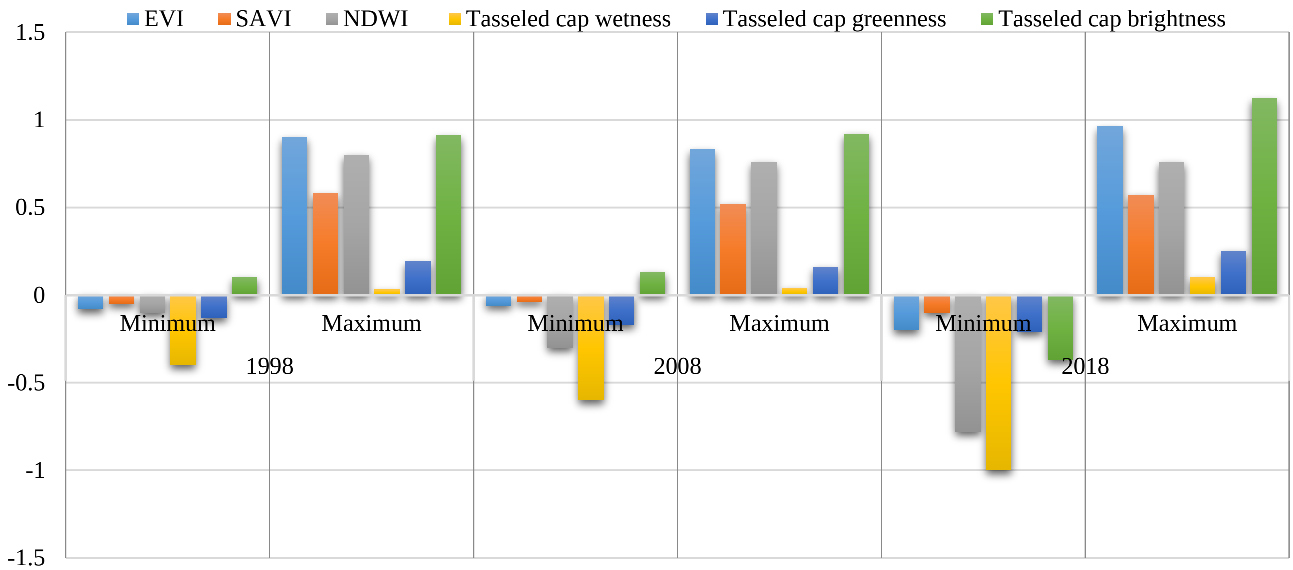

Fig. 3. Graphic illustration of temporal variation in various Vegetation indices for Islamabad.

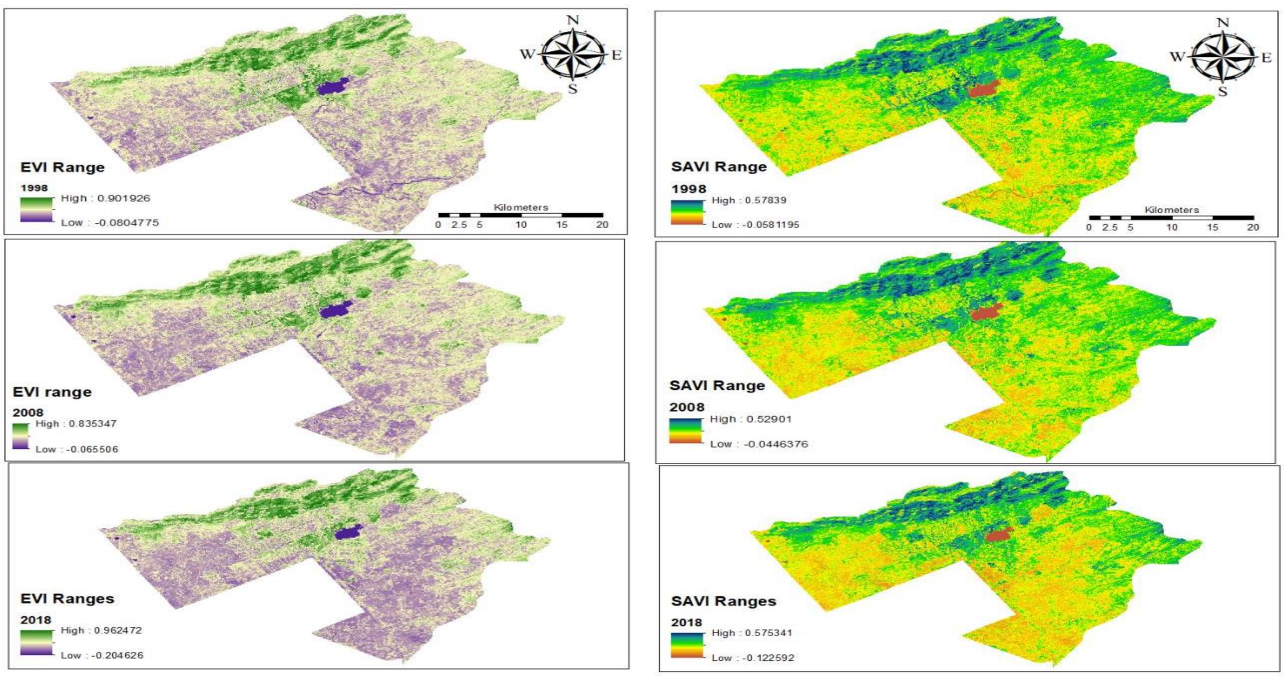

Fig. 4. Spatio-temporal variation in health of vegetative biomass of Islamabad as specified by EVI and SAVI.

References

Ahmad, S.S., R. Murtaza R. Shabir, M.N. Ahmed and T.A. Shah. 2014. Environmental diversification and spatial variations in riparian vegetation: A case study of Korang River, Islamabad. *Pak. J. Bot.,* 46(4): 1203-1210.

Ahmed, K.R. and S. Akter. 2017. Analysis of landcover change in southwest Bengal delta due to floods by NDVI, NDWI and K-means cluster with Landsat multi-spectral surface reflectance satellite data. *Remote. Sens. Appl.: Soc. Environ.*, 8: 168-181.

Allen, S.E., H.M. Grimshaw J.A. Parkinson and C. Quarmby. 1974. *Chemical analysis of ecological materials*. Blackwell Scientific Publications.

Bashir, H., S.S. Ahmad A. Jabeen and S. Erum. 2016. Multivariate Analysis for the Assessment of Herbaceous Roadsides Vegetation of Wah Cantonment. *J. Anim. Plant Sci.*, 26(2): 457-464.

Byomkesh, T., N. Nakagoshi and A.M. Dewan. 2012. Urbanization and green space dynamics in Greater Dhaka, Bangladesh. *Landscape. Ecol. Eng.*, 8(1): 45-58.

Chen, J., F. Guo and Y. Wu. 2011. One decade of urban housing reform in China: Urban housing price dynamics and the role of migration and urbanization, 1995-2005. *Habitat. Int.*, 35(1): 1-8.

da Silva, V.S., G. Salami M.I.O. da Silva E.A. Silva J.J. Monteiro Junior and E. Alba. 2020. Methodological evaluation of vegetation indexes in land use and land cover (LULC) classification. *Geol. Ecol. Landsc.*, 4(2): 159-169.

Ding, H., X. Liu F. Huan Y. Li and X. Zou. 2017. Onset of drying and dormancy in relation to water dynamics of semi-arid grasslands from MODIS NDWI. *Agr. Forest. Meteorol.*, 234-235: 22-30.

Dovjak, M., and A. Kukec. 2019. *Health Outcomes Related to Built Environments*. In Creating Healthy and Sustainable Buildings (pp. 43-82). Springer, Cham.

Dylewski, Ł., L. Maćkowiak and W. Banaszak-Cibicka. 2020. Linking pollinators and city flora: How vegetation composition and environmental features shapes pollinators composition in urban environment. *Urban. For. Urban. Gree.*, 56: 126795.

Farrag, H.F. 2012. Floristic composition and vegetation-soil relationships in Wadi AlArgy of Taif region, Saudi Arabia. *Int. Res. J. Plant. Sci.,* 3(8): 147-157.

Garroutte, E.L., A.J. Hansen and R.L. Lawrence. 2016. Using NDVI and EVI to map spatiotemporal variation in the biomass and quality of forage for migratory elk in the Greater Yellowstone Ecosystem. *Remote. Sens.*, 8(5): 404.

Hemati, T., S. Pourebrahim M. Monavari and A. Baghvand. 2020. Species-specific nature conservation prioritization (a combination of MaxEnt, Co $ ting Nature and DINAMICA EGO modeling approaches). *Ecol. Model.*, 429: 109093.

Lepš, J. and P. Šmilauer. 2003. *Multivariate analysis of ecological data using CANOCO.* Cambridge university press, Britain.

Li, H.U.A., W. Wei-Xiang L. Yu-Xue C.M. Tientchen and C. Ying-Xu. 2008. Heavy metals and PAHs in sewage sludge from twelve wastewater treatment plants in Zhejiang Province. *Biomed. Env. Sci.*, 21(4): 345-352.

Malik, R.N. and S.Z. Husain. 2006. Classification and ordination of vegetation communities of the Lohibehr reserve forest and its surrounding areas, Rawalpindi, Pakistan. *Pak. J. Bot.,* 38(3): 543.

Manes, F., V. Silli E. Salvatori G. Incerti G. Galante L. Fusaro and C. Perrino. 2014. Urban Ecosystem Services: tree diversity and stability of PM10 removal in the Metropolitan Area of Rome. *Ann. Bot.*, 4: 19-26.

Mickelbart, M.V., M.J. Gosney J. Camberato and K.M. Stanton. 2012. Soil pH effects on growth and foliar nutrient concentrations of *Spiraea alba* Du Roi and *Spiraea tomentosa* L. *Hort. Sci.*, 47(7): 902-906.

Nikolsky, G.V. 1963. *The ecology of fishes*. London Academic Press, p351.

Ojoyi, M., O. Mutanga J. Odindi and E.M. Abdel-Rahman. 2016. Application of topoedaphic factors and remotely sensed vegetation indices to enhance biomass estimation in a heterogeneous landscape in the Eastern Arc Mountains of Tanzania. *Geocarto. Int.*, 31(1): 1-21.

Ryan, J., R. Sommer and G. Estefan. 2017. *Methods of soil, plant and water analysis: A manual for the West Asia and North Africa Region*. International Center for Agricultural Research in the Dry Areas (ICARDA).

Samarawickrama, U., D. Piyaratne and M. Ranagalage. 2017. Relationship between NDVI with tasseled cap indices: A remote sensing based analysis. *Int. J. Innov. Res. Tec.*, 3(12): 13-19

Santamouris, M. 2013. *Energy and climate in the urban built environment*. Routledge.

Stan, K. D., and A. Sanchez-Azofeifa. 2017. The Edmonton-Calgary corridor: Simulating future land cover change under potential government intervention. *Land Use Policy.*, 63: 356-368.

Vani, V., and V.R. Mandla. 2017. Comparative Study of NDVI and SAVI vegetation Indices in Anantapur district semi-arid areas. *Int. J. Civ. Eng. Tec.*, 8(4): 287-300.

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