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Geospatial surveillance of urban green gold's response to the built environment of Rawalpindi, Pakistan

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Abstract

Policymakers and city planners actively seek to direct urbanization to uphold the quality of life. Urban green gold plays a crucial role in this process as it impacts the wellbeing of local populations and the long-term sustainability of the cities in a multitude of ways. However, it is challenging to factor in the impact of the built environment on the benefits provided by green gold. The study assessed this impact by amalgamation of Redundancy Analysis and Remotely sensed biomass estimation. The outcomes highlighted that different developmental activities in all four zones of the city i.e. planned developments, rudimentary developments, roadside vegetation, and designated green spaces had significant negative connotations on not only the species diversity but also on its biomass health. The negative influence was most predominant in the rudimentary developments followed by planned developments and roadside vegetation. These outcomes provided the means to assess how different anthropogenic and biogeophysical variables might be responsible for shaping the landscape of today in terms of health and distribution of urban green gold, and consequently wellbeing of Rawalpindi's population.

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Introduction

Green gold is a significant fragment of the cities because it serves as a refuge for many animal and plant species. These areas not only include the natural vegetation but also include parks, private gardens, national reserves, meadows, botanical gardens, roadside vegetation, green roofs, as well as the greenery surrounding the settlements (Baldock *et al.*, 2019). They provide many services to the urban population such as recreation, community connectedness, mental, and physical health boost. Moreover, they play an important role in reducing pollution, the urban heat island effect as well as floods thus making them a key factor in urban well-being (Dylewski *et al.*, 2020). Additionally, even some of the invasive species that were traditionally considered harmful like *Cannabis sativa* and *Parthenium hysterophorus* reportedly have great environmental potential. Since vegetative areas are necessary for the well-being and development of urban ecology, they should be an important consideration in policymaking and urban planning. For successfully incorporating vegetation in developmental plans and policies, however, it is crucial to assess the existing status of vegetation biomass of an area to understand the extent of the problem. Therefore, the present research, aimed to assess the disparity in the level of biotic exchange attributed to new developments in Rawalpindi city using remote sensing and ordination analyses.

Materials and methods

Study area and Methods

To assess the response of Rawalpindi's green gold to its built environment, the following methodology was generally followed: The city was first divided into four distinct zones i.e. planned developments, rudimentary developments, roadside vegetation, and designated green spaces for collecting soil and vegetation data (as shown in Fig. 1).

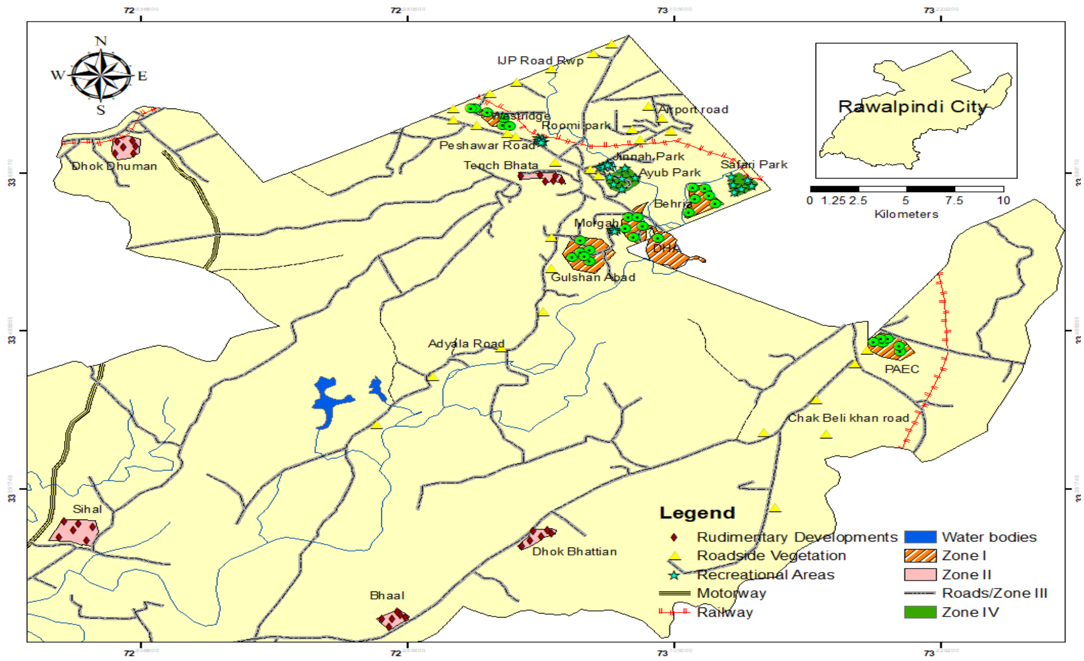

Fig. 1. Study area map of Rawalpindi city showing the sampling sites from all four of the study zones.

For recording the vegetation cover as per Kent and Coker (1995), 6 quadrates were laid in each of the zones of Rawalpindi making a total of 120, and the identification of the species was carried out based on Nasir and Rafiq's (1995) nomenclature. Additionally, 2 soil samples were collected from each zone making the total count of soil samples be 40 which were analyzed to extract the information about the basic physicochemical characteristics that contribute to the distribution of vegetation in the study area by employing the methodology provided by Shabbir *et al.* (2014).

Analysis

Redundancy Analysis (RDA) was performed in the present research since such ordination technique specifically looks for multivariate relationships between two datasets which in the present case translates into soil data (environmental data) and species abundance data by assuming that one set of variables is dependent on the other set (Leps and Smilauer, 2003). It is was applied because it is of paramount significance to quantify the species diversity across different units of land use to document the status of local vegetation distribution, assess the role of management, as well as plan future management (Dalle, 2020). To that effect, RDA was performed following the methodology developed by Ter Braak and Smilauer (1998).

Following that, Landsat data of the past two decades was acquired (1998-2018) from United States Geological Survey's website to be used for biomass assessment. The vegetation biomass of the study area was evaluated using Enhanced Vegetation Index (EVI) and Soil Adjusted Vegetation Index (SAVI) in the ArcGIS environment. The formulae used for calculating the indices are given in the subsequent lines.

EVI= 2.5* (NIR - Red / NIR + 6 * Red - 7.5 * Blue + 1) (i)

SAVI= (NIR - Red / NIR + Red + 0.5) * 1.5....(ii)

Where the top of atmosphere reflectance calculated from the bands was used instead of the actual bands.

Results and discussion

Green gold's response to the built environment

The level of disparity in vegetation's response to the built environment in different zones of the city as determined via Redundancy Analysis showed that in Zone I of Rawalpindi, 47 species were identified with eigenvalues sum 10.576 where 35 active species were present in Zone II of Rawalpindi (eigenvalues sum: 8.43). A total of 38 species from Zone III (eigenvalues sum 10.9) were logged. In Zone IV of the city, however, 39 active species were recorded.

Not only the number of species differed in each zone but their grouping pattern and response to environmental variables also showed considerable disparity among all four zones as indicated by Fig. 2.

In Zone I, for instance, Chromium showed a strong influence on *Conyza canadensis;* electrical conductivity showed a mild influence on *Cynodon dactylon*, *Pinus roxburghii, Rumex dentatus,* and *Hierochloe odorata*; and Organic matter showed a weak influence on *Rosa indica*, *Euclyptus oblique,* and *Dactyloctenium aegyptium*. In Zone II, Electrical conductivity contributed strongly to the abundance of *Hierochloe odorata,* Potassium showed a robust association with *Rumex dentatus, Conzya candensis,* and *Stellaria media* whereas Lead showed a very weak association with *Convolvulus arvensis*.

In Zone III, Nickel showed a strong influence on *Cannabis sativa,* Electrical conductivity showed a strong influence on *Cynodon dactylon* and *Euphorbia helioscopia,* Potassium showed a mild influence on *Malvestrum coromendelanum,* and Phosphorus showed a weak influence on *Parthenium hysterophus*. In Zone IV of Rawalpindi however, it was electrical conductivity that had a remarkable influence on *Hierochloe odorata*. Organic matter had a mild influence on several species including *Fumaria indica, Stellevia media, Sonchus oleraceus,* and *Citrus x meyeri*. Nickel had a weak effect on *Cycas revolute* while Lead had a weak effect on *Medicago polymorpha*.

Urbanization pattern is different for different parts of the cities and so is the effect it has on species distribution. For instance, the results further revealed that in Zone I of Rawalpindi, the soil organic matter concentration varied greatly with Behria phase I having the lowest and Westridge the highest concentration. Gulshan abad had high concentrations of Phosphorus and Nitrogen whereas in PAEC the amount of Nitrogen present in the soil was the lowest.

DHA I, on the other hand, had the most alkaline soil which is why it had the highest concentration of Nickel and Cadmium was present in the soil. Whereas, Gulshan abad had the highest Lead concentration and PAEC had Chromium rich soil. In addition to the propagation of *Cannabis sativa* and *Cynodon dactylon,* these conditions supported the growth of *Hierachleu odorate* as well (Table 1).

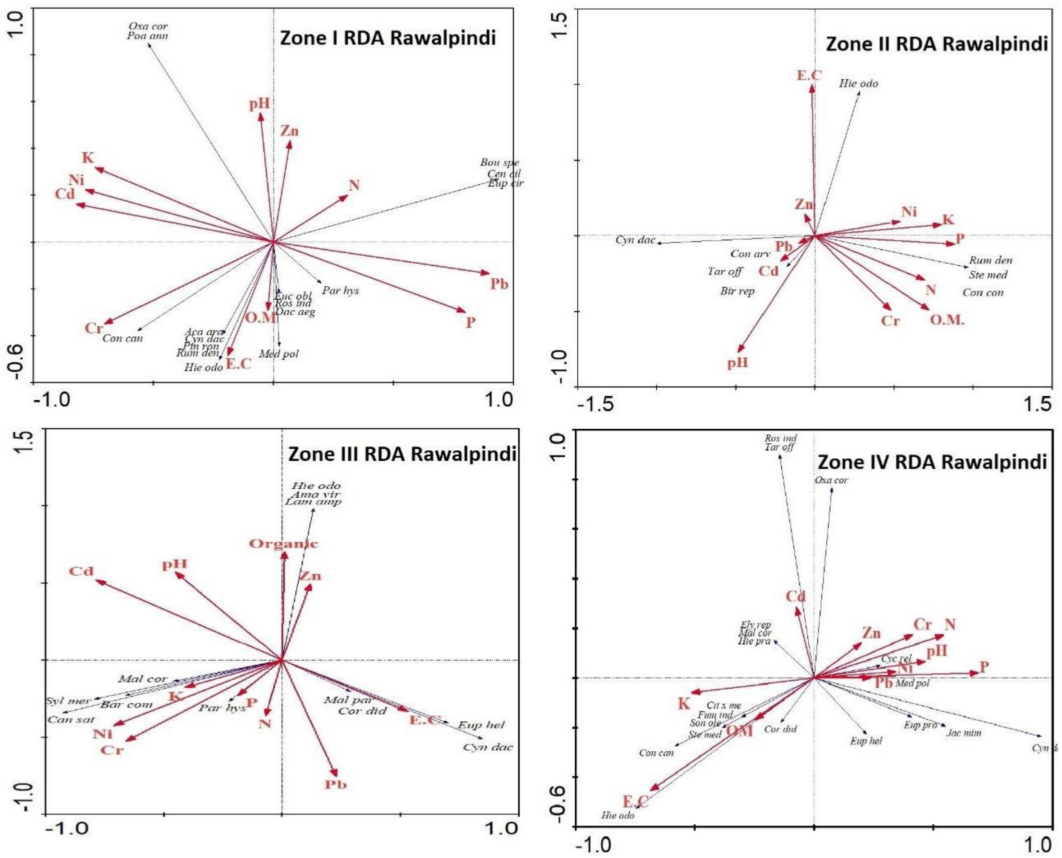

Fig. 2. Redundancy biplot exhibiting relationship of Rawalpindi's response variables with the explanatory variables.

Rudimentary developments of Rawalpindi put a lot of species under stress due to very high concentrations of heavy metals (particularly in Bha'al) because of the vicinity to agricultural land and a higher rate of constructional activities in the area. Dhok Bhattian, Dhok Dhumman and Tench Bhata also showed high concentrations of various heavy metals and alkaline soil. Therefore, these supported mostly the species with high tolerance. In Zone III, Nickel's concentration was high in Peshawar road while low in Adiala road. This greatly influenced the growth of *Parthenium hysterophorus* and *Cannabis sativa*. Zone IV of Rawalpindi revealed a healthy relationship between soil and vegetation.

Table 1. Disparity in species dominance pattern in different zones of Rawalpindi as determined by RDA based Generalized Additive Model (GAM) and General Linear Model (GLM).

Zones of Rawalpindi	Most Abundant Species	Most Stressed Species
Zone I	*Cynodon dactylon, Conyza Canadensis*	*Sisymbrium irio, Withania somnifera*
Zone II	*Hierachleu odorate, Cannabis sativa, Cynodon dactylon*	*Visica hirsuta, Birchiaria Reptan, Medicago doliata*
Zone III	*Cynodon dactylon, Cannabis sativa, Parthinium hysterophorus*	*Amaranthus viridis, Chenopodium album*
Zone IV	*Cynodon dactylon, Cornupus didymus*	*Chloris barbata, Euphobia prostrate*

All in all, Bermuda grass or *Cynodon dactylon* was dominant in planned developments, rudimentary developments, roads, and parks alike because it is not only a drought-tolerant species but can withstand soil flooding as well in addition to other physicochemical extremes (Ashokkumar *et al.*, 2013). *Cannabis sativa* on the other hand was the second most abundant species in both the rudimentary developments as well as on the roadsides (zones II and III).

All these species contribute to the wellbeing of the urban population in a multitude of ways. *Cynodon dactylon,* for instance, is a great laxative, antidiabetic, and antioxidant plus its paste is beneficial in stopping nosebleed. Furthermore, this plant has proven to be of use in snakebite, piles, leucoderma, and cancer treatments (Ashokkumar, Selvaraj, & Muthukrishnan, 2013). *Cannabis sativa* has a lot of proven medical uses as well. Various studies have revealed that it can be used as a cure for the ailments like leukemia, arthritis, AIDS, cancer, glaucoma, rheumatism, and multiple sclerosis. *Conyza Canadensis* L. (dominant species of Zone I, Rawalpindi) is used for the treatment of diarrhea, dysentery, and tonsils. It also proved to be beneficial in the opening of nasal blockage. *Parthenium hysterophorus* is used in skin treatments and the prevention of liver infestation from amoeba. *Coronopus didymus* on the other hand is used to induce a cooling sensation in the body (Ahmad, Khan, and Butt, 2015). All this highlights the reason why green gold biomass is of utmost importance for the urban population. For this purpose, the study further evaluated the health of green gold biomass in the city which is discussed in the subsequent section.

Vegetation Biomass Health

Even though both the vegetation indices recorded all the variations logged by the sensors within the range -1 to 1 (the closer the value gets to 1, the healthier the vegetation biomass), each of them performed better at different levels of vegetative cover. SAVI was sensitive to soil background and thereby represented the areas with sparse vegetation far better than EVI which effectively removed the atmospheric and background influences from areas with dense vegetation cover. Thereby, both the indices classified the vegetation differently but together provided a comprehensive picture of the vegetative health status of the city.

The higher vegetation of the city mostly constituted of tropical dry deciduous scrub forests. The total area covered by vegetation or green gold in 1998 was 53% of the study area (30% vegetation and 23% agriculture).

The total area covered by vegetation increased up to 57% in 2008 though, due to agricultural expansion (25% vegetation and 32% agriculture). In 2018, the overall area covered by vegetation declined again and was 53%, where 24% of this was covered by vegetation while 29% was covered by agriculture.

Furthermore, as designated by the ranges given in Fig. 3, both the indices indicated an overall decline in the vegetative biomass's health throughout 1998-2008 and a slight increase from then to 2018 whereas the influence of soil increased over the years.

Here, EVI classified the areas with dense vegetation as the ones with good biomass health (0.2 -0.9) and the rest as non-vegetative or the vegetation with poor health. SAVI on the other hand classified areas with low vegetation biomass (0.1-0.2) as well as those with high vegetation biomass (dense canopies). da Silva *et al.* (2020) employed a combination of these indices to provide a comprehensive overview of vegetation biomass in Santa Catarina, Brazil. Ahmed and Akter (2017) also found the indices to be adequate for phenological assessments.

The loss of vegetative biomass cover was predominantly so because of the flood of 2001 (among others discussed previously) which affected the vegetation of twin cities in a bad way. However, the effects were more prominent in Rawalpindi because the water level of Nulla Lai and its tributaries rose remarkably, and the flood was recorded as a national disaster. Even though the rainfall intensity was more in Islamabad, the swollen flow of the water invaded its twin city and caused a lot more damage there (Kamal, 2004). The effects of this disaster were so vast that they were still prominent in the year 2008 where biomass health declined intensely in Rawalpindi. The city took a long time to recover and showed slight restoration of biomass by the year 2018 because of restoration and replantation efforts by Parks and Horticulture Authority (PHA).

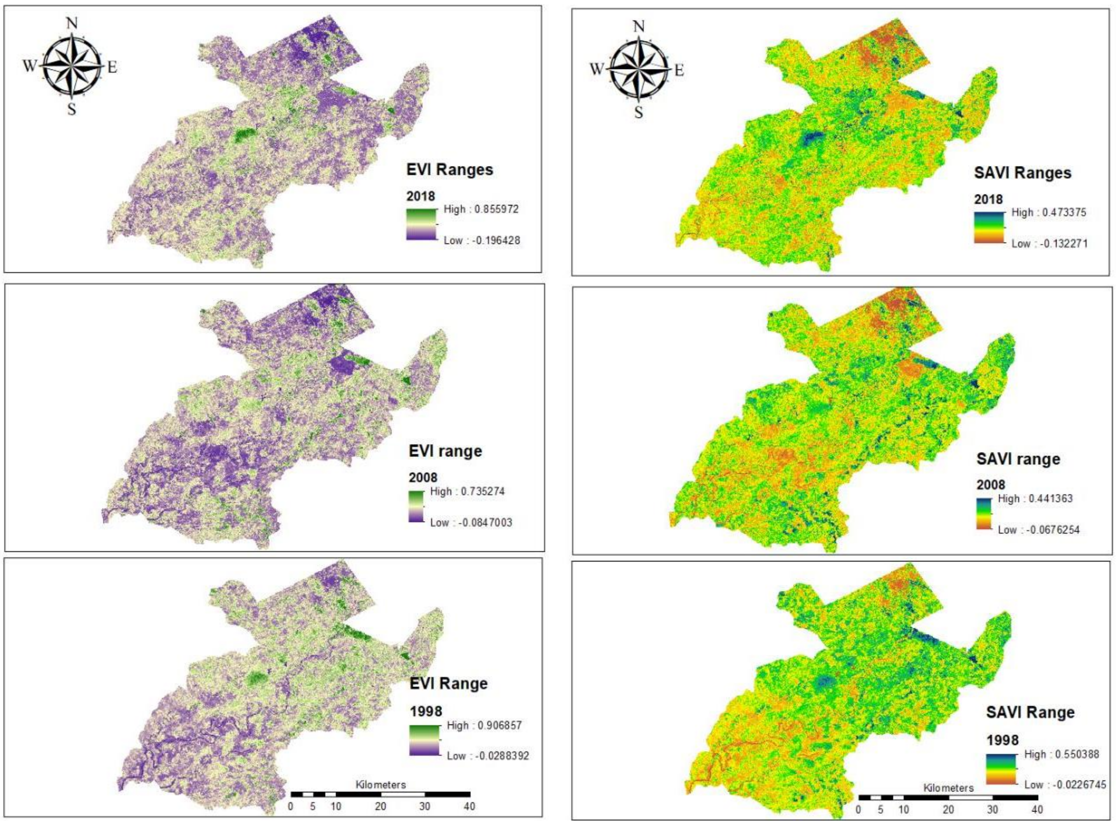

Fig. 3. Spatio-temporal variation in health of vegetative biomass of Rawalpindi as specified by EVI and SAVI.

Conclusion

Spatio-temporal vicissitudes in the distribution and overall health of Rawalpindi's green gold were strongly influenced by the city's built environment in a multitude of ways. The environmental conditions of all four zones of the city affected the green gold in different ways with rudimentary developments favoring dominance over diversity the most followed by planned developments and roadside vegetation.

This was due primarily to the haphazard and unplanned development in some areas while agricultural intensification activities in the others altered the soil parameters such that it put pressure on local flora. Furthermore, the built environment had a significantly negative connotation on the vegetation health over the years. These negative trends will continue to persist without governmental intervention. Therefore, the present research strongly recommends that city planners take steps to protect vegetation biomass, diversity, and distribution by incorporating vegetation in developmental plans not only for its aesthetic value but also for environmental significance. It further recommends that the construction activities in the city be based on green technology to minimize damage to soil and consequently the vegetation depending on it.

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