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GEO-ENVIRONMENTAL ANALYSIS OF URBAN AGRICULTURE: A CASE STUDY OF GUTTER BAGHEECHA SITE TOWN-KARACHI

LUBNA GHAZAL[1] • UZMA ASHIQ[2] • SALMAN ZUBAIR[1] • IMRAN AHMED KHAN*[1] • SAMREEN AKHTAR[2]

[1]Assistant Professor, Department of Geography University of Karachi, Pakistan.
[2] Department of Chemistry, University of Karachi, Pakistan.
*Corresponding Author: imranak32@uok.edu.pk

ABSTRACT

Karachi, the world's 6th largest city, is experiencing rapid urbanization, and facing environmental challenges. Traditional farmlands, vital for vegetable supply, face degradation due to urban sprawl. Proximity to urban centres exposes them to pollutants from domestic and industrial sources, demanding urgent attention. This study pursues two primary objectives. Firstly, it entails a multi-temporal analysis focused on monitoring and mapping spatial-periodic changes in land use spanning from 2001 to 2015. Secondly, it investigates the presence of heavy metals in vegetables grown in areas surrounded by industrial activities. High-resolution satellite images underwent digitization for land use analysis, involving image classification, area calculation, and IDW interpolation of heavy metal concentrations using ERDAS IMAGINE 9.3 and ARC GIS 10.6 software. Results revealed that over the last 10-15 years, substantial alterations in land use, specifically a decline in arable land, have been observed. Analysis of heavy metal concentrations in vegetables, compared to WHO and FAO standards, indicates elevated levels of zinc (Zn), copper (Cu), and iron (Fe) beyond safe limits in all samples. Additionally, lead (Pb) is present in select vegetables, signalling untreated industrial wastewater contamination. Evaluating urban agriculture dynamics is crucial for researchers, environmentalists, and urban planners to implement sustainable practices and minimize health risks for Karachi's inhabitants in this mega-city setting.

KEYWORDS: Urbanization, Agriculture, Industrial waste, Heavy metals, Digitization, IDW

1. INTRODUCTION

Land cover refers to the natural landscape (physical and biological cover) over the land surface, including water, vegetation, bare soil, etc. The land cover and land use setting of any region are the result of various socioeconomic and environmental factors which are determined by their utilization in different times and space (Sajjad and Iqbal (2012). Land use is defined by natural scientists as an outcome of primary and secondary human activities such as mining, forestry, fishing, farming, and construction of industrial, commercial, recreational and residential areas. These all affect and change the biogeochemistry, hydrology and biodiversity of that land. In suburbs, areas to meet the requirement for food growing vegetables and grain crops is an important economic practice of inhabitants. Likewise, a healthy environment and hygienic food are a matter of growing safety concern (Hassan and Mehmood, 2013). An integrated and interdisciplinary socio-economic and environmental approach is required for the systematic investigation to inquire into the causes and impacts of land use and land cover change which has nowadays appeared as the modern discipline of land-change science (Ellis, 2013). Unplanned urbanization for industrial, residential, commercial and recreational growth has resulted in the loss of significant agricultural land in various countries of the World (Kurucu, & Chiristina, 2008). Urban and peri-urban cultivation is a very traditional and important method to access fresh vegetables, grains and fruits at reasonable costs (De Zeeuw et al, 2011). World Watch Institute reported in 2011 that, globally around eight hundred million people are directly engaged in urban agriculture. UN task force strongly suggested that to control the predominant global food crises a customary shift in urban planning design is essential with the core aim of reducing the distance for transporting food within city boundaries. This could mainly be attained by encouraging local food production, especially in peri-urban (immediate surroundings). (UN-Habitat, 2010).

Contamination of Soil and water is a worldwide environmental issue (Khan et al., 2010). Due to natural and anthropogenic activities heavy metals can easily degrade soil and water which ultimately affects the production of food (Sandeep et.al, 2019). Pakistan is also enveloped in various environmental issues and located in scarce water and soil-contaminated stressed zones (Naeem and Ghazal, 2021). Masindi and Muedi, 2018 also studied that the presence of heavy metals is an unsafe constituents of the environment which penetrate soil and food crops and that's why monitoring of food production quality is necessary at the sources to ensure the safety of the environment and people. Increase in the anthropogenic activities has badly affected the environment. Cadmium and Lead are the most common contaminants of soil, water and food which can pose serious health risks to the human body (McIntyre, 2003). Several diseases such as cardiovascular, neurological and renal, are caused due to the consumption of food with excessive amounts of heavy metals. Various biochemical processes cause the entrance of these metals into the food chain and then are biomagnified at high levels and threaten human health. Metals may accumulate in the air, on tree leaves, and in groundwater ponds to toxic concentrations under the influence of certain environmental conditions and may cause ecological damage (Singh & Kalamdhad, 2011). Food crops grown in toxic substances including heavy metals consequently transported to the food chain (Mishras, 2019). Staple cereals and vegetables are important constituents of diet, thus contamination of heavy metals in food cannot be ignored for the sake of human life. Leafy vegetables collect higher contents of pollutants when grown on heavy metal-contaminated soils. The plants absorb heavy metals through their roots.

Heavy metals are subjected to bioaccumulation in food chains due to the environment. Compared to fruits and grains leafy vegetables easily store metals in their edible parts (Kumar, et al. 2019). Studies have shown the risks of increased soil metal concentration and plant uptake caused by anthropogenic factors such as the use of chemical and natural fertilizers (manures), sewage sludge and pesticides. Aerosols found in metal can also pollute commercial, agricultural and residential areas as they penetrate the soil and as a result, they either accumulate on the leaves or get absorbed by the vegetables (Tasrina et al., 2015). Higher risk levels of contamination were seen in the urban farmland vegetables as grown in areas either surrounded or close to the industry (Farooq, et.al, 2008). In an urban environment vehicular fumes, agrochemicals, wastewater irrigation, solid waste disposals, and sludge applications, are the chief sources of vegetable impurity. Fruits and vegetables take up heavy metals and store them in their edible and inedible parts, when these are consumed by animals and human beings cause problems (Khan, et.al, 2016). The daily intakes of contaminated vegetables were investigated in many countries and found harmful impacts on plants and humans. Only after several years of exposure, do these harmful effects become apparent. Food consumption can be the major cause of to deplete of essential nutrients in the body by decreasing immunological defences, such as impaired psycho-social facilities, body and brain growth retardation, and high frequency of upper gastrointestinal cancer rates among human beings (Srinivasan & Reddy, 2009).

There is a contrary relationship in the nutritional value of vegetables affected by heavy metal absorptions which directly influence portions of protein, carbohydrates and fats in the vegetable (Xu, et.al, 2005). In developed countries, frequent studies have been conducted. Conversely, few studies have been conducted in developing regions such as Bangladesh due to financial constraints. The work of (Jaishankar et al., 2014; Islam et.al, 2017; Ara et al., 2018; Proshad et al., 2019; Kormoker et al, 2020); is worth relating to the studies of heavy metal contamination in vegetables and its health risk impacts. In Pakistan, significant data on such topics is not easily available. Industrial and municipal wastewater is commonly used to grow vegetables in the farmlands of northern Lahore. Similarly, in Karachi, the historically famous gutter bagheecha is growing vegetables using sewage water which is being further contaminated by industrial waste and are sold in adjoining urban areas without any quality check. In the Jodhpur district of India, the impact of heavy metals contaminated vegetables irrigated with polluted untreated wastewater from the sewage was monitored and assessed. It was reported that the main cause of soil pollution that leads to the deposition of heavy metals in leafy vegetables was the untreated sewage water in the cultivated land of this area (Das, et.al, 1997) and (Charan, 2014). Point and non-point sources of pollution begin from the direct discharge of untreated solid waste and water from industries and households into nearby water bodies such as drains, rivers, ponds and streams. Moreover, the unchecked and heavy use of chemical fertilizers and pesticides on farmlands eventually percolates in soil and groundwater to cause contamination. Approximately 90 per cent of untreated industrial and municipal toxic waste dumped, penetrates the ground through open drains (Usman et al., 2012).

Controlling the exposure of heavy metals will result in severe complications for a safe environment. Timely monitoring of soil and water used for cultivation may reduce the probable intervention for additional exposure to heavy metals in the environment and humans. The use of remote sensing and GIS technology is considered ideal for the monitoring and assessment of land use changes and dynamics of natural resources such as substantial spatiotemporal variations of cultivated land and vegetation cover (Ghazal et. al, 2015). Satellite data has proven its usefulness, not only for monitoring the multi-temporal changes of Landuse but also for analyzing environmental degradation through mapping of spatial variation of heavy metal concentration in agricultural areas influenced by anthropogenic activities. This helps in highlighting hotspots of disaster (Shaikh et al, 2005). According to the study conducted by (Dewan, & Yamaguchi, 2009) which revealed that rapid urban expansion in developing countries has stemmed from a wide range of environmental concerns; such as the depletion of water bodies, farmland, wetlands and forest cover.

Studying urban agriculture in the context of Gutter Bagheecha Site Town, Karachi is crucial due to its unique challenges and opportunities. This site represents an interface between urbanization and agriculture, highlighting the impact of rapid development on farmlands. Understanding agricultural dynamics here is vital for sustainable urban planning, mitigating environmental risks, and ensuring food security amidst the evolving urban landscape.

2. MATERIAL AND METHODS

2.1. Study Area

Geographically Karachi lies between 24° 45’ north to 25° 37’ North and 66° 42’ east to 67° 34’ east. It is located eighty miles west of the Indus River. Its north and north eastern part is covered by Dadu district, Thatta lies in the east and Arabian Sea in the South and South West. Lasbela District

(Balochistan) is found in the north-west. The largest agriculture space Gutter Bagheecha is located within the core urban area along Manghopir Road S.I.T.E Town is also a famous Industrial and old residential area of Karachi. The geographical coordinates of the site town range from 24°.89’ 54” to 26°N latitude and 66°59’ 46” to 67°.01’ 13” °E longitude, with an average elevation of 45 feet. Originally spanning thousands of acres, the site was designated as a public amenity space, primarily comprising continuous green areas. However, rapid and unregulated urbanization, coupled with illegal encroachments orchestrated by the land mafia, has significantly diminished this once expansive green space to less than five hundred acres.

2.2. Methodology

This study assimilated both primary and secondary data to be processed to analyze the results. The authors conducted a field survey to collect vegetable samples and photographs. During the Survey formal and informal interviews of people were also executed through structured questionnaires. Samples were prepared first by using the digestion method and then sent to a laboratory for testing of heavy metals.

Values were interpolated in ArcGIS software to see the variation of different heavy metals in sample sites. Land use classification was also performed using Landsat images of 2001 and 2015 images respectively to observe the changes in the size of farmland and other land use in and around the study area. The sequence of steps adopted for methodology is shown in the flow chart below Figure 1.

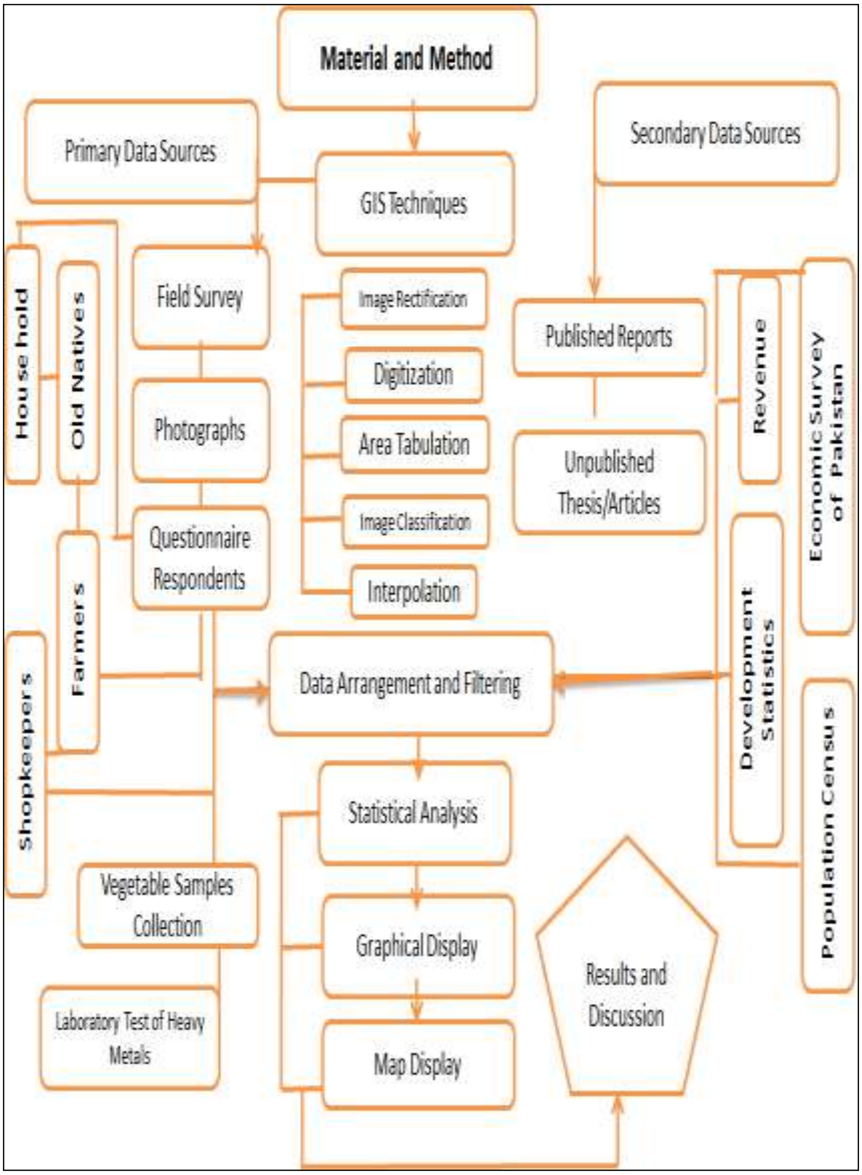

Figure 1. Summary of the adopted methodology

3. RESULT AND DISCUSSION

To cope with the emerging socio-economic and environmental challenges in urban areas use of modern technologies along with traditional research methods has proved to be helpful, and time-saving and ensures both qualitative and quantitative perspectives of any environmental issue. Results of a few of the used techniques are shown in maps and graphs for quick interpretation and understanding. See Figure 2-5.

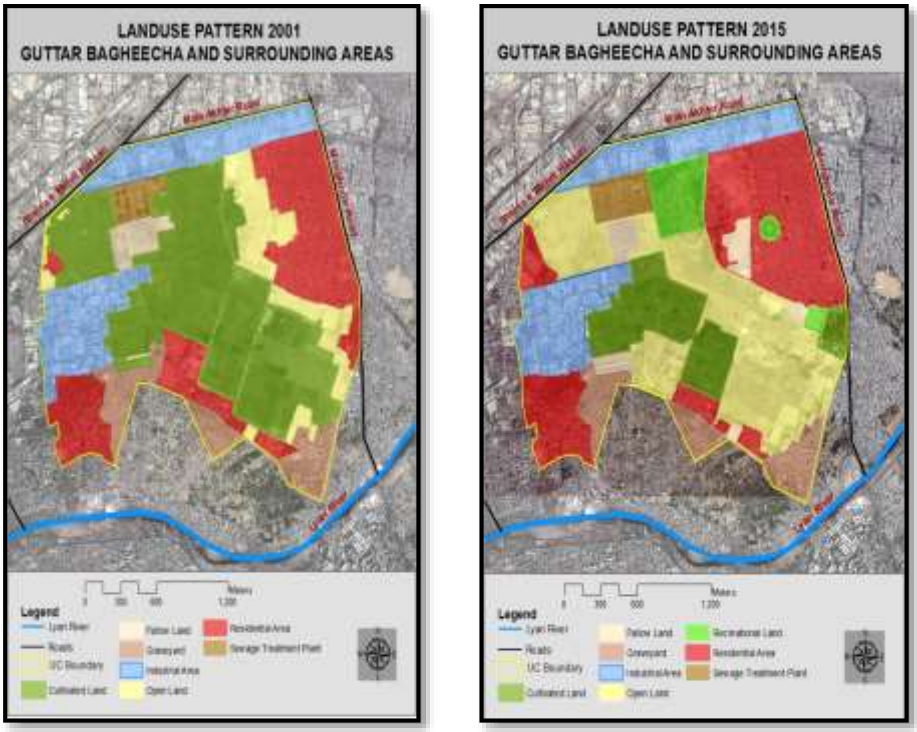

Figure 2: Spatio-temporal Variation of Landuse in the study area during 2001-2015

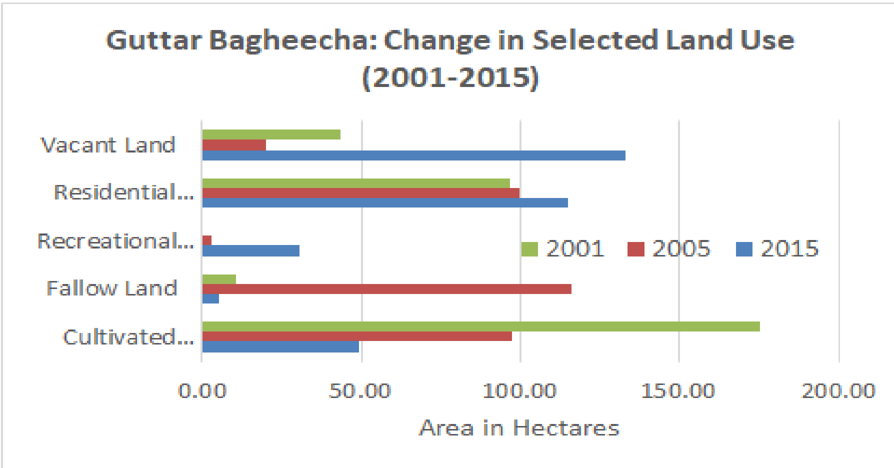

Figure 3: Variation of Landuse change during 2001-2015

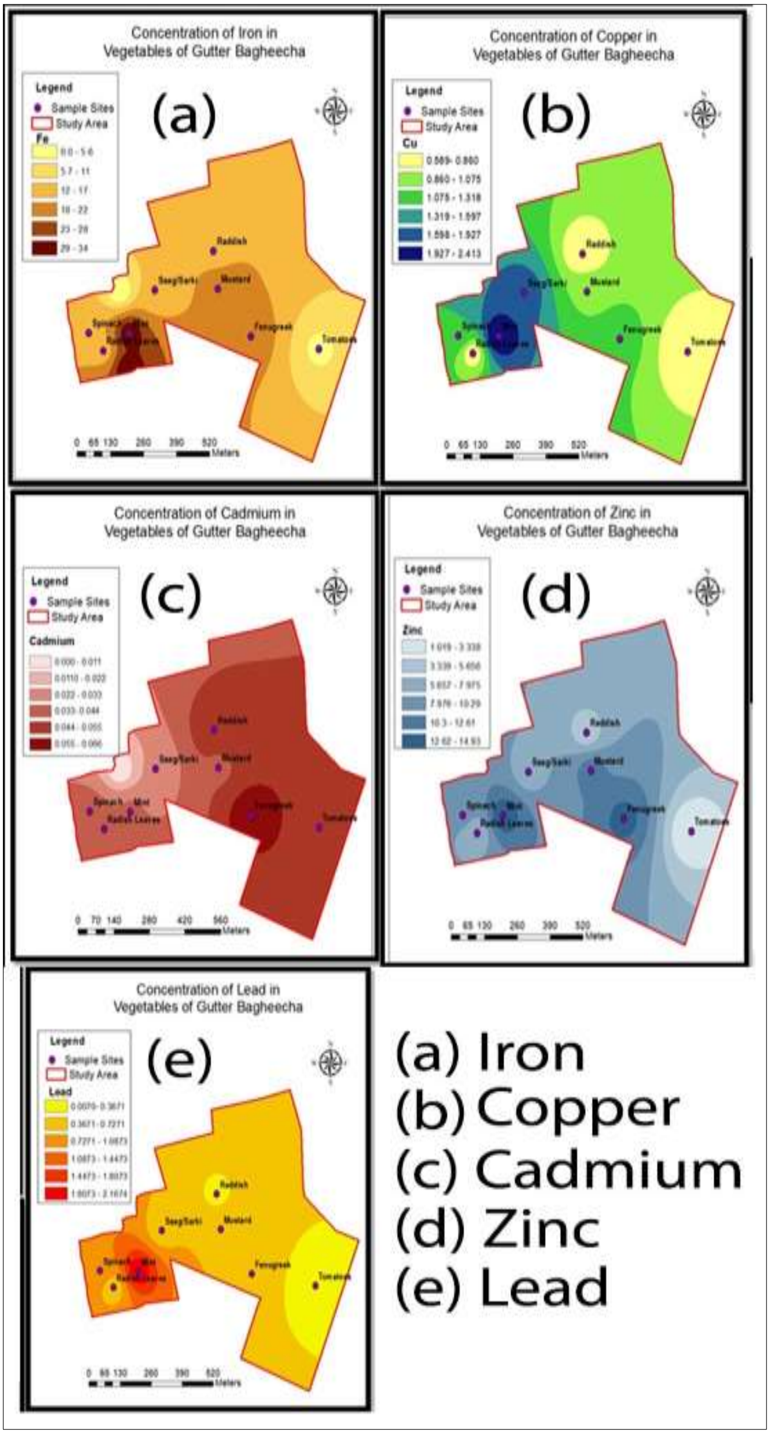

Figure 4: Spatial variation of heavy metal concentration in vegetable samples of the study area (a) Iron (b) Copper (c) Cadmium (d) Zinc (e) Lead

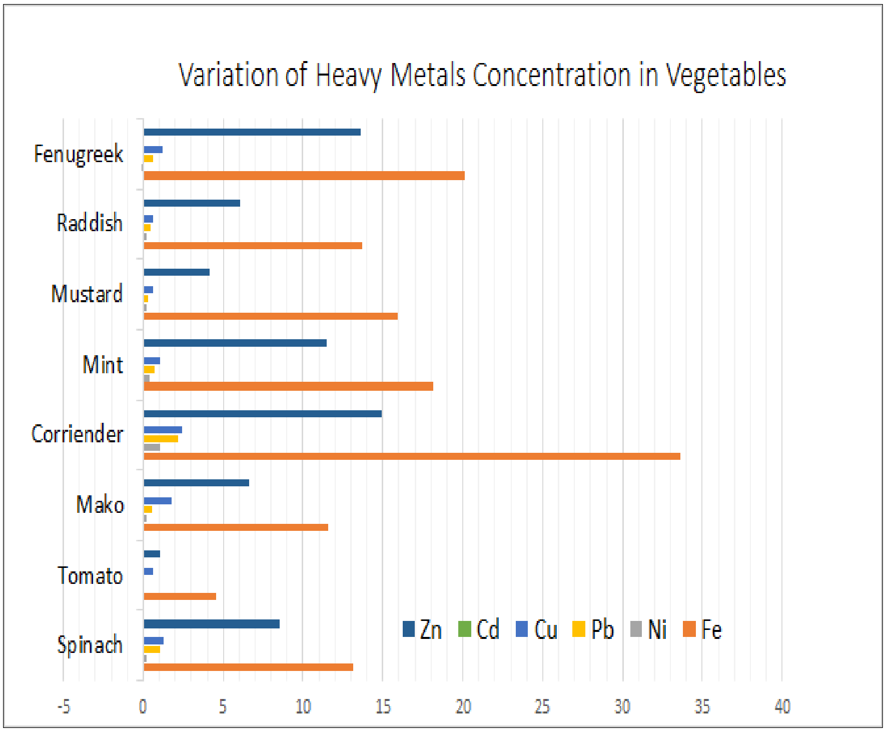

Figure 5: Concentration of lead, copper, Zinc, iron and nickel in vegetable samples *Standard values of vegetables according to WHO.

It is depicted from the graph Figure 5 that except for Tomatoes all compounds have an excess amount of iron with the value of (4.547 ppm) which falls in the range of the safe permissible limit Remaining compounds have higher concentrations. As per concentration highest amount of iron was found in mint which is 33.57 ppm. The study revealed that seven out of eight tested vegetables contain a lower amount of nickel than the permissible limit. Sample of Spinach, Tomato, Sarki, Mustard, Radish, Radish Leaves, and Fenugreek have varying amounts of nickel that is 0.185, 0.051, 0.188, 0.381, 0.184, 0.188 and 0.052 ppm respectively. Compound 4 (Mint) has the highest amount of nickel that was (1.032ppm). Excess of nickel may cause Stroke and bronchial problems, the body becomes more prone to infections and bone development becomes very poor.

The standard value reported for lead according to W.H.O and FAO is 0.1 ppm. As lead is very toxic, therefore, its concentration should be maintained properly in our body. The compounds were analyzed as per the reported method using an Atomic Absorption Spectrophotometer. Results are summarized in Figure 5. It was found that all selected vegetables have a higher amount of lead than 0.1 ppm except for compound 2 (Tomato) having an amount of 0.007 ppm which is in the range of standard value as per reported by W.H.O. Compound 3 (Sarki), 5 (Mustard), 6 (Radish), 7 (Radish Leaves) and 8 (Fenugreek) showed moderately high amount of lead which are 0.506, 0.683, 0.267, 0.458 and 0.64 ppm respectively. On the other hand compound 1 and 4 showed higher values of 1.046 and 2.169 ppm respectively. Hence high concentrations of lead in the body show very toxic effects on almost every organ. It is toxic because it can be absorbed by the body mainly in the blood.

By looking at the maps in Figure 4, this is concluded that high levels of copper were observed in the Mint and Sarki samples grown in the area. The higher levels of copper are distinguished due to the darker shades. Cadmium which is a toxic metal present in studied vegetables is found within the range of safe permissible limits. Table 1 shows the descriptive statistics of the minerals extracted data. Table 2 shows the concentration of different minerals in vegetation types. The Ca concentration shows that all vegetables have significant amounts except tomatoes. Fe, Ni, Pb, Cu, Cd and Zn are mainly found in Corriender and less in tomatoes. While a high quantity of Cd is seen in Mustard. Most Zn is seen in Fenugreek. Pb and Ni show a higher association among vegetables. While can have less association with vegetables.

Table 1: The values of Mineral and heavy metals in vegetables

Mineral/Statistical Description	Ca	Fe	Ni	Pb	Cu	Cd	Zn
Mean	84.111	16.335	0.270	0.722	1.195	0.039	8.305
Median	86.100	14.815	0.187	0.573	1.101	0.039	7.562
Std. Deviation	5.716	8.394	0.332	0.659	0.646	0.016	4.787
Minimum	70.240	4.547	-0.052	0.007	0.589	0.015	1.018
Maximum	87.870	33.570	1.032	2.169	2.415	0.066	14.940

Table 2: Total Concentration (mg/L) of Metals in vegetables

	Total Concentration (mg/L) of Metals in selected vegetables grown in GB							
S.No	Vegetables	Ca	Fe	Ni	Pb	Cu	Cd	Zn
1	Spinach	86.46	13.15	0.185	1.046	1.315	0.041	8.527
2	Tomato	70.24	4.547	0.051	0.007	0.595	0.015	1.018
3	Mako	84.65	11.56	0.188	0.506	1.798	0.023	6.596
4	Corriender	86.02	33.57	1.032	2.169	2.415	0.032	14.94
5	Mint	86.99	18.14	0.381	0.683	1.023	0.042	11.46
6	Mustard/ Sars	84.48	15.89	0.184	0.267	0.589	0.054	4.201
7	Raddish	87.87	13.74	0.188	0.458	0.647	0.037	6.056
8	Fenugreek	86.18	20.08	-0.052	0.64	1.178	0.066	13.64

Table 3: Correlations among extracted heavy metals values

Correlations								
		Ca	Fe	Ni	Pb	Cu	Cd	Zn
Ca	Pearson Correlation	1.000	0.564	0.268	0.451	0.327	0.581	0.645
	Sig. (2-tailed)		0.145	0.521	0.263	0.430	0.131	0.084
	N	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Fe	Pearson Correlation	0.564	1.000	**0.800**	**0.875**	0.689	0.353	0.857
	Sig. (2-tailed)	0.145		0.017	0.004	0.059	0.391	0.007
	N	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Ni	Pearson Correlation	0.268	**0.800**	1.000	**0.869**	**0.722**	-0.223	0.534
	Sig. (2-tailed)	0.521	0.017		0.005	0.043	0.596	0.173
	N	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Pb	Pearson Correlation	0.451	**0.875**	**0.869**	1.000	**0.849**	0.033	**0.777**
	Sig. (2-tailed)	0.263	0.004	0.005		0.008	0.937	0.023
	N	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Cu	Pearson Correlation	0.327	0.689	**0.722**	**0.849**	1.000	-0.170	0.672
	Sig. (2-tailed)	0.430	0.059	0.043	0.008		0.687	0.068
	N	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Cd	Pearson Correlation	0.581	0.353	-0.223	0.033	-0.170	1.000	0.464
	Sig. (2-tailed)	0.131	0.391	0.596	0.937	0.687		0.247
	N	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Zn	Pearson Correlation	0.645	**0.857**	0.534	**0.777**	0.672	0.464	1.000
	Sig. (2-tailed)	0.084	0.007	0.173	0.023	0.068	0.247	
	N	8.000	8.000	8.000	8.000	8.000	8.000	8.000
*. Correlation is significant at the 0.05 level (2-tailed).								
**. Correlation is significant at the 0.01 level (2-tailed).								

The findings significantly contribute to existing knowledge by unveiling the substantial changes in land use over the past 10-15 years in Karachi, particularly the decline in arable land. The elevated levels of zinc, copper, and iron, along with the presence of lead in some vegetables, emphasize the pressing issue of untreated industrial wastewater contamination. These insights are crucial for understanding the environmental impact of urbanization on agriculture and serve as a basis for implementing sustainable practices. However, it's important to acknowledge the limitations, such as the need for further studies to explore the broader implications of these findings and potential variations in different geographic areas within Karachi.

4. CONCLUSION

Urban agriculture practices have been under great pressure from anthropogenic activities due to unchecked urban growth. The application of Satellite images for the monitoring of land use dynamics is of utmost importance. Using ArcGIS software to display the results of heavy metal concentration in soil and water for crop production at the source has proved ideal for highlighting environmental degradation.

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