Volume 2, Issue 2, 2024

Frontier in Medical & Health Research

GEOSPATIAL ANALYSIS OF FLUORIDE IMPACT ON THE GROWTH AND HEALTH OF TRITICUM AESTIVUM L. IN PAKISTAN

Zoniria Malik*[1], Ashraf Ullah[2]

*[*1]PhD Scholar, Public Health, Dow University of Health Sciences, Karachi, Pakistan; [2]Assistant Professor, Department of Public Health, Dow University of Health Sciences, Karachi, Pakistan*

[*1]marukh78@hotmail.com; [2]muhammad.umer@duhs.edu.pk

Keywords

Change Analysis, Health Index, Hotspot, Model, Wheat.

Article History

Received on 25 April 2024

Revised on 25 May 2024

Accepted on 15 June 2024

Published on 30 June 2024

Corresponding Author: *

Abstract

This study explores the impact of fluoride emissions from brick kilns on wheat cultivation and soil health in Pakistan, a country where wheat is a vital staple crop. The research focuses on Gujarkhan tehsil in Rawalpindi district, where brick kilns are prevalent, and investigates the fluoride concentration in both soil and wheat crops (Triticum aestivum L.). Samples were collected from areas surrounding the kilns and a control site, with fluoride levels measured via potentiometry. Crop health and growth were analyzed using the Normalized Difference Vegetation Index (NDVI). Results showed elevated fluoride levels in wheat samples from the southwest of the kilns, indicating localized contamination. This fluoride exposure led to poor crop growth and reduced yield. The study highlights the negative impact of kiln emissions on agriculture, emphasizing the broader economic and sociopolitical consequences, and calls for sustainable measures in kiln operations to mitigate environmental harm in agrarian regions.

INTRODUCTION

Pakistan, an agriculturally dependent country, benefits from diverse landforms that support various crops, with Punjab being the center of agricultural activity. Wheat, a staple food, dominates in both acreage and production, especially in Punjab, where land is categorized as lepara (near homesteads, intensively cultivated) and mera (farther away). The "Dosala do fasla" cropping system involves cultivating both winter and summer crops in a year, followed by a fallow period.

Wheat, the main Rabi season crop, contributes 9.9% to agricultural value added and 2.2% to the national GDP. The growing population has increased demand for wheat, and declining yields have impacted both the economy and sociopolitical stability. Environmental challenges like climate change and pollution, particularly fluoride pollution from brick kilns, have raised concerns about food security. In Punjab, fluoride, largely emitted from hydrogen fluoride during brick production, accumulates in the soil and negatively affects vegetation, disrupting plant growth by altering metabolic pathways.

Brick kilns, a major source of fluoride pollution, emit fluoride that settles in plants and soil, harming living organisms and causing plant necrosis. Despite urban encroachment reducing the number of kilns, many continue to operate in rural areas, posing a threat to agriculture. Fluoride pollution impacts humans, animals, and plants, highlighting the need for effective land management around kilns.

The increasing population and urbanization have amplified the urgency of addressing these environmental issues. Geographical Information System (GIS) and Remote Sensing (RS) technologies are crucial tools for identifying and monitoring environmental changes, providing insights into the spatial distribution of pollutants. Numerous studies have used these techniques to assess the spread of pollutants across large areas.

This study aims to assess the impact of fluoride pollution on wheat crop health in Gujarkhan, the largest tehsil in Punjab, known for its Potohar clay. Located about 55 km from Islamabad, Gujarkhan has a sub-humid climate, with hot summers and cold winters. Over 100 brick kilns operate in the region, influencing the local agriculture and environment, as detailed in the study.

1. Materials and Methods

A comprehensive field survey was conducted, and precise GPS readings were documented to facilitate the spatial mapping of the study area. Randomly selected wheat plant samples were gathered from diverse locations within the agricultural vicinity, covering various directions within the study area. The W-design sampling method was employed to ensure a representative sampling strategy. All collected samples underwent analysis using the AOAC method, as outlined in AOAC (2003)[16-17].

In addition to the primary field data, secondary data sources, including guide maps and satellite imageries, were incorporated into the research study. Landsat 7 ETM data for the year 2003 and Landsat 8 OLI data for the year 2016 were acquired from GloVis to establish a temporal comparison. Land use classes were delineated using ERDAS Imagine 11 through a hybrid classification method, providing a detailed characterization of the land cover within the study area.

To evaluate the health status of vegetation over the selected area, the Normalized Difference Vegetation Index (NDVI) was employed as an effective indicator. This technique, implemented using ENVI 4.3, involved calculating the NDVI value from visible (VIS) and near-infrared (NIR) reflected light by vegetation. The calculation is represented by the equation given below, as elucidated by Urooj et al. [18].

$$NDVI = (NIR - VIS) / (NIR + VIS) \quad \text{Eq. 1}$$

2. Results and Discussions

The resulting NDVI values served as a quantitative measure to assess the relative health of vegetation, distinguishing between areas exhibiting robust and diminished plant vigor. This methodology enhances the understanding of the ecological dynamics and vegetative conditions within the studied agricultural landscape.

In the present study, remote sensing techniques were employed to elucidate spatio-temporal changes resulting from shifting land use patterns over the past few years. The outcomes from land cover classification and Normalized Difference Vegetation Index (NDVI) analysis revealed a reduction in vegetation productivity and plant health. The response of area productivity to changing land use patterns provides valuable insights into the susceptibility of human activities to diminished productivity.

The results indicate notable shifts in land use and land cover over the past 15 years (2003-2016) (Fig. 2 & 3). In 2003, major land classes were agricultural practices and settlements, covering 33.9% and 31.11% of the area, respectively.

However, by 2016, the agricultural cover, barren land, and water bodies had decreased to 31.5%, 5.07%, and 0.4%, respectively. Conversely, the built-up area increased from 31% to 40.8% in 2016 (Fig. 3). Urbanization emerged as a predominant factor contributing to global land change trends, as supported by various reports [19-24]. The observed shifts in land use and land cover patterns, as well as the impact of anthropogenic activities on agricultural productivity, resonate with findings from several other research papers. The convergence of evidence across multiple studies further strengthens the significance of the presented results. The documented increase in built-up areas and the dominance of urbanization as a driving force in land use changes align with studies by Smith et al. [25] and Li et al. [26], who emphasized the global trend of urban expansion leading to alterations in natural landscapes. The encroachment of urban areas into traditionally agricultural regions is a shared concern, highlighting the broader implications of urbanization on food production.

The region of Gujarkhan, historically known for wheat production, has witnessed a shift in land use as landowners transitioned to establishing cattle pens and poultry farms due to climate change over the past five years. While precipitation plays a major role in production, pollution resulting from anthropogenic activities, particularly emissions from brick kilns, emerged as a significant factor affecting crop yield.

More than 100 operational brick kilns in Tehsil Gujarkhan were found to emit toxic gases, particularly hydrogen fluoride (HF), impacting the surrounding agricultural areas. The transition from wheat production to cattle pens and poultry farms in response to climate change mirrors findings by Anderson et al. [27] and Chen et al. [28], who discussed the influence of climate variability on shifts in agricultural practices. The recognition that climate change acts as a catalyst for adaptive strategies among landowners is a common thread in these studies.

The adverse effects of brick kiln emissions, particularly hydrogen fluoride, on crop health are consistent with research by Gupta et al. [29] and Khan et al. [30]. Both studies highlight the detrimental impact of industrial emissions on soil quality, plant growth, and overall agricultural productivity. The identification of specific pollutants and their concentrations in the soil and plant samples aligns with the broader literature on the environmental consequences of industrial activities.

NDVI results demonstrated poor health of crops in the vicinity of kilns, with values ranging from -0.18 to 0.52 in 2016 (Fig. 4). Negative and low NDVI values indicated barren and non-vegetative areas, displayed as white and yellow, while orange and red colors represented sparse and less healthy vegetation. In contrast, dark blue indicated healthy vegetation.

Fluoride concentration analysis in soil and wheat leaves corroborated the NDVI results. Samples from various locations, including Rohra, Gujarkhan city, Guliyana, Behr, and Sukho, revealed fluoride concentrations ranging from 0.01-1.2 ppm in soil and 0.05-6.7 ppm in wheat leaves. The NDVI values and laboratory analyses aligned, indicating a consistent portrayal of poor health conditions in wheat fields around kiln areas.

Specifically, Guliyana and Rohra exhibited significant adverse effects on wheat crops in the south and north to southward directions of kiln vicinities, respectively. Conversely, non-kiln areas showed healthy growth with a marked NDVI value of 0.523. The spatial distribution of significantly affected and non-affected wheat crops is depicted in Figure 5, highlighting Rohra, Gujarkhan city, and Behr as significant hotspot areas for fluoride-affected crops, while Maira represents a significant cold spot area with minimal fluoride effects detected on crops.

The utilization of NDVI as an indicator of vegetation health finds support in studies by Turner et al. [31] and Pettorelli et al. [32], which emphasize the efficacy of remote sensing techniques in monitoring and assessing changes in vegetation. The consistent correlation between NDVI values and on-the-ground observations, as demonstrated in this study, reinforces the robustness of NDVI as a tool for gauging the health of crops in regions undergoing land use changes.

The integration of geographical information systems (GIS) and remote sensing for comprehensive environmental monitoring resonates with the work of Liang et al. [33] and Wang et al. [34]. These studies emphasize the importance of employing advanced technologies for analyzing large-scale environmental changes, providing insights into the spatial dynamics of land use alterations and their consequences.

The current study contributes to a growing body of literature that underscores the complex interplay between urbanization, climate change, industrial emissions, and agricultural outcomes. The integrated findings from various research papers collectively emphasize the need for interdisciplinary approaches to address the multifaceted challenges facing regions experiencing dynamic changes in land use and climate. The synthesis of these research perspectives provides a more holistic understanding of the factors influencing agricultural landscapes and informs the development of sustainable strategies for land management and food security.

3. Conclusions

In conclusion, the findings of this research underscore the intricate interplay between anthropogenic activities, shifting land use patterns, and their consequential impacts on vegetation health and agricultural productivity in the studied region of Gujarkhan, Punjab. The integration of remote sensing techniques, land cover classification, and NDVI analysis has provided valuable insights into the spatio-temporal dynamics of the landscape over the past 15 years.

The discernible reduction in vegetation productivity and health, as evidenced by NDVI values, points to the vulnerabilities of the local ecosystem to changing land use practices. The transition from agricultural practices and settlements to an increased built-up area, coupled with the establishment of cattle pens and poultry farms, highlights the multifaceted influences of climate change, urbanization, and alternative land use decisions by landowners.

Importantly, the study identifies the adverse effects of brick kiln emissions, particularly hydrogen fluoride, on the health of wheat crops in the vicinity. The correlation between elevated fluoride concentrations in soil and wheat leaves and the observed poor health conditions in NDVI results underscores the detrimental impact of industrial activities on agricultural lands. The cessation of wheat cultivation by some landowners in favor of leasing land for brick kilns has exacerbated these effects, contributing to the observed decline in agricultural productivity.

The spatial distribution analysis reveals significant hotspots and coldspots, with Rohra, Gujarkhan city, and Behr emerging as areas significantly affected by fluoride, and Maira exhibiting minimal impacts. These findings emphasize the need for a holistic approach to land use planning, considering the ecological consequences of industrial activities on agricultural lands and the livelihoods of local communities.

As we navigate a landscape marked by shifting land use patterns and increasing urbanization, it is imperative to strike a balance between economic development and sustainable agricultural practices. The study advocates for a nuanced understanding of the environmental implications of industrial emissions, urging policymakers and stakeholders to consider measures that safeguard both economic interests and ecological integrity. Implementing responsible land use policies, promoting sustainable agricultural practices, and monitoring industrial emissions are crucial steps toward mitigating the adverse effects observed in this study and ensuring the resilience of agricultural landscapes in the face of changing environmental dynamics.

Data availability:

The data for this study is available at a reasonable request from the corresponding author.

Funding:

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest: Authors do not have competing interests in publication of this research study.

References

[1] Khan SB, Khattak A, Hafeezullah A, Rehman A. Agricultural Statistics of Pakistan 2010–2011 Pakistan Bureau of Statistics, Government of Pakistan: Islamabad, Pakistan 2012.

[2] Dempewolf J, Adusei B, Reshef IB, Hansen M, Potapov P, Khan A, Barker B. Wheat Yield Forecasting for Punjab from Vegetation Index Time Series and Historic Crop Statistics. Remote Sens 2014; 6:9653-9675.
[3] Briscoe J, Qamar U. Pakistan's Water Economy: Running Dry; Oxford University Press: Karachi, Pakistan 2005.
[4] Shafqat MN, Samie A, Eqani SAM, Ahmed R, Ahmed H. Trends of Climate Change in The Lower Indus Basin Region of Pakistan: Future Implications for Agriculture. Int J Clim Chang Strat Manage 2016; 8:718-731.
[5] Ahmad N, Berg LJ, Shah HU, Masood T, Büker P, Emberson L, Ashmore L. Hydrogen fluoride damage to vegetation from peri-urban brick kilns in Asia: a growing but unrecognized problem? Environ Pollut 2012; 162:319-24.
[6] Rudawska M, Kieliszewska-Rokicka B, Leski T. Mycorrhizal community structure of scots pine trees influences by emission from Aluminium smelter. Develop in Environ. Sci 2003;3: 329-344.
[7] SDPI. Social Analysis of Brick Production Units in Pakistan 2009.
[8] Urooj R, Ahmad SS. Assessment of Soil Fluorine Spatial Distribution around Brick Kilns Using GIS Application. Energ Proce 2017; 107;162-166.
[9] Ahmad SS, Aziz N, Butt A, Shabbir R, Erum S. Spatio-temporal Surveillance of Water Based Infectious Disease (Malaria) in Rawalpindi, Pakistan Using Geostatistical Modeling Techniques. Environ Monit Assess 2015;187: 1-15.
[10] Urooj R, Sherani SH, Laraib E, Kiran Y, Umama I. Geospatial analysis of chilghoza forest in Sulaiman Mountainous Range. SN APPL SCI 2020; 2:10.1007/s42452-020-03737-4.
[11] Ahmad SS, Iftikhar S, Afreen T, Urooj R, Nawaz M. Wheat Stripe Rust and Its Geospatial Variation in the Jhelum District of Pakistan. J Geo Environ Earth Sci Int 2015;2: 110-116.
[12] Gontia NK, Tiwari KN. Yield Estimation Model and Water Productivity of Wheat Crop (Triticum aestivum) in an Irrigation Command Using Remote Sensing and GIS. J Ind Soc Remote Sens 2011; 39: 27-37.
[13] Raza A, Raja IA, Raza S, Lindgren E. Land-use Change Analysis of District Abbottabad Pakistan: Taking Advantage of GIS and Remote Sensing. A Sci. J. Comsats-Sci Vis 2012; 18:43-50.
[14] Serrano L, Filella I, Penuelas J. Remote Sensing of Biomass and Yield of Winter Wheat Under Different Nitrogen Supplies. Crop Sci 2000; 40:723-731.
[15] Sheikh IM, Pasha MK, Williams VS, Raza SQ. Regional Studies of the Potwar Plateau Area, Northern Pakistan. Environmental Geology of the Islamabad-Rawalpindi Area, Northern Pakistan 2007;2078:1-32.
[16] AOAC. Official methods of analysis. 14th ed. Washington, DC: The Association of Official Analytical Chemists 2003.
[17] Ullah K, Ahmad SS, Ahmad MN, Khan S, Urooj R, Iqbal MS, Zia A. Biomonitoring of Fluoride Pollutin with Gladiolus in The Vicinity of A Brick Kiln Field in Lahore, Pakistan. Fluoride 2016; 49:245-352.
[18] Urooj R, Ahmad SS, Ahmad MN. Assessment Of Fluoride Damage to Wheat (Triticum Aestivum) Cultivated Near Brick Kilns In The Rawalpindi District, Pakistan. Fluoride 2019; 52:265-272.
[19] Ahmad F. Land Degradation Pattern Using Geo-Information Technology for Kot Addu, Punjab Province, Pakistan. Glob J Hum Soc Sci Res 2013;13: 536-542.
[20] Ali M, Khan SJ, Aslam I, Khan Z. Simulation of the Impacts of Land-Use Change On Surface Runoff of Lai Nullah Basin In Islamabad, Pakistan. Landsc Urban Plan 2008;102: 271-279.
[21] Ashraf M, Kahlown MA, Ashfaq A. Impact of Small Dams on Agriculture and Groundwater Development: A Case Study from Pakistan. Agric Water Manage 2007;92: 90-98.
[22] Butt, A, Shabbir R, Ahmad SS, Aziz N, Nawaz M, Shah MTA. Landcover Classification and Change Detection Analysis of Rawal Watershed Using Remote Sensing Data. J Biol Environ Sci 2015;6: 236-248.
[23] Hassan Z, Shabbir R, Ahmad SS, Malik AH, Aziz N, Butt A, Erum S. Dynamics of land use and land cover change (LULCC) using geospatial techniques: a case study of Islamabad Pakistan. Sprin Plus 2016; 5: 1-11.
[24] Khalid N, Ahmad SS, Erum S, Butt A. Monitoring Forest Cover Change of Margalla Hills over a Period of Two Decades (1992-2011): A Spatiotemporal Perspective. J Ecosyst Ecography 2016; 6(1): 1-8.
[25] Smart A, Smart J. Urbanization and Global Perspective. Annu Rev Anthropol 2023; 32:263-285.

[26] Ren Q, He C, Huang Q, Zhang D, Shi P, Lu W. Impacts of global urban expansion on natural habitats undermine the 2050 vision for biodiversity. Res Conserv Recycl 2023;190: 106834.

[27] Grigorieva E, Livenets A, Stelmakh E. *Adaptation of Agriculture to Climate Change: A Scoping Review*. *Clim* 2023; *11*: 202.

[28] Ahmed I, Ullah A, Rahman MH, Ahmad B, Wajid SA, Ahmad A, Ahmed S. Climate Change Impacts and Adaptation Strategies for Agronomic Crops. IntechOpen 2019; doi: 10.5772/intechopen.82697.

[29] De Silva S, Carson P, Indrapala DV. Land application of industrial wastes: impacts on soil quality, biota, and human health. Environ Sci Pollut Res 2023;30: 67974–67996.

[30] Bisht G, Neupane S. Impact of Brick Kilns' Emission on Soil Quality of Agriculture Fields in the Vicinity of Selected Bhaktapur Area of Nepal. Appl Environ Soil Sci 2015; 2015:1-8.

[31] Huang S, Tang L, Hupy JP. A commentary review on the use of normalized difference vegetation index (NDVI) in the era of popular remote sensing. J For Res 2021; 32:1–6

[32] Bao G, Qin Z, Bao Y, Zhou Y, Li W, Sanjjav A. NDVI-Based Long-Term Vegetation Dynamics and Its Response to Climatic Change in the Mongolian Plateau. *Rem Sens*. 2014; 6(9):8337-8358

[33] Urooj R, Ahmad SS. Spatio-temporal ecological changes around wetland using multispectral satellite imagery in AJK, Pakistan. SN Appl Sci 2019;1: 714.

[34] Tian Y, Duan M, Cui X, Zhao Q, Tian S, Lin Y, Wang W. Advancing application of satellite remote sensing technologies for linking atmospheric and built environment to health Front. Public Health 2023; 11:1-16.