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RESEARCH ARTICLE

NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI) BASED LAND USE LAND COVER CHANGE DETECTION IN PARTS OF NAINITAL DISTRICT, KUMAUN LESSER HIMALAYA, INDIA

Bahadur Singh Kotlia and Kalpana Gururani
Centre for Advanced Study in Geology, Kumaun University, Nainital, 263001, India.

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Abstract

This study examines the transformation of surface topography in Nainital district (part of Kumaun Himalaya of Uttarakhand), India, from 1972 to 2022, shedding light on the profound changes that have occurred over this half-century period. In 1972, the land area was primarily dominated by forested areas, agriculture and water bodies, constituting 71.35%, 24.79%, and 1.19% of the total land cover, respectively. However, by 2022, these percentages have dramatically shifted to 60.73%, 6.91% and 0.46%, indicating a significant reduction in forested areas, agriculture and water bodies. In stark contrast, barren lands, settlements and grasslands, which occupied a merely 0.78%, 0.91%, and 0.98% of the land in 1972, have expanded considerably to 2.42%, 1.79% and 28.13% by 2022. These substantial changes are graphically represented, further reinforcing the alarming trend of diminishing forests, dwindling agriculture and reduced water resources, juxtaposed with the ominous rise of barren lands, settlements and extensive grasslands. Notably, the NDVI (Normalized Difference Vegetation Index) analysis unveils a clear downward trajectory in forested areas, agriculture and water bodies, accompanied by a conspicuous increase in barren lands, settlements and grasslands. This trend implies that human encroachment and deforestation have driven the intensification of light vegetation (grasslands) at the expense of dense vegetation (forests), exacerbating environmental concerns within the state. The results of this study highlight the significance of these critical land use changes to mitigate their potentially adverse consequences.

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Introduction:-

The primary characteristic of the surface topography which determines its biotic composition and physical state is land cover, whereas land use is the change of land cover in response to man needs (Shelar et al., 2022). Likewise, detecting these changes in Land use land cover (LULC) over a time period is referred to as change detection (Anderson, 1977). Due to their extensive reliance on agricultural output and rising populations, almost whole world is experiencing rapid changes in the LULC. For efficient planning and production management, there is a demand for accessibility to enhanced and up to date LULC databases (Wardlow et al., 2007) and to assist the governments and their policy makers (Liang et al., 2018: Chandra et al., 2023). Due to its wide range of applications for hydrological modeling, use of the LULC data is highly regarded for water resources management (Schilling et al.,

Corresponding Author:- Bahadur Singh Kotlia
Address:- Centre for Advanced Study in Geology, Kumaun University, Nainital, 263001, India.

2008). Since the water accounting is crucial component of hydrological modeling for its effective evaluation, one requires accurate LULC mapping (Bastiaanssen et al., 2000). Traditionally, there is little information available about the spatial distribution of utilization of these data resulting in implausible LULC scenario which results in clumsy judgments about how to manage the overall amount of water resources in various regions. Generally, modification of land use not only alter spatial extent/aspects of a variety of LULC classes but also give rise to a chain of episodes which may ultimately result in the collapse of multiple ecosystems. But the LULC data can capture geographic distribution at higher resolution and there is a growing need for it which cannot meet by extensive ground surveys. There are two main aspects, e.g., (1) the LULC spatiotemporal changes take place very quickly, especially in irrigated areas outside the purview of ground surveys, and (2) cost of the ground surveys is also rather high. This situation necessitates creation of contemporary approaches for collecting and estimating different LULC data from wider areas in a timely manner (Osborne et al., 2011). Alteration to the earth's surface is caused by human activity on the land throughout time (Gibson and Power, 2000). Every small piece of available landmass must be utilized in most sensible manner in order to boost the local economy without further harming the bio-environment and the data on the area's past and present land use and cover are necessary (Chaurasia et al., 1996). The build-up area increased dramatically while the forest cover and water bodies in the Nainital district decreased noticeably in two decades from 2000 to 2020 (Pokhariya et al., 2023). Based to a prediction made by the Google Earth Engine and IDRISI, ratio of change in urban area from 2000 to 2030 was 187.13%. This may be due to the removal of forest, notably in the south and west of Nainital region, which made it feasible for industrialization, settlement and an increase in population. In addition, to forecast changes in 2030 using LU/LC, classifications of forest and barren revealed relatively modest alteration (Mishra et al., 2021; Pokhariya et al., 2023; Singh et al., 2023). Dwivedi et al. (2020) described that the new construction, viz., structures/buildings on vegetation and agricultural land has caused the built-up zone to grow over the past three decades from 1990 to 2018, while in Haldwani township, the area covered by greenery, farmland, water and sand bars has decreased. Many studies on land use land cover mapping based on remote sensing and GIS have been carried out in Nainital area (Dwivedi et al., 2020; Dey et al., 2021; Pokhariya et al., 2021, 2023; Sharma et al., 2022; Upadhyay et al., 2022; Rane and Vincent 2023; Saini and Rawat, 2023; Jain et al., 2023).

The current study emphasizes the use of multi-temporal satellite imageries to define the LULC dynamics in Nainital district, Kumaun Lesser Himalaya. In present exercise, we have calculated normalized difference vegetation index (NDVI) classification method to make land use land cover maps of the study region in order to reveal the LULC dynamics to prove that the study area can be sustained in a scientific manner.

Material and Methods:-

Study Area:

The area is situated between 29°27'30"-29°10'30"N and 79°50'0"-79°28'30"E (Figure 1). The terrain is very rough in terms of geography and includes things like large ravines, elevated and low terrain escarpments, passes, nalas, and rivers. The study area covers land features like, agriculture land, barren land, water bodies, forest cover and grass land. The weather in this region of Kumaon is comfortable and fine; in the heat of the year, it doesn't get above 22°C, and in the colder months, it drops to 5°C. The study area's low-lying valley areas are more pleasurable in the colder months. Majority of lakes in the region are tectonically formed due to upliftment along the subsidiary thrusts of the major inter-crustal thrusts/faults (Kotlia, 1985, 1992; Kotlia et al., 1997, 1998, 2018; Kotlia and Rawat, 2004; Kotlia and Joshi, 2013; Valdiya et al., 1996; Kothyari et al., 2020; Kumar et al., 2020, 2021; Bisht et al., 2021). The weather of the study area is halfway between subtropical/sub humid, as elevation ranging from 474 to 2,581 m and slopes from 0 to 79.07 degree. It is situated within the Main Boundary Thrust (MBT) in the direction of south and the Ramgarh Thrust (RT) to the north and covers an area of approximately 556.23 km^2.

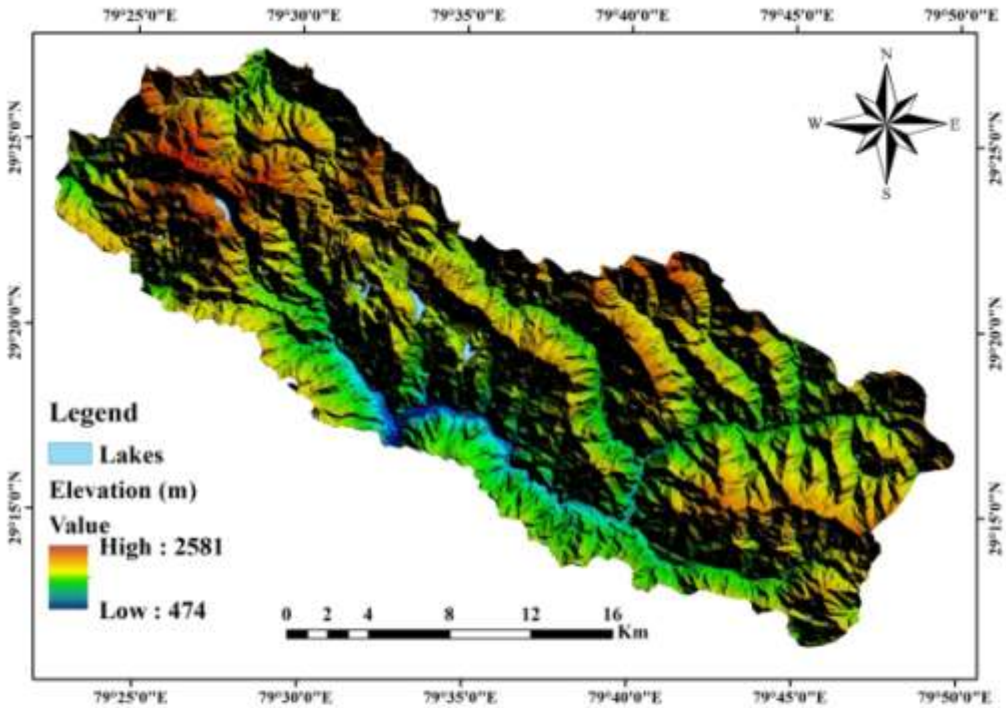

Figure 1:- DEM of the study area.

Image processing and steps of analysis:

Landsat cloud free images (60m resolution) of the Landsat 1 MSS were acquired from June1972 and Sentinel image (sentinel 2B MSI) was obtained from June 2022 when exposed dirt and greenery are at their densest and living spaces can be distinguished most easily (e.g., Coppin and Bauer, 1996). The data were processed using image analysis and GIS software. The satellite images were collected free from USGS and image analysis done by using GIS. The calculation of the top of atmosphere (TOA), layer stacking, extraction of areas of interest, computation of the band indices for producing the spectral differences between the ground features, and cloud masking for the Landsat imageries were included during the pre-processing (Figure 2). The data

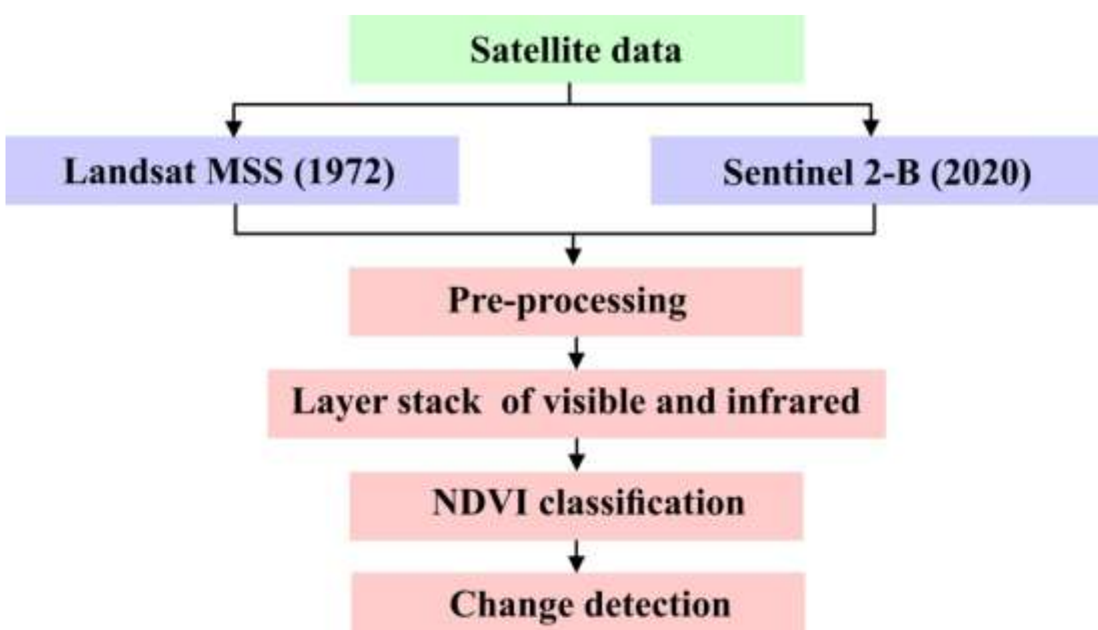

Figure 2:- Flow chart of methodology.

Re-sampling method was carried out to ensure comparability between the Landsat MSS data from 1972 (with a spatial resolution of 60m) and the Sentinel-2 data from 2022. Re-sampling is method for changing the spatial scale of data to a common resolution, in this study, 10m, so that they can be properly compared. We were able to match spatial scale of Sentinel-2 by re-sampling Landsat MSS data, allowing for a meaningful comparison of LULC status between two time periods. DEM (Alos Pal SAR) and toposheet served as additional data for layer development to analyze medium resolution photos (Survey of India toposheet at 1:50000). The Normalized Difference Vegetation Index **(NDVI) based threshold technique** was followed to extract LULC status. It varies from -1 to 0 for water bodies, -0.1 to 0.1 for barren rocks/snow/sand, 0.2 to 0.5 for grasslands or crops, and 0.6 to 1.0 for compact vegetation or rainforest. The NDVI was computed (Lillesand et al., 2015) using equation-1 as below;

NDVI= NIR – Red / NIR + Red………………………………………………… Eq-1

Where, NIR = Near Infrared band, Red = Red band

The NDVI data layer was generated from Landsat and sentinel images in Image Analysis environment. The NDVI images of the 1972 values were compared with 2022 values to obtain the areas where the land cover has changed. The image's area of interest was extracted using sub-setting. The categories of extracted land use/land cover include barren area, settlement, agriculture, water, forest and grassland.

Results and Discussion:-

Figure 3 illustrates the land use land cover distribution in 1972 (Figure 3a) and 2022 (Figure 3b).

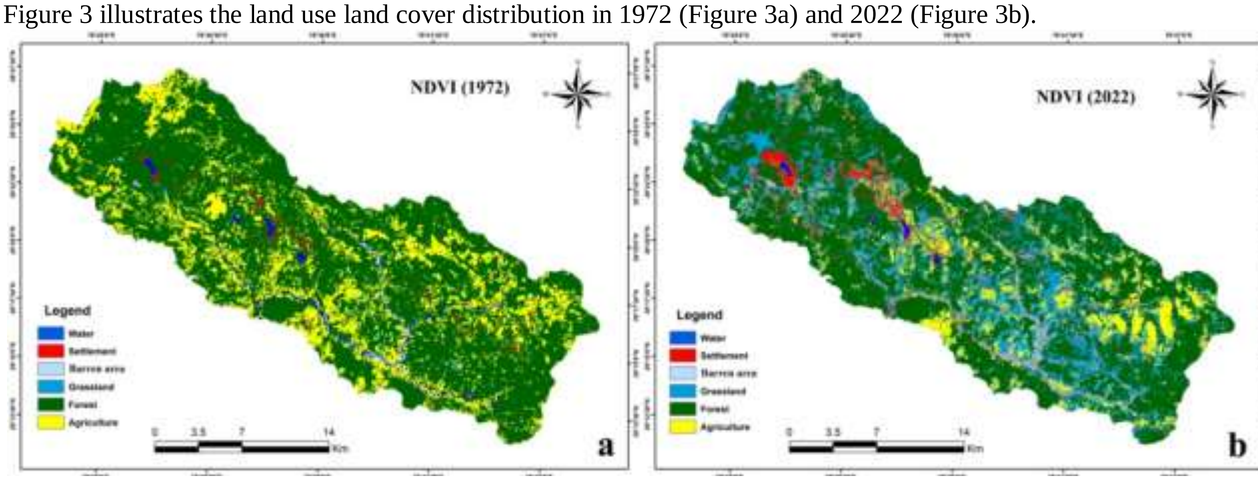

Figure 3:- Land use land cover distribution in 1972 (a) and (b) in 2022.

Likewise, Figure 4 demonstrates how much the area of the study has been transformed from 1972 to 2022. The barren area, settlement and grassland which occupied as 0.78%, 0.91% and 0.98% in 1972 (Figure 4a) have been grown to 2.42%, 1.79% and 28.13% in 2022 (Figure 4b). On the contrary, the forest, agriculture and water which were 71.35%, 24.79% and 1.19% in 1972 have been decreased to 60.73%, 6.91% and 0.46% in 2022 (Figure 4b).

Based on our data set, we deduce that a drastic reduction of forest class, sharp expansion in grassland class and considerable decline in water bodies in a span of fifty years seem alarming, scary and frightening for the state in general and study area in particular. Above mentioned results are further supported by graphical representation of land use land cover changes (Figure 5).

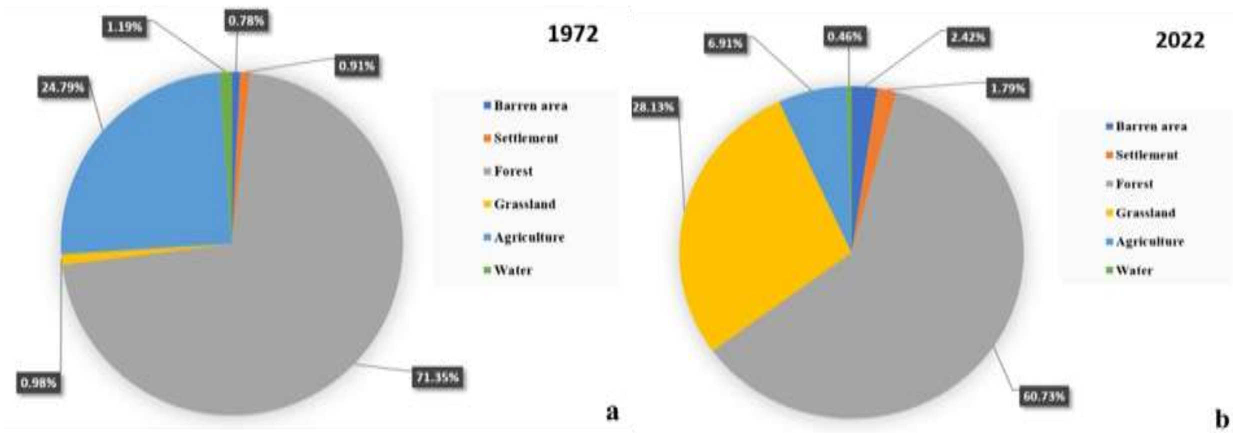

Figure 4:- Diagrammatic illustration of land use-land cover changes from 1972 (a) to 2022 (b).

The forests, agriculture and water computed for 1972 were 396.85, 137.89 and 6.63km^2 respectively, but hugely reduced to 337.78, 38.4877 and 2.56 km^2 until 2022. On the contrary, barren area (4.31 km^2), settlement (5.08 km^2) grasslands (5.44 km^2), calculated for 1972 have been increased up to 13.47 km^2, 9.98 km^2 and 156.49 km^2 respectively. The NDVI analysis clearly reveals declining trend in forest, agriculture and water atanoutrageous rate and increasing drifting the barren area, settlement and grassland. The region has registered astonishing intensification of light vegetation (grassland) at the expense of decline of the dense vegetation (forests) likely as a result of human encroachment into the forests and deforestation. This process appears to be one of the state's atrocious environmental problems. When a piece of land with high concentration of naturally occurring, trees is transformed to accommodate human need, deforestation takes place.

However, the NDVI methodologies demonstrate the remarkable evolution of several land use categories during the previous 50 years. The study employed the NDVI classification method to identify changes in the natural landscape over the course of the last 50 years in a region of the Kumaun Lesser Himalaya and to forecast future land use. The barren area, settlement and grassland in the study area have been increased, however, the forest area, agriculture and water have been decreased from 1972 to 2022.
Deforestation is a significant environmental issue with far-reaching consequences. One of the key impacts of deforestation is its contribution to the exacerbation of several environmental problems. As Verma (2021) suggests, deforestation causes a cascade of negative effects. Firstly, it leads to an increase in temperature due to the removal of the cooling effect of trees through transpiration. This rise in temperature has been observed in the Kumaun highlands and can be linked to climate change. Climate change, in turn, has had a detrimental impact on agriculture in the Kumaun highlands. Rai et al. (2023) note that the majority of the local population was traditionally engaged in agriculture, which served as the backbone of the local economy. However, climate change-induced factors, such as rising temperatures and erratic rainfall (Sharma et al., 2022), have caused a continuous drop in crop yields. These unfavorable conditions have transformed the landscape, with a significant increase in grassland and subsequent migration of people from the highlands.

In addition to the challenges posed by climate change, the changing environment in the Kumaun highlands has introduced new threats. Monkeys and wild boars have become hazards to the rural community by damaging horticultural plants and agricultural crops (Rawat et al., 2022). This further compounds the difficulties faced by the local population.

The situation is further exacerbated by a significant reduction in water bodies. Over the years, the area has witnessed a drastic decrease in water bodies, with coverage shrinking from approximately 6.63 km^2 in 1972 to roughly 2.6 km^2 in 2022. This reduction in water availability is not only disappointing for policymakers and geologists but also has serious implications for agriculture. Water scarcity directly affects crop yields, which can lead to a reduction in agricultural land and potentially force people to leave the state's hills (Ranjan, 2021).

The problem is compounded by population growth in areas surrounding Nainital, Bhimtal, Sattal, and Naukuchiatal, which has expanded almost threefold in recent decades. This population growth places additional stress on the already strained resources and infrastructure in the region. Moreover, climate change is expected to worsen the situation, altering hydrological cycles and increasing the frequency and severity of both floods and droughts.

Hence, the Kumaun highlands are facing a complex web of environmental challenges. Deforestation and climate change have disrupted traditional agriculture, leading to a shift in land use and population migration. Wildlife threats and diminishing water resources further compound the problems. Addressing these interconnected issues will require comprehensive strategies that consider both environmental conservation and sustainable development to ensure the well-being of the region's residents and the preservation of its natural resources.

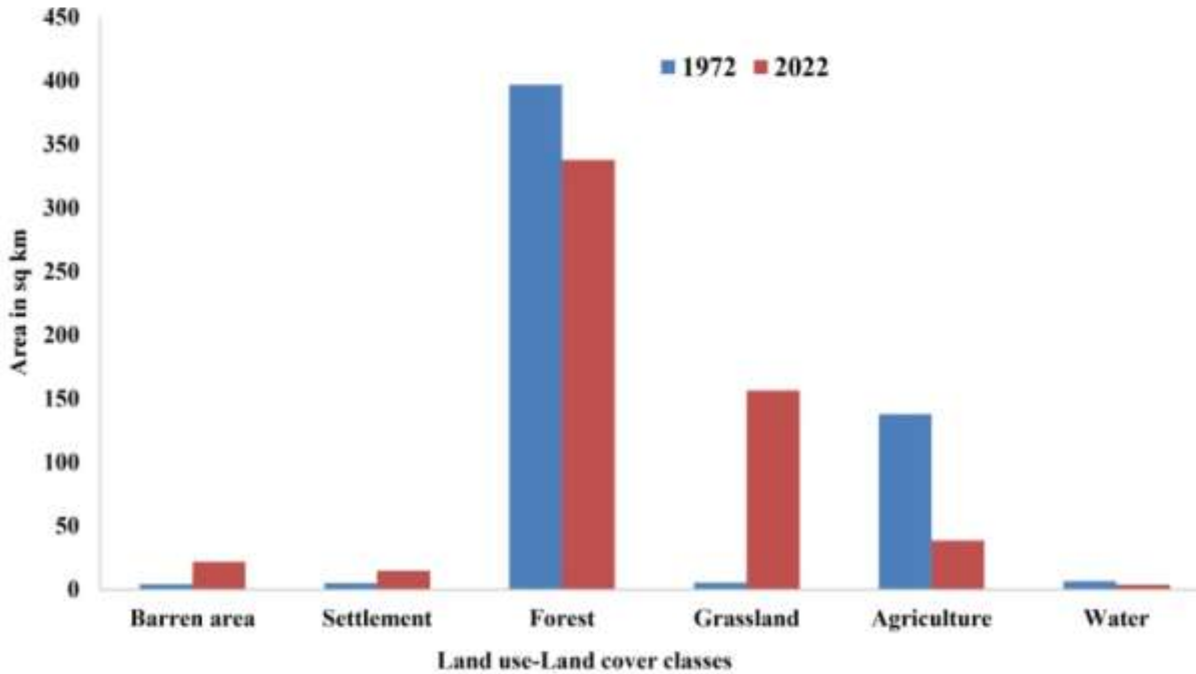

Figure 5:- Graphical representation of different LULC classes in 1972 and 2022.

Conclusion:-

The quantitative evidence shows that since 1972, the area has undergone considerable changes in both land use and land cover. The barren area, settlement and grassland in the study area were expanded continually by 1.65%, 0.88% and 27.16% respectively from 1972 to 2022. However, the extent of forest, agriculture and water decreased by 10.62%, 17.87% and 0.73% respectively during the above-mentioned period. The findings show that cropland agriculture has lost significantly, with a decline of around 18% and a rise of nearly 27% in grassland. Forests, which have shrunk by about 11% in the last fifty years, suggest a similar future. The land cover in the study area is greatly impacted by the pressure of an expanding population and irrational and unreasonable land use practices. This worrying situation necessitates scientific land use management for the area's sustainable growth.

Conflict of interest

The authors declare that they have no conflict of interest.

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