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POPULATION DYNAMICS AND ENVIRONMENTAL PERTURBATION IN SALT RANGE, MIANWALI, PAKISTAN

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Abstract

The Salt Range in Mianwali, Pakistan, faces imminent threats due to unregulated mining, posing a significant risk to its rich biodiversity and demanding a transition towards sustainable economicmodels. The convergence of environmental, economic, and geographical forces necessitates comprehensive management strategies to address changes in topography and hydrology. Climate change intensifies challenges, underscoring the urgency of adopting sustainable practices. Collaborative efforts, as evidenced by scholarly studies, are vital for the holistic preservation of the Salt Range's interconnected dynamics. Utilizing Landsat imagery and diverse data sources, our analysis emphasizes the evolving landscape, demonstrating the importance of informed decision-making for long-term regional resilience. Examining Land Surface Temperature, Normalized Difference Vegetation Index, slope, elevation, population, and economic data provides a nuancedunderstanding of Mianwali's complex dynamics, highlighting the interdependence of environmental, social, and economic factors. Elevation influences ecosystems, weather patterns, and biodiversity, while diverse soil types underscore the delicate balance between natural resourcesand human activities. Variations in slope impact vegetation and temperature, emphasizing the needfor topographical considerations in land-use planning. Alarming temperature trends and changing NDVI patterns reflect broader climate change concerns and underscore the role of informed decision-making for sustainable resource management. Population growth, gender distribution, and urbanization trends raise questions about demographic shifts and their implications. Mineral resource distribution and the number of miners highlight the economic significance of various minerals, emphasizing their role in supporting local and global industries. This holistic understanding is essential for informed decision-making, sustainable resource management, and the preservation of Mianwali's unique natural heritage.

INTRODUCTION

The Salt Range in Mianwali, Pakistan, stands as a testament to the intricate interplay between environmental, economic, and geographical factors shaping the destiny of a region. Nestled in theheart of South Asia, the Salt Range holds unique ecological significance, intertwining with the economic and geographical landscape of the area (Abbas, Shirazi, Mazhar, Mahmood, & Khan, 2021; Yaseen, Naseem, Ahmad, Mehmood, & Anjum, 2021). As we embark on a journey to understand the multifaceted impacts on this region, it becomes imperative to delve into the existingbody of literature that unravels the intricate relationships between the environment, economy, andgeography of the Salt Range (Majeed et al., 2022; Yaseen et al., 2021).

Environmental degradation resulting from unregulated mining activities poses a threat to the richbiodiversity of the Salt Range (Yaseen et al., 2021). Economic challenges arise from the dependency on salt mining, necessitating a shift towards diversified and sustainable economic models (Majeed et al., 2022). Geographical impacts, manifested in changes to the region's topography and hydrology, underscore the need for comprehensive monitoring and management strategies (Majeed et al., 2022).

The environmental dynamics of the Salt Range have been a subject of considerable scholarly attention due to its ecological diversity and sensitivity (M. Khan, Chaudhry, Ahmad, & Saif, 2020). The region is characterized by its unique salt formations, creating a distinctive landscape that harbors a myriad of flora and fauna (M. Khan et al., 2020). However, the delicate balance of this ecosystem is under constant threat from anthropogenic activities and climate change.

Addressing the multifaceted impacts on the Salt Range requires a holistic approach that integrates environmental conservation, sustainable economic practices, and geographical considerations (Zainab et al., 2023). Collaborative efforts involving local communities, government agencies, andresearchers are crucial to ensuring the long-term resilience of this unique and ecologically sensitiveregion (Zainab et al., 2023). As we move forward, it is imperative to build upon the existing body of knowledge to develop practical solutions that safeguard the Salt Range and its interconnected environmental, economic, and geographical dynamics (N. U. Khan, Zhongyi, Ullah, & Mumtaz, 2023).

Mining activities, primarily for salt extraction, have been a major driver of environmental changein the Salt Range. The unregulated and unsustainable extraction practices have led to soil erosion,habitat destruction, and disruption of local ecosystems (N. U. Khan et al., 2023). The once-pristinelandscapes are now marred by scars of extraction, impacting the biodiversity of the region (Shokat& Großkinsky, 2019). Furthermore, the extraction of salt from the range has downstream effects on water resources (Abbas & Mayo, 2021). The brine discharge from salt extraction processes finds its way into local water bodies, affecting water quality and aquatic life (Abbas & Mayo, 2021).

Climate change compounds the environmental challenges faced by the Salt Range. Changing precipitation patterns and rising temperatures exacerbate soil degradation and water scarcity issues(Abbas et al., 2021). The Salt Range, already vulnerable due to its geological composition, becomes more susceptible to desertification and loss of biodiversity (Ahmed, Zounemat-Kermani,& Scholz, 2020). The need for sustainable environmental practices and conservation efforts becomes apparent in the face of these challenges (Ahmed et al., 2020).

The economic dimensions of the Salt Range are closely tied to its mineral wealth, particularly thevast salt deposits that have been a source of economic sustenance for the local communities (U. Khan, Janjuhah, Kontakiotis, Rehman, & Zarkogiannis, 2021). Salt mining, though providing livelihoods, also brings about economic disparities and challenges (U. Khan et al., 2021). The saltindustry in the region has traditionally been dominated by small-scale, informal mining operations.While these operations contribute significantly to the local economy, they often lack proper regulation and environmental safeguards (Ghous & Siddiqui, 2022). This has implications for boththe economic well-being of the local population and the sustainable exploitation of the salt reserves(Ghous & Siddiqui, 2022).

The economic impacts extend beyond the immediate mining activities. The tourism potential of the Salt Range, driven by its unique geological formations, presents an opportunity for economic diversification. However, the environmental degradation caused by unregulated mining practices poses a threat to the tourism industry (Naseem, Fu, Mohsin, Rehman, & Baig, 2020). Sustainabledevelopment initiatives are crucial to harness the economic potential of the region without compromising its ecological integrity. The economic dependency on salt mining also raises questions about the long-term sustainability of such a model (Naseem et al., 2020).

Geographically, the Salt Range plays a pivotal role in shaping the landscape and hydrology of theregion (Salim et al., 2022). Comprising a series of hills and valleys, it acts as a natural divide between the fertile plains of the Punjab region and the arid landscapes to the west. The unique geological features of the Salt Range, including salt mines, faults, and folds, contribute to its significance in both geographical and geological contexts (Salim et al., 2022). The extraction of salt from the range has direct implications for its geological stability (Umar, Kassi, Jamil, Kasi, & Khan, 2023). Unregulated mining practices can lead to land subsidence and instability, affecting the topography of the region (Umar et al., 2023).

From a hydrological perspective, the Salt Range influences the drainage patterns of the region. The rivers originating from the range are a vital source of water for agriculture in the plains (U. Khan et al., 2021). However, the alteration of natural drainage patterns due to mining and other human activities can impact water availability downstream. Understanding these geographical dynamics is crucial for sustainable water resource management in the broader context of the region(U. Khan et al., 2021).

Studies by (Abbas et al., 2021; Ahmed et al., 2020) highlight the loss of several plant species, including rare endemic ones, due to habitat degradation resulting from mining activities. Researchby (M. Khan et al., 2020; N. U. Khan et al., 2023; Majeed et al., 2022; Yaseen et al., 2021; Zainabet al., 2023) underscores the need for comprehensive environmental management strategies to mitigate the adverse effects of salt extraction on the region's water resources. As highlighted by (Abbas & Mayo, 2021; Naseem et al., 2020; Shokat & Großkinsky, 2019) there is a need for diversification of the local economy to reduce vulnerability to fluctuations in the salt market and to create alternative sources of income for the communities residing in the Salt Range. Geographical studies by (U. Khan et al., 2021; Salim et al., 2022; Umar et al., 2023) emphasize the importance of monitoring geological changes induced by mining activities to mitigate potentialhazards such as landslides and ground subsidence. In this study the LST, NDVI, Elevation, Slope,Soil Analysis were performed to assess the environmental and geographical impacts in the study area. The objective of this study is to assess the temperature variation, vegetation pattern and utilization of the resource in the study area.

Material and Methodology

Study Area

Mianwali is a district situated in the northwestern part of the Punjab province in Pakistan. Its geographical coordinates are approximately 32.5867° N latitude and 71.5549° E longitude. The district shares borders with the districts of Attock and Chakwal to the east, Faisalabad to the southeast, Khushab to the south, Layyah to the southwest, Bhakkar to the west, and the province of Khyber Pakhtunkhwa to the northwest. Mianwali is characterized by diverse topography, ranging from the plains in the east to the Salt Range in the west. The Salt Range, a prominent geographical feature, extends through the district from north to south. This range is known for itsunique geological formations, including salt mines, hills, and valleys, which significantly influencethe local landscape. The eastern part of Mianwali is part of the Indus River basin, characterized byfertile plains that support agriculture. As one moves westward towards the Salt Range, the topography becomes more rugged and hilly, creating a transition from the plains to the rocky landscapes of the Salt Range. Mianwali experiences a semi-arid climate, with hot summers and relatively mild winters. Summers are characterized by high temperatures, often exceeding 40°C (104°F), while winter temperatures can drop to around 5°C (41°F). The district receives limited rainfall, primarily during the monsoon season from July to September. The arid climate, coupled with the topographical variations, plays a crucial role in shaping the environmental dynamics of the region. The Salt Range, a defining feature of Mianwali's geography, is renowned for its vast salt deposits. Khewra Salt Mines, located in the district, are among the world's largest and oldest salt mines, contributing significantly to the local economy. Apart from salt, the region is endowedwith other minerals, including gypsum, limestone, and coal. The rivers originating from the Salt Range, such as the Jhelum River, contribute to the water resources of the region. These water bodies are crucial for agriculture in the plains and play a vital role in sustaining local ecosystems.The land use in Mianwali is diverse, reflecting the variations in topography. The plains in the eastern part of the district are predominantly used for agriculture, cultivating crops such as wheat,rice, and sugarcane. The Salt Range, while hosting mining activities, also supports unique flora and fauna. Efforts are being made to explore the tourism potential of the region, leveraging its geological features and natural beauty.

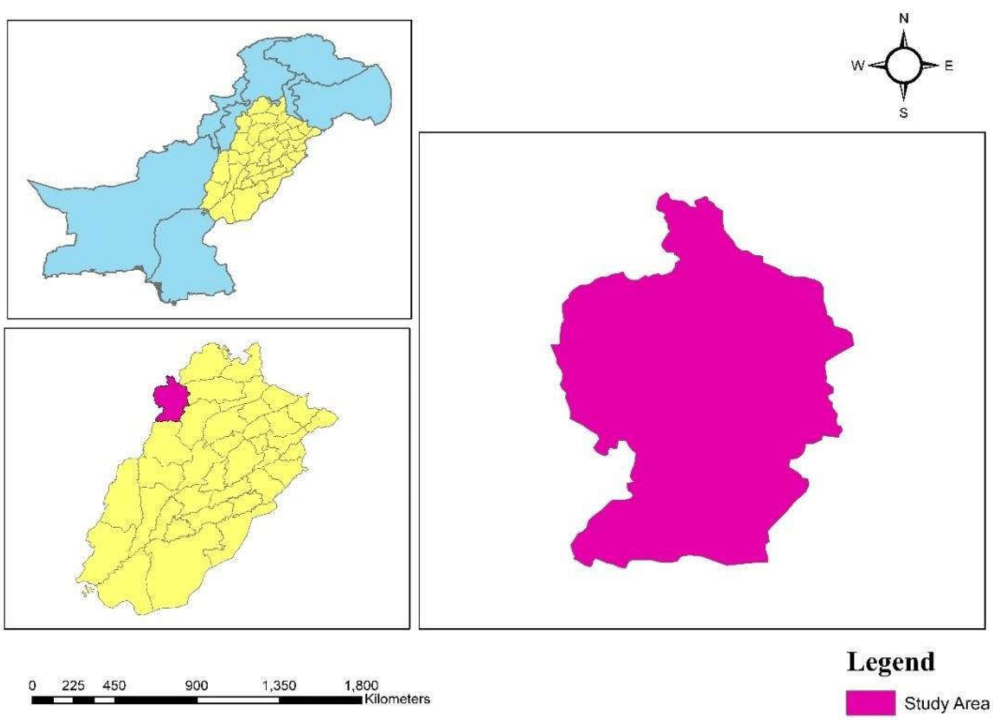

Figure 1 Shows the Study area.Data Source

Landsat satellite imagery plays a pivotal role in capturing the dynamic changes in the landscape of Mianwali over the years 2003, 2013, and 2023. Landsat 7 and Landsat 8 data were acquired from the United States Geological Survey (USGS) website EarthExplorer (usgs.gov). These datasets, characterized by their multispectral capabilities, provide a valuable resource for monitoring land cover changes, assessing vegetation health, and understanding the impact of human activities on the environment. To complement the satellite imagery, soil data were obtainedfrom the CertMapper website (https://certmapper.cr.usgs.gov/). Understanding the soil composition is essential for comprehending the agricultural landscape and assessing the impact ofland use practices on soil health. The CertMapper platform offers detailed soil information, allowing for a nuanced analysis of how soil characteristics may have evolved over the studied years. Population dynamics, a critical aspect of the socio-economic landscape, were investigated using data sourced from the Survey of Pakistan website (http://www.surveyofpakistan.gov.pk/).

Analyzing population trends provides insights into demographic shifts, urbanization patterns, andpotential implications for land use and resource management. This information is crucial for understanding the human dimension of the study area. Economic data, a key component in unraveling the intricate relationship between human activities and the environment, were acquired from the Pakistan Bureau of Statistics website (https://www.pbs.gov.pk/). Economic indicators such as GDP, employment rates, and industrial outputs offer a comprehensive view of the economic landscape of Mianwali. Integrating economic data with other environmental variables allows for a holistic assessment of the region's development and sustainability. The mining sector,often a driver of regional economies but also a source of environmental impact, was scrutinized using data from the Pakistan Mineral Development Corporation (PMDC) website (http://www.pmdc.gov.pk/). The PMDC data provide insights into the types of minerals extracted,mining activities, and the extent of mineral exploitation in Mianwali. Understanding the dynamicsof the mining industry is essential for evaluating its environmental footprint and socio-economic contributions.

Data Analysis NDVI Calculation

The Normalized Difference Vegetation Index (NDVI) serves as a quantitative metric delineating the extent of vegetation by gauging the contrast in reflectance between the near-infrared (NIR) andred portions of the electromagnetic spectrum (Pettorelli et al., 2005; Xu, Yang, Chen, & Liu, 2022).This spectral differentiation becomes crucial as green vegetation strongly reflects NIR, while simultaneously absorbing the red spectrum (de la Iglesia Martinez & Labib, 2023).

The NDVI formula, expressed as:

$$NDVI=(NIR-R) / (NIR+R) \quad (1)$$

where NIR signifies the near-infrared band and R denotes the red band, encapsulates the essence of this spectral analysis (Wang, Moreno-Martínez, Muñoz-Marí, Campos-Taberner, & Camps- Valls, 2023). By evaluating the disparity between NIR and red reflectance, the NDVI encapsulatesthe nuanced interplay between vegetation and its reflective properties (de la Iglesia Martinez & Labib, 2023; Yan, Zhang, Ling, & Han, 2022).

LST Calculation

For the computation of Land Surface Temperature (LST), the thermal bands of Landsat-7,equipped with the Enhanced Thematic Mapper Plus (ETM+) sensor, and Landsat-8, featuring theOperational Land Imager/Thermal Infrared Sensor (OLI/TIR), were employed. Specifically, the Landsat Surface Temperature was derived by utilizing band 6 of the Landsat-7 thermal band fromthe ETM+ sensor and band 10 of the Landsat-8 thermal band from the TIR sensor, as outlined by(Guo et al., 2020).

To initiate this process, the spectral radiance of the thermal bands of Landsat-8 with the TIR sensorwas obtained through the conversion of digital number values, as detailed by (Alves, 2016). Consequently, the Land Surface Temperature was calculated using the brightness temperature of the thermal infrared bands, incorporating the mean and difference in land surface emissivity for the study area, as described by (Cheng, Nnadi, & Liou, 2015).

$$L\lambda = (ML * Q_{Cal}) + AL - 0.5 \quad (2)$$

Where:

$L\lambda$= TOA spectral radiance, ML= RADIANCE_MULT_BAND 10, AL= Radiance_Add_Band_10, Q_{Cal}=Quantized and calibrated DN values, and -0.5 = the inaccuracy ofradiance.

$$BT = (k2 / (\ln (K1/L\lambda) +1)) -273.15 \quad (3)$$

BT= Brightness Temperature, K2=is Calibration constant 2, K1=is Calibration constant 1, $L\lambda$: TOA, Ln: is natural logarithm, and the value 273.15 is used to convert the temperature kelvin to Celsius.

$$NDVI= (NIR – RED)/ (NIR + RED) \quad (4)$$

$$PV = Square ((NDVI-NDVI_{min}) / (NDVI_{max} – NDVI_{min})) \quad (5)$$

$$E = 0.004 * PV + 0.986 \quad (6)$$

$$LST = (BT/(1+(\lambda*BT/P) *\ln(E))) \quad (7)$$

Where: LST = Land Surface Temperature, BT = Brightness Temperature, λ = 10.8 µm, ρ = 1.438 × 10^{-2} mK, and E = Land Surface Emissivity.

Results and Discussion

The holistic analysis of Land Surface Temperature (LST), Normalized Difference Vegetation Index(NDVI), slope, elevation, population, and economic data yields a multifaceted understanding of the intricate interactions that define the study area. By integrating these diverse datasets, a comprehensive picture emerges, illuminating the complex interplay between environmental,social, and economic dynamics. The interdependence of LST, NDVI, slope, and elevation becomesevident as these variables collectively influence the thermal, vegetative, and topographical characteristics of the landscape. High-resolution temperature variations captured by LST data canbe correlated with NDVI trends, shedding light on how temperature influences vegetation health and land cover changes. Meanwhile, slope and elevation play a pivotal role in shaping local microclimates, influencing temperature differentials and vegetation distribution across varying terrains. The integration of population and economic data adds a social and economic layer to theenvironmental narrative. High population density areas often coincide with intensified anthropogenic activities, impacting land use patterns and contributing to urbanization. Economic indicators, such as GDP and industrial outputs, provide insights into the socio-economic drivers behind environmental changes. Understanding these dynamics is crucial for policymakers seekingto balance economic development with environmental sustainability. As we navigate towards futurestudies, there exists a compelling need to delve deeper into the causal relationships between these variables.Unraveling the intricacies of how environmental changes influence social and economic aspects, and vice versa, will provide a more nuanced understanding of the region's dynamics. Longitudinal studies could explore temporal trends, aiding in the identification of emerging patterns and potential tipping points in theecosystem. Moreover, future research endeavors should prioritize the exploration of mitigation strategies for environmental challenges in the region. The insights gained from this holistic analysis can guide the development of targeted interventions, ranging from sustainable land-use planning to community-based conservation initiatives. Engaging stakeholders, including local communities, in the co-creation of solutions will be pivotal for the successful implementation of these strategies.

Elevation

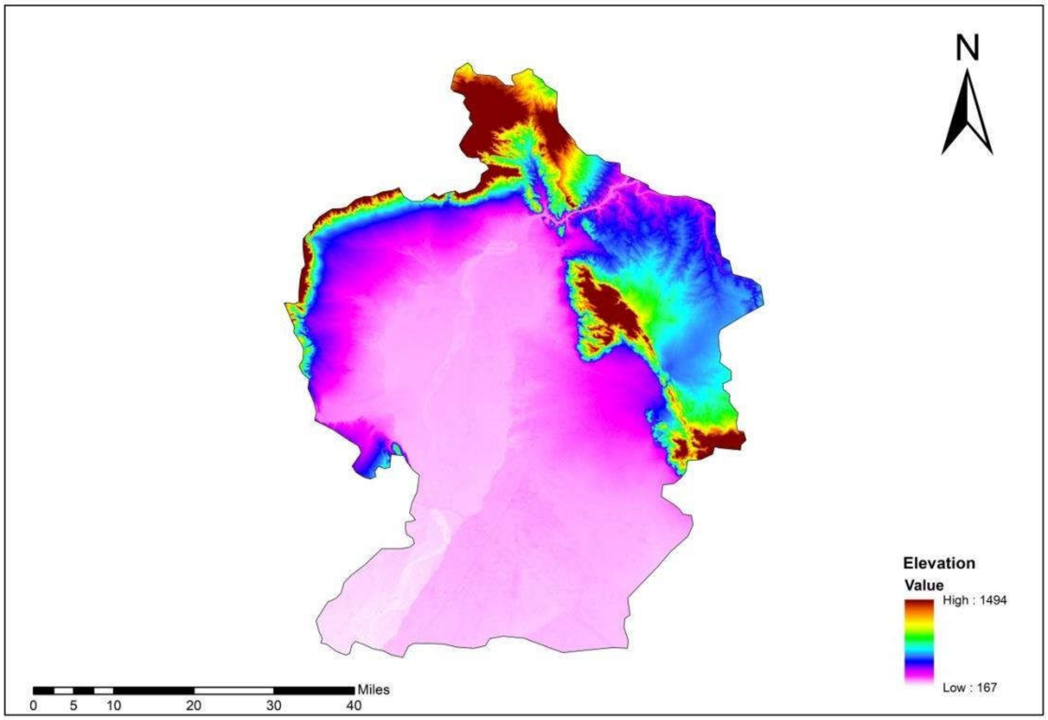

Figure 2 Shows the Elevation of the study area.

The eastern and northern parts of Mianwali, where the Salt Range mountains begin, introduce a dynamic shift in elevation that significantly influences the district's geographical and ecological features. The Salt Range, a noteworthy geological formation, elevates the topography, creating a landscape that ranges from relatively flat plains to the elevated peaks of the mountain range. As one progresses towards the Salt Range, the elevation in Mianwali experiences a gradual ascent, reaching its peak in the highest points of the Salt Range. These elevated areas can soar several hundred meters above the surrounding plains, offering breathtaking panoramic views of the district. The Salt Range's commanding presence not only shapes the physical appearance of Mianwali but also plays a crucial role in modulating local weather patterns. The elevation of Mianwali serves as a critical determinant in the shaping of its diverse ecosystems. The lower-lyingareas, often found in proximity to the plains, may be more prone to aridity due to reduced elevationand potential water scarcity. In contrast, the higher elevations in the Salt Range create cooler andmore varied environmental conditions, fostering a distinct set of flora and fauna adapted to these elevated terrains. This interplay between varying elevations contributes significantly to theecological tapestry of Mianwali. The district's vegetation types are intricately linked to the elevation gradient, with different plant species thriving at different altitudes. Additionally, the elevation gradient contributes to variations in temperature and precipitation patterns, further influencing the distribution of plant and animal life across the region. In essence, Mianwali's elevation is a pivotal factor that defines the district's geographical and ecological characteristics. The juxtaposition of lower plains and higher elevations creates a mosaic of habitats, fostering biodiversity and ecological resilience. The Salt Range, with its towering peaks and distinctive geological features, adds a layer of complexity to Mianwali's landscape, making it an area of considerable geographical and environmental interest in the broader region. Understanding and preserving this elevation-driven diversity is crucial for sustainable environmental management andthe conservation of Mianwali's unique natural heritage.

Soil of Mianwali

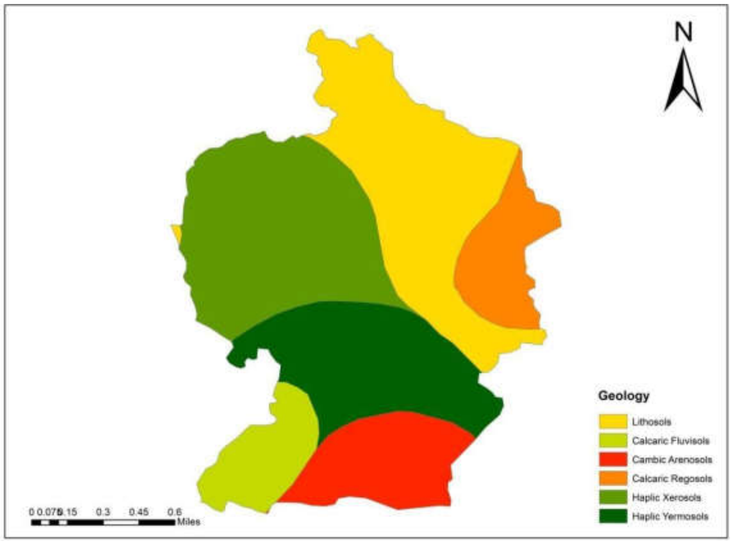

Figure 3 Shows the soil types of the study area.

The study area encompasses a diverse range of soils, including Lithosols, Calcaric Fluvisols, Cambic Aremosols, Calcaric Regosols, Haplic Xerosols, and Haplic Yermosols. This rich soil composition contributes to the unique ecological dynamics within the region. However, the presence of distinct soil types has also led to disruptions in the natural vegetation, and the impactof mining activities has further intensified these disturbances. Lithosols, characterized by shallow,rocky soils, present challenges for the establishment and sustenance of vegetation, leading to fragmented plant cover across the landscape. Calcaric Fluvisols, formed in alluvial deposits, contribute to ecological diversity but are susceptible to alteration due to anthropogenic activities. The Cambic Aremosols, with their distinctive horizon development, play a crucial role in shapingthe local ecosystem, but mining activities have introduced imbalances, affecting the delicate equilibrium. Calcaric Regosols, marked by their calcium-rich content, add to the soil complexity,supporting specific plant species. However, mining-related disturbances have disrupted these natural patterns, influencing the composition and distribution of flora. Haplic Xerosols, found in arid regions, face additional stress due to mining-induced changes in the water table and overall hydrological conditions, impacting the already fragile vegetation. Haplic Yermosols, characterizedby arid and semi-arid conditions, are particularly vulnerable to disturbances caused by mining, exacerbating the challenges faced by the native plant species adapted to such harsh environments. The consequences of these disturbances are not confined to alterations in vegetation alone; they extend to the destabilization of the landscape, resulting in land sliding phenomena. As mining activities continue to unfold in this diverse soil environment, comprehensive ecological monitoringand sustainable land management practices become imperative. Addressing the intricate interplay between soil types, vegetation, and mining-induced disturbances is essential for preserving the ecological integrity of the study area and fostering a harmonious coexistence between human activities and the natural environment.

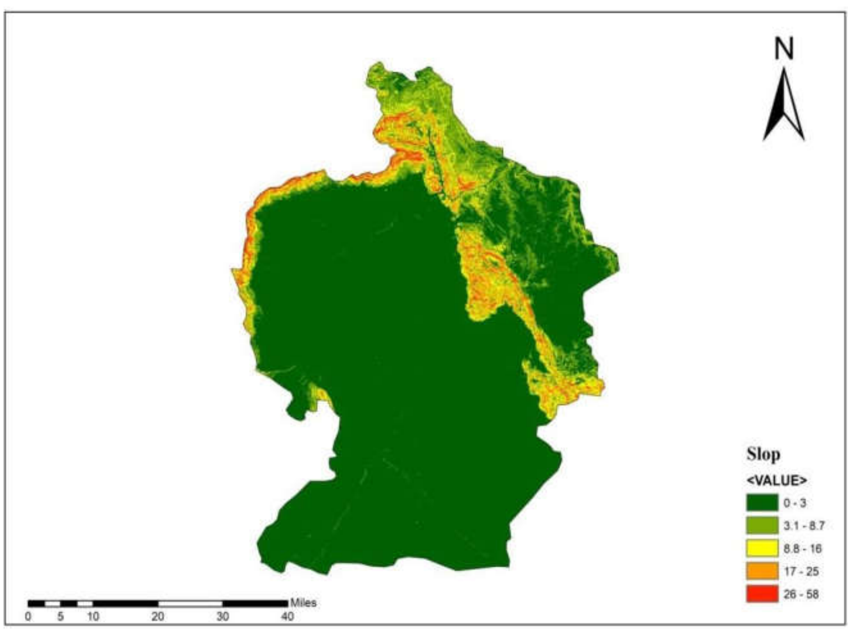

Figure 4 Shows the Slope of the study area.

The study area exhibits a diverse topography, with slopes ranging from the highest at 58^0 to the lowest at 0^0. The variation in slope plays a crucial role in influencing the dynamics of vegetationalactivities and temperature fluctuations within the region. In areas characterized by a higher slope,such as the maximum slope of 580, the terrain tends to be more rugged and steep. Steeper slopes often lead to challenges for vegetation, as the incline can limit soil retention, water availability, and nutrient accessibility. In such environments, vegetational activities may face constraints, andthe overall biodiversity could be influenced by the harsher conditions posed by the topography. Conversely, in areas with lower slopes, including flat or gently sloping terrains, vegetational activities tend to flourish. Reduced slopes often provide more stable conditions for soil retention, water infiltration, and nutrient distribution. The relatively flatter landscapes create a conducive environment for the establishment and growth of vegetation. As a result, a decrease in slope can contribute to an increase in vegetational cover, promoting biodiversity and ecological stability. Furthermore, the relationship between slope and temperature fluctuations is noteworthy. Steeper slopes can contribute to increased exposure to sunlight, potentially leading to higher temperatures,while flatter areas may experience more moderated temperatures due to their orientation and less exposure to direct sunlight. Therefore, a decrease in slope not only fosters vegetational activities but also has the potential to mitigate temperature fluctuations within the study area. Understandingthe interplay between slope, vegetation, and temperature is vital for comprehensive ecosystem management. It highlights the importance of considering topographical features in environmentalassessments and land-use planning. Balancing the preservation of steeper slopes for their ecological value with the potential benefits of flatter areas for vegetational growth and temperatureregulation becomes essential for sustainable land management practices in the study area.

Land Surface Temperature

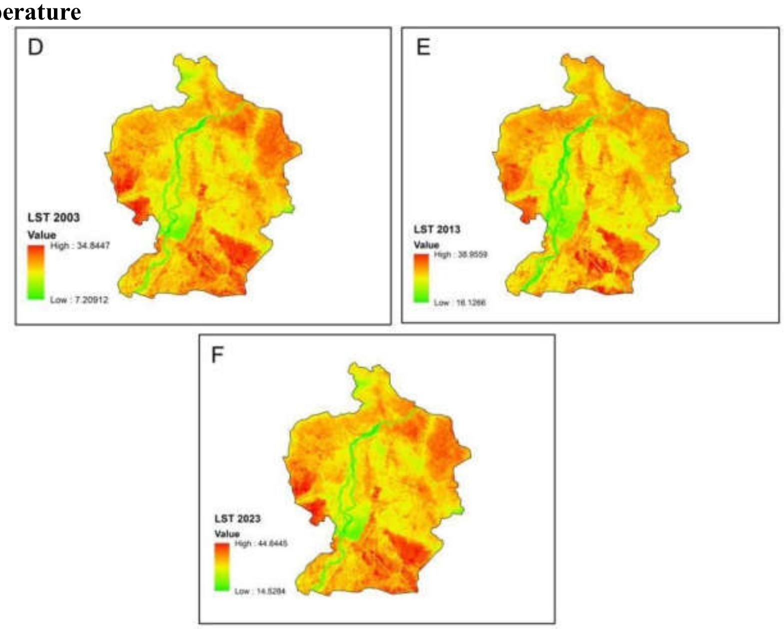

Figure 5 Shows the Land Surface Temperature of the study area.

The figure illustrates the temperature fluctuations in the study area over the past two decades. In 2003, the recorded low temperature was 7.20°C, while the highest temperature reached 34.85°C.

This temperature range has significant implications for the local ecosystem. The variability in temperature appears to contribute to the reduction of vegetation and exacerbate soil erosion, particularly as the low moisture content in the soil makes it more susceptible to erosion processes.Moving forward to 2013, there is a noticeable shift in temperature patterns. The lowest temperaturerecorded increased to 16.13°C, and the highest temperature rose to 38.96°C. These changes in temperature further underscore the dynamic nature of the climate in the study area. The increasingtemperature range may have additional consequences for the local environment, influencing the distribution of plant species and potentially intensifying soil erosion processes. Fast forward to theyear 2023, and the temperature extremes continue to intensify. The lowest recorded temperature is 14.53°C, while the highest has soared to 44.65°C. Such pronounced temperature fluctuations suggest a trend towards harsher climatic conditions. The notable rise in temperatures aligns with the broader global concern of climate change and the associated impacts of global warming. Thisshift in climate dynamics can have cascading effects on the local ecology, with implications for vegetation cover, soil moisture levels, and the overall stability of the ecosystem. The study area isnot immune to the broader climatic shifts occurring on a global scale. The escalating temperaturesobserved over the past two decades underscore the urgent need for adaptive and resilient environmental management strategies. Mitigating the impacts of temperature fluctuations on vegetation and soil erosion will require a comprehensive approach that considers both local and global factors contributing to climate change. The study area serves as a microcosm reflecting thebroader challenges associated with environmental sustainability in the face of a changing climate.

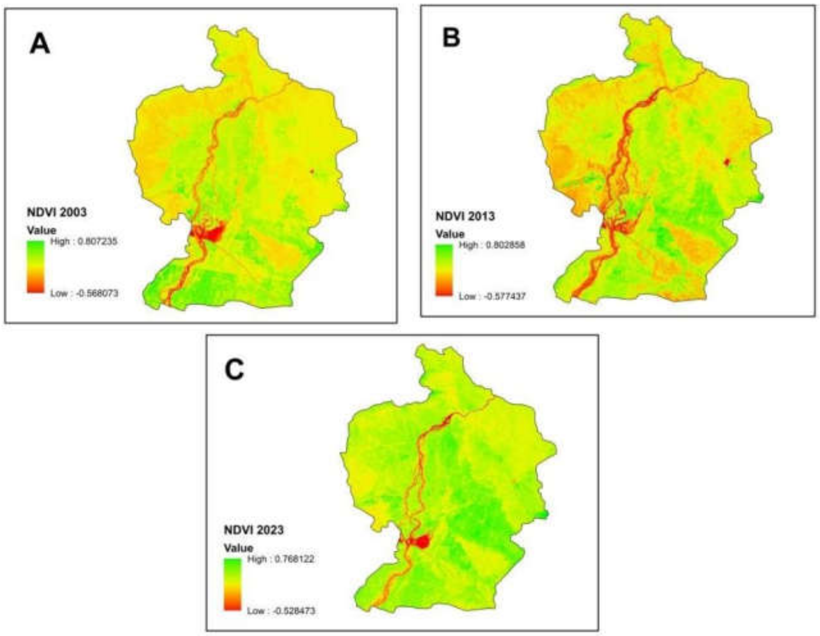

Figure 6 Shows the NDVI of the study area.

The figure provides insights into the vegetation dynamics in the study area, as measured by the Normalized Difference Vegetation Index (NDVI). In 2003, the maximum NDVI value recorded was 0.807235, indicating a high level of vegetation cover in the study area. Conversely, the minimum NDVI value of -0.568073 suggested areas with little to no vegetation. This stark contrastin NDVI values reflects the variability in vegetation density across the landscape. Moving ahead to 2013, there is a discernible shift in the NDVI values. The maximum NDVI decreases slightly to0.802858, indicating a marginal reduction in overall vegetation cover compared to 2003. Conversely, the minimum NDVI value increases to -0.577437, signaling an expansion of areas with little to no vegetation. This shift in NDVI values may be indicative of changes in land use, climate, or other environmental factors affecting the vegetation patterns over the decade. In the year 2023, further changes in NDVI values are observed. The high NDVI value decreases to 0.768122, suggesting a decline in the extent of high vegetation cover compared to both 2003 and 2013. Simultaneously, the low NDVI value increases to -0.528473, indicating an expansion of areas devoid of vegetation. These fluctuations in NDVI values over the years may be influenced by factors such as climate variability, land-use changes, or disturbances that impact the health anddistribution of vegetation in the study area. The observed trends in NDVI values underscore the importance of monitoring vegetation dynamics over time, especially in the context of environmental changes. Analyzing these trends can provide valuable insights into the resilience ofthe ecosystem, the impact of human activities, and the potential effects of climatic variations on the study area's vegetation. The continued monitoring of NDVI values will be crucial for understanding and managing the evolving dynamics of the local vegetation in the face of environmental changes.

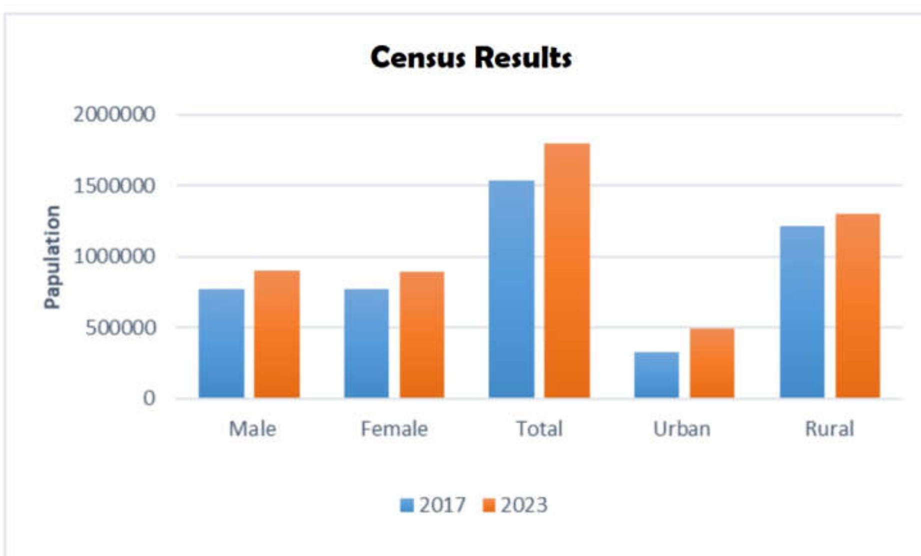

Figure 7 Shows the Population data of the study area.

The provided data presents a demographic snapshot of the population in terms of gender and residence (urban and rural) for the years 2017 and 2023. Let's delve into a discussion of the trendsand implications revealed by the numbers. Between 2017 and 2023, the total population has experienced a substantial increase from 1,542,601 to 1,798,268. This growth raises questions aboutthe factors contributing to the population surge, such as natural population increase, migration, orother demographic dynamics. Examining the gender distribution, both male and female populations have increased. In 2017, there were 771,969 males and 770,502 females, while in 2023, the numbers rose to 906,987 males and 891,281 females. The higher increase in the male population may suggest variations in birth rates, life expectancy, or migration patterns favoring males during this period. The data reveals a noticeable growth in the urban population, rising from327,812 in 2017 to 491,286 in 2023. This trend aligns with global patterns of increasing urbanization, driven by factors such as industrialization, job opportunities, and improved amenitiesin urban centers. While urban areas show a significant increase, the rural population remains relatively stable, moving from 1,214,989 in 2017 to 1,306,982 in 2023. This suggests that, despite the overall population growth, the rural-to-urban migration might be contributing more substantially to the population increase in urban areas.

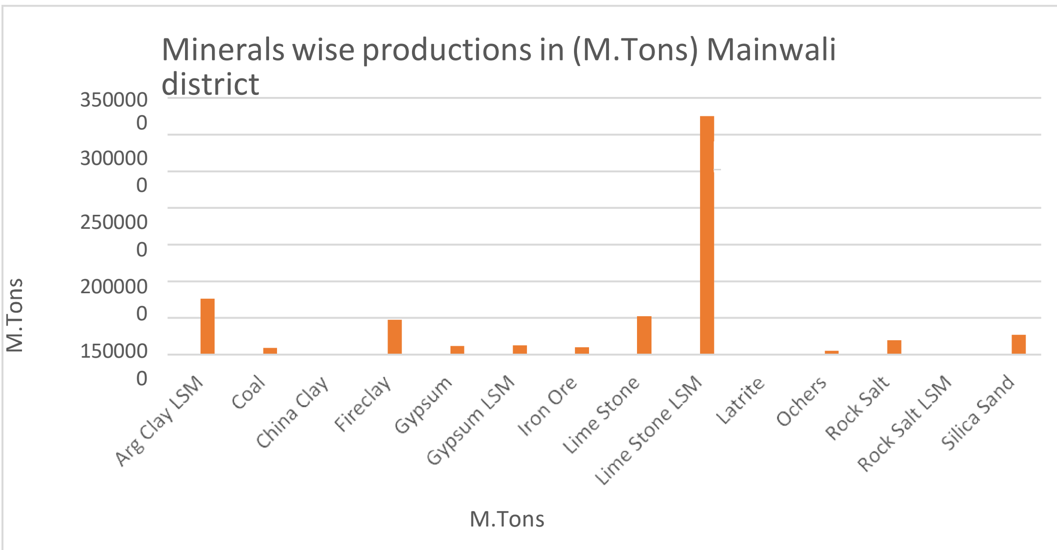

Figure 8 Shows the Mineral production of the study area.

The provided data offers a glimpse into the mineral resource distribution in terms of quantities (inmetric tons). Let's delve into a discussion to analyze the significance and potential implications ofthese mineral quantities. The substantial quantities of Arg Clay LSM (762,635 tons) and Fireclay(478,723 tons) indicate a robust presence of clay minerals in the region. These minerals are essential for various industries, including ceramics, construction, and manufacturing, highlightingthe potential economic significance of these resources. The considerable quantity of Limestone (517,197 tons) and Limestone LSM (3,252,778 tons) suggests a significant reserve of limestone.

Limestone is a versatile mineral used in construction, cement production, and various industrial processes. The large quantity of Limestone LSM indicates a potentially vital resource for the localor regional construction and manufacturing sectors. The presence of 273,925 tons of Silica Sand is noteworthy, given its importance in glassmaking, foundry work, and other industrial applications. This mineral's quantity suggests the potential for economic activities that rely on silica sand within the region. The quantities of Rock Salt (194,595 tons) and Rock Salt LSM (4,065tons) highlight the presence of salt deposits. Rock salt is a crucial resource for various industries,including chemical processing and food preservation. The quantities suggest that the region may contribute significantly to salt production.

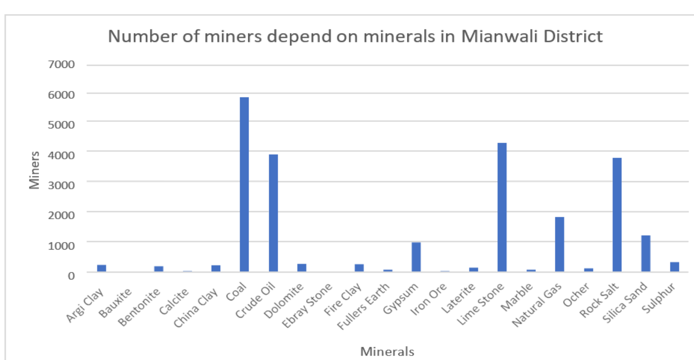

Figure 9 Shows the No of Miners involved in different mining activities in the study area.

The extraction and utilization of minerals plays a crucial role in various industries, contributing significantly to economic development. Here, we examine a diverse range of minerals and the number of miners involved in their extraction, shedding light on the importance of each in the global and local economies. Argi clay, a type of clay rich in minerals, finds applications in potteryand ceramics. The presence of 240 miners suggests a moderate demand for this mineral. Bauxite,a key source of aluminum, is essential for the aerospace and automotive industries. The relativelylow number of miners (10) might indicate a specialized or localized extraction. Bentonite, known for its absorbent properties, is widely used in various industries, including construction and cosmetics. The involvement of 190 miners signifies a notable demand for this versatile mineral. Calcite, a common mineral with diverse applications, is utilized in industries such as agriculture, construction, and pharmaceuticals. The limited number of miners (31) might reflect a specific regional demand. China clay, or kaolin, is crucial in the production of ceramics, paper, and cosmetics. With 230 miners involved, it indicates a substantial demand for this mineral. Coal, a major source of energy, supports various industries and power generation. The involvement of 5,798 miners highlights the significance of coal in meeting global energy demands. Crude oil is a primary source for fuel production, driving industries and transportation. The presence of 3,896 miners indicates a substantial workforce engaged in the extraction of this critical resource. Dolomite, used in construction and agriculture, plays a role in neutralizing soil acidity. The involvement of 267 miners suggests a consistent demand for this mineral. Ebray stone, possibly aspecialized mineral, involves a small number of miners (3), indicating a niche market or specific application. Fire clay, known for its resistance to high temperatures, is crucial in the production ofrefractories. The presence of 261 miners suggests a notable demand in industries requiring heat- resistant materials. Fullers Earth, valued for its absorbent properties, is used in various industries,including oil refining and cosmetics. The involvement of 78 miners indicates a moderate demand.Gypsum, essential in construction and agriculture, is used in the production of plaster and fertilizers. The high number of miners (982) suggests a significant demand for this versatile mineral. Iron ore, a crucial raw material in the production of steel, involves 38 miners, indicatinga focused but important role in supporting the steel industry. Laterite, commonly used in construction, involves 150 miners, reflecting a consistent demand for this mineral in building materials. Limestone, a key ingredient in cement and building materials, engages a large workforceof 4,278 miners, indicating its central role in construction industries. Marble, prized for its use in sculptures and architecture, involves 80 miners, suggesting a specialized market for this high- quality stone. Natural gas, a crucial energy source, engages 1,825 miners, highlighting its importance in meeting global energy demands. Ocher, a pigment in art and industry, involves 127miners, indicating a consistent demand for its applications. Rock salt, vital for de-icing and chemical industries, engages 3,796 miners, emphasizing its importance in various sectors. Silica sand, used in glassmaking and construction, involves 1,214 miners, indicating a substantial demand for this versatile material. Sulphur, essential in various industries, including chemicals and agriculture, engages 325 miners, reflecting its diverse applications. The diversity in the types of minerals and the varying number of miners involved underscore the intricate web of industries dependent on these resources. The data presented here provides insights into the economic importance of each mineral and the corresponding workforce dedicated to their extraction.

Conclusion

In conclusion, the Salt Range in Mianwali, Pakistan, stands at the intersection of environmental, economic, and geographical forces. Unregulated mining activities threaten the rich biodiversity, necessitating a shift to sustainable economic models. Geographical impacts, including changes in topography and hydrology, underscore the need for comprehensive management strategies. Climate change exacerbates challenges, making sustainable practices crucial. Collaborative efforts, as highlighted by scholarly studies, are imperative for the holistic preservation of the SaltRange and its interconnected dynamics. The provided data analysis, utilizing Landsat imagery andother sources, further emphasizes the evolving landscape and the importance of informed environmental and economic decision-making for the region's long-term resilience. The comprehensive analysis of Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI), slope, elevation, population, and economic data provides a nuanced understandingof Mianwali's complex dynamics. The interdependence of environmental, social, and economic factors is evident, shaping the thermal, vegetative, and topographical characteristics of the region.Examining elevation highlights its role in influencing ecosystems, weather patterns, and biodiversity. The diverse soil types in Mianwali underscore the delicate balance between natural resources and human activities. The variation in slope affects vegetation and temperature, emphasizing the need for topographical considerations in land-use planning. Temperature trends indicate an alarming rise, reflecting broader climate change concerns. NDVI fluctuations reveal changing vegetation patterns, crucial for ecosystem resilience. Population growth, gender distribution, and urbanization trends raise questions about demographic shifts and their implications. Lastly, the mineral resource distribution and the number of miners underscore the economic significance of various minerals, emphasizing their role in supporting local and global industries. This holistic understanding is essential for informed decision-making, sustainable resource management, and the preservation of Mianwali's unique natural heritage.

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