Integrating GIS and Remote Sensing Data for Detecting Change in Agricultural Land during 1985-2024 in Qassim Region, Saudi Arabia

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INTEGRATING GIS AND REMOTE SENSING DATA FOR DETECTING CHANGE IN AGRICULTURAL LAND DURING 1985-2024 IN QASSIM REGION, SAUDI ARABIA

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Abstract:

The Qassim region is one of the most significant agricultural areas in Saudi Arabia, particularly for date cultivation. This study investigates changes in agricultural land in the Qassim region between 1985 and 2024, utilizing Geographic Information System (GIS) technology and remotely sensed data to analyze and quantify agricultural land transformations. Key factors contributing to these changes are identified, providing valuable insights into environmental dynamics and land cover patterns. This research aims to inform policymakers and land managers, facilitating sustainable agricultural practices and effective land management strategies.

An object-based data analysis approach was employed for thematic mapping, considering both the spectral and spatial properties of the data extracted from the NDVI index. This method enables more accurate classification by leveraging the contextual information of image objects, resulting in improved extraction of agricultural land. Supervised classification was applied to the NDVI indices produced from Landsat images captured in the years 1985, 2000, 2015, and 2024 to identify agricultural lands.

The results indicate that the agricultural landscape of the Qassim region in Saudi Arabia underwent significant changes over the past two decades. Agricultural lands declined between 2000 and 2015 due to government policies to rationalize water-intensive practices, but more recent data from 2024 shows a 14.4% increase in agricultural area to 2,438.16 square kilometers, attributed to strategic priorities focused on sustainable resource management, food security, rural development, and agricultural productivity. The expansion has been spatially distributed, with the Agricultural Development Fund playing a key role through promoting rational resource use, technology application, and investment facilitation.

Keywords: Remotely Sensed Data, Geographic Information Systems, Qassim, Agriculture Land.

1.Introduction

Throughout history, agriculture has played a pivotal role in the prosperity of many countries (IFPRI, 2017). It serves as a fundamental source of economic development and food security for both developed and developing nations (Vibhute and Gawali, 2012). The increasing human population has led to rising demands for food and housing, resulting in agricultural expansions that have significantly altered natural landscapes and have caused considerable environmental impacts (Yu and Wu, 2018).

According to data from the World Bank, the total agricultural land area in Saudi Arabia was approximately about 17 million hectares in 2020, including 3.6 million hectares of cropland (FAO, 2022). The expansion of cultivated and irrigated land has increased in response to the high demand for food, while the area dedicated to permanent meadows and pastures has significantly decreased. Urbanization has had a detrimental impact on various agricultural land uses, resulting in modifications to ecosystems and alterations to the water cycle (Stavi et al., 2022). Consequently, land use and land change (LULC) have emerged as prominent research areas being addressed by international environmental, food, and agricultural organizations.

Despite the poor quality of soil in the Kingdom of Saudi Arabia (KSA), which is deficient in nutrients, organic matter, and moisture, the country has experienced rapid and successful agricultural development since the 1980s. Among the various regions in KSA, Al-Qassim stands out as one of the most productive areas for agriculture. The soils in this region are extensively cultivated to meet the increasing food demands of the growing population (Al-Wabel et al., 2017).

Furthermore, the agricultural sector in Saudi Arabia witnessed significant trade activities. In 2022, the total quantity of agricultural imports amounted to 29,376 thousand tons, with grains comprising the largest share at 45.2% (Agricultural Statistics Publication, 2022). Conversely, agricultural exports reached 3,687 thousand tons in the same year, experiencing a growth of 14% compared to 2021.

The agricultural sector in Saudi Arabia has also received substantial financial support. In 2022, loans distributed to various beneficiaries, including farmers, agricultural projects, fishermen, and beekeepers, amounted to SAR 5.3 billion (Agricultural Statistics Publication, 2022). Moreover, the Agricultural Development Fund financed 50 agricultural projects, including broiler chicken and greenhouses projects, with respective amounts of SAR 311 million and SAR 149 million (Agricultural Statistics Publication, 2022). Additionally, banks provided a total of SAR 11.5 billion in credit for agriculture and fishing activities in the same year (Agricultural Statistics Publication, 2022).

The Qassim region of Saudi Arabia is recognized as one of the country's most important agricultural hubs. Covering an area of 17,800 square kilometers, the region boasts a significant agricultural land resource, with 84,000 hectares of arable land. This agricultural richness is particularly evident in the region's prominent role in date production, with over 12,000 date farms collectively yielding approximately 370,000 tons of dates annually. Beyond dates, the Qassim region is known for its diverse agricultural output, leading in the cultivation of grapes, lemons, and oranges, contributing to a total annual agricultural production exceeding 1.22 million tons.

In addition to its crop-based agriculture, the Qassim region also supports a thriving livestock industry, with an abundance of rural lands favorable for the rearing of sheep, goats, poultry, and the renowned Saudi Arabian camels. This multifaceted agricultural landscape underscores the critical importance of the Qassim region in Saudi Arabia's overall food security and economic development.

The significance of this study lies in the need to assess the transformations witnessed by the region's agricultural areas. By comprehending the evolving landscape, policymakers and land managers can formulate strategies and controls that are in line with the vision for the Kingdom's future. Such insights and analyses are crucial for sustainable development, effective resource allocation, and the preservation of the environment.

In light of these factors, this study aims to investigate the agricultural land changes that have occurred in the Qassim region. By uncovering the historical trajectory, understanding the prevailing conditions, and elucidating the present state, this research endeavors to develop plans and regulations that align with the future objectives outlined in the Kingdom of Saudi Arabia's Vision 2030.

To accurately measure and analyze these changes, the integration of Geographic Information System (GIS) technology and Remote sensing data has emerged as a powerful approach. GIS provides a robust framework for spatial analysis and visualization, while remotely sensed data obtained from satellite imagery offers a valuable source of information on land cover and land use dynamics. By combining these methods, a comprehensive understanding of agricultural land changes and their impact on the environment can be achieved (ALfehaid and Abd-Elmoniem, 2022). It provides a regional perspective that is challenging to obtain solely through conventional ground surveys (Al-Harbi, 2010). Moreover, satellite imagery can be effectively employed for the management of agricultural resources and the analysis of trends in agricultural changes over the past three decades in the study area.

2.Statement of problem

The agricultural areas in the Qassim region of Saudi Arabia have witnessed significant changes over the past four decades, exhibiting both increases and decreases in land coverage. This dynamic nature of the agricultural lands in the region has raised the need to investigate and understand the underlying factors driving these changes.

The problem addressed in this study is the lack of comprehensive analysis on the patterns and causes of the changes that have occurred in the agricultural areas of the Qassim region during the period between 1985 and 2024. Understanding these changes is crucial for informing decision-makers and stakeholders in the agricultural sector, as it can provide valuable insights to guide the future development and management of agricultural resources in the region.

This research study aims to integrate the use of Geographic Information Systems (GIS) and remotely sensed data to systematically measure and monitor the changes in agricultural land cover within the Qassim region over the specified time period. By leveraging the capabilities of GIS and remote sensing techniques, the study will quantify the magnitude and spatial distribution of the observed changes in agricultural areas, and subsequently explore the potential drivers and factors contributing to the increase or decrease in agricultural land during this period.

3. Objectives

This research aims to investigate the dynamics of agricultural land use in the Qassim region of Saudi Arabia, focusing on the significant changes that have occurred over the past 40 years. Given the challenging agricultural conditions posed by the arid climate, limited water resources, and sandy soils, it is crucial to understand how these factors influence agricultural practices and land use. By leveraging Geographic Information Systems (GIS) and remotely sensed data, this study seeks to provide a comprehensive analysis of agricultural land changes, identify underlying patterns, and contribute to evidence-based decision-making in agricultural planning and resource management. Through this research, we aspire to support policymakers in developing effective strategies that promote sustainable agricultural development in the region.

- Assess changes in agricultural land in the Qassim region over a 40-year period (1985 to 2024).
- Analyze and identify patterns of change in agricultural land use to enhance evidence-based decision-making in agricultural planning and resource management.
- Investigate the various factors that influence changes in agricultural land use in the Qassim region.
- Equip decision-makers with evidence-based

insights to formulate effective policies and strategies for the sustainable development of the agricultural sector.

4. Literature review

This research focuses on conducting a comprehensive literature review regarding the continuous changes in vegetation cover over the past few decades, resulting from significant environmental transformations influenced by both human activities and natural factors. The review encompasses studies conducted within the study area, the Kingdom of Saudi Arabia, as well as global investigations that explore the patterns of vegetation cover changes. These changes have direct implications for land cover patterns and land use practices. Additionally, the review examines the effective techniques employed for monitoring these variables.

Remote sensing technology is widely used for monitoring land use and land cover (LU/LC) changes on a global and regional scale (Huang and Jia, 2012; Raziq et al., 2016). Combining remote sensing data with a Geographic Information System (GIS) database and expert knowledge can enhance the efficiency and effectiveness of LU/LC change detection compared to using remote sensing alone (Huang and Jia, 2012). Temporal analysis of satellite imagery, coupled with modeling techniques, provides crucial information on agricultural dynamics, urban sprawl, and land use changes (Berberoglu et al., 2009).

Numerous studies have employed advanced satellite image analysis techniques to map agriculture and crop areas within the Qassim region of Saudi Arabia and globally (Youssef et al. 2019; Vibhute and Gawali, 2012; Al-Harbi, 2010). One widely utilized approach is the Normalized Difference Vegetation Index (NDVI), which enables the monitoring of cropland and land use/land cover (LULC) changes over different time periods (Jeevalakshmi et al. 2016). Another commonly used technique, supervised classification, is employed to derive land cover types, detect deforestation and fires, assess crop production, and monitor environmental pollution (Potapov et al. 2008). Numerous algorithms, including parallel pipeline, maximum likelihood method, fuzzy-rule based techniques, artificial neural networks, and support vector machines, are applied in supervised classification (Richards, 2006).

In recent years, the use of remote sensing technology and Geographic Information Systems (GIS) has gained traction in monitoring changes in agricultural areas. A notable study examined the Al-Qassim region over a span of 47 years, divided into eight periods from 1973 to 2020. This research analyzed the distribution of agricultural lands, considering both natural and human factors affecting these changes. Relying on satellite data from the open-source Landsat series, along with topographic, soil, and aquifer maps, the study employed a descriptive analytical method to digitally process and analyze satellite images. Various classification methods, including controlled classification and NDVI, were utilized to extract agricultural areas, ultimately concluding that the Al-Qassim region experienced significant fluctuations in agricultural land, marked by periods of both expansion and decline (Bahamdan and Jamil, 2022).

To assess the changes in agricultural land cover in the Qassim region over the past few decades (1985-2024), this study will obtain satellite imagery covering the study period. This includes multispectral Landsat images. Offers updated data and a thorough assessment of agricultural development projects. Given the crucial role of agriculture in the sustainable development process and the development goals outlined by the Kingdom of Saudi Arabia for Vision 2030, this study is particularly relevant, even if similar topics have been addressed previously.

Continuous assessment of agricultural conditions is essential to ensure the success of development initiatives in this vital sector. While previous studies have focused on the same region, they do not diminish the importance of ongoing research. Maintaining a focus on agricultural sustainability is critical for supporting progress and aligning with national objectives.

By integrating the spatial dimension of agriculture into policies, GIS technology has the potential to enhance agriculture sustainability in the Qassim region (Almalki et al. 2022). GIS provides valuable insights into the spatial distribution of agricultural resources, enabling informed decision-making regarding land use, resource allocation, and environmental management. Additionally, GIS facilitates precise agricultural practices by allowing farmers to optimize inputs and minimize environmental impacts.

Historically, various techniques have been utilized to detect land use/land cover changes using remote sensing data. Some studies have focused on using remote sensing techniques specifically for monitoring vegetation cover changes. For instance, Cui et al. (2013) employed Landsat image series to quantify vegetation changes in a semi-arid system. Other studies have integrated remotely sensed data with GIS data, such as slope, topography, and land use, to gain a more comprehensive understanding of land cover transformations (Liping et al. 2018; Alqurashi and Kumar, 2013; MohanRajan et al. 2020).

The use of multispectral and hyperspectral data has proven to be advantageous in monitoring and mapping agricultural land changes. One widely utilized approach is the normalized difference vegetation index (NDVI), which enables the monitoring of cropland and land use/land cover (LULC) changes over different time periods (Jeevalakshmi et al. 2016). Morawitz et al. (2006) conducted a study in Central Puget Sound, utilizing the NDVI to assess changes in vegetative land cover, finding that an increase in NDVI values was primarily driven by green-up resulting from logging activities, human use and development, and seasonal weather patterns.

To gain a comprehensive understanding of changes in agricultural land in the Qassim region, the integration of Geographic Information Systems (GIS) and remotely sensed data becomes crucial. Jeevalakshmi et al. (2016) examined the applicability of the Normalized Difference Vegetation Index (NDVI) in mapping land cover characteristics in the Tirupati Region of Chittoor District, Andhra Pradesh, India. The research focused on distinguishing the vegetation indexes (NDVI) of different land cover types using supervised classification techniques and Landsat images for three distinct seasons in the target region.

Arid and semi-arid lands are characterized by limited water resources and fragile vegetation cover, making the monitoring of vegetation changes crucial. The scarcity and sensitivity of plant cover in these regions necessitate early detection and assessment of vegetation cover changes at local and regional scales to prevent potential biodiversity loss and impacts on land productivity.

Remote sensing data, particularly satellite images, have proven to be valuable tools for monitoring and mapping vegetation cover changes. This data can be obtained using satellite-based and aircraft-based sensors. Integrating remotely sensed images with GIS tools enhances the accuracy of monitoring and mapping techniques.

A previous study conducted by Youssef et al. (2019) utilized multispectral and multi-temporal satellite data to investigate the spatial and temporal changes in agriculture activities within the Al-Jouf region of the Kingdom of Saudi Arabia (KSA). The primary objective of the study was to delineate the expansion of agriculture from 1987 to 2017 by employing the Normalized Difference Vegetation Index (NDVI) extracted from Landsat images within a Geographic Information System (GIS) framework. The study's findings highlighted significant environmental challenges arising from unregulated agricultural activities in the region. Notably, the uncontrolled practices led to the substantial depletion of the groundwater table. Additionally, the sudden emergence of sinkholes, without any prior warning signs, was observed as an adverse consequence of these activities. The paper cautioned that in the absence of regulated restrictions imposed by decision-makers, these environmental impacts would likely exacerbate in the future.

Tewabe and Adametie (2020) emphasized the importance of land use and land cover (LULC) change detection using remote sensing for decision support systems. Their study examined LULC changes in the Tana Basin, Ethiopia, over a 32-year period, utilizing Landsat TM images from 1986, 2002, and 2018, with a resolution of 30 meters. The analysis was carried out using ENVI and ArcGIS software, categorizing land into six classes: water bodies, bushland, grassland, forestland, cultivated land, and residential areas.

Among various studies, the accurate measurement of agricultural land change is of paramount importance in understanding the dynamics of land use and its implications for food security, resource management, and sustainable development. Remote sensing technology, combined with GIS, offers an effective means to monitor and quantify changes in agricultural land over time. The NDVI index has proven to be a valuable tool for assessing vegetation health and dynamics.

For instance, Abdelrahman et al. (2016) utilized remote sensing data, including NDVI and GIS techniques, to assess land suitability and capability for agriculture in the Chamarajanagar district of India. The researchers emphasized the importance of employing NDVI to evaluate vegetation health and monitor changes in agricultural land over time. Similarly, Melyukhina (2011) explored the application of remote sensing, including NDVI analysis, and GIS methods to monitor the changes in agricultural land use in Krasnodar Krai, Russia, focusing on understanding the dynamics of land use and its implications for food security and sustainable development. Additionally, Bégué et al. (2010) demonstrated the use of NDVI derived from remote sensing data to monitor the spatio-temporal variability of sugarcane fields, highlighting the effectiveness of NDVI in assessing vegetation health and dynamics, which is crucial for understanding land use changes and their implications for food production and resource management.

5. Study area

The Qassim region is one of the 13 administrative regions of the Kingdom of Saudi Arabia. It is strategically located at the center of the country and the Arabian Peninsula, spanning latitudes 24° 41′ N to 27° 19′ N and longitudes 41° 38′ E to 44° 50′ E (Figure 1). With an elevation ranging from 600 to 750 meters above sea level, Qassim lies within the solar belt, experiencing favorable climatic conditions for agricultural activities.

The Qassim region of Saudi Arabia has experienced significant changes in land use patterns over the past few decades, particularly in the agricultural sector. These changes have been driven by various factors such as population growth, urbanization, and evolving agricultural practices. Understanding the dynamics of agricultural land changes is crucial for effective land management, sustainable development, and environmental conservation in the region. (Un-habitat. 2020).

Additionally, Qassim benefits from an average annual rainfall of 100 mm, surpassing the national average of 59 mm. Relatively low rainfall rates in the region supplement crop growth and provide an additional source of water for agricultural purposes (Al-Daghiri, 2019).

Qassim is bordered by the Riyadh region to the south, the Eastern region and part of Riyadh to the east, the Hail region to the north, and the Medina region to the west (GASTAT, 2023). Its geographical location positions it as a key hub within Saudi Arabia, covering 69840.1 km2, which is equal to 3.7% of total area of the Kingdom.

Data source: (Qassem Municipality, (2023).

Figure 1: Location of the study area.

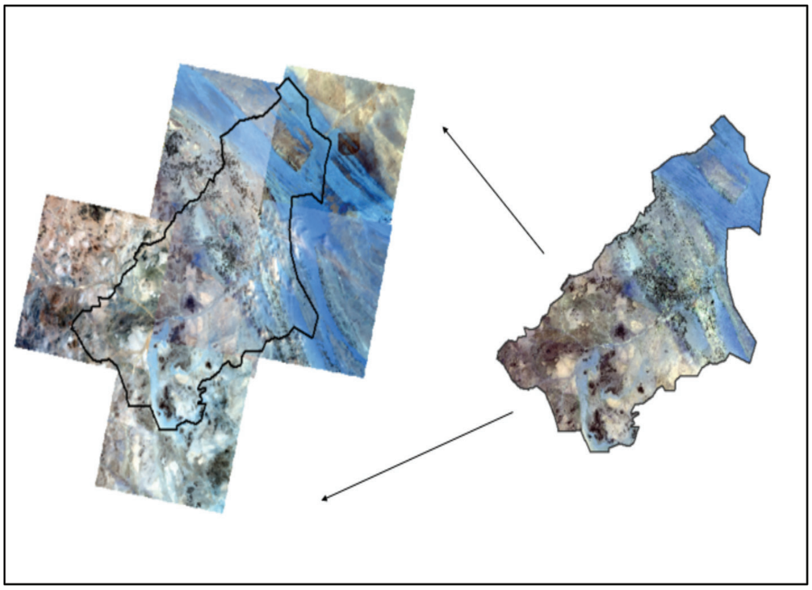
Qassim is situated at an elevation average of 742.44 meters above sea level, and experiences a Subtropical desert climate (Classification: BWh). This type of climate is characterized by hot and arid conditions with little precipitation. Qassim averages approximately 123.6 millimeters of rainfall annually. This relatively low amount of precipitation is distributed over 24.63 rainy days, accounting for approximately 6.75% of the year (mainly from October to May) (NCM,2023).

The climate in Qassim is characterized by its arid conditions, high temperatures, and limited rainfall. These factors, along with the broader context of Saudi Arabia being one of the driest regions globally, significantly shape the environmental and agricultural conditions in the study area. Moreover, the maximum daily temperatures in the study area exceed 33.2°C during the summer months and the minimum daily temperatures exceed 17.6°C during the winter. (NCM,2023).

The region's reputation as the country's "food basket" is primarily due to its remarkable agricultural productivity. It stands as the second-largest agricultural producer and boasts the second highest number of palm trees, approximately 8 million, in the country (Alharbi et al., 2022). Moreover, it plays a pivotal role in global date production, contributing an annual estimate of 370,000 tons. The region hosts a remarkable network of 12,000 modern farms, further emphasizing its agricultural prominence (Monsha'at, 2023). One of the key factors behind this productivity is the abundance of groundwater resources in the region. The availability of groundwater supports irrigation activities, enabling sustained agricultural production. (UN.2021)

6. Data and Methodology

The study utilized data from Landsat-4/5 (1985), Landsat-7 Enhanced Thematic Mapper Plus (ETM+) (2000), and Landsat-8 Operational Land Imager (OLI) (2015 and 2024) processed through Google Earth Engine. This cloud-based platform enabled the processing of a vast amount of geospatial data, including the entire catalog of Landsat images. Digital data from the Qassim Municipality was relied upon to extract the spatial boundaries of the Qassim region from the collected data (Figure 2).



Data source: Landsat images for 2024 and Qassem Municipality (2023).

Figure 2: Raw data from Qassim Municipality showing initial spatial boundaries.

Data collection occurred every fifteen years prior to 2024 during the spring season, which is characterized by the highest vegetation presence. This temporal resolution aimed to capture the impacts of various modern policy instruments on the agricultural sector. Following established methodologies, the study employed a field delineation framework that utilized an annual maximum dissimilarity vegetation index (NDVI) map. The next figure (Figure 3) explains the methodology plan of the research.

The NDVI index has proven to be a valuable tool for assessing vegetation health and dynamics. Its application in measuring agricultural land change during the study period in the Qassim region plays a pivotal role in capturing the spatiotemporal patterns and trends of agricultural activities This NDVI map was derived from the maximum per-pixel normalized NDVI values obtained from Landsat images in each target year. the NDVI index emerges as a crucial tool for assessing and quantifying agricultural land changes. NDVI was computed as

NDVI = (*NIR−RED*) / (*NIR+RED*)

where NIR represents the near-infrared spectral band reflectance and RED represents the red spectral band reflectance.

The NDVI formula operates on the principle that healthy vegetation exhibits higher reflectance in the near-infrared portion of the electromagnetic spectrum and lower reflectance in the red portion. By taking the difference between the near-infrared and red reflectance values and normalizing it with their sum, the resulting NDVI value ranges from -1 to +1. Higher positive values indicate dense and healthy vegetation, while lower values or negative values correspond to bare soil, water bodies, or non-vegetated areas.

To further substantiate the observed trends in agricultural land expansion, a comparative analysis of vegetation index values was conducted across four time periods - 1985, 2000, 2015, and 2024. By examining the positive values of the vegetation index, which represent the extent and health of vegetation cover, a clear pattern emerges (Figure 4).

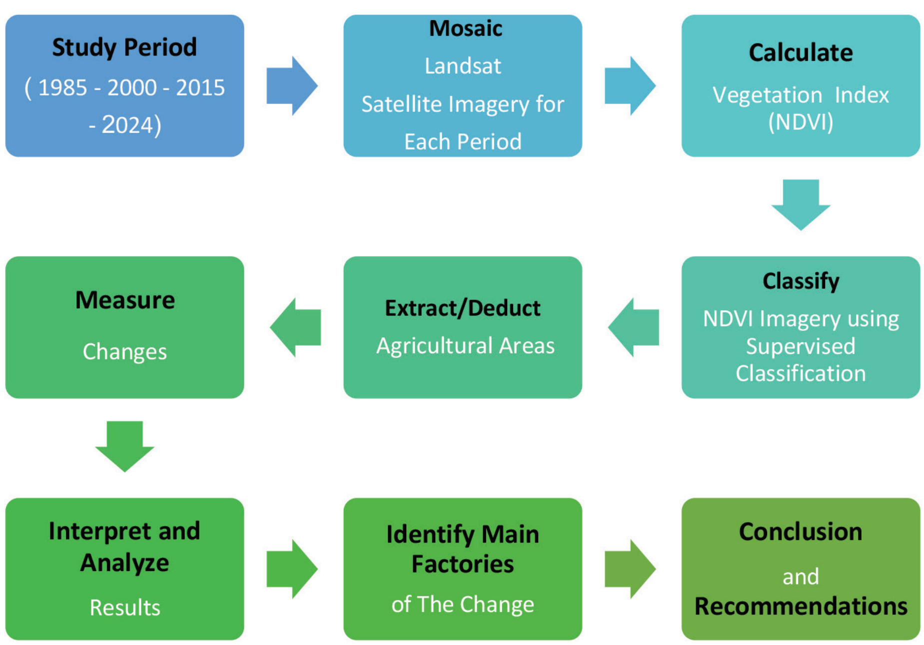
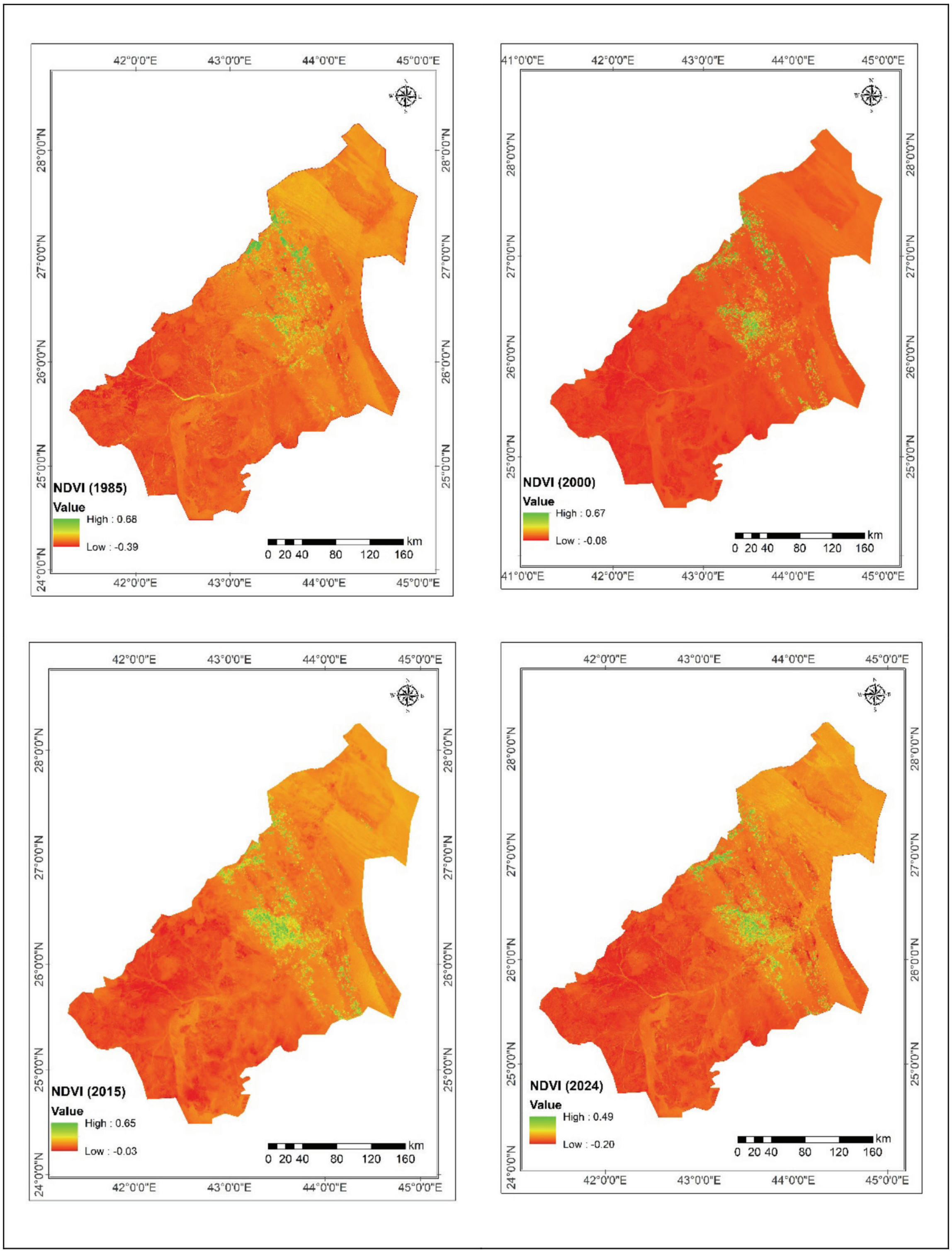


Figure 3: Methodology plan.



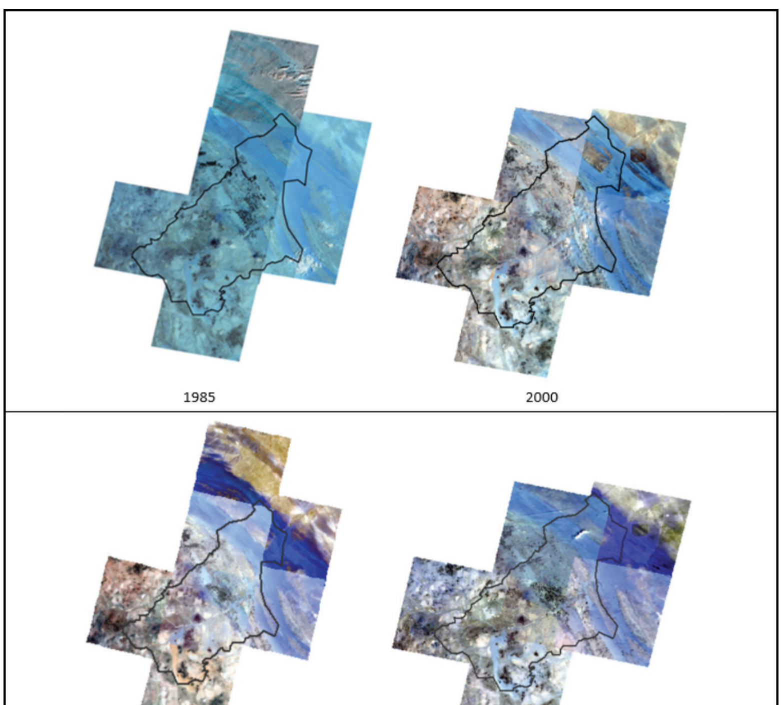
Data source: USGS (United States Geological Survey). (Landsat satellite imagery: 1985, 2000, 2015, 2024). USGS Earth Explorer. https://earthexplorer.usgs.gov/

Figure 4: NDVI index for the study period (1985 to 2024).

The highest positive vegetation index value of 0.68 was recorded in 1985, indicating robust vegetation conditions at that time. This was followed by the year 2000, which also exhibited a relatively high positive vegetation index value of 0.67, suggesting healthy vegetation cover. In contrast, the lowest positive vegetation index value of 0.49 was observed in 2024, pointing to a decline in the overall health and vigor of the vegetation in more recent years. However, it is important to note that the vegetation index values do not directly measure changes in the overall land area under agricultural use. They primarily reflect the biophysical condition and vigor of the vegetation, rather than the spatial extent of the agricultural lands. The vegetation index analysis provides additional insights to support the interpretations drawn from the land use and land cover data.

To cover the entire Qassim region, which is extensive and spans multiple satellite images, a process was undertaken to create an image mosaic (Figure 5). This involved merging spectral bands and combining multiple satellite snapshots from different years. Specifically, seven snapshots were overlapped for the years 1985 and 2015, while six snapshots were overlapped for the years 2000, and 2024.

For processing the satellite images, the ERDAS Imagine 2014 program was utilized. Several steps were conducted, including merging the spectral bands and combining multiple snapshots for each year using an image mosaic technique. Careful attention was given to accurately delineate the boundaries of the study area. Additionally, specific methods were employed to extract agricultural areas, such as applying the NDVI vegetation index then classifying a single category (index image). These techniques facilitated the calculation of the agricultural land area. Furthermore, the extracted results were converted into Shapefile format using the ArcGIS program.

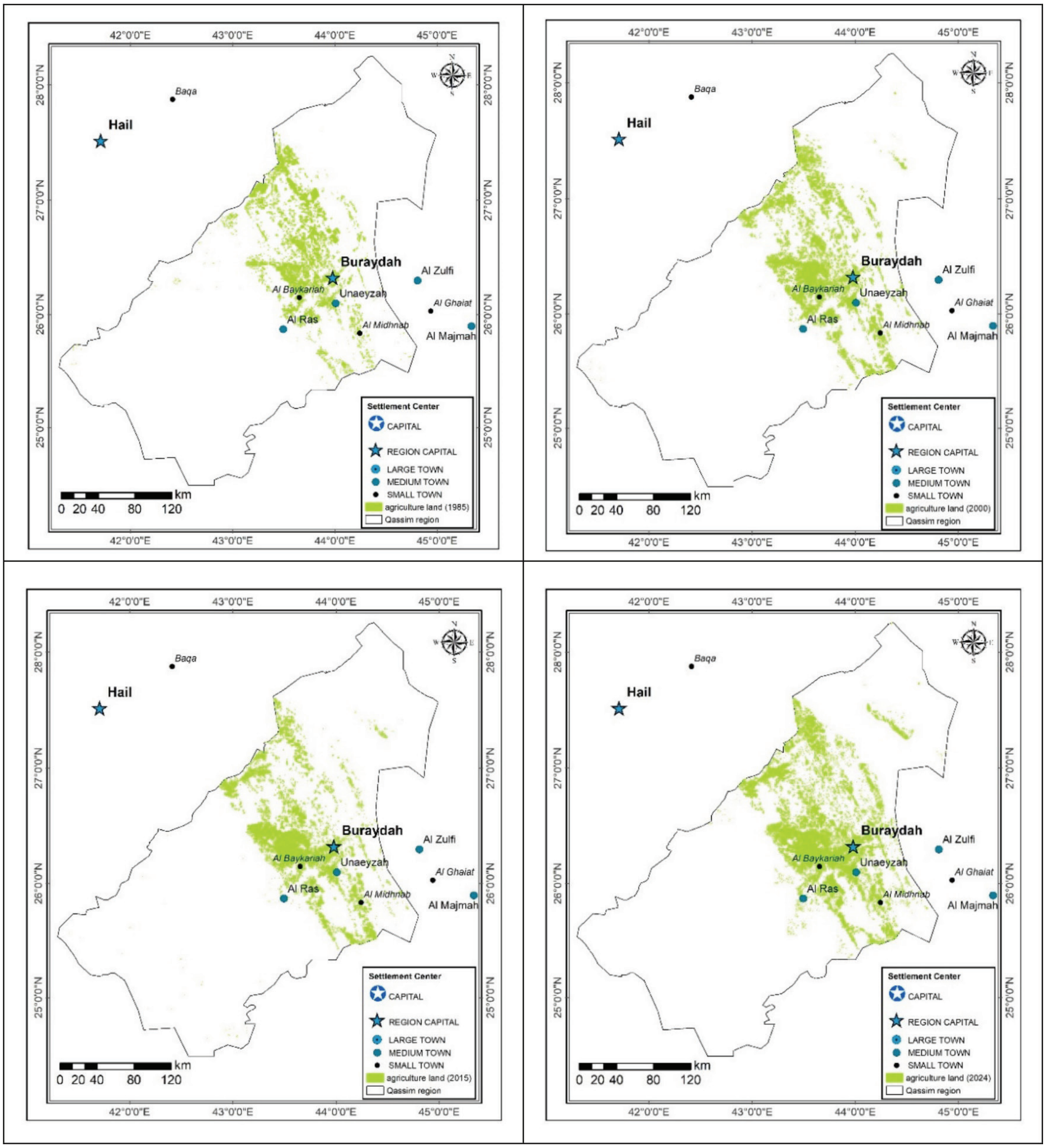


Data source: USGS (United States Geological Survey). (Landsat satellite imagery: 1985, 2000, 2015, 2024). USGS Earth Explorer. https://earthexplorer.usgs.gov/

Figure 5: Image Mosaic of the Qassim Region for the Years 1985, 2000, 2015, and 2024

6.1 Analysis of Agricultural Land Changes

The analysis of agricultural land changes in the Qassim region of Saudi Arabia was conducted using four satellite images acquired in 1985, 2000, 2015, and 2024. By classifying the land cover in each of these images, it was possible to extract and measure the area of agricultural lands over the 39-year period (Figure 6) (Table 1). below.



Data source: Landsat images analyzed during the study period using ArcMap.

Figure 6: Distribution of agriculture areas during the study period.

Table1: The change in agriculture areas during the study period

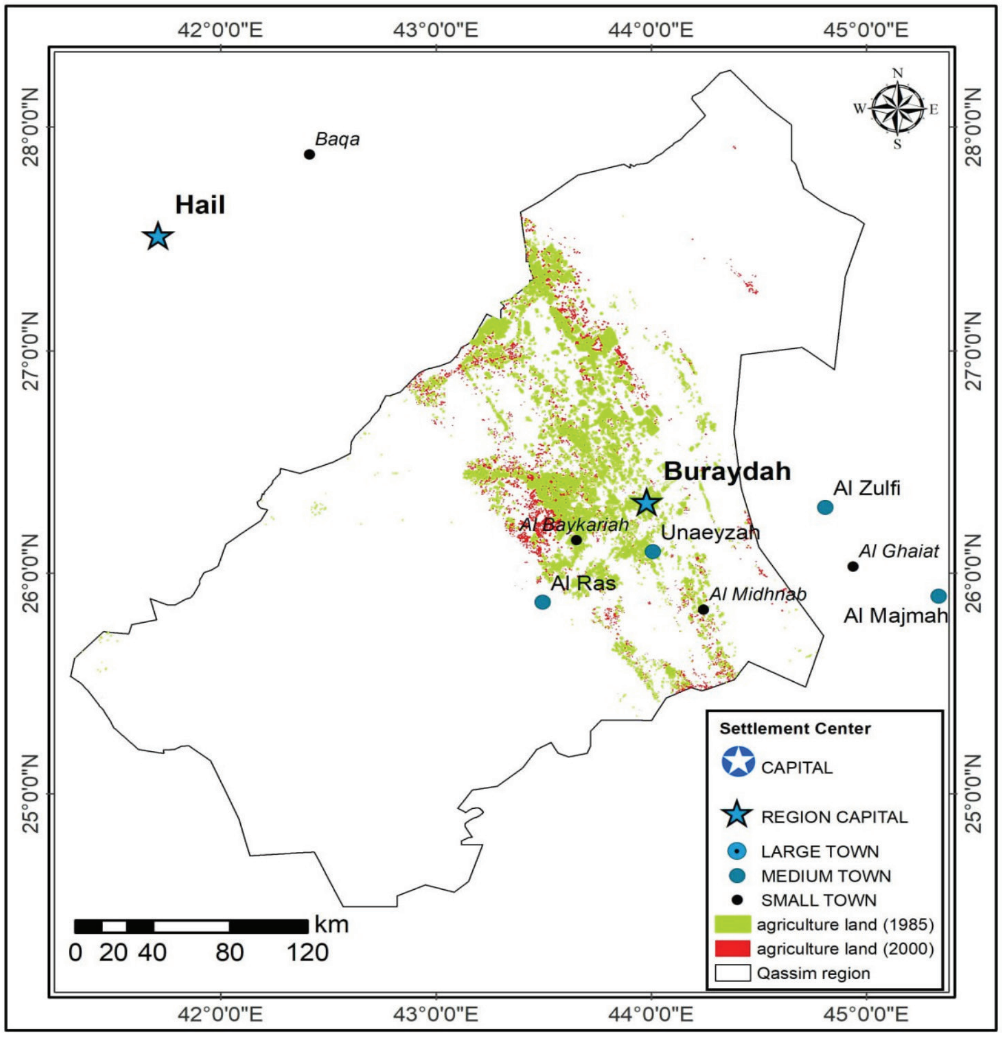
Year	Agriculture land (km²)	Change (%)
1985	1425.98	-
2000	2235.82	56.8
2015	2131.27	-4.68
2024	2438.16	14.4

The results show that the total agricultural land area in the region increased from 1425.82 square kilometers in 1985 to 2235.82 square kilometers in 2000, representing an increase of 56.8% over this 15-year period. However, the agricultural land area then decreased to 2131.27 square kilometers by 2015, a decline of 4.68% from the 2000 levels. The most recent 2024 data indicates an increase in agricultural lands to 2438.16 square kilometers, a 14.4% increase compared to 2015. These findings suggest that while agricultural development expanded significantly in the Qassim region between 1985 and 2000, a slight decline occurred in the 15 years leading up to 2015, followed by a substantial recovery in agricultural lands by 2024. Ongoing monitoring and analysis of these land cover trends will be essential for sustainable agricultural planning and management in the region.

6.2 Factors Influencing Agricultural Land Changes

●Reasons for the Increase in Agricultural Areas (1985-2000).

The significant expansion of agricultural lands in the Qassim region during the 1985 to 2000 period can be attributed to the Kingdom's implementation of a series of comprehensive development plans, namely the Fourth, Fifth, and Sixth Development Plans (Ministry of Economy and Planning, 1985; Ministry of Economy and Planning, 1990; Ministry of Economy and Planning, 1995). These plans placed a strong emphasis on increasing government support and incentives for farmers. Notably, the number of agricultural projects evaluated and supported during this time period reached 3,267. The government actively sought to promote agricultural development by distributing additional uncultivated lands to farmers and providing them with substantial support for agricultural production requirements. This included the provision of financial assistance for the procurement of agricultural machinery and equipment, as well as direct incentives for marketing and purchasing. The government also implemented comprehensive insurance schemes to protect agricultural producers. According to official reports, the level of government support for farmers during this period was, on average, one and a quarter time higher than the support provided in the subsequent years. These targeted policy interventions and financial incentives which were instrumental in driving the 56.8% expansion of the agricultural land area in the Qassim region between 1985 and 2000 (Figure7).



Data source: Landsat images analyzed for the years 1985 and 2000 using ArcMap.

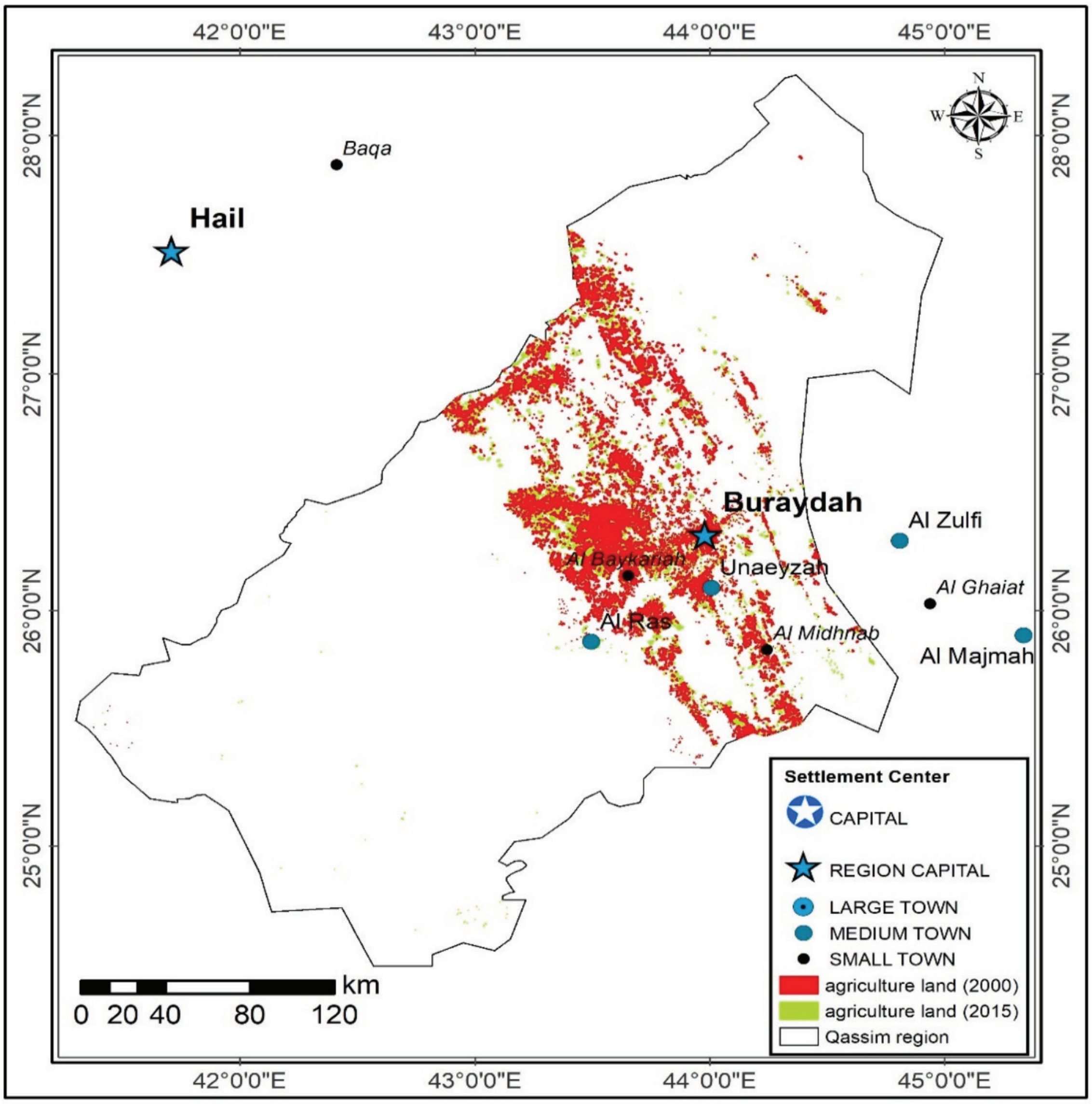
Figure 7: Agricultural Areas (1985-2000).

These targeted policy interventions and financial incentives were instrumental in driving the 56.8% expansion of the agricultural land area in the Qassim region between 1985 and 2000. Spatial analysis further reveals that the increase in agricultural lands was particularly concentrated in the areas surrounding the towns of Al Baykariah and Al Midhnab during this period.

● Factors Contributing to the Decline in Agricultural Lands (2000-2015).

During the period between 2000 and 2015, the Kingdom of Saudi Arabia underwent a significant shift in its water policy approach (Alotaibi et al., 2023). The government implemented the National Water Plan, which aimed to rationalize water-intensive agricultural practices and limit further land reclamation efforts. The primary objective was to strike a balance between water conservation and food security priorities. As a result of this policy shift, the availability of land for agricultural expansion became increasingly constrained.

The following figure (Figure 8) shows the distribution of agricultural areas for both 2000 and 2015, where it is clear that agricultural land generally decreased in the northern parts of the Qassim region, specifically the area northwest of the city of Al Baykariah.



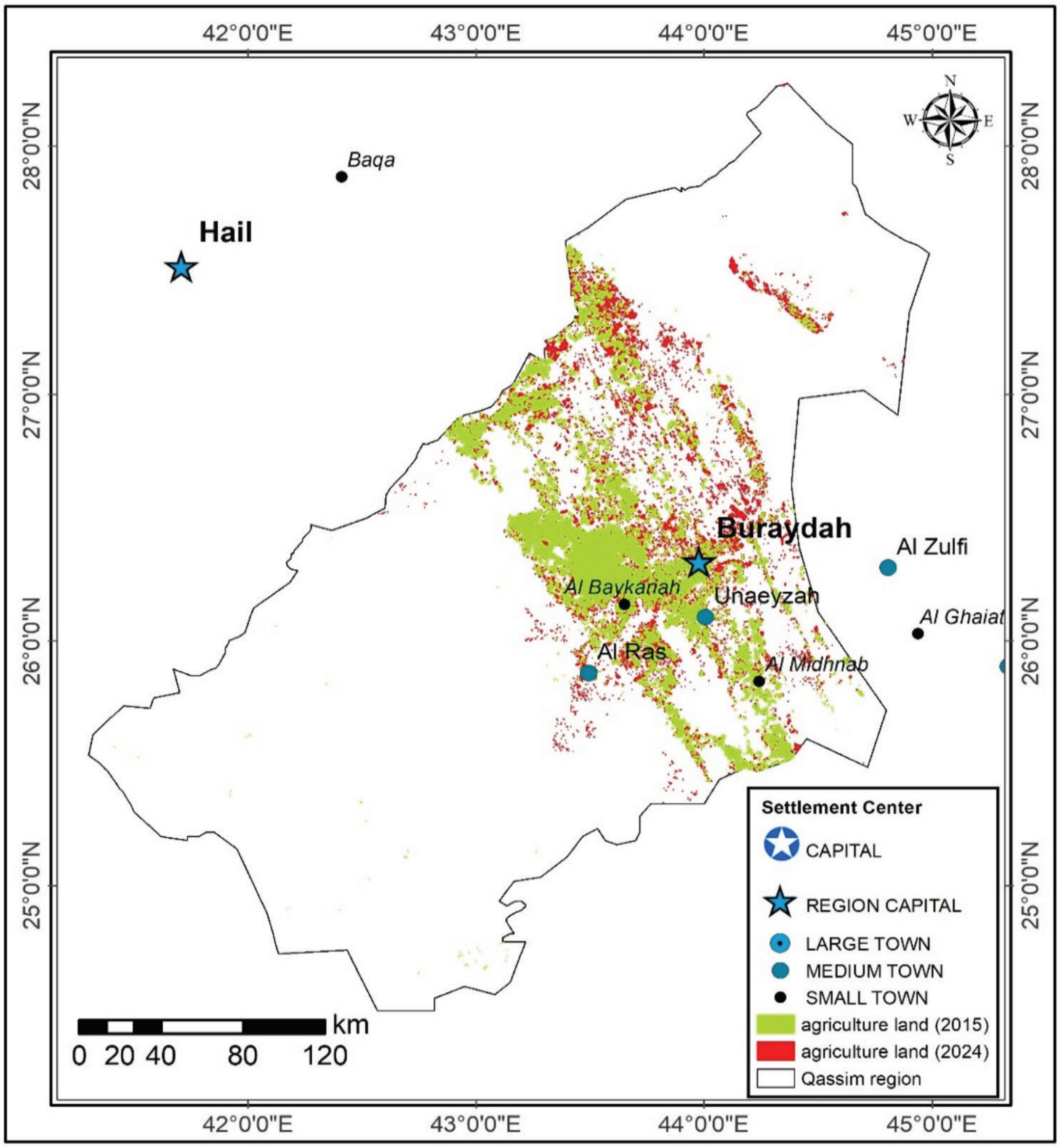
Data source: Landsat images analyzed for the years 2000 and 2015 using ArcMap.

Figure 8: Agricultural Areas (2000-2015).

The policy focus on water management and sustainability led to a reduction in the overall land area dedicated to agriculture during this period. Consequently, the spatial extent of cultivated lands in the Qassim region saw a notable decline between 2000 and 2015, as the government sought to align agricultural development with the country's evolving water resource management strategy, where the area of agricultural land decreased by 4.68% of the total area of agricultural land.

- Resurgence in Agricultural Lands (2015-2024)

The most recent data from 2024 indicates a notable increase in agricultural lands within the Qassim region, reaching an area of 2,438.16 square kilometers, with a 14.4% rise compared to 2015. This reversal in the previous declining trend can be largely attributed to the 2030 strategic framework and policy objectives adopted by the Kingdom of Saudi Arabia during this period (National Water Strategy 2030, 2018). Five key strategic priorities were outlined, which have collectively contributed to the expansion of agricultural lands (Figure 9). These include: 1) protecting and improving the sustainability of natural resources to achieve water security; 2) enhancing food security during both normal and emergency conditions; 3) creating job opportunities and supporting the livelihoods of small farmers; 4) improving production efficiency, competitiveness, and the overall investment environment for agricultural products and services; and 5) enhancing the health and safety of plants and animals while ensuring product safety. Additionally, the Agricultural Development Fund has played a crucial role in promoting sustainable development through the rational management of the Kingdom's natural resources, the application of modern agricultural technologies, and the support of both local and international agricultural investments to bolster food security. These strategic initiatives, combined with targeted efforts to rationalize water use and leverage non-traditional water sources, have collectively facilitated growth in agricultural lands observed in the Qassim region between 2015 and 2024.



Data source: Landsat images analyzed for the years 2015 and 2024 using ArcMap.

Figure 9: Agricultural Areas (2015-2024).

Notably, this increase in agricultural lands has been spatially distributed, extending toward the south, north, and northeast of the region, as depicted in the accompanying figure (Figure 9).

7. Results and Discussion

Given Qassim's significance as a highly productive agricultural region, remote sensing techniques offer valuable tools for monitoring land use changes. Satellite imagery, with its wide coverage and consistent observational parameters, provides a comprehensive and regional perspective that complements conventional ground surveys. These techniques enable the assessment of spatial locations, extents, and cropping patterns in the region, contributing to a deeper understanding of agricultural dynamics.

The Qassim region in Saudi Arabia stands out as a highly productive agricultural area, earning its reputation as the country's "food basket." The availability of groundwater resources, along with a relatively higher annual rainfall compared to the national average, contribute to the region's agricultural success. The cultivation of dates, other fruits, wheat, and vegetables, coupled with the presence of a prominent cattle market, solidify Qassim's agricultural significance.

One of the key challenges in measuring agricultural land change is differentiating farmed areas from other land covers, such as barren land or urban areas. The NDVI index aids in this distinction by capturing the unique spectral characteristics of healthy vegetation. By setting appropriate thresholds, agricultural land can be accurately identified and delineated, allowing for precise quantification of changes in its extent over time.

The results of this study show that the total agricultural land area in the Qassim region increased by 56.8% from 1425.82 square kilometers in 1985 to 2235.82 square kilometers in 2000. However, the agricultural land area then decreased by 4.68% to 2131.27 square kilometers by 2015. The most recent data from 2024 indicates an increase in agricultural lands to 2438.16 square kilometers, a 14.4% increase compared to 2015.

8. Conclusion

In conclusion, the integration of GIS and remote sensing technologies in agriculture holds immense importance for improving evidence-informed policy and practice. The applications of GIS in various areas of agriculture provide valuable insights and tools to enhance sustainability, monitor and manage resources, and make informed decisions. However, there is a need for further research and implementation, particularly in underrepresented regions, to fully realize the potential of GIS in promoting sustainable agri-food systems.

9. Recommendations:

1. Continued monitoring and analysis of the land cover trends in the Qassim region is essential for sustainable agricultural planning and management.
2. Policies and initiatives should focus on promoting the sustainable management of natural resources, particularly water, to ensure a balance between water conservation and food security priorities.
3. Investments in modern agricultural technologies and the facilitation of local and international agricultural investments can further support the expansion and efficiency of agricultural lands in the region.
4. Strategies should be developed to address the spatial distribution of agricultural land

expansion and ensure equitable and sustainable development across the Qassim region.

5. Ongoing research and analysis are needed to further explore the underlying factors driving the changes in agricultural land dynamics within the Qassim region, from the decline observed during 2000-2015 to the subsequent increase documented in the 2024 data.

References:

- Al-Daghiri, A. A. (2019). The physical geography of the Qassim region: Saudi Arabia. Dar Al-Assar Al-Alami for Publishing and Distribution, and the Arab Society Library for Publishing and Distribution, Amman, Jordan.
- ALfehaid, S., Abdelmageed, A., & Abd-Elmoniem, E. (2022). Effect of Chemical, Organic and Bio Fertilizers on Growth, Yield and Quality of Cucumber Plant (Cucumis sativus L.) grown under Greenhouse Conditions. Journal of Sohag Agriscience (JSAS), 7(1), 28-40. doi: 10.21608/jsasj.2022.245699
- Alharbi M, Alharbi F, AlTuwayjiri A, Alharbi Y, Alhofair Y, Alanazi A, AlJlajle F, Khalil R, Al-Wutayd O. (2022). Assessment of health-related quality of life in patients with heart failure: a cross-sectional study in Saudi Arabia. Health Qual Life Outcomes. 30; (1), 20:128.
- Al-Harbi, K.M.. (2010). Monitoring of agricultural area trend in Tabuk region – Saudi Arabia using Landsat TM and SPOT data. The Egyptian Journal of Remote Sensing and Space Science. 13. 37-42. 10.1016/j.ejrs.2010.07.005.
- Almalki, Raid, Mehdi Khaki, Patricia M. Saco, and Jose F. Rodriguez. (2022). "Monitoring and Mapping Vegetation Cover Changes in Arid and Semi-Arid Areas Using Remote Sensing Technology: A Review" Remote Sensing 14, no. 20: 5143. https://doi.org/10.3390/rs14205143
- Alotaibi, Bader Alhafi, Mirza Barjees Baig, Mohamed M. M. Najim, Ashfaq Ahmad Shah, and Yosef A. Alamri. (2023) . "Water Scarcity Management to Ensure Food Scarcity through Sustainable Water Resources Management in Saudi Arabia" Sustainability 15, no. 13: 10648. https://doi.org/10.3390/su151310648
- Alqurashi, A.; Kumar, L. (2013). Investigating the use of remote sensing and GIS techniques to detect land use and land cover change: A review. Adv. Remote Sens. 2, 193–204.
- Al-Wabel, Mohammad & Sallam, Abdelazeem & Usman, Adel & Ahmad, Mahtab & El-Naggar, Ahmed & EL-Saeid, Mohamed & Al-Faraj, Abdulelah & El-Enazi, Khaled & Alromian, Fahad. (2017). Trace metal levels, sources, and ecological risk assessment in a densely agricultural area from Saudi Arabia. Environmental Monitoring and Assessment. 189. 10.1007/s10661-017-5919-1.
- Bahamdan, Nada, Jamil, Abdul Hamid. (2022) Monitoring the change in agricultural areas in the Qassim region (Kingdom of Saudi Arabia) using remote sensing techniques and geographic information systems 1973 - 2020 AD. Journal of Nature, Life and Applied Sciences Volume (6), Issue (4): December 30, 2022, pp: 1 – 25
- Bégué, Agnès & Lebourgeois, Valentine & Bappel, Eric & Todoroff, Pierre & Pellegrino, Anne & Baillarin, Florence & Siegmund, Bernard. (2010). Spatio-temporal variability of sugarcane fields and recommendations for yield forecast using NDVI. International Journal of Remote Sensing. 31. 5391–5407. 10.1080/01431160903349057.
- Berberoglu, S., Satir, O., & Atkinson, P. M. (2009). Mapping percentage tree cover from Envisat MERIS data using linear and nonlinear techniques. International Journal of Remote Sensing, 30(18), 4747–4766. https://doi.org/10.1080/01431160802660554

- Buraidah City Profle. M Ministry of Municipal and Rural Afairs. United Nations Human Settlements Programme (UN-Habitat). ISBN: 978-6038279-03-8. 2019. https://unhabitat.org/sites/default/fles/2020/04/buraidah.pdf. Accessed 11 Nov 2021.
- Cui, X.; Gibbes, C.; Southworth, J.; Waylen, P.(2013). Using remote sensing to quantify vegetation change and ecological resilience in a semi-arid system. Land , 2, 108–130.
- FAO. (2022). World Food and Agriculture – Statistical Yearbook 2022. Rome. https://doi.org/10.4060/cc2211en
- General Authority for Statistics. (2022). Agricultural statistics publication. https://www.stats.gov.sa/en/1176
- Huang, Zhi & Jia, Xiuping. (2012). Integrating remotely sensed data, GIS and expert knowledge to update object-based land use/land cover information. International Journal of Remote Sensing. 33. 905-921. 10.1080/01431161.2010.536182.
- International Food Policy Research Institute (IFPRI). (2017). Global Food Policy Report; IFPRI: Washington, DC, USA; Available online: http://www.Ifpri.Org/publication/2017-global-food-policy-report (accessed on 12 October 2017).
- Jeevalakshmi, D.; Reddy, S.N.; Manikiam, B. (2016) Land cover classification based on NDVI using LANDSAT8 time series: A case study Tirupati region. In Proceedings of the International Conference on Communication and Signal Processing (ICCSP), Chennai, India, 6–8 April 2016; pp. 1332–1335.
- Liping, C.; Yujun, S.; Saeed, S.(2018). Monitoring and predicting land use and land cover changes using remote sensing and GIS techniques—A case study of a hilly area, Jiangle, China. PLoS ONE 2018, 13, e0200493.
- Ministry of Economy and Planning. Fifth Development Plan 1990–1995; Ministry of Economy and Planning: Riyadh, Saudi Arabia, 1990.
- Ministry of Economy and Planning. Fourth Development Plan 1985–1990; Ministry of Economy and Planning: Riyadh, Saudi Arabia, 1985.
- Ministry of Economy and Planning. Sixth Development Plan 1995–2000; Ministry of Economy and Planning: Riyadh, Saudi Arabia, 1995.
- Ministry of Environment, Water and Agriculture. (2018). [National Water Strategy 2030]. https://www.mewa.gov.sa
- MohanRajan, S.N.; Loganathan, A.; Manoharan, P. (2020). Survey on Land Use/Land Cover (LU/LC) change analysis in remote sensing and GIS environment: Techniques and Challenges. Environ. Sci. Pollut. Res. 27, 29900–29926.
- Monsha'at. (2023). SME Monitor Monsha'at Quarterly Report Q3 2023. Retrieved from https://www.monshaat.gov.sa/sites/default/files/2023-11/EN%20Monsha%27at%20Q3%20SME%20Monitor_0.pdf .
- Morawitz, D.F.; Blewett, T.M.; Cohen, A.; Alberti, M. (2006) Using NDVI to Assess Vegetative Land Cover Change in Central Puget Sound. Environ. Monit. Assess. 114, 85–106.
- Potapov, P.; Hansen, M.C.; Stehman, S.V.; Loveland, T.R.; Pittman, K. (2008). Combining MODIS and Landsat imagery to estimate and map boreal forest cover loss. Remote Sens. Environ. 112, 3708–3719.
- Qassim Municipality, 2023. https://www.qassim.gov.sa/
- Raziq, A.; Xu, A.; Li, Y.; Zhao, Q. (2016). Monitoring of land use/land cover changes and urban sprawl in Peshawar City in Khyber Pakhtunkhwa: An application of geo-information techniques using of multi-temporal satellite data. J. Remote Sens. 5, 174.

- Richards, J.A.; Jia, X. Remote Sensing Digital Image Analysis: An Introduction. (2006), 4th ed.; Springer: Secaucus, NJ, USA; p. 263.

- Stavi, I., Roque de Pinho, J., Paschalidou, A. K., Adamo, S. B., Galvin, K., de Sherbinin, A., Even, T., Heaviside, C., & van der Geest, K. (2022). Food security among dryland pastoralists and agropastoralists: The climate, land-use change, and population dynamics nexus. The Anthropocene Review, 9(3), 299-323. https://doi.org/10.1177/20530196211007512

- Tewabe, Dires & Adametie, Temesgen. (2020). Assessing land use and land cover change detection using remote sensing in the Lake Tana Basin, Northwest Ethiopia. Cogent Environmental Science. 6. 10.1080/23311843.2020.1778998.

- The General Authority for Statistics, (2023)

- The National Center for Meteorology (NCM). (2023). https://www.spa.gov.sa/

- Un-habitat. (2020). State of Urban Development in Al-Qassim (2020) Key Statistics in 13 Urban Areas. https://unhabitat.org/sites/default/files/2021/08/state_of_urban_development_in_al-qassim.pdf

- Vibhute, A.D.; Gawali, B.W. Analysis and Modeling of Agricultural Land use using Remote Sensing and Geographic Information System: A Review. Int. J. Eng. Res. Appl. 2012, 3, 81–91.

- Youssef, Ahmed M., Mazen M. Abu Abdullah, Biswajeet Pradhan, and Ahmed F. D. Gaber. (2019). "Agriculture Sprawl Assessment Using Multi-Temporal Remote Sensing Images and Its Environmental Impact; Al-Jouf, KSA" Sustainability 11, no. 15: 4177. https://doi.org/10.3390/su11154177

- Yu, J.; Wu, J. (2018). The Sustainability of Agricultural Development in China: The Agriculture Environment Nexus. Sustainability, 10, 1776.