remote sensing

Article

GIS-Based Progress Monitoring of SDGs towards Achieving Saudi Vision 2030

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Abstract: The United Nations (UN) Sustainable Development Goals (SDGs) serve as a blueprint for securing a sustainable, healthy, and just future for people and the environment. Through the implementation of various policies and initiatives for Vision 2030, the Kingdom of Saudi Arabia has significantly advanced its SDGs. Geographic information systems (GIS) and remote sensing (RS) technologies can play vital roles in tracking and assessing the progress of various government measures. This study investigated the potential of satellite-based RS and GIS technologies for planning, evaluating, and monitoring the status of SDGs. The significance of GIS in Saudi Vision 2030 was examined through a comprehensive literature review and expert interviews. In addition, we reviewed a case study to discuss the role and challenges of utilizing GIS big data for achieving SDGs in Saudi Arabia. Furthermore, we explored the use of large datasets from community scientists and satellite monitoring of SDGs. Overall, we aimed to provide insightful recommendations regarding the utilization of GIS in the effective monitoring of the progress of the SDGs in achieving Saudi Vision 2030. This can aid decision-makers and country leaders in developing assessment frameworks.

Keywords: geographic information systems; remote sensing; review; Saudi Vision 2030; sustainable development goals; sustainability; United Nations

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1. Introduction

Achieving the Millennium Development Goals (MDGs) of the United Nations has encouraged humans to support the 17 United Nations Sustainable Development Goals (UNSDGs) to promote global stability and sustainability, including Saudi Arabia [1]. A collection of quantitative indicators, targets, and observational data was designed to monitor the progress toward each objective [2]. The 2015 SDGs set an ambitious and inclusive agenda that encompassed and surpassed the poverty agenda of the Millennium Development Goals to include climate change, infrastructure, and governance challenges, redefining development as a global struggle [3]. The 2030 Agenda for Sustainable Development, endorsed by all 'UN' Member States (2015), presents a shared roadmap for peace and prosperity for people and the planet [4]. The 17 SDGs are at the core of the Agenda and represent an urgent call to action for all nations, developed and developing, and the promotion of global partnerships.

Alleviating poverty and injustice must be combined with initiatives that promote health and education, decrease inequality, and stimulate economic growth while addressing climate change and striving to protect our seas and forests [5]. Strategies have been incepted for large foreign aid providers, such as Germany, Canada, and Japan, and rapidly evolving countries, such as Brazil, India, and China, to achieve SDGs locally and internationally [6]. One report evaluated India's SDG progress at national and regional levels, identifying areas that require attention to achieve their goals by 2030 [7]. Additionally, G-7 countries' national policies for sustainable development have been assessed, revealing similarities and variations in their approaches [8]. The assessment of the overall achievability of the SDGs under current conditions concludes that although some progress has been made, key indicators, such as access to adequate sanitation and education, continue to pose significant challenges [9]. Concerns have been expressed about the environmental sustainability of SDGs 6, 7, 12, 13, 14, and 15 and the urgent need to control them to prevent previous accomplishments [10]. This necessitates a thorough observation and assessment of local community-level statistics that consider the feedback from various stakeholders.

The UN has focused on issues with data collection capabilities to consistently monitor essential parameters and the need to rapidly develop information technology [11]. Geospatial data is a potentially beneficial data source. It can be used to track the advancement toward the SDGs. MacFeely discussed how big data can be used to analyze SDG indicators. Traditional data sources are insufficient. Therefore, researchers have investigated the applicability of big data in SDG monitoring and discussed the challenges in creating SDG indicators [12]. In 2019, Breuer et al. [13] reviewed approaches to converting interrelated SDGs into policy actions, as well as the current conception of SDGs and the relationships among the 17 goals. The benefits and drawbacks of several popular frameworks have also been assessed; cases from 22 Arab nations have developed innovative integrated strategies to prioritize SDG targets [14].

Geographical information systems (GIS) and remote sensing (RS) represent powerful methods that have been successfully utilized over the last few decades in various sectors, including agriculture, defense, emergency response, environmental management, healthcare, transportation, and urban planning [15]. SDGs can be supported using satellite imaging data, which are gathered through RS and provide details on the biological, chemical, and physical features of the environment [16]. Additionally, sensors have been deployed to quantify these factors at the regional level [17]. Satellite sensors with unique properties are important for tracking and displaying local and global changes. GIS and RS use satellite data to provide a panoramic overview of local and global coverage at different spatial resolutions [18]. In addition to field survey data, these methods can be used to track the effects of climate change on, for example, groundwater and surface water [19]. One analysis highlighted the need to adapt SDGs to a national level. It underscores that modifications to SDG indicators and monitoring systems are necessary, contingent upon the specific circumstances of each country [20].

Evidently, the UNSDGs can be measured efficiently using geospatial information and methodologies [21]. The consequent scientific findings can provide a solid foundation for policymakers to support the sustainable development of local or regional communities [22]. Global progress toward SDG accomplishment was tracked using 231 unique socio-ecological indicators distributed across 169 goals, with RS providing Earth observation data directly or indirectly for 30 (18%) of these indicators. The Committee on Earth Observations' EO4SDG effort is investigating the full potential of RS in SDG monitoring worldwide. Globally, the full potential of RS for SDG monitoring is currently under investigation. According to the Global SDG Indicators Database, as of 21 April 2020 (70 percent) of the RS-based SDG indicators had at least preliminary statistical data, and 10 (33 percent) of the RS-based SDG indicators were included in SDR-ID 2019. However, these statistics do not always represent the current state and availability of raw and processed geographical information for RS-based indicators, which remains challenging. Yet, substantial efforts have been expended in response to the demand for free access to data. RS data can also be used to build relevant alternative indicators or sub-indicators. By doing so, they can contribute to addressing one of the main issues in SDG monitoring: how to best systematize SDG indicators [23]. Notably, the progress monitoring efforts utilizing the GIS and RS were limited to a single or only a few selected goals.

Saudi Arabia is actively monitoring the progress of the United Nations SDGs through various mechanisms and initiatives. These data sources included official government statistics, surveys, administrative records, and other relevant datasets. A pivotal strategy involves the establishment of Saudi Vision 2030, a comprehensive roadmap for the country's economic and social development [24]. This vision aims to diversify the economy, enhance quality of life, and promote sustainable development in line with the SDGs [25]. Additionally, Saudi Arabia has established the National Center for Performance Measurement (Adaa) to monitor the progress of the SDGs at a national level. The Adaa collects and analyzes data from various government entities and provides regular reports on the country's progress towards achieving the SDGs [26]. Difficulties in applying GIS to poor nations include a lack of high-quality geographical and demographic data [27]. Vision 2030 is an ambitious and transformative plan to diversify Saudi Arabia's economy and reduce its dependence on oil by 2030 [28]. This strategic roadmap was launched in 2016 with the goal of creating a vibrant society, a thriving economy, and an ambitious nation. This vision closely aligns with the UNSDGs (Figure 1) [1,25].

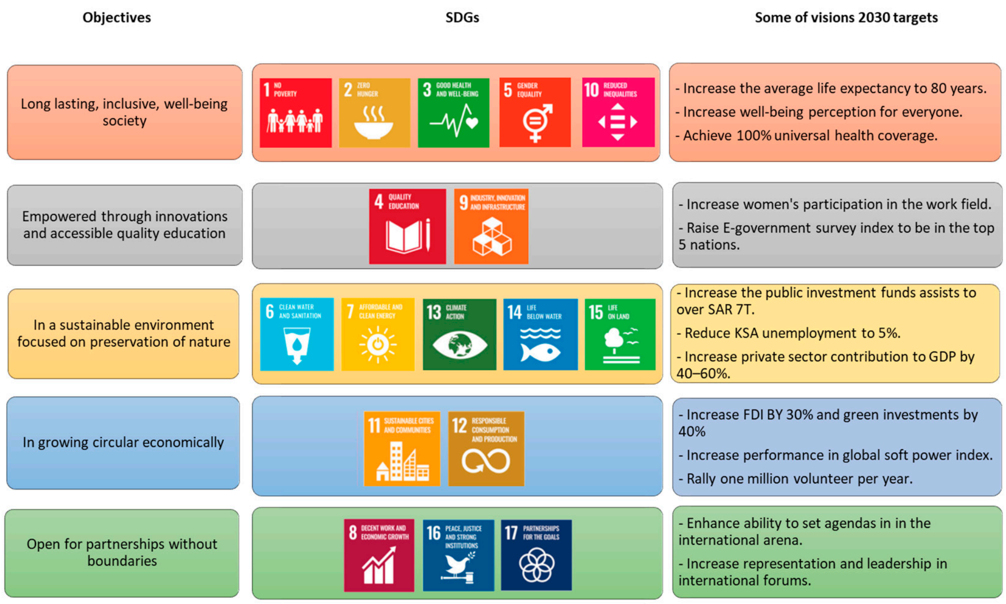

Figure 1. Relationship between SDGs and Saudi Vision 2030 [24].

Through embracing the UNSDGs, Vision 2030 demonstrates a commitment to sustainable development and global cooperation. This vision recognizes the importance of addressing social issues such as poverty, education, and healthcare, which are critical components of the SDGs. It also emphasizes the need for economic diversification, innovation, and investment in tourism, entertainment, and technology, which aligns with the UN's vision to promote inclusive and sustainable economic growth [25,28]. Additionally, Saudi Vision 2030 highlights the significance of environmental sustainability and the responsible use of resources, aligning with the objectives of combating climate change and preserving the planet for future generations. Although significant progress has been made in measuring the key performance indicators of the SDGs and Saudi Vision 2030, the government has identified some challenges. For example, the key performance indicators (KPIs) of Saudi Vision 2030 do not encompass the entire scope of the SDGs. Occasionally, the measurement and data collection methodology for KPIs does not consistently align with SDG methodologies, creating inconsistencies. Moreover, challenges related to outdated data requiring updating, inaccurate measurements, or misreporting remain. These challenges are jointly addressed by GASTAT and Adaa, with support from UN agencies. Therefore, it is essential to acknowledge that, despite efforts to collect data, there may still be gaps and inconsistencies.

Consequently, GIS-based progress monitoring of the SDGs toward achieving Saudi Vision 2030 faces several challenges. First, the availability of accurate and updated data is crucial for monitoring progress. Although Saudi Arabia has made significant efforts to collect relevant data, addressing gaps and inconsistencies remains imperative. Furthermore, there is a need for collaboration among stakeholders in sharing data. Furthermore, ensuring data quality and reliability is essential for effective monitoring of progress. Implementation of data validation and verification processes is necessary to identify and rectify errors or inconsistencies in the data. This is particularly important when using GIS technology because spatial data accuracy is crucial for meaningful analysis and decision-making. Another challenge is the need for capacity-building and technical expertise in GIS and data analysis. Although Saudi Arabia has made progress in building its GIS capabilities, there remains a need for skilled professionals who can effectively analyze and interpret the data. This requires investments in training programs and the development of a skilled workforce that can harness the power of GIS technology to monitor progress. In addition, the scale and complexity of the SDGs and Saudi Vision 2030 present challenges in terms of data integration and analysis. Given that the SDGs encompass a wide range of sectors and indicators, it becomes necessary to integrate data from various sources and conduct comprehensive investigations. Advanced GIS tools and techniques are required to handle large datasets and perform complex spatial analyses.

Overall, this study aims to overcome the limitations of previous research, particularly the lack of countries utilizing GIS or RS technologies to monitor the progress of SDGs, especially in the Middle East. It examines the GIS-based progress monitoring of the SDGs toward achieving Saudi Vision 2030. The specific objectives of this study are as follows:

- Identifying the roles of GIS and RS technologies in monitoring SDG progress and determining additional goals that can be tracked using geospatial data and relevant technologies.
- Enhancement of progress monitoring strategies by combining various state-of-the-art technologies, such as geospatial science, citizen science, and big data analytics.
- Provide recommendations for framework development to assist organizations as a guideline to monitor SDG progress in achieving the objectives of Saudi Vision 2030.

The remainder of this paper is organized as follows: Section 2 describes the materials and methods, and Section 3 presents the results and findings of the investigation. Sections 4 and 5 present the discussion and recommendations for this study. Finally, the conclusions and limitations of this study are presented in Sections 6 and 7.

2. Materials and Methods

After a systematic literature review, interviews with experts in the field and a case study were undertaken. The chart in Figure 2 illustrates the flow of the paper.

Secondary Data: We conducted a systematic review to comprehensively evaluate the relevant research. The following keywords were utilized in the Scopus database to find pertinent papers for the evaluation: “remote sensing and SDGs”, “Sustainable Development Goals”, “remote sensing and GIS and SDGs”, “geospatial data and SDGs”, “monitoring SDGs”, and “monitoring the progress of SDGs”. Figure 1 summarizes how these terms reveal different studies based on multiple parameters. The search timeline was from 2015 to 2023. The results from the literature were evaluated twice. Only abstracts with pertinent keywords were examined in the initial phase to determine whether a manuscript should be selected for additional research. To reduce bias, the initial choice was based solely on the title of the paper and pertinent keywords rather than the authors’ names and nations. In the initial phase of the review, peer-reviewed articles were prioritized.

Expert interviews: These interviews provided valuable insights and perspectives from experts in various fields, allowing for a comprehensive understanding of the progress made towards the Sustainable Development Goals that has not been covered in the literature. By engaging with experts, policymakers, and stakeholders, we can better understand the challenges and opportunities to achieve the targets set by Saudi Vision 2030. This helps identify gaps, assess the effectiveness of existing initiatives, and provide recommendations for improvement. Additionally, they make the monitoring and evaluation process more robust and accurate, as experts provide valuable inputs on the data collection methodology, indicators, and measurement frameworks. The interviews indicated that the GIS-based progress monitoring system gathered qualitative data, ensuring a holistic approach to tracking and measuring the progress of the SDGs. These interviews also facilitated knowledge sharing and collaboration among experts, fostering a multidisciplinary approach to problem-solving. Ultimately, expert interviews enhanced accuracy, reliability, and effectiveness, contributing to the successful implementation of Saudi Vision 2030 and the achievement of relevant SDGs. Critical topics considered in the interviews were GIS's role in achieving SDGs and Saudi Vision 2030, the government's role in GIS platforms, SDGs that can be monitored using GIS, environmental challenges, how GIS can be used to support urban development, and the challenges that might be faced in utilizing GIS as a tool to achieve Saudi Vision 2030.

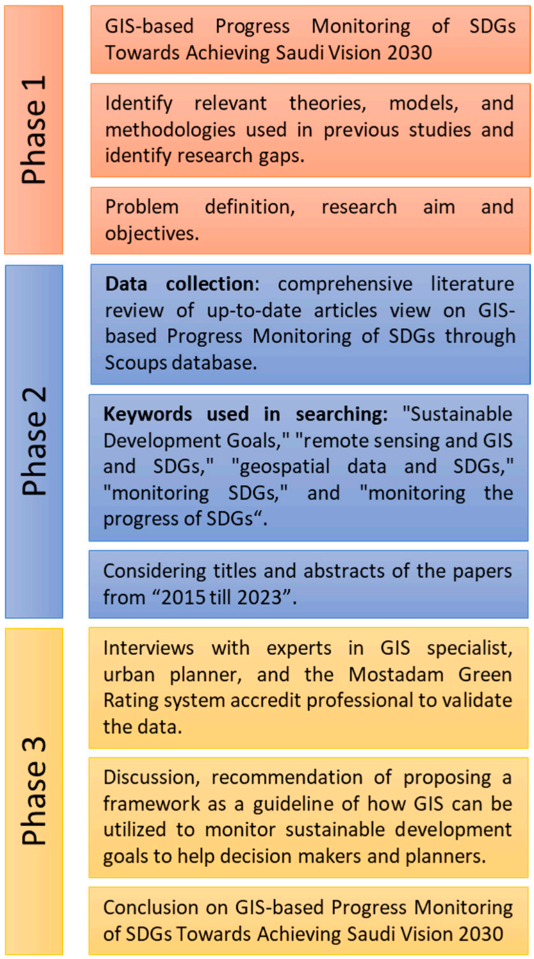

Figure 2. Methodological structure of the paper.

3. Results

The Saudi government developed a framework for the workflow of multidisciplinary tasks in three stages, as shown in Figure 3, where each stage has multiple phases, and each group works on specific goals. By enhancing this framework and incorporating GIS and data capture techniques during the monitoring stage before SDG reporting and documentation, organizations can significantly improve their effectiveness and drive the progress of SDGs. GIS technology collects, analyzes, and visualizes geospatial data, providing valuable insights and informing decision-making processes. By leveraging GIS, organizations can identify patterns, trends, and spatial relationships within the data, enabling them to better understand the complex interplay of various factors influencing progress towards the SDGs. Additionally, data capture techniques ensure the accurate and comprehensive collection of relevant data, which is crucial for generating reliable and meaningful reports. By implementing these tools and strategies at the monitoring stage, organizations can improve their ability to track progress, identify areas of concern, and allocate resources effectively.

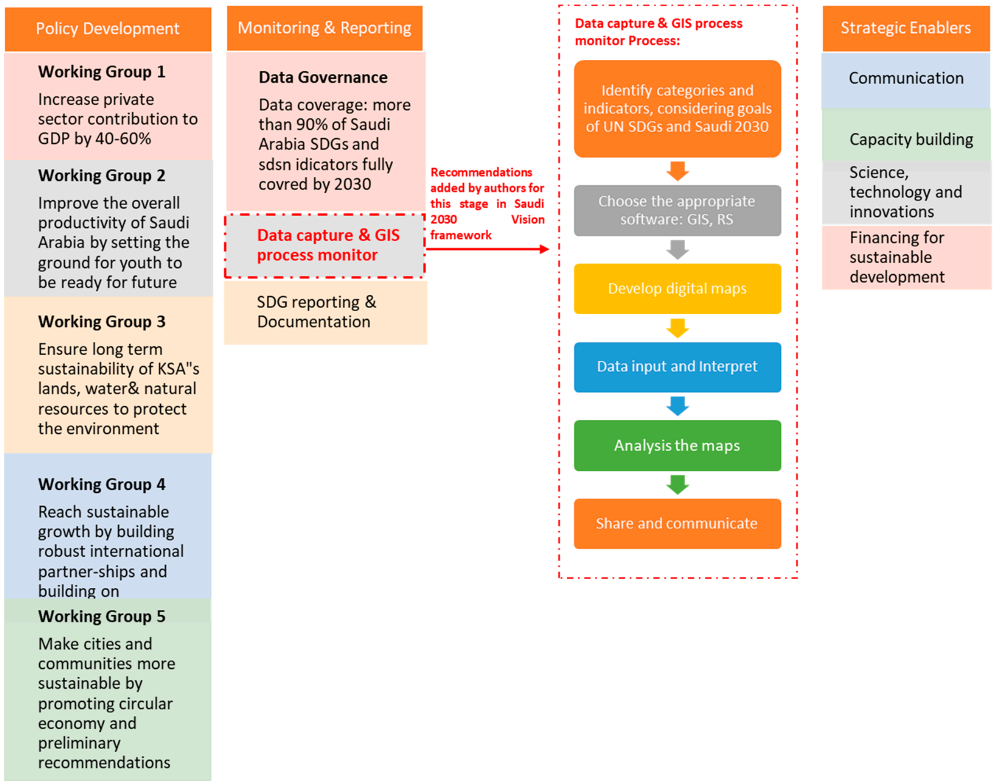

Figure 3. Saudi Vision 2030 and SDGs process [24].

3.1. Monitoring SDGs with GIS and RS

3.1.1. SDG 1: No Poverty

Spatial data derived from satellite sensors in poor nations can aid in the global collection of retrospective census data. For SDG 1, the UN established seven targets and 14 indicators. As updating the data yearly is challenging, the standard approach to measuring poverty relies on census data, generally repeated every 5–10 years. However, census data may not be inaccessible or outdated for various low- and middle-income nations. Methods based on GIS and mobile mapping can be used to update and fill in these data gaps [29].

Geospatial data-based poverty maps reveal the spatial inequalities associated with the main SDG 1 indicators by revealing information on national inequality [30]. As Table 1 below summarizes how GIS and RS are incorporated to assess the progress of SDG 1 digital maps, these maps are increasingly being used to build strategic plans that implement social welfare services to decrease inequality within nations. These schemes include the distribution of benefits, efficient resource usage, medical income, unemployment insurance, and old-age retirement. Multitemporal poverty maps can be employed to track how poverty has changed owing to the implementation of social security measures. Multiple studies have used GIS techniques to help implement policies to meet the SDGs; a few of these studies are discussed below. According to one study, decision-makers on the lowest-income continents of the world are regularly forced to act on incomplete data, notably in Africa. Thus, insufficient data can be filled using machine learning and high-resolution satellite photography [29].

Table 1. Role of GIS and RS in monitoring SDG 1 (No Poverty) [29,31–34].

• The spatial data in poorer nations derived from satellite sensors can aid in the global collection of retrospective census data [29].
• Multi-dimensional poverty has employed an accurate index founded upon mobile phone information, responsibility, phone quantity, and satellite-based nighttime light data [31].
• In Sri Lanka, analyses of indicators like the density of unpaved or paved roads and the density of buildings, roof kinds, and types of farming have been used to predict variation in poverty across small local areas [32].
• Artificial neural networks were utilized to build a transfer learning strategy in which nighttime light intensities were employed as an African poverty forecast using a data-rich proxy [33].
• Decision-makers in the lowest-income continents in the world are regularly forced to act on incomplete data, notably in the region of Africa. Insufficient data can thus be filled using machine learning and high-resolution satellite photography [34].

Multi-dimensional poverty employs a highly accurate index based on mobile phone information, responsibility, phone quantity, and satellite-based nighttime light data [31]. This study demonstrates that extensive data from mobile and satellite sources can be used to assess spatiotemporal poverty. In Sri Lanka, indicators such as the density of unpaved or paved roads, the density of buildings, roof types, and types of farming have been used to predict variations in poverty across small local areas [32]. Driven by the application of existing regulations, geospatial information can be efficiently utilized to offer updated information and track development. In one study, artificial neural networks were utilized to build a transfer learning strategy using a data-rich proxy to employ nighttime light intensities for African poverty forecasts [33]. The results show that even in nations with limited ability to support conventional data-gathering techniques, estimation is possible, and poverty rates are continuously monitored using high-resolution satellite images. Therefore, it can be inferred from the previous literature analysis that geospatial approaches are efficient ways to connect with the most vulnerable populations and implement policies to end poverty entirely.

3.1.2. SDG 2: Zero Hunger

Remote sensing-based agricultural yield estimates can be used to prevent hunger. The UN Food and Agriculture Organization (FAO) maintains enough food production globally to feed everyone. Nevertheless, recent data indicate an increase in undernourished people, rising from 777 million in 2015 to 815 million in 2016 [35]. The struggle against starvation requires international cooperation and is not a simple effort. Comprehending the hunger issue in a region and predicting crop output and water availability can be instrumental in mitigating future challenges. This proactive approach enables the timely development of necessary strategies. Utilizing modeling approaches to offer timely data on agricultural productivity and market demand, satellite data contributes to the global endeavor of eradicating hunger. In addition, precision agriculture promotes the use of unmanned aerial systems (UAVs) to foster sustainable agricultural practices [36]. One study assessed corn yield using UAV data and fertilizer use optimization. GIS can be employed to identify essential locations that are unable to provide enough food [12]. Table 2 below summarizes the role of GIS and RS in SDG 2.

Table 2. Role of GIS and RS in monitoring SDG 2 (Zero Hunger) [36–41].

• By applying modeling approaches to provide timely data on agricultural productivity and market demand, satellite data can help the world reach its objective of ending hunger [36].
• Examining the present location of underweight children in Africa showed that Rwanda, central/northern Eritrea, and the African border areas had the highest prevalence rates [37].
• According to one study that examined the present site of underweight children in Africa, Rwanda, Central/Northern Eritrea, and African border areas had the highest prevalence rates [37]. The researchers suggested that area features, national policies, and conditions influenced cause and prevention. In addition, spots of hunger were analyzed [38].
• In addition to analyzing regions of hunger, the climate change scenario for Sub-Saharan Africa at the subnational level has been examined. The authors discovered that improving residential food security through elevated economic power would mitigate issues in African countries [38].
• Countries can increase agricultural output and climate stability by implementing technologies to feed the world's expanding population [39].
• Precision agriculture promotes employing unmanned aerial systems to produce sustainable agriculture (UAVs). Using UAV data and fertilizer use optimization, (Arroyo et al. 2017) assessed corn yield. To identify essential locations unable to provide enough food, GIS could be employed [40].
• Using timely and precise data at the government level, the crop sector can be evaluated using regional and worldwide geospatial data using ground-based observations and weather data. Information regarding weak growth seasons and years with low agricultural production can be found in satellite data [41].

It also examined climate change scenarios for sub-Saharan Africa at the subnational level. The study found that enhancing residential food security through increased economic power can alleviate challenges in African countries. If climate change continues, some areas in Tanzania, Mozambique, and the Democratic Republic of Congo will face increasingly severe food problems. According to predictions, the achievement of SDG-2 for these nations is contingent upon international cooperation to assist impoverished countries. Using timely and precise data at the government level, the crop sector can be evaluated using geospatial data, ground-based observations, and weather data at the regional and global levels. Information regarding weak growth seasons and years with low agricultural production can be found in the satellite data. The Group for Environmental Investigations Global Agricultural Monitor is a pioneering company that forecasts agricultural production using geospatial data. Countries can increase their agricultural outputs and climate stability by implementing technologies that feed the world's expanding population [39].

3.1.3. SDG 3: Good Health and Well-Being

Georeferencing methods can be used to evaluate healthcare systems and predict viral outbreaks. Improving sanitary conditions, such as access to clean water, is necessary for maintaining optimal health. If SDG 6 (clean water and sanitation) is satisfied, SDG-3 can be completed. It is crucial to remember that the 17 SDGs are interconnected rather than mutually distinct. Using GIS maps, WDI data, the World Water Development Report from the United Nations World Water Assessment Program (UN-Water), and the percentage of the population that has access to clean water (WWAP), the maps display a cluster across Africa, indicating that things need to be changed for the SDGs to be achieved in the future [42]. Like how it may be used to identify hunger issues, a GIS is essential in helping decision-makers take action to improve things. Access to the healthcare system is necessary to preserve excellent health. In addition to sanitation, GIS can be used to analyze regional and global healthcare problems. One study measured the country's spatial access to healthcare to evaluate the state of the healthcare system there [43]. Because they make it apparent which populations in Costa Rica lack adequate access to healthcare, his findings are essential for locally attaining SDG 3. This study was conducted to identify locations that experienced a lack of healthcare personnel [44]. The researchers discovered that these areas were common throughout the state, except in major cities such as Chicago. Both studies suggest that GIS in medical geography can be used to illustrate social inequalities in wealthy nations.

Additionally, reducing inequalities is the objective of SDG 10, also in collaboration with SDG 3, which boosts social conditions. Notably, the general healthcare system is not the only area where GIS is beneficial. It can be used in epidemiological research to stop future pandemics. A case study was developed to demonstrate how a GIS was applied to control Guinea's most recent Ebola outbreak. Combating infectious diseases is difficult in nations such as Guinea because essential data such as geographic and socioeconomic information are lacking [45]. Rapid action is necessary to prevent such outbreaks. A medical human rights organization called Medicine Sans Wild West gathered geographic information to understand how streets connected residential areas and where the cases were reported. They highlighted how challenging it is for nations to control infectious diseases. Furthermore, satellite images were used to investigate the relationship between the radiation risks of heart disease, skin cancer, and heatstroke in South Africa. Differences in radiation and land surface temperatures were brought about by urbanization. Improving the design of prevention and control strategies. A method was suggested for mapping locations with high-road connectivity to hospitals in African countries [46]. Table 3 below summarizes GIS and RS's role in tracking and monitoring the progress of SDG 3.

Table 3. Role of GIS and RS in monitoring SDG 3 (Good Health and Well-being) [43–49].

• A measurement of the country's spatial access to healthcare to assess the state of its healthcare system [43].
• Identifying locations lacking healthcare personnel. It was discovered that these areas were common throughout the US, except in major cities like Chicago. Both studies suggested that GIS in medical geography can be utilized to illustrate social inequalities in wealthy nations [44].
• A case study was developed to demonstrate how GIS was applied to control the most recent Ebola outbreak in Guinea. Combating infectious diseases is difficult in nations like Guinea because essential geographic and socioeconomic data are lacking [45].
• A study used publicly available satellite imagery and deep learning to understand economic well-being in Africa for mapping locations with high road connectivity [46].
• Population percentages with access to clean water (WWAP) can be determined through GIS; the maps display a cluster across Africa that indicates that things need to change for the SDGs to be achieved in the future [47].
• Satellite images were used to investigate the connection between radiation risks for heart disease, skin cancer, and heatstroke in South Africa due to differences in radiation and land surface temperature brought on by urbanization [48].
• GIS is essential in helping decision-makers take action. Access to the healthcare system is necessary for preserving excellent health in addition to sanitation [49].

3.1.4. SDG 6: Clean Water and Sanitation

Clean water and sanitation-related issues are covered by SDG 6. It contains seven goals, which include achieving improved water resources and personal cleanliness. These aims can be supported by geospatial tools. Target 1 requires everyone to have equal, clean, and inexpensive drinking water by 2030. To do this, Machiwal's work, "Assessment of Groundwater Potential in a Semi-Arid Region of India Using RS, Geographical Information System, and decision making of multicriteria techniques called MCDM", offers expert solutions. By combining RS, GIS, and MCDM approaches, the researchers presented a standard methodology for defining groundwater potential zones. They created a groundwater map using each of these approaches; using a groundwater possible indicator, four groundwater potential zones in Rajasthan's Udaipur district were classified as good, moderate, bad, and extremely poor [50].

A separate study conducted in the drought-prone Bundelkhand region showcased the utility of ground survey data, GIS, and RS to locate areas with groundwater potential. This investigation aids in the adaptation to and mitigation of drought [51]. SDG 6′s Target 2 aims to eliminate open defecation and ensure access for all to adequate and appropriate hygiene and sanitation, with special consideration for the specific needs of women, girls, and the most vulnerable individuals. Infrastructure facilities can be developed using data, including land cover acquired from satellite images incorporated into GIS, along with information on property ownership, soil types, slope, and visibility [29]. A second study, conducted in the Nigerian village of Alabata, which lacks essential infrastructure services, demonstrated the significance of RS and GIS techniques in microbiological investigations of water supply to rural communities. This study collected data on water sources, health, sanitation, and water sample stations, plotted them on a GIS, and created a base map. The development of the RS/GIS system enables the creation of a map for management and planning that spatially overlaps information on water source locations and bacteriological quality [52]. By 2020, SDG 6's target five calls for preserving and restoring water-related ecosystems, such as those found in mountains, forests, wetlands, rivers, aquifers, and lakes. Several factors, including wetlands, mountains, and forests, influence water availability. A multipurpose wetland inventory using combined RS/GIS approaches and customized analysis at various scales in response to historical uncertainties and gaps. Moreover, to illustrate the land-use trends caused by modifications to agricultural, sedimentation, and settlement patterns, researchers quantified the state of wetlands along Sri Lanka's western coast using satellite data and GIS [53]. Table 4 below summarizes how to track the process and progress of SDG 6 by utilizing GIS and RS.

Table 4. Role of GIS and RS in monitoring SDG 6 (Clean Water and Sanitation) [29,36,50–53].

• Mapping poverty using mobile phone and satellite data, infrastructure facilities can be developed using data like landcover acquired from satellite images in GIS with information about property ownership, soil types, slope, and visibility [29].
• The possibility for groundwater, inland water bodies, river changes, surface water levels, etc., may be monitored using satellite data [36].
• Combining RS, GIS, and MCDM, one study presented a standard methodology for defining groundwater potential in a semi-arid region of India [50].
• The prone-to-drought Bundelkhand region demonstrated the value of using ground survey data, GIS, and RS to locate areas with groundwater potential [51].
• The value of RS and GIS technologies in microbiology investigations of water supply in rural communities. Data on water sources, health, sanitation, and water sample stations were collected and plotted in GIS, and a base map was created. The development of the RS/GIS system makes it possible to create a map for management and planning that combines and visualizes information on water source locations and bacteriological quality [52].

Table 4. *Cont.*

• A multipurpose wetland inventory was developed using RS and GIS and customized analysis at various scales in response to historical uncertainties and gaps. To illustrate land-use trends brought on by modifications to agricultural, sedimentation, and settlement patterns, the researchers also quantified the state of the wetlands along Sri Lanka's western coast using satellite data and GIS [53].

3.1.5. SDG 11: Sustainable Cities and Communities

To effectively integrate geospatial data into the global goal of building sustainable cities and human settlements, additional financial and technological applications are required. UN-Habitat has already begun working with academic institutions to provide a representative dataset of urban regions that would enable the monitoring of urban land-use efficiency, land-use mix, street connectivity, and other crucial elements of sustainable urban development [54]. The adoption of SDG 11 is transformative as it emphasizes the progressive growth of urban planning, the complex supply of public space, and the accessibility of critical services and transportation networks in the face of the rising population in this unpredictable digital environment. In 1992, the United Nations emphasized the requirement for an integrated strategy for sustainable development and the need for accurate information and data for decision-making [55,56]. Subsequently, the first global sustainable development discussion highlighted a strong need for geographical data. The summit report urged member states to encourage the creation and widespread application of earth observation technologies, such as global mapping, geographic information systems, and satellite GIS, to merge high-quality information on the impacts of the environment, changes in land use, and other topics; this was conducted under the "means of implementation" theme.

The city has several industries that can benefit significantly from geospatial data. Obtaining information on these indicators will be very helpful in achieving SDG 11 by 2030 and implementing sustainable cities as Table 5 depicts. For example, using GIS data to track wastewater flow can help identify and quantify the proportion of safely treated wastewater [57]. Consequently, sustainability indicators offer new perspectives and options for global planning and development. The administration and planning of sustainable cities should be based on an assessment of their effects. An SDG indicator for urban transportation was discussed [58]. GIS offers various quantitative and time-based monitoring options, even though the establishment of resilient, safe, and sustainable cities and communities presents a global community with several severe environmental, social, and economic issues. The utilization of geoinformation significantly lowers network load and building modeling costs. In most construction projects, this results in a 75 percent reduction in labor, time, and cost, significantly advancing the goals of sustainable and low-carbon communities [59].

Table 5. Role of GIS and RS in monitoring SDG 11 (sustainable cities and communities) [57,59–64].

• Using GIS data to track wastewater flow can serve as an indicator to measure the proportion of safely treated wastewater [57].
• Using geodata reduces network load and building modeling expenses dramatically. This results in a 75 percent decrease in labor, time, and cost in most building projects, considerably advancing the objective of sustainable and low-carbon societies [59].
• GIS can offer various quantitative and time-based monitoring options, navigating the severe global environmental, social, and economic challenges posed in aiming to achieve resilient, safe, and sustainable cities and communities [60].
• GIS could be used to evaluate environmental conditions, assess the feasibility of potential development sites, detect competing interests, and model linkages in tourism development [61].
• GIS data can create a city, region, and neighborhood environmental features and walkability index [62].
• GIS is increasingly being utilized for collecting and displaying geographical information related to urban development and aiding decision-making in planning processes [63].
• Integrated GIS visualizations provide more precise measurements and assessments of urban green infrastructure [64].

3.1.6. SDG 13: Climate Action

The key to understanding climate change is to develop a framework that combines historical and present data from multiple sources into a single system utilizing GIS [65]. The use of RS, notably in most nations' development aims and strategies, explicitly refers to climate monitoring and analysis. For instance, Indonesia has begun to work on its national satellite development program to facilitate satellite RS use on domestic issues such as food security and climate change. Additionally, nations such as the Philippines aim for the technical workforce to develop the necessary knowledge using tools such as GIS. It should be noted that RS is now essential for decision-makers to access reliable climate change information bulletins.

Oil spillages are frequent disasters in our oceans and are mainly caused by shipping activities. Due to advancements in sea transportation, pollutants have become more prevalent in recent years. The ecological health of the oceans and aquatic habitats, including aquaculture, sea animals, and corals, can be dramatically affected by oil spills. RS-based algorithms have been extensively applied to oil spill detection. The introduction of wireless remote-sensing methods has significantly improved the ability to detect oil spills [66]. For example, in Norwegian waters, satellite-based oil pollution monitoring capabilities were demonstrated in the early 1990s using images from the ERS-1 satellite [67]. Synthetic Aperture Radar (SAR), which benefits from the development of RS technology, is essential for petroleum tracking [68]. Table 6 below describes the importance of utilizing GIS and RS as tools to monitor and track SDG 13.

Table 6. Role of GIS and RS in monitoring SDG 13 (Climate Action) [29,36,50–53].

• Mapping poverty using a mobile phone and satellite data: infrastructure can be developed using data, such as land cover, acquired from satellite images included in GIS, offering insights into property ownership, soil types, slope, and visibility [29].
• Fog, rain, soil wetness, and the possibility of groundwater, river changes, seawater levels, etc., can all be monitored using satellite data [36].
• Combining RS, GIS, and MCDM approaches, one study presented a standard methodology for defining groundwater potential in a semi-arid region of India [50].
• One study demonstrated the value of using ground survey data, GIS, and RS to locate areas with groundwater potential in the drought-prone Bundelkhand region [51].
• The integration of RS and GIS technologies proved invaluable in the microbiological investigation of water supply in rural communities. Data on water sources, health, sanitation, and water sample stations were systematically collected and plotted in GIS, ultimately contributing to the creation of a comprehensive base map. The development of the RS/GIS system facilitates the generation of a management and planning map that spatially aligns information on water source locations with bacteriological quality assessments [52].
• One study employed a multipurpose wetland inventory developed using RS and GIS and customized analysis at various scales in response to historical uncertainties and gaps. To illustrate land-use trends brought on by modifications to agricultural, sedimentation, and settlement patterns, the researchers quantified the state of the wetlands along Sri Lanka's western coast using satellite data and GIS [53].

3.1.7. SDG 15: Life on Land

Forests are crucial to the global carbon cycle at regional and global scales. According to a MEA (2005) report, trees store 335–365 gigatons of carbon annually [69]. Any substantial modifications or losses to forested areas brought on by land use and land cover changes, selective harvesting, wildfires, pests, and/or disease prevent the forest's reproduction capacity. However, the concept of forest degradation remains ambiguous. An FAO study defines forest degradation as changes inside the woods that significantly influence stand or site form or function, lowering the capability of providing goods and services [70]. Consequently, it is necessary to effectively track, map, and estimate total tree cover loss and damage and calculate aboveground biomass (AGB). RS has been used for many years and can assess total spatial and temporal coverage. Each country must set up transparent, reliable, and efficient remote forest monitoring to support the objectives of SDG 15, which essentially focuses on long-term forest management.

The future of forest ecosystems will undoubtedly be shaped by current human activities and policies. Satellite RS methods and procedures for establishing baseline data on forest loss, against which future rates of change can be assessed, are crucial to the solution [21]. Therefore, there is a great deal of interest in developing methods for measurement, reporting, and verification to create future aboveground forest carbon stocks. One such study was conducted in Riau Province, Indonesia. The investigation created future scenarios to conform with the IPCC Assessment Report using basic ALOS PALSAR-2 Mosaic data at a 25-m spatial resolution (AR5). Three possible policy outcomes were assessed: "business as usual", "government-forest conservation policy", and "government concession for plantations and logging policy". The researchers determined that if the existing practices were maintained, the area would lose its forest cover, which would affect carbon sequestration. These studies are essential for developing and analyzing existing policies and their impact on the future [71]. Table 7 below summarizes some studies that utilized GIS and RS as tools to monitor and track SDG 15.

Table 7. Role of GIS and RS in monitoring SDG 15 (Life on Land) [21,72–74].

• To properly track, map, and estimate the total tree cover, track loss and damaged forest area, and calculate the aboveground biomass (AGB). RS approach has been in use for many years and offers total spatial and temporal coverage [21].
• Satellite RS methods and procedures to establish baseline data on forest loss against which future rates of change can be assessed are a crucial part of these systems [21].
• Data from present satellites are essential for monitoring climatic impacts on rainfall patterns, fire risks, food crop productivity, terrestrial ecosystems, coastal zone ecosystems, water level, and water-related dangers [72].
• Using satellite imagery, carbon accounting, and climate change to investigate the effect analysis [72].
• GIS may address climatic data while analyzing applications in agriculture, ecology, forestry, health, weather forecasting, hydrology, transportation, urban settings, energy, and climate change [73].
• Surface temperature data from satellite thermal sensors for metropolitan areas are underutilized in planning applications. GIS is used in operations to illustrate such correlations for high-rise housing estates in a tropical metropolis where temperature management is critical. This resulted in a strong connection between satellite-derived surface temperature and biomass indices and resemblance to air temperature data [74].

3.2. Interview Results

The interview process involved gathering perspectives on GIS-based progress monitoring of SDGs towards achieving Saudi Vision 2030 from various stakeholders familiar with the progress of SDGs in Saudi Arabia and using GIS technology. The participants included three GIS specialists, urban planners, and the Mostadam Green Rating System, and accredit professionals were asked five open-ended questions. The experts in the interviews emphasized the need to utilize GIS technology to track the development of SDGs. They highlighted that a GIS provides a visual context and allows for the presentation and analysis of complex SDG data. This technology can assist in identifying trends, patterns, and gaps in the application of sustainable development programs. Table 8 summarizes the significant outcomes of the covered questions and answers.

Table 8. Summary of the interview outcomes.

Topics Covered	Opinions	Expert
Role of GIS to achieve SDGs and Saudi Vision 2030	GIS can offer insightful data on community needs and preferences, which can help direct the creation of infrastructure improvements. We can make sure that new infrastructure is constructed where it is most needed by using GIS to analyze data on population density, traffic patterns, and other factors. By boosting inclusive and sustainable growth, encouraging innovation, and creating resilient infrastructure, SDG 11 may be accomplished.	A
	The distribution and accessibility of resources and services, like healthcare and educational facilities, can be mapped out using GIS, which is essential in identifying improvement areas. GIS can also assist in monitoring the progress of SDGs by providing real-time data on issues like SDG 1, SDG2, and SDG6. These data can be used to determine which areas require more resources and attention to meet these goals.	B
	Natural resource availability and reduction can be conducted with the help of GIS. We may be able to manage natural, sustainable resources by analyzing this data and bringing it to decision-making. To ensure sustainable consumption and production, SDG 12 of the United Nations, Saudi Arabia, may be able to achieve this goal with the aid of this strategy.	C

Table 8. *Cont.*

Topics Covered	Opinions	Expert
Government role and GIS platforms	Cooperation and collaboration are necessary to use big data efficiently. Sharing data across different sectors can be challenging because various departments frequently have their own data systems. The government can ensure that all departments can access the same data and collaborate more effectively by creating a centralized platform for GIS data accessibility. Meanwhile, organizations accessing the authoritative portal can use the data to create modern, engaging websites and improve data transparency and collaboration.	A
	The Saudi Arabian Government has proactively collected and updated spatial data, which are the foundation for GIS platforms. This includes data related to land use, transportation networks, population demographics, natural resources, and infrastructure assets. Furthermore, the investment in human capital has strengthened the government's ability to leverage GIS platforms effectively.	B
	The government's promotion of GIS and remote sensing has been continuous. This includes establishing specialized organizations like the National Centre for Remote Sensing and Geoinformatics and the Saudi Geospatial Information Agency (SGIA). These organizations have been tasked with creating and implementing GIS and remote sensing-related guidelines, standards, and guidelines. They also offer technical assistance and training to stakeholders, including the government.	C
SDGs that can be monitored by using GIS	By providing data on water resources, such as groundwater availability, water quality, and water usage rates, GIS can promote SDG 6. This data can assist decision-makers in creating efficient water management plans and ensuring the sustainable use of water resources.	A
	GIS is a powerful tool that can be used to monitor and track progress toward achieving SDG goals. SDG 13 can be tracked. Temperature changes, moisture, and other climatic factors can be tracked through GIS. Policymakers can create plans to reduce the impacts of extreme weather phenomena by mapping out climatic patterns and recognizing regions most sensitive to climate change. GIS may be used to track SDG 15 in development and highlight regions where poor land qualities are exacerbating the effects of climate change.	B
	SDG 2 could be tracked. GIS can be used to monitor food security and identify regions that are suffering from hunger or food shortages. Policymakers can pick up flaws in the food supply chain and create plans to increase food security by mapping food production and distribution systems. GIS may track land-use changes and define regions with expanding or diminishing agricultural activity.	C
Environmental challenges and how GIS can be used to support urban development	Saudi Arabia's efforts to attain the SDG of boosting renewable energy are remarkable. Providing examples of how GIS may help know the potential of solar and wind energy as renewable energy sources. GIS can help decision-makers find suitable locations for renewable energy projects and assess their sustainability.	A
	The value of using GIS to discover the geographic distribution of environmental challenges in a community, such as hotspots for air pollution or regions with high waste generation rates. City planners can map these locations to see which neighborhoods are most impacted by environmental issues and then focus efforts there.	B
	GIS supports sustainable transportation planning; for example, by mapping out cycle paths or public transportation routes. This can lower greenhouse gas emissions and enhance urban air quality.	C
Challenges that might be faced in utilizing GIS as a tool to achieve Saudi Vision 2030	Obtaining contemporary, high-quality satellite imagery is difficult. Many GIS applications need satellite imagery to deliver reliable information. However, obtaining current, high-quality satellite imagery can be expensive and time-consuming, and it can also be challenging.	A
	There are a few issues, including the requirement for workers with more technical backgrounds, upgrades to data quality and accessibility, and developing guidelines for using GIS in decision-making.	B
	One of the biggest challenges was the requirement for appropriate GIS education and awareness. This is necessary for the GIS technology to be used more widely and for its advantages to be realized.	C

3.3. Case Studies of GIS Implementation to Promote Sustainability in Saudi Vision 2030

The study conducted by Garni and Awasthi in 2017 on solar PV power plant site selection, employing the GIS-AHP-based technique, serves as an illustrative example of transitioning from oil consumption to reliance on renewable energy sources, particularly in the context of Saudi Arabia. This study showcases how GIS can effectively contribute to achieving the objectives of sustainable development by aiding in the identification and selection of optimal locations for solar power plants [75]. The Kingdom spans over 2 million km^2 in South Asia. The major cities are Riyadh, Jeddah, Mecca, Medina, and Dammam. Most cities experience desert climates with intense daytime heat and a sharp drop in nighttime temperatures. Saudi Arabia has enormous potential for solar energy due to its location, substantial undeveloped area, and daily solar irradiation levels [76,77].

The Saudi Arabia case study provides a model that uses actual climatological and legal data, including information on roads, mountains, and protected areas. Using actual atmospheric conditions, the ArcGIS solar analysis tool was used to calculate solar insolation across the entire research area. The resulting map overlay revealed that 16 percent (300,000 km^2) of the research region is suitable for installing utility-sized PV power plants, with the best locations being in the north and northwest of Saudi Arabia. The researchers observed that appropriate land follows a pattern that roughly corresponds to the distance from major highways, power lines, and metropolitan centers. Over 80% of the suitable sites exhibited moderate-to-high Landscape Suitability Index (LSI) values, spanning from moderate to high. The amalgamation of GIS and MCDM techniques has demonstrated its efficacy in handling extensive geographic information datasets and large spatial areas, facilitating the manipulation of variables crucial for identifying optimal locations for solar power facilities [75]. According to the optimum site selection criteria, the technical feasibility criteria determined the optimal locations for the utility-scale PV projects. These factors have a direct impact on the performance of solar power plants: average temperature (C1), solar radiation (C2), land aspects and slope (C3 and C4), urban vicinity (C5), highway proximity (C6), and power line proximity (C7). As part of Saudi Vision 2030, the country aims to generate 58.7 gigawatts of renewable energy resources by 2030 [78].

The integration of MCDM-GIS produced an overlaid result map, which revealed that 16 percent (300,000 km^2) of the research region was promising and suitable for installing utility-sized PV power plants (Figure 4). Given its favorable high solar irradiation, gentle slope, and proximity to main roads, grid lines, and urban regions, the central region of Saudi Arabia has more locations suitable for utility-sized PV power facilities. A few sites are suitable in the north and northwest of the study region and have also been identified. A few areas on the eastern and western coastlines have appropriate locations. Because of the relatively high air temperature and low density of major roads, electricity transmission lines, and metropolitan areas, the southeast, home to the largest contiguous sand desert (Rub' al Khali), is unsuitable for establishing such plants [75].

This case study offers a meta-overview of the potential of utility-scale photovoltaic land suitability analysis in the research area by combining a geographic information system and a multicriteria decision-making tool. The importance of each selection criterion was assessed using the analytic hierarchy process (AHP) when selecting an ideal location for utility-scale solar PV power facilities. The suggested model considers technical and financial parameters such as solar radiation, annual average temperature, slope, geographical features, and closeness to power lines, main roads, and urban areas. This methodology effectively created a grid-connected utility-sized PV power plant land suitability assessment for possible sites [75]. The primary benefit of this case study is that it uses existing infrastructure and resources to provide cities with the power they need while protecting the environment. Owing to its ability to incorporate actual atmospheric characteristics, solar analyst modeling in ArcGIS, which produced sun irradiation maps, is a particularly vital tool.

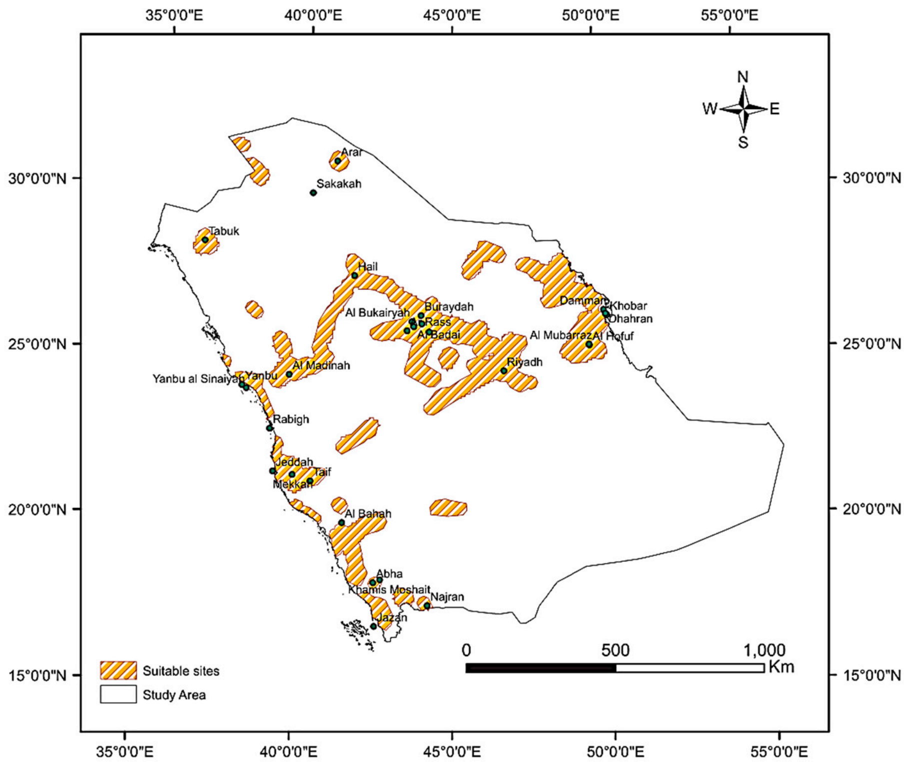

Figure 4. Preliminary results of potential sites (Reprinted with permission from Ref. [75]. Copyright 2023).

Another study conducted in Saudi Arabia, the Green Saudi Initiative, aimed to support the protection of the environment and the building of a sustainable future. GIS and multicriteria decision-making methods were used to assess and map green infrastructure, revealing different suitability classes and areas for planning [79]. Numerous methods are available to assist in multicriteria decision-making. The primary objective is to aid decision-makers in formulating a problem and providing context for the decision-making process prior to evaluating and comparing potential solutions [80–82]. One of the more straightforward methods is the hierarchical multicriteria process (AHP). The AHP facilitates the calculation of a summary score ranging from 0 to 1 by incorporating rankings and weights assigned to all criteria considered in the decision-making process [83]. To delineate the scope of this research, nine GIS map criteria were selected to identify optimal locations for urban green spaces. These chosen criteria incorporate diverse data sources, comprising a digital elevation model, slope map, topographic position index, rainfall map, distance to waterlines, topographic wetness index, distance to roads, wind speed, and global exposure datasets. Together, these criteria collectively contribute to pinpointing suitable areas for the establishment of urban green spaces [79].

The findings regarding Green Infrastructure suitability are illustrated in Figures 5 and 6. Figure 6 provides a detailed overview of the different forms of suitability in the Al-Baha region and presents the respective percentages for each district. The results revealed five distinct suitability classes; namely poor, fair, good, and excellent, which are mapped in Figure 6. The initial class, “poor suitability”, encompasses an area of 12% (1322 km^2) within the Al Baha region of 11,104 km^2. This class is predominantly observed in Qelwah and Elmelkhwah, accounting for approximately 37% (697 km^2) and 34% (471 km^2), respectively. Buljurshi also contributes to this class, with an area of 5% (132 km^2). Other districts displayed poor-suitability areas that did not exceed 12 km^2. The subsequent class, “fair suitability”, exhibits the largest coverage, representing 43% (4808 km^2) of the Al Baha region. This class is present in the Alaqiq, Qelwah, Elmelkhwah, and Buljurshi districts, occupying significant areas of 57% (1766 km^2), 56% (1051 km^2), 50% (693 km^2), and 37% (975 km^2), respectively (Figures 5 and 6) [79].

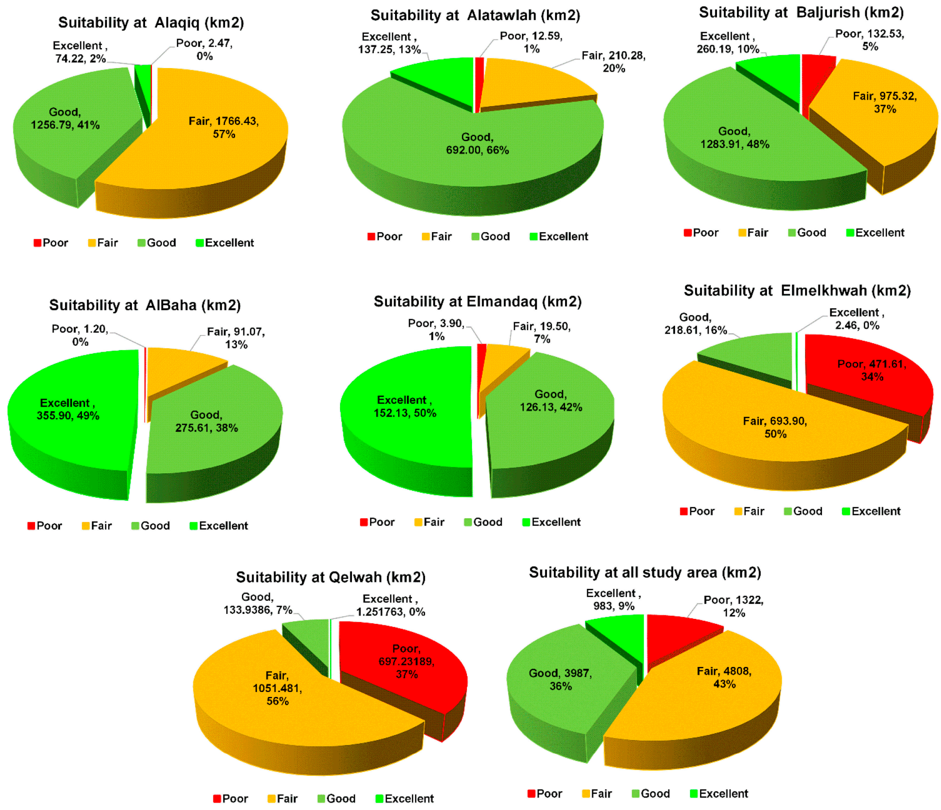

Figure 5. Area and percentage of different classes of Green Infrastructure potential areas in Al Baha region and in seven zones (Reprinted from Ref. [79]: MDPI Publication).

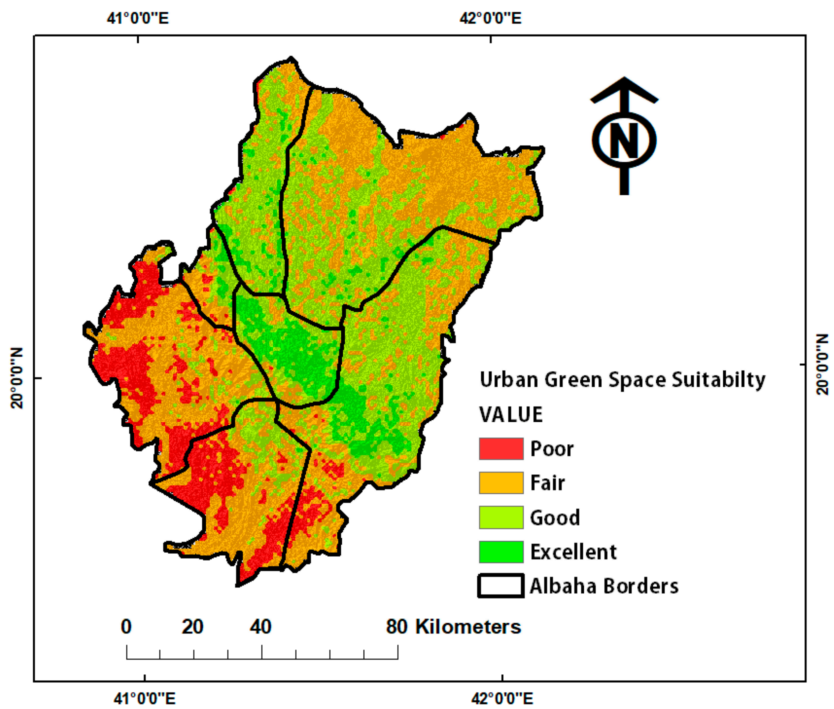

Figure 6. Suitability areas of Green Infrastructure in the Al Baha (Reprinted from Ref. [79]: MDPI Publication).

Conventional oil, including crude oil, condensate, and natural gas liquids, accounted for approximately 97% of global energy demand in 2008. However, the International Energy Agency projections indicate that this reliance will decrease by approximately 90% by 2030. Observers anticipate a decline in oil production and consumption as renewable sources become more cost-effective, advanced, and environmentally sustainable [84,85]. To address declining oil reserves and rising energy demand, the Saudi Arabian authorities introduced Saudi Vision 2030, an extensive strategy aimed at decreasing the nation's social and economic reliance on oil. In January 2017, Saudi Arabia made its initial competitive offering of multi-billion-dollar projects to produce large-scale solar energy, marking its most significant commitment to renewable energy, according to analysts [24]. According to recent studies, Saudi Arabia could become a net oil importer by 2038 if oil consumption in the energy sector is not significantly reduced [86]. Hence, it is of utmost importance to reduce the dependency on crude oil and tap more power from the abundant renewable energy resources of the Kingdom. The following sections detail the research conducted to assess wind energy potential at several sites in the Kingdom [87].

The Kingdom is located between latitudes 17.5 N and 31 N and longitudes 36.6 E and 50 E. The terrain elevation ranges from 0 to 2600 m above mean sea level [88]. According to these statistics, Saudi Arabia is fortunate in terms of its location and appropriateness for diverse renewable energy resources. Most of the Kingdom's areas have a high potential for wind energy generation [89]. Based on the geographic characteristics of the study area, legislative acts in the fields of environmental protection, forest protection, water protection, and life safety standards were analyzed; similar literature was reviewed, and the opinions of decision-makers who dealt with similar problems were considered [90]. Two criteria were identified: assessment criteria for site appropriateness analysis and limitations in rejecting problematic locations. As Figure 7 depicts, the evaluation criteria were used in this study: average wind speed (C1), distance to power lines (C2), distance to roads (C3), distance to settlement areas (C4), and slope (C5), and the following constraints were used: airports, land use, water bodies, and important bird areas. The suitability index of each site on the weighted criteria map was determined by multiplying it by the binary score assigned to each site on the constraint map. This process ensured that only sites suitable for wind farm development were considered. The resulting map excludes areas with a score of 0 and categorizes those with a score of 1 to 4 into four classes: "extremely suitable", "very suitable", "suitable", and "less suitable". Among these classes, C4 represented the most suitable sites, and C1 denoted the least suitable sites [91].

We created a map depicting the suitability of wind farm locations by combining the weighted criteria map and constraint map (Figure 8). This map identified areas deemed suitable for wind farms with varying degrees of suitability. Areas with high suitability were further classified into four categories: less suitable, suitable, very suitable, and extremely suitable. Based on map analysis, it is evident that most areas in northern Saudi Arabia are suitable for wind farms, whereas the southwestern region is highly suitable. The wind location suitability map was discussed in terms of the varying degrees of suitability observed.

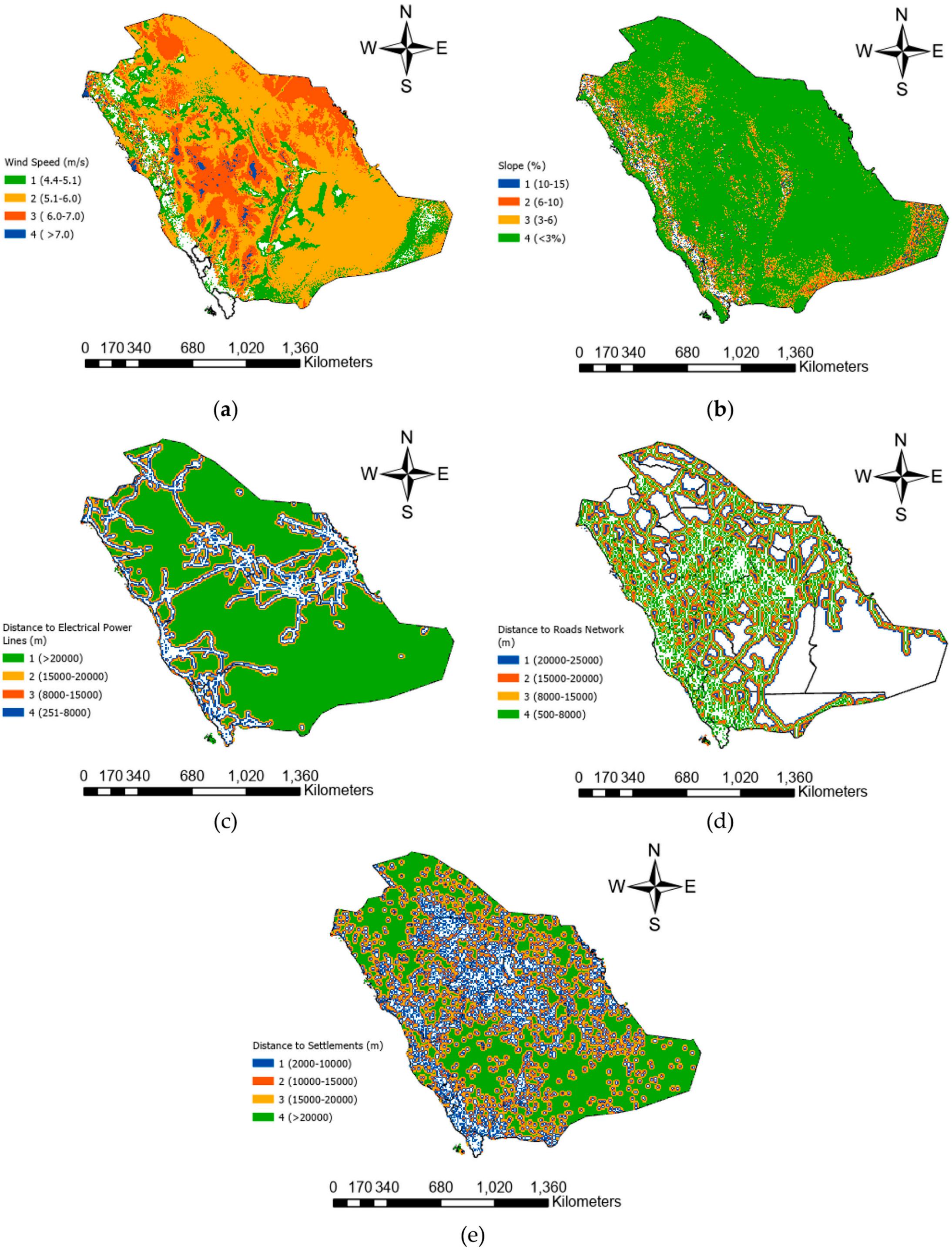

Figure 7. Reclassified maps (**a**–**e**) of Saudi Arabia with each weighted criterion (Reprinted with permission from Ref. [91]. Copyright 2023).

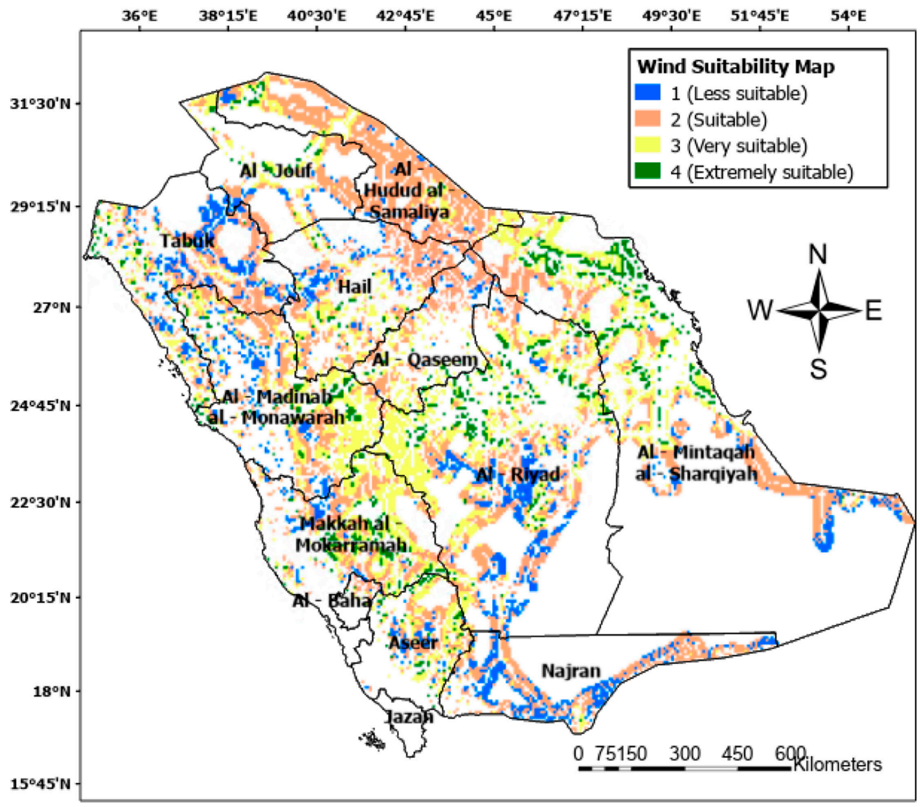

Figure 8. Saudi Arabia wind suitability map (Reprinted with permission from Ref. [91]. Copyright 2023).

4. Discussions

Multiple quantifiable measures can be used to assess SDG performance. In terms of their ability to employ sensor data to supplement census data, RS approaches have played a vital role in the monitoring of roadmaps for accomplishing SDGs [19]. Relevant studies have demonstrated that RS techniques are crucial for monitoring the SDGs. The use of big data, science, and public engagement has been found to be beneficial in tracking and measuring SDG indicators. To directly monitor, demand, or drive improvements on issues that impact them, organizations have produced "citizen-generated data". This utilizes several methods, including surveys, messaging, calls, emails, reports, and social media. The data generated can be qualitative or quantitative and come in various formats [92]. Lessons from the MDGs demonstrate that civil society participation is essential for a framework of accountability that is inclusive, transparent, and participatory [93]. Subsequently, the post-2015 SDG-based strategy stresses prioritizing public participation at all levels. The right to freedom of expression, association, peaceful assembly, and access to information assists in bringing the voices of those who are most marginalized into the discussion [93]. Therefore, citizen-driven data may be crucial for real-time tracking and directing SDG implementation. By contributing real-time, prioritized, and accurate data, citizen-driven data have the potential to close existing gaps. This can ensure the fundamental shifts necessary to address the colossal global challenges and advance SDGs [92].

Citizen science can contribute significantly to the SDGs by enhancing data and capacity, fulfilling multistakeholder partnerships, fostering innovation, promoting widespread data ownership and validity, improving transparency, and enabling continuous image monitoring. Researchers have emphasized the need for rigorous SDG monitoring, emphasizing evidence-based, timely, dependable assessments and disaggregation by diverse societal groups [94]. Data generated by all citizens can significantly advance this goal. Some of the points mentioned above are already present in Google Maps and Google Earth and in the data addition, analysis, and geotagging of images uploaded by people worldwide.

Evidently, people are motivated to make significant contributions to such projects. Examples include finding the largest rainforest in Southern Africa and identifying peculiar cave networks that led to the discovery of a New Human Ancestor [95]. The potential value of near real-time information on public policy issues and their corresponding locations within defined constituencies, improved data analysis for prioritization and rapid response, and deriving insights into various aspects of citizen feedback were highlighted in a 2015 study by Global Pulse on Mining citizen feedback data to improve local government decision-making [96]. Big data has gained attention over the past ten years and has drawn the interest of academic institutions, businesses, governments, and other organizations. Significant sources of innovation, competition, and productivity. With the advent of high-performance computers, increased storage space, and the proliferation of high-resolution satellite data, computer science has recently experienced a tremendous increase of several terabytes daily [97]. Due to the continued use of global earth analysis for environmental monitoring, scientists now refer to RS data as "Big Data" [98]. Moreover, data pooling can improve the identification, diagnosis, and treatment of a variety of health conditions. One such study recommended five SDG priorities: develop metrics, set up monitoring mechanisms, assess progress, improve infrastructure, standardize data, and verify data [99]. Other authors have used information from the 2015 Global Burden of Diseases, Injuries, and Risk Factor Studies to assess the progress of SDG [100]. Big data should be chosen such that it may be utilized to test many areas of sustainable energy production, food security, water security, and poverty eradication [101].

5. Recommendations

In this section, a framework for utilizing GIS to monitor the progress of the SDGs toward achieving Saudi Vision 2030 is presented (Table 9). This guideline has been added to assist planners in tracking the process during the monitoring and reporting stages of the implementation and development of the program, as shown in Figure 3. GIS technology allows data visualization and spatial analysis, enabling the identification of trends, patterns, and relationships that can inform decision-making processes. By incorporating GIS into SDG monitoring, Saudi Arabia can gain valuable insights into the progress made, identify areas that require attention, and allocate resources effectively to address gaps and challenges. This approach enhances the country's ability to track and evaluate its SDG progress, ultimately contributing to the achievement of Saudi Vision 2030.

The integration of GIS technology and big data analysis has the potential to revolutionize the monitoring and evaluation of SDG progress. Satellite imagery and other GIS techniques can provide a comprehensive view of Earth's resources, environmental changes, and human activities, allowing for better decision-making and targeted interventions to achieve the SDGs. For example, GIS data can help monitor changes in land use and cover, deforestation rates, urban expansion, and ecosystem health. By analyzing satellite images, policymakers can identify areas at risk of environmental degradation and take appropriate measures to mitigate these risks. Similarly, GIS can track changes in water resources, such as groundwater depletion or the extent of water pollution, enabling better management strategies to ensure water security (SDG 6). It is essential to increase public understanding of the potential applications of big data and invest in institutional capacity building, data-driven regulation, and policymaking. Building institutional capacity is crucial for harnessing the potential of GIS, big data analysis, and citizen-generated data. Governments, research institutions, and civil society organizations must invest in training programs and infrastructure to effectively collect, analyze, and interpret these data. This will enable them to make evidence-based decisions, track progress, and address data gaps in achieving the SDGs.

Table 9. Role of GIS in achieving Saudi Vision 2030.

1 NO POVERTY	• GIS can provide a comprehensive understanding of poverty. By overlaying different layers of data such as population density, income, education levels, and building density, GIS can also be used to monitor poverty changes over time and identify trends and patterns.
2 ZERO HUNGER	• GIS can be used to monitor SDG 2 by tracking agricultural production. • GIS can be used to analyze land use patterns, crop yields, and soil quality. This information can be used to identify areas where production is low and to develop interventions that increase productivity. • Optimum site selection for agricultural fields.
3 GOOD HEALTH AND WELL-BEING	• GIS can be used to map the location of health facilities and identify areas with gaps in health service coverage. • GIS can map the distribution of different diseases, health conditions, and patterns. • GIS can also be used to track the spread of infectious diseases in real-time, which is critical for controlling outbreaks and preventing epidemics.
6 CLEAN WATER AND SANITATION	• GIS can map out water sources and identify areas where access to clean water and distribution of water pollution are limited. • GIS can monitor water quality in real-time, allowing for early contamination detection and prompt action.
11 SUSTAINABLE CITIES AND COMMUNITIES	• GIS can monitor air quality in urban areas, allowing for early detection of pollution hotspots and prompt action to be taken. • GIS can map out urban areas and identify areas most needing sustainable development (green spaces, bike lanes, and public transportation). • Track roads and asphalt conditions.
13 CLIMATE ACTION	• GIS can be used to monitor changes in land use, such as deforestation and urbanization, which contribute to climate change. • GIS can be used to monitor changes in sea level and temperature, allowing for early detection of climate change impacts and prompt action to be taken.
15 LIFE ON LAND	• Forest monitoring involves using remote sensing data to identify changes in forest cover. • GIS can be used to map land use changes, such as the conversion of forested land to agricultural land, and to identify areas that are at risk of land degradation. • GIS can be used to map the distribution of species and to identify areas that are important for biodiversity conservation.

6. Conclusions

The 17 Sustainable Development Goals were created to improve human welfare, protect natural resources, and decrease the negative environmental effects of human activity on future generations. Both developed and developing countries ratified the SDGs, in contrast to the earlier MDGs. Given their broad focus, monitoring is essential for the success of the SDGs by 2030 and for the revision of current policies for improved implementation.

Regional differences can be visualized using geospatial data. Numerous studies have shown that geospatial data can help track the success and development of SDG-based strategies. However, it has not been utilized entirely for the monitoring and assessment of worldwide issues and objectives. Scientific and political communities should work together to standardize monitoring procedures for all nations to ensure the success of SDGs. This provides an opportunity for the success of the UNSDGs. SDGs 5, 8, 10, and 17 can be improved through geospatial methods.

Achieving the SDGs demands extensive, coordinated global efforts to effectively utilize data sharing, processing, and aggregation in a multidisciplinary context. National geospatial information organizations must collaborate with professional groups at the national statistics and Earth observation levels to provide consistent and reliable data for the creation of comprehensive sustainable development policies.

As per the investigation of this article, the roles of GIS and big data will be pivotal for the successful implementation of SDGs in Saudi Arabia. Depending on the potential uses of the geospatial data, there may be various real-time processing options for satellite data. However, two key elements—participation and transparency—are crucial for a successful, effective, and accessible plan across all SDG levels. Big data, cooperation, and government-supported guidelines can be leveraged to find long-term solutions for implementing the SDGs to achieve Saudi Vision 2030. This study also addresses the limitations of using GIS to monitor SDG progress, conducts a comprehensive investigation to analyze the SDGs trackable by GIS and their roles, introduces methods to enhance measurement through technology, citizen science, and big data, and concludes with a recommendation to develop a framework assisting organizations in monitoring SDG progress in Saudi Arabia to support the achievement of Saudi Vision 2030.

7. Limitations and Future Studies

Data availability is one of the main limitations of using GIS to measure goals and indicators. Local organizations can provide a transparent platform. Some data, such as the base map of Saudi Arabia, were challenging to obtain but could be beneficial as a case study and would support the data. Further research should be conducted to investigate whether other goals and indicators can be measured using GIS. There is a need to explore methods to integrate real-time data into a GIS to improve data accuracy and reliability. This can be beneficial for achieving SDGs that require a timely response. Further research is necessary to determine the most effective scale of analysis for the goals or indicators and to compare GIS with other forms of analysis to determine the most efficient methods. This will provide a more comprehensive understanding of the strengths and limitations of GIS-based progress monitoring compared to alternative approaches. Comparative analysis can combine GIS analysis with other methods, such as statistical analysis or econometric modeling.

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