



Examining the Variables in Dynamic Geographic Information Systems (GIS) Analysis

Iqtiar Md Siddique

Department of Industrial, Manufacturing and Systems Engineering, the University of Texas at El Paso, US.
iqtiar.siddique@gmail.com

ABSTRACT

In today's rapidly evolving world, understanding and managing land use and land cover dynamics are of paramount importance for addressing pressing environmental, social, and economic challenges. This abstract provides a comprehensive overview of the key themes, methodologies, findings, and implications of research on land use and land cover change. Drawing upon interdisciplinary perspectives from geography, environmental science, remote sensing, and policy analysis, the abstract highlights the interconnected nature of land systems and the multifaceted drivers of land cover change. It explores the role of technological innovations, such as remote sensing, Geographic Information Systems (GIS), and machine learning, in advancing our understanding of land dynamics and informing evidence-based decision-making. The abstract also examines the implications of land use and land cover change for ecosystem services, biodiversity conservation, climate resilience, and human well-being. Additionally, it discusses the policy implications and governance challenges associated with managing land resources sustainably in the face of urbanization, agricultural expansion, climate change, and globalization. By synthesizing insights from diverse research disciplines and highlighting emerging trends and future directions, this abstract aims to inform policymakers, researchers, and practitioners engaged in land management and conservation efforts. It underscores the importance of adopting integrated and collaborative approaches to address the complex challenges of land use and land cover change and promote sustainable development for current and future generations. The title beckons researchers, practitioners, and enthusiasts alike to embark on a journey of exploration, unraveling the complexities of GIS analysis and its underlying parameters. It speaks to the dynamic nature of GIS, where the interplay of spatial data, computational algorithms, and user-defined parameters creates a rich tapestry of insights and discoveries. Whether mapping urban growth patterns, assessing natural resource availability, or modeling environmental change, understanding the parameters of GIS analysis is essential for unlocking the full potential of spatial data and informing decision-making processes.

Key words: Sustainability, Air Quality Monitoring, Eco-friendly Air.

INTRODUCTION

In today's rapidly evolving landscape of Geographic Information Systems (GIS), understanding the intricate parameters that govern GIS analysis is paramount. This title encapsulates the essence of delving into the multifaceted dimensions of GIS, where a myriad of factors converges to shape the process and outcomes of spatial analysis. From the selection of input data and spatial layers to the fine-tuning of analytical techniques and model parameters, every step in GIS analysis is governed by a set of parameters that influence the accuracy, reliability, and relevance of the results.

Moreover, the title hints at the transformative power of GIS as a tool for understanding and addressing complex spatial phenomena. By scrutinizing the parameters of GIS analysis, researchers can gain deeper insights into the underlying processes driving spatial patterns and trends. They can identify optimal parameter settings, refine analytical workflows, and enhance the accuracy and precision of spatial models and predictions. In essence, "Exploring the Parameters: Understanding the Dynamics of GIS Analysis" encapsulates the essence of GIS as a

dynamic and evolving field, where the exploration of parameters serves as a gateway to unlocking the full potential of spatial analysis and harnessing the power of geography to address real-world challenges and opportunities.

In the realm of Geographic Information Systems (GIS), the title "Exploring the Parameters: Understanding the Dynamics of GIS Analysis" beckons us into a realm where the complexities of spatial analysis unfold. Here, each facet of GIS analysis is governed by a myriad of parameters, intricately woven into the fabric of data processing, modeling, and interpretation. These parameters serve as the guiding principles, the levers of control, and the keys to unlocking the vast potential of spatial data. Within the domain of GIS analysis, parameters abound at every turn. From the selection of input data sources and the configuration of spatial layers to the calibration of analytical algorithms and the setting of model parameters, each decision influences the outcome of the analysis. These parameters encapsulate not only the technical specifications but also the nuances of spatial context, user preferences, and domain-specific knowledge, shaping the trajectory of spatial analysis and the insights derived from it.

The title embodies the spirit of exploration, inviting researchers, practitioners, and enthusiasts to delve into the intricate dynamics of GIS analysis. It encapsulates the journey of discovery, where each parameter represents a waypoint on the path to understanding spatial patterns, relationships, and processes. Through exploration and experimentation, GIS analysts can uncover hidden insights, reveal underlying trends, and illuminate complex spatial phenomena, enriching our understanding of the world around us. Moreover, the title speaks to the transformative potential of GIS analysis as a tool for understanding and addressing real-world challenges. By understanding the parameters that govern GIS analysis, researchers can refine their methodologies, optimize their workflows, and enhance the accuracy and reliability of their findings. They can navigate the complexities of spatial data, harnessing its power to inform decision-making, solve problems, and drive positive change in our communities and beyond. In essence, "Exploring the Parameters: Understanding the Dynamics of GIS Analysis" encapsulates the essence of GIS as a dynamic and evolving discipline, where the exploration of parameters serves as a gateway to unlocking the full potential of spatial analysis. It speaks to the curiosity, the ingenuity, and the passion that drive GIS professionals to push the boundaries of knowledge, to unravel the mysteries of the spatial world, and to chart a course towards a more informed and sustainable future.

The journey of exploring the parameters of GIS analysis is one of continuous discovery and refinement. It begins with the selection and acquisition of spatial data, where considerations such as data quality, coverage, and format play a crucial role in shaping the analysis outcomes. Next, GIS analysts must navigate the intricacies of data preprocessing, including georeferencing, resampling, and mosaicking, to ensure that the input data is suitable for analysis. Once the data is prepared, attention turns to the selection and configuration of analytical techniques and model parameters. This phase involves a careful balancing act, as analysts must choose the most appropriate methods and settings to achieve the desired outcomes while considering factors such as computational efficiency, model complexity, and spatial context. Throughout this process, GIS analysts must remain vigilant, continuously evaluating the sensitivity of their results to changes in parameters and assumptions and refining their methodologies accordingly. As GIS analysis unfolds, the insights gleaned from spatial data begin to take shape, offering a deeper understanding of spatial patterns, relationships, and processes. Through spatial visualization techniques such as maps, charts, and graphs, GIS analysts can communicate their findings effectively, providing decision-makers with actionable insights to inform policy, planning, and resource allocation.

In essence, the exploration of parameters in GIS analysis represents a journey of discovery, innovation, and impact. By navigating the complex landscape of spatial data and analytical techniques, GIS analysts can unlock the full potential of GIS analysis, revealing insights that have the power to shape our understanding of the world and drive positive change in our communities and beyond.

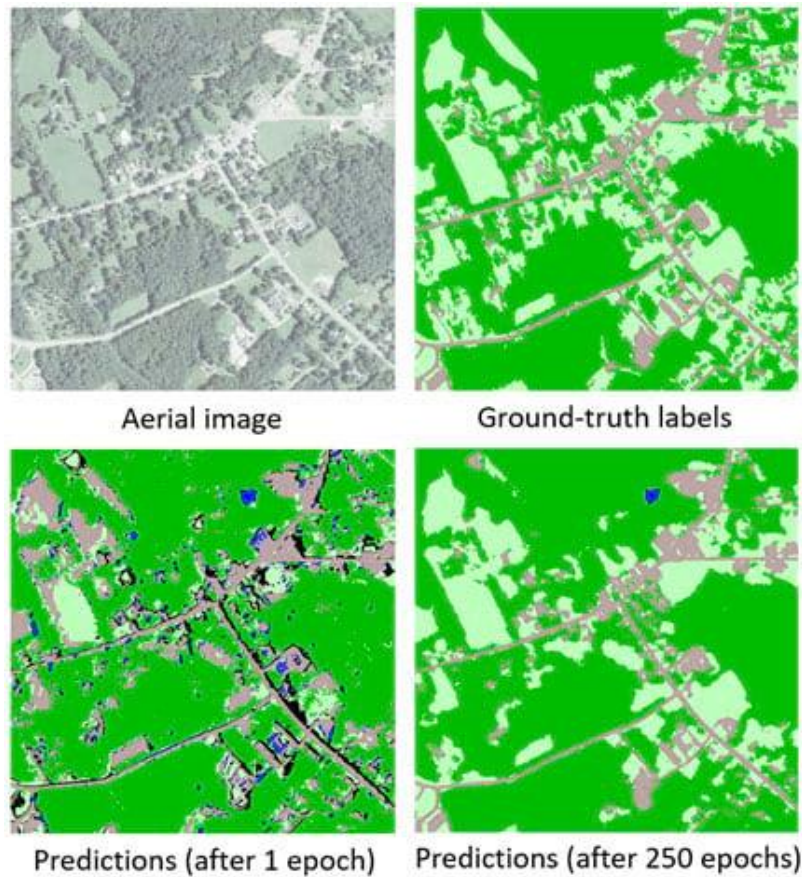


Figure 1. GIS deep learning Applications [5]

GIS PARAMETERS

GIS parameters refer to the various settings, configurations, and specifications that govern the process of Geographic Information Systems (GIS) analysis. These parameters play a crucial role in determining the accuracy, reliability, and relevance of the results obtained from spatial analysis. Some key GIS parameters include:

Input Data Parameters: These parameters pertain to the selection and acquisition of input data, including spatial datasets such as satellite imagery, aerial photographs, digital elevation models (DEMs), and vector layers representing features such as roads, rivers, and land parcels. Input data parameters encompass considerations such as data format, resolution, accuracy, coverage, and temporal extent. Sunny et al. (2024) describes in detail the GIS analysis and the parameters of analysis based on which this research methodology based on this [17].

Spatial Analysis Parameters: Spatial analysis parameters involve the selection and configuration of analytical techniques and algorithms used to process and analyze spatial data. These parameters may include buffer distances, spatial joins, overlay operations, interpolation methods, and proximity analysis settings. The choice of spatial analysis parameters depends on the specific objectives of the analysis and the characteristics of the input data.

Model Parameters: In GIS modeling applications, model parameters refer to the user-defined inputs and assumptions that influence the behavior and outcomes of spatial models. Model parameters may include variables such as coefficients, thresholds, weights, and constraints used in predictive modeling, suitability analysis, and simulation studies. Adjusting model parameters allows GIS analysts to explore different scenarios, evaluate sensitivity, and optimize model performance.

Visualization Parameters: Visualization parameters relate to the display and presentation of spatial data and analysis results. These parameters include symbology settings, color ramps, transparency levels, labeling options, and map layout configurations. Visualization parameters help convey spatial patterns, relationships, and trends effectively, enhancing the interpretability and communication of GIS analysis outcomes.

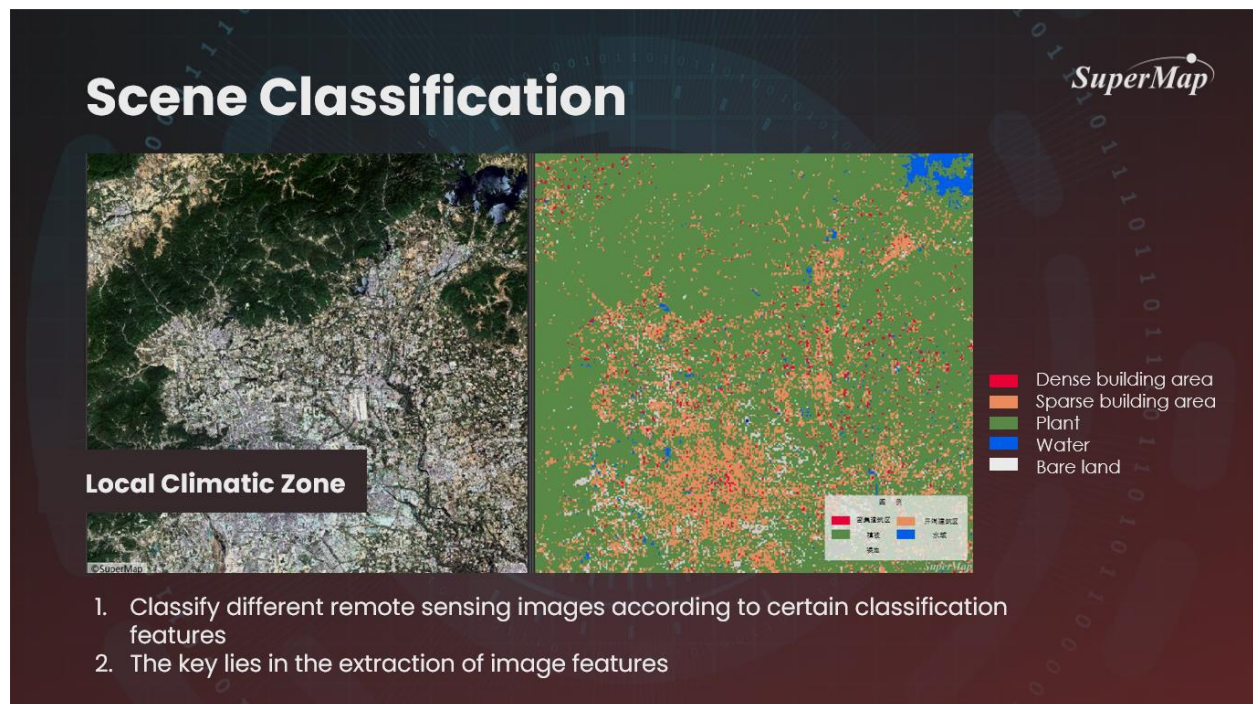


Figure 2. SuperMap Geospatial AI Innovations in Spatial Science for Image Analysis [8]

Processing Parameters: Processing parameters involve settings and configurations used during data processing tasks such as georeferencing, rasterization, resampling, and reprojection. These parameters ensure that spatial data are processed accurately and efficiently, maintaining spatial integrity and consistency throughout the analysis workflow.

Quality Control Parameters: Quality control parameters are used to assess the quality and accuracy of spatial data and analysis results. These parameters include error thresholds, validation criteria, and accuracy assessment metrics used to evaluate the reliability and validity of GIS analysis outcomes. Quality control parameters help identify and mitigate errors, uncertainties, and biases in spatial data and analysis processes.

Overall, understanding and effectively managing GIS parameters are essential for conducting robust and reliable spatial analysis, informing decision-making processes, and generating actionable insights from spatial data. By carefully adjusting and optimizing GIS parameters, analysts can enhance the accuracy, precision, and relevance of GIS analysis outcomes, enabling informed decision-making and addressing complex spatial challenges effectively.

RESEARCH METHODOLOGY:

The methodology employed in a GIS study typically involves a systematic approach to collecting, processing, analyzing, and interpreting spatial data to achieve specific research objectives. Here is an overview of the typical components of a GIS methodology:

Study Design: The first step in GIS methodology is defining the scope and objectives of the study. This involves identifying the research questions, specifying the spatial extent and resolution of the study area, and determining the period or timeframe of analysis. The study design lays the foundation for subsequent data collection and analysis activities.

Data Collection: GIS studies rely on spatial data collected from various sources, including satellite imagery, aerial photographs, digital maps, field surveys, and existing databases. The data collection process involves acquiring relevant datasets that are suitable for addressing the research questions and objectives defined in the study design. This may include data acquisition from remote sensing platforms, data digitization from maps or documents, and data compilation from government agencies or research institutions.

Data Preprocessing: Once the spatial data is collected, they often require preprocessing to prepare them for analysis. This may involve tasks such as georeferencing, coordinate transformation, data conversion, and data cleaning to ensure data consistency, accuracy, and compatibility with GIS software and analysis tools. Data preprocessing aims to resolve any spatial inconsistencies, errors, or anomalies in the input data before analysis begins.

Spatial Analysis: The core of GIS methodology involves conducting spatial analysis to explore relationships, patterns, and trends in the data. This may include tasks such as spatial interpolation, overlay analysis, buffer operations, spatial statistics, and network analysis, depending on the research questions and objectives of the

study. Spatial analysis techniques help extract meaningful insights from spatial data, identify spatial patterns, and make informed decisions based on spatial relationships.

Model Development: In some GIS studies, researchers may develop spatial models to simulate or predict spatial phenomena. This involves defining model parameters, selecting appropriate modeling techniques, and calibrating the model using observed data. GIS-based modeling may include applications such as land use change modeling, habitat suitability modeling, hydrological modeling, and transportation modeling, among others.

Interpretation and Visualization: Once the spatial analysis and modeling are completed, the results are interpreted and visualized to communicate key findings effectively. This may involve generating thematic maps, charts, graphs, and spatial statistics summaries to present spatial patterns, relationships, and trends. Visualization techniques help stakeholders understand the implications of the study findings and facilitate decision-making processes.

Validation and Verification: Finally, GIS studies often include validation and verification procedures to assess the accuracy, reliability, and validity of the analysis results. This may involve comparing model predictions with observed data, conducting sensitivity analyses, and evaluating the robustness of the methodology used. Validation ensures that the study outcomes are credible and can be used with confidence for decision-making purposes.

Overall, the methodology of a GIS study is a structured framework that guides the research process from data collection to analysis, interpretation, and validation. By following a systematic approach, GIS researchers can generate reliable and actionable insights from spatial data, contributing to informed decision-making and addressing complex spatial challenges effectively.

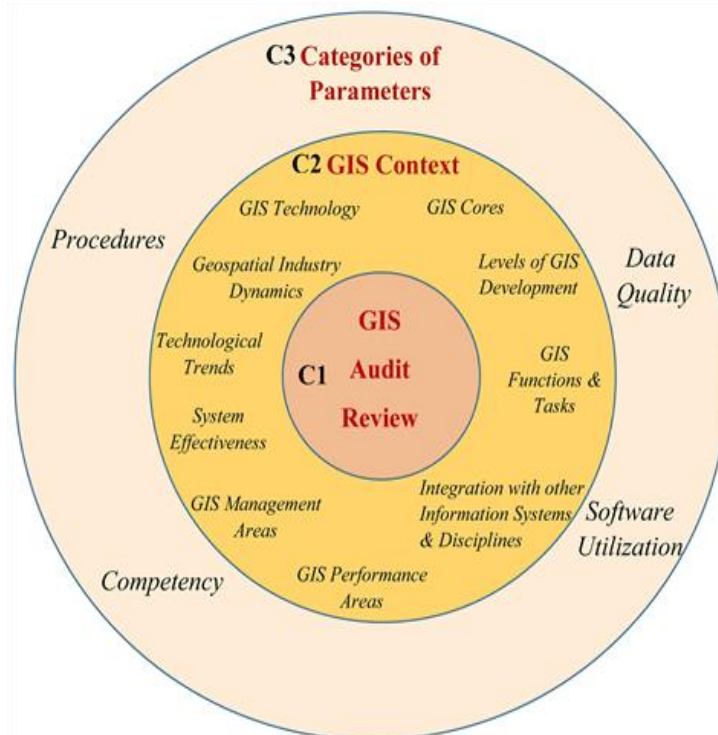


Figure 3. Developing a Conceptual Framework for GIS Audit in an Enterprise Setting [9]

RESULTS AND DISCUSSIONS

Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) is a widely used remote sensing-derived metric that quantifies vegetation greenness and density based on the differential reflectance of near-infrared (NIR) and red-light wavelengths. NDVI values range from -1 to 1, with higher values indicating denser and healthier vegetation cover.

NDVI provides valuable insights into vegetation health, biomass productivity, land cover change, and ecosystem dynamics. It is widely used in various applications, including agriculture, forestry, environmental monitoring, and land management.

In agricultural applications, NDVI is used to monitor crop health, assess vegetation vigor, detect stress factors (such as drought, pests, or diseases), optimize irrigation and fertilizer management, and estimate crop yields. By analyzing temporal NDVI trends, farmers can make informed decisions to enhance crop productivity and

optimize resource allocation. In forestry, NDVI is utilized to map forest cover, monitor deforestation and forest degradation, assess forest health, and estimate biomass and carbon stocks. By analyzing spatial and temporal NDVI patterns, forest managers can identify areas of concern, prioritize conservation efforts, and develop sustainable forest management strategies. In environmental monitoring, NDVI is employed to monitor changes in vegetation cover, detect land degradation, assess habitat suitability, and evaluate the impacts of climate change and human activities on ecosystems. By analyzing long-term NDVI trends, environmental scientists can assess ecosystem resilience, biodiversity conservation status, and ecosystem services provisioning.

NDVI is also valuable for land management applications, such as land use planning, habitat restoration, and natural resource management. By integrating NDVI data with other spatial datasets (such as land cover maps, soil maps, and topographic data), land managers can make informed decisions to conserve biodiversity, protect ecosystem services, and promote sustainable development. Overall, NDVI serves as a powerful tool for monitoring and managing terrestrial ecosystems, providing valuable insights into vegetation dynamics and ecosystem health at local, regional, and global scales. Its widespread use and versatility make NDVI a cornerstone metric in remote sensing and GIS applications for environmental monitoring, agricultural management, land use planning, and ecosystem conservation

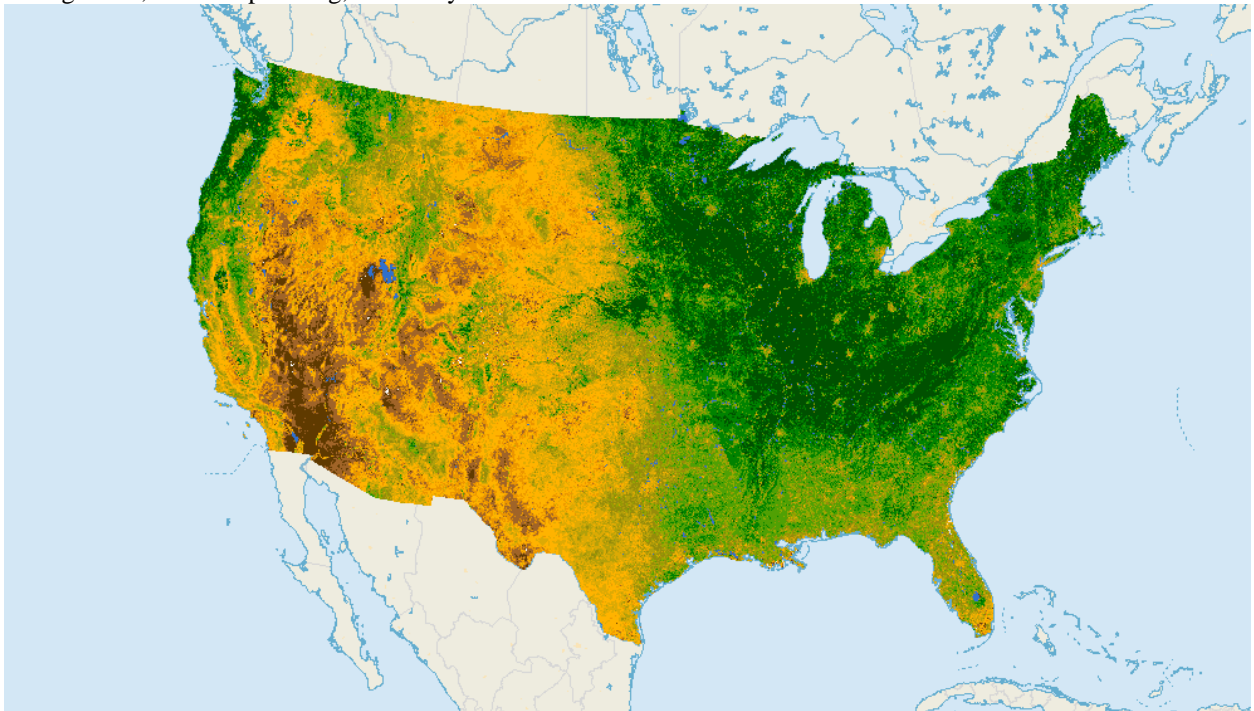


Figure 4. NDVI map using GIS [13]

THE NORMALIZED DIFFERENCE WATER INDEX (NDWI)

The Normalized Difference Water Index (NDWI) is a remote sensing index that quantifies water content and surface water dynamics using satellite imagery. It is particularly effective in distinguishing water bodies from other land cover types and monitoring changes in water availability over time. NDWI is calculated based on the differential reflectance of near-infrared (NIR) and shortwave infrared (SWIR) bands.

NDWI values typically range from -1 to 1, with higher values indicating the presence of water and lower values indicating the absence of water. Negative values may occur in areas with dense vegetation, as water absorbs more near-infrared light than shortwave infrared light.

NDWI is widely used in various applications, including hydrology, water resources management, land cover classification, and environmental monitoring. Some key applications of NDWI include:

Water Body Mapping: NDWI is used to delineate and map surface water bodies such as lakes, rivers, reservoirs, and wetlands. By thresholding NDWI values, water bodies can be extracted from satellite imagery, enabling accurate mapping of water extent and spatial distribution.

Drought Monitoring: NDWI is utilized to monitor changes in water availability and drought conditions over time. By analyzing temporal NDWI trends, researchers and water resource managers can assess drought severity, identify areas of water stress, and prioritize drought mitigation efforts.

Flood Mapping: NDWI is employed to detect, and map flooded areas during and after flood events. By comparing pre- and post-flood NDWI images, emergency responders and disaster management agencies can assess the extent of flooding, identify inundated areas, and prioritize rescue and relief efforts.

Irrigation Management: NDWI is used to optimize irrigation practices and water use efficiency in agriculture. By monitoring NDWI values in croplands, farmers can assess soil moisture levels, schedule irrigation activities, and minimize water waste, leading to improved crop yields and reduced water consumption.

Wetland Monitoring: NDWI is applied to monitor changes in wetland ecosystems and assess wetland health. By analyzing NDWI values in wetland areas, researchers can track changes in water levels, vegetation cover, and habitat conditions, facilitating wetland conservation and restoration efforts. Overall, NDWI serves as a valuable tool for mapping and monitoring surface water dynamics, assessing water-related phenomena, and supporting decision-making processes in various fields, including hydrology, agriculture, ecology, and disaster management. Its simplicity, effectiveness, and applicability to a wide range of environments make NDWI a cornerstone index in remote sensing and GIS applications for water resources management and environmental monitoring [10].

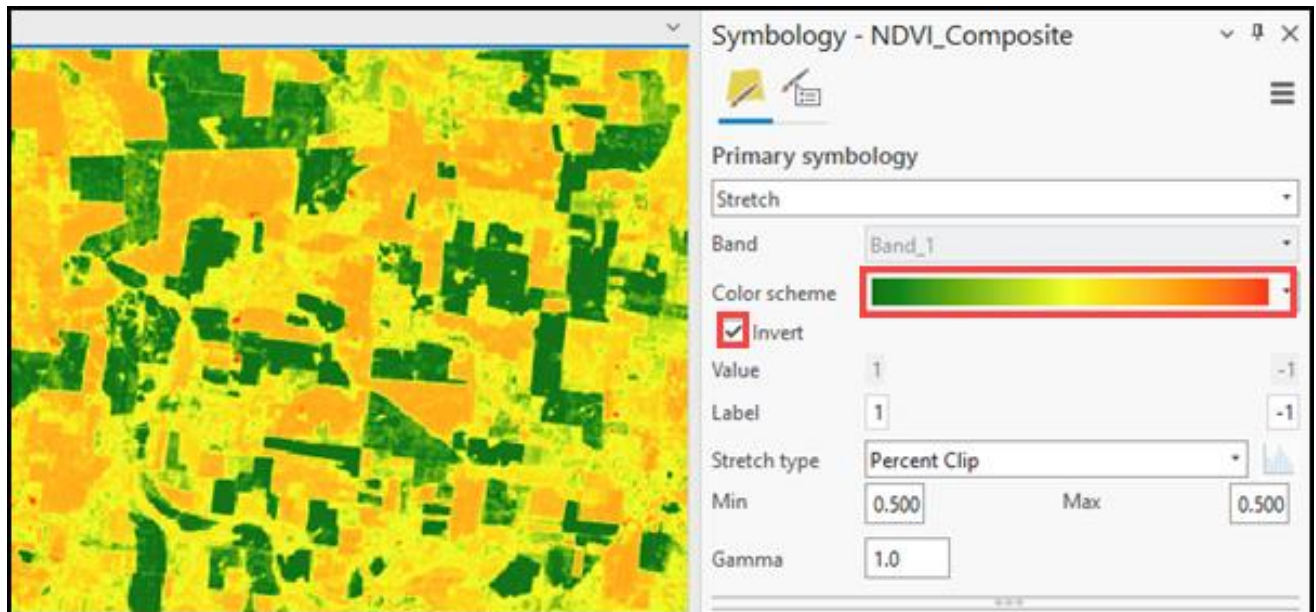


Figure 5. NDWI change detection [15]

THE NORMALIZED DIFFERENCE BUILT-UP INDEX (NDBI)

The Normalized Difference Built-up Index (NDBI) is a remote sensing index used to detect and map built-up areas or urban land cover from satellite imagery. It leverages the differential reflectance of near-infrared (NIR) and shortwave infrared (SWIR) bands to differentiate between built-up areas and non-built-up land cover types. NDBI values typically range from -1 to 1, with higher values indicating the presence of built-up areas and lower values indicating non-built-up land cover types such as vegetation or bare soil. Positive NDBI values usually correspond to urban or built-up areas, while negative values indicate non-built-up land cover.

NDBI is widely used in urban studies, land use planning, and environmental monitoring for various applications, including **Urban Growth Monitoring:** NDBI is used to track changes in urban land cover over time, assess urban sprawl, and monitor patterns of urban growth and development. By analyzing temporal NDBI trends, researchers and urban planners can evaluate the pace and extent of urbanization and its impact on the surrounding environment. **Land Use Classification:** NDBI is employed as a feature in land cover classification algorithms to differentiate between built-up and non-built-up land cover types. By integrating NDBI with other spectral indices and classification techniques, land cover maps can be generated with improved accuracy and detail, facilitating land use planning and natural resource management.

Impervious Surface Mapping: NDBI is used to map impervious surfaces such as roads, buildings, and pavements in urban areas. By thresholding NDBI values, impervious surfaces can be delineated from other land cover types, enabling accurate mapping of urban infrastructure and assessing the extent of impervious surface coverage. **Urban Heat Island Detection:** NDBI is utilized to identify urban heat islands (UHIs), which are areas of elevated temperature in urban areas compared to surrounding rural areas. By analyzing spatial patterns of NDBI and surface temperature, researchers can assess the extent and intensity of UHIs, understand their underlying causes, and develop strategies to mitigate their impacts on human health and the environment.

Socio-Economic Analysis: NDBI data are used in conjunction with socio-economic data to analyze urbanization trends, assess socio-economic disparities, and identify areas of urban poverty or informal settlements. By combining NDBI with demographic and economic indicators, researchers can gain insights into the spatial distribution of population, income, and infrastructure in urban areas. Overall, NDBI serves as a valuable tool for

mapping and monitoring urban land cover, assessing urbanization dynamics, and supporting decision-making processes in urban planning, environmental management, and socio-economic development. Its simplicity, effectiveness, and applicability to a wide range of urban environments make NDBI a fundamental index in remote sensing and GIS applications for urban studies and land use analysis [12-14].

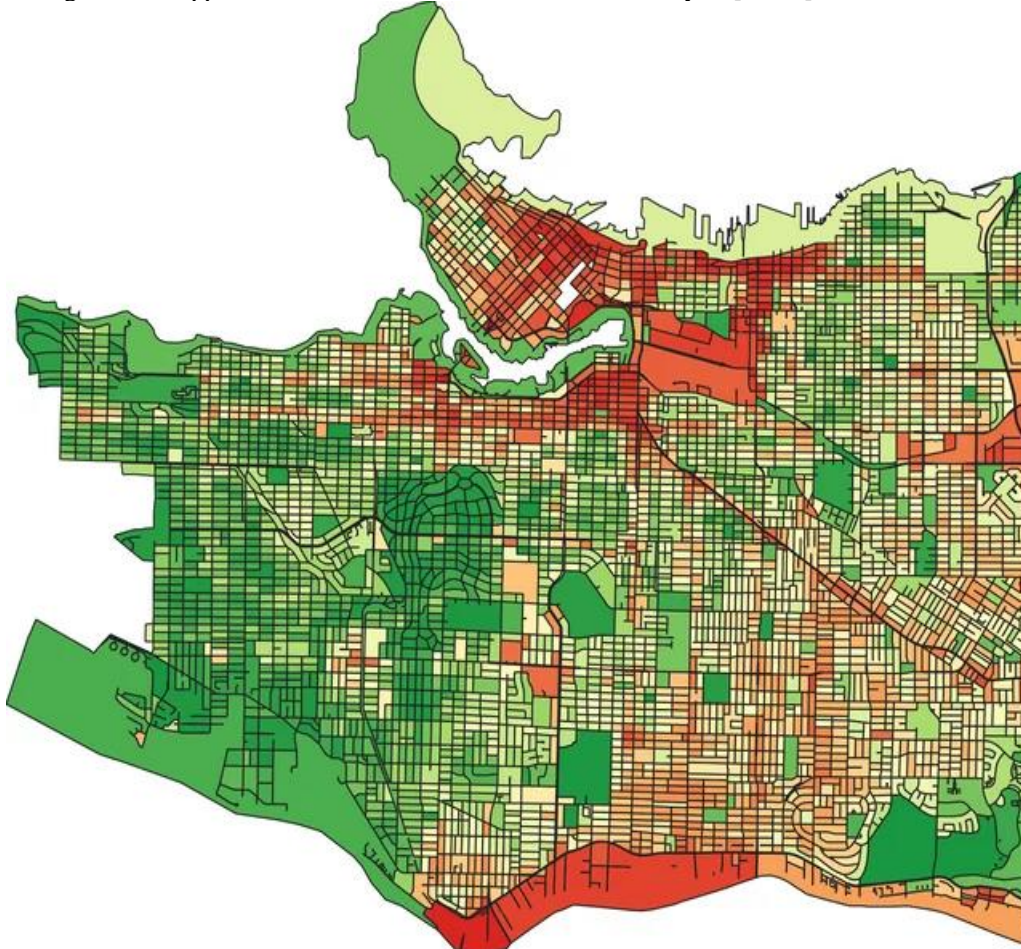


Figure 6. NDBI change detection [15]

FUTURE PREDICTIONS

In the future, advancements in remote sensing technology, data analytics, and machine learning are expected to revolutionize the field of spatial analysis, paving the way for more accurate, efficient, and comprehensive analyses. Integration of multi-source data from satellites, drones, and ground-based sensors will enable a more holistic understanding of spatial phenomena, while advanced data fusion techniques will facilitate the integration of diverse data types for improved analysis outcomes. Moreover, the adoption of cloud computing and high-performance computing (HPC) platforms will empower researchers to process and analyze large-scale spatial datasets more efficiently, unlocking new insights into complex spatial relationships and dynamics. Additionally, the development of automated feature extraction algorithms and deep learning models will streamline the process of extracting meaningful information from spatial data, reducing the need for manual intervention and accelerating analysis workflows. Furthermore, the growing availability of open data initiatives and collaborative platforms will democratize access to spatial data and analysis tools, fostering greater collaboration and innovation in the field. Overall, the future of spatial analysis holds tremendous potential for addressing pressing societal challenges, informing evidence-based decision-making, and advancing our understanding of the world around us.

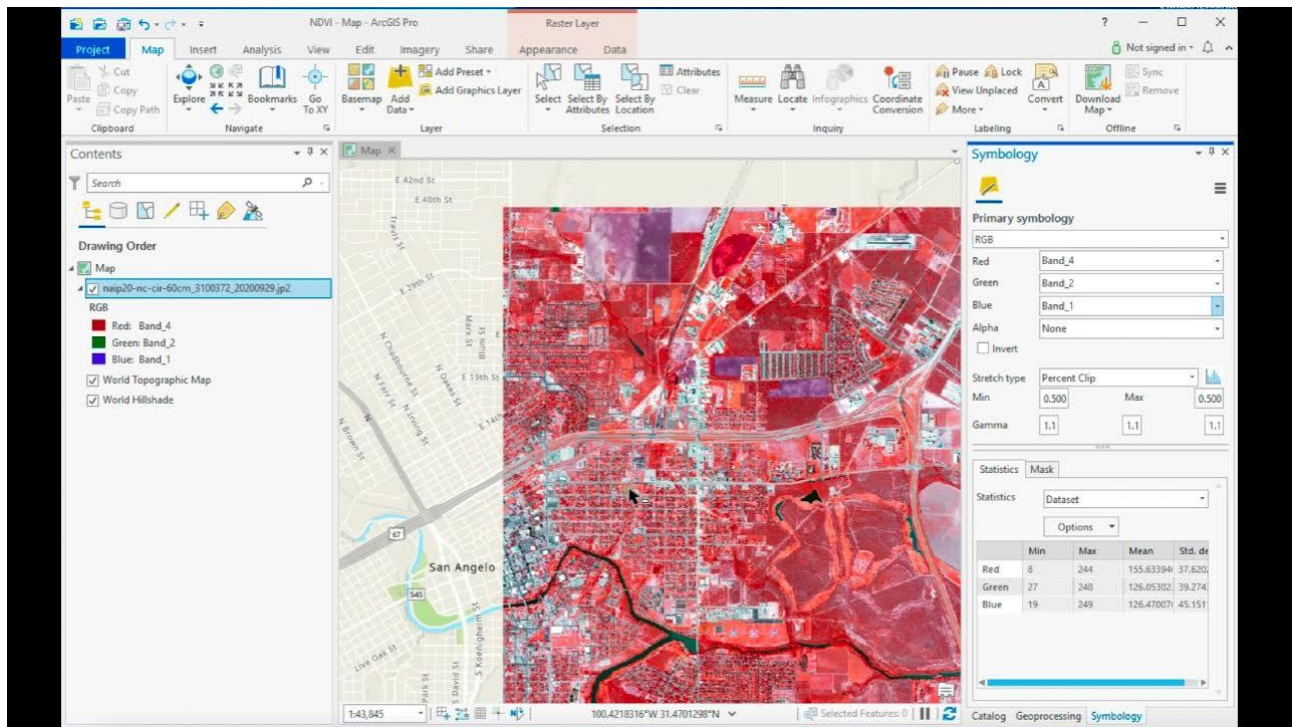


Figure 7. future predictions of GIS [16]

CONCLUSION:

In conclusion, Geographic Information Systems (GIS) play a pivotal role in modern society by providing powerful tools for analyzing, visualizing, and interpreting spatial data. Throughout this exploration, we have delved into the fundamental principles, technical aspects, and diverse applications of GIS, highlighting its versatility and significance across various disciplines. From environmental monitoring and urban planning to agriculture and disaster management, GIS offers valuable insights into complex spatial phenomena, enabling informed decision-making and effective resource management. As we look towards the future, advancements in technology and data analytics promise to further enhance the capabilities of GIS, opening new avenues for research, innovation, and collaboration. However, it is essential to recognize the challenges and limitations inherent in GIS analysis, including data quality issues, computational constraints, and ethical considerations. By addressing these challenges and embracing emerging opportunities, we can harness the full potential of GIS to address pressing societal challenges, promote sustainable development, and create positive change in our communities and beyond. In essence, GIS represents a powerful tool for understanding and navigating the complexities of our interconnected world, empowering us to make informed decisions and shape a better future for generations to come.

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