International Journal of Engineering and Geosciences

https://dergipark.org.tr/en/pub/ijeg

e-ISSN 2548-0960

A Case Study: Making Decisions for Sustainable University Campus Planning Using GeoAI

Esra Kumaş [*1], **Damla Sivrioğlu Aslan** [2]

[1] OSTİM *Technical University, Management Information Systems, Türkiye, esra.kumas@ostimteknik.edu.tr*
[2] *Integration Solution Development, Huawei Turkiye R&D Center, Ankara, Türkiye, damla.sivrioglu.aslan@huawei.com*

Cite this study: Kumaş, E., Sivrioğlu Aslan. (2025). A Case Study: Making Decisions for Sustainable University Campus Planning Using GeoAI. International Journal of Engineering and Geosciences, 10 (1), 22-35.

https://doi.org/10.26833/ijeg.1506265

Keywords
Sustainable City
Green Campus
Sustainabilty
GeoAI
Urban Planning

Research Article

Received:27.06.2024
Revised: 26.08.2024
Accepted:10.09.2024
Published:01.02.2025

Abstract

The increasing availability of geospatial data, the development of AI and the availability of large computational capacities have contributed to the growing importance and potential of GeoAI. GeoAI has an important role in advancing traditional AI technologies and developing new ways to solve problems posed by the massive, complex, diverse and ever-increasing nature of geospatial data. Geospatial data is widely used in many scientific fields and applications such as smart cities, transportation, business, public health, public safety, resilience to natural disasters, climate change and many more. Especially because of the huge growth in population and the need to analyse United Nations sustainability impacts oblige the experts to utilize GeoAI. The future vision, sustainable cities and green campuses provide acceleration in the IoT and planning with GeoAI. In this scope this preceding enlightens campus planning by GeoAI as beginning step of the digital twin mechanism. This article is applied to: (1) GeoAI and campus planning techniques; (2) QGIS and KooMap utilization for AI based image recognition; (3) interpreting the output of GeoAI based map and giving sustainability recommendations related with campus planning; (4) Strengths and shortcomings of the research. GeoAI usage is proven as a beneficial way to make decisions on university campus by using automatically recognized satellite images. It is the first step for digital campus management system.

1. Introduction

With the increasing global population and urbanization rates, the management of cities has become increasingly challenging. This population growth has led to an increase in consumption, highlighting the need for efficient use of resources, while also contributing to environmental pollution issues. The influx of people into cities has led to increased traffic and environmental pollution, while the expansion of urban areas has disrupted ecological balance. The challenges associated with managing the growing population, coupled with increasing environmental pollution and degradation, have prompted countries to create smart and sustainable cities. While countries allocate significant budgets to the development of smart and sustainable cities, some cities are planned to be rebuilt, while others focus on making their traditional cities smart and sustainable [1]. A smart city is defined as a city that uses digital technology to improve its operations and management and address the problems affecting the modern city [2]. Smart cities are seen as an important potential for the future as a solution to global climate and ecological problems [3]. Since it would be expensive, difficult, complex, and time-consuming to completely change the infrastructure of an entire city for experimentation purposes, testing these applications on a smaller scale, such as a university campus, could be a good alternative [4]. Increasing access to higher education in many countries has led to a significant increase in the number of students [5] and campuses have become prototypes of cities with their student numbers, vehicle traffic, infrastructure services and increasing management problems.

Advancements in information and communication technologies (ICT) enable data generation from various sources, different times, and locations in cities, while also making it possible to process this data. Data obtained through the 2D or 3D scanning of the physical environment, objects, and humans, such as satellite images and LiDAR point clouds, are used to simulate, plan, design, and manage cities. Developments in Artificial Intelligence (AI) algorithms also make it possible to collect, process, analyse, and visualize big datasets. Interdisciplinary spatial analytics known as Geographic Spatial Artificial Intelligence (GeoAI) is a technological solution for data-intensive geospatial problems, heralding a new stage of data-intensive discovery that complements empirical, theoretical, and computational paradigms characterizing the evolution of scientific research so far [6]. It can be said that there is a general consensus in the literature about the central role that real-time or near-real-time GeoAI supported data analytics can play in monitoring and operating a city or campus [6]. The continuous flow of directed, automated, and voluntary big data collected from a wide range of mobile and fixed data sources about buildings, assets, urban infrastructure, citizens, and the environment, including physical and social perceptions, enables the real-time simulation of urban data.

In this scope the main contribution of our article is the usage of GeoAI as an opportunity to plan sustainable campuses which are the miniature of the cities and the core components of this issue. To plan our campuses smartly, we should use state-of-the-art solutions such as geospatial data driven approaches [7].

2. Background

2.1. Geospatial artificial intelligence

Geospatial Artificial Intelligence (GeoAI) can be defined as a new discipline that combines innovations in spatial science, artificial intelligence methods such as ML and DL, data mining and high-performance computing, aiming to assist in the processing and spatial analysis of big data [8].

GeoAI uses ML [9-16], and DL [17-27]. GeoAI now has an important role in advancing traditional AI technologies and developing new ways to solve specific problems posed by the massive, complex, diverse and ever-increasing nature of geospatial data, which are considered geo-referenced data containing geo-tagging locations or location marker. Geospatial data is widely used in many scientific fields and applications such as smart cities, transportation, public safety, natural disasters, climate change and many more.

GeoAI has significantly advanced GIS and mapping methods in recent years and the integration of advanced computing tools enables more innovative applications for GeoAI and Earth observation. GeoAI has become a driving force in advancing the use of GIS data [8]. Although the application of GeoAI for mapping is increasing, there is still a need to improve application development in various aspects. In Table 1, studies related to GeoAI are presented, including the techniques used in these studies and the objectives of the studies.

Table 1. GeoAI studies and their aim(s)

Author/ Year	Aim(s)
VoPham, et al. 2018 [28]	To provide an overview of GeoAI and potential future directions for GeoAI in environmental epidemiology.
Janowicz et al. 2020 [29]	It examines the work on GeoAI, how increased data sharing is accelerating GeoAI efforts, and its future potential.
Cugurullo 2020 [30]	The paper explores how the development of artificial intelligence intersects with urban development, both theoretically and practically, and examines the case of Masdar City, an urban experiment in the United Arab Emirates. It shows that the emergence of urban AI is part of a long-term process of technological development and a political-economic agenda that enables the transition from automation to autonomy.
Arundel et al. 2020 [31]	In this paper, data containing 200 examples for each of 10 natural feature classes is tested on an object detection problem using a region-based convolutional neural network. It also discusses the main challenges in developing training data in the geospatial domain, such as scale and geographic representation.
Döllner 2020 [32]	The paper characterizes 3D point clouds as a master data category and describes the role of 3D point clouds for building the foundation of geodigital twins, the applicability of M and DL approaches for 3D point clouds. Examples are also given to illustrate how ML/DL allows to efficiently create and maintain the underlying data for geodigital twins, such as virtual 3D city models, indoor models or building information models.
Gao 2021 [33]	Studies describing the importance of GeoAI are reviewed, from basic spatial representation learning to spatial prediction and various advances in cartography, earth observation, social perception and geographical meanings.
Liu and Biljecki 2022 [34]	They aimed to familiarize beginners with the basics and state-of-the-art of GeoAI and to draw attention to the potential of spatially explicit GeoAI for studying socio-economic dimensions of urban life.
Pierdicca and Paolanti 2022 [35]	The study outlines AI-based techniques for analyzing and interpreting complex geomatics data.
Alastal and Shaqfa 2022 [36]	The paper provides an overview of GeoAI technology and guides the reader on integrating artificial intelligence with geographic information systems and utilizing GeoAI tools and technologies. The paper also includes a case study on the use of GeoAI in Kuwait and a set of recommendations.
Ang et al. 2022 [37]	It includes key discussions on the implications of geographic information on Smart City transportation, machine learning approaches for Smart City transportation, innovative artificial intelligence (AI) approaches for Smart City transportation, and recent emerging trends using integrated DL.

Song et al. 2023 [38]	The study discusses GeoAI applications in a broad framework. Usage areas of GeoAI applications; They examined them in four categories: building and infrastructure problems, analysis for land use, natural disasters and management of social problems.

Liu and Biljecki [34] stated that the development of spatially explicit GeoAI models is still at an early stage, but the applications of deep neural network-based methods are increasing. They show that DL is the most widely used method especially in recent years, the average rate of DL is 80% compared to ML's rate, while ML's rate is 20% [34].

The aim of this study is to provide an overview of the main concepts surrounding the emerging field of GeoAI, to clarify the differences between GeoAI and more general AI, to integrate AI with GIS, making visualization and software with AI capabilities crucial. Furthermore, this paper discusses the main steps for geospatial data analysis that have been successful in main areas such as application and model development, including visualization. Additionally in this study, object classification was performed using a combination of ML and DL methods.

2.2. Green Metric Index

In September 2015, the United Nations adopted the 2030 Agenda for Sustainable Development, which outlines 17 Sustainable Development Goals (SDGs) to be implemented by member states. Higher education institutions, including public institutions, play an important role in achieving sustainable development. The core activities of higher education institutions, such as teaching, research and management, profoundly affect the economy, the environment and society, as recognized by the 2030 Agenda.

The term “green campus” has its origins in the concepts of “environmental protection” from the 1972 Conference on the Human Environment and “sustainable development” from the 1987 World Commission on Environment and Development. Sustainable development has come to play a key role in higher education institutions, both for the organization, teaching and research, and for the sustainability of the physical environment of the campus. Green campus assessment systems have been launched to evaluate the sustainability performance of campuses. The Sustainability Tracking, Assessment, & Rating System (STARS) was launched in 2006 and so far 342 out of 1204 registered higher education institutions have received a STARS rating. Subsequently, the University of Indonesia (UI) launched world university rankings in 2010, later known as the UI GreenMetric World University Rankings, to measure the sustainability efforts of campuses. The aim of the Green Metric is to create a self-assessment tool on campus sustainability for higher education institutions around the world. In 2010, 95 universities from 35 countries participated in the ranking and by 2022 this number had grown to 1050 universities from 85 countries. The UI GreenMetric assesses university policy and performance across six categories Environment and Infrastructure (SI), Energy and Climate Change (EC), Waste (WS), Water (WR), Transport (TR) and Education and Research (ED). The index is derived by administering a remote, online survey to derive a sustainability ranking of universities. Some data is self-reported, while others require evidence to be uploaded [39]. Factors such as the fact that the index is largely based on the statements of participating universities and that some criteria are far above national requirements make it difficult to obtain objective results [40]. In the UI green metric ranking, universities are divided into 6 categories according to the characteristics of their campuses. In this study, the campus of OSTİM Technical University, which is in the “high-rise building” category, is analysed. It is thought that the study will also contribute to the development of a decision support tool that can automate the results by taking satellite images in the evaluation of evidence and external environmental factors such as the size of the campus area, green area ratio, parking ratio, building ratio, open space ratio, and to obtain more accurate results.

There are various studies in the literature on the Green Metric ranking of universities. Examples of these studies are given below;

Table 2. Green Metric Index studies and their aim(s)

Author/ Year	Aim(s)	Results
Karasan et al. 2023 [41]	To develop a methodology for green metric evaluation and decision making using multiple expert knowledge for uncertain environments.	It is shown that the green index of universities can be calculated using a multi-stage decision-making model.
Boiocchi et al. 2023 [42]	The UI GreenMetric World University Ranking system aims to examine the effectiveness and fairness of universities in measuring their sustainability efforts.	Suggestions for improvement were made regarding the indicators of the ranking system.
Sari et al. 2023 [43]	It is aimed to examine the positive effects of participation in UI GreenMetric on the performance of universities in creating sustainable campuses.	UI GreenMetric participation has been shown to have a positive impact on their standing in THE Impact Rankings.
Galleli et al. 2022 [44]	It is aimed to compare UI green metric and times higher education sustainability university rankings.	It is reported that there are differences in the structure, limitations and areas for improvement in both rankings.
Atıcı et al. 2020 [45]	It is aimed to explore the relationship between universities' environmental sustainability efforts and their performance in UI GreenMetric and global rankings.	It has been shown that environmental sustainability can be a global competitive advantage for universities.

Ariesanti et al. 2019 [46]	It is aimed to analyse the online disclosure of environmental responsibilities of Indonesian universities.	It was found that most Indonesian universities do not disclose their environmental activities on their websites.
Rochim &Sari 2015 [47]	It aimed to analyse the relationship between Institutional Archives visibility and waste management in Indonesian universities.	It has been suggested that there is a strong correlation between academic resource accessibility and environmental sustainability efforts.

2.3. Smart and Sustainable Campus

According to the Turkish Language Association, the word "smart" means "capable of distinguishing right from wrong, good from bad, able to act correctly and cautiously as it should be by taking lessons from the experiences it has gained and seeing the reality well". Today, especially thanks to advances in artificial intelligence, there has been a tremendous development in the number and usage areas of smart devices. Machines have also become smarter and have gained the ability to distinguish right from wrong like humans and to act correctly and cautiously as they should by learning from their experiences.

Smart campuses aim to create more efficient, optimized and more sustainable environments thanks to the data obtained from people and objects inside and outside the campus. Smart campus studies have recently gained momentum, especially with the rise of smart cities. While increasing population and limited resources require optimization in areas, the increase in the number of data obtained from people and objects has made it possible to improve by drawing meaningful conclusions from this data. While some of the studies on smart campuses have focused on tools to improve learning skills, others have focused on ensuring their sustainability, and a significant number have focused on developing conceptual models due to the newness of the concept and the lack of applications. The table below compares some of the case studies on smart campuses;

Table 3. Smart campus studies and their aim(s)

Author/ Year	**Aim(s)**	**Results**
Polin *et al.* 2023 [48]	The aim of the study, which is a literature review, is to highlight the more comprehensive conceptualization of smart campuses and their practical applications in various fields.	The conceptual framework is presented.
Mahariya *et al.* 2023 [49]	Through observation and analysis, it is aimed to explore the role of industry 4.0 technologies in enabling innovation and sustainability.	Innovative facilities aimed at achieving sustainable development goals are presented.
Silva-da-Nóbrega *et al.* 2022 [50]	Using importance performance analysis, it is aimed to identify key elements and gaps in smart campus dimensions and provide priorities for decision makers.	Opportunities and challenges for an education based on sustainable development goals are reported.
Paspatis *et al.* 2022 [51]	It is aimed to demonstrate the role of smart campus microgrids in sustainable energy transition through case studies.	The applicability of microgrids is demonstrated through the example of Hellenic Mediterranean University.
Alnoman *et al.* 2022 [52]	Developing a smart campus application that emphasizes technology-oriented, student-centered learning with framework development method.	The use of technology is important in improving the student learning experience and data privacy challenges were also addressed.
Liu 2021 [53]	Developing a smart campus by using educational information systems in Vocational Schools through case study.	A smart campus information environment enriched by the integration of cloud computing, IoT, big data and AI has been developed.
Chen 2020 [54]	Demonstrate the deployment of a smart campus ecosystem in the case of Sichuan University using a case study.	A smart campus ecosystem was presented, supported by progressive construction ideas and the use of cutting-edge technology.
Dong *et al.* 2020 [4]	It is aimed to determine the definition and framework of smart campuses.	An integrated perspective of technological advances and educational concepts was presented..
Sari *et al.* 2016 [43]	Through technology implementation, it is aimed to demonstrate how IoT can be used in smart campus development.	The impact of IoT on real-time and technologically integrated teaching approaches and external partnerships is demonstrated.
Rha *et al.* 2016 [55]	Through a literature review, it is aimed to illuminate the current state of smart campuses and provide a framework.	A multifaceted framework is proposed across the dimensions of learning, technology and user engagement.

2.4. Campus Planning

Smart campuses are a given name for the small applications of the smart city facilities. The university campus is an example for the smart campus. In the vision of the smart campus for the future there are lots of studies that try to analyze land-use land cover (LULC) maps, and make decisions for planning campus area in the literature [56-71].

At these researches multiple ML classification, time-framed change analysis, remote sensing and manual demonstration methodologies were applied to assess satellite imagery.

On the other hand, limited number of works present campus planning decision making by the behalf of GeoAI. Table 4 interprets the studies in literature with their methodologies and results.

It is our contribution to the literature and the originality of our study that we provide aspects and views by a case study in the applied GeoAI science domain. To guide the authorities who make campus planning we interpret them the usage of AI based LULC maps and give potential opportunities and threats by evaluating analysis output.

Table 4. Campus planning studies and their content

Author-Year	**Methodology**	**Result(s)**
Thar et al. 2018 [56]	Agisoft, QGIS, ArcGIS,Image Classification	Analysis of planning buildings, stadiums, swimming pools, parks and recreation centres in the university campus. Any sustainability planning decision was given.
Kinoti and Nyaga 2018 [57]	GIS, Remote Sensing, LULC Changes	Analysis of land use and land cover change in Karatina University. They give an overview guiding to update the university policy.
Hwang and Wiseman 2020 [58]	Photo Interpretation, Image classification	Analysis of urban tree canopy and comparison the outputs of two techniques. Any sustainability planning decision was given.
Bozdağ et al. 2020 [59]	Spatial and Statistical Area Analysis (manually with GIS tool)	Social and behavioral analysis of spatial legibility. Any sustainability planning decision was given.
Haq and Panduardi 2020 [60]	QGIS, AHP Statistical Analysis	Social and behavioral analysis of campus planning for academic success. It gives a new approach suggestion that can be used for academic suitability analysis. But any sustainability planning decision was given.
Zaki et al. 2020 [61]	GIS, Statistical Analysis (Morphological Parameters)	GIS analysis as a useful tool in smart city urban planning. They give an overview related with environmental impacts guiding to sustainable and proper campus planning.
Papua et al. 2020 [62]	QGIS, Manual Assessment	Map analysis by spatial data. It is related with the development of a new web-based GIS for campus review. But any sustainability planning decision was given.
Srivastava and Chinnasamy 2021 [63]	LULC Changes, Google Earth Pro, Manual Classification	Ecological analysis of campus by environmental sustainability impacts. They give an overview related with environmental impacts guiding to sustainable campus planning.
Shao 2021 [64]	LIDAR Metrics, Statistical Analysis	They give insights related with environmental impacts.
Hong et al. 2022 [65]	Hyperspectral Image, Convolutional Neural Networks (CNNs), Transformers	AI based mathematical model is suggested. But any sustainability planning decision was given.
Ikara et al. 2022 [66]	ArcGIS, Manual Mapping	Any sustainability planning decision was given.
Anushya 2020 [67]	ArcGIS, Google Earth, 3D Model	It gives insights related with indoor planning.
Alastal and Shaqfa 2022 [36]	GeoAI, GIS	AI based geographical analysis. But any sustainability planning decision was given.
Çaliskan 2023 [68]	LULC Changes, Remote Sensing	It gives insights related with campus planning.
Çetin and Yastıklı 2023 [69]	LIDAR Metrics, DBSCAN clustering	It gives insights related with detecting trees.
Özaydın et al. 2024 [70]	Open source building datasets	It gives insights related with detecting buildings.
Li et al. 2024 [71]	GPS, GIS	Solution analysis for parking efficiency.

3. Materials and Methods

Object detection locates objects of interest in an image and returns location and category information. With the development of remote sensing (RS) technology, both the size of single satellite images and the amount of information they contain are rapidly increasing. Unlike close-range imaging, satellite images usually cover a large area and have a complex background as well as different projection orientations. Therefore, it is very difficult to accurately detect all objects in a satellite image. The currently available automatic image interpretation approaches cannot meet the needs of many real-world applications in the RS community. Therefore, the question of how to quickly and accurately detect objects from satellite imagery has become a focus of research. To counter the challenges, existing object detection algorithms often combine template matching, knowledge representations, object analysis and machine learning [72].

DL and ML algorithms are frequently used for GeoAI. Especially Convolutional Neural Networks (CNN), Recurrent Neural Networks and Transformers [65] are common techniques for image processing and classification by identifying and labelling patterns, textures and characteristics [35]. By these technologies the detected objects can be displayed on satellite image. Various land uses and objects can be recognized and demonstrated as different task types by mapping with geotif files and geojson data. The characteristics of the pixels are analysed and clustered on the regions based on similarities in colour and shape. The images can be separated to the segments such as foreground, background or road, car, sky, pedestrian, bike. In addition, the files that have low resolution can be updated with high-quality resolution by data augmentation methodologies. These algorithms and techniques are helpful for several industries such as agricultural crop recognition, urban planning, automatic map updating, medical diagnosis, autonomous driving, video surveillance, and machine vision.

There are several solutions such as SenseEarth and ArcGIS to serve these GeoAI applications digitally. ArcGIS is an ESRI product to integrate artificial intelligence, machine learning, and deep learning with GIS technology to produce knowledge, solve problems, quantify risks, and find opportunities faster. ArcGIS system automates workflows, creates rich models of the real world, and analyses all kinds of data at scale, including imagery, 2D and 3D features, tabular data, videos, unstructured text, and time-series data. SenseEarth is an AI-powered Geospatial Analytics Tool to cover land use, crop recognition, change detection and object detection etc. It provides land use classification compatible with both drone and satellite images by extracting over 25 classes of ground features automatically.

In our paper KooMap alternative solution was determined because of its comprehensive Cloud foundation models which is continuously pre-trained and fine-tuned. Its strengths are the capabilities to combine IoT backstage solutions and GeoAI for digital twin applications. These tools were used for several years to establish smart campuses and smart cities. Therefore, the algorithm components have high accuracy with its comprehensive and robust database data models from different regions of World [73].

In this research the applications utilizing these cutting-edge technologies are chosen and the research methodology given in Figure 1 was applied. QGIS application is an open-source geographical information system (GIS) software to view, analyse, edit and print spatial information, in addition to composing and exporting graphical maps. QGIS is popularly used by GIS analysts and experts. QGIS is a geographic information system software that is free and open-source. QGIS supports Windows, MacOS, and Linux. KooMap is an application platform as a service (aPaaS) which is served through Huawei Cloud. KooMap allows users to make LULC and object detections on satellite images. It is an AI-powered, cloud-native geospatial analytics and applications platform. KooMap provide insights for the city planners and other industry experts for the domains smart city, campus, telecom, agriculture, architecture, sustainability, energy and mechanical engineering by GeoAI applications. KooMap also aims to produce digital twin cloud maps. Huawei Cloud Map Service is also a satellite image processing service that converges high-quality satellite sources and provides global satellite image processing, supporting application transformation and innovation for government and enterprise customers. It provides industry assets, builds an open platform, and provides one-stop out-of-the-box space-time information services, such as spacetime processing, analysis, and visualization.

OSTİM Technical University ranked 886th among 1182 universities with 4425 points out of 10000 points in the UI Green Metric ranking. In the ranking, universities are subjected to 6 categories and 24 sub-categories such as the ratio of open areas to total areas, the ratio of green areas, smart building applications, green building applications, the ratio of vehicles to the campus population, and the ratio of parking areas on campus. For this reason, in order to make an automatic measurement for the subcategories mentioned in the study, buildings, trees, roads and vehicles were identified and their ratios were determined from satellite images. OSTİM Technical University's location in the capital city and in an industrial zone was an important selection criterion. These regions are the places where the most steps need to be taken and planning needs to be done in terms of sustainability.

In this study area scope 5 different geospatial data type were analysed. These are building AI detections, roads AI detection, trees AI detections, vehicle AI detections and vehicle AI detections by data augmenting. All of these output data types are generated by KooMap. Deep learning methods such as Convolutional Neural Networks algorithms were applied to the Google Map images in the background of this application. By data augmentation method the geospatial data were increased by rotating, re-colouring, zooming.

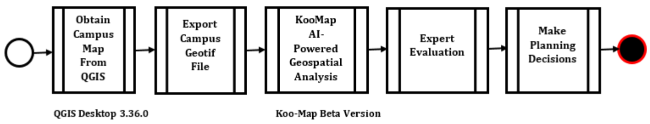

Figure 1. Research approach flow

Geospatial data collection was operated as follow. Firstly, OSTİM Technical University campus satellite image was obtained by using QGIS and the map on URL: http://mt0.google.com/vt/lyrs=s&hl=en&x={x}&y={y}&z={z}. During data pre-processing the raster polygon points were set and the campus area defined with latitude and longitude information. By clipping the raster, the georeferenced image was exported from QGIS in .tiff format as the second step.

Thirdly, the campus tif file was analysed by KooMap using image recognition AI algorithms for building, road, tree and super resolution vehicle detections. To provide these object detections, feature extraction and model training phases were executed in the background of the KooMap. KooMap benefits from the pre-trained foundation models being executed in Cloud. These foundation models [74] were pre-trained with 100 billion parameters by multiple data sources and multiple data types such as enterprise, public network, tables, images, video etc. These models are fined-tuned with multiple scenarios using PostgreSQL, Oracle and Huawei-developed distributed relational database GaussDB. Computer Vision Foundation Model comprises from classification, segmentation and inspection methods for pre-training. After pre-training fined-tuned models are deployed according to different scenarios in the pipeline and the cycle continues by the iterations for continues model trainings. These B2B applications are used for smart cities, smart campuses and industry specific digital twins [74]. The training efficiency of the models is average more than 40% and 95% accuracy.

The obtained detection layered satellite image was evaluated by experts from OSTİM Technical University. The experts reviewed and discussed the campus according to its building structure, road infrastructure, tree density and vehicle density by comparing with other structures surrounding the campus in the GIS.

At the end of the methodology the experts made some decisions related with their campus planning considering the results of AI powered geospatial analysis.

The aim of this scientific approach is to present some sustainability decisions for a university campus with the supervision of the environmental GeoAI insights.

4. Results

Figure 2 and Table 5 depict the analysis output of the full range buildings, road, tree and vehicle detected with and without augmented resolution tasks. The geotiff size is 3.36 MB that includes 0,220 km2 geospatial area between 32° 44' 29.84'' N - 32° 44' 48.00'' N longitudes and 39° 58' 4.28'' E - 39° 58' 13.99'' E latitudes. It has 3743*2612 pixels resolution with 96dpi with 32-bit depth. Building, road, tree are the LULC, and vehicle is the object which were detected by using Analysis module of KooMap. KooMap provides a City Information Modeling (CIM) for decision making on environmental and civil engineering optimized planning.

The colors that define the objects in Figure 2 are as follows; blue-GeoAI detected buildings, green-GeoAI detected trees, purple-GeoAI detected vehicles, red-GeoAI data augmented detected vehicles, yellow–GeoAI detected roads.

Figure 2. Analysis output

Table 5. Quantitative analysis output

Type	Area (km2)	Percentage	Count
Building	0.06302	55.5761%	19
Tree	0.03323	29.3049%	48
Road	0.01299	11.4556%	12
Vehicle	0.004154	3.6633%	617

4.1. Image recognition

4.1.1. Buildings

Reducing carbon emissions in buildings is critical to achieving the Paris climate goals and net zero emissions by 2050. Buildings represent 39% of global greenhouse gas emissions, of which 28% are operational emissions and 11% are building materials and construction. Buildings can achieve zero carbon performance by using renewable energy for heating, reducing the use of refrigerants with high global warming potential and using low-carbon, recycled materials in construction. Energy efficiency is one of the top priorities for zero carbon buildings. Digitalization is a key enabler of energy efficiency in buildings. Smart buildings leverage advanced sensing and controls, system integration, data analytics and energy optimization to actively reduce energy use and demand. The potential energy savings from smart buildings are significant. Automated systems can save 10-15% of energy in commercial buildings. More advanced functions such as demand-controlled ventilation can save an additional 5-10%. Integrating building systems can deliver incremental energy savings of 8-18% compared to basic HVAC (heating, ventilation and air conditioning) and lighting control. Energy Information Management Systems that use advanced metering infrastructure and monitor end-use in buildings can save an average of 3%, while automated fault detection and diagnosis can save an average of 9% in energy use [75].

As seen from Figure 3 the region located in OSTİM Technical University includes large buildings because it is in the largest industrial zone of Ankara. OSTİM Technical University consists of three blocks formed a single file as the figure below. This figure shows an output from KooMap application to analyse OSTİM Technical University campus buildings detected automatically by image recognition method.

These blocks` quick bird views are differentiating from other building in the industry zone, it comes through the construction of an educational center. This construction style can be continued for next campuses. The accessibility is easy to other blocks from one thanks to the internal connections between buildings.

Figure 3. Building evaluation

It is seen from Table 5 that the building area is relatively much more than the tree, road and vehicle areas. An extensive area 55% of the campus is occupied with concrete rather than other types. Considered that greenery places should be constructed balanced with concrete field for next campuses.

The fact that the largest part of the campus area consists of buildings has made energy saving and the use of renewable energy in buildings the most important element of sustainability for the university. The university can prioritize building energy efficiency to increase its sustainability score. It can also increase energy efficiency by making buildings smart. Again, as seen in Figure 3, energy needs can be met from renewable energy by installing solar panels in the areas of building transitions or terrace areas.

4.1.2. Road

Roads surrounding campus was evaluated by experts in Figure 4. This figure shows an output from KooMap application to analyse OSTİM Technical University campus closest roads detected automatically by image recognition method. The campus has a main road at the left side of the neighbor mosque of campus. Other sides are the parts of side lines connecting campus to OSTİM industrial zone. By looking at these streets campus is in the top intersection of the three distinct avenues (Alinteri Avenue, Baskent Avenue and 100. Yil Avenue).

Figure 4. Road evaluation

It is seen from Table 5 that the road area covers 11% of the all types of the GeoAI detected areas. The total of buildings and roads cover 66% of the types in percentage. Considered that greenery places should be constructed balanced with concrete field for next campuses.

4.1.3. Trees

Green spaces contribute greatly to a sustainable city and the improvement of the environment. Green spaces play an important role in sustainable development. Green space interventions nurture the existing character of settlements, improve environmental conditions, encourage outdoor recreation and active lifestyles. On a larger scale, they also reduce heat island effects and runoff. In recent years, their role in reducing carbon emissions and improving people's health has also been emphasized [76]. The benefits of green spaces can be divided into three main categories: environmental benefits, economic and aesthetic benefits, and social and psychological benefits [77]. In the UI Green Metric assessment, green spaces account for 500 out of 10000 points.

Figure 5 shows an output from KooMap application to analyse tree density inside OSTİM Technical University campus and closest area detected automatically by image recognition method. It is seen in Figure 5 that the trees are so rare that the pavements cover the big area of the scene. This situation causes not be cleaned of the polluted air and an uncomfortable atmosphere by campus students. Sustainable development and the development of green spaces is of great importance, not only for the natural environment, but also as an urgent need to improve people's lifestyles. Quality of life is positively influenced by a number of important roles played by green spaces. To increase life conditions, it is necessary to increase greenery areas near the campus. It is possible to take various actions inside and outside the building to increase green areas. Green roofs for campus buildings and increasing green area might be an optimized choice to provide green area for students. Greening the campus environment, irrigation of green areas by collecting rainwater, vertical greening on the building surface can be listed among the main solutions that can be done. In Milan, Italy, architects created a "vertical forest" of 800 trees, 4,500 shrubs and 15,000 plants on two residential tower blocks. If planted on the ground, the "forest" would cover an area the size of three and a half football fields. Similar projects are underway in cities in Switzerland, the Netherlands and China [78]. The campus budget will may be planned to invest for this problem for next academic years.

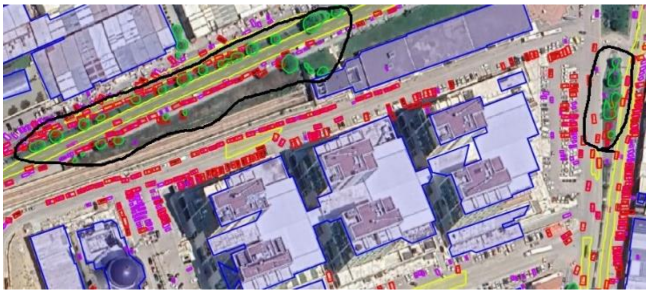

Figure 5. Tree evaluation

It is seen from Table 5 that the tree area covers 29% of the all types of the GeoAI detected areas. Considered that greenery places should be increased to the 50% for next campus plans.

4.1.4. Vehicles

Figure 6 shows the vehicles parked near the campus. This figure presents an output from the KooMap application, used to analyze vehicle density within the OSTİM Technical University campus and its surrounding area, detected automatically through the image recognition method. It is seen that there are a huge number of vehicles parking in the area surrounding campus. Some of these vehicles are belongs to the employees of the workplaces and some of them belongs to the students. It is conspicuous that parking zones and areas are insufficient rationally to the vehicle quantity. Therefore, this problem should be resolved by allocating more place for parking. Considered that special parking zones should be constructed for next campuses. In addition, students can be encouraged to use bicycles to reduce carbon emissions and electric transportation vehicles can be prioritized within the campus for the next campus area.

Figure 6. Vehicle evaluation

It is seen from Table 5 that the vehicle area covers 4% of the all types of the GeoAI detected areas.

5. Discussion

A Sustainable University is an institution of higher education that works to minimize the negative environmental, social and economic impacts of its activities and leads society towards a sustainable way of life. In the global fight against climate change, universities should also be role models for implementing sustainable practices. In this context, the creation of carbon neutral campuses is an urgent priority to accelerate climate action and catalyze transformative change in society. A carbon neutral university campus is one that reduces greenhouse gas emissions as much as possible and offsets the rest by investing in projects that eliminate or avoid equivalent emissions, such as reforestation or renewable energy generation. This involves a comprehensive transformation that encompasses energy efficiency, sustainable mobility, waste management and the adoption of clean energy.

At the global level, the UN promotes the Sustainable Development Goals, a universal call to action to end poverty, protect the planet and improve the lives and prospects of all. In 2015, all member states adopted the SDGs and emphasized the importance of achieving the SDGs outlined, targeting the years 2030 and 2050. The importance of urban sustainability is expressed in the UN's sustainability goal number 11: Sustainable cities and communities. Part of this goal emphasizes the "creation of green public spaces", which cannot be achieved without significantly transforming the way we build and manage our urban spaces [79]. Universities play a critical role in the development and welfare of states and serve as an important stakeholder in the realization of the Sustainable Development Goals. On the other hand, with their large scale and population, universities can be seen as micro cities with direct and indirect impacts on the environment. Therefore, it is imperative for universities to integrate the SDGs into their strategic planning and policies and reflect them in their daily activities. In 2021, at the Times Higher Education Climate Impact Forum, 1,050 universities from 68 countries made a series of new commitments to achieve net zero emissions by 2050 and transform their impact on nature. Academic institutions around the world have joined the UN's Race to Zero campaign by committing to reduce their carbon emissions to zero by 2050 at the latest.

As the population of cities around the world grows, how to make living spaces sustainable has been a major topic of discussion. This study focuses on how ever-increasing spatial data can contribute to the creation of more sustainable spaces. In this study, objects and their densities in the campus areas of universities were identified through object identification using satellite imagery of a university campus area. It is thought that identifying objects from satellite images and determining their densities in the total area will facilitate the policies to be created to make campuses and cities more sustainable.

OSTİM Technical University is the first university located within an industrial zone in Turkey. OSTİM is an organized industrial zone that plays an important and pioneering role in Ankara and Turkish industry today, with 6,200 businesses and 60,000 employees operating in 17 main sectors and 139 sub-sectors. OSTİM Technical University has set itself the vision of being the "University of Industry". The university is a third-generation entrepreneurial university that focuses on talent and competence, combining theory and practice by placing them at the center of its education and training system, and establishing a strong network through institutional collaborations. The university, being the university of industry, is highly demanded, which leads to a significant increase in the number of students day by day. The increasing number of students and the university's location within a dense industrial zone necessitate some measures regarding campus planning. One of the main measures is to take steps to reduce vehicle and traffic congestion and the resulting carbon emissions. In this study, steps have been taken towards the digital mapping of the campus area, and it is aimed to develop applications for traffic control by ensuring the simultaneous updating of the digital map in the future. Researchers hope to develop an application using the digital map, which is continuously updated with real-time data from the campus, to both eliminate the parking problem and reduce carbon emissions caused by the increased parking search time. This way, the application can guide drivers to the nearest available parking space around the campus.

A broad literature review was processed and it was seen that remote sensing and GeoAI methods are today`s state-of-art technologies because of their user-friendly usage. These procedures were superior to the previous alternatives such as LULC. As the calculation and operations of processing for these techniques have lower number of steps than other manually operated activities.

As stated in [80] the GeoAI successed to make automation on base maps in Kuwait by changing new roads, buildings etc., our study achieved its goal by making decision for sustainable and green campus detecting buildings, roads, trees and vehicles. Besides, gave insights to the stakeholders and contributors of urban planning the usage of GeoAI by the help of the commercial applications. Therefore, this research can be accepted as an output of cooperation in the geospatial analytics technology of industry, academy and needer authority (enterprise) mentioned in the Recommendations of the [80] research.

It was seen that using data augmentation performing GeoAI in the tool to convert image to higher resolution is more effective for objects such as vehicle rather than land uses such as buildings, roads and trees. Because some more quantities of vehicles were recognized by data augmentation feature compared with the image which was not applied any data augmentation to make higher resolution. The count of vehicles increases from 415 to 617 when the data augmentation method is used in KooMap.

Working with civil engineers, urban planners and architectures can be the future work to construct new campuses. The geospatial data should be reviewed with their expertise. In addition, OSTİM Technical University's campus should be compared with other university campuses to evaluate the effectiveness of the learning and living centers for university students.

Our research proved that the applicability of GIS as a useful tool in campus planning in addition to the earlier case study [60]. The environmental sustainability impacts can be analysed by GIS analytics demonstrated in [61]. Our research is supportive for this issue from the aspect of the GeoAI analysis usage. In next studies the dynamic monitoring and detection can be tried to solve campus sustainability problems by the IoT sensors and remote sensing. Because this research shows that GeoAI is so beneficial for smart campuses not only in planning but also in managing them. In instance like given in [71] the parking problem can be prevented by showing the drivers empty park areas utilizing outdoor parking sensors in the surrounding of the campus.

In our study the image based qualitative and geospatial quantitative data is assessed in both as the result output of GeoAI tool. The percentage area and counts information is used to make decision for the potential actions in university campus planning. By this way the hydro-ecological parameters can be evaluated in addition to GeoAI and can be made estimations related with condition changing as a future work. These estimations` accuracy can be increased by evaluating with the LULC changes in similarity with [67]. The approaches utilized in [67] can be combined with our GeoAI methodology.

It was seen by our research that model outputs provide decision-makings for sustainable campus planning as below [39]. These are evidence required indicators while they are answered in UI Greenmetric Questionnaire.

- Building type, their height and amount (Figure 3) show concretion and campus type. It is related with Setting & Infrastructure (SI) aspect criteria - 1.4 Campus setting indicator, 1.7 Total campus buildings area indicator.
- Tree amount (Figure 5) shows greenery area. It is related with SI aspect criteria - 1.10 Total area on campus covered in planted vegetation (SI.3) indicator.
- Vehicle amount (Figure 6) shows number of vehicles in campus and close to the campus. It is related with Transportation (TR) aspect criteria - 5.4 The total number of vehicles (cars and motorcycles with combustion engines) divided by the total campus' population (TR.1) indicator.
- Road distribution (Figure 4) shows vehicle roads by distinguishing from parking areas, pedestrian paths. It is related with TR aspect criteria - 5.12 Total ground parking area indicator.

These relationships of our suggested model can be visualized in Figure 7.

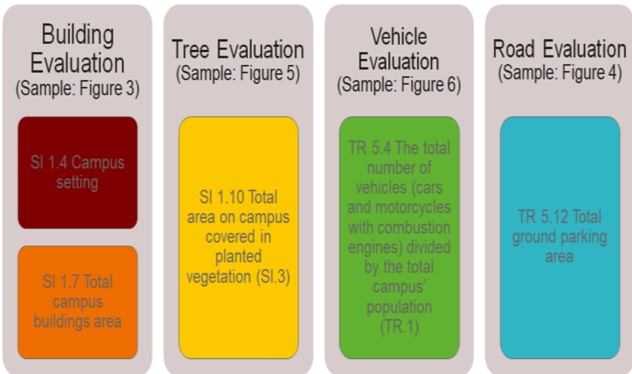

Figure 7. GeoAI - UI GreenMetric Evaluation Model

As a future work it is planned that the research can be expanded quantitatively by analyzing area (m2) of the GeoAI indicators.

The GreenMetric ranking, which was developed for the Sustainable Campus concept, is based on declarations. The fact that the index is largely based on the statements of participating universities is one of the factors that make it difficult to obtain objective results. The more the data is based on evidence rather than statements, the more accurate the results will be. This study will also provide a new approach to the use of satellite imagery in the assessment of buildings and their surroundings and to easily obtain evidence-based data through object identification.

Author contributions

Both authors contributed equally to the research and the writing.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Ullah A, Anwar SM, Li J, Nadeem L, Mahmood T, Rehman A, Saba T. Smart cities: the role of Internet of Things and machine learning in realizing a data-centric smart environment. Complex and Intelligent Systems. 2024;10(1). 1607-1637. doi.org/10.1007/s40747-023-01175-4
2. Li W, Batty M, Goodchild MF. Real-time GIS for smart cities. In International Journal of Geographical Information Science. 2020;34(2):311-324. doi.org/10.1080/13658816.2019.1673397
3. Hoang GTT, Dupont L, Camargo M. Application of decision-making methods in smart city projects: A systematic literature review. Smart Cities. 2019;2(3):433-452. doi.org/10.3390/smartcities2030027
4. Dong ZY, Zhang Y, Yip C, Swift S, Beswick K. Smart campus: definition, framework, technologies, and services. IET Smart Cities. 2020;2(1):43-54. doi.org/10.1049/iet-smc.2019.0072
5. Stephenson J, Yorke M. Capability and quality in higher education. Routledge; 2013. ISBN: 9781315042046. doi.org/10.4324/9781315042046
6. Mortaheb R, Jankowski P. Smart city re-imagined: City planning and GeoAI in the age of big data. Journal of Urban Manag. 2023;12(1):4-15. doi: 10.1016/j.jum.2022.08.001.
7. Costa DG, Bittencourt JCN, Oliveira F, Peixoto JPJ, Jesus TC. Achieving Sustainable Smart Cities through Geospatial Data-Driven Approaches. Sustainability. 2024;16(2):640.
8. Fauzi C. A Review Geospatial Artificial Intelligence (Geo-AI): Implementation of Machine Learning on Urban Planning. In: International Conference on Applied Science and Technology on Engineering Science 2023 (iCAST-ES 2023); 2024; Atlantis Press. p. 311-329.
9. Mahdavifard M, Ahangar SK, Feizizadeh B, Kamran KV, Karimzadeh S. Spatio-Temporal monitoring of Qeshm mangrove forests through machine learning classification of SAR and optical images on Google Earth Engine. International Journal of Engineering and Geosciences. 2023;8(3):239-50.
10. Başara A. C., Şişman Y. Landslide susceptibility mapping of Tokat (Turkey) province using weight of evidence and random forest. Advanced GIS. 2021;1(1);1-7.
11. Memduhoğlu A. Identifying impervious surfaces for rainwater harvesting feasibility using unmanned aerial vehicle imagery and machine learning classification. Advanced GIS. 2023;3(1); 01-06.
12. Yalpır Ş., Yalpır E. Comparative evaluation of the performance of different regression models in land valuation. Advanced GIS. 2024;4(1);10-14.
13. Xiao Z, Wang Y, Fu K, Wu F. Identifying different transportation modes from trajectory data using tree-based ensemble classifiers. ISPRS International Journal of Geo-Information. 2017;6(2):57. doi: 10.3390/ijgi6020057.
14. Türk S. T., Balçık F. Rastgele orman algoritması ve Sentinel-2 MSI ile fındık ekili alanların belirlenmesi: Piraziz Örneği. Geomatik. 2023; 8(2):91-98.
15. Duman H. S., Başaraner M. Şekil göstergeleri ve topluluk öğrenmesi sınıflandırma algoritmaları ile bina detaylarının şekil karmaşıklık analizi. Geomatik. 2022; 7(3):197-208.
16. Günen MA., Beşdok E. Effect of denoising methods for hyperspectral images classification: DnCNN, NGM, CSF, BM3D and Wiener. Mersin Photogrammetry Journal. 2023;5(1);1-9.
17. Bakırman T, Sertel E. A benchmark dataset for deep learning-based airplane detection: HRPlanes. International Journal of Engineering and Geosciences. 2023;8(3):212-23.
18. Dos ME. Determination of city change in satellite images with deep learning structures. Advanced Remote Sensing. 2022;2(1); 16-22.
19. Gong X, Yao Q, Wang M, Lin Y. A Deep Learning Approach for Oriented Electrical Equipment Detection in Thermal Images. IEEE Access. 2018;6:41590-41597. doi: 10.1109/ACCESS.2018.2859048.
20. Çetin ŞB. Real-ESRGAN: A deep learning approach for general image restoration and its application to aerial images. Advanced Remote Sensing. 2023; 3(2); 90-99.
21. Duan Y, Liu S, Hu C, Hu J, Zhang H, Yan Y, Tao N, Zhang C, Maldague X, Fang Q, Ibarra-Castanedo C, Chen D, Li X, Meng J. Automated defect classification in infrared thermography based on a neural network. NDT E International. 2019;107:102147. doi: 10.1016/j.ndteint.2019.102147.
22. Yang X, Ye Y, Li X, Lau RYK, Zhang X, Huang X. Hyperspectral image classification with deep learning models. IEEE Transactions on Geoscience and Remote Sensing. 2018;56(9):5408-5423. doi: 10.1109/TGRS.2018.2815613.
23. Wen C, Sun X, Li J, Wang C, Guo Y, Habib A. A deep learning framework for road marking extraction, classification and completion from mobile laser scanning point clouds. ISPRS Journal of Photogrammetry and Remote Sensing. 2019;147:178-192. doi: 10.1016/j.isprsjprs.2018.10.007.
24. Uzar M., Öztürk Ş., Bayrak OC., Arda T., & Öcalan NT. Performance analysis of YOLO versions for automatic vehicle detection from UAV images. Advanced Remote Sensing. 2021;1(1);16-30.
25. Akram MW, Li G, Jin Y, Chen X, Zhu C, Ahmad A. Automatic detection of photovoltaic module defects in infrared images with isolated and develop-model transfer deep learning. Solar Energy. 2020;198:175-186. doi: 10.1016/j.solener.2020.01.055.
26. Demirel Y., Türk, T. Automatic detection of active fires and burnt areas in forest areas using optical satellite

imagery and deep learning methods. Mersin Photogrammetry Journal. 2024; 6(2); 66-78.
27. Balado J, Sousa R, Díaz-Vilariño L, Arias P. Transfer Learning in urban object classification: Online images to recognize point clouds. Automation in Construction 2020;111:103058. doi: 10.1016/j.autcon.2019.103058.
28. Vopham T, Hart JE, Laden F, Chiang YY. Emerging trends in geospatial artificial intelligence (GeoAI): Potential applications for environmental epidemiology. In Environmental Health: A Global Access Science Source. 2018;17(1):1-6. doi: 10.1186/s12940-018-0386-x.
29. Janowicz K, Gao S, McKenzie G, Hu Y, Bhaduri B. GeoAI: spatially explicit artificial intelligence techniques for geographic knowledge discovery and beyond. In International Journal of Geographical Information Science. 2020;34(4):625-636. doi: 10.1080/13658816.2019.1684500.
30. Cugurullo F. Urban Artificial Intelligence: From Automation to Autonomy in the Smart City. Frontiers in Sustainable Cities. 2020;2(38). doi: 10.3389/frsc.2020.00038.
31. Arundel S. T., Li W., Wang S. GeoNat v1.0: A dataset for natural feature mapping with artificial intelligence and supervised learning. Transactions in GIS. 2020;24(3):556-572. doi: 10.1111/tgis.12633.
32. Döllner J. Geospatial Artificial Intelligence: Potentials of Machine Learning for 3D Point Clouds and Geospatial Digital Twins. PFG - Journal of Photogrammetry, Remote Sensing and Geoinformation Science. 2020;88(1):15-24.
33. Gao S. Geospatial artificial intelligence (GeoAI). Vol. 10. New York: Oxford University Press; 2021.
34. Liu P, Biljecki F. A review of spatially-explicit GeoAI applications in Urban Geography. International Journal of Applied Earth Observation and Geoinformation. 2022;112:102936. doi: 10.1016/j.jag.2022.102936.
35. Pierdicca R, Paolanti M. GeoAI: a review of artificial intelligence approaches for the interpretation of complex geomatics data. Geoscientific Instrumentation, Methods and Data Systems. 2022;11(1):195-218. doi: 10.5194/gi-11-195-2022.
36. Alastal AI, Shaqfa AH. GeoAI Technologies and Their Application Areas in Urban Planning and Development: Concepts, Opportunities and Challenges in Smart City (Kuwait, Study Case). Journal of Data Analysis and Information Processing. 2022;10(2):110-126.
37. Ang KLM, Seng JKP, Ngharamike E, Ijemaru GK. Emerging Technologies for Smart Cities' Transportation: Geo-Information, Data Analytics and Machine Learning Approaches. ISPRS International Journal of Geo-Information. 2022;11(2):85. doi: 10.3390/ijgi11020085.
38. Song Y, Kalacska M, Gašparović M, Yao J, Najibi N. Advances in geocomputation and geospatial artificial intelligence (GeoAI) for mapping. International Journal of Applied Earth Observation and Geoinformation. 2023;120:103300. doi: 10.1016/j.jag.2023.103300.
39. Instituting UI GreenMetric, Guidelines. Instituting UI GreenMetric, Guidelines. 2024. Available from: https://greenmetric.ui.ac.id/publications/guidelines/2024/english [Accessed 20 Aug 2024].
40. Ünel, F. B., Kuşak, L., Yakar, M., & Doğan, H. Coğrafi bilgi sistemleri ve analitik hiyerarşi prosesi kullanarak Mersin ilinde otomatik meteoroloji gözlem istasyonu yer seçimi. Geomatik, 8(2), 107-123..
41. Karasan A, Kutlu Gündoğdu F, Aydın S. Decision-making methodology by using multi-expert knowledge for uncertain environments: Green metric assessment of universities. Environment, Development and Sustainability. 2023;25(8):7393-7422.
42. Boiocchi R, Ragazzi M, Torretta V, Rada E. Critical Analysis of the GreenMetric World University Ranking System: The Issue of Comparability. Sustainability. 2023;15(2):1343. doi: 10.3390/su15021343.
43. Sari MW, Ciptadi PW, Hardyanto RH. Study of smart campus development using internet of things technology. In: IOP Conference Series: Materials Science and Engineering. 2017;190(1):012032. IOP Publishing.
44. Galleli B, Teles NEB, Santos JARD, Freitas-Martins MS, Hourneaux Junior F. Sustainability university rankings: a comparative analysis of UI GreenMetric and the Times Higher Education World University Rankings. International Journal of Sustainability in Higher Education. 2022;23(2):404-25.
45. Atıcı KB, Yasayacak G, Yıldız Y, Ulucan A. Green University and academic performance: an empirical study on UI GreenMetric and World University Rankings. Journal of Cleaner Production. 2020;250:119517. https://doi.org/10.1016/j.jclepro.2020.125289
46. Ariesanti A, Sutanto A, Bidayati U. Online disclosure of university environmental responsibility: A case of Indonesia. In: 3rd International Conference on Accounting, Management and Economics 2018 (ICAME 2018); 2018 Dec 5-7; Atlantis Press; 2019. p. 401-9.
47. Rochim AF, Sari RF. Study on the correlation of web repository ranking to the green campus ranking of Indonesian Universities. In: Proceedings of the International Conference on Information Technology and Electrical Engineering (ICITACEE); 2015 Nov 18-19; IEEE. p. 148-52. doi.org/10.1109/ICITACEE.2015.7437788
48. Polin K, Yigitcanlar T, Limb M, Washington T. The making of smart campus: a review and conceptual framework. Buildings. 2023;13(4):891. doi:10.3390/buildings13040891.

49. Mahariya, S. K., Kumar, A., Singh, R., Gehlot, A., Akram, S., Twala, B., Iqbal, M. I., & Priyadarshi, N. (2023). Smart Campus 4.0: Digitalization of University Campus with Assimilation of Industry 4.0 for Innovation and Sustainability. Applied Sciences and Engineering Technology, 32(1), 120-138. doi.org/10.37934/araset.32.1.120138
50. Silva-da-Nóbrega, P. I., Chim-Miki, A. F., & Castillo-Palacio, M. (2022). A Smart Campus Framework: Challenges and Opportunities for Education Based on the Sustainable Development Goals. Sustainability, 14(15), 9640. doi.org/10.3390/su14159640
51. Paspatis A, Fiorentzis K, Katsigiannis Y, Karapidakis E. Smart Campus Microgrids towards a Sustainable Energy Transition—The Case Study of the Hellenic Mediterranean University in Crete. Mathematics. 2022;10(7):1065. doi:10.3390/math10071065.
52. Alnoman A. A Framework for Technology-based Student-centered Learning in Smart Campus. In: 2022 Advances in Science and Engineering Technology International Conferences (ASET); 2022 Jun 14-17. IEEE; 2022. p. 1-4.
53. Liu Z. Planning and Practice of Smart Campus in Higher Vocational Colleges from the Perspective of Education Informatization 2.0. In: 2021 2nd International Conference on Big Data and Informatization Education (ICBDIE); 2021 Dec 17-19. IEEE; 2021. p. 497-500. doi.org/10.1109/ICBDIE52740.2021.00119
54. Chen X. Exploration and Practice of the Construction of Smart Campus—Taking Sichuan University as an Example. In: Proceedings of the 4th International Conference on Digital Technology in Education; 2020 Oct 14-16. p. 36-41. doi.org/10.1145/3429630.3429647
55. Rha JY, Lee JM, Li HY, Jo EB. From a literature review to a conceptual framework, issues and challenges for SMART Campus. Journal of Digital Convergence. 2016;14(4):19-31.
56. Thar SAAB, Tun ST. GIS application: Mapping and Area Analysis for MAEU Campus. International Journal of Current Innovations in Advanced Research. 2018;1-7.
57. Kinoti KD, Nyaga NP. Understanding universities land policy and their implementation strategies in Kenya: The case of Karatina University main campus, Kenya. International Journal of Landscape Planning and Architecture. 2018; 8:13.
58. Hwang WH, Wiseman PE. Geospatial methods for tree canopy assessment: A case study of an urbanized college campus. Arboriculture & Urban Forestry. 2020;46(1):51-65. doi:10.48044/jauf.2020.005
59. Bozdağ A, Gümüş MG, Gümüş K, Durduran SS. Evaluating spatial legibility of the university campus using GIS. Aksaray University Journal of Science and Engineering. 2020;4(2):127-147.
60. Haq ES, Panduardi F. GIS-based area suitability analysis for development planning purposes campus: Case study Banyuwangi State Polytechnic. Journal of Engineering and Scientific Research. 2020;2(2):78-84.
61. Zaki SA, Othman NE, Syahidah SW, et al. Effects of urban morphology on microclimate parameters in an urban university campus. Sustainability. 2020;12(7):2962. doi.org/10.3390/su12072962
62. Papua O, Kumaat JC, Runtuwene JPA, Rompas PTD. In Proceedings of the 7th Engineering International Conference on Education, Concept and Application on Green Technology, Semarang, Indonesia: SCITEPRESS-Science and Technology Publications. 2020;330-334. doi.org/10.5220/0009010803300334
63. Srivastava A, Chinnasamy P. Investigating impact of land-use and land cover changes on hydro-ecological balance using GIS: insights from IIT Bombay, India. SN Applied Sciences. 2021;3(3):343. https://doi.org/10.1007/s42452-021-04328-7
64. Shao YB. Baselining UBC Vancouver Campus Urban Forest and Land Use: Developing and Validating Up-to-date Tree Inventory and Land Classification Map of the UBC Vancouver Campus. Vancouver: University of British Columbia Library; 2021. doi.org/10.14288/1.0400162
65. Hong D, Han Z, Yao J, Gao L, Zhang B, Plaza A, Chanussot J. SpectralFormer: Rethinking Hyperspectral Image Classification with Transformers. IEEE Transactions on Geoscience and Remote Sensing. 2022;60:1-15. doi.org/10.1109/TGRS.2021.3130716
66. Ikara AI, Umar YH, Dauda BD. Mapping of Geotechnical Properties Using ArcGIS: A Case Study of Abubakar Tafawa Balewa University Bauchi, Gubi Campus. Iconic Research and Engineering Journals. 2022;5(9):1-5.
67. Anushya A. 3D Reality Planner for University of Hail Using ArcGIS. International Journal of Computer Science Engineering (IJCSE). 2020;9(1):2319-7323.
68. Çelik, M. Ö., & Yakar, M. (2023). Arazi kullanımı ve arazi örtüsü değişikliklerinin uzaktan algılama ve cbs yöntemi ile izlenmesi: Mersin, Türkiye örneği. Türkiye Coğrafi Bilgi Sistemleri Dergisi, 5(1), 43-51..
69. Çetin Z, Yastıklı N. Automatic detection of single street trees from airborne LiDAR data based on point segmentation methods. International Journal of Engineering and Geosciences. 2022;8(2):129-137.
70. Özaydın E, Amirgan B, Taşkın G, Musaoğlu N. Derin öğrenme uygulamalarında kullanılan uzaktan algılama verilerinden oluşturulmuş açık kaynaklı bina veri setleri: Karşılaştırmalı değerlendirme. Geomatik. 2024;9(1):1-11.
71. Li R, Guan Q. Environmental campus: Managing campus parking meters using GPS and GIS. ISWREP 2011 - Proceedings of 2011 International Symposium

on Water Resource and Environmental Protection. 2011.

72. Wu ZZ, Wang XF, Zou L, Xu LX, Li XL, Weise T. Hierarchical object detection for very high-resolution satellite images. Applied Soft Computing. 2021;113:107885.
73. Huawei Investment & Holding Co., Ltd. Annual report. 2023. Available from: https://img.corrierecomunicazioni.it/wp-content/uploads/2024/03/29124138/annual_report_2023_en.pdf. Accessed on 20 Aug 2024.

74. Huawei Technologies Co., Ltd. Striding Towards the Intelligent World White Paper: Cloud Computing. 2022. Available from: https://www-file.huawei.com/-/media/corp2020/pdf/giv/striding-towards-the-intelligent-world/the_intelligent_world_cloud_computing_en.pdf. Accessed on 20 Aug 2024.
75. World Economic Forum. How to build smart, zero carbon buildings - and why it matters. 2021. Available from: https://www.weforum.org/agenda/2021/09/how-to-build-zero-carbon-buildings/#:~:text=The%20potential%20energy%20savings%20from%20smart%20buildings%20is,ventilation%2C%20can%20save%20an%20additional%205-10%25%20in%20energy. Accessed on 20 Aug 2024.

76. Lange ISG, Rodrigues CN. Urban Green Spaces: Combining Goals for Sustainability and Placemaking. EuropeNow-a journal of research & art. 2021;(Special feature).
77. Haq SMA. Urban Green Spaces and an Integrative Approach to Sustainable Environment. Journal of Environmental Protection. 2011;2(5):601-608. ISBN:9780429155680.
78. World Economic Forum. 7 Innovative Projects Making Cities More Sustainable. 2020. https://www.weforum.org/agenda/2020/09/cities-sustainability-innovation-global-goals/ (accessed on 20.08.2024).

79. United Nations. Transforming Our World: The 2030 Agenda for Sustainable Development: Resolution / Adopted by the General Assembly. 2015. https://digitallibrary.un.org/record/3923923?v=pdf (accessed on 20.08.2024).
80. Cugurullo F. Urban Artificial Intelligence: From Automation to Autonomy in the Smart City. Frontiers in Sustainable Cities. 2020;2(38). doi.org/10.3389/frsc.2020.00038

© Author(s) 2024. This work is distributed under https://creativecommons.org/licenses/by-sa/4.0/