ISSN: 2148-9173 **Vol: 9 Issue:4 December 2022**

International Journal of Environment and Geoinformatics (IJEGEO) is an international, multidisciplinary, peer reviewed, open access journal.

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Abstracting and Indexing: TR DIZIN, DOAJ, Index Copernicus, OAJI, Scientific Indexing Services, International Scientific Indexing, Journal Factor, Google Scholar, Ulrich's Periodicals Directory, WorldCat, DRJI, ResearchBib, SOBIAD

International Journal of Environment and Geoinformatics 9(4):138-150 (2022)

Research Article

The potential contribution of remotely sensed images for GreenMetric ranking

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Received: 06.07.2022
Accepted: 25.09.2022

How to cite: Incekara et al., (2022). The potential contribution of remotely sensed images for GreenMetric ranking, *International Journal of Environment and Geoinformatics (IJEGEO)*, 9(4): 138-150. doi. 10.30897/ijegeo.1141366

Abstract

GreenMetric (GM) ranks the universities worldwide to determine their sustainability levels. Ranking depends on the scores which is calculated based on the evidence provided for various criteria. In this study, it is suggested to use remotely sensed images both as data to be used in score calculation related to greenery level and as evidence to be presented. In this context, GM scores regarding the sustainability indicators of the first category were determined by using satellite images. The main campuses of two universities from Turkiye were selected as study areas. Sentinel-2B satellite images of the campus areas were exposed to digital image processing techniques to derive statistical values regarding greenery. Based on these data and information, the total scores of the setting and infrastructure category for both campuses were calculated as 1000 and 925, those officially claimed were 1050 and 825. When considering the main campus of a university, remotely sensed image has high potential to obtain the required information about green and non-green areas. Therefore, thematic maps to be produced from such data can set a standard for statistical evidence requested by GM in various indicators. This approach will also contribute to the more reliable evaluation.

Keywords: Green Area, Green Metric, Indicator, Remote Sensing, Sustainability, Thematic Map

Introduction

The main campus of a university generally looks like a compact small city due to its mission and vision as well as its several campus opportunities (Alshuwaikhat and Abubakar, 2008). However, the term university represents much more than a group of buildings distributed in the campus area. In addition to buildings used for academic and administrative purposes, there are common areas such as the library, stadium, social centers, and roads providing access to all these structures. That is why the condition of a campus is not only represented by the number and quality of laboratories, the newness of buildings, number of lecturers per student, competence of graduates and similar to those factors. The environment of the campus is also a critical issue when evaluating it as a whole. Moreover, campus conditions with all aspects have an important role not only in the preference of the universities by the students, academicians and administrative personnel; but also in their demands to remain later on (Dagiliūtė et al., 2018; Mshelia et al., 2021). This continuity requires the sustainable use and management of universities which is directly proportional to the quality of campus life. Therefore, many universities around the world are taking precautions and applying implementations in this respect.

The educational aspect of sustainability was firstly alleged at the Stockholm Conference in 1972. After that, various ideas were put forth or existing ones were updated according to the requirements of the period. Sustainability activities implemented by the universities from past to present can be investigated in the researches of Alshuwaikhat and Abubakar (2008), Lozano et al. (2013) and Ragazzi and Ghidini (2017). Concept of sustainability and its importance for universities were thoroughly handled by Lauder et al. (2015) and Ragazzi and Ghidini (2017).

The quality of life on the campus is measurable with metrics similar to those applied for cities, and this is essential for the management of the current situation and plans as well. For this purpose, various rating systems are used in the evaluation of a campus in terms of sustainability. Among these, GreenMetric (GM) is accepted as a global measurement system alleged in 2010. The first appearance of the GM was by Universitas Indonesia. In the GM, which was initially ranked with the participation of 95 universities from 35 different countries, 956 universities from 80 countries compete with each other as of today. These universities can easily include themselves in the GM by filling out the necessary information in the online questionnaire.

Universities' attitudes towards sustainability for previous years and their academic studies in this sense were investigated by Velazquez et al. (2006). The emergence and development process of GM was examined in detail by Suwartha and Sari (2013). The difference of GM from previous metrics stems from the way it handles the concept of sustainability. Most of the evaluation and rating systems prioritize academic popularity and quality

of education. GM, on the other hand, cares about the relationship of the university with the environment as referred by Ragazzi and Ghidini (2017). The approach difference in the evaluation of GM is that the impact of universities on the environment is remarkable due to educational activities (Marrone et al., 2018).

GM is represented by six main categories. These are setting and infrastructure (SI), energy and climate change (EC), waste (WS), water (WR), transportation (TR), and education and research (ED), respectively (GM Guideline, 2019). According to the total scores obtained from all categories, universities are ranked in terms of being a green campus. The distribution of total points for each category is presented in Table 1. Depending on the total scores of 10000, these indicators are appointed by 1500, 2100, 1800, 1000, 1800, and 1800.

First of these categories (setting and infrastructure) provides information about the university's opinion on the environment (GM Guideline, 2019). SI has specific indicators as presented in Table 2 and, Table 3 indicates the individual points of each indicator which constitutes the total score of the regarding category.

Table 1: Six main categories and their contribution to the ranking (GM Guideline, 2019)

No	Category	Distribution of total points (%)
1	Setting and Infrastructure	15
2	Energy and Climate Change	21
3	Waste	18
4	Water	10
5	Transportation	18
6	Education and Research	18

Table 2: Indicators of SI and their points as in the GM guideline of 2019.

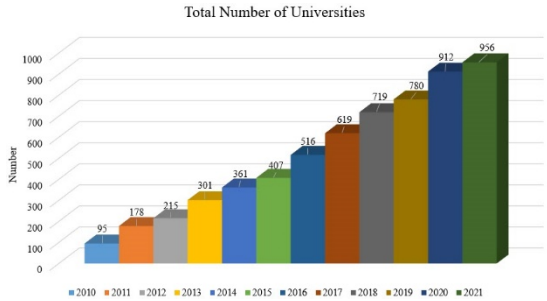
No	**Category SI**	**Points**
SI-1	The ratio of open space area to the total area	300
SI-2	Total area on campus covered in forest vegetation	200
SI-3	Total area on campus covered in planted vegetation	300
SI-4	Total area on campus for water absorption besides the forest and planted vegetation	200
SI-5	The total open space area divided by total campus population	300
SI-6	Percentage of university budget for sustainability efforts within a year	200
	TOTAL	1500

Table 3: Calculations related to SI indicators in GM 2019.

SI Id	**Calculation Result**	**Corresponding Score**
SI-1	≤ 1%	0
	> 1% - 80%	0.25 x 300
	> 80% - 90%	0.50 x 300
	> 90% - 95%	0.75 x 300
	> 95%	1 x 300
SI-2	≤ 2%	0
	> 2% - 9%	0.25 x 200
	> 9% - 22%	0.50 x 200
	> 22% - 35%	0.75 x 200
	> 35%	1 x 200
SI-3	≤ 10%	0
	> 10% - 20%	0.25 x 300
	> 20% - 30%	0.50 x 300
	> 30% - 40%	0.75 x 300
	> 40%	1 x 300
SI-4	≤ 2%	0
	> 2% - 10%	0.25 x 200
	> 10% - 20%	0.50 x 200

	> 20% - 30%	0.75 x 200
	> 30%	1 x 200
SI-5	≤ 10 m^2	0
	> 10 - 20 m^2	0.25 x 300
	> 20 - 40 m^2	0.50 x 300
	> 40 - 70 m^2	0.75 x 300
	> 70 m^2	1 x 300
SI-6	≤ 1%	0
	> 1% - 3%	0.25 x 200
	> 3% - 10%	0.50 x 200
	> 10% - 12%	0.75 x 200
	> 12%	1 x 200

There may be updates in the scope and scoring of the criteria year by year. The change in scoring for 2019 compared to 2018 is the change in the percent distribution of the coefficients (GM Guideline, 2018; GM Guideline, 2019). Year-by-year changes in previous evaluations of GM were explained by Marrone et al. (2018). In the 2021 and 2022 guidelines, the number of subcategories of SI has been increased to 11. The Covid 19 pandemic has had an impact on the updates in these years. In the 2019 to 2022 guidelines, the change in threshold values for the first 6 subcategories of SI was only for heading 1.18 (SI-6). Therefore, it is not significant which of the guides of the last 4 years has been used in examining the contribution of satellite images to the ranking. Details of other indicators related to other categories can be reached through GM guidelines.



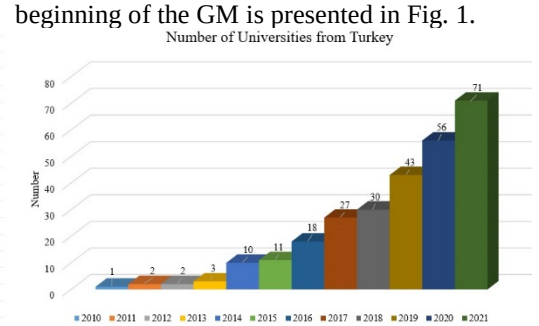


Fig. 1: Change in the number of participating universities

Although the SI category constitutes only 15% of the maximum score (10000) that can be taken, it accounts for about 18% of the total score taken by universities in Turkiye. This value was about 16% for all universities participating in the GM 2019. Therefore, the SI category has more importance in obtaining the green label than it seems. This is also supported by GM itself because GM defines the SI category as follows: "*The campus setting and infrastructure information will give the basic information of the university consideration towards a green environment. This indicator also shows whether the campus deserves to be called the Green Campus. The aim is to trigger the participating university to provide more space for greenery and in safeguarding environment, as well as the development of sustainable energy*".

In the scope of the study, scores were calculated separately depending on the modified version of the criteria in Table 3. As distinct from the standard guide,

In this study, indicators of the first category, namely sub-categories of SI, were determined using image processing techniques for two universities in Turkiye. The university ranked 1st in GM's first ranking was the University of California Berkeley. Bilkent University was the only university from Turkiye to be included in this ranking, with the 83rd rank. In the last GM evaluation, the university ranked 1st in the general ranking is the University of Wageningen with a total of 9300 points. 71 of the 956 participants in this last ranking are institutions operating in Turkiye. The change in the number of participating universities since the beginning of the GM is presented in Fig. 1.

the 2nd and 3rd sub-categories were evaluated under one category as "green areas". Since the last category is independent of the image data and is related to the budget, the values presented directly to the system were used. Obtained values were compared with the official GM results and the potential contribution of remotely sensed images to GM criteria was discussed. In other words, the supportive nature of satellite images was examined for a university that aims to be associated with its green campus identity. GM requests evidence of the values presented for the relevant indicators and universities provide various sources as evidence. Fig. 2. represents evidence template available to users on the GM official web page. The contribution of remotely sensed images in this regard are discussed for use as evidence which indicates the reliability and transparency of the evaluation. Apart from all these, the relations of SI, which is the basic category determining greenery, with other categories were also examined by means of fundamental statistical analyses such as Pearson correlation coefficient, box-plot graphs etc.

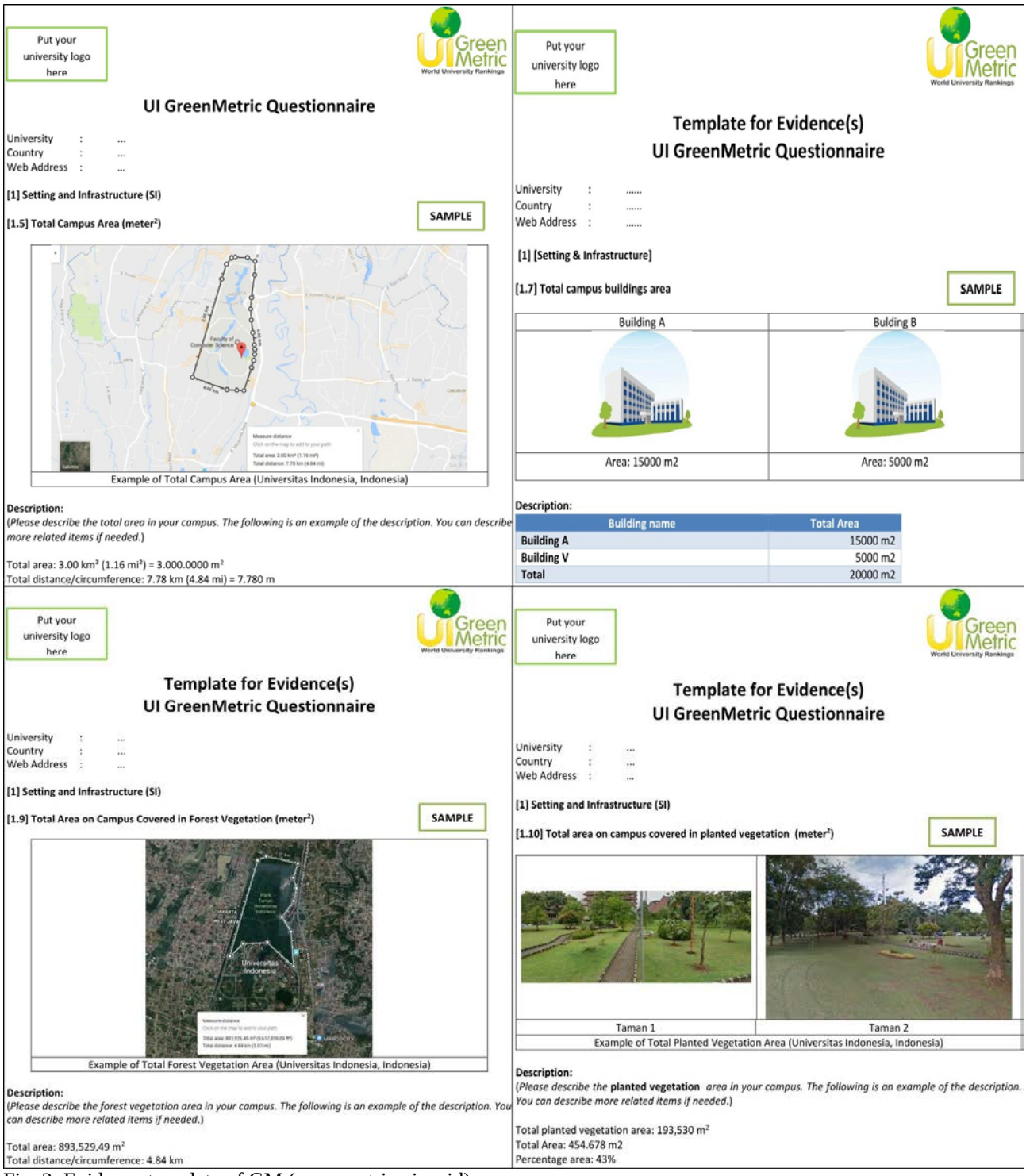


Fig. 2: Evidence template of GM (greenmetric.ui.ac.id)

Case Studies

Study Areas

Various universities in Turkiye, state or foundation, have incorporated themselves into the system since the beginning of GM in 2010. Istanbul is the city with the highest number of universities participated in the GM on a provincial basis (URL-1). Two study areas from Turkiye were determined to investigate the possible contribution of remotely sensed imageries to the GM criteria. Because the availability of various official information required for comparative analysis was easier for the authors, investigated universities were from Turkiye. However, the proposed method is valid for all universities.

Study areas from Turkiye were Istanbul Technical University (ITU) and Tokat Gaziosmanpasa University (TOGU) both located in Turkiye as illustrated in Fig. 3. The names of the main campuses where they joined the GM are Ayazaga and Tasliciftlik for ITU and TOGU, respectively. The scores received by both universities in the 2019 ranking are comparatively presented in Table 4 for each category. While ITU was ranked 54th in the general ranking with a total of 7600 points, TOGU was

ranked 504th with 4375 points. The individual scores in the SI category constituting the focus of this study were 1050 and 825, respectively. ITU was able to get 70% of the maximum score that can be taken from this category. This value was 55% for TOGU. Only based on the SI category, ITU was 101st among all universities while TOGU was 323rd.

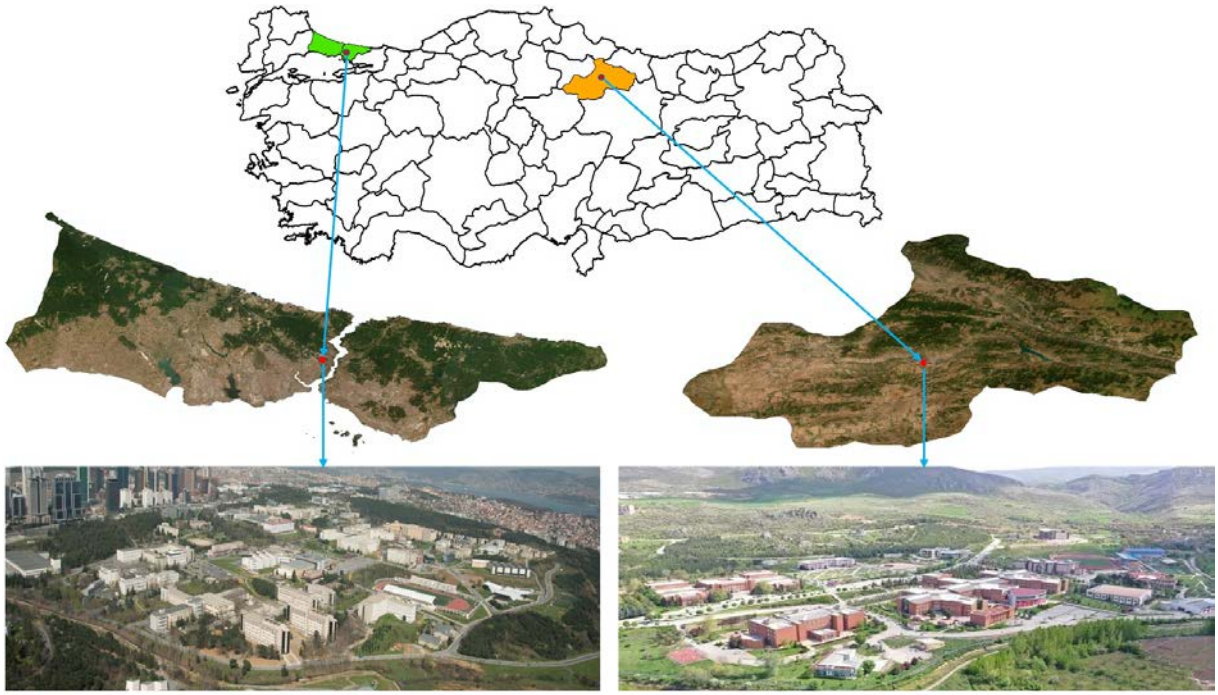


Fig. 3: Study areas: ITU Ayazaga Campus and TOGU Tasliciftlik Campus.

Table 4: Comparison between ITU and TOGU for the GM 2019 ranking

Category	ITU	TOGU
SI: Setting & Infrastructure	1050	825
EC: Energy & Climate Change	1150	850
WS: Waste	1575	675
WR: Water	800	400
TR: Transportation	1425	1025
ED: Education & Research	1600	600
Total Score	7600	4375
GM 2019 Ranking	54	504

Data and Methodology

In this study, Sentinel 2 imageries that are freely available were used to derive information about greenery level of the universities. Sentinel imageries are produced from two identical satellites and named as Sentinel-2A (S2A) and Sentinel-2B (S2B). These satellites operate together to shorten revisit time. In this way, the number of recently available images of the same area are increased. There are 13 spectral bands for both S2A and S2B. Four of them (Band 2-4 and Band 8) have a spatial resolution of 10 m which were also used in this study (URL-2). Based on these bands, varied objects can be distinguished from their surroundings utilizing spectral reflectance characteristics. In terms of vegetation, generally, there is a high reflectance in the near-infrared (NIR) region of the electromagnetic spectrum compared to the visible region which roughly covers the range from 0.4 µm to 0.7 µm in the spectrum. Unlike vegetation, water structures have slight spectral reflection along the infrared region. Satellite imageries used in this study were S2B imageries with the acquiring date of April 23 for ITU and April 24 for TOGU. Since the evaluation was made according to the 2019 ranking, the images of 2018 were used.

S2B imageries were initially exposed to radiometric calibration and atmospheric correction process to remove adverse effects on the image during the acquisition of data. The dark object subtraction method was employed in the atmospheric correction steps. As a result of these processes, pixel brightness values were converted to surface reflection values which are between 0 and 1. Then, 4 band images were obtained by stacking blue, green, red and NIR bands among all spectral bands. For campus areas, 4 band images were obtained by using official campus boundaries in vector formats. Subset images obtained after this stage are presented in Fig. 4 with true color (4-3-2) combination.

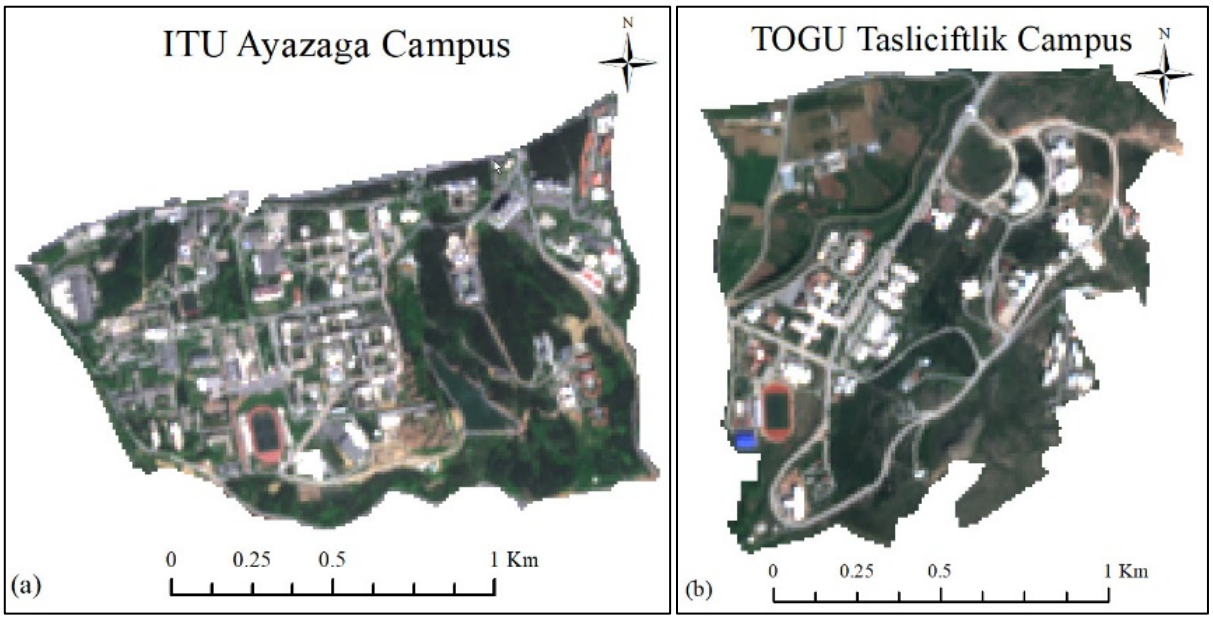


Fig. 4: Subset images: (a) ITU Ayazaga Campus; (b) TOGU Tasliciftlik Campus.

Rule-based feature extraction, namely object-oriented classification, technique was applied to the satellite imageries which covered only the current campus areas. The first step of object-oriented classification is the segmentation process in which the image was divided into meaningful parts. Each of them was called a segment or image object (Wei et al., 2005). The rule created based on Normalize Difference Vegetation Index (NDVI) values were applied to these segments. NDVI was calculated by the formula given below that enabled to separate green and non-green areas (Rouse et al., 1973). NDVI takes a value between -1 and +1. The high reflectance value in the infrared region and the low reflectance in the visible region provide values closer to 1 for green areas in the formula. NDVI images for ITU and TOGU are presented in Fig. 5. Those represented in black correspond to constructions and water surfaces. Shades in white represent green areas and places with higher NDVI values. NDVI value used as a threshold to separate green areas from non-green areas were 0.5 for both campuses. Thus, segments with an NDVI value greater than 0.5 corresponded to green areas. Overlapping of green areas detected by the classification result with the original 4 band image is presented in Fig. 6. Each of the green areas obtained as a result of classification was surrounded by a vector in a polygon format which represented a closed and filled area. The vectors of these areas are presented in Fig. 7 for both campuses. Therefore, the extent of the area covered by each green area became evident in this fully scaled dataset.

$$NDVI = (NIR-Red)/(NIR+Red) \quad (Eq.1)$$

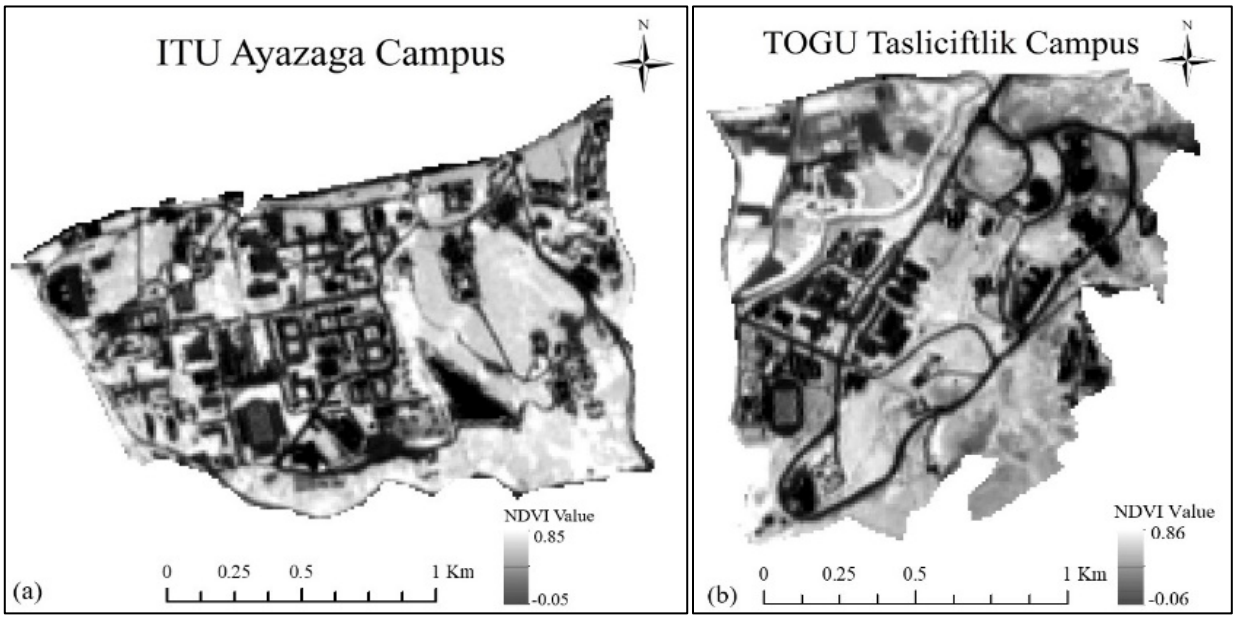


Fig. 5: NDVI images: (a) ITU; (b) TOGU.

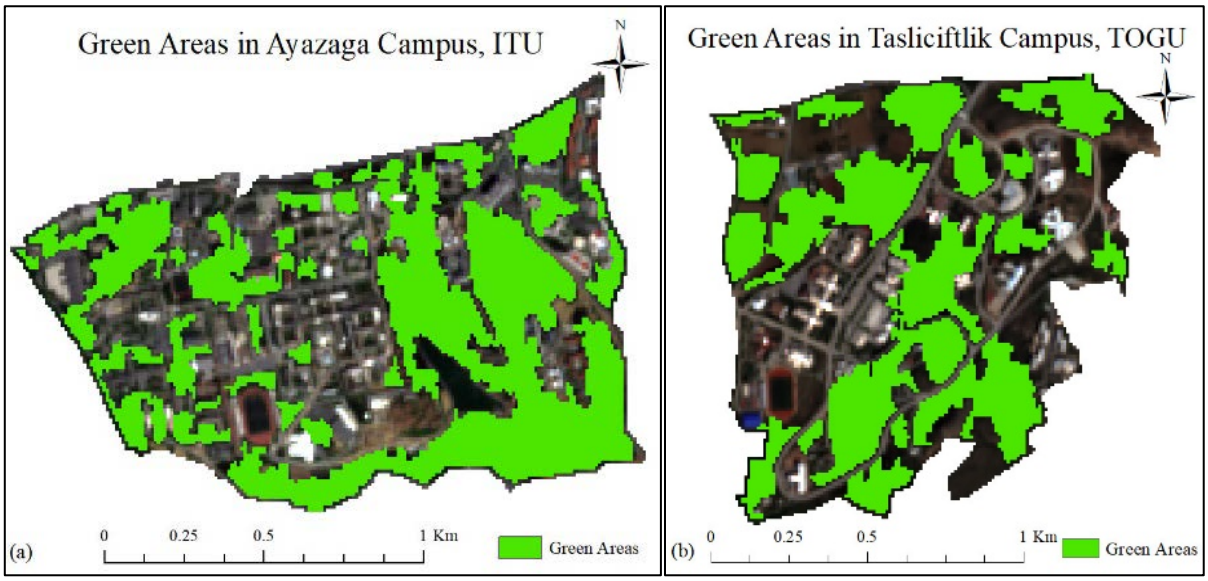


Fig. 6: Green areas on the campuses: (a) ITU; (b) TOGU.

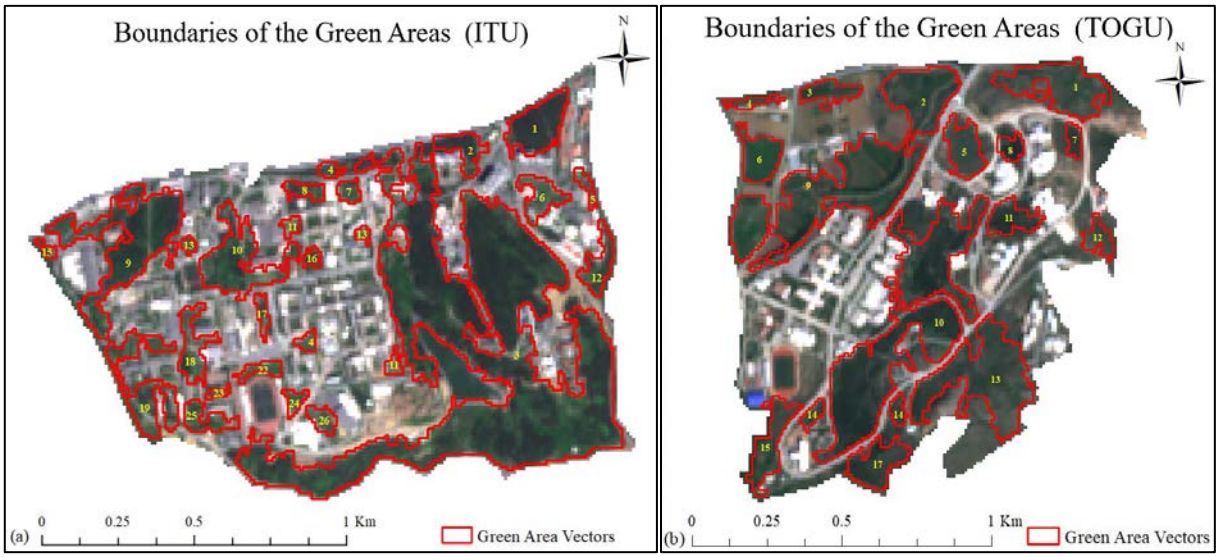


Fig.7: Outer boundaries of the green areas on both campuses: (a) ITU; (b) TOGU.

Score Calculations

During scoring of the indicators presented in Table 2, a slight update was made in the criteria specified in Table 3. It is also possible to see new suggestions in researchers' studies on GM. Marrone et al. (2018) examined how campus morphology affects the score achieved, and they have defined a new index called urban morphology index. Puertas and Marti (2019) proposed a new indicator for change in GM using data envelopment analysis. However, a detailed study in which remotely sensed images are included in the score calculation has not been carried out yet. Most of the studies have already researched evaluating the current situation rather than taking GM forward with new ideas.

In this study carried out by using remotely sensed imageries, the regions corresponding to the green areas were not considered separately as planted vegetation and forested vegetation. Regardless of the type, the total green areas were taken into account. Therefore, the maximum score that can be obtained for SI-2 which was 200 and the maximum score that can be obtained for SI-3 which was 300 were considered as a single category. Thus, the coefficient corresponding to the calculated percentile was multiplied by 500. SI-2 in the 2019 guideline was taken as a reference for threshold values in percentiles since it has already been a known fact that the forested vegetation was much more than the planted vegetation which has been formed generally for landscaping.

The criteria included in the calculation are stated in the guide with explanations under the title of the Questionnaire (Criteria and Indicators). In order to make it more understandable for the readers, the same subtitle numbers corresponding to the relevant indicator was used. For a detailed comparison, it is recommended to browse the GM guideline of 2019. The ones used to calculate the scores of the SI category are presented in Table 5.

Table 5: Subtitles of the indicators as in the GM guide and required information.

Subtitle Id as in the guide	Indicator & Required Information	Indicator Explanation & Formula	Used Data & Formula
1.5.	Total campus area (m^2)	Area in which academic activities are conducted	Area covered by campus outer boundary (Red line in Figure 8)
1.6.	Total campus ground floor area of buildings (m^2)	Total area of the ground floor parts of university buildings in the campus	Total area values extracted from campus ownership status (Areas represented in yellow in Figure 8)
1.8.	SI-1	The ratio of open space area to the total area (%)	$\left(\left(\frac{1.5\ -1.6}{1.5}\right) \times 100\%\right)$
1.9.	SI-2	Total area on campus covered in forest vegetation (%)	Area covered in vegetation in the form of forest (Figure 6, Figure 7)
1.10.	SI-3	Total area on campus covered in planted vegetation (%)	Area covered in planted vegetation (Figure 6, Figure 7)
1.11.	SI-4	Total area on campus for water absorption besides the forest and planted vegetation (%)	No data used
1.12.	Total number of regular students	Registered and active students	Annual facility reports (Url-3, Url-4)
1.14.	Total number of academic & administrative staff	Academic and administrative staff working in the university	Annual facility reports (Url-3, Url-4)
1.15.	SI-5	The total open space area divided by total campus population	$\left(\frac{(1.5\ -1.6)}{(1.12\ +1.14)}\right)$
1.18.	SI-6	Percentage of university budget for sustainability efforts within a year (%)	The option selected by the university in Table 3 was used directly.

It is stated in the GM guideline that the total area should be considered only as the area where academic activities are carried out and that forests and other areas can only be considered if they are used for academic purposes. Because of the presence of the Geomatics Engineering department which conducts educational activities on all around both campuses, the boundaries of both campuses were used to calculate the total area directly. The outer boundaries were extracted from the 2D maps demonstrating the current state plan of the campuses. The same maps were also used to calculate the total campus ground floor areas of the buildings. Maps representing the current state plan of both campuses are presented in Fig. 8. Since the main objects of interest in the study are outer boundaries and structures, their simplified versions were presented.

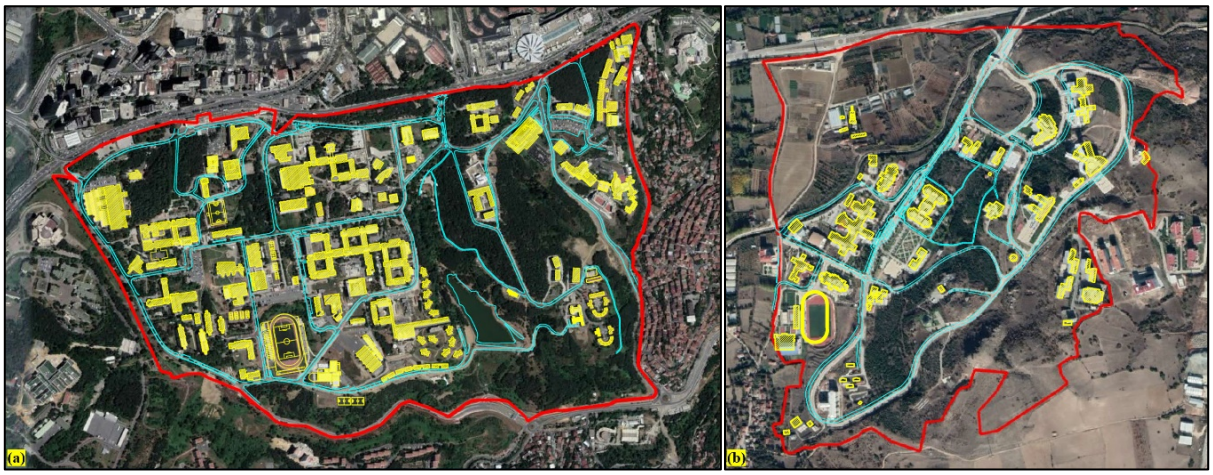


Fig. 8: Ownership status of the universities: (a) ITU; (b) TOGU

The values required for calculations is summarized in Table 6. Regarding the budget, the percentile marked by TOGU in the system was shared with the authors by the university. No information was shared about the values entered into the system by ITU. For this reason, considering the superior success of ITU in GM 2019, the option of SI-6 was accepted as >12%. Option marked by TOGU for SI-6 was >1 – 3%. Since TOGU shared the values entered for other sub-categories, it was also possible to make a comparison on an indicator basis. For ITU, only total score comparison was made because of limited information sharing in terms of both the presented values and the supporting evidence.

Table 6: Values required for calculations.

Information	ITU	TOGU
Total area	1651,000 m^2	1448,599 m^2
Total campus ground floor area of buildings	188,392 m^2	78,074 m^2
Open space area	1462,608 m^2	1370,525 m^2
Green area (Forested + Planted)	717,000 m^2	549,000 m^2
Population (Students, Academicians and Administrative Staff)	45955	37187

Relationship between SI and other categories

SI category gives an idea for the green campus approach of the university. This situation is already mentioned in the GM guideline. In this context, the relations of the SI with the other categories were analyzed by means of basic statistical analysis. For this purpose, Pearson product-moment correlation coefficient values were calculated. Pearson correlation coefficient is an index that takes a value between -1 and +1 and, reflects the scope of a linear relationship between two data sets. If the value of r is close to +1, this indicates a strong positive correlation. While SI was the independent variable, EC, WS, WR, TR, and ED were the dependent variables. Determining the linear relationship were made both for participant 780 universities and only 42 universities in Turkiye. The following formula was used for the coefficient r to be found by calculation.

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2(y-\bar{y})^2}} \qquad (2)$$

where **Hata! Yer işareti tanımlanmamış.** $\bar{x}$ and $\bar{y}$ are the sample means of the two arrays of values.

In addition to the relationship determined by the Pearson coefficient, box-plot graphs of each category were also obtained within the scope of statistical analysis of the categories. These graphs were examined both for all participant universities and Turkiye in particular. Thus, the distribution characteristic of the data set was tried to be determined.

Results and Discussion

The scoring is presented in Table 7 and Table 8. SI-4 is not an indicator that can be extracted from a 10 m spatial resolution image. Although a water absorption surface beside the forested and planted vegetation are not usually created, the percentile selected in the system for TOGU already corresponds to zero points. For ITU, this value was taken as zero point in the calculations due to image data used.

Table 7: Score calculations for ITU.

SI Id	ITU		
	Calculation	**Percentile Range**	**Score**
SI-1	(1.462,608 m^2 /1.651,000 m^2)*100	> 80% - 90%	0.5*300 =150
SI-2&3	(717.000 m^2 /1.651,000 m^2)*100	> 35%	1*500 = 500
SI-4	-	-	-
SI-5	(1.462,608 m^2 / 45955)	> 20 - 40 m^2	0.5*300 =150
SI-6	-	> 12%	1*200 = 200
	Total Score		**1000**

Table 8: Score calculations for TOGU.

SI Id	TOGU		
	Calculation	**Percentile Range**	**Score**
SI-1	(1.370,525 m^2 / 1.448,599 m^2)*100	> 90% and 95%	0.75*300 = 225
SI-2&3	(549.000 m^2 / 1.448,599 m^2)*100	> 35%	1*500 = 500
SI-4	-	-	-
SI-5	(1.370,525 m^2 / 37187)	> 20 - 40 m^2	0.5*300 = 150
SI-6	-	> 1% - 3%	0.25*200 = 50
	Total Score		**925**

As a result of the scores calculated with the help of digital image processing techniques applied on remotely sensed imageries, 1000 and 925 points were obtained for ITU and TOGU, respectively. The equivalents of these values in the GM ranking 2019 are 1050 and 825. The differences are likely to have several causes. Firstly, the 2nd and 3rd of the sub-categories were combined and considered as a single category. This category recommended by the authors is used to evaluate the green area as a single category representing greenery rather than separating it as forested and planted vegetation. Choices entered into the systems by TOGU were >35% for SI-2 and <=10 for SI-3, which indicates that 200 points were taken from these two indicators. In this study, higher scores were calculated for green areas since the forested and planted vegetation was collected together in a single sub-category and evaluated over 500 points. It will not be efficient to distinguish the forested and planted area from a medium resolution satellite image. Moreover, these two features representing greenery may be mixed in some regions of the campuses.

Another issue relates to the sub-category of SI-5. This indicator gives information regarding the amount of open space per person. The numbers related to the population in the universities were taken directly from the annual activity reports. Both universities in this study participated in the ranking with their main campuses. However, population information in the annual activity reports covers the entire university. When only TOGU is considered, it can be said that the number of people used in the calculation in this study differs from the number of people used in their calculations. Although the calculations in the first category are made on a single campus, it is not possible to make a restriction on the number of students or staff for the main campus. Because each person can use the main campus of the university. For example, while a student takes his classes on a different campus, he/she can use the dormitory on the main campus for accommodation. For this reason, the total number of people was used in this study and the open space area per person in TOGU was found approximately 37 m^2. The option selected by TOGU in the system was >40-70 m^2, as the value they calculated was 57.44 m^2 per person. This is because the number they used for the total population is 23623. Besides, the total campus ground floor area of buildings was 91703 m^2, which led to the difference in the open space area value they specified (1356896 m^2) in the system from that calculated in this study. The authors did not include the floor areas of the buildings located outside the campus boundaries but on land used by the TOGU for rent. The detailed comparison was realized only for TOGU. Due to not sharing the data that ITU provided for GM with the researchers, similar comparison could not be realized.

Pearson product-moment correlation coefficient values were presented in Table 9 below. While SI was independent variable, other categories were dependent variables. The values obtained show which category is more related to SI. For Turkiye, the strongest relation of the SI category is with the ED with the r value of 0.413. The category with the lowest correlation with the SI is

WS. The r value between them was calculated as 0.079. For all participating universities, the strongest relation of the SI is with the TR with the r value of 0.415. The lowest correlation with the SI category was EC. However, this low correlation is not just as in 42 universities in Turkiye. The r value between the SI and EC for all 780 universities was 0.260. These results show that the effect of WS category on the main category representing the green campus identity of the universities in Turkiye is negligible. There is a more balanced distribution when 780 universities are considered.

Table 9: Pearson correlation values between SI and other categories,

Categories	42 Universities in Turkiye	780 Universities in the World
	SI	**SI**
EC	0.284	0.260
WS	0.079	0.343
WT	0.362	0.390
TR	0.208	0.415
ER	0.413	0.378

Box-plot graphs of the categories for 42 universities in Turkiye and 780 universities in the world were presented in Fig. 9 and Fig. 10. Considering the graph for the 42 universities in Turkiye, it is seen that the extreme values were in SI category. It can be determined that there is a certain deviation between the median and the mean in all categories. Although a perfect normal distribution is not expected, the skewness value of -0.483 for the SI category shows that the data set is symmetrical to a certain extent. For the 780 universities in the world, there was no outlier values for the SI category. Due to the number of data, it is seen that the median line is closer to the mean in almost all categories. Skewness value of the SI category for 780 universities were -0.152, which indicates a more balanced data set. In other words, the gap between the lowest score and the highest score for the 42 universities in Turkiye were more pronounced.

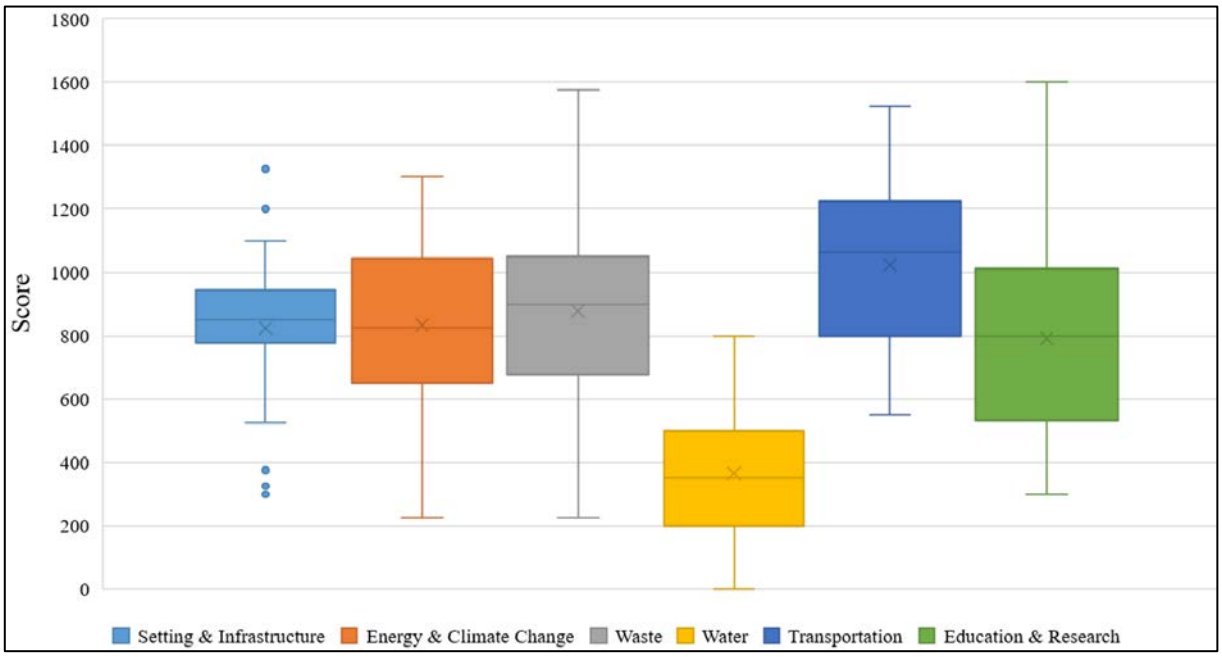


Fig. 9: Box-plot graph for the 42 universities in Turkiye.

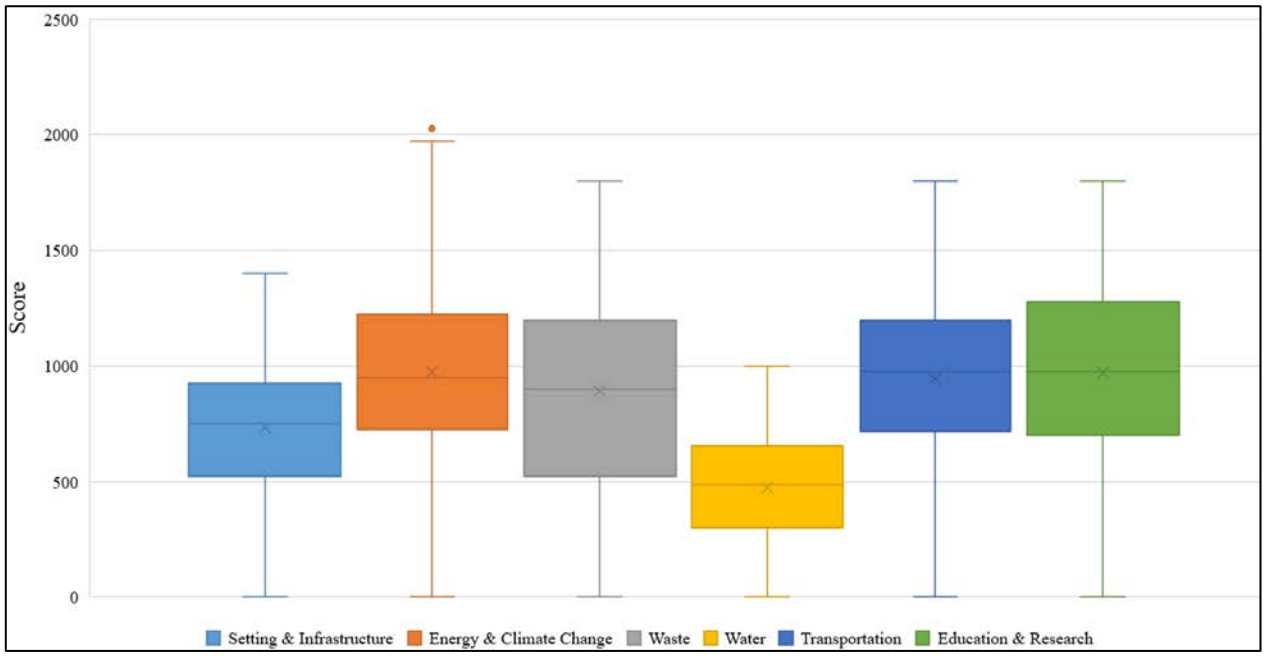


Fig. 10: Box-plot graph for the 780 universities in the world.

Conclusions

The possible contribution of the remotely sensed imageries to the GM rating system was examined and two indicators under the first category were proposed to be evaluated together. It was also revealed that data derived from satellite images can be used for evidence requested by GM. Universities present images taken from Google Earth as evidence for areal values such as forested vegetation and total campus area. However, there should be a standard for the evidence presented. The thematic maps in Fig.6 and Fig.7 are the suggested evidence for the greenery of the campus in this study. These maps demonstrate the green areas extracted from the satellite images in scale. Providing this type of dataset as evidence will contribute to the reliability of the evaluation, especially when compared to Fig. 2. The techniques used in this study are simple but effective methods that can be easily applied. Therefore, thematic maps can be requested as evidence in the next GM guidelines. Although similar thematic maps could be produced more accurately by using higher resolution images, Sentinel images proved to be sufficient for this study. The map representing the current site plan of the campus can also be used as an auxiliary data.

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