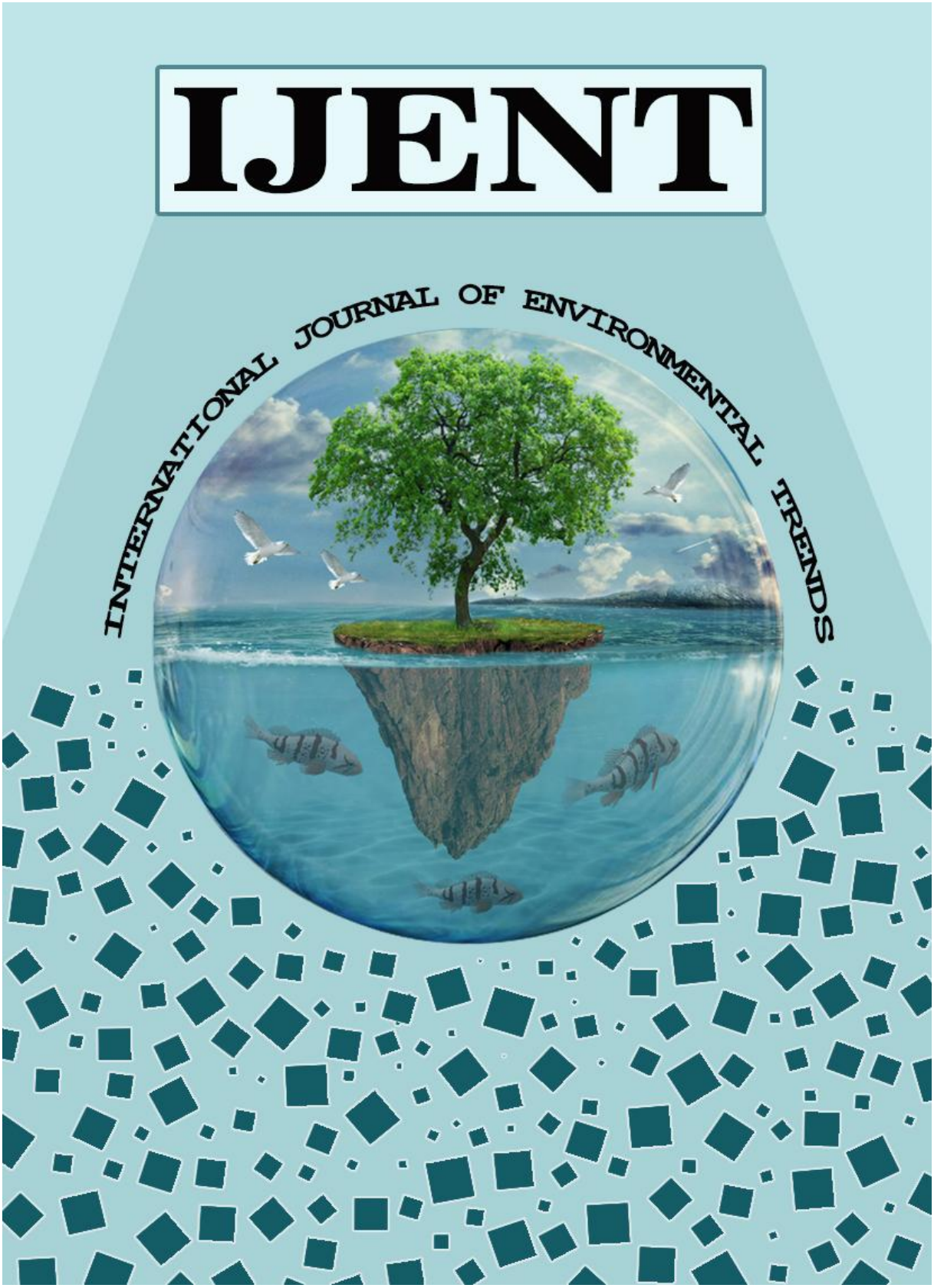


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**Research Article**

# Color Differentiation of Wall Stones: Historic Karatay College Building

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**Abstract**

People in Anatolia have lived mainly in residential houses constructed by concrete and bricks. There are also historic houses in small towns and villages which were built by using building stones, bricks, adobe and wood in combination. However, in the case of public buildings, dimension stones had been used in Anatolia for the main construction material since early times in history. Similarly, Karatay College, (Karatay Madrasah, "*Karatay Medresesi*") buildings in Konya had been built by using stones, wood and dimension stones in combination in 1251 for educational purposes. It is logical to think that this building have been repaired several times in history. Some of the early historic photographs (dated 1890) of Konya which were taken for general scenery purposes, covered also Karatay College building. These photos present the college's main entrance door and its frontier wall. Dimension stones in this wall were also identified through the earlier photographs and their current digitized surface colors have been defined one by one. Color differentiation among them, together with similar stone types' surface colors observed around Konya city were determined to evaluate weathering influences on this frontier wall stones. Defined surface color changes for analyzed frontier wall stones demonstrated rock weathering due to climate, environments and human influences which should be set to minimum level to protect Karatay college building.

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## INTRODUCTION

Education has also been main concern of States in history like today. Therefore, Seljuk Empire governing Middle-East and Anatolia during 1037-1157 established several education centers in their homeland. Konya city located at the centre of the Anatolia had been main residential and governing base in the history. Thus, Seljuk Empire State and its successors Anatolian Seljuk State (1077-1308) in later years had paid enough attention to this city as well. Moreover, Konya had been the capital of the Anatolian Seljuk State until the Ottomans' had become governing body in Anatolia. Therefore, Konya had not been only the capital city, but also trade, culture and education centre for Anatolian Seljuks at those years. Colleges for education purposes had been established in Konya and nearby cities. One of them was "Karatay College" named after "Celaleddin Karatay" who was one of the high degree civil officers after Sultan in Anatolian Seljuk State. Odabası [1] presented information about history of the college together with the meaning of the headers on its monumental entrance door. Karatay College was the school for theological, religious and natural sciences. Karatay College building was located at the centre of Konya and it had been started to build just near the Konya Castle (~125 meters away) in 1251.

Karatay College buildings had been constructed by using different materials like bricks, stones, marbles, woods and dimension stones. In this work, dimension stones which were used to cover outer face of the frontal wall were analyzed for their surface colors. This wall surrounds South-East side of the college building and its current height (October_2018) and length are around 6.75m and 15.50m respectively. Since this wall is also bordering frontier side of Karatay College building, (together with aesthetic preferences to enhance the main college entrance door's features), it was built in mainly flat appearance (without ornaments). Karatay College frontier wall's thickness is around 126cm and it was built by using mortar and stone combination (Fig. 1b). However, dimension stones facing outer part of the wall were selected purposely and they were dimensioned to form flat but monumental appearance (Fig. 1a). Frontal appearance of Karatay College building contains this flat, plane, stone-wall and monumental entrance door together with doomed main hall became visible at the backside of the wall. Dimension stones used to cover the frontier wall have height, width and thickness dimensions around; 40-45cm, 25-75cm and 15-40cm respectively. The rocks selected for the face of the wall were locally supplied building stones; mainly light-brown colored rhyodacite-dacite, grayish-light brown colored andesitic (pyroclastic) tufts and whitish limestone/travertine rocks. Rhyodacite-dacite had mainly been deposited near Sille village [2] and it is approximately 10km away from the Karatay College building in Konya city center. Andesitic tuff rocks can be located at west part of Konya city limits and they are member of the Kucuk Muhsine (KMuhsine) formation. These rocks have widespread outcrops around Kucuk Muhsine village (15 km away from Konya).


**Figure 1**. Karatay College building photographs; a) Karatay College main entrance and frontal wall, photo, dated Feb.2017, [3], b) Back side of Karatay College frontal wall, dated Feb.2017, [3].

Sille dacites are well known building stone around Konya and they had been used to build several monuments, mosques, houses, bridges in Konya throughout the history. Konya city has several limestone/travertine rock resources as well and Godene travertine resource (18 km away from Konya) is one of them. There are 12 dimension stone layers one over the others at the apparent face of the Karatay College frontier wall. Top layers of the wall were especially built in a way that magmatic/volcanic rocks (andesitic tuffs / rhyodacite-dacite) and limestone / travertine building stone layers were placed simultaneously. This wall was built (or repaired) in a way that limestone/travertine building stones might have purposely used to obtain the top layer of the wall (Fig. 1a and 1b). General conditions of Karatay College building and its frontier stone wall were also evaluated here through the historical photographs and related literatures. It is obvious that this frontier wall is original part of Karatay College building and probably it hasn't been repaired in macro scale since 1890. Yilmaz & Ulusoy [4] wrote about the architectural features of Karatay College building and they mentioned a few totally ruined inner room walls and demolished outside walls at South-East part of the building according to officially archived documentation. According to Yilmaz & Ulusoy, first repair work was performed in 1609 (there is no recorded data for pre-1609 periods), they also reported several other repair works which were performed in 1935, 1952, 1953 and 1957, [5, 6, 7, 8]. Karatay College building was repaired over again a few times by *"General Directorate of Foundations"* of Turkey at 1988, 1993, 2008, 2015, and 2018 (last restoration work has still continued in December 2018). Dimensioned face stones on this frontier wall were analyzed for their surface colors differentiations. Different shades of colors can be identified on the surfaces of the stones by even with naked eyes (Fig. 1a) which might have been resulted due to weathering of rock materials in various environmental factors.

## MATERIAL AND METHOD

There are monumental historic buildings in Konya and most of them have still been used for public purposes as; governor building, hotels, mosques or museum buildings. There are rare historic private houses which were built by using dimension stones in Konya. Most of the people had lived in one or two storey houses which were built by using brick, adobe, stone and wooden materials in Konya until 1950s'. Since then concrete has been started to be used for much more modern houses and apartments. Due to limited number of dimension stone resources, trade of these stones and its tradition in private house construction have not common in Konya like in Kayseri, Gaziantep and Mardin cities in Turkey.

### Dimension stone potentials around Konya city

There are several rock masses available to produce building and dimension stones around Konya but, they are around 10-25km away from the city centre. These distances might have been far enough for ordinary people to compensate their supply costs. Another reason might have been physical and mechanical features of stone resources. There are limestone and travertine sources around Konya but it was difficult to produce dimension stones because of their strength and (building stone block) chipping, shaping, properties. When the building stone productions steps are considered (quarrying, excavation, dimensioning, shaping and transportation) for historical quarry conditions, mining operations should be considered especially for those years, human and horse powers were the only option to handle the building stones. Therefore, stone workers had preferred the rock types which had lightweight and good chipping features. That's may be the reason, why these workers had preferred rhyodacite-dacite and andesitic tuff stones to built most of the historical public buildings in Konya. Because it is valuable asset, dacitic and andesitic rock resources near Sille village have been studied by

several researchers. Saydam [2] had studied on mechanical, mineralogical, geochemical and puzzolanic properties of Sille stone and he wrote that Sille stones are part of *Sulutas volcanites* in the region. Erturk [9] pointed also that Goger & Kiral [10] called this rock type as *Sulutas andesite unit* in *Dilekci rock formation*. Eren studied [11] structural geology around Sille village. He called this rock unit as *Sulutas volcanites*, and he pointed their age as *Late-Miocene and Early-Pliocene*. This unit consists of calcaleno-dacites, dacites, rhyodacites, rhyolites, andesites and minor amount of basaltic rocks [11]. Saydam [2] worked also on chemical compositions of the Sille stones and he plotted related data on diagram offered by Winchester & Floyd [12] to define the rock types (Fig. 2). He wrote that one of his samples (obtained from KMuhsine formation) was defined as *andesitic tuff*. The other tuff samples from the same rock formations were defined as rhyodacitic-dacitic tuffs.

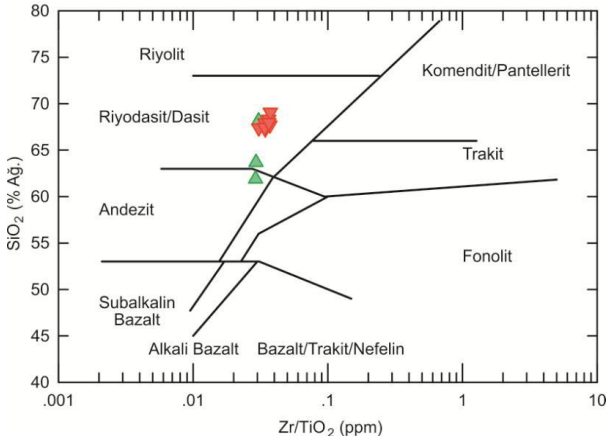


**Figure 2.** Classification of rocks according to $SiO_2$ - $Zr/TiO_2$ composition on Winchester & Floyd [12] diagram; Green triangles: Tuff samples from KMuhsine formation, Red triangles: Lava rocks from Sulutas volcanites, [2].

Saydam defined his samples obtained from *Sulutas formation (lava rocks)* as *rhyodacite-dacite* by using the graph given in Fig. 2. Besides geological background of Sille stones (mainly Sulutas volcanics), certain mechanical properties of this rock have also been studied by other researchers [13, 14, 15] to understand Sulutas volcanites' building stone behaviors and characteristics. Fener & Ince [15] named their test samples obtained from Sulutas volcanites (Sille stone quarry) as *quartz-andesite*. They tested these building stones for freeze-thaw characteristics. They wrote that freeze-thaw cycles influenced *quartz-andesite* stone samples' physico-mechanical properties. Kansun [16] worked also on Sille stones and he noted that, quartz-andesitic and rhyodacitic-dacitic rocks are very similar to each others and they can transitionally be observed in Sulutas rock formation at Sille quarry. Andesitic rocks especially andesitic tuffs as a member of KMuhsine formation give outcrops widely enough around Kucuk Muhsine village near Konya. As Ozkan [17], wrote that, KMuhsine rock formation consist of beige, creamy and pink colored volcanic breccias, tuffitic rocks, tuffs and agglomerates. Ince [18] pointed that andesitic tuffs around Konya have also been used for building purposes together with Sille stones throughout the historical times.

Building stones have been selected (preferred) by experiences after observing their long-term durability properties. However it is obvious that; porosity, permeability, density, hardness, toughness, trimming, weathering, decomposition, mechanical strength values, elastic modulus, heat isolation characteristics of building stones are mainly very important on their usage as a building stones. These properties are influenced by freeze-thaw cycles occurred in winter times. Wedekind etal.'s [19] works can be given here as an example to define building stones' long-term durability. They tested 14

different rocks to define their suitability for building stones category. They concluded (similar to common observations) that; "*moisture expansion in natural building stones is considered one of the most important factors affecting their weathering and deterioration*". They stressed also on the importance of swellable clay mineral ratio in building stone compositions. They said that clay minerals were main reasons of building stones weathering. However, they showed also that moisture expansion could also be taken place in "*volcanic tuffs stones almost free from clay minerals*". At this point the work performed by Jamshidi etal. [20] is required to be mentioned. They tested 14 different building stones for their long-term stability against freeze-thaw action by a decay function model supplied by Mutluturk etal., [21]. In this model, test samples' mechanical properties (density, porosity, water absorption, Brazilian tensile strength, and point load index values) were first determined. Then 30 cycles of freeze-thaw were performed. After every 5 cycles, Brazilian tensile strength and point load index values of the test samples were determined. They said that freeze-thaw action influenced all the tested building stones and these tests revealed that the longest half-life ($N_{1/2}$) values were obtained for Dacite, Amphibolite and Granite-II samples (Fig. 3). Another conclusion they supplied that *"half-life has no meaningful pattern based on the rock type"*. For example; they obtained different half-life values for "Granite" samples; Granite-I and Granite-II.

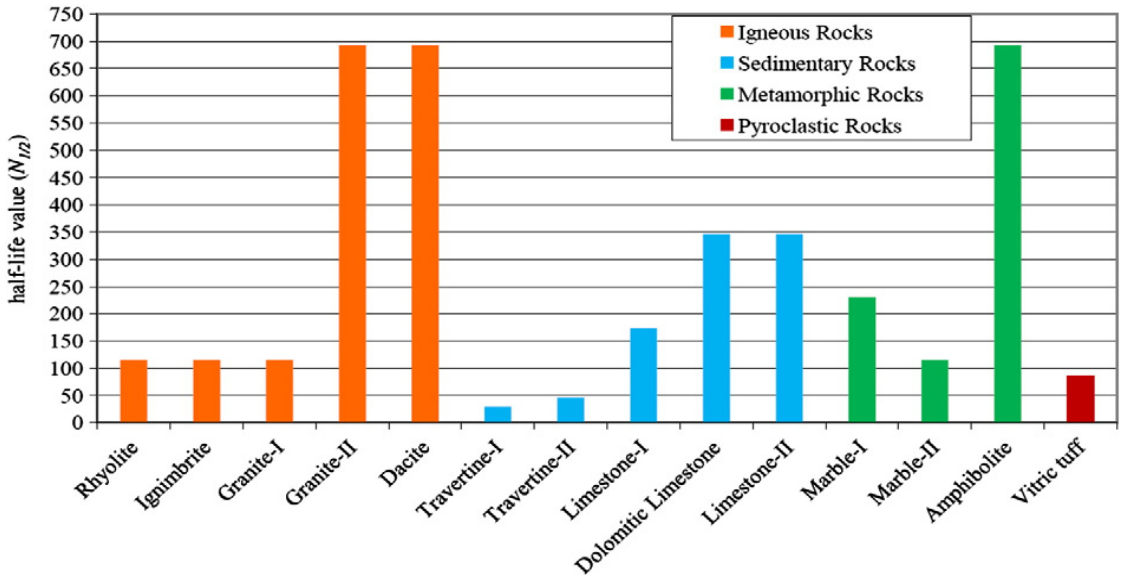


**Figure 3.** The half-life values of Brazilian tensile strength (for 14 different building stones). The half-life ($N_{1/2}$), of the tested rocks is defined as the number of cycles required to reduce Brazilian tensile strength (in this graph) to its half value, [20].

**Rock surface colors to define physical surrounding environments**

Rock masses have particular colors according to their mineral contents. Some colors can be differentiable by naked human eyes, but 255x255x255=16,581,375 different rock surface color tones in Red-Green-Blue (RGB) format could definitely be separated by digital manner [22]. Original fresh rock surface colors can then be digitized to use in engineering purposes. If colors of the rock surfaces are important in certain projects, companies are advised to describe colors not only by human eye descriptions, but also by means of digitized RGB color codes. When the rock surface have started to exposed sunshine and climate effects, like at the outcrops, their colors changed in time due to weathering effects. In nature, original rock mass colors have been changed in mainly two manners. First one is occurred during chemical weathering of rocks. In this case, chemical compositions of original rock masses are differentiated during weathering processes. Second type of rock surface color

changing is happened due to surface dying of main rock masses by colorful intrusions through discontinuities (i.e. external sources of dying material; colorful gasses, cohesive liquids and dusts etc). When colors of building stones have been changed at historical monuments, there may be combined effects of them. Colors of building stones at historic houses, mosques, churches, bridges, college buildings, status etc. have gradually changed due to chemical reactions or surface covering/dying effects of climate. Building stone's surface colors can also be differentiated by the traces of colored liquid (groundwater, contaminated rain water or industrial/residential/commercial waste waters etc.) run over them. Building stone's surface colors are also definitely influenced by sequential growth of micro organism on them (biological influences).

Chemical compositions which influence visible lights returning from building stone's surfaces determine the final surface colors of them. Weathered rock surface colors on the other hand include slow rate of weathering progresses in general. Thus, weathering rock surfaces have colors which gradually differentiating in time. Surface dying (light and dark), surface acidic or basic chemical reactions through discontinuity surfaces, rock surface decaying/weathering, rocks' total weathering as a whole mass have changed the rock and rock surface appearances. These changes might be occurred only on rock surface colors or surface color changes may be occurred together with rocks' (inside as well) color changes. Color is very sensitive physical differentiation property; therefore even slight surface dying (or slight chemical reaction) is realized on rock surfaces, this new conditions produce new rock surface appearances. These slight color changes might not be sensible by human eyes but, image analyses methods in color detection systems lead to determine these differences in digital manner [22, 23, 24, 25, 26, 27]. Rock surfaces at outcrops or rock masses interrupted by different discontinuity sets have influenced by climate and groundwater factors and their colors are differentiated. These changes for certain rock mass samples have been determined in digital manner (RGB color values) in detail and filed as computer image captured data. Gokay [28, 29] coded fresh (just broken) and weathered rock surfaces to comprehend color changes due to rock weathering. Pixels' RGB values obtained from different rock surfaces were plotted to obtain general color changing behavior of the tested rocks (Fig. 4). In nature, rock surfaces and the rocks' inner layers next to the rock surfaces have usually different colors. To describe color differentiation due to weathering, riverbank rocks' weathered surfaces can be counted here as an example. In order to express weathering actions on these rock surfaces followings are the adjectives which are used; rusty, wet, greenish, brownish and brown covered by dark green algae, dark black mud covered limestone, etc. When the usage of natural stone under consideration for human civilization; houses, bridges, cottages, mosques, churches, castle and monuments should be analyzed for their dimension stones' color characteristics as well.

If there are written documents for these building stones, mining sites (or mining sites can be resolve by evaluations), their appearances can be compared with respect to original fresh rock surface colors. Weathering of rocks has been continuous progress and it can be observed at natural rock masses located in underground or surfaces. Weathering is also natural fact for dimension stones used for buildings. There are always influencing factors which disturb the dimension stones' integrity and surfaces. However, natural stone usages (for pavements, house & garden walls, monuments, mosques, museums, churches etc.) have increased as the cities have gradually been expanded in time. Thus, it is

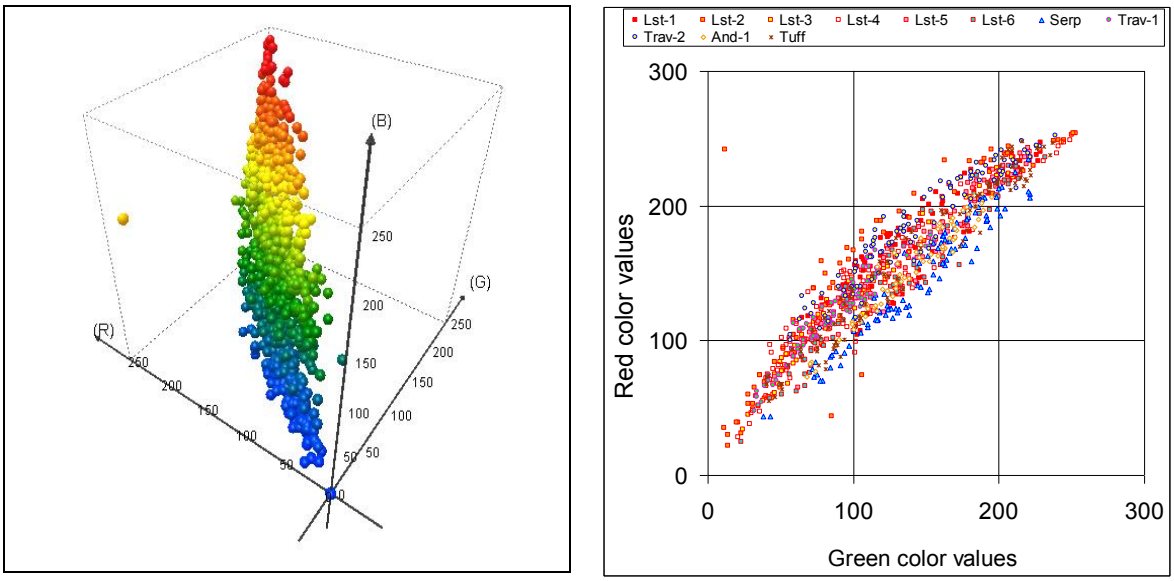


**Figure 4.** Selected 3D and 2D color-band graphics for selected rock surface colors (digitized in RGB data) obtained for fresh and weathered rock masses around Konya-Turkey region; *[Limestone formations (**Lst-1**: Konya-Yukselen road cut, **Lst-2**: North-west side, Konya, **Lst-3**: Cement factory quarry, Konya, **Lst-4**: Limestone aggregate quarry, Konya, **Lst-5**: Landslide area, Taskent-Konya, **Lst-6**: Hydraulic dam construction area, Ermenek-Karaman), **Serp**: Serpentine rock mass outcrops, Dere village, Meram-Konya, **Trav-1**: Travertine mine, Ardicli-Konya, **Trav-2**: Abandoned travertine mine, Esentepe-Konya, **And-1:** Andesite quarry, Sandikli–Afyon, **Tuff:** Crystalline tuff mine, Evliyatepe, Konya]*, [29].

better to have control manner for dimension stone businesses (especially in historical building restoration projects) to have required knowledge of rock related chemistry and rock mechanics. In this study; importance of rock surface colors has been explained. Then, beside the mechanical, chemical and related physical properties of dimension stones, their surface colors are advised to be determined to understand any color changes which have been taken places (Fig. 5). If colors of dimension stones used for walls have changed due to acidic environments, these changes might also be the sign of rock or rock surface decomposition. Therefore after recognizing color changes, in some limits, on surfaces of building stones, other physical, chemical and mechanical etc. tests should be followed to reach final


**Figure 5**. Digitized photograph of Karatay College frontal wall [3]. Dimension stones were numbered according to their positions over the main road (pedestrian, pavement) level.

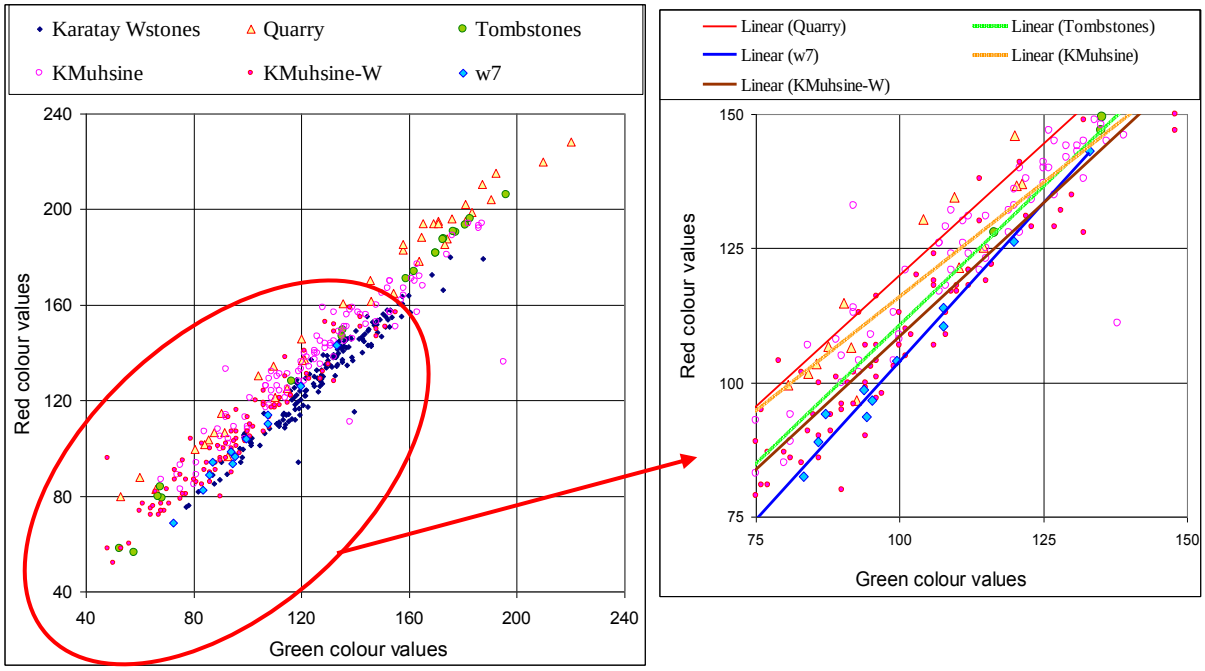


**Figure 6.** Green–Red digital color codes of selected Sille stones' and KMuhsine tuffs' surfaces colors *(together with representative linear lines to compare their positions);* **Karatay Wstones**: Karatay wallstone surface colors, **Quarry:** Sille stone surface colors at the quarry (fresh rock surfaces), **Tombstones:** Rhyodacitic-dacitic tombstones in Sille cemetery (200-400 years of weathering), **w7:** Rhyodacitic-dacitic stones used at Karatay College frontal wall's 7th layers (more than 128 years of weathering). **KMuhsine**: Surface colors of andesitic tuffs in KMuhsine formation, **KMuhsine-W:** Surface colors of weathered andesitic tuffs around Kucuk Muhsine village.

decisions if the stones should be replaced or not. In this research Sille stones, (rhyodacitic-dacitic lava rocks in Sulutas formation) and andesitic tuffs (KMuhsine formation) were analyzed for their surface color changes. After obtaining each building stone's surface colors, their differences were evaluated through Green-Red and Blue-Red color band graphics (Fig. 6 and 7) as it was performed for weathered rocks before (Fig. 4). In addition, recognized rhyodacitic-dacitic stones used as tombstones in Sille-Konya were then photographed together with these rocks' mining sites at Sille stone quarry. Thus, the data sets for rhyodacitic-dacitic lava rocks' surface colors were formed for further color analyses to recognize their color differences. Surface colors of weathered rhyodacitic-dacitic rocks in this data set were obtained from; Karatay College frontal wall, historic Sille cemetery tombstones. Fresh rhyodacitic-dacitic rock surface colors were also digitized through the photographs of related locations at Sille stone quarry site. Similar data set were prepared for andesitic tuffs and weathered surface of them. Surface colors obtained from rhyodacitic-dacitic Sille stones and andesitic tuffs were plotted in Fig. 6 and 7 to understand if there is any pattern for logical reasoning and conclusions. In these graphs, colors of Karatay College frontier wall's face stones can be differentiated without difficulty from the other test samples. They have in general lower Red color values and higher Green and Blue color values. Especially face stones of 7th layers of this wall have illustrated more darkened colors (Fig. 5) which were distinguished through the color graphics given in Fig.6 and 7. Curves defining color data obtained from face stones of Karatay College frontier wall's 7th layers stones have:

$y=(1.1776)x+13.859$ ($R^2=0.9835$), $y=(1.4127)z+29.595$ ($R^2=0.9516$) linear relation.

Similar color relations for rhyodacitic-dacitic quarry stone surfaces have:

$y=(0.9788)x+22.118$ ($R^2=0.9796$), $y=(0.9293)z+47.295$ ($R^2=0.8566$)

similar linear color relation of rhyodacitic-dacitic tombstone surfaces at Sille cemetery have:

y=(1.0366)x+6.7428 ($R^2$=0.9956), y=(1.0758)z+17.388 ($R^2$=0.9835)

similar linear color relation of andesitic tuffs and weathered andesitic tuffs surfaces observed around Kucuk Muhsine village simultaneously have:

y=(0.8541)x+30.332 ($R^2$=0.8656), y=(0.7148)z+63.564 ($R^2$=0.7519)

y=(0.992)x+9.3924 ($R^2$=0.9405), y=(0.8642)z+31.099 ($R^2$=0.7857)

In these equalities, y, x and z variables are representing x: Red, y: Green and z: Blue color codes in RGB color system.

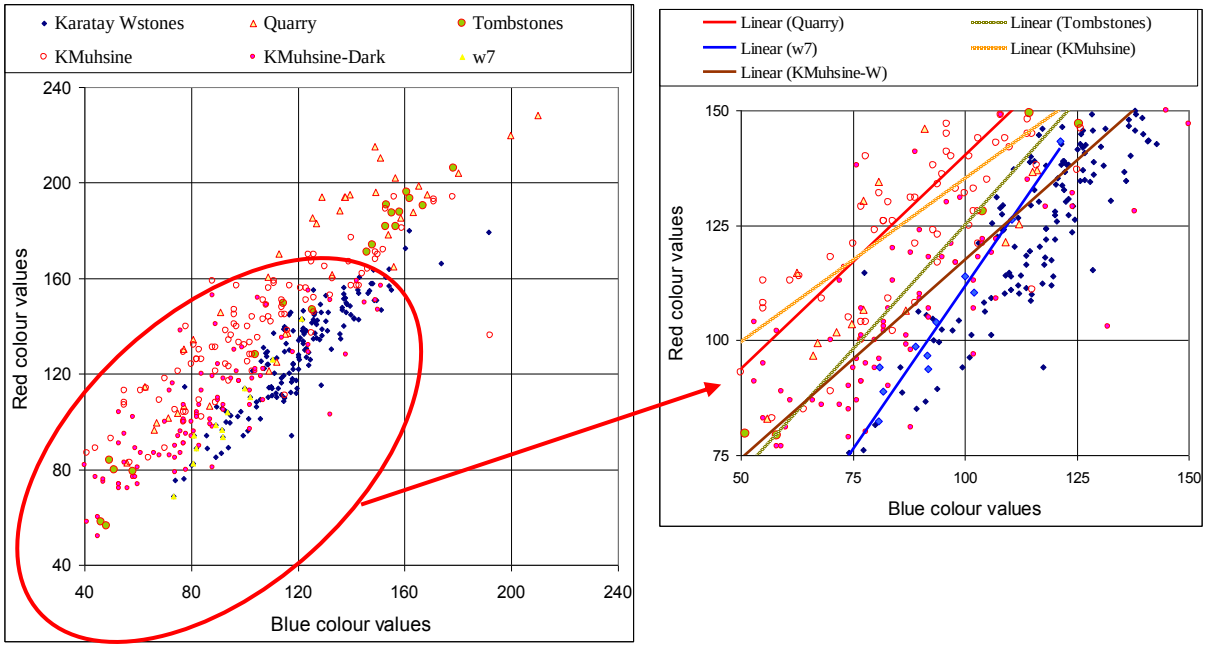


**Figure 7**. Blue–Red digital color codes of selected Sille stones' and KMuhsine tuffs' surfaces colors *(together with representative linear lines)*; **Karatay Wstones**: Karatay wallstone surface colors, **Quarry:** Sille stone surface colors at the quarry (fresh rock surfaces), **Tombstones:** Rhyodacitic-dacitic tombstones in Sille cemetery, **Sille-Wstones:** rhyodacitic-dacitic Sille stones used at the walls of Sille village historical houses, **w7:** rhyodacitic dacitic stones used at Karatay College frontal wall's 7th layers. **KMuhsine**: Surface colors of andesitic tuffs in KMuhsine formation, **KMuhsine-W:** Surface colors of weathered andesitic tuffs around Kucuk Muhsine village.

## RESULT AND DISCUSSION

Surface colors (RGB values) of dimensioned building stone used for Karatay College building frontier wall's outer face had been determined one by one through the digitized photograph shown in Fig. 5. The differences in RGB colors among face stones of the wall and other rhyodacitic-dacitic and andesitic tuff stones surfaces photographed for this research can easily be detectable in Fig. 6 and 7. Karatay College wall stones have been influenced by weather conditions similar to Konya city centre. These face stones were situated in vertical plane and thin concrete protection (8 cm thick) layer at the top of the wall was molded at earlier repair works. Therefore, building stones of this wall have rarely been affected by direct snowing and raining. However, indirect influences on the wall have possibly been occurred for years. In addition, foundation of this wall might have been bothered by groundwater (capillary effects). Beside of these features, the wall stones have been dreadfully influenced by heavy city traffic vibrations, exhaust fumes and particles. One of the busy city roads in Konya is just located after 3 meters of pavement (Fig. 1a). This fact has been one of the main disturbing factors on surface colors of the wall. In addition, Karatay College rooms at the back of the analyzed frontier wall were diminished in history [4]. Therefore, any permanent/temporary room

facilities had been located there have roof structures intersecting the backside of analyzed frontier wall (Fig. 1b). These roof facilities might have been effective on extra moisture (water seepage) inside the Karatay College frontier wall. This wall has 3 small gaps of embrasure at 7th layer as well. Since, moisture content in each dimension stones at this wall seems slightly different, absorption, adsorption and adhesion characteristics of them have been expected dissimilar. When surface colors of stone layers at Karatay College frontier wall were plotted, the graph given in Fig. 8 was obtained. The color differences in these layers produced different slope ratios for their linear curves. Almost all of the slope ratios are analogous to each other (most of the curves were determined almost parallel to each others) except the one obtained from 7th layer. The curve obtained at Upper-Left corner *(higher Red codes - lower Blue codes)* in this graph is the one representing *rhyodacitic-dacitic quarry stone* surfaces (Fig. 8). That means this curve was plotted by using the data obtained from fresh surface colors of rhyodacitic-dacitic stones in Sille stone quarry. The other layers' curves are listed according to their distance to this quarry curve as follows (nearest first); w8, w4, w5, w6, w9, w12, w3, w10, w11, w2, w1. Besides these curves, 7th layer's curve in Fig.8 presents different situation, this curve is crossing the other curves because it has higher slope angle. Karatay College frontier wall's 7th layer's stones were showed comparably darker (weathered stones) surface color shades. They had also normal levels of surface color values which were nearer to quarry stone surface colors as well. In the supplied list above, underlined layers (w8, w12, w10 and w1) have limestone/travertine type building stones, the others (w4, w5, w6, w9, w3, w11, and w2) have rhyodacitic-dacitic/andesitic-tuffs building stones. These layers are given in here, in ordered lists, which present degree of weathering; from less affected to highly affected, weathered, ones. According to the list; rhyodacitic-dacitic/andesitic-tuffs stones showed worst weathering color differences for w2 layer. After w2 layer, w11 layer was determined second worst weathered layer for the same stone types. At this wall, w11, is highest layer built by using rhyodacitic-dacitic/andesitic-tuffs stones.

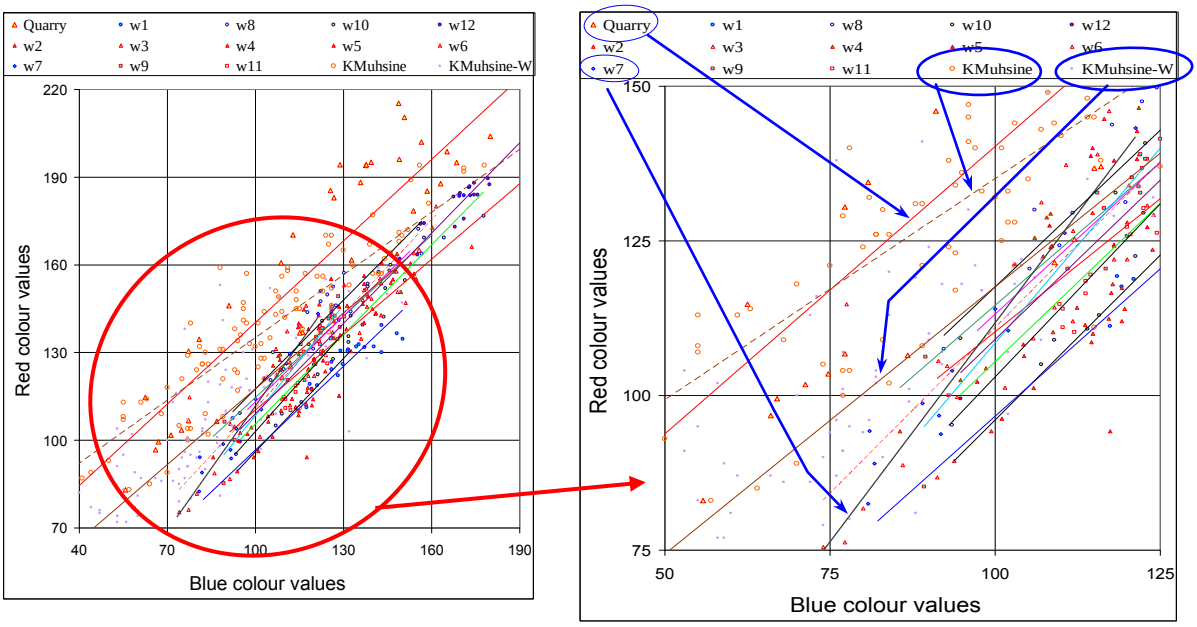


**Figure 8**. Blue–Red digital color codes of selected Sille stones' and KMuhsine tuffs' surfaces colors *(together with representative linear lines)*; **Karatay Wstones layers:** w1, w2, w3, w4, w5, w6, w7, w8, w9, w10,w11, w12, **Quarry:** Sille stone surface colors at the quarry (fresh rock surfaces), **KMuhsine**: Surface colors of andesitic tuffs in KMuhsine formation, **KMuhsine-W:** Surface colors of weathered andesitic tuffs around Kucuk Muhsine village.

## CONCLUSION

Experience in house and monumental building constructions in history turn out different manners to build them. Building stones usage was one of the methods which stones carry the building loads. Rhyodacitic-dacitic Sille stones and andesitic tuffs have mined around Konya for building stone purposes. These rocks have been used for houses, mosques, tombstones, bridges and college buildings in history. Sille stone's handling and practical shaping features have made it convenient building stone. Rhyodacitic-dacitic Sille stones used as tombstones are also the indications that Sille stone's long time durability had been experienced in history as well. Similarly, Jamshidi etal. [20] stated that their dacitic test samples presented higher valued half-year (longer durability) strength features with respect to many other building stones. In different locations, digitized surface colors of rhyodacitic-dacitic and andesitic tuffs stones were determined in this study to compare their color differences. Color differentiations on these rock surfaces are given in Fig. 6, 7 and 8 to illustrate color differences between the test samples. Surface color analyses showed that climatic weathering has gradually differentiated rocks surface colors. It was determined that rock surface color changes were higher for some of the Karatay College frontier wall's outer face stones with respect to tombstones located in Sille-Konya. It is necessary to point here that if there are micro organisms living on/in historical tombstones and historical wall stones, they have changed appearance of the building stones and tombstones totally. These kinds of biological weathering effects are sometimes combined with air pollution of cities (together with traffic fumes) to form darkened surface colors of building stones. It was concluded that Karatay College frontier wall's face stones have been affected from fumes, dust and chemical exhaust particles (air pollution) originated from vehicles and residential houses around. Digitized rock surfaces' colors pointed these color changes (weathering effects, Fig. 8) for different rock surfaces at different location. It was evaluated that moisture content and air pollution are considerably influencing surface colors of building stones in cities.

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**Research Article**

# Geodesign for Urban Planning : A Case Study from Harran University's Campus Master Plan

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**Abstract**

Since 10 years Geodesign has been applied in regional and urban planning throughout the world. The Department of Geomatics, Harran University (HU) has been charged with the design of a new master plan using Geodesign technology. "Geodesign Hub", an online software for collaborative Geodesign, has been selected for this project. Evaluation maps created based on the judgment of experts in the respective field of specialization. ESRI's CityEngine used for the creation of realistic models that can easily be understood by the higher management. This is being realized by conducting several workshops with the participation of the higher management of HU. The most striking feature of Geodesign Hub was that the participants could see the impacts of the individual projects that made up their designs immediately.

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## INTRODUCTION

### *Master planning in Turkey*

Nowadays, the concept of Master Plan is thought to be the design of many elements, including the different parts of a region and the transportation corridors connecting them, guided by a certain mission and vision. In fact, this is in full compliance with the definition of the Master Plan in Construction Law No. 3194 [1]. First, in these plans it is necessary to see the general land use of the parts of the territory on maps (using cadastral maps as background if available) from the regional development or environmental plan. Then, in a broad framework of major regional units the plan should consider to remove disparities in future population densities, related building densities when necessary, and the development directions and sizes and principles of the various settlement areas. At the last stage, it is necessary to show aspects like solutions for transportation problems within the region and in relation to neighboring regions and to make arrangements based on the preparation of applied regional development plans and to present the plan in full detail in the context of a detailed report.

This concept of master plan can easily be applied to universities. Universities, which address at least a major part of the educational need of a region, are a miniaturized model of a city consisting of social facilities, laboratories and classrooms having their own administration and a transportation network ranging from sidewalks to roads and providing accommodation and food in the form of restaurants, canteens and dormitories. When planning the above-mentioned components of a university campus, not only the number of buildings or roads, but also the number of students, academicians and administrative staff and their families who are expected to study, work and live at the university every year should be considered. In this context, the compounds of universities should be organized and planned in accordance with a specific plan, namely the provisions of a Master Plan.

Master planning in the above-mentioned sense has started at Turkish universities as joint studies between their academic and administrative units. For example, the Master Plan of Atatürk University (AU) Campus was created under the name of Atatürk University Sustainable Campus Master Plan. Following the first master plan prepared in 1955, this new plan consists of 1/5000 scale spatial development and 1/1000 scale implementation plans and their additions as well as a physical 3D model at a scale of 1/1000. With this plan, it is thought that the university will be able to direct all of the spatial changes, transformations and developments that will be experienced in the coming 100-year period [2].

An example of the sustainable campus approach is the changes that Abdullah Gül University (AGU) has planned for its Sumer Campus. The project aims to make the buildings belonging to the Sumerbank Kayseri Cloth Factory and Lodgings established at the beginning of the Republic re-functional. These buildings that have not been used within the campus boundaries until now, have been re-acquired to made them usable for educational purposes [3]. Another research conducted within the scope of the sustainable campus approach is the planned study of comprehensive targets and strategies for the Gebze Technical University (GTI) Campus of Çayırova. In this study, the role of universities in sustainable development was first discussed, and then sustainable campus guidelines and objectives prepared by the United Nations Environment Program (UNEP) and the International Sustainable Campus Networks - Global University Leaders Forum (ISCN-GULF) campus design goals have been formulated [4].

After the historic HU was abandoned about 1500 years ago, the new HU was established in the Province center of Sanliurfa in the year 1992. In 1993, its main campus, Osmanbey located 20 km distant to the city center was created from scratch (Figure 1). With an area of 2870 ha Osmanbey Campus has an enormous development potential. In 2016, a new master plan was created by a private company. As this master plan was designed neglecting the current natural environment and realistic future projection, the Department of Geomatics Engineering of HU applied for the design of a new master plan using Geodesign technology that was approved in early 2017.


**Figure 1.** Location of Osmanbey Campus

***Master planning using Geodesign***

According the author's research, the word "Geodesign" has been mentioned for the first time by the German urban planner Klaus R. Kunzman in the article "Geodesign: Chance oder Gefahr?" (Kunzman, K.R., 1993) [5] in 1993. However, its practical usage can be traced back to the earliest beginnings of human culture. The word Geodesign consists of two components: 1) Design, which is almost the same as planning of any kind and 2) Geo, which as a prefix is taken from the Greek word γη or γαια meaning "earth", usually in the sense of "ground or land". That means that in a broader sense any planning reaching beyond the closest surrounding of humans (like for example interior design) could be considered to be Geodesign.

While many researchers have dealt with Geodesign in the 20th century, the work of three of them has to be mentioned in more detail when discussing Geodesign; Ian McHarg, Carl Steinitz, and Jack Dangermond. In 1969, McHarg, landscape architect and lecturer at University of Pennsylvania, USA, wrote the book "Design With Nature" (McHarg, I., 1969) [6], which is often considered to express the principles of Geodesign for the first time. It expresses the value of designing with nature as related to the fields of landscape architecture and regional planning. On the level of methodology, based on the early works of Warren H. Manning in 1923 (Steinitz, C. A, 2012) [7] he introduced the concept of overlaying thematic layers of geographic information to assess the best location for a particular land use. Of course, at that time this overlaying technique was totally non-digital using paper maps. Still, this technique laid the foundation for digital Geographic Information Systems (GIS) by organizing geographically referenced thematic layers of the physical environment and social-economic conditions and by analyzing them for obtaining conclusive results.

In 1995, Carl Steinitz who was working with his colleagues and students over a period of approximately 30 years at the Harvard Graduate School of Design developed a complete framework for doing geodesign as applied to regional landscape studies. This framework originally called Framework for Landscape Planning and later renamed to Framework for Geodesign (Steinitz, C. A, 2012), advocates the use of six models to describe the overall planning (geodesign) process as shown in Figure 2.

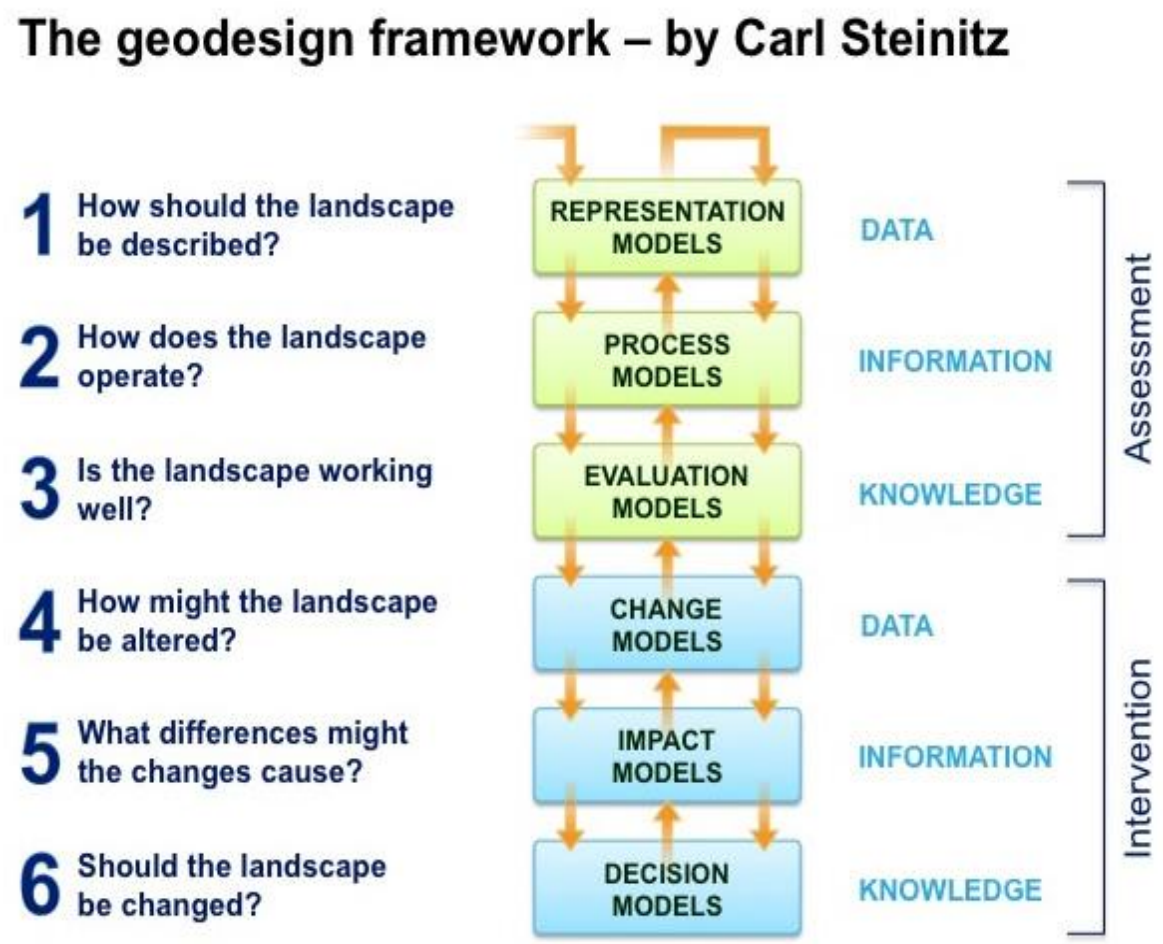


**Figure 2.** Six models of the Geodesign process

In "Framework for Geodesign" the author delineates the conceptual framework for doing Geodesign, which is considered to be the standard book for both practitioners and academics.

Jack Dangermond, president and founder of Esri, was one of Steinitz's students at Harvard. He was studying landscape architecture but was also keenly interested in the work at the Laboratory for Computer Graphics and Spatial Analysis. After graduating in 1970, he used Harvard's SYMAP, one of the first computer mapping programs to start his company, which is now the world leader in GIS technology. In 2005, it is reported that it was him who made the term popular. This happened during a demonstration of a then newly developed extension for ArcGIS called "ArcSketch", a tool that enables the sketching of land use plans without using complicated GIS tools (Miller, W. R., 2012) [8].

Since 2010, ESRI is holding an international conference on Geodesign in Redlands on a yearly basis. Since 2013, similar conferences on the European level take place.

Every organization, large or small, public or private, does three things: it gets and manages information (data), analyzes or assesses that information with respect to some purpose (analysis), and (based on that information and those assessments) creates or re-creates goods and/or services (design). It is, in fact, the creation or re-creation of goods and/or services that gives most organizations their reason for being. If for this creation GIS is used then actually, we can speak of Geodesign.

In his book "Geodesign – Case Studies in Regional and Urban Planning" McElwaney (McElwaney, 2012) [9] lists seven key characteristics of Geodesign. However, during the ongoing discussions of our project the following three characteristics have been determined as the most important ones:

1. Goedesign provides a fast feedback on your changes to a plan making the impacts of it immediately visible.

2. Geodesign supports a participatory approach giving all stakeholders a voice for the planning of their future.
3. Geodesign uses an intuitive GUI that allows the active participation of a multidisciplinary project team and decision-makers at the same time.

There is nothing like "the" Geodesign methodology. This has to be found out for each project separately. After testing of different systems, we decided to go with "Geodesign Hub" found by Ballal (Nyerges, 2016) [10]. Geodesign Hub is an online software for collaborative geodesign. It enables teams to create and share concepts, to design collaboratively, and to receive change-assessments instantly – all in a highly synergetic, efficient and easy to use environment.

**MATERIAL AND METHOD**

***Work on evaluation models***

For the Osmanbey Campus 10 systems, for which an intervention in means of new developments or any other major change in the near or middle term are expected, have been selected. A list of these system with a short description and its criteria is given below (Table 1). Criteria are those parameters that are used to evaluate whether changes fall in one of the five evaluation classes: feasible, suitable, capable, not appropriate or impossible (here called "existing"). Under criteria the respective GIS layers that have been used as an input are indicated.

**Table 1.** A list of 10 systems with a short description

| System | Description | Criteria |
|---|---|---|
| Teaching Facility | | distance to water courses, distance to existing facilities, land cover classes |
| Transportation | Includes highways, major roads, connecting streets and pedestrian walks. | distance from road centerline, land cover classes |
| Housing | Middle density housing (up to 5 floors) for staff and students | distance to water courses, distance to highway, land cover classes |
| Villa | Low density housing (1-2 floors) for staff | land cover classes, distance to water courses, distance to highway |
| Agriculture / Food Production | Suitability for agriculture and food production | land cover classes, soil capability classes, distance to highway |
| Greenhouses | | land cover classes, distance to water courses |
| Small Food Processing Facilities | SMALL ORGANIC AROMTIC PLANTS AND SUN DRYING | land cover classes, distance to water courses, distance to main road and highway |
| Forest and Protected Areas | | land cover classes, conservation typea |
| Recreation Areas | | land cover classes, distance to water courses, distance to conservation sites |
| Spa and Related Facilities | Extension to existing hospital | land cover classes, distance to water courses, distance to existing hospital, soil capability classes |

Each system is similar to a suitability map. The difference to the standard approach to suitability analysis is that instead of producing one suitability map, ten suitability maps for each system are produced.

Input data describing the data and process models (the first and second model according to the Geodesign framework of Steinitz) have been processed using GIS technology. The underlying data have been produced based on accepted scientific standards (e.g. soil suitability map) and are not further dealt with in this paper.

On the other side, the selection of criteria and its classification into five evaluation classes cannot fallow a clearly defined scientific methodology. They are subjective and depend on the values and priorities of the persons who work on the evaluation. To give one example from the sytem "Greenhouse", one may argue that locations having a slope of more than 20 % are not appropriate. Someone else might consider all land feasible for such kind of development arguing the return of investment for greenhouses is so high that even taking additional measures for ground stabilization will lead to profitability in the long run.

The above said had two consequences for this project: 1) The opinion of different subject matter experts had to be taken into consideration. 2) The evaluation models had to be revised several times. In addition, based on the input of subject matter experts even one system had to be taken out completely and to replaced by one that better suited the needs of Osmanbey Campus.

The final evaluation models were documented in the form of a spreadsheet (Figure 3). Based on this spreadsheet evaluation maps were produced using the underlying input GIS layers of the criteria contained in it (Figure 4). In many cases, the review of the first evaluation maps showed wrong classification results at some campus locations. Usually, these mistakes were a result of wrong logical expression, e.g. using an AND statement instead of an OR statement. Considering the amount of different input layers, their different classes and different logical operators the total amount of possible combination is quite high and consequently, in some cases finding a sound expression took its time.

| Teaching Facility | | | | TEACH |
|---|---|---|---|---|
| System 1 | | | Contact / Expert Name | |
| Description of Evaluation: Different land use types classified according to suitability for building teaching facilities. Criteria: land cover, distance to water courses, distance to existing facilities | | | | |
| Feasable | Suitable | Capable | Not Appropriate | Existing |
| land cover class = all other classes, distance to water courses > 70 m, distance to existing facilities < 600 m | land cover class = all other classes, distance to water courses > 70 m, 100 m < distance to existing facilities < 1000 m | land cover class = all other classes, distance to water courses > 70 m, 600 m < distance to existing facilities < 1000 m | land cover class = 'landscaping', 10 m < distance to water courses < 70 m, distance to existing facilities > 1000 m | land cover class = 'hospital' OR 'housing' OR 'other building' OR 'teaching facilities' OR 'roads' OR 'canal' OR 'forest' OR 'pond', distance to water courses < 10 m |

| Transportation | | | | TRANS |
|---|---|---|---|---|
| System 2 | | | Contact / Expert Name | |
| Description of Evaluation: Includes highways, major roads, connecting streets and pedestrian walks. The only criteria for suitable areas to build new roads is distance from existing roads. By this, remote areas that have the highest need for new roads are defined as feasible. However it has to be mentioned that in order to connect existing roads all other classes including non appropriate have to be considered for the construction of new roads. Criteria: Distance from road centerline, land cover. | | | | |
| Feasable | Suitable | Capable | Not Appropriate | Existing |
| land cover class = all other classes, distance from road centerline > 200 m | land cover class = all other classes, distance from road centerline > 100 m | land cover class = all other classes, distance from road centerline > 100 m | land cover class = 'landscaping', distance from road centerline > 40 m | land cover class = 'hospital' OR 'housing' OR 'other building' OR 'teaching facilities' OR 'roads' OR 'canal' OR 'forest' OR 'pond', existing roads. |

| Housing (middle density, 5 floors) | | | | HOUSE |
|---|---|---|---|---|
| System 3 | | | Contact / Expert Name | |
| Description of Evaluation: Geology map is evaluated against durability in case severe earthquake. Criteria: land cover, distance to water courses, slope | | | | |
| Feasable | Suitable | Capable | Not Appropriate | Existing |
| land cover class = all other classes, distance to water courses > 20 m, distance to highway > 200 m | land cover class = all other classes, distance to water courses > 20 m, distance to highway > 200 m | land cover class = all other classes, distance to water courses > 20 m, distance to highway < 200 m | land cover class = 'landscaping', 10 m < distance to water courses < 20 m, distance to highway < 200 m | land cover class = 'hospital' OR 'housing' OR 'other building' OR 'teaching facilities' OR 'roads' OR 'canal' OR 'forest' OR 'pond', distance to water courses < 10 m |

| Villa (low density, 1-2 floors) | | | | VILLA |
|---|---|---|---|---|
| System 4 | | | Contact / Expert Name | |
| Description of Evaluation: Criteria: land cover class, distance to water courses, distance to highway | | | | |
| Feasable | Suitable | Capable | Not Appropriate | Existing |
| land cover class = all other classes, distance to water courses > 20 m, distance to highway > 500 m | land cover class = all other classes, distance to water courses > 20 m, distance to highway > 500 m | land cover class = all other classes, distance to water courses > 20 m, 200 m < distance to highway < 500 m | land cover class = 'landscaping', 10 m < distance to water courses < 20 m, distance to highway < 200 m | land cover class = 'hospital' OR 'housing' OR 'other building' OR 'teaching facilities' OR 'roads' OR 'canal' OR 'forest' OR 'pond', distance to water courses < 10 m |

| Agriculture / Food Production | | | | AGRI |
|---|---|---|---|---|
| System 5 | | | Contact / Expert Name | |
| Description of Evaluation: Suitability for agriculture and food production has ben determined by evaluating different soil capability classes. Low number means very high capability, high numbers indicate low capability. | | | | |
| Feasable | Suitable | Capable | Not Appropriate | Existing |
| land cover class = all other classes, soil capability class II, distance to highway is > 200 m | land cover class =all other classes, soil capability class III or IV, distance to highway is > 200 m | land cover class = all other classes, soil capability class VI, distance to highway is > 200 m | land cover class = all other classes, soil capability class > higher VI, distance to highway is < 200 m | land cover class = 'roads' OR 'canal' OR 'teaching facilities' OR 'other building' OR 'housing' OR 'hospital' OR 'pond' OR 'garden' OR 'old olive' OR 'pomegranate' OR 'vineyard' OR 'reforestation area' OR 'forest' OR 'wasteland' OR 'landscaping' OR 'new almond' OR 'new olive' OR 'new pistachio' |

| Greenhouses | | | | GREEN |
|---|---|---|---|---|
| System 6 | | | Contact / Expert Name | |
| Description of Evaluation: Criteria: Land cover, distance to water courses, slope SLOPE NOT IMPORTANT | | | | |
| Feasable | Suitable | Capable | Not Appropriate | Existing |
| land cover class = all other classes, distance to water courses > 20 m | land cover class = all other classes, distance to water courses > 20 m | land cover class = all other classes, distance to water courses > 20 m | land cover class = 'landscaping', 10 m < distance to water courses < 20 m | land cover class = 'hospital' OR 'housing' OR 'other building' OR 'teaching facilities' OR 'roads' OR 'canal' OR 'forest' OR 'pond', distance to water courses < 10 m |

| Small Food Processing Facilities | | | | FOOD |
|---|---|---|---|---|
| System 7 | | | Contact / Expert Name | |
| Description of Evaluation: Small organic aromatic plants and sun drying facilities. Criteria: Land cover, distance to water courses, distance to main roads and highway | | | | |
| Feasable | Suitable | Capable | Not Appropriate | Existing |
| land cover class = all other classes, distance to water courses > 20 m, distance to main road and highway > 1 km | land cover class = all other classes, distance to water courses > 20 m, distance to main road and highway < 1 km | land cover class = all other classes, distance to water courses > 20 m, distance to main road and highway < 750 m | land cover class = 'landscaping' classes, distance to water courses < 20 m, distance to main road and highway < 600 m | land cover class = 'hospital' OR 'housing' OR 'other building' OR 'teaching facilities' OR 'roads' OR 'canal' OR 'forest' OR 'pond', distance to water courses < 10 m |

| Forest and Protected Areas | | | | FOREST |
|---|---|---|---|---|
| System 8 | | | Contact / Expert Name | |
| Description of Evaluation: Forest are only used for protection and recreation purposes, not for economic purposes. Criteria: Land cover class, conservation sites | | | | |
| Feasable | Suitable | Capable | Not Appropriate | Existing |
| land cover class = 'land' OR 'steppe', conservation type = none | land cover class = 'new almond' OR 'new olive' OR 'new pistachio' OR 'pomegranate', conservation type = none | land cover class = 'old almond' OR 'old olive' OR 'vineyard', conservation type = none | land cover class = 'garden' OR 'quarry' OR 'reforestation area' OR 'wasteland' OR 'landscaping', conservation type = none | land cover class = 'hospital' OR 'housing' OR 'other building' OR 'teaching facilities' OR 'roads' OR 'canal' OR 'forest' OR 'pond', conservation type = 'archeologic' OR 'flora' OR 'geologic' |

| Recreation Areas | | | | RECRE |
|---|---|---|---|---|
| System 9 | | | Contact / Expert Name | |
| Description of Evaluation: Criteria: Land cover, distance to water courses, distance to conservation sites | | | | |
| Feasable | Suitable | Capable | Not Appropriate | Existing |
| land cover class = 'forest' OR 'landscaping' OR 'pond', distance to water courses < 12 m, distance to conservation sites < 100 m and conservation sites | land cover class = 'quarry' OR 'reforestation area', 100 m < distance to conservation sites < 200 m | land cover class = all other classes, distance to conservation sites > 200 m | land cover class = 'road', distance to conservation sites < 200 m | land cover class = 'hospital' OR 'housing' OR 'other building' OR 'teaching facilities' OR 'canal', distance to conservation sites > 200 m |

| Solar Energy Plant | | | | SOLAR |
|---|---|---|---|---|
| System 10 | | | Contact / Expert Name | |
| Description of Evaluation: Criteria: Land cover, distance to water courses, distance to existing hospital | | | | |
| Feasable | Suitable | Capable | Not Appropriate | Existing |
| slope = between: 3 % - 15 %, Aspect = South, Southeast, Southwest | slope = between: 15 % - 35 %, Aspect = South, Southeast, Southwest | slope = between: 25 % - 35 %, Aspect = South, Southeast, Southwest | slope = between: 0 % - 3 %, Aspect = South, Southeast, Southwest | land cover class = 'hospital' OR 'housing' OR 'other building' OR 'teaching facilities' OR 'roads' OR 'canal' OR 'forest' OR 'pond', slope = higher than 35 %, Aspect = North, Northeast, Northwest, East and West |

**Figure 3.** Final evaluation models

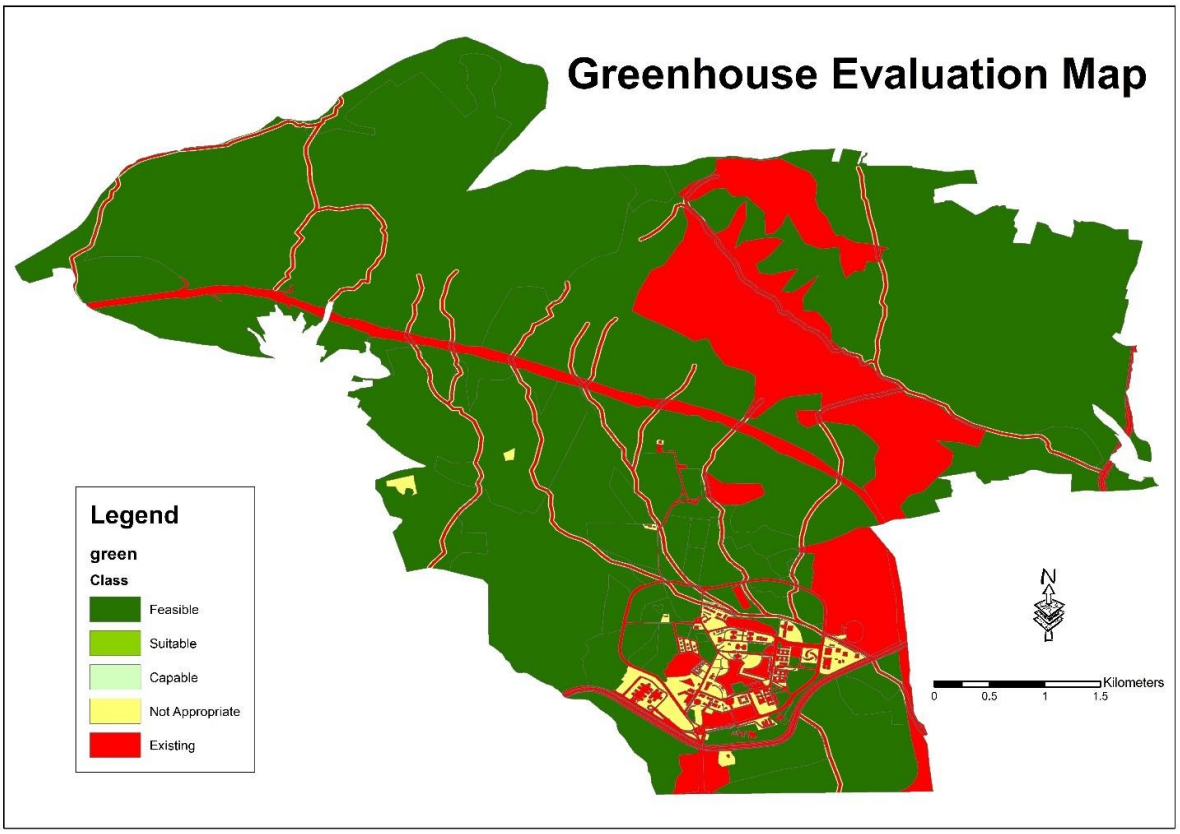


**Figure 4.** Evaluation map for system "Greenhouses"

Both, the natural environment and the build-up and man-made environment are very dynamic systems. They consist of different subsystems and all of them are linked with each other meaning a change in any of these systems will have an impact on all other systems to a higher or lower degree. Therefore, in addition to these evaluation models "cross system impact models" are created. This creation is based on the existing evaluation models and they subjective evaluation of subject-matter-experts.

***Anticipated development of student numbers***

The heart of a university is made of its students and professors. Any campus master plan that is not based on a sound needs analysis will just remain a nice map with beautiful symbols without any relevance. In the case of HU, collection of the required data for a need analysis was not as straightforward as anticipated. In order to come up with a meaningful master plan, data concerning the number of students and academic staff and the currently available space for both kind of campus users were required at least on the level of faculties. Because the faculties collect data on their own, standards differed widely and required a process of making them comparable (Figure 5).

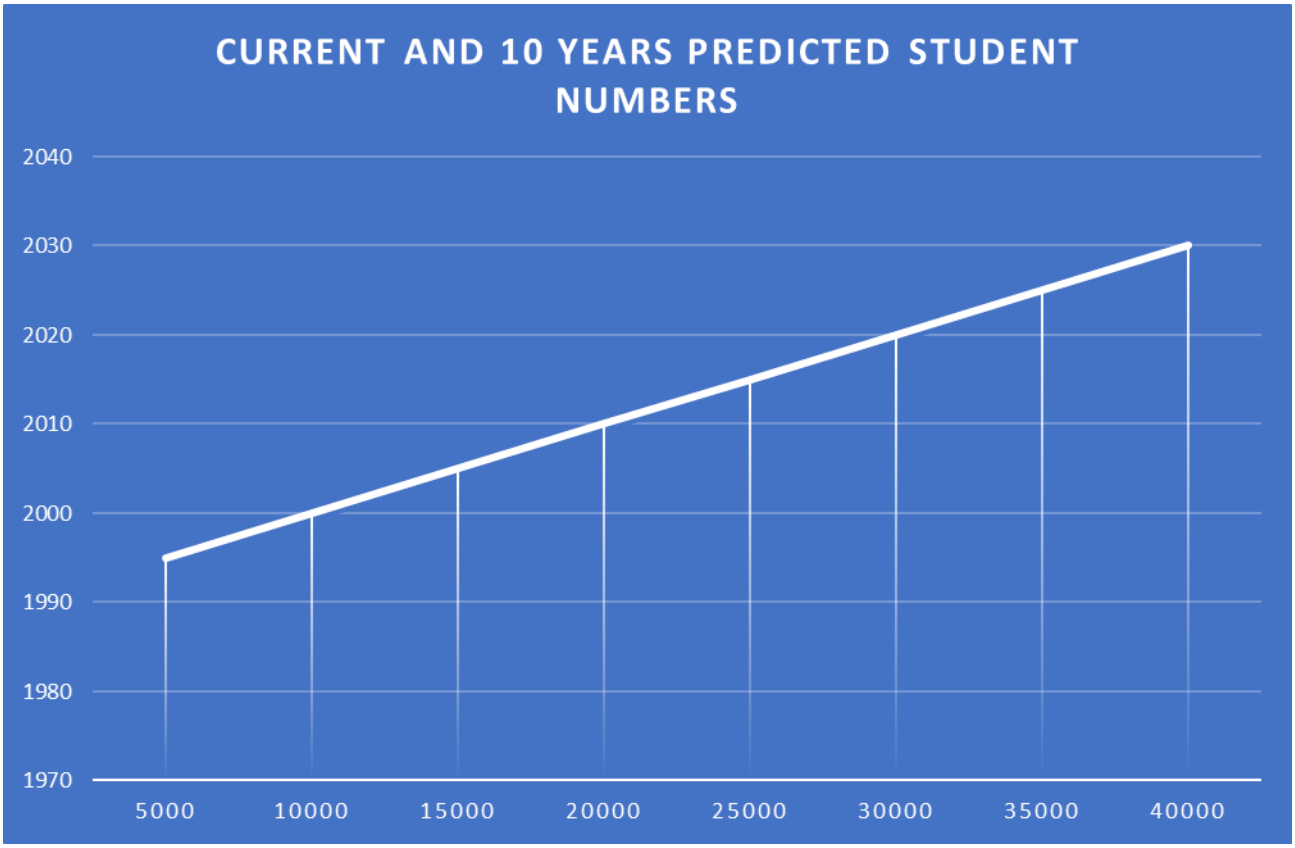


**Figure 5.** Anticipated students numbers for Faculty of Engineering

Using these data, an evaluation of the current status had to be done. For this, three different standards (American, British and EU) were used. Following these three standards, three different evaluations concerning needs based on the current numbers for students and academic staff were carried out.
Based on these three evaluations, 3 different scenarios for the future development spanning a period of 5 and 10 years were created. As the statistical analysis of historic data revealed non-linear increase of students and academic staff during the last 25 years, the computation of a shorter period of only the last 13 years led to more reasonable results. Still, due to the nature of the highly volatile status of the higher education system our findings might require major corrections in the future.

***Change and Impact Models***

The next steps according to the Geodesign framework of Steinitz are the elaboration of change models and impact models. Both models are discussed together because it is one of the outstanding characteristics of Geodesign that someone can get an immediate feedback on results of any changes to one of the systems used in a project are likely to be.
Change models were created based on three different input data: 1) Information on expected or desirable development of the campus that had already be collected by the core project team. For example, since years efforts have been spent to explore the potential of geothermal resources already used in the neighborhood of Osmanbey Campus. It is very likely that such resources can exploited in the near future and thus, allowing for new development of greenhouse projects and thermal therapy facilities of the existing university hospital. 2) Information included in an older master plan that has already become obsolete due to a missing sound data base. 3) Data created during a Geodesign workshop, which is explained in more detail below.

***Workshop***

Theoretically, as the used Geodesign Hub software is a web-based solution that supports the concurrent participation of many users a project could be carried out without a physical gathering of

participants. Nevertheless, it has become good practice to organize workshops after the project has advanced to a point when evaluation models have been created. This is due to the nature of decision processes especially concerning major development projects. Decision-makers and heads of technical departments usually lack the required skills to use spatial decision support systems. The graphical user interface of Geodesign Hub might seem relatively simple for a professional GIS user whereas a decision-maker would see this very differently.

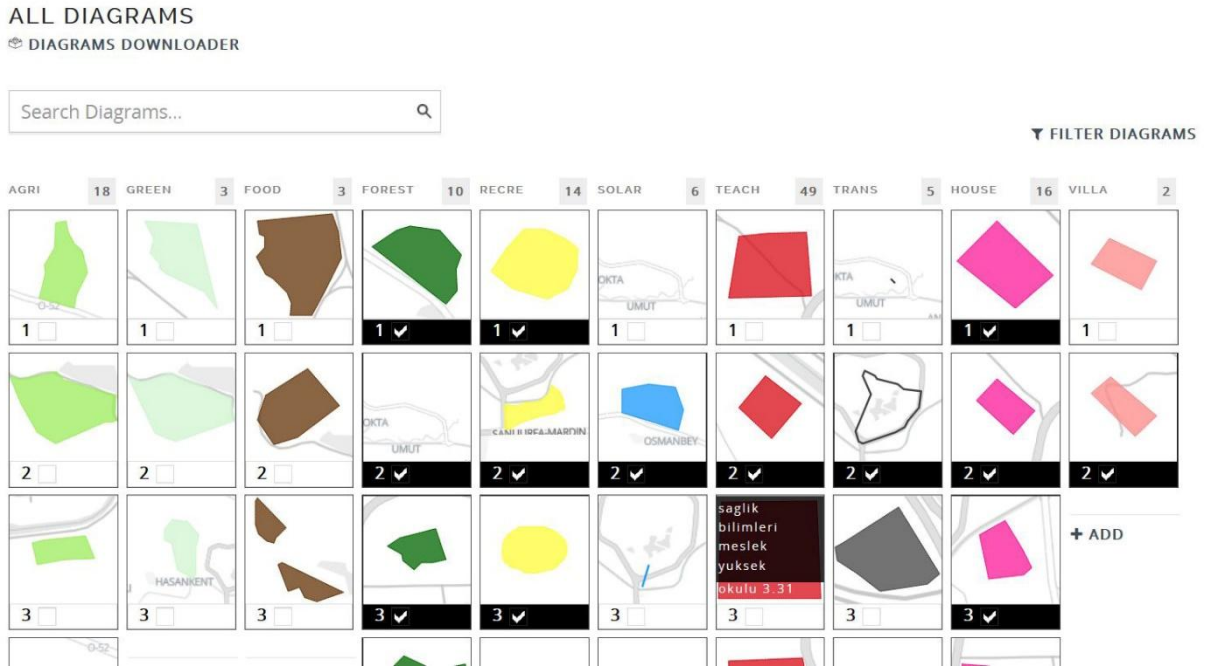


**Figure 6.** GUI of Geodesign Hub

The overall purpose of workshops was to bring together groups having different attitudes towards projects due to their different professions, interests and political orientation representing all important stakeholders in the area of interest. Following an iterative process, they had to come up with one or several optimized design for a new master plan. For this project, four groups were formed: an environmentalist, a developer, an educational, and an agricultural group. The groups were made up of decision-makers (deans of four faculties and several heads of administrative departments) and teaching staff.

During this workshop the following workflow was conducted:

Introductory presentation: As most of the participants had very limited or even no knowledge of spatial based technologies and the concept of Geodesign a short presentation of this subject was given. This included a summary of the most important features of Geodesign Hub.

Presentation of evaluation models and maps: Although quite some time had already spent of the optimization, the gathering of so many matter-subject-experts was a great opportunity to receive comments for further improvements. Works on it started after this workshop.

Creating of change diagrams: Diagrams are simple sketches of anticipated or intended changes to one of the 10 systems. Usually, they consist of bigger development projects like a new faculity building or an addition to the existing hospital. These diagrams were created directly digitizing with a mouse using the GUI of Geodesign Hub. Due to the limited time of the workshop (about 3 hours) some projects had been created beforehand. Thus, for each system an unlimited amount of change diagrams could be created. As a general rule, projects for a new system should be placed at locations having the highest suitability degree. They should address the results of the needs analysis. However, the participants were free to choose less suitable location if they felt a special need for it. A short excerpt is shown in Figure 6 above. Change diagrams were created by all groups concurrently.

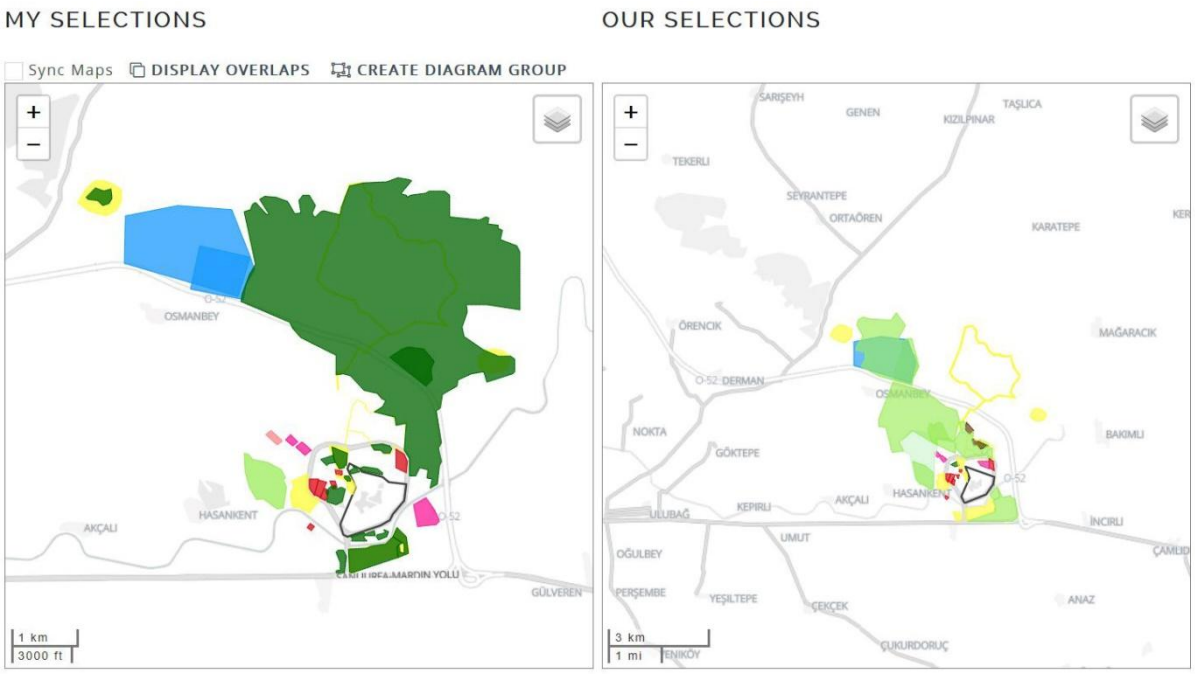


**Figure 7.** Excerpt of change diagrams created during the workshop.

Creating of impact models: By selecting the most suitable change diagrams each group generated one or more designs for a new master plan. During this process every group had access to all diagrams created by the different groups. This first selection process was characterized by mostly personal preferences. During the impact analysis, the percentage of projects for the 10 systems in relation to the total development area is computed. In addition, the impact analysis considers the impact that the change in one system has on all other systems classified into 5 categories: best, good, neutral, bad worst. This impact is shown as a graphic for all systems and an overall score is computed (Figure 7 and 8). Because many people are not very comfortable with 2d maps we offered the option to show the created projects in 3d embedded in a 3D model of the Osmanbey Campus using ESRI's CityEngine (Figure 9).

Refining change models: Using the impact summary for each system, projects that cause a more negative score can be addressed. By moving them to more appropriate locations as indicated on the evaluation maps the overall scoring can be improved. This circle of changing, reevaluation, and refining was repeated several times until each group came up with designs that satisfied them.

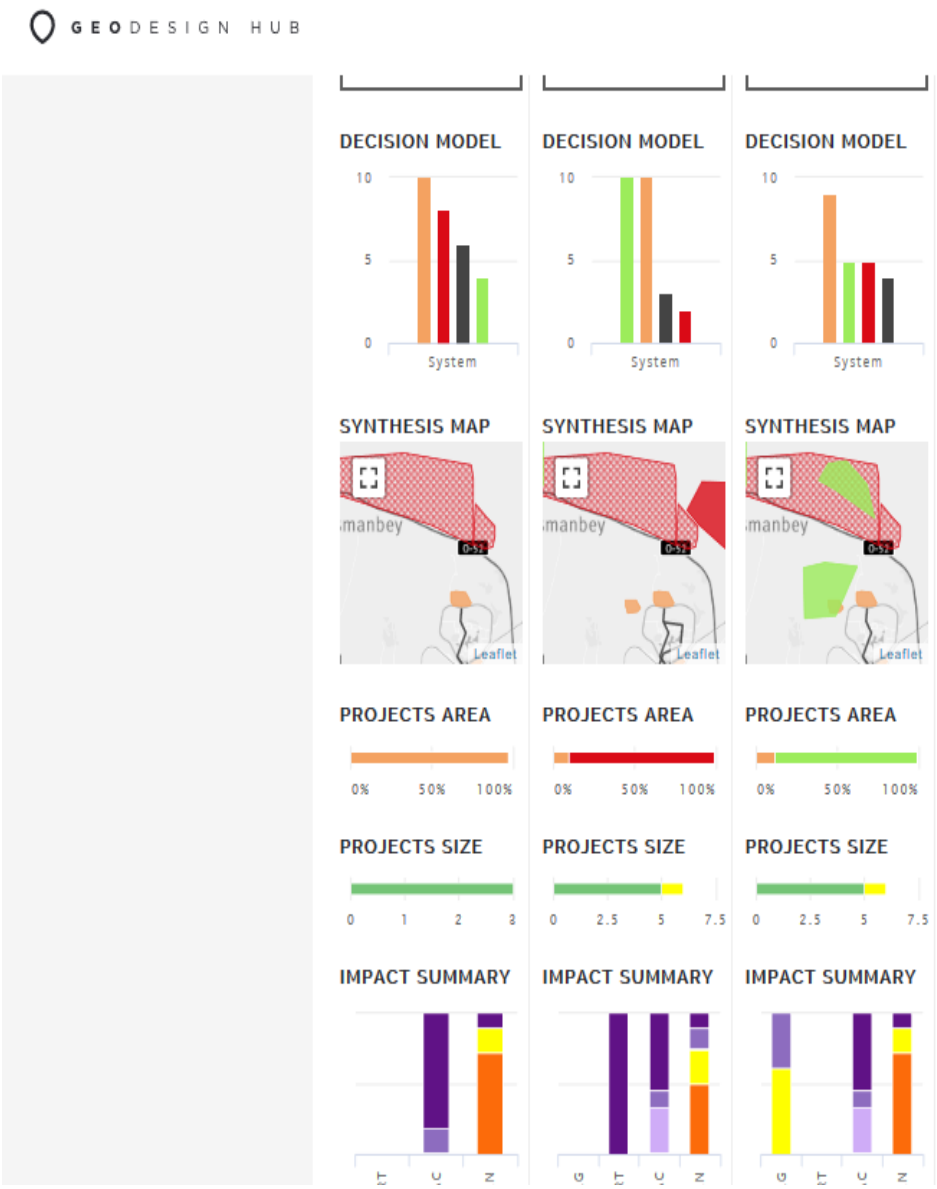


**Figure 8.** Overall score of impacts in Geodesign Hub

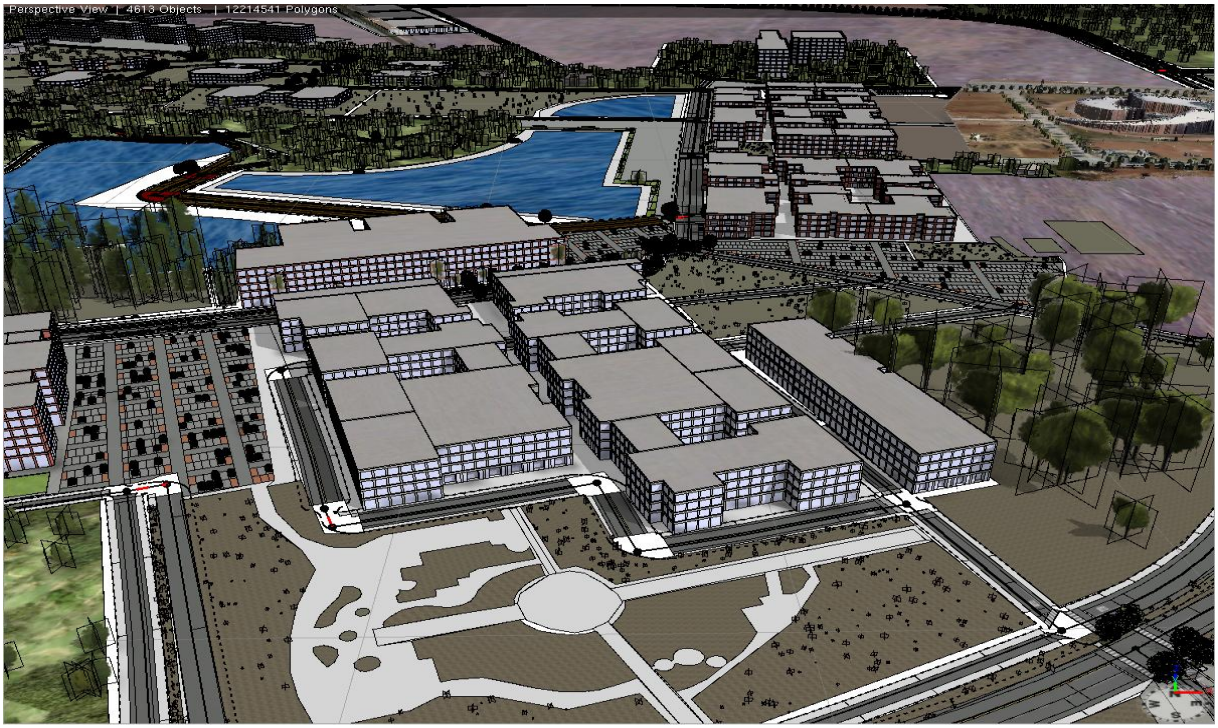


**Figure 9.** One proposed project in 3d embedded in a 3D model of the Osmanbey Campus

The last step according the Geodesign framework by Steinitz, creation of decision models, in which it is tried to find a consensus between the different interest groups and their developed designs, was not part of this workshop. It will be dealt with during the next workshop.

## RESULT AND DISCUSSION

A new master plan for the Osmanbey Campus of HU following the Geodesign concept is underway. During the first two steps according to the Geodesign framework data and process models were created describing the current status of the natural and built-up environment in a very accurate way for the first time. This model served as an input for the creation of evaluation models based on the judgement of matter-subject-experts. Using the online tool Geodesign Hub, objective models based on scientific methodes could be combined with subjective evaluation models in a transparent way.

The most important step in a creating a new master plan was the establishment of change and impact models addressing the findings of the needs assessment that was conducted as part of this project. By means of a workshop the most important stakeholders were brought together to develop their own designs in an iterative way using the intuitive tools offered by Geodesign Hub.

## CONCLUSION

Development of master plans, especially for university campuses, has much progressed towards the goals of sustainability in Turkey during the recent years. Still, the effective involvement of all stakeholders during an early stage of planning is missing causing an insufficient acceptance and low degree of implementation. Using the Geodesign approach for the development of a new master plan for the Osmanbey Campus of HU, the domains of scientific based fact finding and value based decision making could brought together. Instead of emotion loaded lengthy discussion as they prevail during hearings on major development projects, all stakeholder were enabled to create their own design following a well-documented transparent process that could be repeated by others. Thus, the best projects of other could be combined to achieve a more enhanced design of a new potential master plan.

The most striking feature of the used tool, Geodesign Hub, was that the participants of a workshop, in which new potential designs for a new master plan were created, could see the impacts of the

individual projects that made up their designs immediately. By this, the time period usually required for reviewing and enhancing a master plan could be reduced from months to hours.
By definition, a master plan consists of two-dimensional maps and explaining reports. Because it is much easier for human beings to envisage a future scenario of their environment in 3D mode the option of displaying new project in 3D was much appreciated by the participants of the workshop.
Although the presented approach to master planning offers a lot of advantages compared to classical approaches there is much room left for improvements. Especially, two subjects should receive more attention in the future: 1) The conversion of evaluation models into evaluation maps is very cumbersome and time consuming. To speed up this process works on an interface that could automate this process have already started at the Department of Geomatics Engineering. 2) The display of projects in 3D has been done manually requiring the presence of a CityEngine professional. Using the existing API of Geodesign Hub the development of a user-friendly interface is desirable.

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**Review Article**

# A review on Urbanization, Pollution and Biodiversity in İzmir

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**Abstract**

Izmir is a town with rich habitats in biodiversity as urbanization is rapidly increasing. In this study, the studies on ecology of Izmir have been compiled and important natural areas are mentioned. Urbanization and pollution have also been noted.

The purpose of this study is; the bringing together of scientific data on urbanization, pollution and ecology of Izmir and the constituting a basis for evaluating the factors that threaten the ecological situation and environmental health which are not taken into consideration in the projects planned or the projects to be carried out.



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## INTRODUCTION

Although urbanization is an increase in the number of cities and population, it is a process that changes the attitudes and behaviors and social structure of people emerging with some technological, economic, social and political phenomena. As cities include different ethnic groups, cultures, social strata and occupational groups, the relations at individual and group levels differ in cities. The resulting individualization is the source of intergenerational conflict arising from value differences. In the context of urbanization in Turkey, while Izmir, Ankara and Istanbul are metropolitanizing, medium-sized cities have also migration [1]. Cities have an urgent need for green spaces because the exponential growth of the population in third-world countries that have no green spaces in their cities can lead to physical, social, physiological, psychological and environmental hazards. In recent years, the Ministry of Forestry has established forests in cities. In addition, existing forests are divided into infrastructure, industry, firewood, recreation areas such as mining, education campuses, waste storage, growing cities, tourism, electricity and transportation provider [2].

The Environmental Protection Agency (EPA) defines pollutants as "priority pollutants", which may be waterborne, organic or inorganic. Priority pollutants are selected based on mutagenic, embryo development disrupting or acute poison effects [3]. An increase in the incidence of psychotic disorders and other health problems can be observed with environmental pollution [4]. Mining activities, agriculture, waste storage, industrial and urban wastewater, natural geogenic oscillations are mainly responsible for global pollution of waters [5].

The world is not an unlimited area for human activities, ecosystems must be known and protected to prevent environmental problems. The measures taken for the protection of wildlife are more efficient and more economical than the correction process after environmental problems [6]. Humanity and wildlife problems are caused by the negative impact of human behavior on the wildlife and habitats, the negative impact of wildlife on some stakeholders, some people's wildlife-oriented behaviors causing negative interactions with other people and also often conflicts of worth. Therefore, humanity - wildlife problem contains human - wildlife interaction, human - human interaction or both. [7].

Today, Izmir is a popular city because of being a tourism center, migration of people from Anatolia to the coastal areas, preference of people a quieter life against the complex life of Istanbul, searching new areas for construction sector and advertisements by various mass media such as social media, television and radio. In this study, the biodiversity of Izmir (including microbiota, fauna and flora), urbanization and environmental pollution are reviewed for creating a general perspective in a holistic approach.

## GEOGRAPHICAL STATUS OF IZMIR

The city of Izmir was founded at the end of the bay that took its name from it, and it has developed since ancient times and has become the most important settlement of the Aegean Region. Originally settled on the eastern edge of the bay, the city later expanded to the alluvial plain between the Kadifekale Foothills and the Meles Delta. The port city (Pales Smyrna) was abandoned when the alluvial layer was formed. Thanks to its large water resources, the city has rich agricultural lands and it is estimated that the population is rapidly rising. In the 4th century BC, a castle was built by Alexander the Great on the Pagos Mountain (Kadifekale). By the protection of the fortress, trade developed and new settlement areas were opened towards the mountain [8].

The end of Izmir Bay are connected to the Gediz, Küçük Menderes and Büyük Menderes valley channels with roads of created by nature. This geographic location creates a large ard zone. The city is surrounded by mountains overlooking the bay. Manisa Mountain in the northeast, Mount Yamanlar in the north, Mount Nif in the east, Kizildag in the south, and Karaburun Peninsula in the west, which limits the first region of Izmir Bay. Between these mountains, Belkahve pass (260 m.), Sabuncubeli (700 m.) which is on the Sipil Mountain, the Menemen (Emiralem) strait which the

railway passes through, such as the low passes connects the city around to the surroundings. In addition, a low passage of 130 m. follows the valley of Meles and connects to Cumaovası and Torbalı plain [8].

The boundaries of the province of Izmir are between 37° 45' and 39°15′ N latitudes and 26° 15′ and 28° 20′ E longitudes. The length of the province in the north-south direction is approximately 200 km and the width in the east-west direction is 180 km. Its surface area is 12.012 km2 [9].

The city of Izmir, is located in the west of Turkey and is the third largest metropolitan city of the country. The city is under the risk of natural disasters as earthquake, flood, landslide and rock falls. Due to the tectonic regime in Western Anatolia, there are many fault lines in the immediate vicinity that threaten the city. There is a fault line known as Izmir fault along the metropolitan area [10].

**URBANIZATION**

Traffic problems occur with increasing urbanization and population in Izmir. As a solution to the traffic problem, solutions such as the development of pedestrian and bicycle paths, the development and expansion of alternative roads, the increase of vehicle parks, the development of public transportation, the establishment of different centers in the city, the arrangement of roads according to the new houses, the creation of intelligent traffic systems are presented [11]. While these suggestions were made, the city of Barcelona was taken as an example but the differences between Izmir and Barcelona were not taken into consideration. Barcelona has its own political and geographical conditions. Main road systems which have an important place in road transportation depend on geographical conditions, natural boundaries, population density and topological effects [12]. The related article does not mention the differences caused by these effects.

By the Metropolitan Law No. 6360, the villages became a neighborhood of the city. Service access became more difficult with centralization. There is a need for developments that protect the traditional texture and life of rural areas, preserving the nature and socio-cultural characteristics of rural areas, improving the working and living areas of rural people and preserving the architectural textures [13]. Risks in urbanization are increased vehicles and motorways in short term, loss of property owners, loss of green areas, loss of agricultural areas, negative impact of bay, fishery and wetlands, an area open to disasters, increase in density, loss of rural gardens and picnic areas. Besides that long term the risks are air pollution from traffic and problems, gentrification, soil pollution - so the formation of urban heat island, environmental issues, rather than local food imported food consumption, degradation of land and marine ecosystems, increasing contamination of air - land - surface and underground water resources, a depressed society that is closed to the inside [14]. While accessibility is increased by the construction of new roads in the cities, the housing prices are increasing, however, there are negative effects such as traffic density and noise pollution [15].

Urban transformation refers to the strategies and actions developed by the integrated approach with a comprehensive consideration of the economic, social, physical and environmental conditions of the urban space that has been degraded. Unhealthy built-up areas, squatter areas, collapse zones caused by disasters and wars, settlements with risk of natural disaster, business areas that lose economic vitality, urban structures and areas that need protection are the areas of application of urban transformation projects. The reason of urban transformation in Izmir is that it is a region that can be exposed to a disaster or it is the cleaning of the unhealthy living areas [16].

While urbanization and population plans are made in Izmir, the carrying capacity of water resources is not taken into consideration [17]. Nevertheless, Izmir is rapidly becoming a metropolitan and losing its natural characteristics. For example, in the town of Çiğli, which hosts the Gediz Delta, the coastal areas have been destroyed due to the building, agriculture and forestation that were created against the ecosystem and began to lose their natural characteristics [18]. When the 1980 and 2010 maps of Gediz Delta were compared, coastal wetlands were exposed to significant pressures and threats [19]. The importance of wetlands for a sustainable urban life should be understood and any irreversible mistakes should be avoided.

**POLLUTION**

Dust and sulfur dioxide which cause air pollution in Izmir are among the causes of asthma [20]. It has been revealed that the pollutant sources located outside the Izmir metropolitan area have significant risks for urban air quality. The results show that industry, which is the most pollutant sector, contribute to total $SO_2$, Particulate matter (PM), $NO_x$ and CO emissions of 91%, 41%, 90% and 70%, respectively [21]. Izmir Bay contains high concentrations of nutrients throughout the year. Densities in the inner and middle parts of the bay are more than the Aegean Sea exterior. A negative trend was observed in the outer parts of the bay for phosphorus and nitrate, whereas for the nitrate there was a negative trend in the middle and inner parts of the bay. The ciliates found in different parts of the Izmir Bay showed a positive trend. Contamination outside the bay is important, but there is a high eutrophication inside the interior and may extend to the outside. The wastewater treatment plant established at the beginning of the 2000s is sufficient to purify nitrogen while it is insufficient to purify the phosphate. The amount of nutrients on the surface is relatively high at the mouth of the Gediz River. The heavy metal concentration in Izmir Bay is higher than the Aegean Sea and the Mediterranean Sea. The Gediz River is the main anthropogenic source polluting the Izmir Bay due to poorly treated wastes. Petroleum hydrocarbon wastes, which are the other anthropogenic pollution source, are located in the bay due to sea traffic and industrial activities. The average amount of Hg and Cd in fish Aegean Sea and the Mediterranean are more likely than not to let the dirty parts. Mussels and fish in the Bay of Izmir may be the biological indicator of polycyclic aromatic hydrocarbons and heavy metals. The most common trace metals Hg, Cd, Pb, Cr, Cu and Zn are the leading organic pollutant chlorinated organic pesticides and petroleum hydrocarbons. The burden of accumulated impurities from the environment for 50-60 years in the Bay of Izmir has disturbed the ecosystem quality of Izmir Bay [22].

Chlorinated organic pesticides and polychlorinated biphenyls are persistent organic compounds that disrupt the health of humans and ecosystems by causing environmental pollution. The chlorinated organic pesticide in the sample of 18 sediments taken along the Izmir Bay ranged from 0.12 ng/g to 11.35 ng/g, while polychlorinated biphenyls ranged from 0.22 ng/g to 43.53 ng/g. The highest total amount of chlorinated organic pesticides was found inside the bay and in the mouth of the Gediz River and the total polychlorine biphenyl was found in the bay [23].

According to the Gediz Basin Pollution Prevention Action Plan of the Turkish Republic Ministry of Environment and Urbanization General Directorate of Environmental Management, by the regulation on Surface Water Quality Management in accordance with the quality criteria and classes, Gediz Basin Water Quality is II. class according to general conditions, IV. class according to oxygen parameters, IV. class according to nutrient parameters, III. class according to trace elements, II. class according to bacteriological parameters. This action plan by the ministry in the short, medium and long-term measures to be taken have been identified [24].

**ECOLOGY AND BIODIVERSITY**

A microbial ecosystem includes cyanobacteria, green algae, diatoms, ciliates, bacteria, archaea and viruses in salt marches [25]. The strains belonging to the families of Gammoproteabacteria, Firmucutes, Actinobacteria and Halomonadaceae, Vibrionaceae, Bacillaceae, Micrococcaceae, Enterobacteriaceae were isolated from the salts in Gediz Delta which contain Çamaltı Salt Marsh [26]. The Gediz Delta and the Izmir Bay create a suitable environment for the accumulation and attachment of Dinoflagellate cysts. 36 Dinoflagellate species were identified including *Dubridunum caperatum*, *Gymnodinium cf. nolleri*, *Lingulodinium machaerophorum*, *Polykrikos kofoidii*, *Quinquecuspis concreta*. Potential toxic cysts types observed as *Alexandrium* genus. They should be monitored for commercial fishing and public health. The sediments of the bay of Izmir are rich in Dinoflagellate cyst and are suitable for the investigation of the ecology and biogeography of the cyst-forming Dinoflagellates [27]. *Artemia spp*. which is known as salt marsh shrimp is also important part of ecosystem [28]. 47 ring

worm species have been identified in the study conducted between February 1998 and May 1999, in 16 station which temperatures were between 8 ºC and 31 ºC, dissolved oxygen measurements were between 0 mg/L and 14 mg/L, pH values were between 7 and 9.93, salinities were between % 0,056 and % 3,88 [29]. The algal flora of Çamaltı Saltworks was given in December 2017 as Cyanophyceae, Chlorophyceae, Bacillariophyceae, Phaeophyceae, Rhodophyceae, Monocots and a total of 29 taxa were determined [30].

In the mid-winter water bird counts of 2015, 64579 individuals were counted under 59 species in Gediz Delta. 6277 individuals were counted under 20 species in Izmir Bay [31]. Reproduction, wintering, population size, distribution and seasonal changes of the coastal birds (plovers) in Gediz delta were examined and 38 different species were observed [32].

In a study which crustacean diversity is researched, 81 species and 2179 individual were identified from Aegean Sea. 29 species and 271 individual were collected from Dikili, 23 species and 268 individuals were collected from Şakran in Aliağa, 26 species and 218 individuals were collected from Foça, 244 individuals and 30 species were collected from Alaçatı [33]. 17 Amphipod species were identified from 9 stations along the Aegean Sea coast of Cesme Peninsula [34].

Myxomycetes are multi-nucleus, organisms that do not have cell walls, which can produce single or multiple sporophores. 16 genus of myxomycetes including *Arcyria* genus were found in around of Kemalpaşa in Izmir [35].

Key biodiversity areas (KBAs) where biodiversity is protected on a global or local scale. Doga Dernegi, which is non-governmental organization for the protection of key biodiversity areas in Turkey takes an active role. Alacati Peninsula, Boz Mountains, Dilek Peninsula, Foca Peninsula, Gediz Delta, Karaburun Peninsula, Nif Mountain, Spil Mountain and Yamanlar Mountain are the KBAs in Izmir. Estimated carrying capacity for *Lynx lynx*, which is known as the Anatolian lynx, is 17 pairs in the Boz Mountains, 1 pairs in the Dilek Peninsula, 2 pairs in the Nif Mountain, 2 pairs in the Spil Mountain. Estimated carrying capacity for *Hyaena hyaena* is 4 pairs in Alaçatı Peninsula, 1 pairs for Foça Peninsula and 3 pairs for Yamanlar Mountain. Estimated carrying capacity for *Felis chaus* is 6 pairs in Gediz Delta. Estimated carrying capacity for *Caracal caracal* is 12 pairs in Karaburun Peninsula [36].

## RESULT AND DISCUSSION

Due to the rapidly growing population, urbanization and pollution caused by humans, Izmir's ecosystem is in danger. Since people are also part of the ecosystem, the negative impacts will affect health of them. For example, changes in the physical parameters of Izmir Bay, such as temperature, pH, decrease of water flow, overgrowth or decrease of some species, can cause chain problems in ecosystem which may affect human health negatively by causing the reproduction of toxins or spreading disease factors. Besides that, pollutant factors may interfere with food, drinking water or air and adversely affect public health.

Unplanned structures which are rapidly constructed in Izmir and distorted urbanization which will be triggered by projects such as the gulf transition project where the effects of the environment are not considered with a holistic approach; threatens nature, the environment and human health. If necessary measures are not taken in the near future, irreversible environmental destruction can be caused.

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**Research Article**

# REGRESSION MODELS BY GRETL AND R STATISTICAL PACKAGES FOR DATA ANALYSIS IN MARINE GEOLOGY

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**Abstract**

Gretl and R statistical libraries enables to perform data analysis using various algorithms, modules and functions. The case study of this research consists in geospatial analysis of the Mariana Trench, a hadal trench located in the Pacific Ocean. Technically, data modelling was performed using multi-functional combined approach of both Gretl and R libraries. The study aim is modelling and visualizing trends in the variations of the trench's properties: bathymetry (depths), geomorphology (steepness gradient), geology, volcanism (igneous rocks). The workflow included following statistical methods computed and visualized by Gretl and R libraries: 1) descriptive statistics; 2) box plots, normality analysis by quantile-quantile (QQ) plots; 3) local weighted polynomial regression model (loess), 4) linear regression by several methods: weighted least squares (WLS) regression, ordinary least squares (OLS) regression, maximal likelihood linear regression and heteroskedasticity regression model; 5) confidence ellipses and marginal intervals for data distribution; 6) robust estimation by Nadaraya–Watson kernel regression fit; 7) correlation analysis and matrix. The results include following conclusions. First, the slope angle gradient has a correlation with the geological settings of the trench and distribution of volcanic igneous rocks. Second, the sediment thickness varies by the tectonic plates showing unequal distribution in space. Third, there is a correlation between the slope gradient and aspect degree. Forth, geospatial analysis of the bathymetry shows that the deepest part of the trench is located in the south-west.

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## INTRODUCTION

Gretl (abbreviation stands for: GNU Regression, Econometrics and Time-series Library) is a functional cross-platform software package for the econometrics and statistical data analysis developed by A. Cottrell and R. Lucchetti, written in the C programming language [1], [2]. Gretl is a part of the a GNU (GNU is Not Unix) project by the Free Software Foundation (FSF) promoting free open source software [3]. Having an intuitive GUI to operate, flexible functionality of the modules and embedded statistical functions, Gretl was chosen in this research as a useful software for statistical data analysis. R, a programming language with a powerful functionality of statistical packages [4], [5] was selected as a comparative instrument to perform advanced plotting (multi-facetted plots and scatterplots with overlaid dots) for complex data analysis and modelling through scripting.

Nowadays, data science and data analysis are important part both in industry and in academic research, because the computerization and increased amounts of information lead to the need of processing large amount of data. Therefore, in both academia and economic domain, proper effective data analysis, methods, approaches and techniques are widely discussed [6], [7], [8], [9]. Data analysis specifically in geosciences as a general Earth science domain, and in geology as its sub-branch, also received attention [10], [11], [12]. As for marine geology, there are some examples of using R [13], [14] and Python [15], [16] libraries for the data modelling and analysis. However, processing data in marine geology is mostly limited by the GIS analysis based on geoinformatics and cartography. Current research highlights the effectiveness of the geospatial data processing by means of pure statistical software, such as Gretl and R, filling the gap between the mathematical approaches in the data analysis and geospatial data processing. Presented study aims at modelling, visualizing and understanding trends in spatial variations of the properties of the ocean trench.

A case study of this research is the Mariana Trench, the deepest place of the Earth located southeast of the island of Guam, west Pacific Ocean, reaching from Japan to Palau as a 2550 km long geometric arc. It is the deepest trench in the world, with a maximum depth of ~11,000 m [17]. Mariana Trench is a geologically unique place formed as a typical example of the tectonic plate spreading in an oceanic subduction system: the Pacific tectonic plate subducts beneath the Philippine Sea plate forming Mariana Trench. Such tectonic activities results in the formation of the active volcanic arc near the Mariana Trench which consists in 9 islands and more than 60 seamounts, around 20 of which are hydrothermally active [18]. The

motion of the tectonic plates naturally affects the geomorphology of the trench. Furthermore, the interaction between the subducting plates and the underlying mantle cause gradual motion of the trench itself. Thus, the seafloor of the Mariana trench represents the site where oceanic lithosphere subducts into the mantle with many factors that influence the rate and direction of the trench migration [19]. The details of the tectonics and tectonophysics properties of the Mariana Trench subduction system are discussed in more details in various research papers (e.g. [20], [21], [22]).

Although until recent, the hadal deep-sea trenches were thought to be an almost biological deserts and understanding of their biology and ecology was very scarce due to the inaccessibility, it is now proved [23] that there are deep-ocean ecosystems even at such great depths as the Challenger Deep, the southernmost part of the Mariana Trench, existing due to the supply of nutrients and energy in form of chemical species. This becomes possible because of the constant ocean motion and waves turbulence upbringing sufficient nutrients for the organisms living in the trench [24]. Nevertheless, Mariana Trench is notable for the low temperature and low productivity comparing to other world trenches, as well as intermediate bottom temperature underlying the lowest surface productivity comparing to other trenches [25]. Being a hadal trench, Mariana Trench has higher hydrostatic pressure and relatively isolated bathymetry, while other geophysical and biogeochemical conditions, such as temperature, salinity, and dissolved oxygen are similar to those in abyssal settings [26].

As for topography of the Mariana Trench, it reflects rather complex geological situation: there are detected changes in strike of the bathymetric shape of the trench axis around 142°20E, being N 85°E to the east and N 80°E to the west of that longitude. The elongated depressions are located along the trench axis, not parallel with the trench axis. Other remarkable topographic feature of the Mariana Trench include a set of the elongated ridges and escarpments, having a shape of a half graben topographically. These geomorphic structures are accompanied by the plate bending on the outer slope, as well as soft and smooth seafloor of the western depression of the Mariana Trench [27].

## 2. MATERIALS AND METHODS

The research aim and specific task of this work is to analyze the correlation trends in several factors affecting the submarine ecosystem of the Mariana Trench: bathymetry (depths), geomorphology (slope steepness gradient), geology (location on four tectonic

plates: Mariana, Caroline, Pacific and Philippine Sea), volcanism in the adjacent area (igneous rocks). The data set consisting of the 25 cross-sectioning profiles with 518 observation samples in each. The workflow included following statistical methods computed and visualized in Gretl and R libraries: 1) descriptive statistics (mean, extremes, median); 2) data distribution by box plots, normality analysis by quantiles (QQ) plots; 3) local weighted polynomial regression (loess), 4) linear regression forecast evaluation by weighted least squares (WLS), ordinary least squares (OLS), limited information maximal likelihood (LML) and heteroskedasticity; 5) visualized confidence ellipses and marginal intervals for data distribution; 6) robust estimation modelling by Nadaraya-Watson fit; 7) correlation analysis: pairwise, triple and matrix plotting for all factors from the data set.

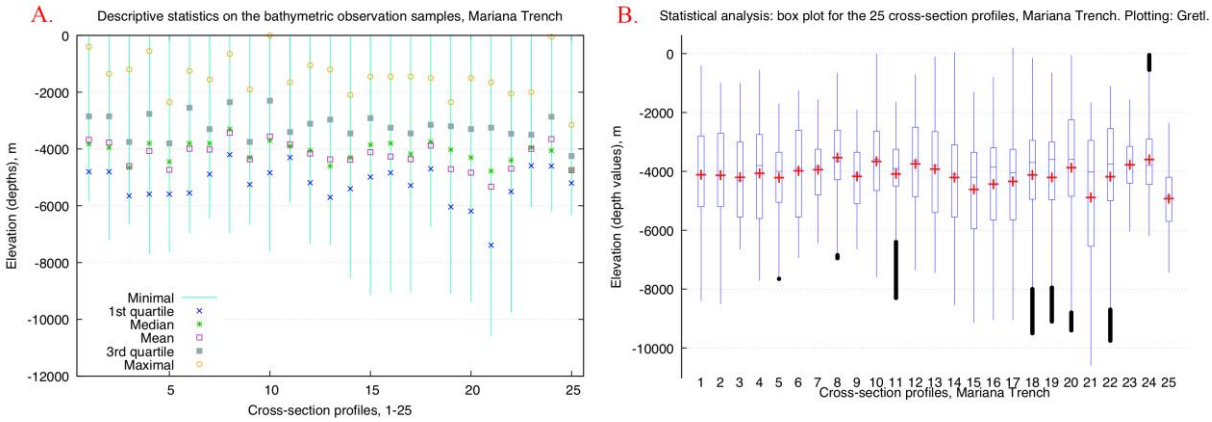


**Figure 1**. Descriptive statistical analysis of the bathymetry in the study area: minimal, mean, median and maximal values (A); box plots of the cross-sectional profiles (B). Plotting: Gretl

The descriptive statistical analysis (Figure 1) was computed by the 'View / Graph specified vars / Boxplots' where the initial data set (25 profiles with 518 observations in each) was imported as a .csv table with structure of the data set chosen as 'Panel' type of the data structure and Panel data organization as 'Stacked cross sections'. The multi-faceted quantiles (QQ) and regression analysis plots (Figure 3 and 4) were performed in R for visualizing the variability of the bathymetric data values (elevation depths) by 25 profiles. The statistical approach followed common existing methods [28], [29]. The quantile-quantile plot (QQ) for the 25 profiles was modeled (Figure 3) by R packages {ggplot} and {qqplotr} by function stat_qq(). The faceting for the 25 profiles combined in one plot was performed using {ggplot2} package of R by function: facet_wrap( ~ profiles, labeller = label_both). The same scales were used for all panels for comparability of the sub-plots (Figure 3).

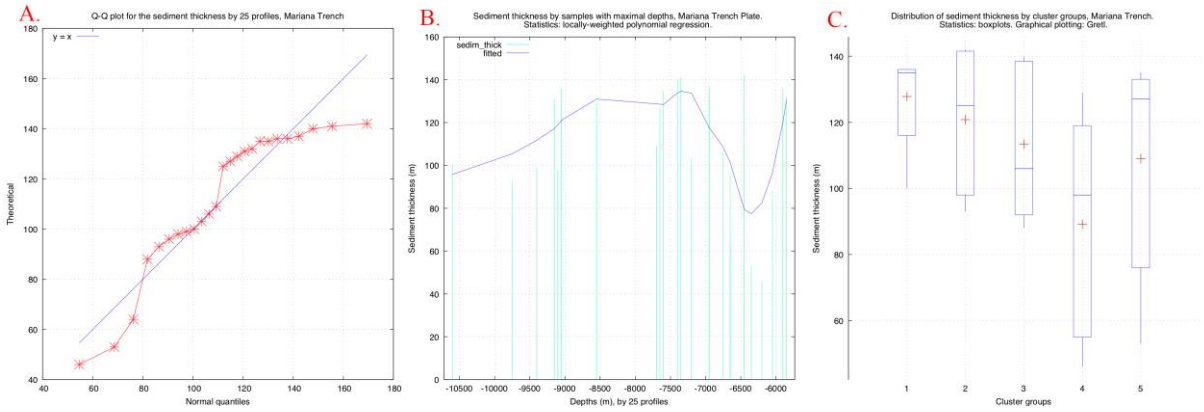


**Figure 2.** Statistical analysis of the sediment thickness: QQ plot (A), locally-weighted polynomial regression (B); box plots ranked by clusters (C).

The regression analysis (Figure 4) was plotted using {ggplot} package of R by the following function: ggplot(MarDF_NEW, aes(x = observ, y = value, shape = "Observation points", color = "Observation points", size = "Observation points"). Statistical lines were added by special calls of geom_point(), geom_quantile() and geom_smooth(). The local polynomial regression was computed by fitting a smooth curve between the two variables by 25 profiles, respectively: depths values by 518 observation samples in each profile (Figure 4).

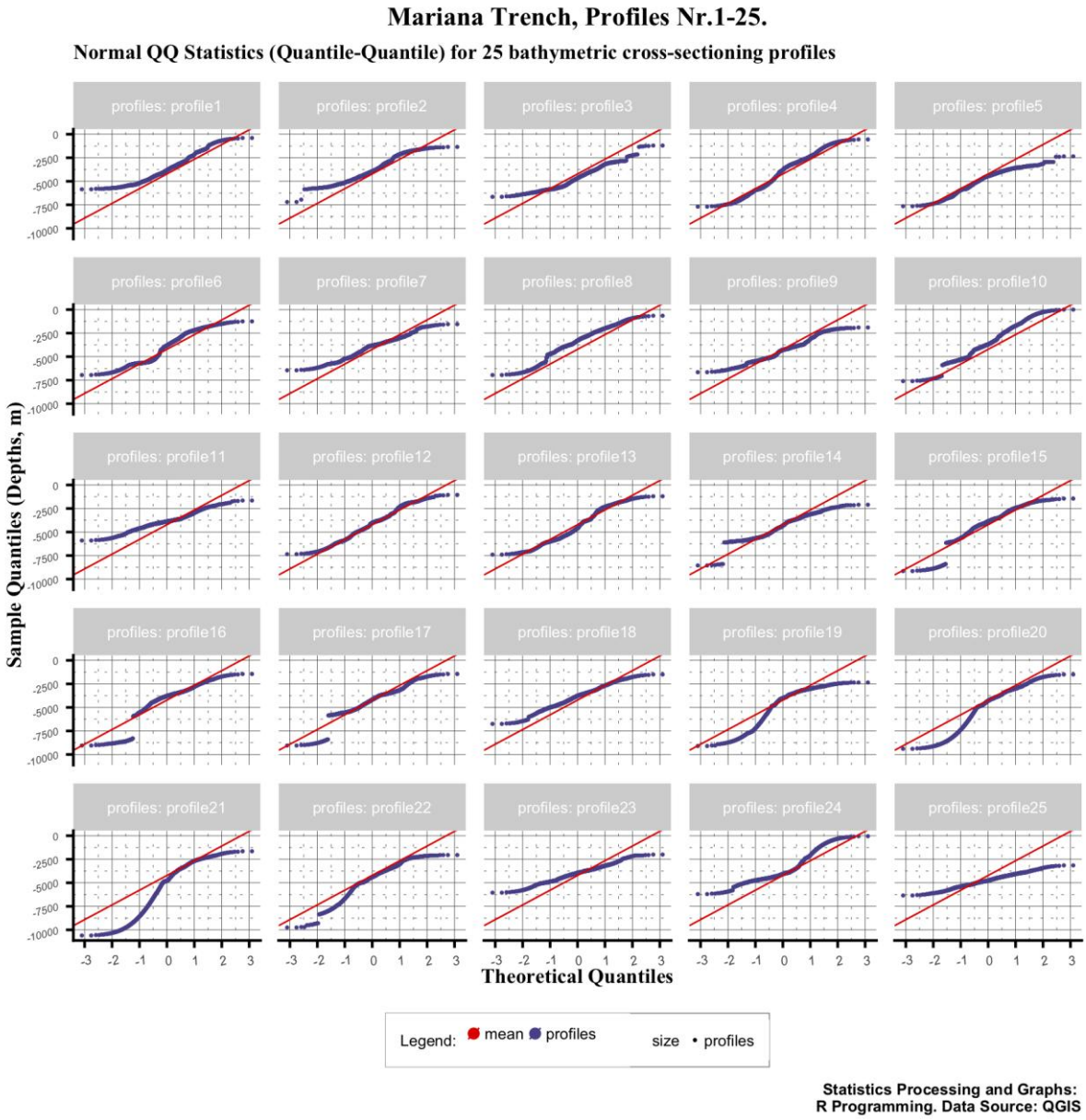


**Figure 3.** Statistical quantile-quantile (QQ) plot for the 25 cross-sectioning profiles

The order of the polynomial in the independent variable and the proportion of the observation samples used in each local regression were specified in bandwidth, defined in R package {ggplot} by the following command: geom_smooth(aes(x = observ, y = value, colour = "Loess method"), method = loess, se = TRUE, span = .4, size=.2, linetype = "solid", show.legend = TRUE), Figure 4.

The

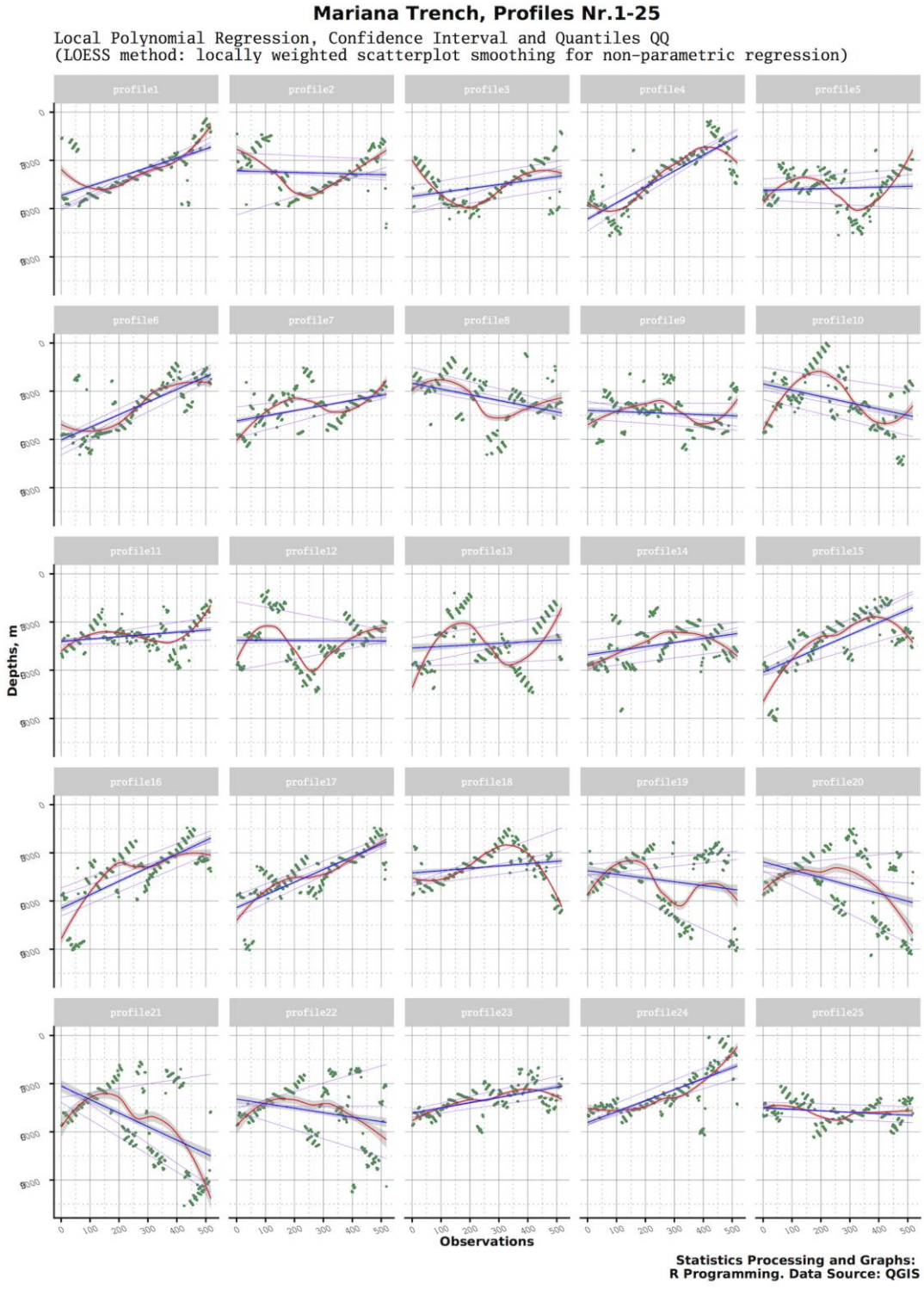


**Figure 4.** Statistical regression analysis for the 25 cross-sectioning profiles

The analysis of inter-dependancies by factors was performed using data set containing multiple variables (25 rows for values on geomorphology, geology, maximal and minimal depths, gradient slope steepness angle in tangent, etc. The table was imported as a .csv into Gretl environment with a 'Cross-sectional' type of the data structure. The method for

Ordinary Least Squares data modelling (Figure 6) followed 'Model / OLS' function in the menu. The dependent variable was selected as sediment thickness and several regressors were chosen for each sub-plot (Figure 6, A-F): tectonic plates (Mariana, Pacific, Philippine Sea), gradient angle steepness, volcanic rocks, tangent slope angle.

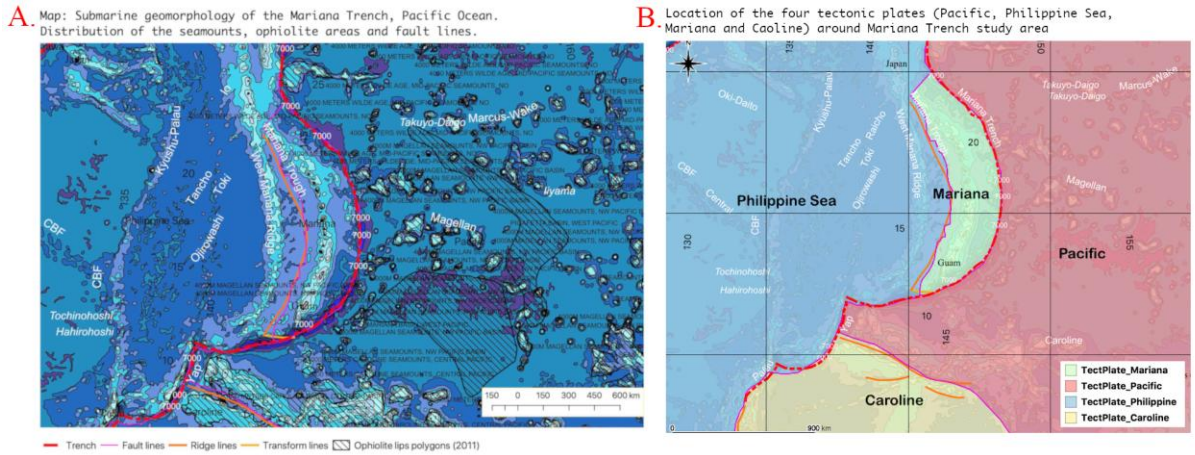


**Figure 5.** Study area: Mariana Trench crossing four tectonic plates

Other statistical methods were tested following existing described methodological approaches [30], [31], [32] via the command 'Models / Other Linear Models' in Gretl menu: Limited Information Maximal Likelihood (LIML), Weighted Least Squares (WLS), Heteroskedasticity-corrected, respectively (Figure 6, G-I). methodology for plotting Locally-Weighted Polynomial Regression (Loess) model [33] (Figure 7) followed 'Model / Robust Estimation / Loess' command of Gretl. Loess visualizes a series of sub-plots (Figure 7, A-D) showing predicted values of the dependent geological variable of sediment thickness for each non-missing value of the independent variable of the tectonic plates: Mariana, Pacific, Philippine Sea, Caroline. Confidence ellipses (Figure 8) illustrate the generalization of a confidence interval represented as an ellipsoid around an interval of observation samples containing 95% of the pairwise against geologic data variable (sediment thickness) (Figure 8, following from A to F): igneous volcanic areas, Caroline Plate, Pacific Plate, minimal depths, Philippine Plate, Mariana Plate.

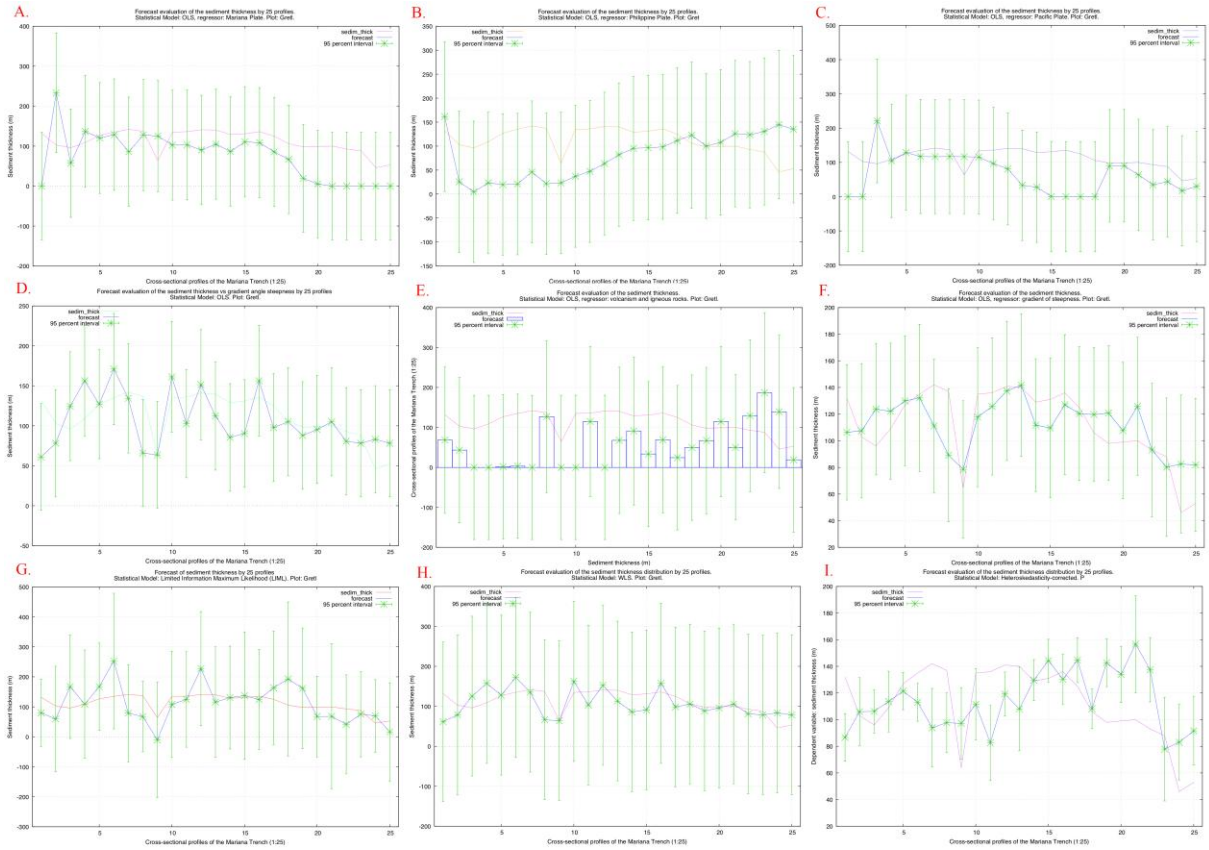

**Figure 6.** Forecast evaluation of the spatial variations in sediment thickness. Modelling methods: OLS (A-F); LML (G); WLS (H); Heteroskedastisity-corrected (I). Plotting: Gretl

Methodological approach in finding correlation between the variables consists in finding similarities between the selected values by existing algorithms [34], [35], [36]. The algorithms for the used approaches of OLS, WLS and LIML are provided in the existing statistical and reference literature [37], [38]. Specifically in this research the correlation matrix was computed using the 'View / Graph specified vars / Correlation Matrix' command.

## 3. RESULTS

### *3.1. Descriptive statistical analysis of the bathymetric and geological factors, Plotting: Gretl*

Findings in the primary statistical analysis of the examination of bathymetric data distribution show the most prominent depth by the profiles 20, 21, 22 located in the south-western part of the Mariana Trench (Figure 1).

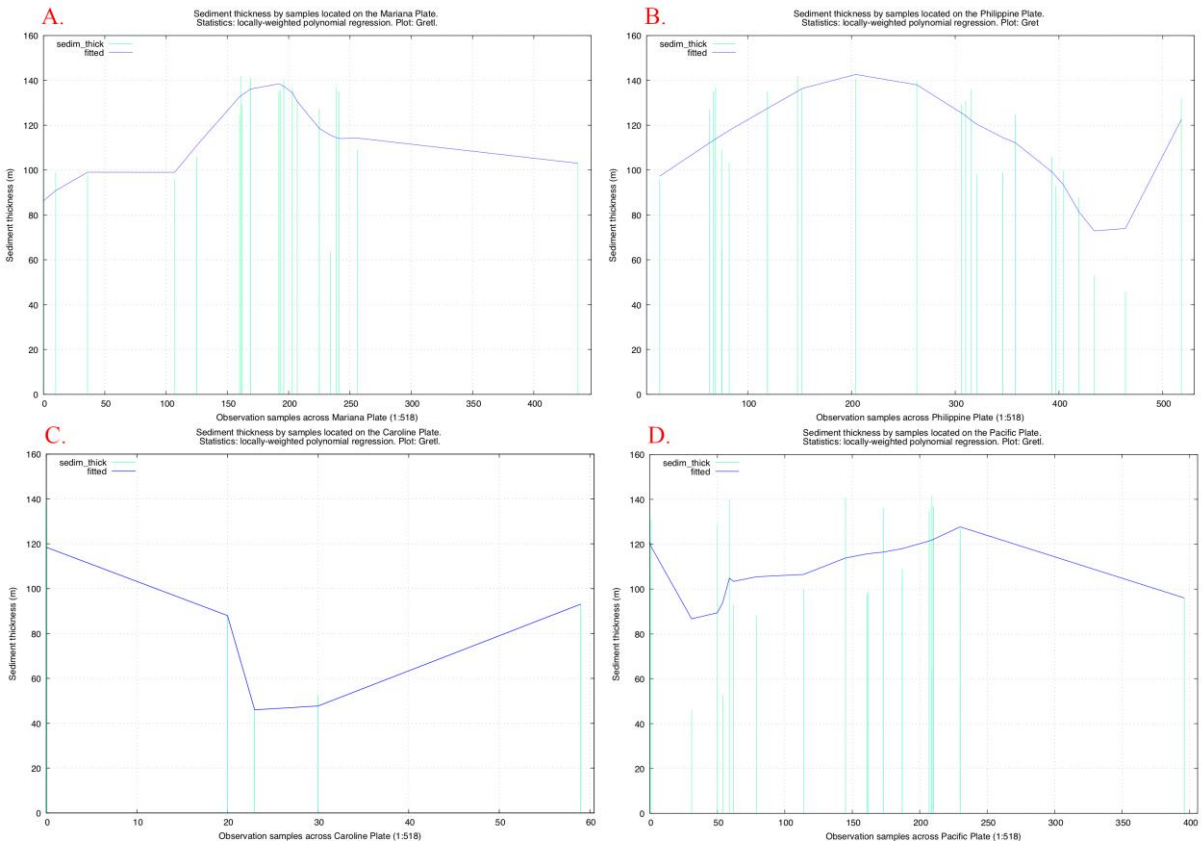


**Figure 7**. Spatial variations of the sediment thickness by four tectonic plates. Plotting: Gretl.

Data records on the sediment thickness have normal distribution patterns (Figure 2 A). The increased values in the sediment thickness can be noted (Figure 2) in the profile groups with the depths range -9,000 to -9,200 m (Figure 2 B) and from -7,700 to -7,000 meters with a gradual decrease thereafter. Profiles with depths ranging from -6,500 to -6,000 meters show lesser values in sediment thickness (Figure 2 B). Grouping profiles by values of the sediment thickness values (Figure 2 C) shows five distinct clusters with mean values of 138, 124, 114, 98 and 125 m, respectively (Figure 2 C). The QQ for the 25 profiles shows sample and theoretical quantiles for the bathymetric data (depths, in m) for each of the 25 profiles. The data shows normal distribution character. The Local Polynomial Regression for the 25 profiles was modeled in a facetted plot (Figure 4) using methodology explain in a previous chapter.

### *3.2. Evaluation of the spatial variations of the geological factors. Plotting: Gretl.*

The particular spatial characteristics of the Mariana Trench consists in its form: a crescent shape crossing four tectonic plates: Mariana, Caroline, Pacific and the Philippine Sea (Figure

5). Hence, to analyze spatial variations in the attribute data distribution across the plates, a spatial analysis by four plates was performed, which is discussed in this chapter.

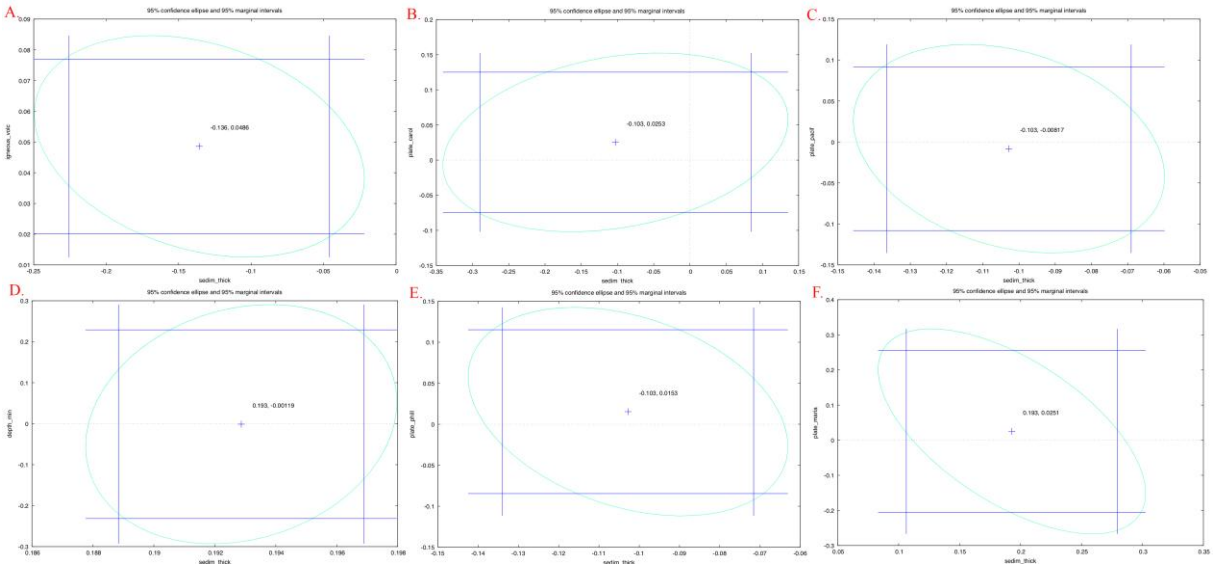


**Figure 8.** Confidence ellipse and marginal intervals for the data distribution. Plotting: Gretl.

Close examination of the Figure 9 shows that the geomorphic, geologic and bathymetric variables are distributed unequally by tectonic plates. There include the following tested parameters: slope angle expressed in tangent degree, sediment thickness, maximal depths and igneous volcanic rocks. The variations may be explained by the diverse geospatial conditions and geological settings in these areas (Figure 9).

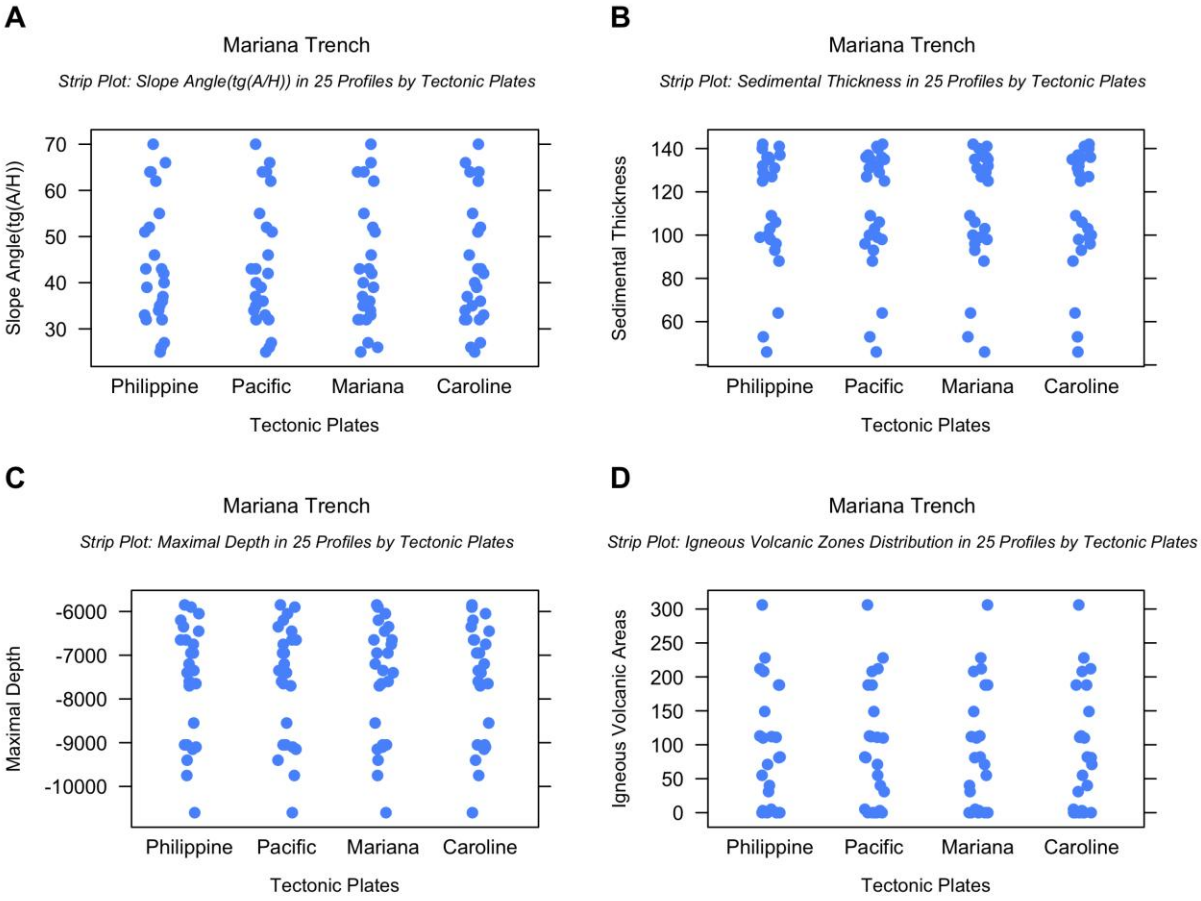


**Figure 9.** Variations in the geomorphology (A), geology (B), bathymetry (C), volcanism (D) visualized by strip plot. Plotting: R.

The geology of the trench (sediment thickness) has a correlation with geomorphic parameters of the slope shape: slope angle gradient, steepness tangent angle and aspect degree location of the igneous rocks (volcanism effect), Figure 10.

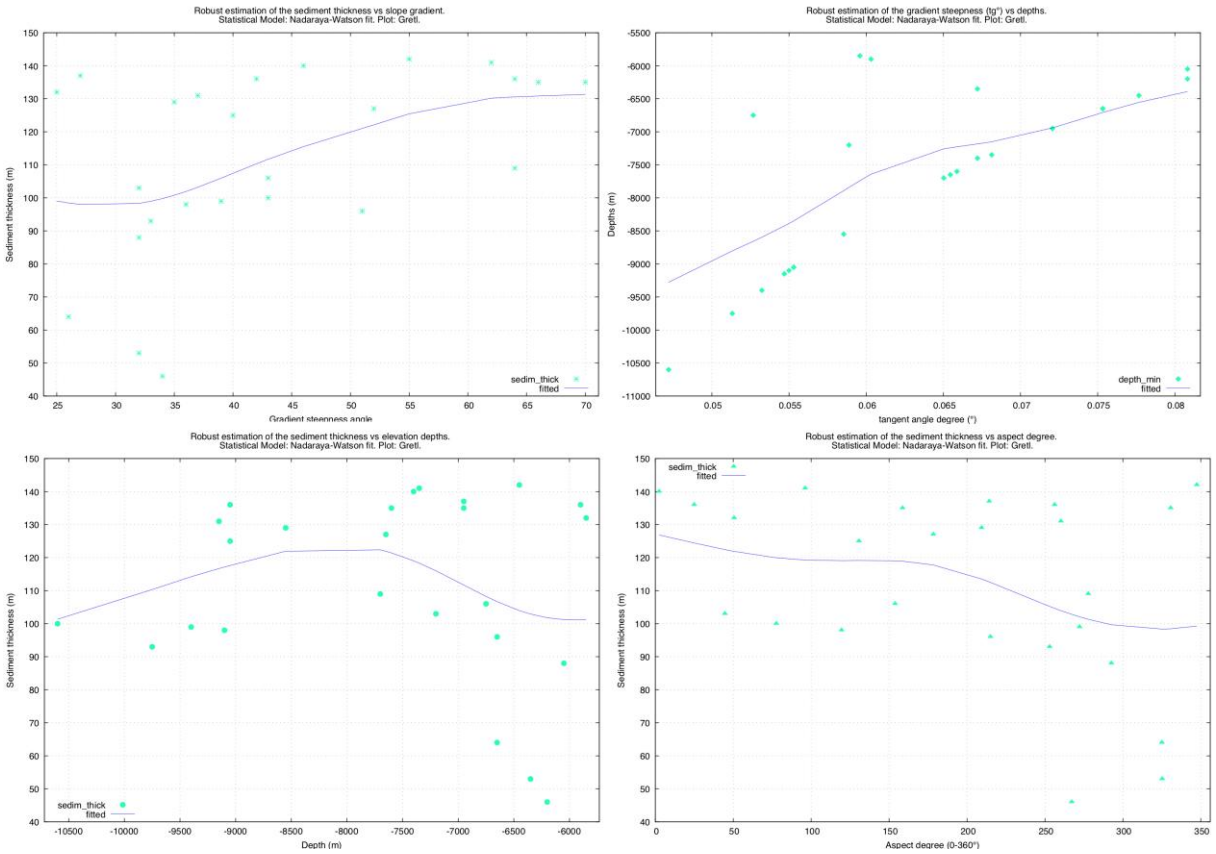


**Figure 10.** Robust estimation of the correlation trend. Model method: Naradaya-Watson Fit.

### *3.3. Correlation analysis of various factors: geomorphology, bathymetry and geography*

The relevance of variations in multiple factors (Figure 13) was studied in relation to the cross-sectional profiles across the trench (Figure 12), and specifically pairwise, for slope angle gradient and sediment thickness, slope angle gradient and igneous volcanic areas, and slope angle gradient and aspect degree (Figure 12 from upper to lower sub-plots, respectively). Besides, there is correlation between the slope gradient observations and aspect degree for the profiles located in the north and north-eastern part of the trench: 1-6, 16-19, 13-14, Figure 12. The 3D visualization of the triple correlation between geomorphic and geological variables (Figure 12) shows dependancies between these factors and tectonics, examples of the Pacific and the Philippine Sea plates (Figure 12 A).

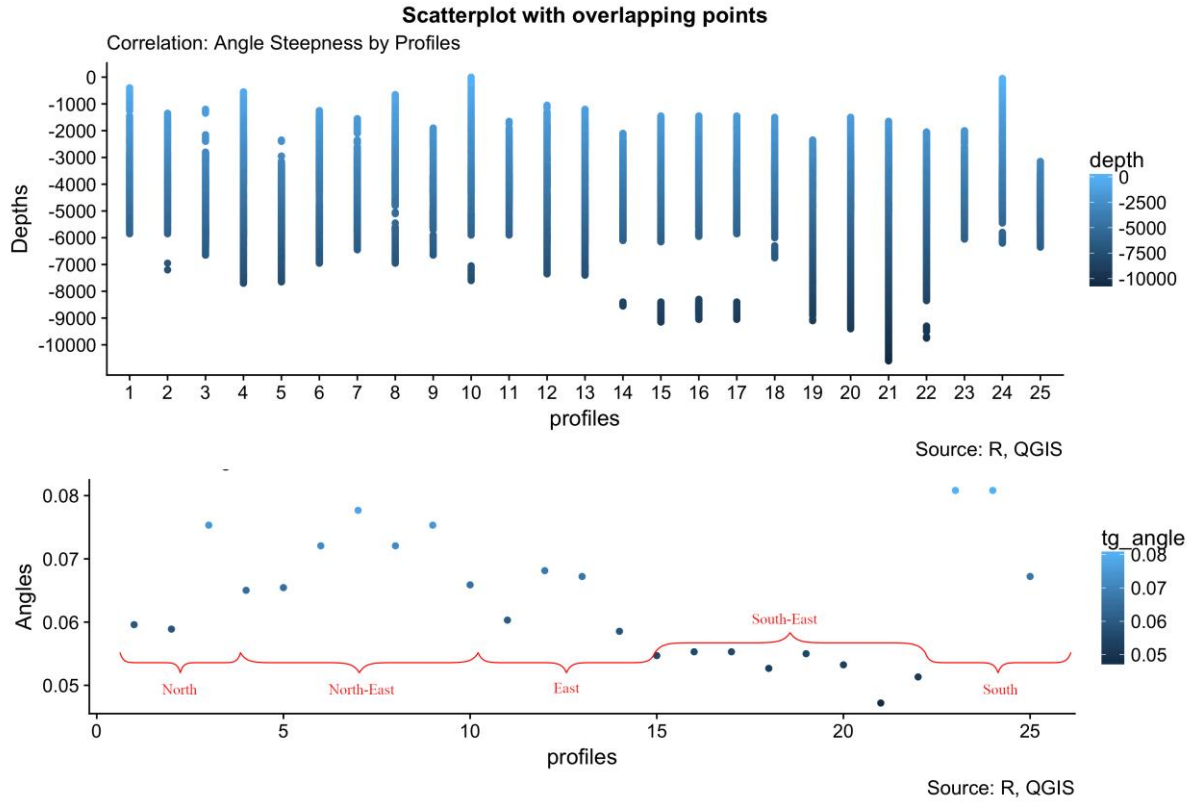


**Figure 11.** Scatterplot visualization of the dependancies between factors: elevation range by cross-sectioning profiles (upper plot); slope gradient and geospatial location (lower plot).

Overall, a strong relationship was not observed between tectonic plates (dependence < -0.5). However, a closer look revealed that the bathymetric values (depths, m) have a high correlation value, especially at profiles 14 to 17 and 1 to 6 (Figure 13, B).

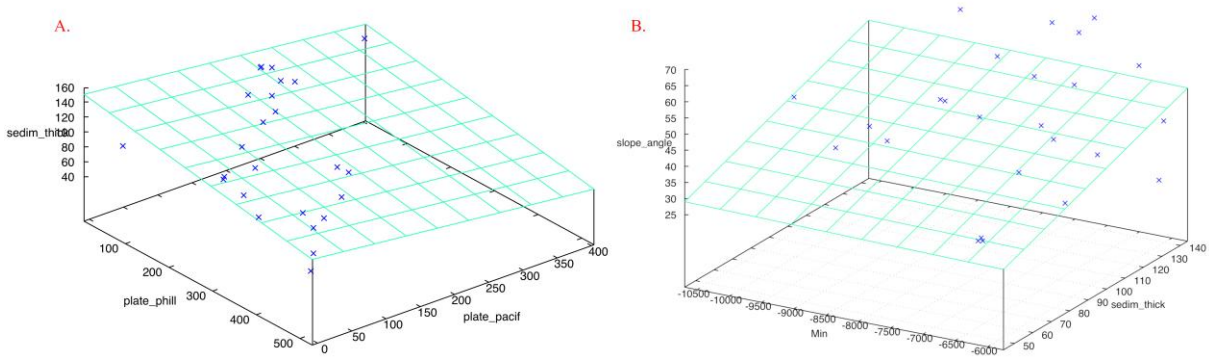


**Figure 12.** 3D visualization of the triple correlation between variables. Plotting: Gretl.

In this case, the geospatial effects could be the factors explaining this relationship (location in the northern and central part of the trench), Figure 11. A similar pattern, but with a higher

correlation, was observed for the slope gradient angle and sediment thickness (correlation > 0.75, Figure 13, A).

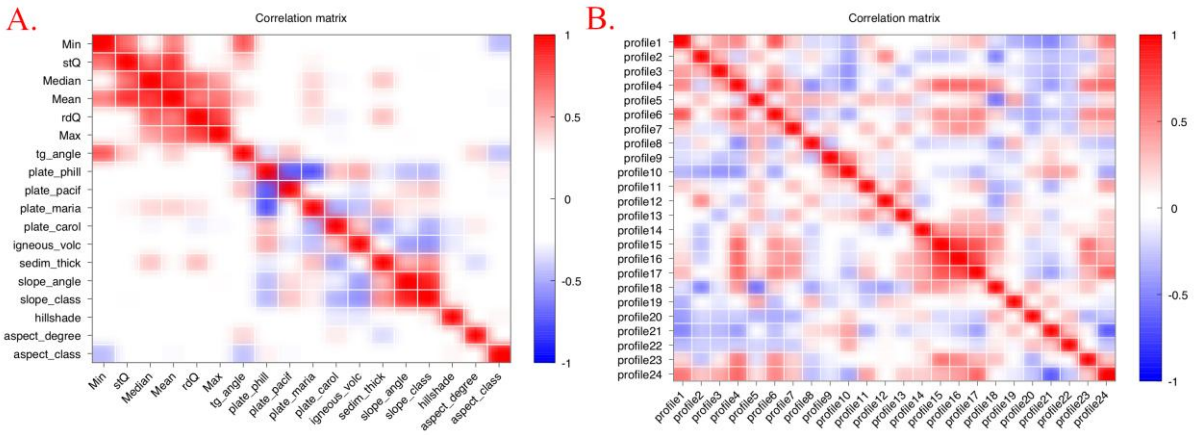


**Figure 13.** Correlation matrix between variables: similarities on factors (A); Correlation matrix between cross-sectioning profiles: similarities on geomorphology (B). Plot: Gretl.

## 4. CONCLUSION

Mariana Trench marks the location at which the Pacific plate subducts beneath the eastern edge of the Philippine Sea plate [39]. Therefore, the tectonic activities in the study area strongly affect the geomorphology of the trench. This study demonstrated quantitative and qualitative analysis of the correlation between various geospatial factors affecting Mariana Trench geomorphology by technical means of Gretl and R based data modelling. Hence, the research aim was to analyze factors affecting the variations of the Mariana Trench shape by various tectonic plates and how they correlate with each other.

Gretl based tests and data models proved to be supportive of the geospatial dependence between the factors affecting the trench geomorphology, which further reinforces geospatial data modelling interpretations made in this regard by R showing strip plots of data correlation: slope angles, maximal depths, sediment thickness and volcanism in the study area. The distributions of the depth values in the bathymetric patters across the trench show an important difference: the most prominent depth is detected in the south-western part of the Mariana Trench and decrease gradually from there until the north-eastern part of the trench. The increased values in the sediment thickness can be noted in the profile groups with the depths range -9,000 to -9,000 m and from -7,700 to -7,000 meters with a gradual decrease thereafter. Profiles with bathymetric values ranging around -6,500 meters show a contrast of

the intensity of sedimentation rates showing lesser values in the sediment thickness. A simulation model applied to the profiles grouped by the sediment thickness showed five distinct clusters showing variation of the sediment thickness according to the spatial distribution of the data samples. Overall, the bathymetric values (depths, m) have a high correlation value in the central part of the trench. Hence, the parameter of sediment thickness has a distinct correlation with geomorphic parameters of the slope shape: angle gradient, steepness and aspect, as well as distribution of the igneous rocks.

This brings up the issue of how these parameters are actually distributed in space. Gretl-simulated data modelling showed that the geomorphic, geologic and bathymetric variables are distributed unequally by the tectonic plates. Thus, the 3D visualization of the triple correlation between the geomorphic and geological variables shows dependancies between these factors and tectonics, e.g. the Pacific and the Philippine Sea plates. Virtually, the variations may be explained by the diverse geospatial conditions and geological settings in these areas. The remaining outliers in the data can be explained by the local variations in the geological parameters. The relevance of variations in multiple factors was studied in relation to the cross-sectional profiles across the trench and specifically pairwise, for the slope angle gradient with sediment thickness, igneous volcanic areas, and aspect degree, respectively. Finally, there is correlation between the slope gradient observations and aspect degree for the profiles located in the north and north-eastern part of the trench.

As demonstrated in the results, there is a distinct correlation between the volcanic activities and slope gradient angle of the trench, sediment thickness and depths in the places of the bathymetric sample points. This proves that trench motion caused by high tectonic activities in the study region directly impacts the geometry and shape geomorphology of the Mariana Trench. Furthermore, the influence of the geomorphic, geologic and bathymetric variables is assessed by the computing and measuring correlation effects, as well as visualized by graphic plotting and data modelling using Gretl and R statistical packages. The descriptive statistical analysis and correlation matrices yielded following results: sediment thickness correlate with the variations in depths and slope gradient angles, as well as changes in geographic locations moving from north southwards. Using a combination of statistical packages of R and Gretl demonstrated effective results visualized by the multifaceted plots and subplots, pairwise and triple correlation graphs, correlation matrices and other types of the graphical output.

Selecting a suitable software for statistical analysis is always important step in the research methodology. Most of all, it requires a review in choice, an argued approach comparing both pros and contras in the functionality of the particular software [40], [41], [42]. Methodologically, comparing Gretl with R, Gretl offers a more user-friendly possibilities: intuitive GUI enabling user to more smoothly perform analysis. In terms of functionality, R, comparing to Gretl, contains more packages and additional modules for diverse types of the statistical analysis that were not performed here due to the scope of this paper.

Graphical plotting is important part of the research in data analysis [43]: besides aesthetic value of the high-quality scientific plotting, effective visualization enables to highlight dependancies between variables and to put an accent on the groups variables that can be overlooked otherwise. R has powerful possibilities of graphical visualization due to such packages as {RColorBrewer}, {viridis}, {graphics}, {ggplot2}, {plotfunctions}, {ggplotgui}, {extrafont}, {fontLiberation}, {crayon}, {gridExtra}, {grid}. R enables to switch between necessary packages, adjust graphical plotting at the advanced level, create multi-plots, faceted plots, as well as enables a variety and flexibility in the statistical modelling and approaches, and many more. However, Gretl, due to the user-friendly GUI enables to focus more on the research and statistical analysis without strong skills in syntax of programming language, as required by R. To conclude, both Gretl and R are useful for the geological data analysis. Using combination of the both packages demonstrated positive results: data analysis, statistical modelling with possibilities to tune functions, select variables, options, as well as fine visualization plotting.

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**Research Article**

# Evaluating climate variability from rainfall and temperature: insight from Niamey and Maradi in Niger

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**Abstract**

Niger is one landlocked West African country located between parallels 11° 37 and 23° 33 Northern latitudes, meridians 16 °East longitudes and 0 °10 West longitude and covers 1,267,000 kilometers square. This country has different agro-climatic zonation which are divided into northern Saharan arid with a total annual rainfall average about 20-75 mm, Saharan-tropical; 75-160 mm and Sahelian area with an estimated total annual rainfall average of 250-800 mm. Therefore, the country rainfall pattern varies from one region to another and within one region. Niger as a poor country which agriculture sector employs about 85% of rural population and accounting approximately 45.2% of national economy climate variability may reduce the sustainability of this sector. In addition, Maradi is one of country's important agricultural production regions, but it is recently most exposed to food insecurity while Niamey is a region crossed by the country river. Accordingly, this article aims to evaluate climate variability in these regions during 1979-2013s. Buishand Homogeneity test was being conducted to detect the temporal break of climate variability and regression analysis was being used to estimate its magnitude in these regions. The findings indicate the two regions experienced a variation their total annual rainfall and monthly temperature averages. More, Niamey is more temporal sensitive, but the climate variability is higher in Maradi. Accordingly, during the period 1979-2013 the total annual rainfall of Maradi has fallen by 76% and its monthly temperature has increased by 13,6% whilst total annual rainfall of Niamey has fallen by 46.2% and its monthly temperature mean has increased by 13.6%. Consequently, it urges to implement large mitigation and climate variability reduction strategies to sustain the agriculture sector especially in Maradi as well as to minimize the risk of extinction of the Niger River.



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## 1. Introduction

During the last decades the climate change and variability become key studied concepts by many authors [1, 2, 3]. The climate change and variability can occur at all locations, but recently most attention has been given to their regional and basin scales to carry out more specifics and key information for implementing more profitable and sustainable local socioeconomic activities [4]. More, for practical environmental management the rainfall and temperature trends have been considered as proxies in investigating climate change and variability [5, 6, 7, 8, 9].

Since the 1950s, numerous anthropogenic activities lead to climate change warming, especially in West Africa which was confronted to several droughts with as outcome important decreases of river flows during the era 1960s-1990s [10, 11, 12, 13].

Also, climate variability is expected to increase the occurrence of droughts, floods and heavy storms in Africa [14, 15]. Similarly, the Sahel is expected to face a rapid increasing of its temperature and more unpredictable rainfall pattern that may lead to uncertain crop production with severe yield drop [16, 13]. In addition, these circumstances represent a risk, especially for the area's small-scale farmer, so that [13] underscore the climate change could a key obstacle for producing sensitive crops such as maize, millet and sorghum in Africa.

Niger is one of West-African countries which economy is strongly dependent agriculture sector which includes about 85% of the country's rural population and accounts approximately at 45.2% of its GDP in 2010 [17]. Therefore, from post-colonial period several agricultural strategies and milestones have been executed in Niger to enhance the country's food security. They are mostly targeting at diversifying a country's agricultural products.

However, Niger agriculture sector depends mainly to total annual rainfall and most of agricultural systems are extensive, so that these agricultural systems are likely to cause environmental degradation and an increasing risk of desertification.

Earlier it has been projected a decline of Millet production by 13% and its yield decline about 42% from increasing temperature and rainfall variability by 2030s, so that in Sahelian countries the desertification questions the long-term viability of agriculture sector [18, 19].

On another hand, since 1992 Niger is a signatory country of United Nations Convention on Climate Change (UNCCC) and recently in 2004 a country signatory of Kyoto. Hence, Niger has implemented several policies such as United Nations Emissions Reductions from Deforestation and Forest Degradation which target at planting trees by providing incentive financial support to Sahelian farmers to reduce the climate pressures [20, 21].

Nevertheless, in the Sahel the climate change leads to inter-annual variability and sensitivity to rainfall, so that the availability of freshwater depends on climate change and variability and represents a key future challenge for sustainable development [5, 22, 23, 24, 25, 26, 27]. Furthermore, the climate approaches based mainly on global and large-scale climate vulnerability are specific timescales (e.g. inter-annual) or regional hydrological datasets [28, 29], so that data scarcity and high variability may be major constraints in apprehending multi-timescale climatic teleconnections driving streamflow variability.

In Niger previous studies investigate mostly the inter-annual climate variability, affected the relationship between rainfall–runoff and the river regimes based on Hydrological and hydro climatic dataset through some complex hydrological methods. However, evaluating climate variability from total annual rainfall and monthly temperature mean could be more practical for agricultural development institution and policy makers to reinforce their ongoing implemented strategies over different timescales. Hence, a good comprehension of temporal climate variability and its magnitude, especially in one of the country vital agricultural region almost permanently exposed to food insecurity as well as in Niamey the only region crossed by the main country water resource may offer a way for implementing short-middle and long-term climate change and variability mitigation strategies in this region.

This study aims to evaluate climate variability from daily rainfall and temperature records, especially to detect a temporal break in total rainfall and monthly temperature as well as to estimate magnitude of this variability during the period 1979-2013. Accordingly, the study attempts to answer the questions: (1) are temporal total annual rainfall and monthly temperature variabilities similar in Maradi and Niamey? (2) Although temporal total annual rainfall and monthly temperature variabilities differ Maradi and Niamey do they have the same magnitude? (3) What is the region more sensitive to total annual variation? (4) What is the region more sensitive to monthly temperature variation?

## 2. Material and Methods

### 2.1 Study areas

With about 255 kilometers square Niamey is situated in the South West of Niger between 13°28’- 13°35’ of latitude North and 02°03’ - 02°12’ of longitude while Maradi is situated the southern part of Niger between parallels 13 ° and 15 ° 26' North latitude and parallels 6 ° 16' and 8 ° 36 'East longitude and covers about 41,796 km² as shown in figure 1 below.

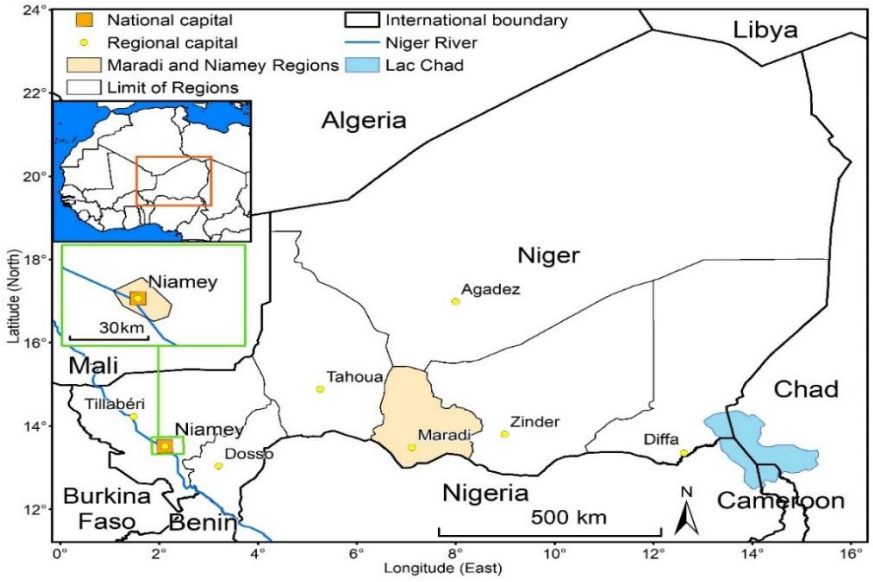


**Figure 1. S**tudy areas

### 2.2 Study data

Data for 1970-2013 have been computed from daily secondary data obtained from the national office of meteorology of Niger and they include daily rainfall and temperature records.

### 2.3 Data analysis

From the daily rainfall and temperature, the monthly temperature means, and total annual rainfall have been calculated. Accordingly, the annual cumulative rainfall of each region has been determined by summing up their daily record with the formula $TAR = \sum_1^n Xi$ (1) where TAR refers to total annual rainfall value and Xi the daily recorded rainfall.

Depending on [30] the direct use of daily temperature mean may underestimate its value which commonly occurs according the non-linear relationship between saturation vapor pressure-temperature.

Hence, the two regions' monthly temperature means have been determined in two steps. According to [30] a monthly temperature mean is determined with the formula $\mathbf{TMean} = \frac{(\mathbf{TMin+TMax})}{\mathbf{2}}$ (2) where, TMean refers to daily mean temperature of air, TMax daily maximum temperature of air and TMin daily minimum temperature of air all in degree Celsius (ºC). Then, monthly temperature mean was being determined with the formula $\boldsymbol{MTA} = \frac{\sum_1^i \boldsymbol{DAT}}{\boldsymbol{N}}$ **(3)** where MTA refers to monthly temperature mean and DTA the represents the daily temperature mean and N refers to the number of the days of a month.

Furthermore, Buishand's Homogeneity Test has being conducted to detect a trend variation of total annual rainfall and monthly temperature amen in the two regions while

regression analysis has been conducted to estimate the magnitude of total annual rainfall and monthly temperature means which may be observable on the trend obtained from Buishand's Homogeneity Test.

### 2.3.1 Buishand Homogeneity Test

To carry out intra and inter regional the trend of total annual rainfall and monthly temperature mean Buishand Homogeneity Test was being conducted. Originated from a formulation given by [31], the Buishand statistic derived from Gardner's statistic which is commonly used for carrying out two-sided break test based on average value for an unsettled period. Gardner's statistic is determined with the formula:

$$G = \sum_{K=1}^{N-1} Pk\left\{Sk/\sigma x\right\}^2$$

Where $S_k = (X - Xm)$

$P_k$ is the probability that the break occurs just after the $K^{th}$ observation while the variance $\sigma_x$ is assumed a known value.

On other hand, if $\sigma_x$ is an unknown value it can be substituted by the variance of the sample D2x and if $P_k$ is homogeneously selected so that the statistic U is determined with the formula:

$$U = \frac{\sum_{K=1}^{N-1}\left(Sk/\sigma x\right)2}{N(N+1)}$$

Where $\mathrm{D2x} = \sum_{i=1}^{n}(Xi - Xm)^2/N$

The critical values of statistic U were being assumed by [32] and then it was being used in Monte Carlo method. Afterward [33] has better estimated U value, so that Buishand Homogeneity Test become the most applied in evaluating the distribution of haphazard variables or parameters according the properties examined in normal case, so that Buishand homogeneity Test is predominantly used in normal event.

### 2.3.2 Regression model

The regression model is a statistical procedure that allows estimating the linear relationship between two or more variables. It measures the amount of change in one variable that is associated with change in another variable or variables. The regression was used to test the statistical significance whether the observed linear relationship could have emerged by chance or not. Accordingly, the linear regression model has been used to estimate a causal relationship between a break on total rainfall and monthly temperature means. Accordingly,

the independent variable (occurrence of break) was labelled X and the dependent variables (variation in total annual rainfall and monthly temperature) was labeled to determine the straight-line relationship that connects X and Y. Hence, the linear relationship between temporal occurrence of break and total annual rainfall and monthly temperature can be stated algebraically as Y = a + bX where a refers to the intercept and b is the slope of the line.

## 3. Results

### 3.1 Buishand Homogeneity Test

#### 3.1.1 Temporal trend of total annual rainfall

The figure 1 bellow shows a break representing a reduction in total annual rainfall both in Maradi and Niamey. Mardi total annual rainfall dropped from 807.77 mm to 265 since 1998 while in Niamey it had fallen from 458.87 mm to 141.71mm. Therefore, temporally a reduction in total annual rainfall has earlier occurred in Niamey (1997) and then in Maradi (1998), so that Niamey is temporally more sensitive to total rainfall variability than Maradi.

However, Niamey accounts a reduction of 317. 16mm from 1997 whilst in Maradi this total annual rainfall reduction is about 542.77mm from 1998. Accordingly, although Niamey is temporally more sensitive to total annual rainfall the fall of the annual rainfall in Maradi is more drastic as show on the figure 1.

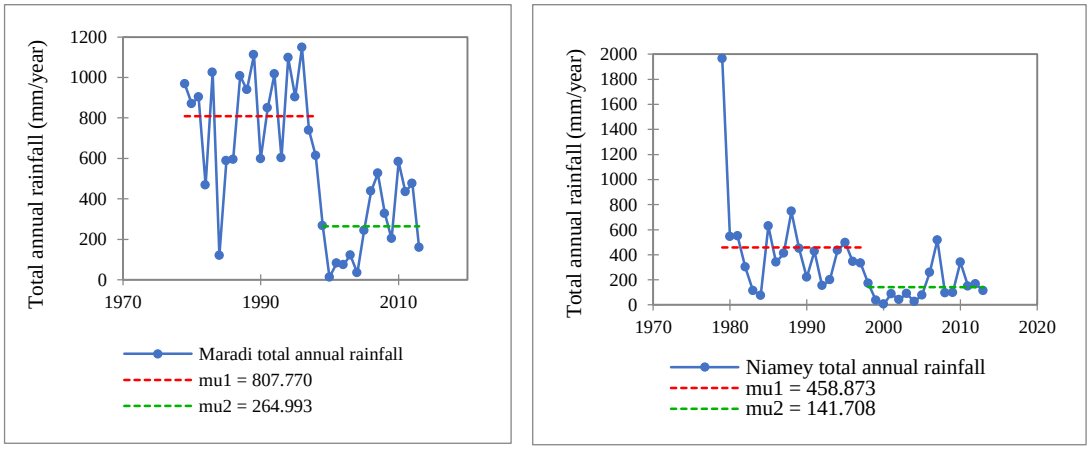


**Figure 2.** Temporal trend of total annual rainfall

#### 3.1.2 Temporal trend of monthly temperature means

Buishand's tests showed there is a break representing an increase of monthly temperature means both in Maradi and Niamey. In Niamey the monthly temperature mean increases from 30.17 C to 31.284C whereas it passed from 28.92C to 30C in Maradi. Yet, this temporal increase in monthly temperature means occurs in Niamey since 1997 but recently in

2000 in Maradi, so that Niamey is temporally more sensitive to total monthly temperature variability than Maradi. This break in monthly temperature means is shown on the figure 2.

However, Niamey accounts an increase of 1.11C in its monthly temperature since 1997 whilst in Maradi an increase of 1.08C monthly temperature occurs in 2000. Hence, the increase in monthly temperature mean is slightly higher in than in Maradi as well as Niamey is temporally more sensitive to monthly temperature than Maradi as shown on Figure 2.

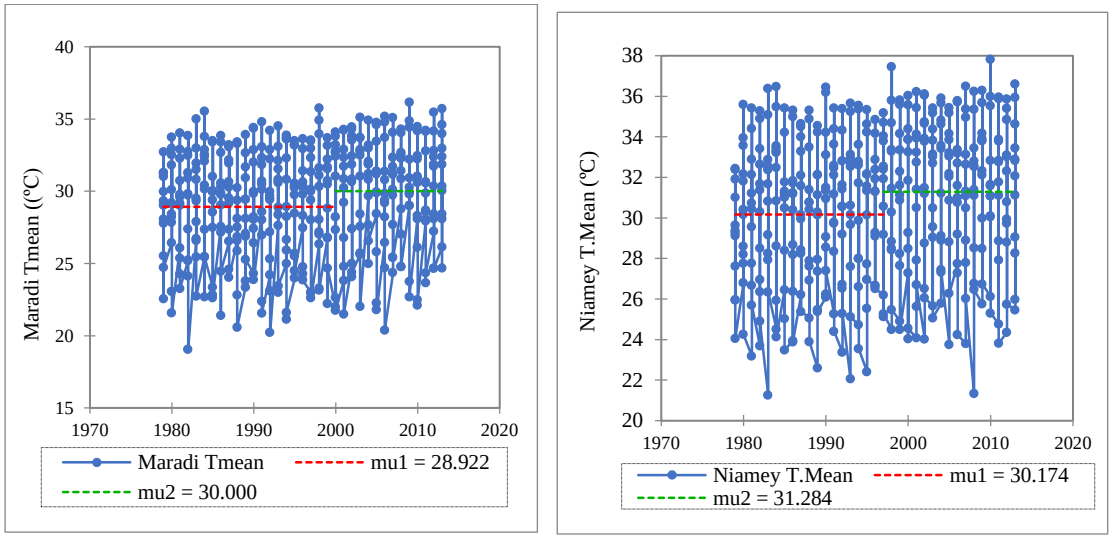


**Figure 3.** Temporal trend of monthly temperature means

### 3.2. Regression analysis

#### 3.2.1 Total annual rainfall and monthly temperature

The total annual rainfall mean is greater in Maradi (575.15mm) than in Niamey (313.9 mm). Otherwise the coefficient of variation (ratio of standard deviation to total annual mean) is about 62% for Maradi whilst it accounts about 110.45% in Niamey. Hence, Niamey is temporally more sensitive to total annual rainfall than Maradi. Similarly, the monthly temperature in Niamey (30.70 C) is slightly greater than in Maradi (29.34C) whist the coefficient of variation of monthly temperature is about 11.85% in Niamey and 12.72% in Maradi as shown in table 1.

**Table 1.** Total rainfall and monthly temperature means, maximum, minimum and coefficient of variation

| Variables | Minimum | Mean | Maximum | Std. Deviation | C.V (%) | N |
|---|---|---|---|---|---|---|
| Maradi total annual rainfall | 12.64 | 575.15 | 1147.85 | 356.60 | 62 | 35 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Maradi monthly temperature mean | 19.05 | 29.34 | 36.15 | 3,7341 | 110.45 | 420 |
| Niamey total annual rainfall | 4.13 | 313.90 | 1962.96 | 346.71 | 11.85 | 35 |
| Niamey monthly temperature mean | 21.5 | 30.70 | 37.81 | 3,639 | 12.72 | 420 |

### 3.2.2 Magnitude of temporal variation in total annual rainfall

To estimate the variation magnitude of a break obtained with Buishand Homogeneity Test and its impact in booth total annual rainfall and monthly temperature means in the study regions we define a dummy variables. Hence we attribute the value one (1) was for all the year during which there is not any appearance of breaks on trend and a value zero 0) otherwise. The regression analysis results show that the standardized coefficient Beta of total annual rainfall is greater in Maradi (0.7649) than in Niamey (0.462). Accordingly, the occurrence of temporal break in the trend of total annual rainfall mean has significantly impacted the total annual rainfall in Maradi than Niamey so that Maradi is more sensitive to total annual rainfall variability than Niamey.

On another hand, the regression analysis show that the standardized coefficient Beta of monthly temperature means is slight greater in Niamey (1.236) than in Maradi (1.32), so that the occurrence of break in monthly temperature means has significantly impact the monthly temperature in Niamey but not in Maradi. The results are shown on the table 2.

**Table 2.** Regression results of total rainfall and monthly temperature

| Regions | Model | Standardized Coefficients Beta | t | Sig. |
|---|---|---|---|---|
| Maradi | Constant (total annual rainfall) | | 4,396 | 0.000 |
| | Occurrence of break in total annual rainfall | **0.764** | 6,807 | **0.000**** |
| | Constant (monthly temperature mean) | | 101,071 | 0.000 |
| | Occurrence of break in monthly temperature | -0.132 | -2,724 | 0.007 |
| | Constant(total annual rainfall) | | 1,817 | 0.078 |
| | Occurrence of break in total annual rainfall | **0.462** | 2,996 | **0.005*** |

| | | | | |
|---|---|---|---|---|
| Niamey | Constant (monthly temperature mean) | | 119,932 | 0.000 |
| | Occurrence of break in monthly temperature means | **-0.136** | -2,812 | **0.005*** |

***The bold and asterisk the significant level (1%, 5%) in the study regions; Sig. = Significance.***

## 4. Discussion

The results from the figures 2 and 3 both Maradi and Niamey experienced a variability of their total annual rainfall and monthly temperature. Furthermore, these variabilities differ between the two regions, so that Maradi total annual rainfall had fallen from 807.77 mm to 265 mm since 1998 while in Niamey it dropped from 458.87 to 141.70mm since 1997. Accordingly, Maradi with a reduction of 542.7 mm of its total annual rainfall is more sensitive to total annual rainfall than Niamey (317 mm). These results are similar to the findings of [10, 34, 35, and 36] that highlight that West Africa experiences strong spatial and temporal rainfall variability, especially the Sahel areas. Yet, the total annual rainfall's coefficient of variation in Maradi (76%) is greater than in Niamey (46%). This corroborates the previous results found by [35, 36, 37, 38, and 39] that underline Niger experiences a decrease of its annual rainfall by 3.1% per decade during 1950-2014, mainly during the droughts (1970-1980s).

Previously [40] highlights that the climate change is seriously impacting the crop production, especially beans production which is a significant source of protein in Maradi region, so that the sensitivity to total annual rainfall may reduce not only the development of agriculture sector in this region but it could also increase its food insecurity level.

Besides, both Maradi and Niamey reveals sensitive to monthly temperature, so that since 1997 Niamey monthly temperature means has increased by 1.1 C whilst Maradi recorded an increase of its monthly temperature of 1.08 C since 2000. Although there is time lag in increasing monthly temperature between the two regions, Niamey is slightly more sensitive to monthly temperature than Maradi. Though the climate variability was assessed at the level of two regions of Niger the findings corroborate those of [41] who highlight that Niger is amongst one of the highest West African countries vulnerable to climate in West Africa.

### *Conclusion and recommendation*

Rainfall and temperature series have been used to evaluate the climate variability and the impact of the occurrence of break in total annual rainfall and monthly temperature in the

regions of Maradi and Niamey. Besides, Maradi which reveals more sensitive to total annual rainfall is important agricultural production of the country as highlighted by [42], so this region's sensitivity to total annual rainfall could reduce the development of its agriculture sector. Additionally, the slight sensitivity of Niamey to air temperature could cause an increase of Niger watercourse, so that it may question its long-term sustainability.

This study therefore aimed to evaluate climate variability in these regions. The Buishand Homogeneity Test identified two main breaks in the total annual rainfall and monthly temperature means. Accordingly, Maradi has experienced a decrease of its total annual rainfall in 1998 while Niamey total annual rainfall falls since 1997. The regression analysis shows that the magnitude of total annual rainfall was 76.4% for Maradi and 46.2% for Niamey and this magnitude was 13.2% and 13.6% for monthly temperature means respectively for Maradi and Niamey. More specifically, the regression results show that total annual rainfall is significant by region ($\beta = -0.76$; $p \leq 0.000$ for Maradi and $\beta = 462$; $p \leq 0.005$ for Niamey) as well as for monthly temperature means ($\beta = -132$; $p \leq 0.007$ for Maradi and $\beta = -0.136$; $p \leq 0.005$ for Niamey).

From the research findings, a large implementation of resilient climate change strategies to reduce the regional sensitivity, especially in Maradi could help to improve agriculture sector as well as to the region's food security. Also, the implementation of more climate friendly resource practices may enhance the sustainability of Niger River while reinforcing the practiced agricultural and fishery activities on Niger River bank.

## Conflict

None

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**Research Article**

# Sustainable Urban Management in Bursa

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**Abstract**

The concept of sustainable city is to create livable and people-oriented cities for today and for the future. Bursa is economically the fifth largest city in Turkey. Agriculture, industry, trade and tourism are carried out, the city also constitutes a wealth of minerals. An increase in urban population, industrialization; lack of housing and infrastructure; difficulty in accessing work, goods and services; unemployment, inequality and misuse of natural resources negatively affect urban sustainability. In order to serve the purpose of urban sustainability as well as to determine new policies; the central government should coexist and work with local administrators, urban planners, academics, non-governmental organizations and the public. With this study measurements of air quality, noise complaints, quantity of solid waste and it's composition, land usage and greenhouse gas inventories were examined in Bursa. Parameter changes over the years for the purpose of the study is explained by tables and graphs, and sustainability indicators have been developed recommendations for the adverse change in the accepted parameters.



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## 1. INTRODUCTION

Cities should be inherited over from past generations with a quality life to their present guests and should be delivered to future generations in a usable and sustainable way. The sustainable city should not only include the city where the environment is protected also contains the economic and social changes and developments. Bursa is one of our rare cities which carry the characteristics of agriculture, trade, tourism, industry and culture with a total area of 10,819 $km^2$ and 17 districts. Long-term and short-term policies should be identified and implemented to achieve the goal of urban sustainability. In this study, air pollution, noise, waste quantity and composition, land use and greenhouse gas issues in Bursa were investigated. Primarily general information is given about these issues and then information about the current situation in Bursa was assessed. Lastly, recommendations were developed about the environmental issues.

## 2. AIR POLLUTION

Air pollution is a condition which causes life and physical harms and causes economic losses due to the increase in the emissions which are not normally found in the air or in amounts which are normally not harmful [1].

### 2.1 Air Quality Index

Air quality index is an important indicator showing air pollutant's level in the atmosphere to protect human health, short-term and long-term negative effects in the environment. The air quality index is used to monitor the air pollution and to inform the public in terms of health effects.

It gives information about the air pollution of the region whether it is clean or not and health effects as can be seen. It indicates the health effects that may occur within a few days or a few hours after the inhalation of the polluted air.

The air quality index is arranged between the range of 0-500 as shown in Table 1 according to EPA. The higher the air quality index value is the higher risk of air pollution and the health risk. When the air quality index value is 50, the air quality is designated as good and the air quality index value over 300 shows bad quality reflecting with colors [1]. Table 2 shows the national air quality breakpoints. It has been shown that $SO_2$, $NO_2$, CO, $O_3$ and $PM_{10}$ will have good, medium, sensitive, unhealthy, bad and dangerous effects.

**Table 1.** EPA (Enviromental Protection Agency) Air Quality Index [2]

| **Air Quality Index (AQI) Values** | **Health Concern Levels** | **Colors** | **Meaning** |
|---|---|---|---|
| Air Quality Index Ranges | Air Quality Conditions | The colors symbolized | Meaning of Colors |
| 0-50 | GOOD | GREEN | Air quality is satisfactory and air pollution is low risk or no risk. |
| 51-100 | MİDDLE | YELLOW | Very few people are susceptible to air pollution, but are unusually susceptible to air pollution, so there may be moderate health concerns for some pollutants. |
| 101-150 | SENSİTİVE | ORANGE | Health effects can occur for sensitive groups. In general, it is not possible for the public to be affected. |
| 151-200 | UNHEALTHY | RED | Anyone can start experiencing health effects, serious health effects for sensitive groups may be in question. |
| 201-300 | BAD | PURPLE | Can create an emergency in terms of health. The entire population is likely to be affected. |
| 301-500 | DANGEROUS | BROWN | Health alarm. Everyone may experience more serious health effects. |

**Table 2.** National Air Quality Index Breakpoints [2]

| **Index** | **NAQ** | **$SO_2$(µg/$m^3$) 1h mean** | **$NO_2$(µg/$m^3$) 1h mean** | **CO(µg/$m^3$) 8h mean** | **$O_3$(µg/$m^3$) 8h mean** | **$PM_{10}$(µg/$m^3$) 24h mean** |
|---|---|---|---|---|---|---|
| Good | 0-50 | 0-100 | 0-100 | 0-5.500 | 0-120[L] | 0-50 |
| Medium | 51-100 | 101-250 | 101-200 | 5.501-10.000 | 121-160 | 51-100[L] |
| Sensitive | 101-150 | 251-500 | 201-500 | 10.001-16.000[L] | 161-180[I] | 101-260[W] |
| Unhealthy | 151-200 | 501-850 | 501-1000 | 16001-24.000 | 181-240[W] | 261-400[W] |
| Bad | 201-300 | 851-1.100 | 1.001-2000 | 24.001-32.000 | 241-700 | 401-520[W] |
| Dangerous | 301-500 | >1.101 | >2001 | >32.001 | >701 | >521 |

L: Limit Value I: Information Threshold W: Warning Threshold

## 2.2 Bursa Province and Air Pollution

Table 3 shows the average measurements of $SO_2$ and $PM_{10}$ between the years of 2000 and 2014 in Bursa.

**Table 3.** Changes in the average value of $SO_2$ and $PM_{10}$ amounts in Bursa [2]

| **YEARS** | **$SO_2$ (Average)** | **$PM_{10}$ (Average)** |
|---|---|---|
| **2000** | 62 | 45 |
| **2001** | 57 | 35 |
| **2002** | 60 | 71 |
| **2003** | 74 | 34 |
| **2004** | 95 | 44 |
| **2005** | 40 | 21 |
| **2006** | 66 | 118 |
| **2007** | 59 | 55 |
| **2008** | 46 | 30 |
| **2009** | 80 | 24 |
| **2010** | 61 | 13 |
| **2011** | 61 | 12 |
| **2012** | 56 | 34 |
| **2013** | 29 | 77 |
| **2014** | 17,2 | 80,6 |

In Table 4 and 5, monthly average values of $SO_2$ and $PM_{10}$ parameters of Bursa Station are indicated.

**Table 4.** Bursa Station Monthly Average Values of $SO_2$ Parameter [2,3,4,5,6]

| $SO_2$ | 1. M. | 2. M. | 3. M. | 4. M. | 5. M. | 6. M. | 7. M. | 8. M. | 9. M. | 10. M. | 11. M. | 12. M. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2012** | 72 | 82 | 58 | 124 | 275 | 290 | 22 | 36 | 27 | 51 | 52 | 55 |
| **2013** | - | - | - | 6 | 5 | 2 | 4 | 4 | 9 | 8 | 14 | 17 |
| **2014** | 14 | 10 | 6 | 6 | 2 | 2 | 2 | 2 | 4 | 4 | 7 | 11 |
| **2015** | 14 | 10 | 6 | 6 | 2 | 2 | 2 | 2 | 4 | 4 | 7 | 11 |
| **2016** | 10 | 6 | 4 | 4 | 3 | 3 | 2 | 3 | 5 | 4 | 16 | 12 |

M: Month

**Table 5.** Bursa Station Monthly Average Values of $PM_{10}$ Parameter [2,3,4,5,6]

| $PM_{10}$ | 1. M. | 2. M. | 3. M. | 4. M. | 5. M. | 6. M. | 7. M. | 8. M. | 9. M. | 10. M. | 11. M. | 12. M. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2012** | - | - | - | - | - | - | - | - | - | - | - | - |
| **2013** | 34 | 17 | 13 | 22 | 41 | 63 | 57 | 63 | 72 | 99 | 111 | 88 |
| **2014** | 81 | 77 | 66 | 98 | 86 | 84 | 78 | 87 | 96 | 96 | 151 | 155 |
| **2015** | 81 | 77 | 66 | 98 | 86 | 84 | 78 | 87 | 96 | 96 | 151 | 155 |
| **2016** | 124 | 121 | 99 | 98 | 66 | 66 | 53 | 65 | 68 | 83 | 131 | 146 |

### 2.3 Some measures to be taken on Air Pollution

In the light of these measurements and to list the precautions to be taken for air pollution, fuel has to be controlled in the first choice for the short term. For this purpose, fuels for heating with low sulfur content have to be used. Control of the vehicles is also very important. For this purpose, the use of catalytic converters in order to ensure the maintenance of engine maintenance with the aim of increasing the combustion efficiency of the vehicles, the use of catalytic converters in order to minimize the pollutants in the exhaust, and the use of suitable catalysts to ensure full combustion are the main preventions. Maximum use of thermal insulation techniques are advised in order to save fuel. Another prevention is to concentrate on public awareness about the combustion technology and energy saving. It is necessary to ensure good quality fuel distribution in all housing, including the stove houses, whose negative contribution to air pollution is difficult to control. The availability of good quality fuel reserves to be used in periods when pollution is extremely high is another measure to be considered. Prevention of unnecessary heating can be regulated by using a heat

meter in buildings which use fuel oil for heating. In order to avoid high increases in the pollution concentration, the heating hours of the heaters should be adjusted according to the districts. Cleaning the flame pipes of the stoves and boilers also increases the combustion efficiency. Yet another prevention can be the application of sanctions by the municipalities for the control of the buildings that generating more fumes from their chimneys.

In the medium term, the use of appropriate technologies to minimize the contamination of existing fuels can be advised. Improvement of combustion systems, implementation of necessary standards and legal regulations, technical control and documentation for this purpose are the things to be considered. In buildings to ensure maximum thermal insulation, determination and implementation of economic isolation measures has to be conducted. City master plan and story height of buildings has to be made in a way that does not prevent dominant wind direction of the city.

In the long term, extension of heating with natural gas or central system in districts where contamination is very intensive has to be evaluated from the point of view of economic and technical aspects. On the other hand, gas and dust control, creation of green belts around the city are the important preventions directed to reduce air pollution. Considering that solar energy which is one of the renewable energy sources, alternative plans can be put into practice by holistic approaches [1].

## 3. NOISE

Noise is a problem that affects everyone. A lot of studies have shown that there are permanent hearing problems in persons exposing to high noise levels in long durations. Table 6 designates the ranges of noise levels.

**Table 6.** Noise Levels [7]

| Ranges of noise (Desibel) | Noise Level |
|---|---|
| 0-30 | Very Silent |
| 30-50 | Silent |
| 50-60 | Moderately Noisy |
| 60-70 | Noisy |
| 70-80 | Very Noisy |

### 3.1 Effects of Noise on Human Health

In the case of lower levels or in short durations, it is not easy to determine a significant damage to hearing. But, many research has shown that noise has negative effects on human health, behavior and happiness. In the report published in 1996 by the Organization for Economic Co-operation and Development (OECD), health effects of noise level were indicated [8].

**Table 7.** Noise Level and its Effects on Human Health [8]

| Noise Level | Exposure Range (dBA) | Effects on Health |
|---|---|---|
| 1st degree noises | 30-65 | Confusion, discomfort, anger, sleep disorder and concentration disorder. |
| 2 st degree noises | 65-90 | Physiological reactions; increased blood pressure, acceleration in heartbeat and respiration, decreased pressure in brain fluid, sudden reflexes. |
| 3 st degree noises | 90-120 | Physiological reactions, headaches. |
| 4 st degree noises | 120-140 | Permanent damage to inner ear, disturbance of balance. |
| 5 st degree noises | >140 | Serious brain damage, eardrum explosion. |

#### 3.1.1 Physical Effects of Noise

The negative effects of noise on hearing can be examined temporarily and permanently in two sections. The most common transient effects are temporary hearing loss known as hearing fatigue. Hearing loss is persistent in cases where the effects are very high [8].

### 3.1.2 Physiological Effects of Noise

These are changes in the human body due to noises. Main physiological effects are; muscle stresses, stress, increased blood pressure, heart rate and blood circulation changes, pupil growth, respiratory acceleration, circulatory disorders and sudden reflexes [8].

### 3.1.3 Psychological Effects of Noise

The psychological effects of noise are nerve disorder, fear, discomfort, uneasiness, fatigue and slowness in mental effects. The sudden increase in noise levels can cause fear in humans [8].

### 3.1.4 Effects of Noise on Performance

The effects of noise on performance are termed as reduction of work efficiency and unrecognition of voices. The prevention of functions such as being able to detect and understand speech is largely related to the level of background noise. Studies on the effects of noise on work efficiency and productivity have shown that the complex workplace environment has required quiet and simple noise. In summary, in the case of more background noise for a particular job or function in the workplace, work efficiency was decreased [8].

## 3.2 Noise in Bursa Province

Table 8 shows the distribution of noise complaints in the province of Bursa between 2013 and 2016.

**Table 8.** Distribution of Complaints on Noise in Bursa between 2013 and 2016 (Bursa Metropolitan Municipality, Osmangazi Municipality, Nilüfer Municipality, Yıldırım Municipality) [2,3,5,6]

| BURSA | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|
| **Workplace** | 125 | 125 | 125 | 125 |
| **Entertainment** | 67 | 67 | 67 | 67 |
| **Industry** | 19 | 19 | 19 | 19 |
| **Building site** | 11 | 11 | 11 | 11 |
| **Traffic** | 9 | 9 | 9 | 9 |
| **Other** | 13 | 13 | 13 | 13 |

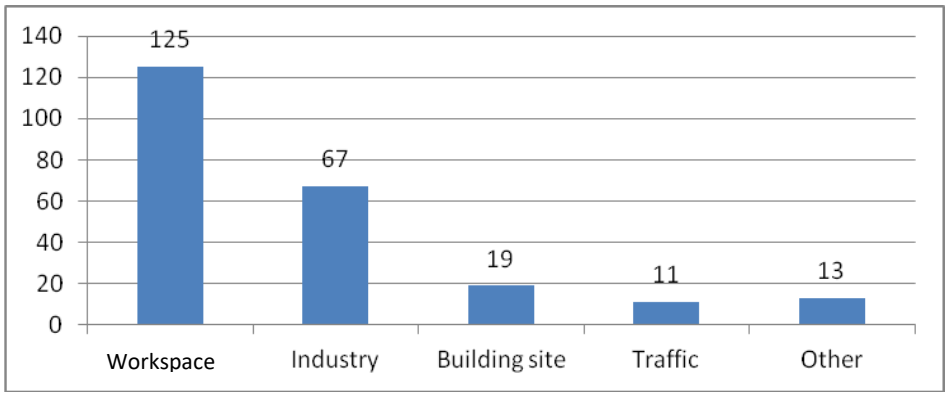


**Figure 1.** The Distribution of Complaints on Noise in the City of Bursa between 2013-2016 (Bursa Metropolitan Municipality, Osmangazi Municipality, Nilufer Municipality, Yıldırım Municipality) [2,3,5,6]

### 3.3 Actions to be taken in regard to Reduce Noise

In environmental policy, reduction and prevention are important recognized rules. First of all, the formation or presence of a source of noise should be controlled or prevented, and then the emissions and the resulting locations should be minimized as far as possible. Countermeasures should be taken for the existing emissions. In the planning and improvement of commercial and industrial facilities, it should also be checked whether the roaring machines or machine parts can be replaced by the quiet ones. The emissions of the machines are also depended on the condition of maintenance. Noise formation can be considerably reduced by the removal of inadequate lubrication, imbalance, loose parts, worn parts (bearings, guides, wheel gears) and the like.

Due to the noise generated by entertainment areas cannot be distinguished easily from the noise generated by industrial facilities; the abatement measures specified for industrial facilities should also be implemented for such facilities. Precautions should be harmonized noise reduction measures should be considered in the planning phase and should be included in the approval documents.

In order to reduce the noise generated by traffic, individual motor vehicle use can be limited in some areas and carrying capacity of public services can be increased, pedestrian walk can be encouraged and attractive and safe bicycle lane can be constructed [9].

It is an important measure to create noise sensitive areas with a good urban planning and away from areas where traffic is intense. Motor vehicles without silencer and other parts of noise-attenuating are not being allowed to hit the roads. Other prevention is to comply to speed limitations in urban areas.

Noise generated by road or building construction equipment at the evening hours in residential areas has not been allowed. Other prohibition to be put on noise pollution is to impose restriction to street weddings and fireworks in residential areas. Also, noise level of television and musical instruments in these areas should be reduced. Construction of airports and industrial areas has to be planned on non-residential areas [9].

## 4.WASTE MANAGEMENT

Waste is a substance generated by production and consumption activities and harmful to human and environmental health with direct or indirect discharge to receiving environment. Waste types are classified as domestic wastes, medical wastes, hazardous wastes, industrial wastes and construction wastes [10].

Waste management is a form of management which includes reduction of waste at its source, separation according to its property, collection, temporary storage, intermediate storage, recovery, transportation, disposal and disposal control and similar operations [6]. When integrated waste management approach in Turkey is analyzed, ‘Solid Waste Control Regulation’ is the starting point of the concept and emphasizes the waste.

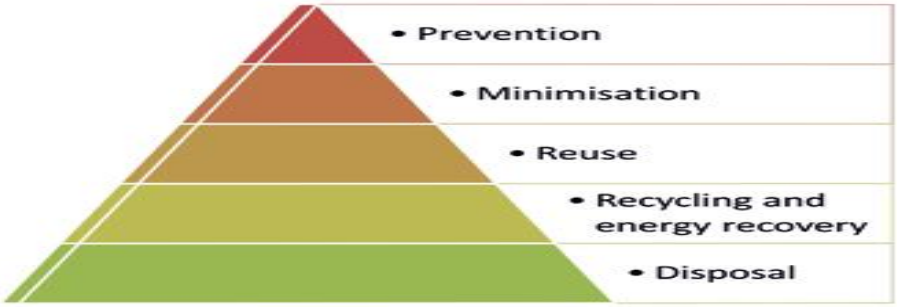


**Figure 2.** Waste Management Pyramid [10]

The issue of waste management in Turkey has gained momentum with the regulations which started to be published in 2003, and nowadays it has turned into integrated waste management strategy. Figure 2 shows the main steps in waste management pyramid [10].

Solid waste management can be defined as a discipline covering the control, collection, accumulation, transportation, transportation, processing and final disposal of solid wastes taking into account the production and consumption habits of the society. It is related to human and environmental health, economy, engineering and conservation. The main purpose of the concept is the ultimate disposal of the unwanted material. Beside, for the best or appropriate waste management system, ‘’Solid Waste Management’’ target should include the following objectives in a way to maintain environmental health, to improve urban environmental quality, to support the efficiency and adequacy of the economy, to generate employment and income, and to ensure the establishment of sustainable solid waste management systems [11].

### 4.1 Bursa Province Waste and Waste Management

#### 4.1.1 Waste Amounts

The amount of wastes generated in the province of Bursa are shown in Table 9.

**Table 9.** Bursa Province Waste Amount [12]

| **Years** | **Population** | **Amount of waste (ton / year)** | **Amount of waste (ton / day)** |
|---|---|---|---|
| **2015** | 2.819.423 | 1.075.822 | 2.947 |
| **2018** | 2.923.359 | 1.192.522 | 3.267 |

| | | | |
|---|---|---|---|
| **2023** | 3.100.754 | 1.413.811 | 3.873 |
| **2035** | 3.499.772 | 2.084.393 | 5.711 |
| **2050** | 3.933.533 | 3.271.467 | 8.963 |

### 4.1.2 Amount of Solid Waste

The amount of solid waste collected in Bursa are shown in Table 10 and the composition of collected solid wastes is also shown in Table 11 respectively.

**Table 10.** Solid Waste Amount in Bursa Province [2,3,4,5,6]

| | **Population** | | **Collected Avg. Solid Waste Mic. (ton / day)** | | **Recovered Avg. Waste Mic. (ton / day)** | | **Produced per capita Waste Mic. (kg / day)** | |
|---|---|---|---|---|---|---|---|---|
| **Years** | **Summer** | **Winter** | **Summer** | **Winter** | **Summer** | **Winter** | **Summer** | **Winter** |
| **2012** | 2 431782 | 2358727 | 10344,7 | 12194,6 | 152,9 | 150,6 | 17,16 | 16,54 |
| **2013** | 2 740970 | 2 740970 | | | | | | |
| **2014** | 2 740970 | 2 740970 | 2352 | 2270 | | | 1,03 | 0,93 |
| **2015** | - | - | - | - | - | - | - | - |
| **2016** | - | - | - | - | - | - | - | - |

**Table 11.** Bursa Province Annual Percentage of Solid Waste Collected by Municipalities [2,3,4,5,6]

| **Years** | **Kitchen Waste** | **Paper** | **Plastic** | **Glass** | **Metal** | **Other Non-Flammable / Other Burners** |
|---|---|---|---|---|---|---|
| **2012** | % 45 | % 28 | % 10 | % 4 | % 2 | % 6 - % 5 |
| **2013** | % 43 | % 29 | % 11 | % 6 | % 3 | % 5 - % 3 |
| **2014** | % 43 | % 29 | % 11 | % 6 | % 3 | % 5 - %3 |

| **Years** | **Organic** | **Paper** | **Plastic** | **Glass** | **Metal** |
|---|---|---|---|---|---|
| **2015** | % 87,88 | % 6,47 | % 2,12 | % 2,68 | % 0,85 |
| **2016** | % 81 | % 10 | % 4 | % 4 | % 1 |

### 4.1.3 Packaging waste quantities

The quantity and recovery percentages of packaging wastes in Bursa province are given in Table 12.

**Table 12.** Bursa Province Between 2012-2016 Packaging Waste Amount And Recovery Percentages [2,3,4,5,6]

| Years | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|
| **Amount of Packaging waste Produced (Kg)** | 319.747.380 | 372.362.974 | 253.440.849 | 649.408.258 | 1.866.061.831 |
| **The amount of package put on the market (Kg)** | 193.241.541 | 283.151.378 | 329.047.058 | 76.632.574 | 403.209.998 |
| **Recovery rates (%)** | 40 | 42 | 44 | 48 | --- |

### 4.1.4 Amount of hazardous waste

The amount and management of hazardous waste in the province of Bursa is shown in Table 13.

**Table 13.** Hazardous Waste Management According to TABS [2,3,4,5,6]

| Years | Total Recovery | Total Disposal | Total On-site | Total Stock | Total Exports | TOTAL |
|---|---|---|---|---|---|---|
| **2012** | 25.288,390 | 4.006,005 | 100,311 | 87,340 | 2,228 | 29.484,27 |
| **2013** | 31.786,902 | 29.756,000 | 492,399 | 80,981 | 0,000 | 61.623,88 |
| **2014** | 52.441,275 | 22.713,072 | 197,159 | 155,93 | 3,922 | 75.314,19 |
| **2015** | 58.652,7 | 9.250 | 39,9 | 1946,8 | 217 | 68.354,7 |
| **2016** | 91.338 | 7.744 | 0 | 2876 | 711 | 102669 |

### 4.1.5 Amount of waste oil

Table 14 shows the amount of waste oil recovery and disposal in Bursa province.

**Table 14.** Waste Oil Recovery and Disposal Amount in Bursa Province (TABS, 2017) [6]

| Years | Recovery (ton) | Additional fuel (ton) | Final disposal (ton) |
|---|---|---|---|
| **2011** | 1.839,268 | 1.650,742 | 121,782 |
| **2012** | 2.093,420 | 1.094,015 | 157,672 |
| **2013** | 2.836,067 | 1.041,825 | 36,006 |
| **2014** | 3.746,553 | 661,676 | 247,168 |
| **2015** | 4.154.8 | 7.71,7 | 678.3 |
| **2016** | 3.734.3 | 2.77.5 | 81.6 |

### 4.1.6 Amount of waste batteries and accumulators

The amount of waste battery and waste batteries collected in Bursa between 2011-2016 is given in Table 15.

**Table 15.** Amount of Waste Battery and Waste Accumulator Collected in Bursa Province (Kg) [6]

| Type | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| **Waste Battery** | 22.220 | 13.845 | 21.798 | 19.472 | 20.277 | 25.786 |
| **Waste Accumulator** | 44.160 | 56.872 | 325.043 | 479.473 | 667.870 | 870.453 |

Recycling of these substances is of great importance. Recycling of wastes have the meaning of possibility of reassessment of wastes with various physical or chemical processes and convertion of them into secondary raw materials. It is defined as retrieval of recyclable waste materials into production proceses as a raw material by recycling technologies. It should be kept in mind that natural resources are finite sources and they will be exhausted if they are not used carefully. Some countries and manufacturers have improved various methods for recycling and reuse of wastes in order to prevent waste of resources and to cope with the energy crises [11].

### 4.3 Actions to be taken on Waste Management

Projects organized by municipalities, public institutions, private and educational institutions intended for solid wastes, packaging wastes, hazardous wastes should be taken into consideration rigorously. Cooperation and communication between municipalities and public institutions and organizations with the public is needed to develop. Contribution in the processes of collection, transportation and disposal of wastes as well as in the reduction of harm to public health and economy is the responsibility of all citizens. It is important to raise awareness among consumers about the recycled products and packaging materials in terms of sustainable consumption and environmental protection. At the same time, promotion of

consumers to buy recycled products labeled in the market is an important action to be taken in waste management [11].

## 5. LAND USE

Since land is the basic place of human activities, it has an important place both in individual and social life and being a finite resource. Therefore, sustainable management of land is needed. Sustainable land management can only be achieved with the existence of a healthy land policy developed in the long run. The most common implementation of land policies is carried out through laws and institutions in accordance with the adopted policies. Therefore, in assessing the effectiveness of a country's land policy, evaluation of the laws and corporate governance on land are the main indicators to be assessed [13].

### 5.1 Bursa Province and Land Use

In order to illustrate the annual variation in the use of land in the province of Bursa, the land use status and land use percentages between the years of 1990 -2012 were shown on Table 16. When the table is assessed, there is an increase in unnatural areas while a decrease in agricultural, forest and semi-natural areas.

**Table 16.** Land Use Status Between 1990 and 2012 (Ministry of Forestry and Water Affairs, Corine Database) [6]

| **BURSA** | **1990** | **1990** | **2000** | **2000** | **2006** | **2006** | **2012** | **2012** |
|---|---|---|---|---|---|---|---|---|
| **Land Class** | hec | % | hec | % | hec | % | hec | % |
| **1)Artificial Areas** | 16.963,21 | 1,57 | 27.326,73 | 2,53 | 33.088,70 | 3,05 | 36.545,6 | 3,38 |
| **2) Agricultural Areas** | 487.909 | 45,25 | 478.993,02 | 44,42 | 479.214.98 | 44,33 | 476.343,27 | 44,06 |
| **3) Forest and Semi-Natural Areas** | 523.724,74 | 48,57 | 522.059,54 | 48,42 | 519.302,95 | 48,04 | 517.241,19 | 47,84 |
| **4) Wetlands** | 4.075,48 | 0,38 | 5.731,16 | 0,53 | 5.643,25 | 0,52 | 5.643,25 | 0,52 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **5) Water Structures** | 45.592,56 | 4,23 | 4.4154,5 | 4,09 | 43.904,61 | 4,06 | 45.304,66 | 4,19 |
| **TOTAL** | 1.078.294,99 | 100 | 1.078.264,95 | 100 | 1.081.074,49 | 100 | 1.081.078 | 100 |

Land variety of Bursa province are shown in Table 17 and land use percentages is indicated in Table 18 between the years of 2012-2016. There can be seen a reduction in agricultural areas within five years.

**Table 17.** Bursa Province Land Use Status Between 2012-2016 [2,3,4,5,6]

| **AREA (ha)** | **2012** | **2013** | **2014** | **2015** | **2016** |
|---|---|---|---|---|---|
| **Farmland** | 365.217,2 | 365.217,2 | 343.872,7 | 340.912,5 | - |
| **Forest and Shrubbery** | 484.067,1 | 484.067,1 | 484.067,1 | 484.067,1 | - |
| **Meadow Pasture** | 24.345,2 | 24.345,2 | 24.345,2 | 24.345,2 | - |
| **Water Surfaces** | 54.912,4 | 54.912,4 | 54.914,5 | 55.291,6 | - |
| **a) Natural Water Surfaces** | 50.595 | 50.594 | 50.595,6 | 50.595,6 | - |
| **b) Stream Surfaces** | 1.466 | 1.466 | 1.466 | 1.466 | - |
| **c) Pond Surfaces** | 239,6 | 239,6 | 317,4 | 684.8 | - |
| **d) Dam and Pond Surfaces** | 2.611,8 | 2.611,8 | 2.535,5 | 2.545,2 | - |
| **Other** | 160.096,1 | 160.096,1 | 181.438,5 | 184.021,6 | - |
| **TOTAL** | 1.088.638 | 1.088.638 | 1.088.638 | 1.088.638 | - |

**Table 18.** Bursa Province Land Use Percentages between the years of 2012-2016 [2,3,4,5,6]

| **Total Area(%)** | **2012** | **2013** | **2014** | **2015** | **2016** |
|---|---|---|---|---|---|
| **Farmland** | 33,53 | 33,53 | 31,6 | 31,3 | 31,1 |
| **Forest and Shrubbery** | 44,47 | 44,47 | 44,5 | 44,5 | 44,7 |
| **Meadow Pasture** | 2,25 | 2,25 | 2,2 | 2,2 | 2,2 |
| **Water Surfaces** | 5,05 | 5,05 | 5,0 | 5,1 | 5,1 |
| **Other** | 14,70 | 14,70 | 16,70 | 16,9 | 16,9 |
| **TOTAL** | 100 | 100 | 100 | 100 | 100 |

### 5.2 Land Use Measures

When the current situation of Bursa province land as indicated in the tables above, Bursa has urgently in need of an effective land use policy including viable land use planning. Land use policy has a strong relationship with agriculture and economic policy. The protection of land tenure is a necessary condition to support the development of the land. National land use policy should be in accordance with responsibility of local institutions and has an important role in the protection of environmental, economic and social costs of deterioration.

In order to meet the needs of the fast-growing population, there are some measures to be taken as to increase in efficiency of land resources, to encourage the sustainable use of land and to establish incentives in order to provide basic infrastructures. Also, the protection of the natural environment and public services supported by taxation and land-based income are other preventive measures to be applied [13].

## 6. GREENHOUSE GAS

Since industrial revolution, humanity has faced the problem of climate change with the intensive use of fossil fuels. The increase in the amount of greenhouse gases generated by the use of fossil fuels that are used directly in the production process has caused climate change. The amount and composition of greenhouse gases have started to change with the industrialization. With the increase in production, the energy requirement, one of the most fundamental inputs of the production process, has increased steadily. Increasing energy needs from fossil fuels such as coal, oil and natural gas has stimulated the climate change. As a result of the burning of fossil fuels, a significant amount of carbon dioxide gas has been released into the atmosphere as a reason increase of carbon dioxide concentration which has the largest share in greenhouse gases. Because of this situation, the composition and density

of greenhouse gases in the atmosphere has been changed and heat permeability of the atmosphere has been prevented leading to the global warming process. In this context, there is a strong connection between energy use, global warming and thus climate change [14].

### 6.1 Bursa Province and Greenhouse Gas

Total greenhouse gas inventory of Bursa are shown in Table 19. The percentage distribution of greenhouse gas inventory is plotted in Figure 3.

**Table 19.** Bursa Total Urban Greenhouse Gas Release Inventory [15]

| BURSA | MWh | $tCO_2e$ | % |
|---|---|---|---|
| **Building Equipment/Energy Consumption in Facility and Industries** | 22.198.338 | 7.929.941 | 61,8 |
| **Energy Consumption in Transportation** | 9.374.422 | 2.491.541 | 19,4 |
| **Other Oscillations** | 0 | 1.565.373 | 12,2 |
| **Energy Production** | 4.143.326 | 838.290 | 6,5 |
| **TOTAL** | **35.715.085** | **12.825.146** | **100** |

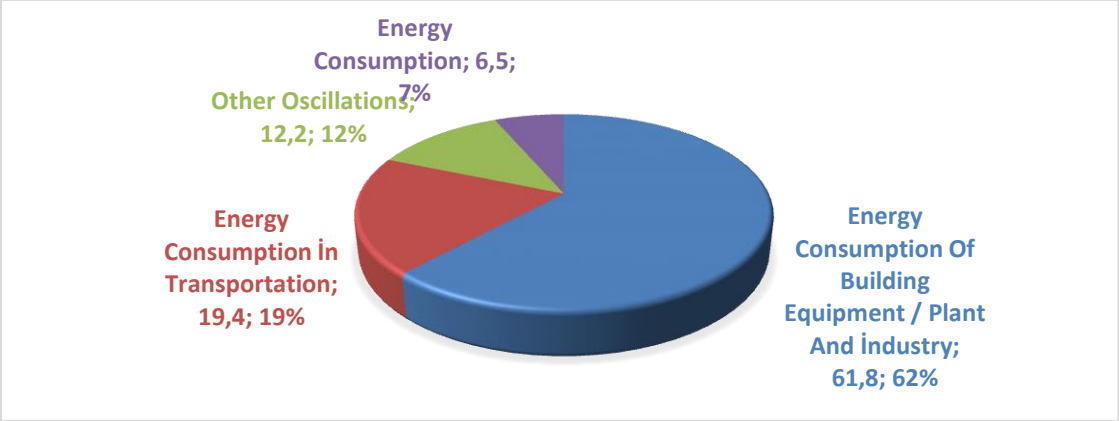


**Figure 3.** The percentage distribution of greenhouse gas inventory of Bursa [15]

The distribution of the greenhouse gas inventory in Bursa and the percentages in total share are shown in Table 20 and in Figure 4.

**Table 20.** Bursa City Urban Greenhouse Gas Inventory 2014, % [15]

| **Inventory Distribution of Bursa Province** | **Ton$CO_2e$** | **%** |
|---|---|---|
| **Industrial, Electricity + Fuel** | 4.072.530 | 32 |
| **Housing, Electricity + Fuel** | 2.612.599 | 20 |
| **Transportation + Bus Station+ Airport** | 2.490.554 | 19 |
| **Commercial, Official, Electrical + Fuel** | 1.246.171 | 10 |
| **Energy Production Facilities** | 838.290 | 6 |
| **Enteric Fermentation and Fertilizer Management** | 769.007 | 6 |
| **Industrial, Process Emissions** | 604.662 | 5 |
| **Wastewater Treatment** | 105.381 | 1 |
| **Solid Waste** | 85.951 | 1 |
| **TOTAL** | **12.825.146** | **100** |
| | | |

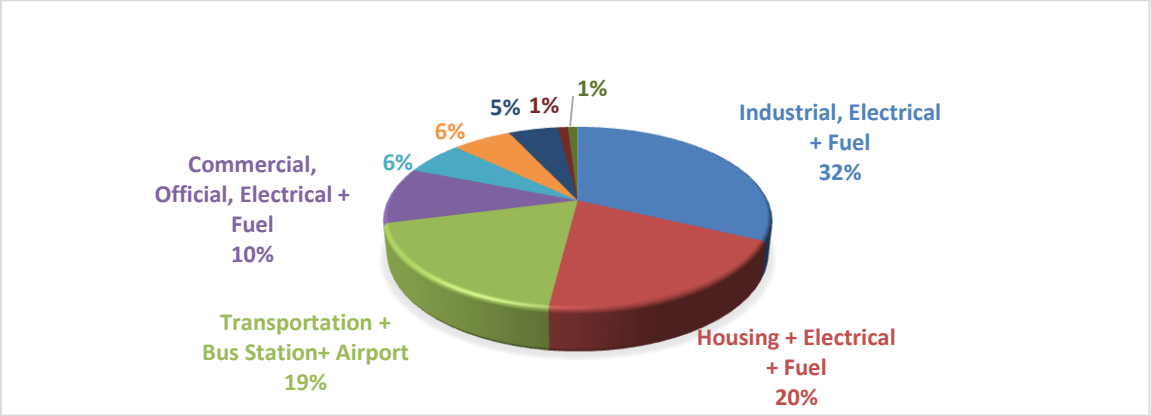


**Figure 4.** Bursa City Urban Greenhouse Gas Inventory 2014, % [15]

### 6.4 Actions to be taken on Greenhouse Gas Reduction

Some preventive measures to be taken in residential areas can be listed as follows; integrated building design, dissemination of photovoltaic systems in buildings, dissemination of distributed power generator applications in collective settlements, increasing energy efficiency in electrical tools and equipment, minimizing energy losses and leaks.

Sustainable transportation systems, dissemination of direct injection and diesel engines, development and dissemination of automotive fuel cells, reduction of emissions with full fuel cycle, development and use of biofuels, development and dissemination of hybrid electric vehicles and dissemination of lightweight building materials are also major precautions to be taken in transportation sector.

In the manufacturing and industrial sector, the expansion of fuel conversion, increase in energy efficiency and savings, use of renewable energy, $CO_2$ capture and improvement of material efficiency were determined as key issues. In waste management, landfill management, the importance of recycling and reuse, digestion process, wastewater management and preventive environmental management are the main actions proposed [16].

## 7. CONCLUSION AND RECOMMENDATIONS

This study has assessed the current situation of air quality, noise, waste management, land use and greenhouse gas problem in Bursa. The content of the research was supported by tables, graphs and figures. It can be concluded that there are studies and action plan taking place for the betterment but in order to comply with national and international standards, a more effective strategic plan is absolutely needed for the city. Both the environment and the related issues should be examined in detail. The stages of the plans should be investigated from the point of technical, social and environmental view in the short, medium and the long-term by the participants of public institutions and relevant partners. Under the leadership of the central government, relevant institutions and organizations, academics, NGOs and the public should be brought close together with participation and implementation.

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