European Journal of Research Development and Sustainability (EJRDS)
Available Online at: https://www.scholarzest.com
Vol. 2 No. 10, OCTOBER 2021,
ISSN: 2660-5570

RAINWATER HARVESTING USING GEOGRAPHIC INFORMATION SYSTEM (GIS) CASE STUDY: GAZA STRIP, PALESTINE

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Article history:

Received: 14th August 2021
Accepted: 11th September 2021
Published: 13th October 2021

Abstract:

The quality of the groundwater has worsened as a result of the present shortfall in the Gaza Strip's water budget. Salinity in the form of chloride ions reached above 1500 mg/liter. In most areas, the groundwater level dropped steadily until it was a few metres below sea level. The average annual precipitation in the Gaza Strip is 350 mm, resulting in a significant quantity of rainwater of 114 million cubic metres per year, of which only 45 million cubic metres naturally soak into the groundwater, while the remainder evaporates or runs into the sea. Rainwater harvesting is required to utilise water for agriculture and aquifer artificial replenishment.
In addition to the arc-map software, the researcher utilised descriptive and analytical methods. This study included all types of rainwater harvesting (rainwater harvesting at the basin level, rainwater harvesting at the agricultural level, and rainwater harvesting from street rooftops). According to the study, the researcher used geographic information systems to determine the optimum locations for ponds to collect and filter rainfall. Rainwater harvesting in urban areas has become an important water resource that plays a key role in improving water resource management. Its potential income in the runoff is approximately 28 million cubic metres per year, with 22 million cubic metres coming from urban areas based solely on current land use.
The study discovered that the study area is suitable for rainwater harvesting, as the majority of filtering ponds feed a large percentage of the underground reservoir. Rainwater harvesting contributes to the agricultural level, alleviating the water crisis for farmers as well as problems with aquifer salinity and power outages. The arc map software, in particular.
Score 5 is concentrated in the north, particularly in Beit Lahiya, whereas degree 4 is spread throughout the North Governorate, Gaza Governorate, the Middle Governorate, and Khan Yunis Governorate. Rainwater harvesting basins will be monitored by municipalities.

Keywords: Rainwater harvesting, Runoff, Multi-criteria, GIS, Gaza Strip and Palestine

I.INTRODUCTION

Given that rain is one of the most significant natural resources in semi-arid and dry settings, the shortage of water resources in Palestine in general and the Gaza Strip in particular is critical to the execution of development programmes and plans. Rain is the sole source of surface water run-off and feeding of the subterranean reservoir in Gaza, and it helps to profit from water collecting (Ajjur, & Mogheir, 2020). Rainwater is only accessible for a few months of the year, and its significance grows in places where other water sources, such as groundwater or surface water, are unavailable. In this situation, rainwater is the most effective in ensuring human, animal, and plant life.

Rainwater harvesting is a concept that aims to collect water in various forms during a specific stage of the hydrological cycle, such as the arrival of rain on roofs of buildings or lands, or even the stage of water flow in the form of torrents, or partial financing for valley and river drainage, or the reservation of river or valley water by building a dam. In the course of its operations, or transformative facilities with the goal of storing and using this water in times of drought or lack of rain (Mushtaha, Van Camp, & Walraevens, 2019).

Traditional rainwater gathering methods are utilised across the Gaza Strip, including collecting water in ponds and watersheds, collecting water from the roofs of agricultural greenhouses where it is used for agricultural reasons, and collecting water from rooftops. Furthermore, the infrastructure for collecting rainfall is inadequate, and the majority of the torrents occur due to this (Abualtayef, Abd Rabou, Afifi, Abd Rabou, Seif, & Masria, 2021). The Mediterranean receives a deluge of rain.

The use of sand dunes with high permeability in the construction of housing units, paving streets, etc., had serious consequences that were reflected in the underground reservoir, and the surfaces of rainwater run-off became impermeable surfaces, resulting in a deficit in the underground reservoir in exchange for an increase in water demand. Water that caused sea water to intrude and move towards the coastal area displacement of fresh water and replacement of salt water (Zohar, & Erickson-Gini, 2020).

Rainwater harvesting from basins to collect and filter rainwater, rainwater harvesting at the agricultural level, and rainwater harvesting from roofs are all investigated in this study, as well as the use of GIS technology in the study region with digital, hydrological, and morphological data. Furthermore, every economy's water sector is inextricably connected to poverty alleviation, particularly in emerging nations where the rural economy is heavily reliant. Water shortage in the municipal, industrial, and agricultural sectors has exacerbated food insecurity, health issues, poverty, and a lack of basic socioeconomic amenities in third-world nations.

As a result, tackling water scarcity problems holistically would help to achieve the Millennium Development Goals. This is true because rising demand affects environmental sustainability in areas where water is scarce (e.g., arid and semi-arid regions), and water availability is also critical for environmental and socio-economic sustainability. The primary issue in managing water resources, however, is the fragmentation of many industries and civilizations. This issue must be handled holistically in the context of the whole water framework, which must include the idea of integrated water resource management (El-Hallaq, 2021). The fast depletion and deterioration of current water supplies in quickly expanding cities of developing nations in general, and the Gaza Strip in particular, has come from the extraordinary rise in population, urbanisation, and agricultural activity in recent times. Climate change, which is projected to worsen water shortages, has been added to these issues. Over the next 100 years, it will have an impact on the hydrological cycle, resulting in increased precipitation, evaporation, the incidence and frequency of storm water events, and substantial changes in bio-biochemical processes influencing water quality (Siam, Al-Khatib, Anayah, Jodeh, Hanbali, Khalaf, & Deghles, 2019; Abukashif, & Riza, 2019). The reality is also a major source of worry.

According to Ghazi Al-Sourani (Mushtaha, Van Camp, & Walraevens, 2019), the amount of water extracted from the Gaza Strip's coastal basin reached 167.2 million cubic metres in 2016, and this amount is considered unjust pumping because 97 percent of the water does not meet international health standards for drinking water.

The salinization of the coastal aquifer is exacerbated by one or a combination of mechanisms, such as saltwater intrusion, salty water supply from deeper sections of the aquifer, and sewage intrusion (El-Hallaq, & Odwan, 2018). Furthermore, Gaza Strip would need 212 MCM of fresh water by 2025 to satisfy local and agricultural demand, which groundwater supplies will be unable to supply. Based on the above, rainwater collecting at the local level is a suitable coping technique against natural stress. To keep up with the growth of anthropogenic water resources, the researcher utilised GIS technology to simplify the identification of suitable locations to construct watersheds.

II.STUDY AREA

The Gaza Strip is part of the State of Palestine, and it stretches along the Mediterranean Sea's eastern coast for 51 kilometres, with Egypt to the southwest for 11 kilometres and the 1948 armistice line (the areas seized by Israel) in the southeast and northeast. The Gaza Strip is a transitional zone between the semi-humid coastal regions in the north, the semi-arid region in the east, and the Sinai desert in the south, located between latitude (31°25′59′′N) and longitude (34°22′34′′E). As indicated in Map No. 1, the Gaza Strip has a total area of (365) km (2), a length of (42) km, and a width that ranges between (6) km in the centre and (12) km in the southern portion of the territory (1).

Map 1: Place of The Study Gaza Strip

III.WEIGHTED OVERLAY METHOD

The ARC GIS software will be used to deal with these layers. The two techniques include determining the optimum locations for rainwater collection. The first approach is to utilise ARC TOOL BOX to create a weighted overlay. The second approach involves using Model Bulder in conjunction with ARC TOOL BOX in the ARC GIS software. Figure out how many stages there are in Weighted Overlay.

To begin, we utilise the Arc Toolbox, which is a collection of geoprocessing tools for data analysis, editing, and transformation. Each toolbox includes its own collection of specialised spatial analytic tools, and some toolboxes are included in the standard ArcGIS installation. Others, on the other hand, are accessible as ArcGIS extensions and add-ons. Overlay that is weighted the overlay of multiple raster data using a similar scale and weights for each according to its significance is known as a weighted overlay.

The floating-point floating point must first be transformed to a raster integer before it can be utilised in weighted overlay, and reclassification tools offer an efficient method to do so. A new value is given to each value category in the input raster data based on the Rating Scale. The original input values have been reclassified into these new values. As illustrated in Figure 1: Steps in the Weighted Overlay Method, a limited value is utilised to exclude regions from the study. The stages involved in the weighted superposition technique are shown in Figure 1.

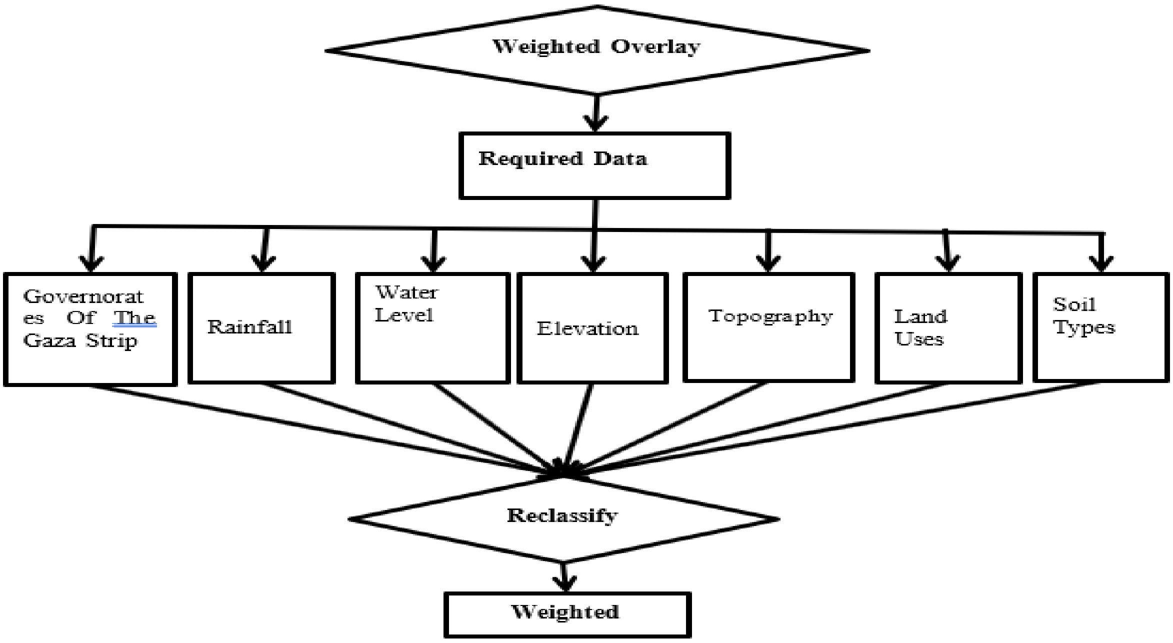
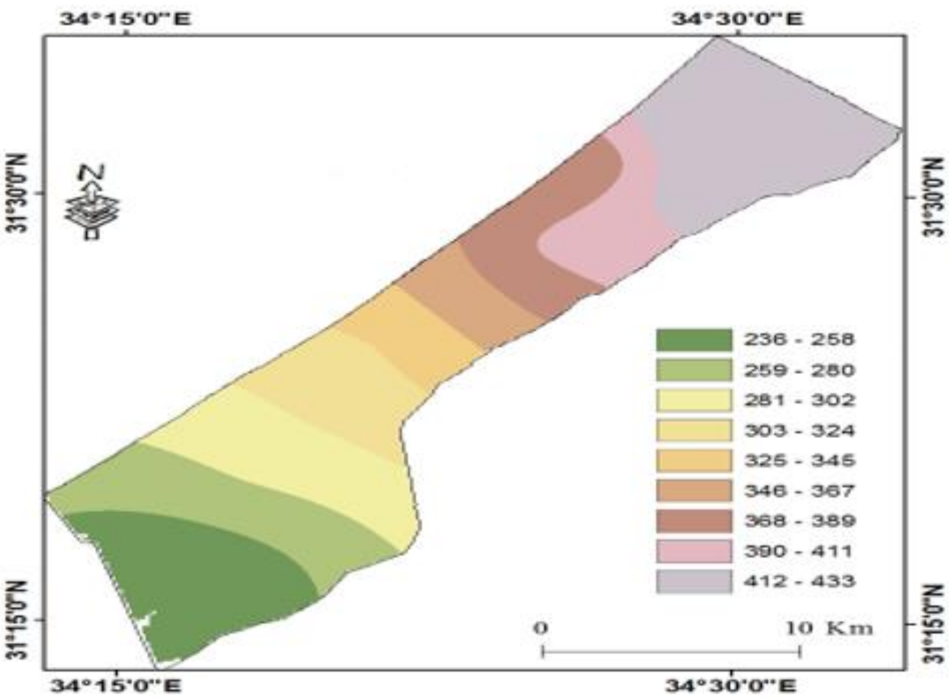


Figure 1: Steps Involved Weighted Superposition Method

IV.DISTRIBUTION OF AVERAGE RAINFALL OVER THE GAZA STRIP

The rainfall layer represents the distribution of average rainfall over the Gaza Strip as determined by the kriging tool from analyst tools, where the 3D analysis toolbox provides a collection of geoprocessing tools for a wide range of analysis, data management, and data transformation on surface models and 3D vector data.

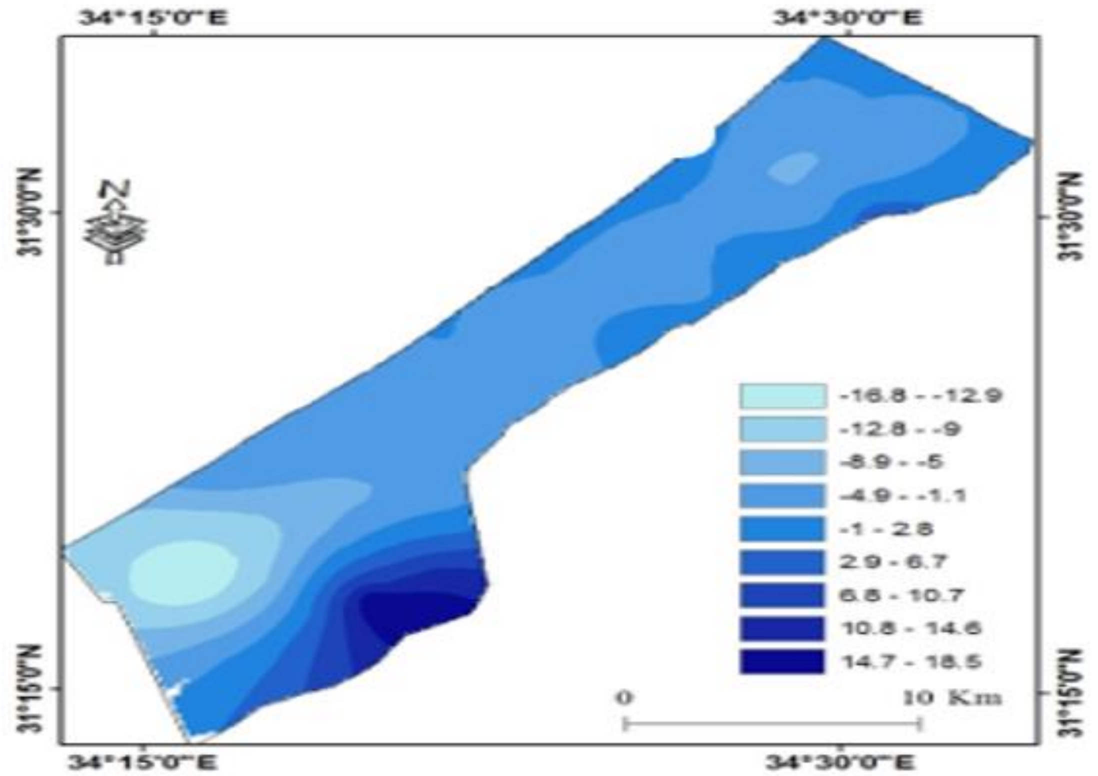
Surface data may be created and analysed using 3D analysis tools in raster, terrain, TIN, and LAS forms. 3D data can be translated from a wide range of formats, including Collada, lidar, SketchUp, Open Flight, and many more. Other services offered by 3D analysis tools include study of geometric connections and feature characteristics, raster interpolation, and different trigonometric irregular network (TIN) models, as well as surface property analysis. Using the kriging technique, Map 2 depicts the distribution of rainfall rates across the Gaza Strip.



Map 2 showing the distribution of rainfall rates in the Gaza Strip using the kriging method for the year 2019

V.GROUNDWATER WATER LEVEL

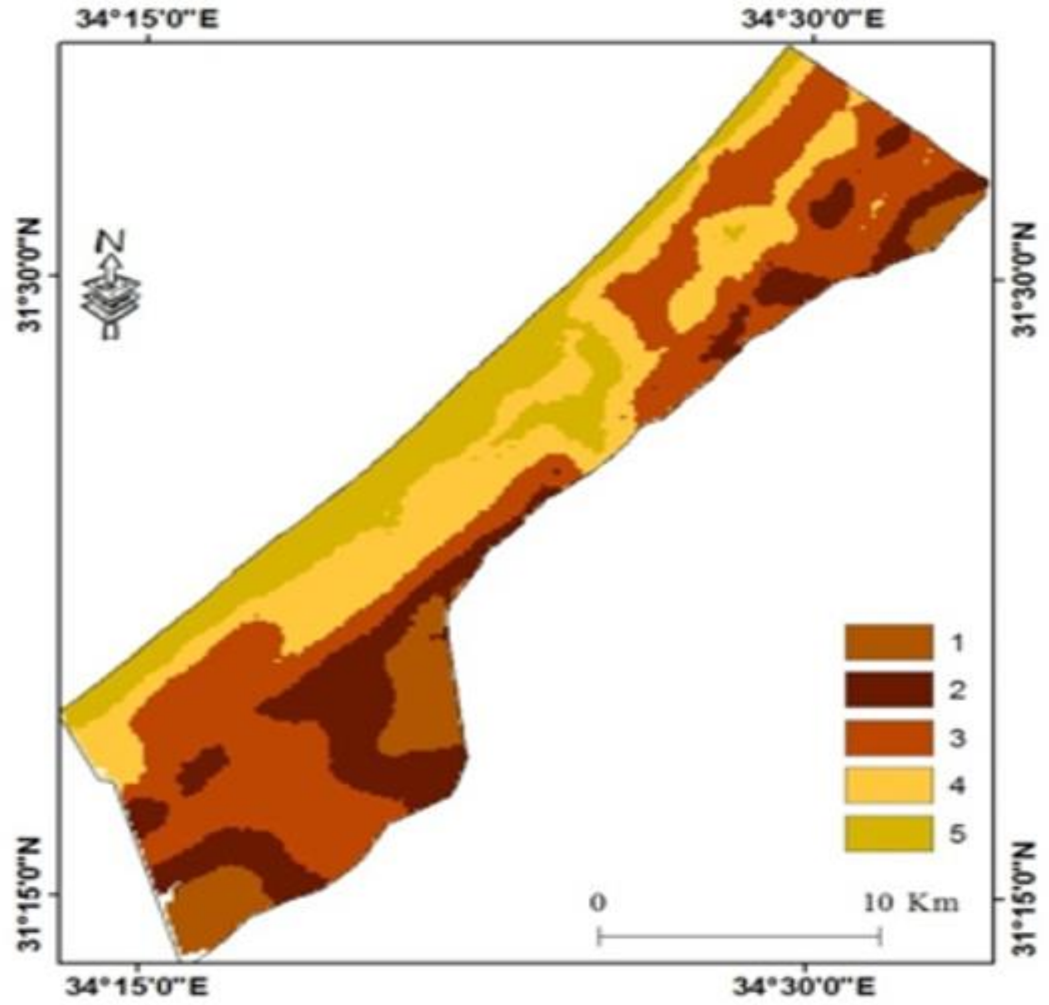
It is noted from the map that the areas in which the groundwater level is low are concentrated in the south, specifically, the city of Rafah, where the level reaches (-12.9 -16.8) as a result of excessive and unfollowed withdrawal from the responsible authorities, while the level (-1.1 - -4.9) is concentrated in all governorates from Khan Yunis through In Wasta, Gaza Governorate, and North Governorate, as shown in Map 3 showing the groundwater level in the Gaza Strip using the kriging method.



Map 3: Groundwater Water Level

VI.TOPOGRAPHY OF THE GAZA STRIP USING THE RECLASSIFY TOOL

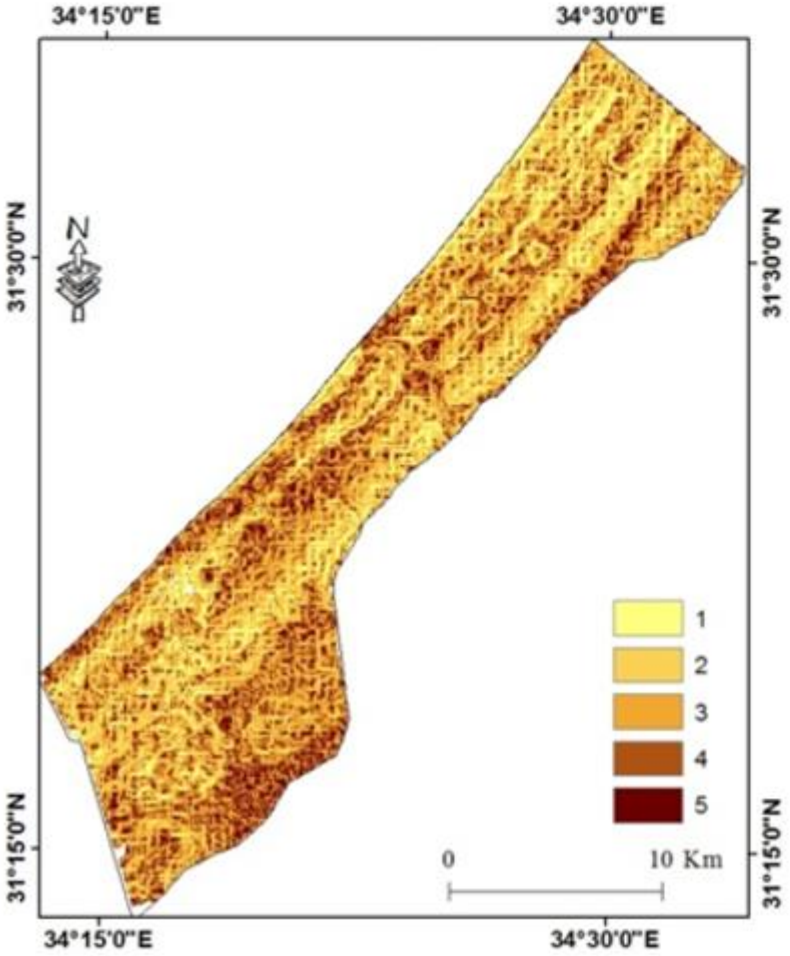
It is noted from the map that degree No. 5.4 is the deepest and most affected area from the rest of the Gaza Strip and is located in the eastern region of Rafah Governorate, while degree No. 3 is concentrated in Gaza Governorate, Al Wusta Governorate and the North Governorate. Map 4 shows the topography of the Gaza Strip using the reclassify tool. Map 18 showing the topography of the Gaza Strip using the reclassify tool.



Map 4: Topography Of The Gaza Strip Using The Reclassify Tool

VII.REGRESSIONS IN THE GAZA STRIP USING THE RECLASSIFY TOOL

Also, the regression map using reclassify, where it is known that the regression goes from the eastern regions to the western regions. Map 5 shows the regressions in the Gaza Strip using the reclassify tool.

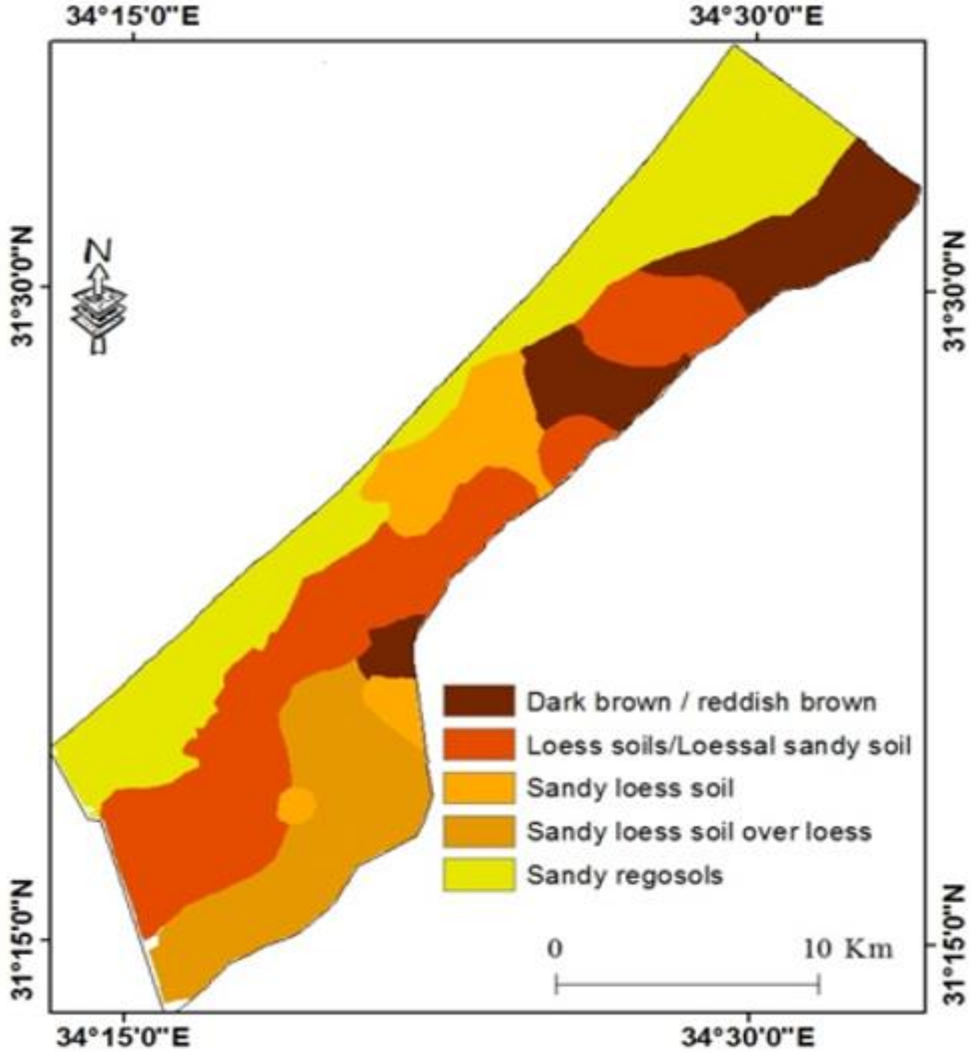


Map 5: Regressions In The Gaza Strip Using The Reclassify Tool

VIII.SOIL TYPES IN THE GAZA STRIP USING THE RECLASSIFY TOOL

Grade No. 5 was assigned to the coastal area, particularly in the Al-Mawasi region, which stretches from Deir Al-Balah to Rafah, which is sandy soil, while degree No. 1 is focused in the eastern parts, which is clay soil, using reclassification in the topographic map 6 of the Gaza Strip.

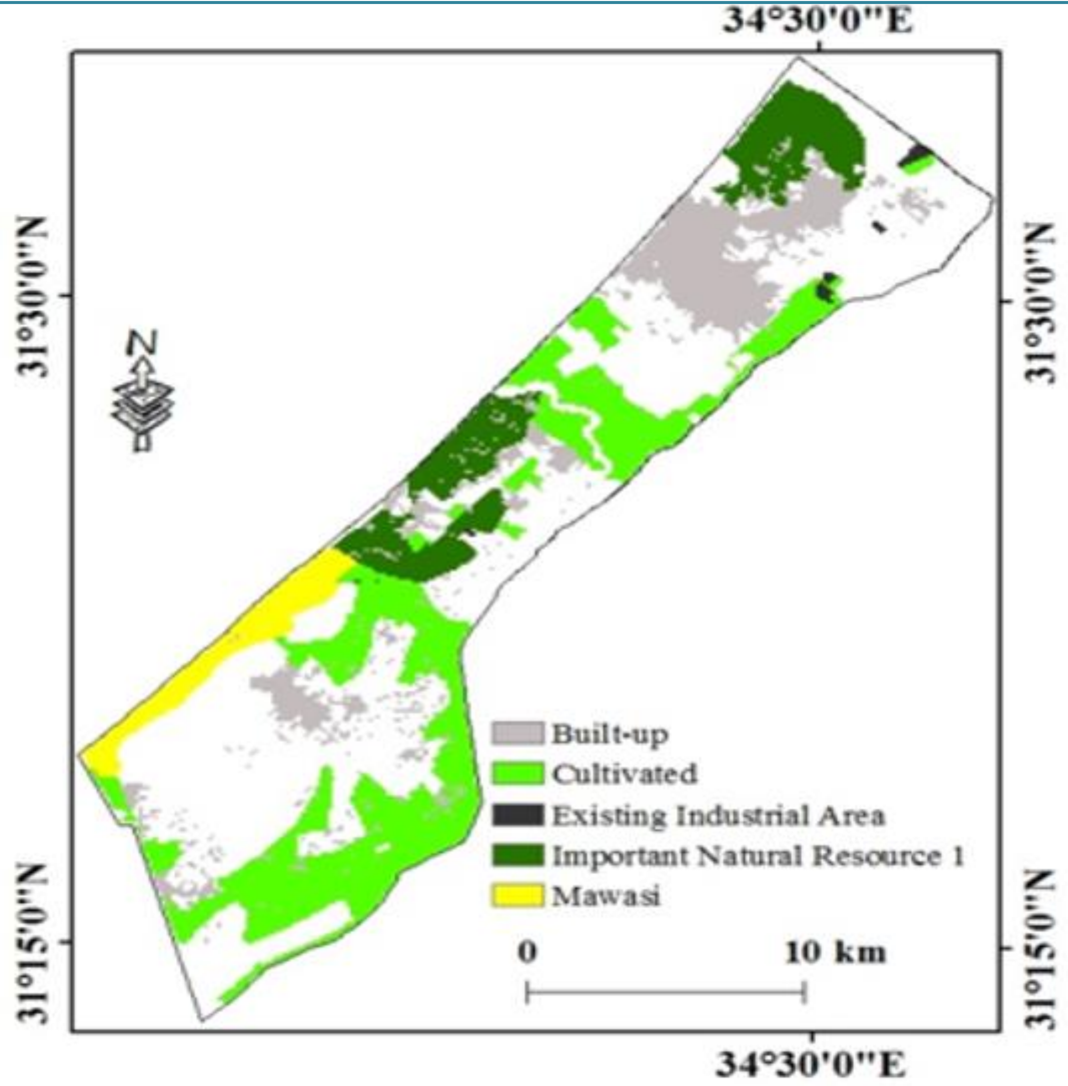
The soil types were dispersed in the Gaza Strip using the reclassification tool, with sandy regosols spread in yellow in the western region, the coastal plain area, al-Mawasi area, and the sand dunes area in Gaza and the north, and sandy loess soil over loess spread in dark orange in Gaza and the north. The clay soil in the eastern parts of the North and Gaza governorates is dark brown / raddish brown, according to Gaza Valley logic.



Map 6: Soil Types In The Gaza Strip Using The Reclassify

IX.LAND USES IN THE GAZA STRIP USING THE RECLASSIFY TOOL

The map 7, of land uses using the reclassify tool shows the distribution of built-up areas of gray color, which are concentrated in the city centers and the most concentrated in Gaza City. As for the cultivated areas of light green color, they are concentrated in the outskirts of the cities, while the important natural resources and forests of dark green color are concentrated in the governorate middle.

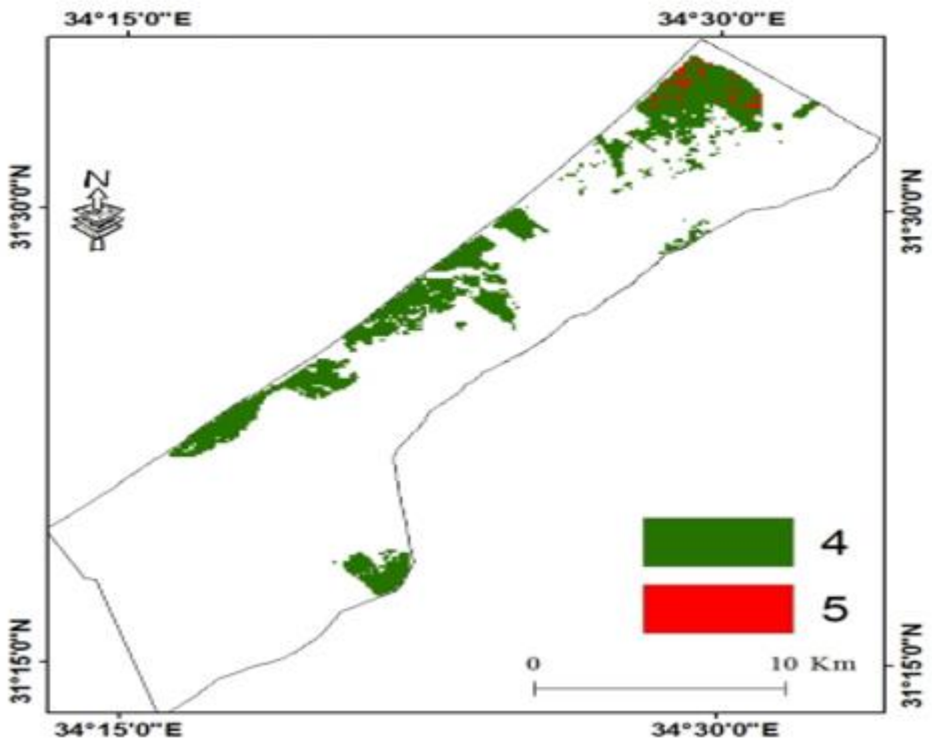


Map 7: Land Uses In The Gaza Strip Using The Reclassify Tool

X.BEST LOCATIONS FOR HARVESTING RAINWATER GRADE 4,5

We note from map No. 8 that degree 5 is concentrated in the North Governorate, while No. 4 is distributed over the governorates of Gaza, the Middle, Khan Yunis, and the North, while degree 3 is distributed over all the governorates. The researcher indicates that No. (4,3,2,1,5) is the best because These are natural areas for rainwater harvesting.

On the other hand, the northern region is the highest in the amount of rainfall, where the average rainfall is estimated at 420 mm annually in 2019, and this rainfall decreases as we head south due to the impact of the southern governorates on the Negev desert and the Sinai desert.



Map 8: Showing The Best Locations For Harvesting Rainwater Grade 4,5

XI.SUITABLE AREAS FOR RAINWATER HARVESTING IN SQUARE KILOMETERS

Through map 8, we extract the areas of areas that could be suitable areas for rainwater harvesting, as shown in the table that separates each governorate and its area in square kilometers Table 1.

Table 1: Suitable Areas For Rainwater Harvesting

Governorate	Area / km2
North	1.546672
Gaza	7.624069
middle	15.597416
Khan Younes	5.382311
Total	30.15047

XII.RESULTS AND DISCUSSION

This study also shown how rainwater harvesting systems have a long-term and beneficial influence on rainfall management by decreasing the risk of water contamination, improving water conservation, and being cost-effective when compared to conventional rainwater systems. The research's thesis was built on the natural features of the studied region. By providing a literature study on sustainability, Gaza Strip topography and the shape of the Gaza Strip aquifer, water sources, aquifer recharge amount, and surface water. In terms of sustainability, all of these issues are connected. To avoid issues connected with future population increase, changes in land use or urbanisation, and many communities flooding, choices must be taken on a local scale based on an awareness of macro-sustainability effects. The water crisis, for example, is causing damage to the aquifer in Gaza Strip rainfall collecting and filtering basins due to salt and seawater intrusion. Floods have resulted from paved roads and an increase in concrete area, as well as a lack of aquifer filtration, exacerbating the water problem. Geographic information systems were utilised in this study to measure areas, create a comprehensive map of the Gaza Strip, and input correct data, in order to stay up with the progress in scientific research and the application of the newest technology. Rain, filtration, and rainwater collection on agricultural land, followed by rooftop rainwater harvesting. Furthermore, It's an excellent situation for researching pond placements, water collecting, and housing conditions for urban rainwater harvesting systems. There is an intriguing connection between urban development and the proportion of rainfall run-off on the surface. The infrastructure's potential environmental effect and the usage of rainwater collecting, Water harvesting has a major impact on the preservation of the plant environment, followed by the animal ecosystem, since an increase in salt and substantial pollution in the water causes many kinds of plants to die. It was discovered throughout the research that rainfall was collected and either pumped into the aquifer or utilised for agricultural reasons. Establishing tree and grassland spaces that may be used as parks and leisure places for Gaza Strip inhabitants.

XIII.RAINWATER HARVESTING ECONOMIC ANALYSIS

The cost of a rainwater collecting system is affected by the size and kind of basin. This cost is cheap when selecting the appropriate natural location by studying rainwater harvesting and understanding natural rainwater collection locations, as the research found that the higher the drop, the lower the financial cost for many reasons. HACCP Only three variables are needed for a quick environmental evaluation of the rainwater collecting system. First and foremost, the proper scale must be determined. In order to evaluate the possible environmental effect of rainwater collecting, it is also necessary to know the water supply-demand ratio, water storage capacity, and storage capacity. Water scarcity and rooftop rainwater harvesting (Mohanty, Bardhan, & Dey, 2020)

The research also revealed that fresh water is in limited supply in Gaza and that there is a significant water harvest in urban areas with poor filtering rates. The research discovered the significance of collecting rainwater from building rooftops, as towns must consider the usage of rainwater channels in the development of new communities. comparable to it, but from the roofs of greenhouses in agricultural regions. Using ARC-GIS10.1 to Find the Best Places to Harvest Rainwater (Lancaster, 2019)

Rainwater harvesting in Gaza and the development of different studies (technical, economic, environmental, and social) to evaluate the long-term viability of water resources. The study collecting data, followed by the researcher entering the data into the GIS programme by entering the layer of soil type, land use, average rainfall layer, groundwater level, topography of the Gaza Strip, and surface slope are the most sensitive variables, according to the analysis and assumptions of the model. The researcher utilised two weighted matching techniques, one of which was to construct a MODEL BUILDER model, and the other was to use two weighted matching methods. According to the model, the North Governorate is one of the finest governorates in the Gaza Strip for the building of rainwater collecting basins, and this is owing to the North Governorate's high rainfall.

XIV.RECOMMENDATIONS

There are many methods to expand on the findings of this study. The following are some of the researcher's suggestions:

(1) Increasing the use of geographic information systems to better anticipate the optimum locations to gather rainwater using geo-metrological data.

(2) Conduct a thorough economic study of rainwater harvesting projects and evaluate rainfall technologies using a cost-benefit financial analysis. In order to evaluate the life cycle analysis of RWHS in contrast to alternative choices, a complete economic analysis should be conducted (eg rainwater infrastructure network, rainwater injection sites, green roofs, etc.). The expenses of maintaining the basins and the rainwater infrastructure network must be factored in.

(3) Developing codes for water harvesting areas in the Gaza Strip, given the current lack of knowledge and experience in this area, to be used by the Palestinian Water Authority, the Coastal Municipalities Water Authority, institutions involved in the Gaza Strip's water sector, and Gaza Strip municipalities.

(4) Developing a strategic plan to improve and develop the Gaza Strip's water management objectives through a comprehensive water management programme that leads to large-scale water conservation and the adoption of a variety of sustainable rainwater practises, as well as seeking grants to fund sustainable water management projects.

(5) Integrated management between municipal councils to monitor and supervise rainwater collection and filtration basins before the commencement of the winter season via training courses and monitoring and supervising rainwater collection and filtration basins.

- The following suggestions may be summarised in this paragraph.
- Creating databases pertaining to the Gaza Strip's different water resources.
- Incorporation of the findings gained via these methods into the formulation of water security policies and plans.
- The importance of taking use of this research in institutions, universities, and specialised scientific institutes.
- Work on creating technological methods to enhance the capability of employees in different institutions by using geographic information systems and establishing specialised units for monitoring and deducing natural variables (climate changes, floods, land uses....etc)
- Effective security of rainwater collecting and filter basins via the installation of strong fences and pumps to fulfil the requirement to drain water from the basin during floods, as well as the presence of basin guards.
- Develop backup plans for towns and decision-makers to utilise in the event of an emergency or catastrophe.
- Organizing instructional seminars on rainwater and rainwater collecting and filtration basins in all Gaza Strip municipalities in collaboration with the Coastal Municipalities Authority, the Palestinian Water Authority, and the water ministries.

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