Peertechz

Journal of Civil Engineering and Environmental Sciences
ENGINEERING GROUP
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Open Access Journal
ISSN: 2455-488X DOI: https://dx.doi.org/10.17352/jcees

Short communication

Use of water resources and sustainability with concepts, definitions and examples

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Received: 08 April, 2024
Accepted: 23 April, 2024
Published: 24 April, 2024

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Keywords: AHP; GIS; Global warming; Remote Sensing technique; Water resources; Watershed modeling

Abstract

Water is a vital resource for all living things (people, ecosystems, economic development, energy production, national security). Coordination and harmony in spatial and intersectoral planning and decision-making processes can be achieved through the rational and sustainable use of water resources. Protection and sustainable use of water resources is extremely important. Nowadays, problems such as drought and water pollution arise due to global warming and increasing environmental pollution. This situation reduces drinking water resources. Serious measures need to be taken worldwide to ensure the continuity of life protect water resources from drought and keep them clean. Techniques used to evaluate the potential of water resources, which have become increasingly important in recent years, and to create conscious use of water resources, require effective data systems. Currently used systems do not represent very large areas. For this reason, it is necessary to develop representative methods by integrating the data received from ground stations and the parameters of remote sensing techniques. Many extensions of the programs, which are widely used in the world and evaluated using Geographic Information System (GIS) supported Analytical Hierarchy Process (AHP) methods in database studies for the use of water resources, are extremely useful for basin modeling. The purpose of this study; It is a study on the potential of GIS-based multivariate statistics for evaluating the use and sustainability of water resources and the use of water stored in a geographical database.

Introduction

Precipitation per unit area, a measure of the corresponding spatial distribution of the world's water resources, is strongly correlated with denser populations. This finding is readily explained by the fact that one of the key factors influencing food production capacity and, thus, future population expansion is water. The majority of people reside near rivers or other easily accessible water sources. However, as the world's population and economy rise, so does the need for water, and the natural water cycle's ability to replenish this essential resource is dwindling. In response to this seeming contradiction between the finite supply of natural water and the growing water demand of human society, the concept of sustainable water resources was established [1].

In addition to its fundamental role in ecology, water also serves as a social and economic resource. The need for water resources in sufficient quantity and quality for human consumption, sanitation, agricultural irrigation, and production will increase as the world population increases and urbanization, industrial, and commercial expansion accelerates [2]. Water is life's river; it affects everything from human strength to the health of the surrounding natural ecosystems, from the fields of farmers to the manufacturing of consumer goods. While making economic and social decisions about the allocation and use of water, it is imperative that sustainability efforts fully consider the state and functioning of aquatic ecosystems as well as the environmental value of watersheds [3].

Through the coordination and integration of spatial and intersectoral planning and decision-making processes, it is possible to ensure the rational and sustainable use of water resources. When it comes to managing water resources,

Citation: Aslan V (2024) Use of water resources and sustainability with concepts, definitions and examples. J Civil Eng Environ Sci 10(1): 021-025. DOI: https://dx.doi.org/10.17352/2455-488X.000079

there are two main concerns: safeguarding the supplies and sustainably managing their usage [4].

The amount of freshwater that can be used in the world is 3.5% of the total water. 1.74% of this amount is in solid form in glaciers, and 97% of the remaining water consists of groundwater. Only 3.5% of available water can be used. If oceans, seas, and polar ice caps remain on one side, the amount of usable freshwater remains in lakes and streams [5].

With the rapid growth of the world population and the increasing demand for water, struggles, and conflicts on economic, political, and environmental issues have become much more common and serious. Especially in the last 20 years, the increasing human population and the resulting increasing demand for water have brought about a global water crisis. Water resources; It faces many serious problems in terms of quantity, quality, and all other sectoral uses.

Water use is an indicator of development. While agricultural water use is around 70 percent in underdeveloped countries, non-agricultural water use reaches 65 percent in developed countries. The existing water potential used by sectors is polluted. Freshwater, which is quite limited and valuable, is irreversibly polluted, especially as a result of the lack of treatment of industrial and domestic wastes. One liter of untreated wastewater pollutes eight liters of clean water and makes it unusable. However, obtaining clean water from dirty water requires great costs [6].

Streams that are about to dry up due to irrigation, lakes that have lost their natural boundaries as a result of the opening of artesian waters and the withdrawal of groundwater, and streams that have become incalculably polluted cause major conflicts in the sharing of water. For this reason, it causes major conflicts in sharing the remaining amount of fresh water [7].

Ecological restoration, improvement of water quality, and creation and management of mechanisms that will rearrange water consumption according to industrial, agricultural, and natural needs have an important place in the management of water resources. In this context, existing and planned projects need to be reviewed. The solution to water-sharing problems lies in creating basin management plans to be managed by boards where all parties are represented [8].

This issue was addressed to contribute to regional or country planning by determining the usage potential, efficient and effective use, and sustainability of water resources, analyzing the collected data, and offering solutions to the problems based on the findings obtained.

Definition of sustainable water resources

The management of water flow to ensure water availability and quality for as long as the existing climate persists is known as the sustainability of water resources. Four interconnected stages explain this definition:

A) **Phase one:** The water flow from a sustainable water source is determined by the hydrological cycle, which represents the water supply's natural rate of renewal. The amount of water stored does not determine a sustainable water supply. When it comes to groundwater aquifers, natural lakes, and artificial reservoirs, this divergence is very crucial. The rate at which a groundwater aquifer recharges determines how valuable the aquifer is as a source of water. It is more reasonable to use the hydrological notion of the aquifer as a reservoir for water in this instance rather than the geological definition of the aquifer as a formation that holds water. Analogously, flow into artificial and natural reservoirs is a crucial factor to take into account while evaluating the corresponding sustainable water supply [9].

B) **Phase two:** Water quality is an important factor to consider when determining whether a water source is sustainable. Water accessibility and quality are equally crucial. These two problems are not, however, unrelated to one another. The benefit of an abundance of nutrients may be limited by aquifer contamination. However, excessive extraction from an aquifer can lead to a decline in water quality, which can reduce the water supply's usefulness.

C) **Phase three:** The sustainability of a water source depends largely on how it is managed. Water management practices are not sustainable when used without consideration of the corresponding replenishment rate of water stored in any reservoir. The long-term availability and quality of the water supply should be the goal of sound management techniques. This is the only way to achieve sustainability. Otherwise, the quality of water and its availability for future generations will be endangered.

D) **Phase four:** It is emphasized that there is a clear relationship between climate change and the sustainability of water resources. One of the most significant impacts of climate change is its potential to alter how sustainable water resources are distributed. In the case of climate change, a water source that is deemed sustainable under the existing conditions might no longer be so. The dominant climate regime affects the distribution of precipitation as well as other significant hydrological variables, like river flow and recharge.

Dangers to the water resources sustainability

There are three main threats to sustainable water supply; these are the negative effects of climate change, water pollution, and water resources management practices. The notion of sustainable water resources forms the basis for these dangers.

Changing climate: Water moves from the atmosphere to the surface as precipitation, which is a significant climatic variable. Rainfall rate determines all other significant hydrological variables, including recharge and river flow. The distribution of precipitation and, by extension, all other key hydrological

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variables in the water cycle, including river flow and groundwater recharge, will probably alter in response to any considerable change in climate. Therefore, the sustainability of water supplies may be threatened by climate change. That being said, this might not hold in every situation involving climate change. There is a good chance that the impacted area will have more sustainable water supplies if climate change causes the distribution of precipitation to move toward wetter circumstances.

The parameter that guarantees the passage of water from the atmosphere to the surface and constitutes a significant climate variable is the amount of precipitation, which is proportionate to significant hydrological variables like river flow and recharge. Changes in the distribution of precipitation associated with significant climate change are expected to affect the distribution of key hydrological variables including river flow and groundwater recharge across the water cycle.

Climate change can have both natural and human-caused causes. Significant alterations in the global environment are caused by human activity, emissions of greenhouse gases that modify the chemical makeup of the atmosphere, and deforestation and desertification that result in changes in the land cover of the planet. Significant climatic changes that could affect how sustainably available water is distributed may be caused by these human activities.

Pollution of water: The sustainability of water resources may be seriously threatened by any human activity that alters the hydrological cycle's water quality. These actions by humans;

- Acid rain is caused by industrial emissions that pollute the air.
- Contamination of runoff from hazardous chemicals such as pesticides due to drainage from implemented irrigation schemes.
- Lake and groundwater pollution brought on by discharges of industrial waste.

Sustainable water resources may be shielded from these dangers by implementing pollution control strategies and creating technology for contaminated areas to be treated.

Non-sustainable methods of management: It is a method of managing water resources that puts short-term gains first and overlooks long-term effects that directly jeopardize the resource's sustainability:

The management of groundwater reservoirs that permit excessive water pumping at rates higher than the rate of groundwater recharge, leading to a notable drop in the aquifer's water level,

Developing and overseeing dam and reservoir structures with operational guidelines that optimize water utilization without causing sediment build-up, thereby restricting the reservoir's lifespan,

Handling irrigation schedules to optimize immediate gains without giving due thought to salt buildup in the topsoil layer, which can contaminate soil and water supplies.

Data and methods

This study used geological, hydrological, and other available information, as well as remote sensing images from various sensors, to identify potential water source locations. Ten effective thematic maps such as elevation, drainage density, slope, precipitation, lineaments, fault density, as well as auxiliary data obtained through remote sensing such as geology, geomorphology, land use, and soil class, have been integrated using GIS. Based on GIS GIS-assisted AHP method these methods were used to visualize images to process remote sensing.

Digital Elevation Models (DEMs) have a resolution of 30 m. Drainage density was created using the DEM technique in the GIS software program environment.

Methodology

In the study, indicators regarding water use and management were determined. To do this, a comprehensive revision of specific literature review indicators on water use and management was carried out. Indicators were classified within the framework of GIS and an evaluation matrix was created according to the AHP method, including their definitions and explanations.

GIS software application in water resources

GIS, a data management tool, is a program that develops a hydrological model using remote sensing methods. GIS includes topics such as agricultural land mapping, statewide open space planning, coastal use studies, power plant siting, water quality studies, oil spill contingency plans, and habitat studies.

GIS is important for water resources managers. Because base maps can show several related data layers. It is an important program to produce layers for each water class (I, II, III, IV), one showing waters that meet the standards and the other showing waters that meet the standards. Researchers have added many layers over time, including oyster and clam beds open and close to the fishing grounds and distribution. It can show the flow of aerial photographs, field surveys and existing map data through analysis and planning with GIS. Additionally, by showing map examples at each step, it can provide data with higher spatio-temporal resolution and accuracy. With this program, more numbers can be calculated in a short time with less cost and are much more easily accessible [10]. It can perform many geoprocessing operations commonly found in GIS software;

- ✓ Capturing data through digitization
- ✓ Converting data from vector to raster format
- ✓ Reducing data size by eliminating dots and lines
- ✓ Detect and edit errors in ArcMap data

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- ✓ Allowing users to manually edit line data
- ✓ Merge and label polygons with ArcMap data
- ✓ Manual editing of polygon data
- ✓ Matching the edge of a new map piece with neighboring map pieces.

Descriptions of the parameters prepared in the ArcMap environment, the GIS software program included in the study, are given below:

AHP method

The Analytic Hierarchy Process (AHP), a technique for converting subjective evaluations of relative importance into a set of weights, was introduced and developed [11,12]. Proven to be very useful, AHP is very good at helping to choose from a limited number of alternatives. The method is also used to develop and rank linear utility functions that reflect the relative importance of decision objectives or problem features (such as location selection, and choosing the best cities to live) used for mathematical programming. This method is an important tool for developing measurements in physical or social environments where physical or statistical measurements cannot be made and for converting subjective evaluations into relative values in the social environment [11]. When working with the AHP method, three systems are applied;

- Problems are separated by determining important criteria,
- Comparative judgments are made on the factors that differentiate the problems,
- Measurements are obtained with the help of pairwise comparison matrices of relative importance. Ultimately these are recombined into an overall rating of available options.

The AHP method takes place in five steps:

Step 1: Creating a pairwise comparison matrix for evaluation criteria,

Step 2: Each element of the matrix to be compared is divided by the sum of its column to obtain the normalized comparison matrix,

Step 3: The average value obtained after calculating the row average in each row for the normalized comparison matrix is to reveal the importance of the criteria,

Step 4: Calculation of the consistency sum, i.e., Consistency Index (CI) (Equation 1).

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (1)$$

λ_{max}: Obtained by dividing the weight vector by the relative importance level.

Step 5: Calculating the Consistency Ratio (CR) (Equation 2).

$$CR = \frac{CI}{RI} \quad (2)$$

RI: Randomness Index

If CR = 0, it means the matrix is completely consistent.

If CR < 0.1, the matrix is consistent.

If CR ≥ 0.1, the comparison continues until the matrix is consistent [13].

Conclusion and recommendations

Leaving aside the oceans, seas, and polar ice caps that exist worldwide, the amount of usable freshwater remains in lakes and streams (about 3.5% usable). Especially in the last 20 years, the increasing human population and the resulting increasing demand for water have brought about a global water crisis. In addition, with the demand for water, struggles, and conflicts on economic, political, and environmental issues have reached much more widespread and serious levels. Water resources; It faces many serious problems in terms of quantity, quality, and all other sectoral uses.

Streams that are about to dry up due to irrigation, artesian waters that are opened, lakes that lose their natural boundaries as a result of the withdrawal of groundwater, and streams that are polluted to an incalculable extent cause major conflicts in the sharing of water [14].

Ecological restoration, improvement of water quality, and establishment and management of mechanisms that will rearrange water consumption according to industrial, agricultural, and natural needs have an important place in the management of water resources. In this context, existing and planned studies need to be reviewed. The solution to water-sharing problems lies in creating basin management plans to be managed by boards where all parties are represented. These plans can only be realized with technological applications (GIS, MCDM, and other technical programs).

GIS; It is one of the most up-to-date technologies that integrate functions such as collecting, storing, analyzing, and presenting data to the user. Combining the power of geography and information systems, GIS software and AHP technology are the ideal solutions for the effective management of water resources infrastructure and superstructure. These techniques are among the rapidly growing industries worldwide. In this study, the relationship between the GIS-supported AHP method and the management of water systems is explained and the importance of these techniques is tried to be emphasized. Moreover, these techniques are increasingly recognized as a powerful tool for watershed management due to their ability to link physical, social, and economic data. Applications of these techniques are of great importance in improving the management of systems such as water, wastewater, rainwater, and sewage. Recently, the delimitation of watersheds and mapping of impervious surfaces remains a critical task for

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GIS, AHP, and remote sensing methods. These methods have undergone a great change from past to present and their use has increased. Today's GIS permeates nearly all areas of water-related studies. As a result, the studies examined show that there is an increasing interest in the use of GIS in water resources. Additionally, this study attempted to show that although GIS software has improved greatly from the past to the present, there are still challenges that limit its use in water resources science and engineering [15].

Within the scope of this study, a water quality index was developed using GIS and AHP methods to evaluate water resources across the country in terms of drinking and utility water. The criteria that constitute the potential and quality index of water resources were selected by taking into account expert opinions, field analyses, and water quality standards, and a score indicating the water quality status was obtained for each criterion. In this way, an index showing the suitability rate of total water quality has been developed. For the water potential and quality index distribution of the study area; the categories are defined as very high quality, high quality, medium quality, and low quality.

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