Irrigation canal assessment using geomatics techniques

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Abstract. Water is one of the most important resources supporting life on Earth, yet this seemingly ubiquitous resource has become the source of multiple different emergencies rising significant concerns at international and national levels. This research examines the water crisis faced by Iraq as a consequence of a large portion of its water originating from outside of its boundaries, including sources in Iran, Turkey and Syria; more specifically, it studies the issue of the water shortage in the Wend River by evaluating the placement of the Blajo canal using a GIS based TOPSIS method. The approach taken evaluates existing canal dependency using TOPSIS as one of the MCDM techniques to consider the distance between every option from both the positive perfect point and from the negative perfect point. This was done to ensure that the best option had optimal distance from both the positive point and the from the negative point. The results showed that the best spatial location for the Blajo canal was in alternative a4, which was ranked 3 within the TOPSIS method. This rating reflects the site is near to arable areas and satisfies some criteria but is not the best location with respect to other factors.

Keywords: Drainage, Geomatics, Remote Sensing, TOPSIS.

1. Introduction
One of the most important challenges in the world is to expand food production to feed growing populations. Global growth and production challenges along with unbalanced consumption patterns have thus placed great pressure on the water resource of the world to irrigate land, water and meet various basic needs (Degirmenci et al., 2005). The water crisis is one of the fundamental issues confronting Iraq, particularly due to its disputes with neighbouring nations, as many of its rivers have their sources outside the country, in areas such as Iran, which have rejected earlier agreements and protocols with regard to water, hampering new projects built on rivers that stem from their lands. Iran has additionally cut off water from the al-Wind River, which had watered enormous plots of agrarian land in Iraq, prompting a diminishment of arable areas and damage to plantations, as well as an absence of drinking water. The Iraqi Ministry of Water Resources thus set up the Blajo canal project to compensate for the decrease in the water from the al-Wind in order to irrigate agricultural land.

The point of the water system designed by the executive is to acquire the correct stream division inside a trench arrangement to cover the fields, releasing waterways to satisfy the need for water on these farms. An unguided stream division may cause releases to be excessively high in certain farms and excessively low in others, which could prompt water disputes between farmers. To accomplish an adequate and impartial conveyance of water to the fields as required, it is thus necessary to compute the releases from the waterways, as estimated with or without a release estimation structure.
The spatial location of irrigation canals is very important factor in determining how successful the canal system will be. A methodology was thus developed to assess such locations based on the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methodology, which is as one of MCDM approaches that assesses the distance of each alternative from both the most positive point and the most negative point. Hence, the best option presented by the approach ought to be optimally positioned with regard to the positive perfect arrangement while being as far as possible from the most negative. Majid Behzadian et al (2012) offered an example of TOPSIS use, while Hwang and Yoon (1981) suggested that the classification of alternatives should be based on the shortest distance from the positive ideal solution and furthest away from the negative optimal solution.

The study area for this work is situated in Diyala province, in Khanaqin, about 57 km from Baghdad. This is one of the provinces with an international border, being bordered on the north by Sulaymaniyah and part of Salah province and to the west by Baghdad. Figure 1 represents the boundaries of the study area, showing the distribution of the different crops. Agricultural watersheds are usually drained by agricultural drainage schemes and constructed to allow for the clear transportation of water from the land to allow greatest benefit from irrigation and agricultural production due to the decreased water levels in the fields. This must be available within the information on irrigation management available to assist the relevant decision makers, and areas can be geographically distinguished by the information relevant to irrigation. The use of spatial information systems is of considerable significance in the development of these irrigation repositories, as these make it easy to obtain reliable information without data being gathered and documented in an unnecessarily centralised manner. Creating an information source that is the basis of the knowledge system is important, however. Drainage is a commonly used method for water conservation in developed countries, yet in most developing countries, agricultural production and growth are yet to hit the threshold to make this a sustainable investment for numerous reasons, including a lack of understanding among farmers and decision makers, structural deficiencies, and non-conductive government policies, which together account for much of the gap between developed and emerging countries (Smedema et al. 2002). While geospatial system software can create useful maps, the geographic information systems are more than mapping systems, with GIS offering an incredibly high degree of capability within a range of irrigation management undertakings such as planning, database integrity, and decision making (Fipps et al., 2003).

The purpose of the current work is to adapt a GIS based TOPSIS approach to assessing and evaluating the most appropriate regions for the new canal, including assessing the existing Blajo canal. Ideally, the location selected should be more suitable in terms of proximity of agricultural areas. Choosing the right venue for this endeavour is not an easy activity, however, as the investigation must also consider other relevant considerations related to the research field, including the government's intentions and previous participation in this work. The regional knowledge about the relevant drainage channel systems is minimal and the drain channel conditions and formats are perplexing, rendering the positioning of subsurface systems the most significant available instrument for determining field hydrology and understanding the potential for development.

The main objectives of the current study are thus

a) To identify the conditions that will allow appropriate determination of the position of the canal;
b) To create GIS maps within the research area to be used for review and strategic planning; and
c) To evaluate the actual site of the canal.
2. Methods and materials

2.1. GIS Layers

Spatial data based on land use, such as satellite imagery and field visits, offers important evidence to help differentiate between saturated and dry zones; markers include observable soil associations between crops and unique soil salt combinations. In addition, land use data are important for the identification of practical benefits for the management of project problem areas. The available information on land use is commonly used for interpretation purposes, with the main limitation being that this material must be updated and approved regularly; GIS assistance is very important in this respect. Remote sensing and geomatics have led to an expansion of research using the TOPSIS method to organise spatial information from GIS, including DEM, Land use/Land cover, Water bodies, and Soil type: datasets showing water bodies, waterways, and soil types in the study area are of particular importance, as gathered via Landsat OLI imagery. To achieve the aims of this study, a range of criteria scores and indicators were determined by means of a questionnaire and literature review to assess these images.

2.2. Selected indicators related to canal location

Indicators were determined based on questionnaires completed by experts and a literature review. Four criteria and five alternatives thus emerged, and these were ranked using the TOPSIS method (Table 1).
Table 1. Characteristics of indictors

| Name                        | Type | Weight | Source/ Explanation                                                                                                                                 |
|-----------------------------|------|--------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| 1  | Slope of River (percent)   | +     | 0.25  | Topography should be explicit, as slanting territory can awkward. The Spill Water System works best if the edges flow over topographic lines. Framework run times can be modified by deflecting overload. The Voyagers and Centre Turn Frameworks are a guideline for rugged and genuinely sloping terrain. (Nosenko, 1976; Worqlul et al, 2019, 2018) |
| 2  | Residential Area (km)      | +     | 0.25  | Must be close to canal (You et al., 2011)                                                                                                                                                                                                 |
| 3  | Proximity to fertile Area (km) | +    | 0.25  | Such regions are considered to be the key goal of any drainage system; it is therefore beneficial to have access to arable fields that should be watered                                                                                           |
| 4  | Soil type (unitless)       | +     | 0.25  | Soils with a low or medium infiltration capacity (De Jong 1979).                                                                                                                                                               |

2.3. Model building
The details of valid locations were outlined using the model builder in ArcGIS10.4, with results made dependent on the evaluation of multiple criteria (Malczewski, 2000; Shihab and Al-Hameedawi, 2020).

2.3.1. TOPSIS Method
As one of the MCDM methods, TOPSIS takes into account the disparity between each alternative and both the positive ideal and the negative ideal. The shortest path to the positive ideal and the longest path to the negative ideal are incorporated into the option. This requires the following steps:

I. Normalise the decision matrix.
The following formula can be used for such normalisation:

\[
r_{ij}(x) = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m}x_{ij}^2}} \quad i = 1, ..., m \ ; j = 1, ..., n
\]

where i is the criterion index (i = 1 . . . m); m is the number of potential sites; and j is the alternative index (j= 1 . . . n).

II. Determine the weighted, decision-making matrix.
The normalized matrix is multiplied by the weight of the various criteria according to the formula below:

\[ v_{ij}(x) = w_j r_{ij}(x) \quad i = 1, \ldots, m ; j = 1, \ldots, n \]

III. Determine the positive ideal and negative ideal solutions.

The goal of the TOPSIS technique is to compute the appropriate level of separation from the positive and negative ideals for every other option. In this progression, the ideal positive and negative arrangements can be characterised according to the following formulas:

\[ A^+ = (v_1^+, v_2^+, \ldots, v_n^+) \]
\[ A^- = (v_1^-, v_2^-, \ldots, v_n^-) \]

So that

\[ v_j^+ = \{(\max v_{ij}(x) \mid j \in j_1), (\min v_{ij}(x) \mid j \in j_2)\} \quad i = 1, \ldots, m \]
\[ v_j^- = \{(\min v_{ij}(x) \mid j \in j_1), (\max v_{ij}(x) \mid j \in j_2)\} \quad i = 1, \ldots, m \]

where \( j_1 \) and \( j_2 \) denote the negative and positive criteria, respectively.

IV. Determine distance from the positive and negative ideal solutions

The TOPSIS model measures each alternative depending on its specific degree of similarity to both the optimistic ideal and distance from the worse-case option. In this step, the calculation of the ranges between each option and positive and negative solutions is thus carried out using the following formulae:

\[ d_i^- = \sqrt{\sum_{j=1}^{n} [v_{ij}(x) - v_j^-(x)]^2} \quad i = 1, \ldots, m \]

V. Calculate the relative proximity of alternatives to the ideal solution

In this stage, the relative proximity of each option to the optimal situation is calculated using the appropriate formula. If the proportional degree of similarity is close to 1, the option has a shorter range from the positive ideal solution and a greater range from the negative ideal, making it a preferable choice.

\[ C_i = \frac{d_i^-}{(d_i^+ + d_i^-)} \quad i = 1, \ldots, m \]

3. Results and Discussion

The main purpose of constructing a database for the study area with a focus on the installation of the irrigation canal path through GPS points is to address water shortages in the province and to feed the
river to replace the water lost because of international disputes with Iran. This area was previously supplied with water from the al-Wind river, which irrigated about 50 thousand acres of agricultural land and orchards in the province of Diyala. On losing this water, the Iraqi government set up an irrigation work canal (Canal Blajo) to supply water to the river and thus irrigate farmland, which suffered from drought as the river water reduced.

3.1. Application of GIS Integrated TOPSIS Method

When the decision matrix from the selection process was prepared, it required standardisation. Table 2 shows the standardised matrix.

| Alternatives | Slope of river | Residential area | Proximity to fertile area | Soil type |
|--------------|----------------|------------------|---------------------------|-----------|
| a1           | 0.074          | 0.651            | 0.65                      | 0.594     |
| a2           | 0.444          | 0.081            | 0.361                     | 0.339     |
| a3           | 0.296          | 0.488            | 0.072                     | 0.254     |
| a4           | 0.665          | 0.407            | 0.433                     | 0.085     |
| a5           | 0.517          | 0.407            | 0.505                     | 0.679     |

This was then multiplied with the appropriate weighting indicators. Table 3 shows the weighted normalised decision matrix.

| Indicators       | Positive ideal | Negative ideal |
|------------------|----------------|----------------|
| Slope of River   | 0.166          | 0.018          |
| Residential Area | 0.163          | 0.02           |

The positive ideal (A+) and the negative ideal (A-) responses are defined in the weighted decision matrix by formulae, with J is connected with the favourable attributes and J’ associated with the unfavourable attributes. This allows determination of the difference between each alternative and the ideal and the non-ideal response. The relative similarity of each possible position to the optimal solution is then determined for each advantageous alternative. Table 4 shows both positive and negative ideal values.

| Indicators       | Positive ideal | Negative ideal |
|------------------|----------------|----------------|
| Slope of River   | 0.166          | 0.018          |
| Residential Area | 0.163          | 0.02           |
The maximum value is thus naturally the best one, and if the value is less than the value of 1, the condition is reasonable. The TOPSIS method thus ranks each option dependent on the relative degree of proximity to the positive ideal and the distance from the negative ideal. Table 5 shows the differences between positive and negative potential solutions.

| Proximity to fertile Area | 0.162 | 0.018 |
|--------------------------|-------|-------|
| Soil type                | 0.17  | 0.021 |

Table 5. Distance to positive and negative ideal points

| Distance to positive ideal | Distance to negative ideal |
|----------------------------|----------------------------|
| a1    | 0.149 | 0.239 |
| a2    | 0.189 | 0.133 |
| a3    | 0.206 | 0.123 |
| a4    | 0.169 | 0.191 |
| a5    | 0.08  | 0.229 |

Where the relative degree of proximity is close to 1, this implies that the option has a shorter distance from the positive ideal value and a longer distance from the negative ideal value. Table 6 shows the relative similarity of each option to the optimal value, and thus its ranking.

| Ci       | rank |
|----------|------|
| a1       | 0.616 | 2    |
| a2       | 0.414 | 4    |
| a3       | 0.375 | 5    |
| a4       | 0.53  | 3    |
| a5       | 0.742 | 1    |

Table 6. Ci values and rankings

3.2. Land Suitability for Drainage System

Agricultural drainage is a scheme whereby water is drained into soil to increase the quality of agricultural crops. In any selection method for appropriate areas, it must thus be remembered that the most important point is for non-agricultural areas to be omitted from the method of assessment, leaving only agricultural areas. These can then be reclassified in such a manner that the related data sets can be merged to construct an accurate map to classify all possible areas of the irrigation scheme.
However, this is not necessarily feasible with raw data, as to combine such information, data sets must have certain similarities. To order to combine the data sets in this research, they were thus adapted to a common scale. Figure 2 below shows the relevant Ci values.

![Ci values](image)

Figure 2. Ci values.

The assessment of the Blajo Canal project showed that alternative a4, ranked 3, was the best option according to the TOPSIS process (Figures 4 and 5). The key features of this site were its proximity to arable areas and its fulfilment of various standards; however, it is not the ideal location with regard to some other options.

Planning and maintenance of canals and associated operations such as control of irrigation water quality and participation of stakeholders is crucial to ensure the long-term progress and acceptability of these types of frameworks. Rural users are the main stakeholders in the bulk of agricultural irrigation ventures, though other investors, such as environmental and local agencies and road authorities, are also essential investors whose viewpoints should be taken into consideration. Development considerations should thus include the interests of these stakeholders and balance the needs of farmers' groups with those of other interested parties. Irrespective of whether the initiative is new or part of the redesign, improvement, or enhancement of a current programme, stakeholder engagement is vital to positive progress (Figure 3).
Figure 3. Excel sheet with coordinates of the existing canal

Figure 4. Location of Canal.
4. Conclusion
The selection of indicators by which irrigation channels can be evaluated was conducted in this study based on the existing literature and expert opinions; the more accurate the indicators, the more realistic the evaluation. The use of spatial analysis based on constructing a model using ArcGIS software confirmed that there are potential preferable locations for the Blajo Canal, based on preferences determined according to the TOPSIS method. The assessment of the Blajo Canal project showed that alternative a4 was ranked 3 in the TOPSIS process, being near to the relevant arable areas and meeting several standards; however, it is not the ideal location when compared with other options.

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