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Developing a Land Suitability Index for Agricultural uses in Dry Lands from Geologic Point of View Using GIS - a Case Study from Jordan

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Abstract - In the context of the study, a Multi-criteria evaluation (MCE) in GIS was used in developing suitability index to optimize suitable lands for agricultural uses and seasonal farming in dry lands from geologic point of view. This study was performed in the areas between Mafraq and Zarqa Cities in Jordan which are classified as arid lands. The study aims at protecting groundwater from pollution, reducing soil salting, reducing irrigation water loss caused by evaporation, and increasing crop productivity. The geo-environmental parameters of the named area including geology, groundwater depths, soil depths and textures, climatic conditions, topographic settings, and groundwater vulnerability conditions were mapped and converted into layers with special rates, given weights, and then modeled using the multi criteria evaluation (MCE) option, using Decision Making Modeling in IDRISI (GIS software) to reach at the best choice of lands for agricultural activities, and also to determine which of these lands are suitable for summer farming and which are suitable for winter farming.

Keywords: GIS, arid lands, geo-spatial mapping, multi criteria evaluation, seasonal farming

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Introduction

Background

There are many types of land use management that matches the needs and activities of the people just like the municipal, agricultural, industrial, and others; some of them have bad environmental effects and others can be considered environmental friendly (Denman, 1997). Wise management for the natural resources is the most important factor of the economic and environmental setting for a targeted area, where this enhances more balance between these elements, the applying of the suitability maps for different activities is important to prevent any environmental harms that may affects the environmental resources.

In the developing countries, unplanned and random land-use leads to losing of fertile types of soils, pollution, and to the absence of sustainability. Local food security and sustainability of productive soils are issues that cannot be separated. Elevated evaporation rates and water shortage in countries like Jordan call for scientific-wise choosing of agricultural lands.

The lack of water in Jordan and the importance of groundwater as the main source for drinking purposes call to protect the quality of the aquifers, and also call for wise management in the abstraction. On the other hand, the accelerating population growth calls for more food production. Smart land use planning is a crucial issue to reach a balance between environment and development.

The increasing population growth rates (natural growth besides the growth of refugees) add pressure on water resources of the country, on the lands and on the environmental resources; these allow the uncontrolled land use growth and fuzzy building and planning scattering around and in some cities.

Groundwater basins in Jordan are distributed in twelve major basins (MWI, 2010), where the second basin in area is Amman-Zarqa Basin which faces environmental threats like desertification, biodiversity loss, and pollution of water and soil resources. Therefore, there is a need to restore and rehabilitate its ecosystem while maintaining its development sector (Salahat *et al*., 2014).

From environmentalists' point of view and in an arid country like Jordan, the capital of the country (Amman) was expanded along the last five decades in a fertile area; they assume that it was better if it was kept as an agricultural area and productive aquifers, according to its high rainfall amounts (300 mm/y), low evaporation rates, presence of shallow renewable groundwater aquifers beneath its lands, and its fertile soil types and thicknesses. Recently in Amman, land use encroachment prevents groundwater recharges (Al Farajat, 2006). In addition to that, groundwater aquifers beneath Amman has been polluted (Salameh, 1996). The capital city should be expanded some tens of kilometers eastern of its recent site, where the area is classified as arid.

This study aims at developing land suitability index for the agricultural uses in arid lands like Jordan from earth sciences point of view, aiming at protecting groundwater from pollution, reducing soil salting, reducing irrigation water loss caused by evaporation, and increasing crop productivity. This will be reached by modeling the geo-environmental layers of the targeted area. Also the research tries to reach at the best plan of management for land use by mapping suitable agricultural lands and lands of summer and winter farming, in order to have the better environmental, economic, and social stability for the area in the future.

Study Area

The study area is located between cities of Zarqa and Mafraq (Figure 1), which forms free lands (out of land use). It was chosen according to the high population density in the named cities in addition to the pressure that was added

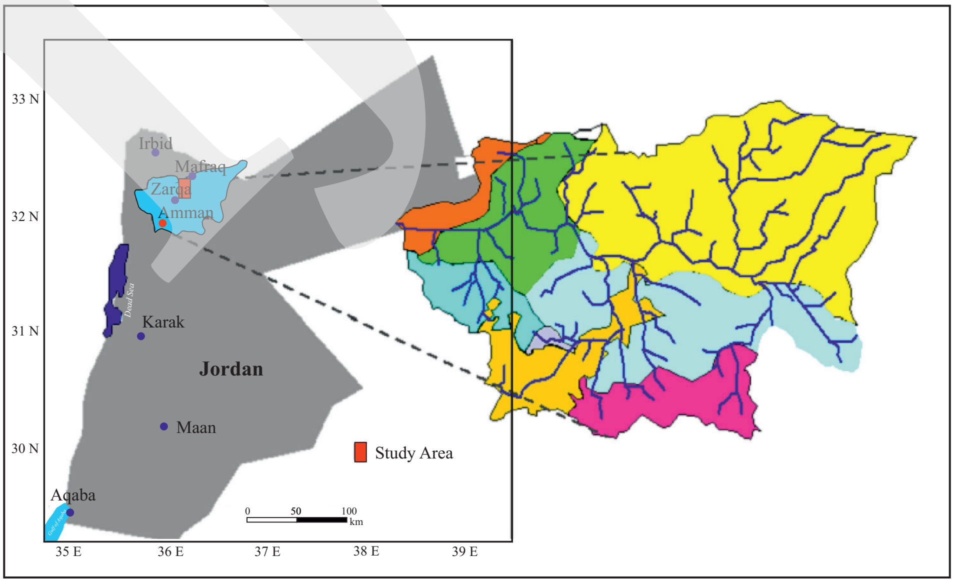

Figure 1. Study area location map (red rectangle); the map shows the cities of Zarqa and Mafraq and the main cities in the country. To the right is the extension of the Amman-Zarqa sub-basins (multi-colored) and the drainage nets in blue lines.

because of the increasing numbers of refugees since 2011, in addition to the social problems that are connected to those areas such as poverty and workless issues. The area is a candidate for being encroached by land use expansion.

The outcropping rocks in this site are of Upper Cretaceous (Bender, 1974; Powell, 1989). The following explanations represent a brief description of the exposed rocks:

- The Wadi As Sir Formation (Turonian) covers broad areas to the south of the studied area. The formation is 90 m thick and consists of bedded massive limestone, hard buff dolomitic limestone with subsidiary marls and chert nodules common in the middle and upper parts. According to Powell (1989) this formation was deposited in a shallow marine environment.
- The Wadi Umm Ghudran Formation (Coniacian-Santonian) is up to 15 m thick andconsists of massive, white buff-grey, hard, detrital chalk that contains fish teeth and shell fragments and thin layers of chert. The formation was deposited in a moderate to deep-water pelagic environment (Powell, 1989).
- The Amman Formation (Santonian-Campanian) consists of dark brown to grey thickbedded chert, silicified limestone, chalk, marl, siliceous coquina and cherty phosphate, and brecciated chert; it outcrops at the landfill and its surrounding areas and varies in thickness from 80 m to 150 m (Howard and Humphreys, 1983). The distinguishing feature of this formation is the presence of undulations, in addition to fracturing and jointing in the chert beds. This formation was deposited in a shallow marine environment (Powell, 1989).
- Al Hasa Formation (Campanian-Maastrichtian) is 25 m thick and composed of thin to medium-bedded phosphate, cherty phosphate, limestone, coquina, and marl. The formation was deposited in a shallow marine environment. This formation forms part of the phosphorite belt in which the phosphate horizons were mined at Russeifa area. The Wadi fill deposits overlie the Amman and Wadi Sir Formations and consist of sands and gravel with a variable thickness from 15 to 20 m (Bender, 1974).
- Muwaqqar and Umm Rijam Chert- Limestone Formations (Eocene) are widespread and exposed well in the study area. The exposed part of the formations is few meters thick and consists of limestone, chalky limestone, and chert (Bender, 1974).
- Thick soils with different textures are covering wide areas of the site.

Physiographic and climatic conditions of the area are to be shown within the geospatial models in the coming sections of the article.

Scientific Review

The science of geomorphology is dealing with the changing of earth's surface which is vital to farming. Hill slope dynamics, soil erosion, water movement both over land during rain, floods, and irrigation purposes deal with the smallest geologic time scale and can help someone to model and predict how a landscape, in this case a farm, will change over time. It helps to understand how the farm will impact the land (lots of soil erosion as run off for example if there's a lot of tilling. This in turn reduces nutrient levels meaning that you need to use more fertilizers). Land suitability analysis is an important task for designing a land of specific cropping pattern in a sustainable agricultural production of a country. One of the most important and urgent problems in Jordan is to improve agricultural land management and cropping patterns to increase the agricultural production with efficient use of land resources. In Land Suitability Analysis, Remote Sensing plays a vital role both at regional and local levels. Remote sensing offers an efficient and reliable method of mapping agricultural lands. It can also give us information about the health of the vegetation. The spectral reflection of a field will vary with respect to changes in the growth and type, and that can be measured and monitored by multispectral sensors.

Interpretations from remote sensing data can be input into a geographic information system (GIS), and combined with other data, to provide information about the study area. Integrated Remote Sensing and GIS can clearly visualize the spatial distribution of the agricultural land suitability. This new technology can reduce the time and cost in organizing the data in arriving at precise conclusion and decisions for planners and decision makers (Gopala Krishna and Regil, 2014).

Understanding the geomorphic influence of land use on stream ecosystems requires a properly scaled context of disturbance mechanisms (White and Pickett, 1985; Frissell *et al.,* 1986; Allan *et al.,* 1997). Agricultural practices may represent a press disturbance (sensu Bender *et al*. 1984) to riparian and floodplain vegetation, in the sense that stream-side woody vegetation is removed and growth is suppressed through tilling, mowing, or livestock activity (National Research Council, 1992). As a result, the stream-riparian system exists in a human-maintained steady-state. Other mechanisms of agricultural disturbance may include channel redirection, floodplain tiling or ditching, and enhanced bank erosion by livestock activity (National Research Council, 1992). These potential geomorphic changes affect the hydraulics and sediment biogeochemistry of small streams. Many agricultural practices have resulted in increased fine-grained (*i.e.* sands, silts, and clay particles < 2 mm) sediments, hereafter referred to as "fines", in stream substrates. Land use at sites of the current study included pastures and hay fields, and the landscape was not regularly tilled. If excess fines were present, local sources would likely to improve bank erosion due to livestock activity and lack of vegetative support (National Research Council 1992; Brunke and Gonser, 1997), and can subsequently change hydraulics (Schälchli, 1992; Packman and MacKay, 2003) and biological function (Mulholland *et al*., 1997; Valett *et al*., 1997; Boulton *et al*., 1998).

One of the most important applications of GIS is the display and analysis of data to support the process of environmental decision-making. A decision can be defined as a choice between alternatives, where the alternatives may be different actions, locations, and objects. For example, one might need to choose where the best location for hazardous waste facility is or perhaps identify which areas will be best suited for a new development.

Modeling of the hydro-geo-environmental factors existing within a targeted area is one of the wise management tools for the total environment. Land use management is one of the most important tools also, whilst the Multi criteria evaluation (MCE) method is an effective tool to help the decision makers to best land use management; it models different environmental. The method is one of the decision making tools in IDRISI which is a non-profit project within Clark Labs: a research center within the George Perkins Marsh Institute at Clark University, and is dedicated to furthering the development and understanding of computer-assisted geographic analysis.

From the Help Option in the IDRISI Guide Volume 2, a detailed explanation of the MCE method was taken. To meet a specific objective, it is frequently the case that several criteria will need to be evaluated. Such a procedure is called Multi-Criteria Evaluation (Voogd, 1983; Carver, 1991). Another term that is sometimes encountered for this is modeling.

However, this term is avoided here since the manner in which the criteria are combined is very much influenced by the objective of the decision. Multi-criteria evaluation (MCE) is most commonly achieved by one of the two procedures. The first involves Boolean overlay whereby all criteria are reduced to logical statements of suitability and then combined by means of one or more logical operators such as intersection (AND) and union (OR). The second is known as weighted linear combination (WLC) wherein continuous criteria (factors) are standardized to a common numeric range, and then combined by means of a weighted average. The result is a continuous mapping of suitability that may then be masked by one or more Boolean constraints to accommodate qualitative criteria, and finally thresholded to yield a final decision.

While these two procedures are well established in GIS, they frequently lead to different results, as they make very different statements about how criteria should be evaluated. In the case of Boolean evaluation, a very extreme form of decision making is used. If the criteria are combined with a logical AND (the intersection operator), a location must meet every criterion for it to be included in the decision set. If even a single criterion fails to be met, the location will be excluded. Such a procedure is essentially risk-averse, and selects locations based on the most cautious strategy possible - a location succeeds in being chosen only if its worst quality (and therefore all qualities) passes the test. On the other hand, if a logical OR (union) is used, the opposite applies - a location will be included in the decision set even if only a single criterion passes the test. This is thus a very gambling strategy, with (presumably) substantial risk involved.

Now compare these strategies with that represented by weighted linear combination (WLC). With WLC, criteria are permitted to trade off their qualities. A very poor quality can be compensated by having a number of very favorable qualities. This operator represents neither an AND nor an OR-it lies somewhere in between these extremes. It is neither risk averse nor risk taking.

For reasons that have largely to do with the ease with which these approaches can be implemented, the Boolean strategy dominates vector approaches to MCE, while WLC dominates solutions in raster systems. But clearly neither is better – they simply represent two very different outlooks on the decision process-what can be called a decision strategy. IDRISI also includes a third option for Multi-Criteria Evaluation, known as an ordered weighted average (OWA) (Eastman, 1996; Eastman and Jiang, 1996). This method offers a complete spectrum of decision strategies along the primary dimensions of degree of trade off involved and degree of risk in the solution.

Agricultural activities are affected by different natural and environmental factors that may affect its productivity, such as sunshine. This factor plays a major role in agricultural activities because of the importance of the sunlight in the photosynthesis process. In addition to the sunlight amounts, the direction of the sunshine is another important natural factor that may affect the activities, for example the summer plants need a topographical orientation far away from the direct sunshine and the winter plants need the direct sunshine direction as shown in Figure 2 (Haroon, 2001) which represents the topographic orientations in relation to the sunshine directions and the seasonal crops of both summer and winter. Aspect model (topographic orientation model) that can be derived from a digital elevation model using GIS using Surface Modeling option can produce topographic orientations that locate between 0 and 360 degrees from the geographic north.

Temperature is also another important factor that effects the crop production and then the suitability map. Warm temperature increases the ability to different crops to reach their suitable growth rate, and both high and low temperature rates limit the farmers abilities to farm certain crops in their areas according to the weather conditions that they have their farms there.

Rainfall and humidity both have a great important role in the farming process, where these factors are affected by the amounts of evaporation and evapotranspiration which are affected directly by the temperature. Increasing temperature leads to the increasing evaporation amounts and then decreases the amounts of the available water to the crops to be grown (Barlowe, 1983).

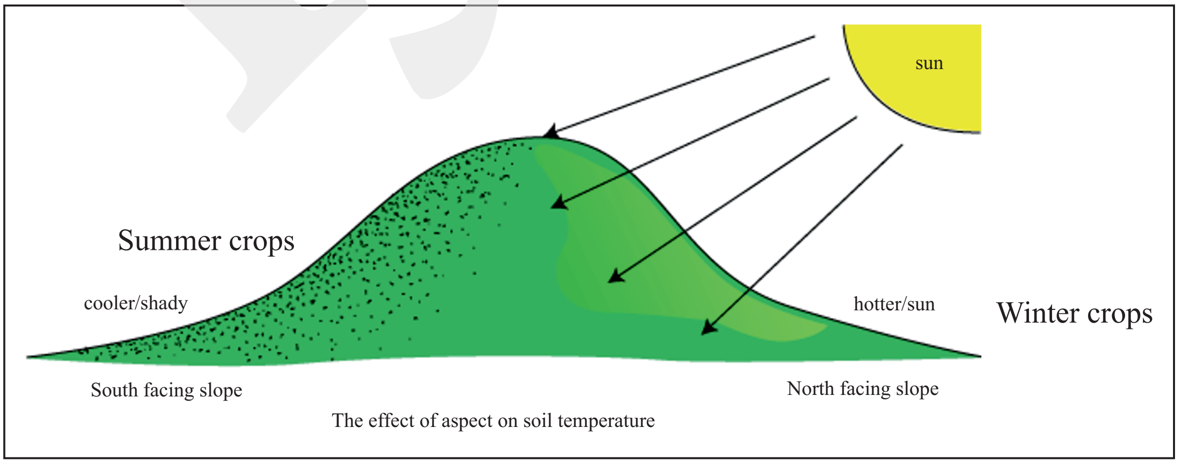

Figure 2. The effect of sunlight aspect on soil temperature and consequently on crop productivity (Haroon, 2001).

Topography is one of the important factors that affect agricultural use, as high slopes decrease the ability of the crops to be planted and grow in steeply areas where the areas with gentle slope are better to have agricultural activity there (Barlowe, 1983).

Soil; the natural cover that covers the land and differs in its sizes and contents; this cover ranges in size from clay and silt size to pebbles and gravels size. The soil affects the productivity of land to the crops and agricultural activities (MOA, 1996), and soil texture has an impact on the soil-water hydraulics and the so called "available water for the plant" that can be taken by the roots.

In selecting agricultural areas according to the environmental conditions as shown before, different factors have their roles in the agricultural productivity, such as the weather conditions, water abundance, and others. Figure 3 shows how different environmental factors are dealing together in selecting the suitable areas for agricultural activity (Kelsey *et al*., 1995).

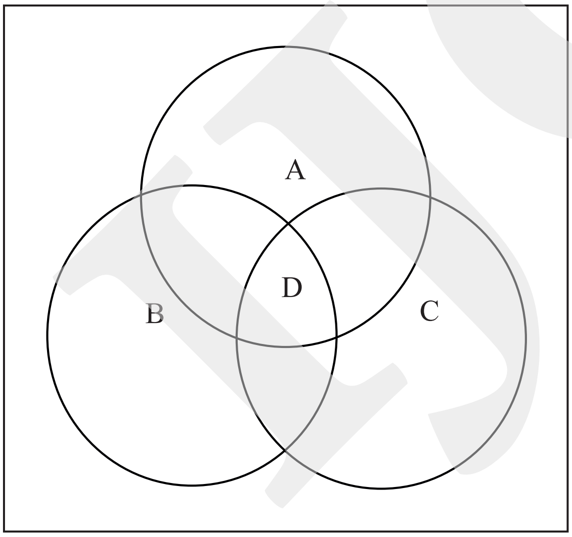

Figure 3. Natural conditions that might affect agricultural productivity (Abu Ali, 2004).

Let's assume, in Figure 3, that the area A is the area with the best rainfall condition for certain crop productivity, the area B is the better topography conditions, and the area C is the best soil conditions, then the area D is the most suitable area for planting this crop (Abu Ali, 2004).

Geo-spatial factors that may affect a study area are given specific weights according to their importance in the evaluation process, then using an assumed land suitability index the model is built to evaluate the best area for certain activity to be done (PDTRA, 2012).

Methods

This study will define the geo-spatial variables of the land of the study area such as topography, climate, geology, natural resources, soil, groundwater depths, then each factor of the inputs will be scaled into weight scale in order to give its value that will be calculated in the model. By adding to that, the groundwater vulnerability map will be evaluated in terms of geology of the Vadose Zone Rocks in order to consider the water sensitivity of the study area.

After having all factors ready to be gathered, an MCE (Multi Criteria Evaluation) using IDRISI GIS will be used to overlay the layers in order to produce the suitability map (Figure 4). The steps are summarized as follows:

1. Building of the hydro-geo-environmental maps for the study area
2. To suggest an agricultural suitability index for the targeted area
3. To model the maps using the suggested suitability index
4. Building the final agricultural suitability map

Result and Processing Using Gis

Visions of the local Communities of their lands

There are many environmental parameters that exist in the study area and give an important reason to choose this study area to elaborate this work in. Local community is the most important factor that this work dealt with, including the vision for the local community in the study area and their needs and hopes to the future of this area. A questionnaire (Table 1) was developed to find out the most popular vision to the local community for their area.

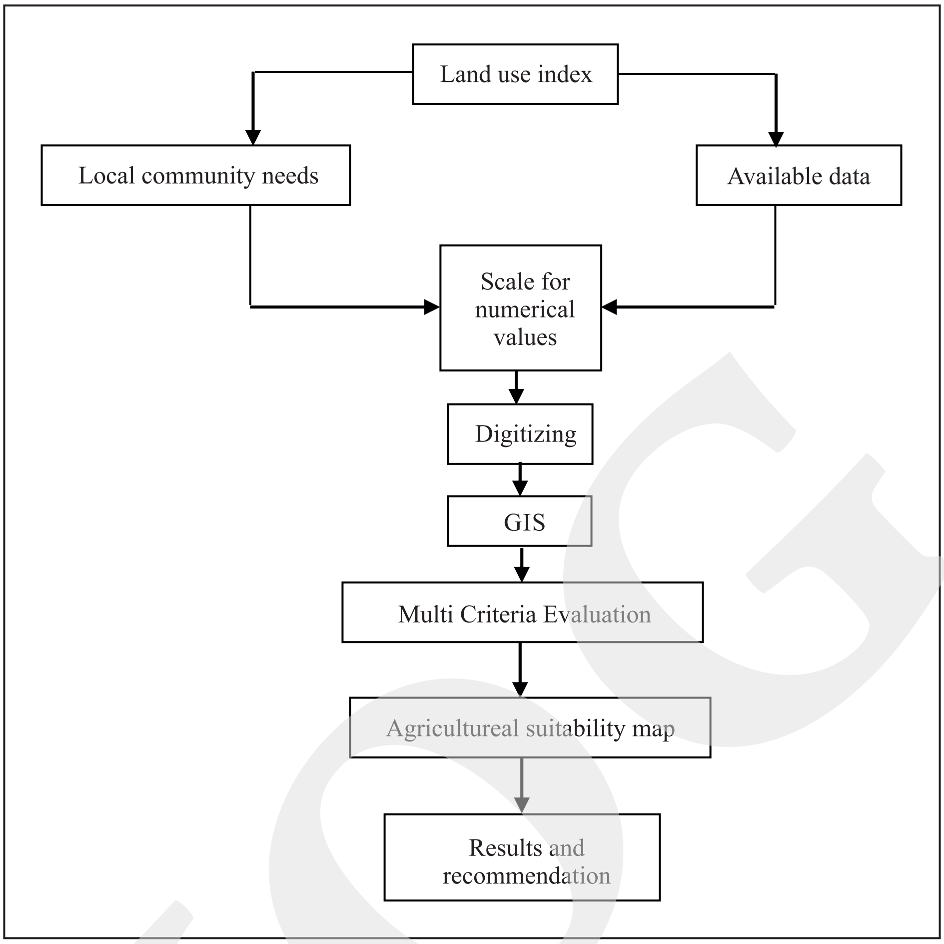

Figure 4. Flow chart of the methodology of the work.

Table 1. Statistical Analysis for the Opinion of the Local Community Needs and Vision for the Targeted Area

Part	Agricultural Pattern	Mean	Standard Deviation	Importance	Description
1	Rain-fed crops	3.5	0.715	1	strongly agree
2	drip irrigated crops	3.45	0.768	2	moderately agree
3	fruit trees	3.37	0.859	3	moderately agree
4	grazing pattern	3.35	0.911	4	agree

Topographic Modeling

The digital elevation model (DEM) of the study area shown in Figure 5, was used in GIS Surface Modeling option in order to draw different important maps that are used to develop the suitability map, such as watershed map, aspect model, elevation map, and drainage system map. The topography of the area ranges from 540 to 930 m a.s.l. The area is mountainous with side wadis elongated mainly in south-north and east-west directions.

Watershed Modeling

Watershed could be developed by using the IDRISI techniques that exists in the Arc GIS software. This option uses the DEM to produce the surface water basins as shown in Figure 6.

Building Aspect Model

Aspect maps also was modeled in order to determine the exposure amounts of sunshine that shines over the targeted area, using DEM for the targeted area and under the environment of the

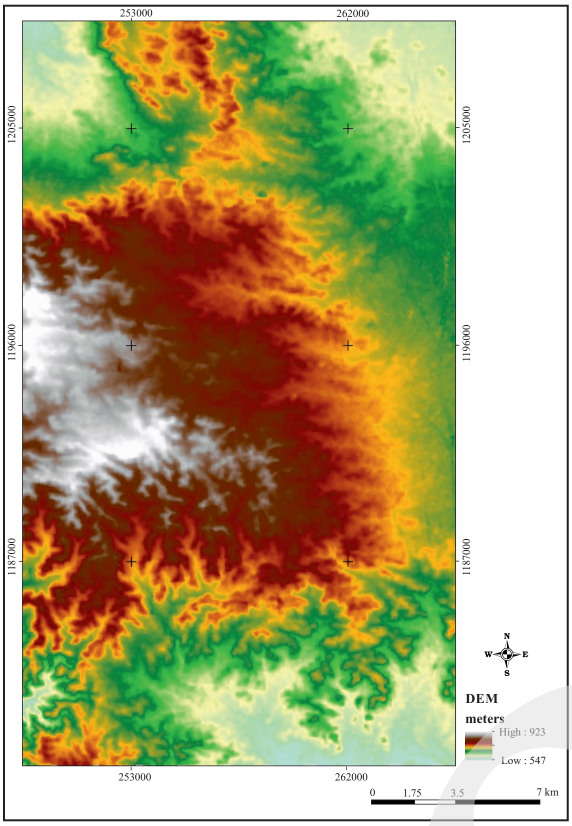

Figure 5. Digital elevation model for the targeted area (MWI, 2010).

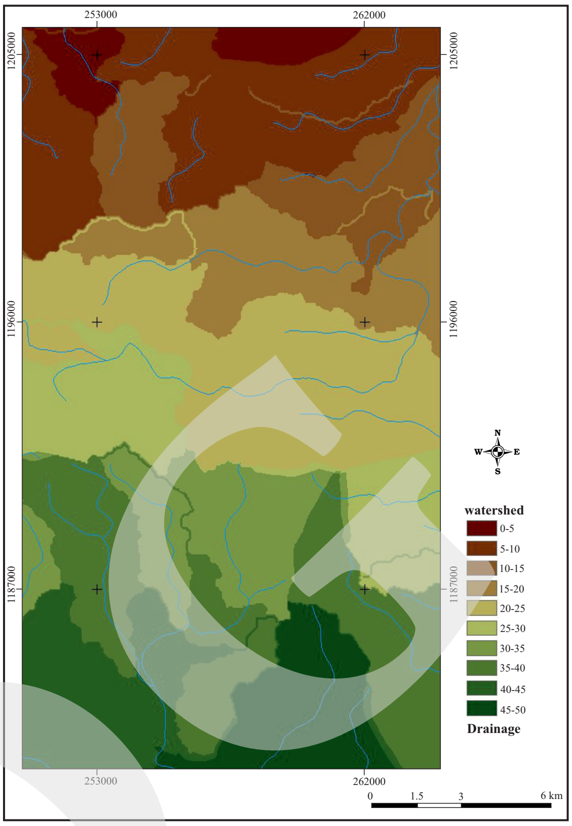

Figure 6. Surface water basins within the targeted area with drainage nets in blue lines.

GIS the aspect map was produced. Figure 7 shows the aspect map which helps in locating the best place for the activities that need sunlight such as the agricultural activities here. The area shows a variety in topographic orientations.

Depth to Groundwater

After drawing the aspect map, another important environmental factor was produced, such as the depth to the groundwater table map referring to the distance between the water in the aquifers and the ground surface. For agricultural activity, it is important to have shallow water levels (economic causes related with water abstraction costs from the wells). Data of the study area were collected from the MWI (2004 and 2010) for different wells within the targeted area, then a depth to a water table map was drawn (Figure 8). The depths range from 100 to 300 m.

Water Quality

Water salinity is another important factor that affect the suitability of agricultural activity in

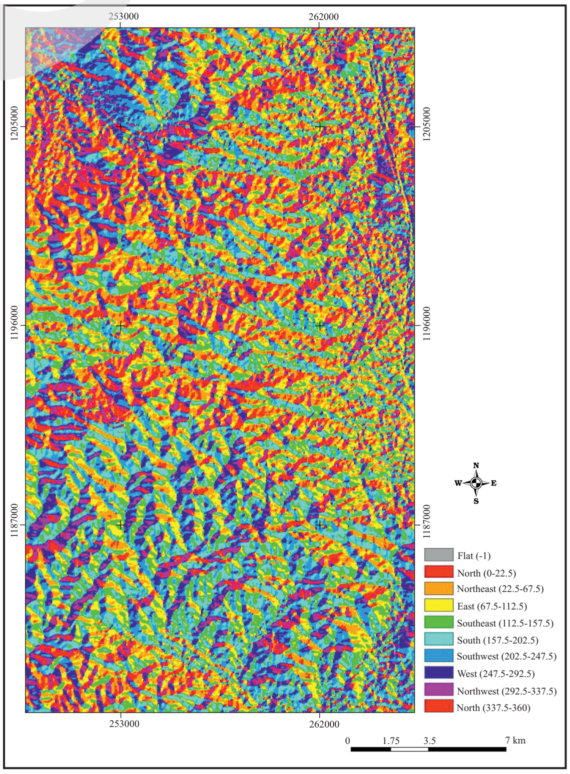

Figure 7. Aspect map for the targeted area.

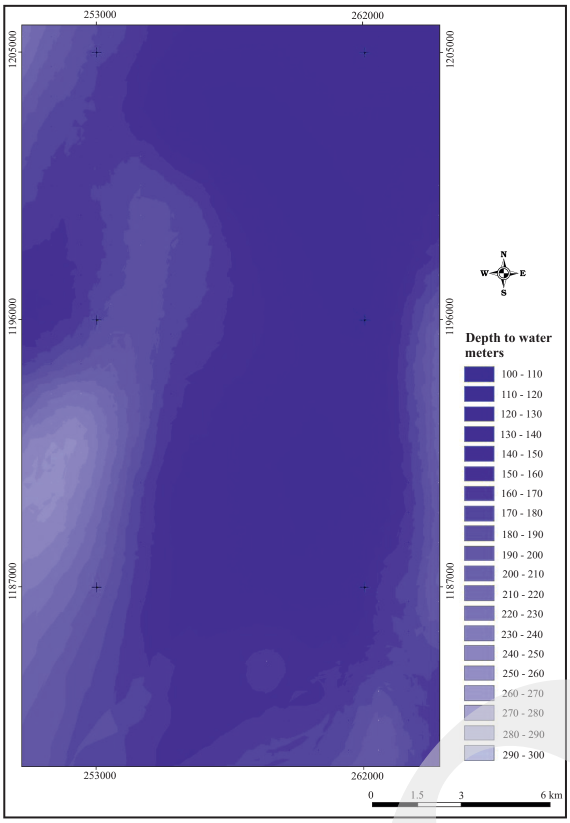

Figure 8. Depth to water table for the targeted area.

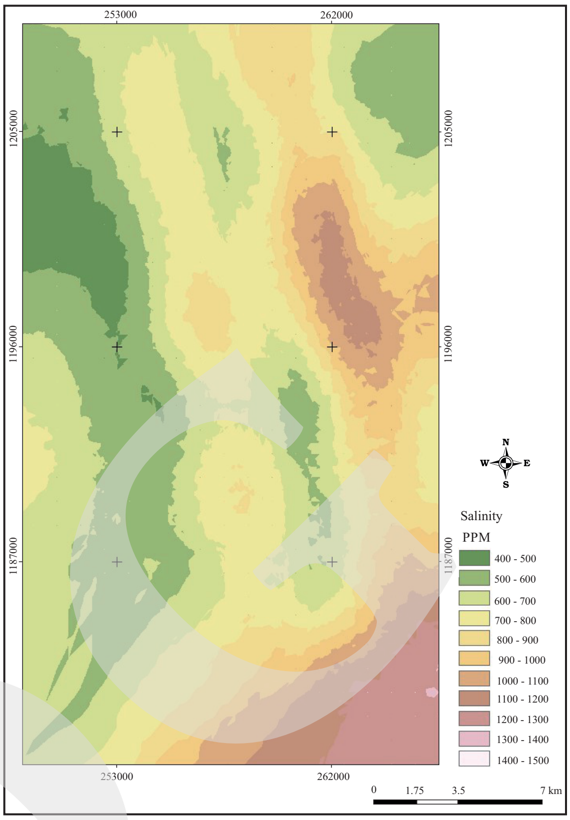

Figure 9. Salinity map of the groundwater within the targeted area.

such a place. This factor includes the quality of the available water in the study area that will be used for irrigation. A salinity map for the study area (Figure 9) was modeled from the wells data that was collected from wells located within the study area (MWI, 2010).The salinity ranges from 400 to 1500 ppm.

Rainfall Distribution

Adding to the water quality part, rainfall amount is another important factor that affects the agricultural suitability of the lands. Rainfall amounts in the study area range from 50 up to 350 mm/yr. Distribution of rainfall amounts in the targeted area is shown in Figure 10.

Soil Depths

Soil depths refers to the distance between ground surface and the rock surface. The data was collected from reference maps of the soil of the study area that was obtained from the MOA (1996). Figure 11 shows the soil depths in the study area, ranging from 50 to 110 cm.

Groundwater Vulnerability against Pollution

Type of rocks in the unsaturated zone (Vadose Zone) controls the percolation of the pollutants from the surface, and also reflects the potential of the self purification process for the pollutants. Mostly, the study area seems to be resistant for pollution, except the areas having karstified limestone, sand, and gravel. Vadose zone rocks indicates the type of the rocks that exist over the aquifer rocks containing the groundwater. This condition helps in determining the probability if the groundwater is polluted within the targeted area. Values of the rocks of Vadose Zone is shown in Table 2 and resulted map is shown in Figure 12.

Agricultural Suitability Map

A land suitability index was assumed in the context of this study (Table 3). The different geo-spatial variable models were given assumed weights according to their expected impact of the crop productivity. The variables that were of a high importance for this study in selecting the

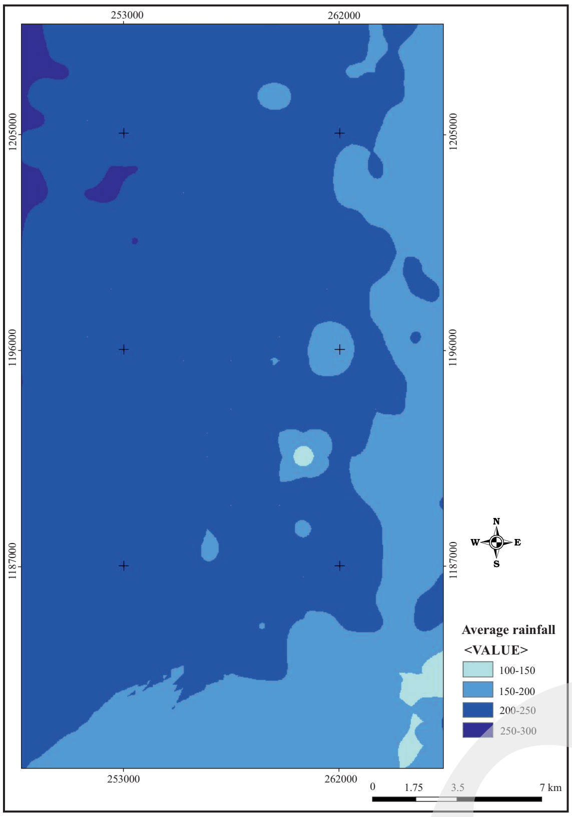

Figure 10. Rainfall distribution over the study area.

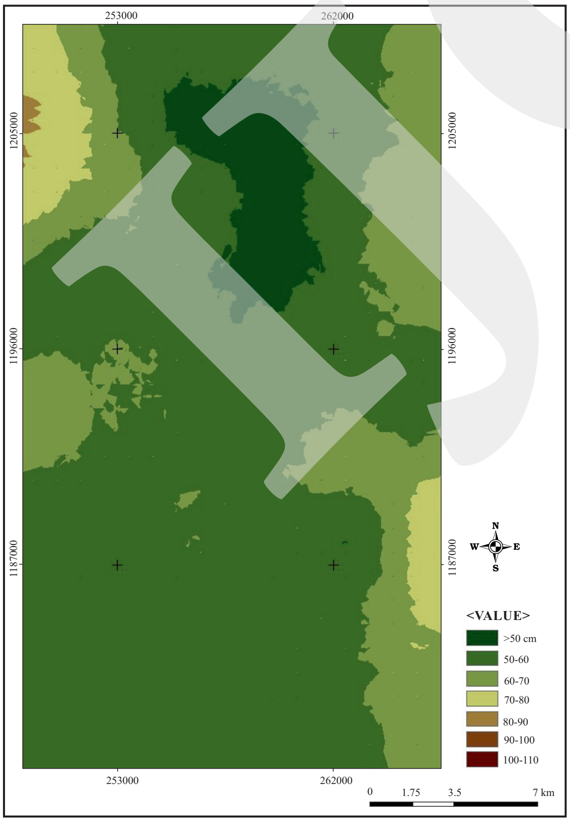

Figure 11. Soil depths distribution for the targeted area.

Table 2. Vadose Zone Weights for Different Rock Types, taken from the "DRASTIC Index of groundwater vulnerability" (Aller *et al*., 1987)

UNSATURATED ZONE MATERIAL	TYPICAL RATING
Confining layer	1
Silt/clay or Shale	3
Limestone or Sandstone	6
Bedded limestone, sandstone shale	6
Sand and gravel with significant silt & clay	4
Metamorphic / igneous	8
Sand and gravel	9
Basalt and Karst limestone	10

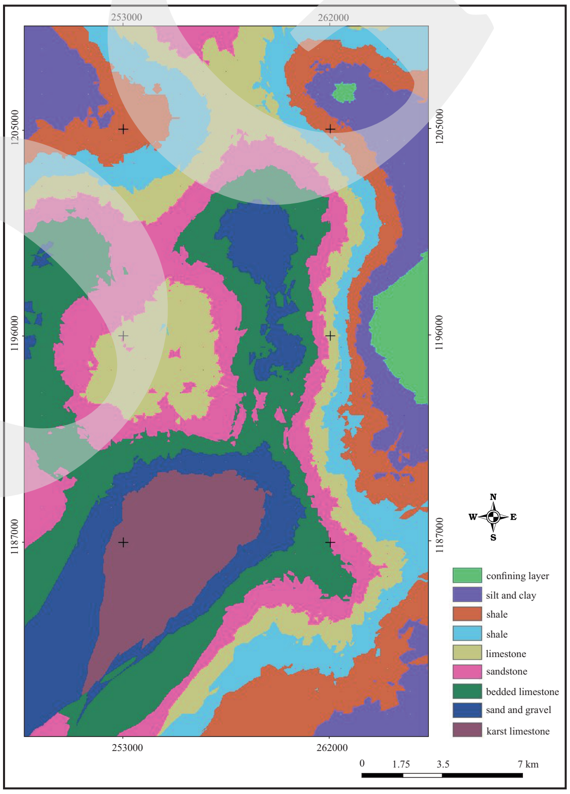

Figure 12. Groundwater vulnerability against pollution produced from modeling Vadose Zone rocks for the targeted area.

agricultural areas are the soil, water, and sunshine variables, which were given the highest weight values for the model building as shown in Table 3.

Applying the methods presented in Figure 3 and Table 3 resulted in producing two maps (Figures 13 and 14) that refer to the suitability maps for agriculture in the targeted area in summer and winter seasons.

Table 3. Building of the Agricultural Suitability Map Methodology with Assumed Weights of the Parameters

Parameter	Justification of the importance	Weight	Perfect lands characteristics
Aspect model (orientation of the reliefs from 0 - 360°)	Represents period of the exposure of a land for the sun rays.	0.025	For winter lands with aspect rates between 90 - 270°, and for summer with 270 - 360°
grain size factor	loamy soil is the best for agricultural activities	0.0125	areas of soils with grain size larger than .0185 mm of silty and loamy type
soil depths	deep soil is better than shallow soil for the agricultural activities	0.05	areas of soils with depth more than 50 cm is better
groundwater salinity	water salinity is a drive factor for the crop productivity fresh water is a positive point	0.05	sites with salinity less than 900 micron Siemens per cm (µS/cm) are selected
rainfall amounts	rainfall increase the ability to the crops to be grown better	0.55	sites with rainfall exceeds 120 mm/yr
groundwater vulnerability	Vadose zone is an important factor that plays a major role in protection the GW	0.025	Vadose zone with rocks having low factors of vulnerability against pollution that does not permit water to the aquifer
depth to water table	the shallower groundwater reflects better crops quality	0.15	areas with groundwater shallower than 200 m
DEM in the study area	areas with higher elevation is better because of decreasing the evaporation limits and increasing soil fertility	0.025	areas higher than 600 m above sea level were chosen

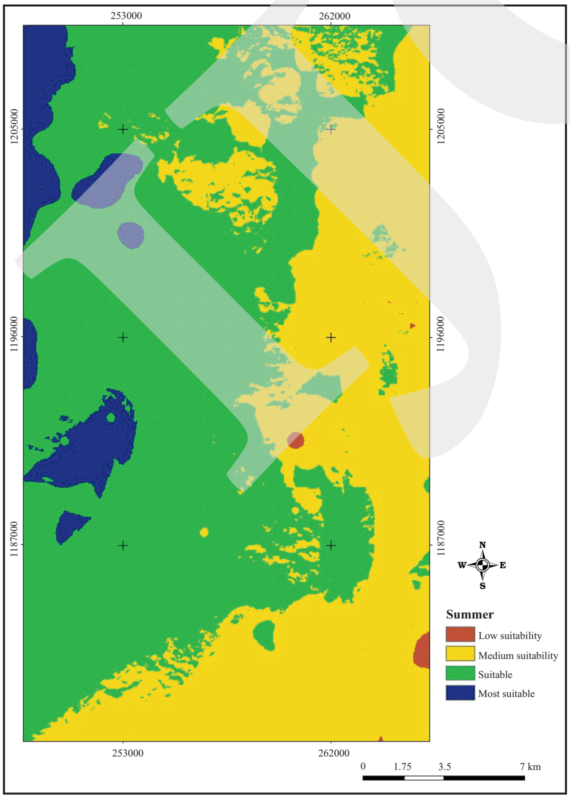

Figure 13. Produced model for summer agricultural activities of the study area.

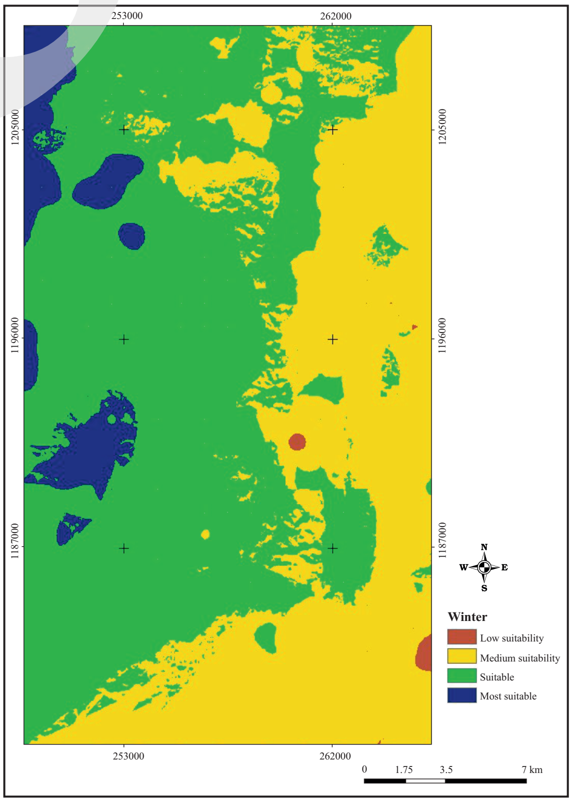

Figure 14. Produced model for winter agricultural activities of the study area.

Discussion

Table 1 shows that the rain-fed crops are the most important field of agricultural activities for the local community, with a mean of 3.5, a standard deviation of 0.715, and an evaluation of "strongly agree"; the grazing activities came in the final score with a mean of 3.35 and a standard deviation of 0.911; the whole agricultural parts give a mean of 3.42 and a standard deviation of 0.805 as shown in Table 1.

With the assumed suitability index in the context of this study, the produced models in Figures 13 and 14 are able to point to the suitable lands for agricultural activities, and it is also possible to delineate lands suitable for seasonal crops farming for both summer and winter seasons.

As shown in Table 3, the parameters that are included in building of the agricultural suitability map are depth to water table, salinity of the water, vulnerability of the aquifer in terms of Vadose zone rocks properties, digital elevation model for the targeted area, rainfall amounts, soil depths and particle size, and the sunshine amounts. Each parameter of these has a reason to be included in this study and has a weight that is used for the calculation method.

Figure 13 shows the suitability map of the study area for the summer agricultural activities. This shows that most of the study area with percentages of 93.6% of the area ranges between suitable and medium suitable for the agricultural activities. The area of the most suitable for the agriculture is 6.2% which is located in the western parts of the study area.

Figure 14 shows the winter agricultural activities indicating a little difference between the winter season crops. This map shows that a percentages of 94% of the study area is with the suitable and medium suitable for agricultural activities, while an area with the average of 6% is the most suitable ones.

Table 4 shows the percentages of the suitable areas of the agricultural activities for the summer and winter crops, and it is clear that about 61% of the targeted area falls under suitable and most suitable areas of the agricultural activities.

Table 4. Distribution of the Suitable Lands for Agriculture within the Targeted Area, with the Percents of the Summer and Winter suitable Lands for Farming

Rank	Percentage of Area %	
	Summer	Winter
low suitability	1	0.5
medium suitability	38	39
suitable	54.8	54.5
most suitable	6.2	6

Conclusions

The suitability index for agricultural lands suggested in the context of this study makes use of different geo-spatial factors. It can be best implemented in dry areas where live water shortage occurs.

In an area like Jordan which has a Mediterranean type of climate (hot dry in summer, and wet cold in winter), this method can lead to the following points: decreasing soil salting, decreasing irrigation water loss caused by evaporation in summer seasons, protecting vulnerable aquifers from pollution by addition of fertilizers and pesticide, and increasing exposure for sunshine in winter seasons for good crop productivities.

The method is still in need for validation and also for more development. On the other hand, it needs to be implemented experimentally in the field to investigate its effectiveness and efficiency, and how can it be reflected on water saving and crops productivity. An impact analysis should be implemented also to study the impact of each factor on the final results.

The need of good and wise land planning is highlighted and must be done to save as much as possible of Jordanian's areas; taking into consideration environmental, economic and social aspects of the targeted area, if not a very serious expensive environmental problems related to the sustainability will be faced.

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References

Abu Ali, S., 2004. *Agricultural geography*. Arabic Publishing, 1st edition, Kuwait.

Al Farajat, 2006. *An Introduction in Environmental Impact Assessment*. Text book. Al al-Bayt University publications. Mafraq-Jordan.

Allan, J. D., Erickson, D.L., and Fay, J., 1997. The influence *of catchment land use on stream integrity across multiple spatial scales. Freshwater* Biology, 37, p.149-161. DOI: 10.1046/j.1365-2427.1997.d01-546.x

Aller, L., Bennett, T., Lehr, J. H., Petty, R.J., and Hackett G., *1987. DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings*. Ada, Oklahoma, U.S. Environmental Protection Agency.

Barlowe, R., 1983. Changing land use and policies: the lakes states. *In*: Flader, S.L. (ed.), *The Great Lakes Forest: An Environmental and Social History*. University of Minnesota Press, Minneapolis. Original edition, p.137-156.

Bender, F., 1974. *The geology of Jordan, contribution to the regional geology of the Earth*. Supplementary edition of Volume 7, Berlin, Gebrueder Borntraeger, 196pp.

Boulton, A. J., Findlay, S., Marmonier, P., Stanley, E.H., and Valett. H. M., 1998. The functional significance of the hyporheic zone in streams and rivers. *Annual Review of Ecology and Systematics*, 29, p.59-81.

Brunke, M. and Gonser, T., 1997. The ecological significance of exchange processes between rivers and groundwater. *Freshwater Biology*, 37, p.1-33. DOI: 10.1046/j.1365-2427.1997.00143.x

Carver, S.J., 1991. Integrating Multi-Criteria Evaluation with Geographical Information Systems. *International Journal of Geographical Information Systems*, 5(3), p.321-339. DOI:10.1080/02693799108927858

Denman, D.R., 1997. *Land use introduction to proprietary land use analysis*. London, George Allen. DOI: 10.2307/2230302

Eastman, J.R., 1996. Uncertainty and decision risk in multicriteria evaluation: implications for GIS software design. *Proceedings, International Institute for Software Technology Experts Group Workshop on Software Technology for Agenda 21: Decision Support Systems*, Section 8.

Eastman, J.R. and Jiang, H., 1996. Fuzzy measures in multi-criteria evaluation. *Proceedings, 2nd International Symposium on Spatial Accuracy Assessment in Natural Resources and Environmental Studies*. Fort Collins, GIS World Inc., p.527-534.

Frissell, C. A., Liss, W.J., Warren, C.E., and Hurley, M.D., 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. *Environmental Management*, 10 (2), p.199-214. DOI:10.1007/BF01867358

Gopala Krishna, G.V.T. and Regil, R., 2014. Agricultural Land Suitability Analysis of a River Basin Area using Remote Sensing and GIS. *International Journal of Geospatial Engineering and Technology*, 1 (1), p.37- 42.

Haroon, A., 2001. *Economic geographic principles*. Arabic Publishing, 1st edition.

Howard, J. and Humpreys, E., 1983. Monitoring and evaluation of the Amman-Zarqa aquifer. *Amman, Jordan, Amman Water and Sewerage Authority Report*, 1, 235pp.

Kelsey, T. W., Smith, S.M., and Luloff, A.E., 1995. The Impact of an Aging Rural Population on Local Tax Structures. *Agricultural and Resource Economics Review*, 24 (2), p.174-184.

MWI (Ministry of Water and Irrigation of Jordan), 2004. *Annual Reports*, open files, Amman-Jordan.

MWI (Ministry of Water and Irrigation of Jordan), 2010. *Annual Reports*, open files, Amman-Jordan.

MOA (Ministry of Agriculture of Jordan), 1996. *National soil project*, Amman-Jordan.

Mulholland, P. J., Marzolf, E.R., Webster, J.R., Hart, D.R., and Hendricks, S.P., 1997. Evidence that hyporheic zones increase heterotrophic metabolism and phosphorus uptake in forest streams. *Limnology and Oceanography*, 42 (3), p.443-451. DOI: 10.4319/lo.1997.42.3.0443

National Research Council, 1992. Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy. *Report of the Committee on Restoration of Aquatic Ecosystems*. National Academy Press. Washington, DC, USA. DOI: 10.1002/iroh.19930780304

Packman, A. I. and MacKay, J.S., 2003. Interplay of stream-subsurface exchange, clay particle deposition, and streambed evolution. *Water Resources Research*, 39 (4), p.1097, DOI:10.1029/2002WR001432.

PDTRA, 2012. Strategic Master Plan of Petra, a study performed for the Petra Development and Tourism Region Authority by the consortium of the firms ATC Austria. *Design Workshop USA and JCP Italy*. Petra- Jordan.

Powell, J. H., 1989. Stratigraphy and sedimentation of the Phanerozoic rocks in central and south Jordan, Pert B: Kurnub, Ajlun, and Belqa Groups (Geology Directorate, Natural Resources Authority, Amman Jordan). *Jordan Bulletin*, 11, 130pp.

Salahat, M., Al-Qinna, M., Mashal, K., and Hammouri, N., 2014. Identifying major factors controlling groundwater quality in semiarid area using advanced statistical techniques. *Water resources management*, 28, Springer. DOI:10.1007/s11269-014-0712-1

Salameh, E., 1996. Water quality degradation in Jordan. *Friedrich Ebert Stiftung and Royal Society for the Conservation of Nature*, Amman-Jordan, 179pp.

Schälchli, U. 1992. The clogging of coarse gravel river beds by fine sediment. *Hydrobiologia*, 235/236, p.189-197. DOI:10.1007/978-94-011-2783-7_16

Valett, H. M., Dahm, C.N., Campana, M.E., Morrice, J.A., Baker, M.A., and Fellows, C.S., 1997. Hydrologic influences on groundwater-surface water ecotones: heterogeneity in nutrient composition and retention. *Journal of the North American Benthological Society*, 16 (1), p.239-247. DOI: 10.2307/1468254

Voogd, H., 1983. *Multicriteria Evaluation for Urban and Regional Planning*. Pion, Ltd., London.

White, P. S. and Pickett, S.T.A., 1985. Natural disturbance and patch dynamics: An Introduction. *In*: Pickett, S.T.A. and White, P.S.(eds.), *Natural Disturbance and Patch Dynamics*, Academic Press. San Diego, California USA. DOI:10.1016/B978-0-12-554520-4.50006-X