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Land Suitability Evaluation Using FAO Approach and Spatial Analysis for Mujib Basin – Jordan

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Abstract

The objective of this study is to investigate the suitability of land use for different purposes in the Mujib Basin in Jordan by using the FAO suitability approach. The current land use was assessed by using the supervised classification which was applied on multi-spectral sentinel satellite images to identify the land use types. The potential land use was evaluated based on different utilization types such as field crops, vegetables, tree crops, forests, and rangelands. The suitability degree was derived by using spatial overlay techniques which were applied to specific criteria for each land utilization type. This study shows that the northern parts of the region have the highest suitability degree due to the high rainfall quantities, good soil quality, and gentle slope. It is also highlighted that these areas are embedded by urban expansion which led to a loss of fertile lands. The study shows as well that the highest suitability area in the basin is for field crops and vegetables while the lowest suitability area is for the forest and irrigated crops. It is recommended to orient the urban expansion in the southern part of the basin to preserve existing fertile lands.

Keywords: *FAO approach, Land evaluation, optimal land use, spatial analysis, supervised classification, Jordan.*

1. Introduction

The inappropriate land use practices lead to the degradation of existing land resources. However, utilization of the soil and land resources based on their capabilities can support the resources over a long time without negative environmental impact (Makhamreh, 2019). The process of determining the degree of land suitability for specific land use is closely related to the physical conditions of the region which includes topography, vegetation, climatic characteristics, and soil properties, in addition to the socio-economic factors (FAO 1983).

The Mujib basin is in the southeast of the Dead Sea and it is characterized by arid dry climatic conditions (MWI, 2018). It suffers from water scarcity which is considered a major constraint for agricultural production, and it is subjected to increased desertification risks due to the climate change impacts (RSCN, 2019), in addition to the effect of the population growth and increased urban expansion on the available agricultural land resources (Ministry of Agriculture, 2017). All these factors increased the pressure on the natural resources and decrease the possibilities of achieving sustainable development in the basin.

Land suitability mapping can only be used as an initial step in spatial planning since actual suitability can only be judged based on a detailed investigation (Proske et al, 2005). The geographic information system is one of the important techniques in analyzing the extent of land suitability for urban growth through its reliance on a multi-criteria analysis approach by combining several criteria to form an evaluation indicator. This is an effective method that helps planners and decision-makers analyze all data before reaching a final decision of determining a specific land use type in the presence of competition between different types of uses.

Remote sensing data can be integrated with a geographical information system to perform agricultural land use classification (Makhamreh, 2018), and land suitability for various uses (Abdel Rahman et al, 2016). Also, remote sensing can be used for general suitability analysis (Vazquez et al, 2020), agriculture suitability evaluation (Shalaby et al, 2006; Majumdar, 2020), and land suitability analysis for urban and industrial development and other land use analysis (Ramamurthy et al, 2020). In this context, the high spatial resolution Sentinel-2B images were used to enable accurate classification of land use types, mapping of land cover types (Ngo et. al, 2020), and use classification (Tong et, al, 2020; Brinkhoff et al, 2020) and identification of land use pattern under agricultural landscapes (Abdi, 2019). In Jordan, many studies had been conducted using the FAO approach to investigate the agricultural land use suitability and land vulnerability to land degradation (MOA, 1995; Hatten, 1998, Makhamreh, 2005; Mazahreh, et al., 2018; Makhamreh 2019). Therefore, the objective of this study is to integrate remote sensing techniques and spatial analysis to assess land suitability based on the FAO approach in the Mujjb basin.

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2. Materials and Methods

2.1 Study area:

The Mujib basin is located between latitudes 30°39'09", 31°51'37"north, and longitudes 35°32'38", 36°32'58"east. it covers an area of 6585 km^2 which constitutes about 7% of the total area of Jordan as shown in figure 1.

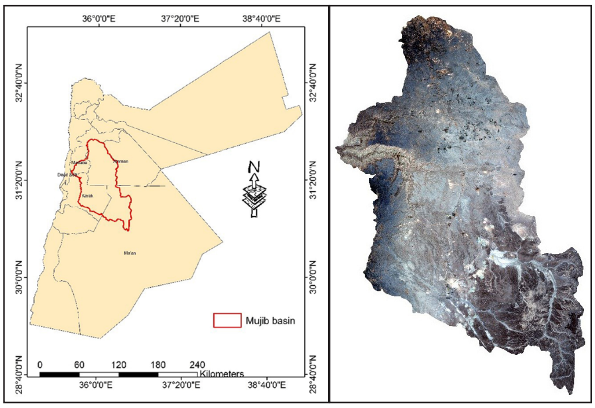

Figure 1. Location map of Mujib basin in Jordan

Mujib basin is a major source of water production for drinking and irrigation purposes in Jordan. It is characterized by semi-arid to arid conditions with low amounts of rainfall, particularly in the eastern parts of the basin. The rainfall begins in October and lasts until May, but most of the precipitations occur during December and January, and annual rainfall decreases from 450 mm in the western parts of the basin to less than 100 mm in the eastern part (DOS, 2018). Hydrologically, the basin comprises two watersheds, one is known as upper Mujib with an area of 4485 km^2 and the other is Wala with an area of 2100 km^2, which is drained by a distributed stream network (Ijam and Al-Tarawneh 2012). More than 80% of the basin is covered by rangeland; bare land and 20% is occupied by agricultural and built-up activities (Abu-Allaban et al. 2015).

2.2 Methodology

Figure 2 shows the methodological approach which uses the optimal land use in the Mujib basin. In this study, a high-resolution Sentinel-2B satellite image for October 2018 with a spatial resolution of 10m was uploaded from European Space Agency (ESA) (website: https://scihub.copernicus.eu) and used in the study. The supervised classification approach was used to derive the map of current land uses for the Mujib basin. The Digital elevation model (DEM) was downloaded from USGS with a spatial resolution of 30m, it was used to derive the slope map and extract the basin hydrological properties. The climate and groundwater data were obtained from the Ministry of Water and Irrigation which include rainfall, well information... etc. The soil data were obtained from the Ministry of Agriculture which include soil texture, soil depth, erosion severity, stones size…etc.

The criteria of different land attributes were classified based on the ranges as indicated in tables (1-7), then a convenient weight was given for each criterion and based on a limitation factor method (FAO, 1983: Makhamreh, 2019). Accordingly, identification of suitability level was identified. Each land use suitability map was classified into four classes according to the land suitability classification method (FAO, 1976). Then the resulting raster maps were derived using the sum overlay weighted analysis to determine the optimal land use map for the Mujib basin.

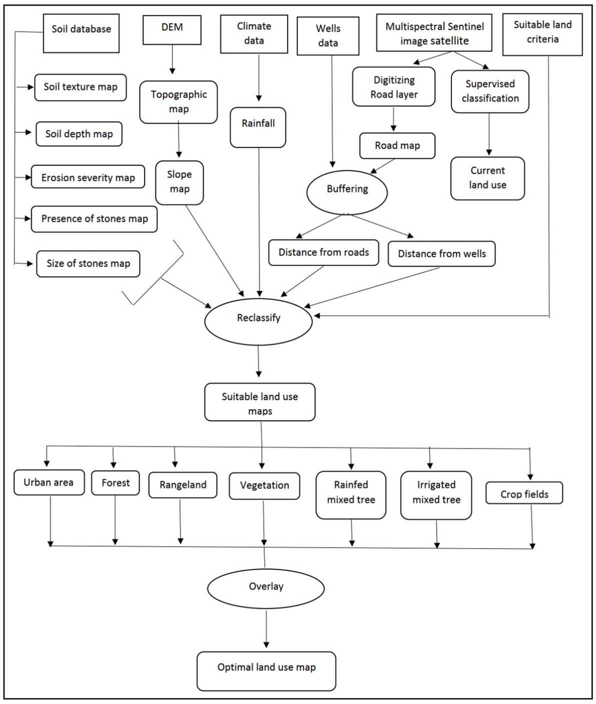

Figure 2. The methodological approach used to derive the optimal land use in the Mujib basin

2.3 Suitability for agricultural land use

The lands use suitability for agricultural production were divided according to the FAO evaluation approach into four categories (FAO, 1976), namely:

i. Highly suitable: lands having no significant limitations and level of production is high with the lowest possible costs.
ii. Moderately suitable: lands having moderate limitations which will reduce production levels but are still physically and economically suitable for agricultural use.
iii. Marginally suitable: lands having a series of limitations that will reduce production levels such that it is economically marginal for agricultural use.
iv. Not suitable: Lands not suitable for agricultural production.

A set of land characteristics has been selected to perform the suitability analysis for determining the optimal suitability degree of each type of agricultural land use. Some criteria are considered limiting factors such as climate, soil depth, and erosion type. However, some other criteria that can be altered or changed by low cost and effort are considered as not-limiting factors such as the presence of stones and road construction. A set of criteria was selected to evaluate suitable sites for different land utilization type in the Mujib basin as shown in Tables (1-7). The list of land utilization types that have been selected to perform the suitability analysis is field crops, irrigated mixed tree crops, rain-fed mixed trees, vegetables, rangelands, forests, and urban expansion. The criteria which have been used to derive the suitability degree for each land utilization type are related mainly to soil climate and topography. The most important criteria are the soil texture, considering soil's main classes: sand, silt, and clay which are important to determine the water holding capacity and soil moisture content, etc. The second factor is soil depth, which is important for plant growth. Soil texture and depth maps are derived using the Inverse distance weighted method based on a set of field samples taken by the Ministry of Agriculture. The slope degree was derived from the DEM raster data, which is a critical factor in determining the suitability class and risk of soil erosion. The rainfall has a direct effect on crop growth and the success of agricultural production while the erosion processes lead to soil losses with reduced depth and fertility and the presence of stones limits the workability and diversity of crop utilization. The weighted average percentage for each criterion is as follows: The soil criteria are 30%, the topography (slope) is 30%, the stones are 5%, and the road accessibility is 5%. The water availability is represented in two criteria either climate for Rainfed agriculture or groundwater for irrigated land use. In both cases, the weighted average percent for climate (rainfall) is 30%, and for groundwater is 30%. Accordingly, the summation of percentages is 100%. The justification for these weighted percentages is that the influence of soil, topography, and water availability on agricultural land use in Jordan is equally contributed and for this reason, it is given the same percentage which is 30% each. Also, we have to recognize that water availability is represented either by climate or groundwater availability according to the land use types. In addition, the 10 % left which is 5% for the stones and road accessibility criteria are important for tillage and ease of accessibility.

Table 1. Land criteria for evaluation of field crops in the Mujib basin

Indicator	Sub-indicator	Unit	Highly suitable	Moderately suitable	Marginally suitable	Not suitable
Soil	Soil texture	Class	Silty, Silty loam	Loam, silty clay	Sandy clay	Sand, clay
	Soil depth	Cm	>75	50-75	25-50	<25
	Erosion severity	Class	Nil	slight	moderate	Severe
Topography	Slope	Degree	<3	3-6	6-12	>12
Climate	Rainfall	Mm	>350	250-350	200-250	<200
Stones	Presence of stones	%	<5	5-20	20-35	>35
	Size of stones	Class	very small	small	moderate	Large
Roads	Distance from roads	M	<1000	10003000-	30005000-	>5000

(Makhamreh, 2005; MOA, 1995; JAZPP, 2000)

Table 2. Land criteria for evaluation of irrigated mixed tree crops in the Mujib basin

Indicator	Sub-indicator	Unit	Highly suitable	Moderately suitable	Marginally suitable	Not suitable
Soil	Soil texture	Class	Silty loam	Loam, silty clay	Sandy clay	Sand, clay
	Soil depth	cm	>90	60-90	30-60	<30
	Erosion severity	Class	nil	slight	moderate	Severe
Topography	Slope	Degree	<5	58-	8-16	>16
Stones	Presence of stones	%	<10	10-20	20-35	>35
	Size of stones	Class	very small	small	moderate	Large
Groundwater	Distance from wells	m	<500	5001000-	10002500-	>2500
Road	Distance from roads	m	<1000	10003000-	30005000-	>5000

(Makhamreh, 2005; MOA, 1995; Hatten, 1998)

Table 3. Land criteria for evaluation of rain-fed mixed trees in the Mujib basin

Indicator	Sub-indicator	Unit	Highly suitable	Moderately suitable	Marginally suitable	Not suitable
Soil	Soil texture	Class	Silty loam	Loam, silty clay	Sandy clay	Sand, clay
	Soil depth	cm	>120	80 – 120	50-80	<50
	Erosion severity	Class	nil	slight	moderate	Severe
Topography	Slope	Degree	<16	16-25	25-40	>40
Climate	Rainfall	mm	>400	300-400	250-300	<250
Stones	Presence of stones	%	<10	10-20	20-35	>35
	Size of stones	Class	very small	small	moderate	Large
Road	Distance from roads	m	<1000	10003000-	30005000-	>5000

(Makhamreh, 2005; MOA, 1995; Hatten, 1998)

Table 4. Land criteria for evaluation of vegetables in the Mujib basin

Indicator	Sub-indicator	Unit	Highly suitable	Moderately suitable	Marginally suitable	Not suitable
Soil	Soil texture	Class	Silty loam	Loam, silty clay	Sandy clay	Sand, clay
	Soil depth	cm	>75	40-75	<40	
	Erosion severity	Class	nil	slight	moderate	Severe
Topography	Slope	Degree	<2	2-4	4-8	>8
Stones	Presence of stones	%	<5	5-20	20-35	>35
	Size of stones	Class	very small	small	moderate	Large
Groundwater	Distance from wells	m	<500	5001000-	10002500-	>2500
Roads	Distance from urban areas	m	<1000	10003000-	30005000-	>5000

(MOA, 1995; JAZPP, 2000)

Table 5. Land criteria for evaluation of rangelands in Mujib Basin

Indicator	Sub-indicator	Unit	Highly suitable	Moderately suitable	Marginally suitable	Not suitable
Soil	Soil texture	Class	Sand, sandy loam	Silty loam, silty	Clay loam, silty clay	Clay
	Soil depth	cm	<25	25-40	>40	
	Erosion severity	Class	slight ، nil	moderate	severe	
Topography	Slope	Degree	<25	25-50	>50	
Climate	Rainfall	mm	>300	200-300	<200	
Stones	Presence of stones	%	<20	20-40	>40	
	Size of stones	Class	very small	small	moderate	Large
Roads	Distance from roads	m	>2500	50002500-	<5000	

(Jafari, 2010; JAZPP, 2000)

Table 6. Land criteria for evaluation of forests in Mujib Basin

Indicator	Sub-indicator	Unit	Highly suitable	Moderately suitable	Marginally suitable	Not suitable
Soil	Soil texture	Class	Silty loam	Loam, silty clay	Sandy clay	Sand, clay
	Soil depth	cm	>90	60-90	30-60	<30
	Erosion severity	Class	nil	slight	moderate	Severe
Topography	Slope	Degree	<15	3015-	>30	
Climate	Rainfall	mm	>400	400-300	200-300	<200
Stones	Presence of stones	%	<5	5-20	20-35	>35
	Size of stones	Class	very small	small	moderate	Large

(MOA, 1995; Hatten, 1998)

Table 7. Land criteria for evaluation of urban expansion in Mujib Basin

Indicator	Sub-indicator	Unit	Highly suitable	Moderately suitable	Marginally suitable	Not suitable
Soil	Soil texture	Class	Sand, Loamy sand	Silty, silty loam	Silty clay	Clay
	Soil depth	cm	<25	25-40	40-50	>50
Topography	Slope	Degree	>15	10-15	5-10	<5
Climate	Rainfall	mm	>350	250-350	<250	
Stones	Presence of stones	%	<5	5-20	20-35	>35
	Size of stones	Class	large	moderate	small	very small
Roads	Distance from services	m	<500	500-1000	1000-2500	>2500
Urban areas	Distance from urban areas	m	<1000	10003000-	30005000-	>5000

(Aburas et al,2017; Park,2011; Hossain et al, 2009)

3. Results and Discussion

The land use suitability for agricultural activities has been investigated. The main agricultural activities which have been tested for their suitability in the study area cultivation of field crops, irrigated vegetables, forests, rangelands, and irrigated and rain-fed mixed trees.

3.1 Current land use

The supervised classification was applied on the multi-spectral Sentinel-2b satellite image to identify the land use types in the study area. The result shows that 12 types of classes were classified and determined, including bare rock, basalt rock, soil, water, crops (olive tree, mixed tree, field crop, and vegetables), urban area, streams valleys, forest, and rangeland.

Figure 3 shows the spatial distribution of the land cover and land use types in the Mujib basin. The results show that the northern part of the basin includes the urban areas and it includes also the existing forest and main agricultural lands within the urban vicinity. The presence of water bodies is limited to the Mujib and Wala dam. It is noticed that the agricultural lands are concentrated in the northern part of the basin and it decreases in density when moving towards the southern and eastern parts of the basin. However, the southern parts of the basin include other types of land cover such as rangeland, bare soil, and rocks. It is noticeable that the cultivation of fruit and olive trees is spreading out in the basin and is characterized by varying densities, and the presence of field crops and vegetables is related to the rainfall and water resources.

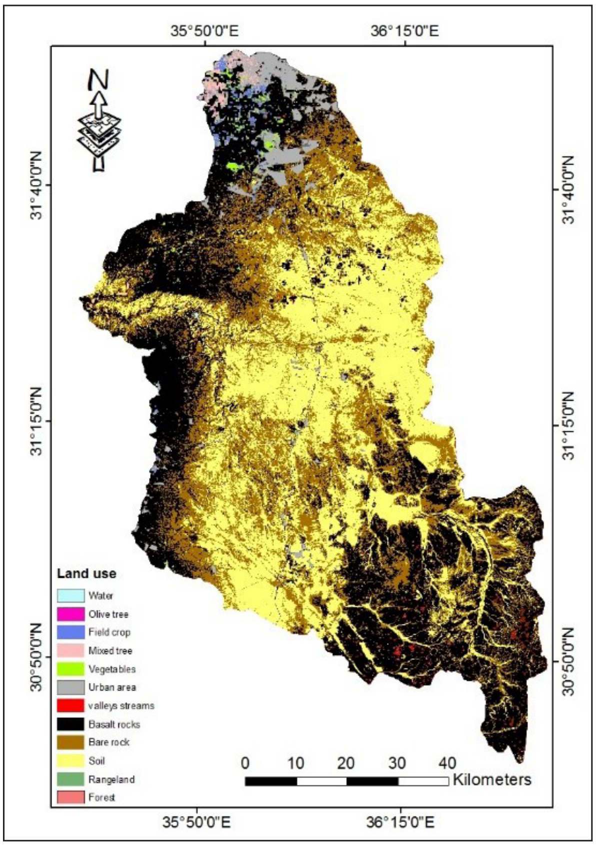

Figure 3. The spatial distribution of land use types in the Mujib basin

Table 8. Land use types in the Mujib basin

Land use	Area (km^2)	Percentage (%)
Water	2.41	0.04
Olive tree	10.36	0.16
Field crops	18.75	0.28
Mixed tree	2.30	0.03
Vegetables	38.61	0.59
Urban area	299.13	4.54
Valleys streams	9.75	0.15
Basalt rocks	1862.12	28.29
Bare rock	2057.58	31.25
Soil	2194.91	33.33
Rangeland	86.54	1.31
Forest	2.14	0.03
Total Area	6584.6	100

Table (8) lists the area and percentage of each land use type in the Mujib basin. The result shows that the bare rock and bare soil are dominating large proportions of the basin, with an area of 6114.6 km^2 which comprises 92.8% of the total area. The agricultural land consists of olive trees, fruit trees, summer vegetables of all kinds, and field crops reaching 1%, with an area of 70 km^2, urban areas occupied 4.5%, rangelands 0.36%, valleys streams 0.15%, water 0.04%, forests 0.03% of the basin area.

3.2 Land use suitability for field crops

Figure 4 shows the suitability map for field crops in the Mujib basin. The highest suitability areas are distributed spatially in the northern and western areas. This is because of the existence of fertile soil with good depth, low slope, and high amount of rainfall. The existing urban area and the Rocky land were masked from the analysis as shown on all suitability maps. The lowest degree of suitability is shown in the southern areas of the basin due to inadequacy of land characteristics such as soil texture, presence of basalt rocks, limited soil depth, high slope degree, and low amounts of precipitation. The total areas highly suitable for cultivation of field crops reach 639 km^2, with a percentage of 27%, moderately suitable areas of 734 km^2 with a percentage of 31% and marginally suitable areas of 804 km^2 with a percentage of 34%, and not suitable areas of 189 km^2 with a percentage of 8% of the total area of Mujib Basin.

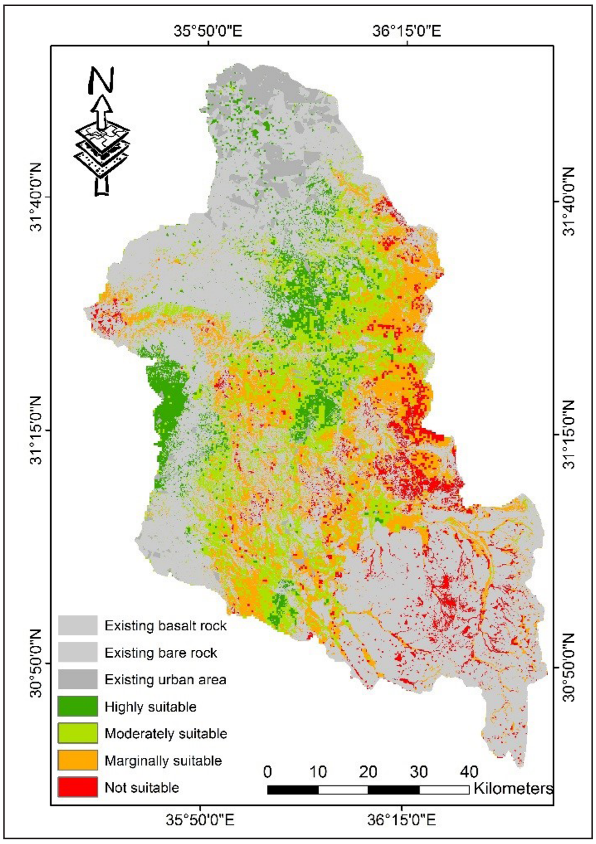

Figure 4. Suitability map of field crops in the Mujib basin

3.3 Land use suitability for irrigated mixed trees

Mixed trees grow well, and their roots stabilize properly when soil depth is deep enough and fertility is of good quality. This help in meeting the water and nutritional needs of the trees.

Figure 5 shows the suitability map of irrigated mixed trees in the Mujib basin. The areas suitable for this type of cultivation are characterized by the presence of fertile soil, deep soil, relatively high slope, and proximity to groundwater wells. The highly suitable areas for cultivation of field crops reach 781 km^2 with a percentage of 33%, and moderate suitable area of 923 km^2 with a percentage of 39% and marginally suitable area of 520 km^2 with a percentage of 22%, and not suitable areas of 142 km^2 with a percentage of 6% from the total area of Mujib Basin.

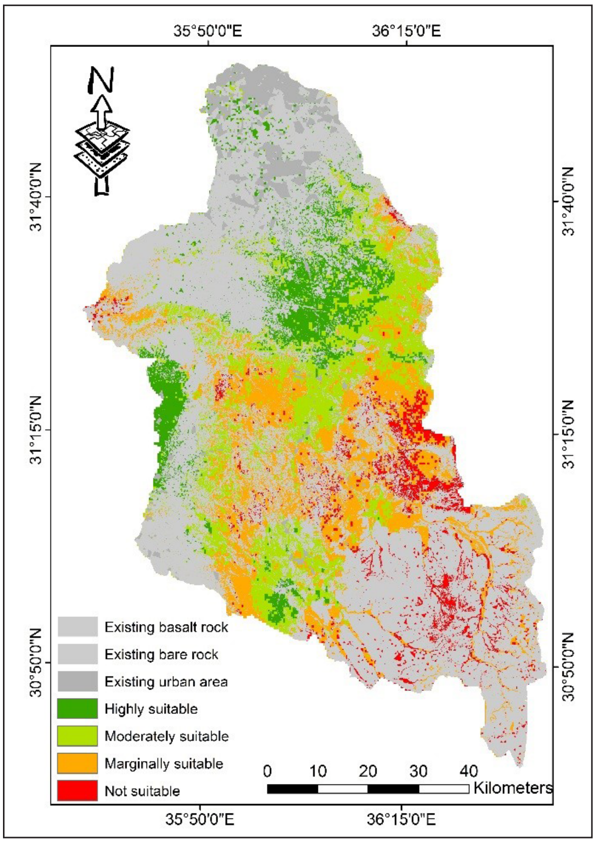

Figure 5. Suitability map of irrigated mixed trees in Mujib basin

3.4 Land use suitability for rainfed mixed trees

Mujib Basin has extremely dry climatic conditions for six successive months starting from May and lasting until October. This drought period has a bad consequence on the growth of tree crops since the amount of available water in soils doesn't meet crop water requirements during the summer months. This leads to low productivity of these trees; therefore, rainfall amounts play a limiting factor for rain-fed tree utilization.

Figure 6 shows the suitability map of the rain-fed mixed trees in Mujib Basin. The suitable sites for this type of rain-fed agriculture are small and confined to the northern and some western regions. These parts are characterized by fertile soil with adequate depths, a high amount of rainfall reaching 300mm, and a low slope. The highly suitable areas for rain-fed mixed trees reach 71 km^2 with a percentage of 3%, and moderate suitable area of 284 km^2 with a percentage of 12% and marginally suitable area of 1278 km^2 with a percentage of 54%, and not suitable areas of 733 km^2 with a percentage of 31% of the total area of Mujib Basin.

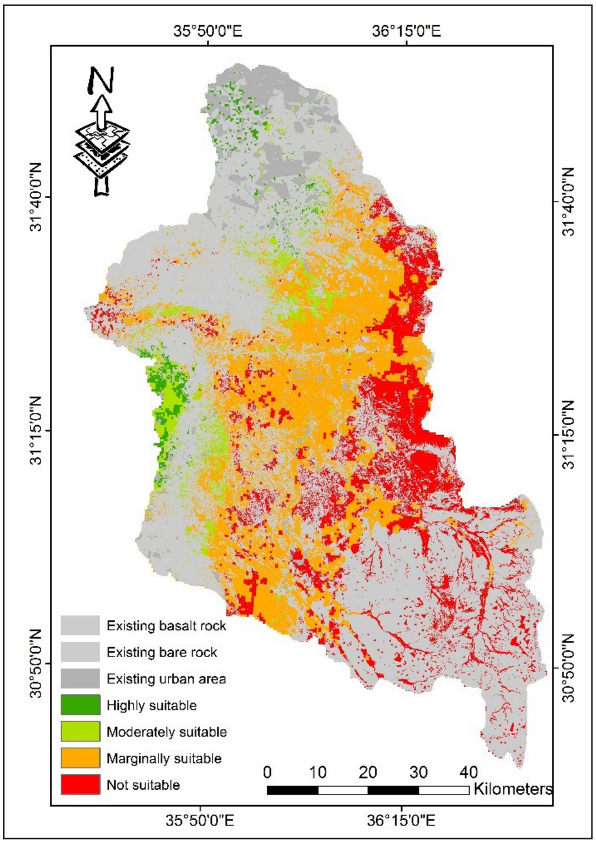

Figure 6. Suitability map of rain-fed mixed trees in the Mujib basin

3.5 Land use suitability for vegetables

Vegetables need a set of specific conditions to grow well and give high productivity. A set of indicators have been chosen that work to achieve these suitable conditions for production.

Figure 7 shows the suitability map for vegetables in the Mujib Basin. The areas suitable for the cultivation of vegetables are concentrated in the northern and western parts of the basin, because of high soil depth, high amount of rainfall, and appropriate soil fertility. The highly suitable area for vegetables reaches 591 km^2 with a percentage of 25%, a moderate suitable area of 805 km^2 with a percentage of 34%, and marginally suitable area of 568 km^2 with a percentage of 24%, and not suitable areas of 402 km^2 with a percentage of 17% of the total area of Mujib Basin.

3.6 Land use suitability for rangelands

Rangelands are characterized by their low requirements and their ability to adapt to a different land and climatic conditions.

Figure 8 shows the possibility of establishing rangelands and expanding existing rangelands in different areas of Mujib Basin. The results show that a highly suitable area reaches 331 km^2 with a percentage of 14%, a moderate suitable area of 1112 km^2 with a percentage of 47%, and marginally suitable area of 710 km^2 with a percentage of 30%, and not suitable area of 213 km^2 with a percentage of 9% of the total area of Mujib Basin.

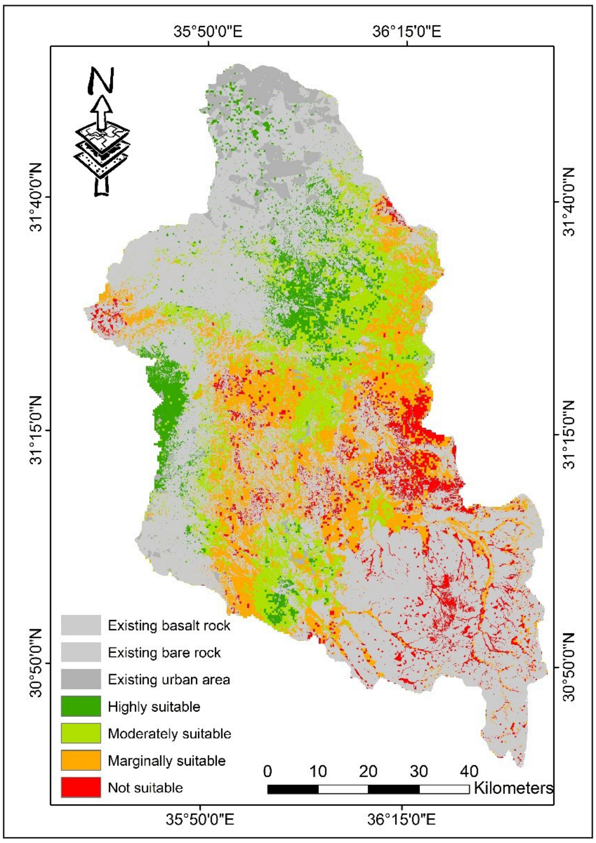

Figure 7. Suitability map of vegetables in the Mujib basin

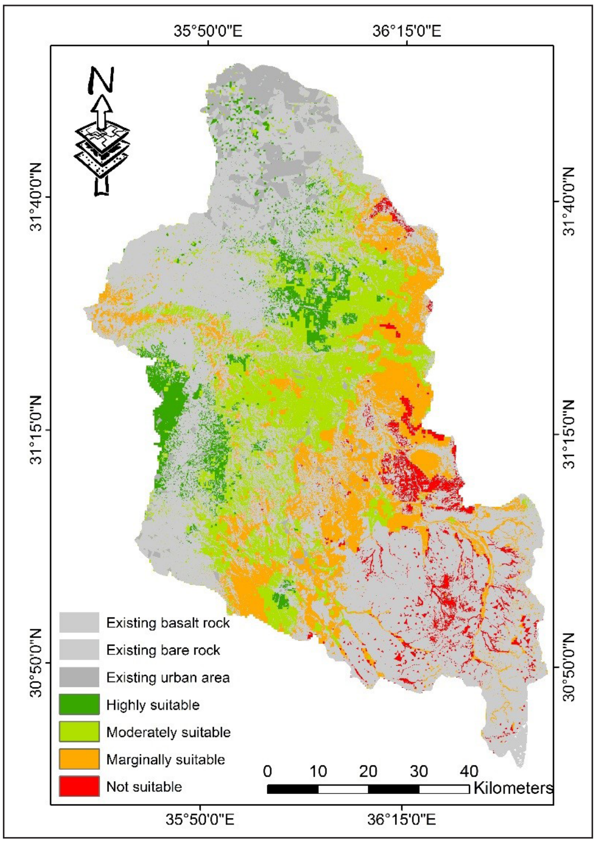

Figure 8. Suitability map for establishment rangelands in the Mujib basin

3.7 Land use suitability for Forests

Forests in Jordan are important for conserving the biodiversity level and contributing to maintaining the environmental balance. Therefore, Forests must be preserved and expanded where possible.

Figure 9 shows the spatial distribution of the suitability map for forests in the Mujib Basin. It is noticed that the suitable areas for forests are small and confined to specific locations in the northern and western areas of the basin. The most limiting factor in growing the forest is the rainfall amounts. The locations of the highly suitable areas for forests reach 95 km^2 with a percentage of 4%, and moderate suitable area of 757 km^2 with a percentage of 32%, and marginally suitable area of 1254 km^2 with a percentage of 53%, and not suitable areas of 260 km^2 with a percentage of 11% from the total area of Mujib Basin

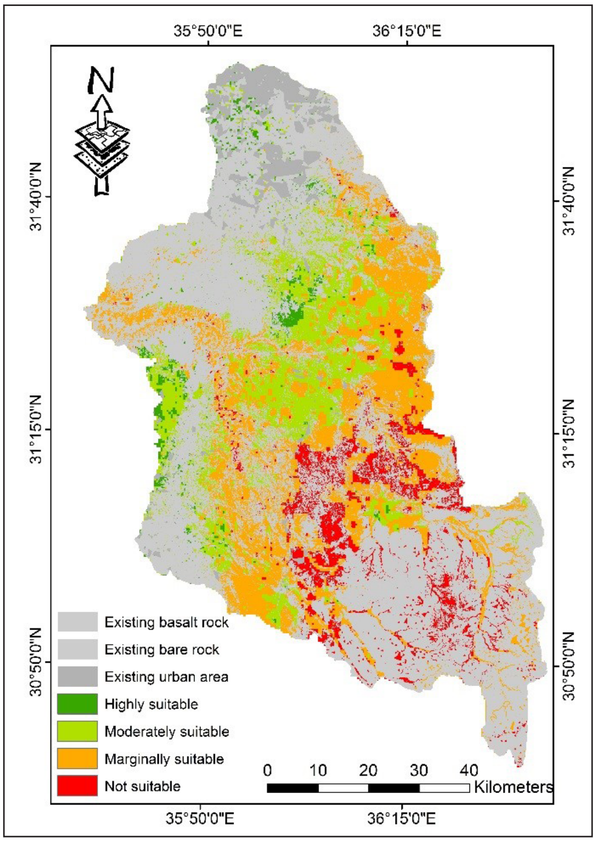

Figure 9. Suitability map for the presence of forests in the Mujib basin

3.8 Land use suitability for urban expansion

One of the most important issues in urban planning and management is determining the directions and locations of appropriate areas for urban expansion. It is vital to maintain the balance between the need to develop residential, commercial, and industrial sectors and the desire to preserve agricultural land ecosystems, biodiversity, and landscapes, especially in a small country like Jordan.

The efforts to achieve sustainable development have faced many challenges mainly related to the costs of agricultural lands due to rapid population growth and urban expansion.

Figure 10 shows the spatial distribution of the suitability map for urban expansion in the Mujib Basin. The highly suitable area for urban areas reaches 548 km^2 with a percentage of 9%, and moderately suitable area of 1382 km^2

with a percentage of 22%, and marginally suitable area of 2156 km^2 with a percentage of 34%, and not suitable areas of 2200 km^2 with a percentage of 35% from the total area of Mujib Basin after excluding the area of urban class area.

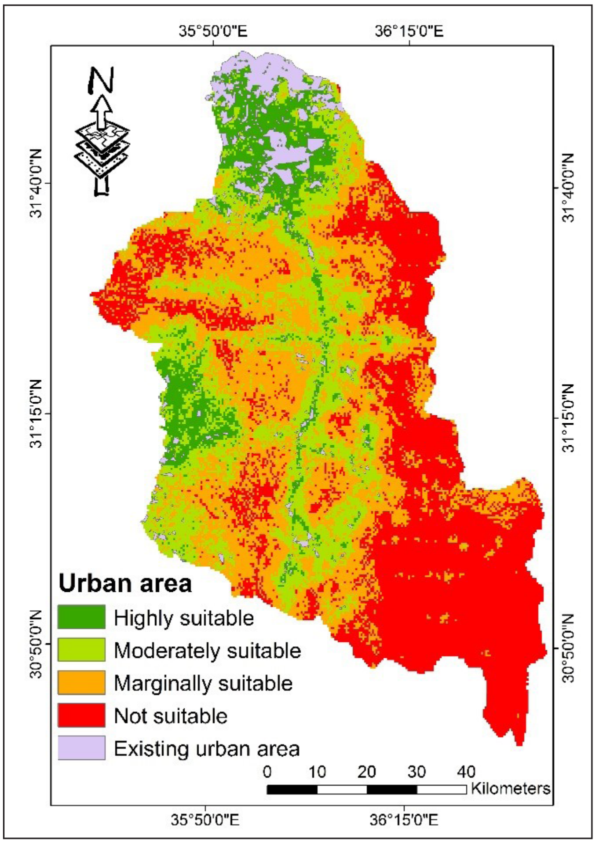

Figure 10. Suitability map for urban expansion in the Mujib basin basin

3.9 Optimal land use in the Mujib basin

The land suitability classification process is defined as an assessment of specific land in terms of its suitability for specific use. Classification of land use according to its capabilities and suitability to plan a specific use is vital to reach optimal use. The importance of planning for the best use of the land is to achieve objectives of sustainability, increase land productivity and reach food security. It also conserves the resources from degradation and deterioration, especially with increasing population pressure and climatic changes effects. After performing the suitability analysis for different land utilization types such as vegetables, field crops, irrigated and rain-fed mixed trees, rangeland, forests, and urban expansion, a map of optimal use was derived for the Mujib Basin.

Figure 11 shows the optimal land use map for the Mujib basin. The final map shows there is a capability that some land units could be used for more than one land use, which provides a good basis to choose the most appropriate land use for the basin.

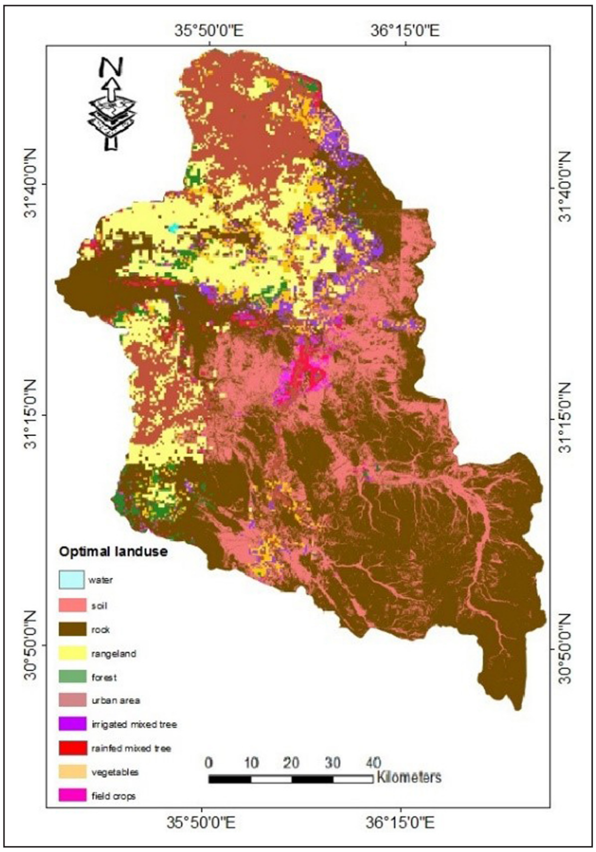

Figure 11. Optimal land use in the Mujib basin

4. Conclusions

Based on this analysis the following conclusions can be made:

i- Land suitability evaluation is employed to determine the appropriateness of land for specific use. It is a complex and multidisciplinary process, involving knowledge of the land's natural characteristics, including land use and land cover, which requires the integration of a wide range of data to develop a spatial analyzing system to determine the land suitability for each use.

ii- Suitability maps have been derived into their classes based on the following main land characteristics which are slope degree, slope depth, rainfall amounts, and existing land use map.

iii- The results of the analysis for each land utilization type are shown below:

- Land use suitability for the cultivation of vegetables showed that the areas of suitability classes are 25% for highly suitable areas, 34% for moderately suitable areas, 24% for marginally suitable areas, and 17% for not suitable areas.
- Land use suitability for field crops showed that the areas of suitability classes are 27% for highly suitable areas, 31% for moderately suitable areas, 34% for marginally suitable areas, and 8% for not suitable areas.
- Land use suitability for rain-fed mixed trees showed that the areas of suitability classes are 3% for highly suitable areas, 12% for moderately suitable areas, 54% for marginally suitable areas,

and 31% for not suitable areas.

- Land use suitability for irrigated mixed trees showed that the areas of suitability classes are 33% for highly suitable areas, 39% for moderately suitable areas, 22% for marginally suitable areas, and 6% for not suitable areas.
- Land use suitability for rangelands showed that the areas of suitability classes are 14% for highly suitable areas, 47% for moderately suitable areas, 30% for marginally suitable areas, and 9% for not suitable areas.
- Land use suitability for forests showed that the areas of suitability classes are, 4% for highly suitable areas, 32% for moderately suitable areas, 53% for marginally suitable areas, and 11% for not suitable areas.
- Finally, Land use suitability for urban expansion showed that the areas of suitability classes are9% for highly suitable areas, 22% for moderately suitable areas, 34% for marginally suitable areas, and 35% for not suitable areas.
- The current land use was obtained with a high level of detail by applying a supervised classification on a high-resolution multi-spectral Sentinel satellite image. Then, the optimal land use map was compared with the current land use map and the results showed that there is an acceptable similarity and compatibility between them.

A disadvantage of this method might be in different opinions of experts in giving the appropriate weights to the criteria and in determining the priority of land characteristics, which is a complex process and faces many conflicts between the different sectors of economic, social, and environmental issues, especially for limited land resources regions such as Jordan, which must be utilized carefully to maintain the food security and minimize the damage to the environment.

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References

Abdel Rahman, M. A., Natarajan, A., and Hegde, R. (2016). Assessment of land suitability and capability by integrating remote sensing and GIS for agriculture in Chamarajanagar district, Karnataka, India. The Egyptian Journal of Remote Sensing and Space Science, 19 (1), 125141.

Abdi, A. M. (2019). Land cover and land use classification performance of machine learning algorithms in a boreal landscape using Sentinel2 data. GIScience and Remote Sensing, 120.

Abu-Allaban, M., El Naqa, A., Jaber, M., and Hammouri, N. (2015). Water scarcity impact of climate change in semiarid regions: a case study in Mujib basin, Jordan. Arabian Journal of Geosciences, 8(2), 951959.

Aburas, M. M., Abdullah, S. H., Ramli, M. F., and Asha'ari, Z. H. (2017). Land suitability analysis of urban growth in Seremban Malaysia, using GIS based analytical hierarchy process. Procedia Engineering, 198, 11281136.

Brinkhoff, J., Vardanega, J., and Robson, A. J. (2020). Land Cover Classification of Nine Perennial Crops Using Sentinel1 and2 Data. Remote Sensing, 12(1), 96.

DOS (Department of Statistics), (2018), Jordan in figure, Amman, Jordan. http://dosweb.dos.gov.jo/DataBank/JordanInFigures/2018.pdf . (May. 12,2021).

FAO (Food and Agriculture Organization). (1976), a framework for land evaluation, Rome, Italy.

FAO (Food and Agriculture Organization). (1983), Guidelines: Land evaluation for rainfed agriculture. FAO Soils Bulletin. No. 52, Rome.

Hatten, C. J (1998), improvement of agriculture productivity in arid and semiarid zones of Jordan, visit report of land resources specialist, school of agriculture food and environment, Cranfield University, UK.

Hossain, M. S., Chowdhury, S. R., Das, N. G., Sharifuzzaman, S. M., and Sultana, A. (2009). Integration of GIS and multicriteria decision analysis for urban aquaculture development in Bangladesh. Landscape and Urban Planning, 90(34), 119133.

Jafari, S., (2010). Land Suitability Analysis using Multi-Attribute Decision Making Approach. International journal of environmental science and development, 1(5), 441.

JAZPP (2000), improvement of agriculture productivity in arid and semiarid zones of Jordan: annual report, SEM/O3/628/021. University of Jordan, Amman, Jordan.

Ijam, A., and Tarawneh, E. (2012). Assessing of Sediment Yield for Wala Dam Catchment Area in Jordan. European Water, 38, 4358.

Majumdar, S. (2020). Land Suitability Analysis for Periurban Agriculture Using Multicriteria Decision Analysis Model and Crop Condition Monitoring Methods: A Case Study of Kolkata Metropolitan Area. In IoT and Analytics for Agriculture (pp. 165185). Springer, Singapore.

Makhamreh, Z. (2005). Optical remote sensing and Geo-spatial analysis for assessing and monitoring of land degradation in northern Jordan. Remote Sensing Department, University of Trier, Germany. (Published Ph.D. Thesis).

Makhamreh, Z., M. (2018). Derivation of vegetation density and land-use type pattern in mountain regions of Jordan using multi-seasonal SPOT images: Environmental Earth Sciences 77: 384. https://doi.org/10.1007/s12665-018-7534-z.

Makhamreh, Z. M. (2019). Land degradation vulnerability assessment based on land use changes and FAO suitability analysis in Jordan. Spanish Journal of Soil Science, 9(2).

Mazahreh, S., Bsoul, M., Ziadat, F., and Abu Hamoor, D (2018). Participatory land suitability analysis to identify the optimum land use for a Mountainous Watershed in Jordan. Journal of Engineering Research and Application, Vol. 8, Issue 7 (Part -II), 41-55.

Ministry of Agriculture. (2017), annual statistical report, Amman, Jordan. http://moa.gov.jo/Portals/2017/pdf (May. 12,2021).

MOA (1995). The Soil of Jordan. Report of the National Soil Map and Land Use project, Undertaken by Ministry of agriculture, hunting technical services Ltd. And European commissions. Level one, level two, level three, and JOSCIS manual.

MWI (Ministry of Water and Irrigation). (2018), Jordanian Water Sector, Facts, and numbers, Amman, Jordan. http://waterjo.mwi.gov.jo/Ar/NewsCenter/Pages.aspx (September. 23,2020).

Ngo, K. D., Lechner, A. M., and Vu, T. T. (2020). Land cover mapping of the Mekong Delta to support natural resource management with multitemporal Sentinel1A synthetic aperture radar imagery. Remote Sensing Applications: Society and Environment, 17, 100272.

Park, S (2011), Prediction and comparison of urban growth by land suitability index mapping using GIS and RS in South Korea. Landscape and urban planning, 99(2), 104114.

Proske H, Vlcko J, Rosenbaum MS, Dorn M, Culshaw M, and Marker B (2005) Special-purpose mapping for waste disposal sites. Bull Eng Geol Environ 64(1):1–54.

Ramamurthy, V., Challa, O., Naidu, L. G. K., Kumar, K. A., Singh, S. K., Mamatha, D., and Mishra, B. B. (2020). Land Evaluation and Land Use Planning. In The Soils of India (pp. 191214). Springer, Cham.

RSCN (Royal Society for the Conservation of Nature). (2019), sponsorship opportunities for nature protection programs, Amman, Jordan. https://www.rscn.org.jo/sites/default/files/basic_page_files/RSCN Sponsorship Menu2019-EnglishVersion.pdf (May. 12,2021).

Shalaby, A., Ouma, Y. O., and Tateishi, R. (2006). Land suitability assessment for perennial crops using remote sensing and Geographic Information Systems: A case study in northwestern Egypt, Archives of Agronomy and Soil Science, 52(3), 243261.

Tong, X. Y., Xia, G. S., Lu, Q., Shen, H., Li, S., You, S., and Zhang, L. (2020). Landcover classification with high-resolution remote sensing images using transferable deep models. Remote Sensing of Environment, 237, 111322.

Vazquez-Quintero, G., Prieto-Amparan, J. A., Pinedo-Alvarez, A., Valles-Aragon, M. C., Morales-Nieto, C. R., and Villarreal-Guerrero, F. (2020). GIS-based multicriteria evaluation of land suitability for grasslands conservation in Chihuahua, Mexico. Sustainability, 12(1), 185.