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AGRICULTURAL LAND USES SUITABILITY ANALYSIS FOR NORTHERN AND EASTERN AREAS OF THE UAE

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Abstract— Land is the main source of all agricultural activities, as the choice of suitable types for agricultural activities depends mainly on the type of land and natural resources available. There is a competitive trade-off between different land uses and the gradual growth of population growth, making the demarcation of potential agricultural land a top priority. This is done using GIS and remote sensing techniques, through which it is possible to determine the optimal use of agricultural land, and its suitability for growing different types of field and horticultural crops.
The ultimate objective of this study is to assess the suitability of land for agriculture in the UAE, specifically the northern and eastern regions (Sharjah, Ras Al Khaimah, and Fujairah) where it can be used by state officials and decision-makers to plan and expand future agricultural activities, direct agricultural investment activities, and finance them in areas with high agricultural suitability. Using the analytical hierarchy (AHP) and geographic information systems (GIS) method, many data were used to achieve the objective of the study, which is categorized into six main groups: soil characteristics, geology, topography characteristics, climatic factors, and land-use/land cover elements. The results showed that the Emirate of Fujairah came in the first place with a degree of suitability for agriculture, followed by the Emirate of Ras Al Khaimah with a degree of suitability and then Sharjah with a marginally appropriate degree, under all the elements of the study. The study recommends conducting further research on the type of crops suitable for the nature of the soil and its characteristics within the scope of the study to determine the best arable crops in that region, and determine their economic feasibility and investment opportunities, which helps in drawing the map of agricultural development in that region.
Index Terms—Land suitability for agriculture, Sharjah, Ras Al Khaimah, Fujairah, Analytical hierarchy (AHP), GIS.

I. INTRODUCTION

Agriculture in the UAE plays a significant role in the economy, but limited water resources and arid climate require efficient land use. GIS and AHP techniques enable identification of suitable agricultural areas, considering factors like soil type, water availability, and climate. Utilizing these tools promotes sustainable agricultural development, addresses challenges such as water scarcity, and enhances food security in the UAE.

A. Agricultural land suitability analysis

Land use suitability mapping is a crucial part of land management and planning, involving considerations of various factors to determine the best areas for different agricultural activities. Remote sensing and GIS technologies have revolutionized this analysis by enabling the collection, processing, and analysis of vast amounts of spatial data, leading to accurate maps of land suitability. Multi-criteria decision analysis techniques like AHP, TOPSIS, and SAW are commonly used to incorporate multiple criteria and stakeholder preferences in decision-making for agricultural land suitability mapping.

B. Vegetation in arid land

Arid lands typically have sparse vegetation consisting of drought-tolerant species like desert shrubs, succulents, and cacti. The UAE has implemented agricultural practices to enhance food security, but limited water resources and the arid climate restrict crop options. However, crops such as dates, figs, citrus fruits, and certain vegetables like tomatoes, cucumbers, and eggplants can be grown. Modern techniques like hydroponics and vertical farming have been introduced to increase yields and cultivate a wider range of crops, including leafy greens, herbs, and strawberries. Hydroponics offers the potential to meet local food demand regardless of climate, soil quality, or import reliance.

C. Soil Quality Assessment

Soil quality assessment involves analyzing the physical, chemical, and biological properties that affect crop growth. It is evaluated through laboratory analysis, field measurements, and remote sensing. Laboratory techniques analyze nutrients, pH, organic matter, and soil texture, while remote sensing provides data on moisture, temperature, and vegetation indices to infer soil properties, especially over large areas.

D. Water availability

Water availability and irrigation management play a vital role in agricultural land suitability analysis, impacting crop growth. Factors like climate, soil, and topography influence water availability, while effective irrigation management optimizes crop growth and minimizes water loss. Techniques such as soil moisture measurement, crop water requirement estimation, and irrigation scheduling are employed to evaluate water availability and manage irrigation for agricultural land suitability.

Climate change impact

Climate change has a significant impact on agricultural land suitability mapping, affecting resource availability, extreme weather events, and necessitating adaptation strategies like climate-resilient crops, sustainable land management, precision irrigation, and climate-smart agriculture practices for improved productivity and reduced emissions.

Study Area

The northern-eastern region of the UAE, including Fujairah, Sharjah, and Ras Al Khaimah, is characterized by a mountainous landscape, arid climate, and low rainfall. The area faces challenges with soil salinity but is economically significant due to oil and gas reserves, tourism, and major ports.

Methodology

Agricultural land suitability analysis (ALS) is well-suited for controlled environment agriculture (CEA) in indoor settings, making it adaptable to remote communities, urban centers, and extreme climates. The selection of suitable sites is necessary to accommodate high-energy grow lights used in indoor farming. ALS utilizes multi-criteria evaluation (MCE) and geographical information systems (GIS) to assess land quality and solve land-related issues, integrating geospatial techniques and multi-criteria decision-making (MCDM) for effective land use decision-making.

Phase 1: Data Collection

- Land cover data: This type of data describes the soil physical features of the land surface (Soil Salinity ppm), including vegetation cover, bare soil, water bodies, and built-up areas.
- Water resources data: This type of data describes the availability and quality of water resources, including groundwater and surface water (Salinity mg/L).
- Geology data: This type of data provides information about the underlying geological formations, which can affect soil fertility, drainage, and water retention.
- Meteorological and climate data: This type of data describes the prevailing weather conditions, including temperature, precipitation, and wind patterns.
- Soil data: soil type such as, costal sabkha camrashes, Semi ophiolite. This type of data provides information about soil properties, such as texture, organic matter content, and nutrient availability.
- Digital Elevation Model (DEM) at 90 meters resolution was processed to create a thematic map of ground surface elevation grids required to determine the drainage networks, drainage basins, slope values, and directions, and flow accumulation in the ponding zones.
- Satellite images: These images provide a detailed view of the land surface and can be used to classify.

Phase2: Data processing

- Geoprocessing to clip layers
- Image enhancement, filtering, and fusion
- DEM processing and stream network delineation
- Supervised classification for land cover mapping

These steps help identify suitable areas for agriculture while considering factors like terrain, water availability, and land cover types.

Phase3: Data Analysis

- Assessment of criteria weight based on their relative importance. It can be done through expert opinion and literature review. The weights are assigned on a scale of 0 to 1, where 0 indicates no importance and 1 indicates the highest importance.
- Mapping criteria and reclassifying maps into a suitable format for analysis.
- Compose a pairwise matrix for AHP comparison: This step involves creating pairwise comparison matrix for the Analytic Hierarchy Process (AHP).

(AHP) approach, an index of consistency, known as the consistency ratio (CR), is a ratio between the matrix's consistency index and random index. CR is used to indicate the probability that the matrix judgments).

$CR= CI/RI$ (1)

(RI) is the average of the resulting consistency index.

(CI) is the consistency index and can be expressed as

$CI= (\lambda max - n) / (n-1)$ (2)

λmax is the largest or principal specific value of the matrix.

Our results showed that:

λmax = 5.02

CI= (5.02-5) / (5-1) = 0.01

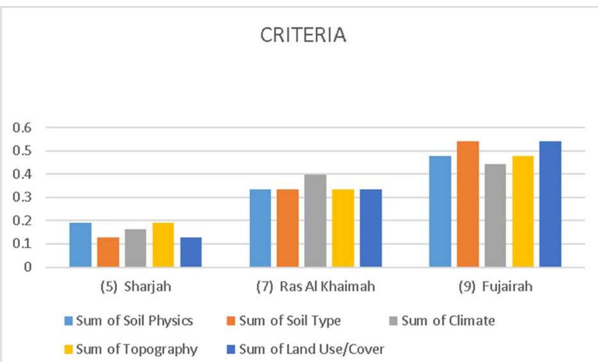
CR= 0.1/1.12= 0.01

CR of 0.10 or less is a reasonable level of consistency.

CR above 0.1 requires revision of the judgments in the matrix.

Results

By performing these data analysis steps, we can create a reliable and accurate agriculture land suitability map that can be used to guide land use planning and decision-making in Northern and Eastern UAE.



Study criteria

- Agroforestry has great potential in the UAE due to its numerous benefits. Salt-tolerant genotypes of food crops have been identified, allowing effective cultivation in saline conditions. Salt-tolerant grasses and trees, such as Chloris guayana, Panicum turgidum, Acacia spp., and Prosopis spp., are commonly used for grazing and as additional sources of fodder for livestock. Agroforestry systems such as alley-cropping, silvopasture, windbreaks, riparian buffer strips, and forest farming have been shown to enhance productivity on marginal lands and improve soil nutrient management. The semi ophiolite soil in Fujairah contains various mineral elements, including calcium, magnesium, potassium, phosphorus, iron, nitrogen, and manganese. These elements can contribute to increasing soil fertility for agriculture.
- Groundwater salinity is lowest in Fujairah, followed by Ras Al Khaimah and Sharjah,

indicating that Fujairah has more suitable groundwater for agriculture. Various crops such as carrots, onions, tomatoes, date palm, pearl millet, barley, sorghum, maize, and wheat can be grown in these areas.

- The pH levels in farms of Ras Al Khaimah show a decrease, possibly due to increased agricultural activities. In sabkhas, Fujairah has a lower pH rate compared to Ras Al Khaimah. A pH level around 7 indicates suitable conditions for growing crops and fruits.
- Soil electrical conductivity (Ec) is highest in Ras Al Khaimah farms, indicating higher salinity and decreased suitability for agriculture. In sabkhas, Sharjah has the lowest Ec rate, followed by Fujairah and Ras Al Khaimah. Low Ec values suggest better land suitability for agriculture. High pH and Ec levels make the land unsuitable for crops like wheat, sorghum, barley, and maize. Factors such as soil salinity, texture, depth, slope, elevation, water supply, and water salinity impact cereal plantation and sorghum yields. Sorghum, which requires less water, can be grown in the eastern parts of Fujairah where precipitation of 40-45 cm during the growing season is sufficient. Jojoba is a crop that thrives in marginally fertile soil, requires little water, tolerates salinity, and does not rely heavily on fertilizers or chemical treatments.
- Halophytes, plants that can tolerate high salt levels in soil or irrigation water, are suitable for protecting habitats, maintaining ecological stability, and developing agriculture in saline soils. They can grow in various environments such as marshes, estuaries, cliffs, and dunes.Halophytes are particularly suitable for coastal and inland soils in arid and semiarid climates where evapotranspiration exceeds precipitation. They have adaptations that allow them to tolerate salinity by adjusting their internal water relations and removing salts from the soil through various mechanisms. Some halophytes have also shown the ability to remove heavy metals from soils.In the UAE, the establishment of halophytic plants, such as Atriplex species, can be beneficial in coastal areas with salt flats (sabkhas). Once these soils are rehabilitated, it becomes possible to grow non-halophytic trees, shrubs, and grasses. Halophytes have the potential to inhabit thin layers of aeolian sand deposited on the sabkha surface, supporting dense vegetation.

Several halophytic plant species, including Suaeda maritime, Sesuvium portulacastrum, Arthrocnemum indicum, Suaeda fruticosa, Tamarix aphylla, Atriplex nummularia, and Atriplex halimus, have been used to clean contaminated and salt-affected soils by absorbing salts in their tissues. Halophytes can maintain agricultural productivity up to a certain salinity level if effective leaching is practiced. In the UAE, 76 commonly existing halophyte species have been recognized, including seawater halophytes, halophytes, semi-halophytes, and parasitic plants from the Chenopodaceae and Zygophyllaceae families.

In the UAE, tree production systems can be of great value because of the presence of sandy soils and saline groundwater. However, the success of the sea water plantations will depend on the effectiveness of selected plant species grown for the management of salt concentrations in the root-zone and the concentration of sodium carbonate in the irrigation water.

Since leaching fractions for the sandy soils are high, areas with deeper water tables will be most suited for these plantations. Integration of fodder halophytes into the agro-silvi-pastoral system can offer cost-effective rehabilitation of degraded rangelands and farm lands.

- Climate (Temperature and Rainfall): This result indicates that the temperatures and annual rainfall in Fujairah are more suitability for agriculture than Ras Al Khaimah, followed by Sharjah.
- Slope suitability (%):Slope gradient has great impact on work efficiency, erosion control practices and crop adaptability. First Rating factors were given for each slope gradient of the study area based on literature review and FAO guidelines. Using this rating the study area was reclassified in to five classes according to its land qualities and characteristics of the slope.

No	Land form	Slope range (%)	Slope suitability class
1	Flat-Undulation plain	0-8	S1
2	Rolling to undulating	8-15	S2
3	Hill to rolling	15-30	S3
4	Steep	30-50	N1
5	Very steep escarpment	> 50	N2

regression Analysis

Descriptive Statics

Table 5. Descriptive Statistics

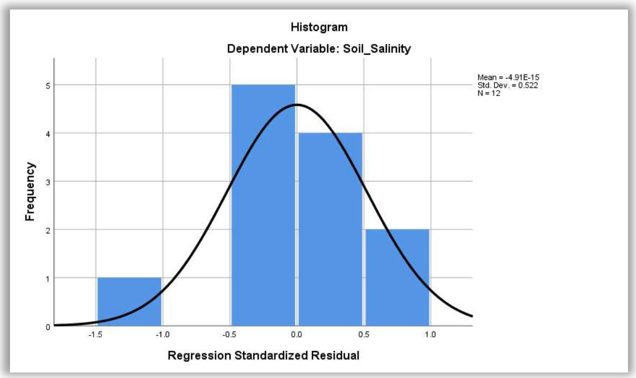
	Mean	Std. Deviation	N
Soil Salinity	18866.67	21177.66	12
Rainfall	90.83	26.78	12
pH in Farm	8.44	1.68	12
pH in Sabkha	8.47	0.36	12
Ec in Farm	8.00	5.67	12
Ec in Sabkha	110.63	59.02	12

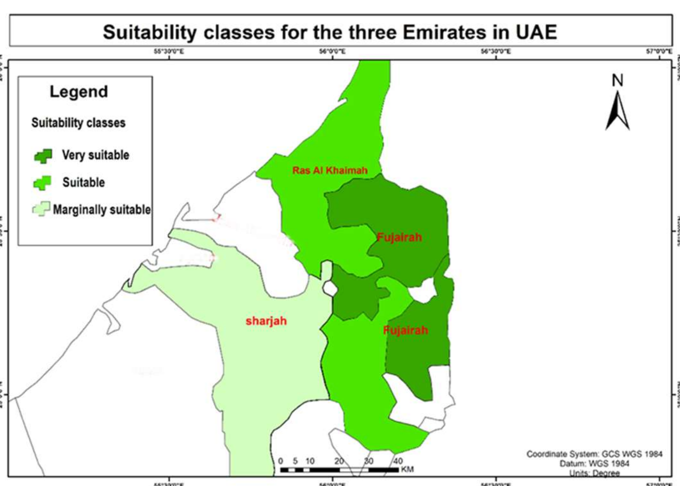
Temperature	27.57	0.43	12
Groundwater	24150.00	19365.45	12
Slope	14.67	11.34	12

From the variance table model summary. It explains that the independent variables (Slope, Ec in Farm, pH in Farm, Temperature, pH in Sabkha, Ec in Sabkha, Rainfall, Groundwater) explain about (R Square) 99% of the variation in the value of salinity, which is a significant percentage.

Also, it is clear from the ANOVA table that the value of F is equal to (46.031) with a level of significance of (0.05), which indicates the rejection of the (0) hypothesis and the acceptance of the alternative hypothesis, which is that the regression is significant and not equal to (0), and therefore there is a relationship between the dependent variable, which is salinity, and the independent variables.

As for the coefficient table, we find that salinity is the only variable that has a significant effect because the Beta significant values are (0) and less than 5%. While the independent factors have no effect in the regression equation because the value of Beta is greater than 5%.





Discussion

This study provides a detailed map of agricultural land suitability in the northern and eastern regions of the United Arab Emirates (UAE). The map can be utilized by state officials and decision-makers for planning and expanding agricultural activities, directing agricultural investments, and identifying areas with high agricultural potential. The evaluation of soil physical land qualities in the study area indicates favorable conditions for agricultural crops. The suitability classification considered factors such as soil physical properties, soil type, temperature, rainfall, pH levels in farms and sabkhas, soil, and land use-cover.

Using the Analytic Hierarchy Process (AHP), the study found that the Fujairah region had the highest suitability for agriculture, followed by Ras Al Khaimah and then Sharjah. The primary factor contributing to suitability was soil physical properties, particularly salinity, followed by other criteria such as soil type, rainfall, temperature, pH, electrical conductivity (Ec), and groundwater salinity.

Based on the results, the crops identified as suitable for cultivation in the three study areas are sorghum, jojoba, herbal medicine, and shrubs like Jatropha curcas. The study recommends further research to determine the specific crop types suitable for the soil characteristics in the study area. This research would help determine the economic feasibility and investment opportunities associated with these crops, facilitating the development of an agricultural plan for the region.

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