Research Article

Geospatial Analysis of Management Indicators for Some Ghammas Soils in Integration with Sentinel Data

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Abstract | For the purpose of assessing the state of soils suitability to cultivate spelt and rice with spatial analysis based on complementarity between field investigations and laboratory tests with Sentinel data, this study carried out in Ghammas county of Iraqi Diwaniyah governorate between two Circles of latitude of 31 ° 37 '08.9732 "N to 31 ° 43' 23.2848" N two lines of longitude of 44 ° 32 '27.1115' E to 10.446 "E. The study comes up to the existence of five series of DM115, DM86, DM96 and MM11 belong to Typic Torrifluvents. The study discovered that the geochemical soil of the area has an original calcareous alluvium, with a decrease in lime amount, most of which consists of secondary lime from irrigation operations carrying it with an abundance of calcium carbonate which has a fundamental role in the physical and chemical behaviour of soil. The study showed that the suitability of study area soils to cultivate spelt indicated the absence of the item Highly Suitable (S1) while the rest of the items; Moderately Suitable (S2), Marginally Suitable (S3), Currently not Suitable(N1) and Permanently not Suitable (N2) occupied 14.46%, 67.27%, 14.21% and 4.06% of the study area, respectively. While the suitability of study area soils series to cultivate rice indicated the absence of the item Highly Suitable (S1) while the rest of the items; Moderately Suitable (S2), Marginally Suitable (S3), Current not Suitable (N1) and Permanently not Suitable (N2) occupied 11.32%, 72.96%, 12.91% and 2.81% of the study area, respectively. The study also found that 43.82% of the study area is mostly cultivated with spelt plant, the bushland occupied 29.61% while the rest of the area without vegetation through NDVI values for March. The DM115 series exceeded the MM11 in having a healthy spelt vegetation and bright green growth. The NDVI values, measured in July (the Iraqi dry season), also showed the effected absence of rice plant in the study area measuring a high difference between the NDVI values during spring (the spelt growing season) and its values in July (the rice growing season). In this study, it is reckoned that integrating the results of field investigations and laboratory tests with Sentinel2 data are important to obtain indicators for the management of some Ghammas soils to assess its suitability for rice, the district most famous plant, and spelt plant imposed by the current situation.

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Introduction

The assessment of soil management indicators is accompanied by how findings are directed towards targets and identifying obstacles to overcome them. So, adopting the integration of field investigation results with laboratory tests and remote sensing data in a digital environment represented by the GIS software is the most rapid, suitable and accurate means (Sadik and Taha, 2016).

A study, of Mubarakah and Al-Waeli (2019) carried out in the central of Iraq, showed the importance of using geological statistical functions in GIS software to assess the distribution of soil suitability items for spelt plant. Tashayo *et al*. (2020) also showed the importance of using geomatics to present the soil suitability maps of economic plants in Iran and its role in laying down sustainable agricultural policies. Because soil management indicators include assessing soil suitability for economic plants by analysing various factors such as soil texture, pH, nutrients content, inland drainage patterns, and land slope, the use of geomatics techniques creates a comprehensive approach to collect, analyse and conceive spatial data on soil management indicators which is necessary for informed decision-making on crop selection, land management practices, and resource allocation in agricultural activities (Al-Waeli *et al*., 2020).

Dengiz *et al*. (2022) confirmed that the use of Normalized difference vegetation index (NDVI) derived from Sentinel2 data gave promising results to assess soil suitability for cultivating rice in Turkey.

This study aims at using geomatic technologies as an early warning tool for agricultural and environmental efforts in the study area in order to adopt sustainable management at short range.

Materials and Methods

Location of the study area

The study was carried out in Ghammas county of Iraqi Diwaniyah governorate between two Circles of latitude of 31 ° 37 '08.9732 "N to 31 ° 43' 23.2848" N and two lines of longitude 44 ° 32 '27.115 "E to 44 ° 37' 10.4046" E with an area of 5582 hectares. The soil samples of 30 sites were obtained by auger and its coordinates dropped by G.P.S. to isolate the soil units according to grid method required spatial analysis procedures proposed by Lark (2009) and Wong (2009) and thus prepare them for classification procedures to the level of Soil Series under Soil Survey Division Staff Manual (1999) and Al-Agidi (1976) on the classification of soil series in central and southern Iraq, as shown in Figure 1.

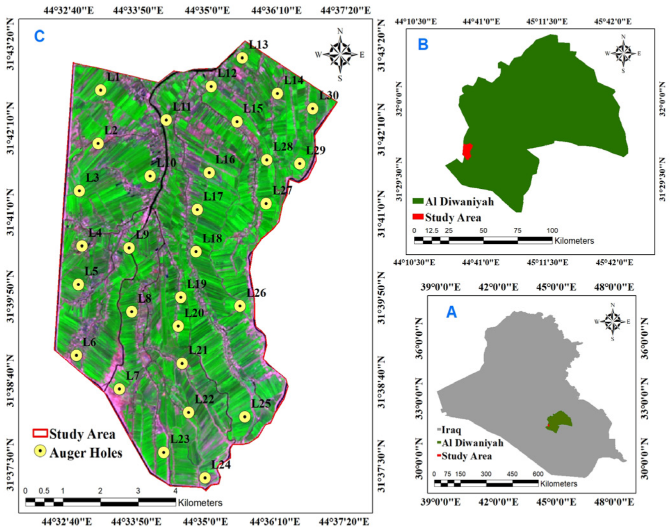

Figure 1: *A: Location of the study area for Iraq. B: Location of the study area in Diwaniya governorate. C: Distribution of soil samples collection sites with augers.*

Laboratory analysis of soil samples

The relative distribution of soil particles size was estimated by absorbent method after removing the bonding materials according to Black (1965). The soil solution was extracted from the saturated soil paste by section, which was used to estimate the degree of soil interaction with the pH-meter, as well as to measure the electrical connectivity of the Ec-meter according to Page *et al*. (1982).

The exchangeable ions of calcium, magnesium, sodium and potassium were also estimated after being extracted with ammonium acetate1 (N). Exchangeable calcium and magnesium were estimated by calibration with EDTA while exchangeable potassium and sodium were estimated using Flamephotometer according to Page *et al*. (1982). The exchangeable capacity of positive ions was estimated according to Papanicolaou (1976) for gypsy and limescale soils, the percentage of exchangeable sodium is calculated as in the Equation 1.

$$ESP\% = \frac{exchangable(Na^+)}{CEC} \times 100 \ldots (1)$$

The apparent cation exchangeable capacity was calculated as shown in Sys *et al*. (1993) and according to the Equation 2:

$$Apprent\ CEC = \frac{CEC}{Clay(kg)} \ldots (2)$$

The total carbonate metals were also estimated by gravimetric method according to Richards (1954) while the soil content of lime was estimated by sedimentation through acetone solution and measuring the sediment's electrical conductivity according to Richards (1954). Organic matter was estimated by moist oxidation with potassium dichromate and add concentrated sulfuric acid as a heat source and then titration with ammoniac ferrous sulphate according to Walkely and Black method.

The digital processing of sentinel data

The measurement of the study area topographic characteristics: A radar shot of the sensor Sentinel-1 was downloaded from the website https://scihub.copernicus.eu/dhus/#/home which was captured on 19/7/2023 of the study area and being processed and converted to DEM according to the profiles on the website https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1 by SNAP Desktop program. The elevations and inclinations of the study area were calculated by ArcMap and 10.8.2

The atmospheric effects of Sentinel-2 data captured on 19/3/2023 and 7/7/2023 were removed by ENVI 5.6 with FLAASH (Fast Line of sight Atmospheric Analysis of Spectral Hypercube Model) and then calculate the Normalized Difference Vegetation Index (NDVI) which was derived by Rouse *et al*. (1973) as in the Equation 3:

$$NDVI = \frac{[NIR - Red]}{[NIR + Red]} \ldots\ldots (3)$$

The Calculation of soil suitability for economic plants in the study area: was calculated according to Storie equation reported by Sys *et al*. (1993) as in the Equation 4:

$$I = A * \frac{B}{100} * \frac{C}{100} * \frac{D}{100} * \frac{E}{100} * \frac{F}{100} * \frac{G}{100} * \frac{H}{100} * \frac{J}{100} * \frac{K}{100} * \frac{L}{100} * \frac{M}{100} \ldots . [4]$$

Whereas A is soil depth, B is rock, C is soil texture, D is calcium carbonate, E is apparent cationic exchangeable capacity, F is soil reaction degree, G is organic soil carbon, H is soil salinity, J is the percentage of exchangeable sodium in soil, K is soil inclination, L natural drainage condition, M is lime.

Spatial analysis

Spatial analysis of laboratory measured soil characteristics was carried out with Inverse Distance Weighted (IDW) interpolation application by ArcMap program and 10.8.2 and was classified according to Al-Rifaee and Al-Rubay (2017) as shown in Table 1.

Table 1: *The types of soil characteristics measured according to Iraq's environment and as proposed by* Al-Rifaee and Al-Rubay (2017).

Soil characteristics	Description	Scales
Soil salinity (ECe) $dS.m^{-1}$	Low	< 4 $dS.m^{-1}$
	Moderate	4-8 $dS.m^{-1}$
	High	8-16 $dS.m^{-1}$
	Very High	> 16 $dS.m^{-1}$
Soil organic matter (S.O.M.)%	Very High	> 3%
	High	2-3%
	Moderate	1-2%
	Low	0.5-1%
Drainage	Excessively Well	> 150 cm
	Well	90-150cm
	Moderate	50-90cm
	Imperfectly	25-50cm
	Poor	<25 cm
	Very Low	< 15 cm
Slope %	Very Low	< 6 %
	Low	6 – 18 %
	Moderate	18 – 35 %
	High	> 35 %

While the classification of soil suitability for economic plants was carried out according to the classification of FAO (2012) and as follow:

Table 2: *Kinds of suitability of soil units for field crops* FAO (2012).

Symbol	Definition	Index
S1	Highly Suitable	80-100
S2	Moderately Suitable	60-80
S3	Marginally Suitable	40-60
N1	Currently not Suitable	25-40
N2	Permanently not Suitable	0-25

Statistical analysis

In order to test the variation between kinds of soil series in salinity, soil content of organic matter and its suitability for economic plants, Least Significant

Difference test was carried out based on unequal replications according to Al-Waeli (2020), Applied by GenSTAT12. The descriptive statistics was measured and the simple correlation of Pearson was tested by SPSS25 Program. All graphics were drawn using Microsoft Excel 2013.

Results and Discussion

The characteristics of the study area soil series

The study has found that Ghammas soils are classified as Typic Torrifluvents according to the Soil Survey Division Staff Manual (1999). While soil series according to Al-Agidi Rules (1976) were distributed in five series as in Figure 2A. The series occupied DM115, DM86, DM96, MM11 and TM465 7.79%, 20.45%, 33.63%, 27.34% and 10.79% of the study area, respectively (Figure 2B). Because of Ghammas soils are part of Iraq's sedimentary plain, their textures vary in their types within a single soil profile depending on the variability of the sedimentation factors and their phases, as well as the nature of the transporting water stream, resulting in the Stratification phenomenon in Figure 2C. The study of Muhaimeed *et al.* (2014) indicates that, in 2008 in his study of the evolutionary situation in central Iraq, the variation in the number of genetic horizons and the type of its textures in alluvium soil is caused by river transport processes and the variation in the momentum of sedimentation intensity whose most important morphological aspect is Stratification which means the sudden change in textures within single soil horizon. In addition to the contribution of the administration in this area since the beginning of civilization, the construction of irrigation channels, cleaning up rivers and continuous accumulation, which increased the activity of Stratification and was a fundamental reason in developing horizons, whether surface or subsurface.

In Figure 3A, three soil textures are observed to be prevailed in the study area: Loam, Silty Clay Loam and Silt Clay, and in Figure 3B, they occupied 21.83%, 56.36% and 21.81% of the study area, respectively. In this study, it is reckoned that the diversity of textures in this way is due to the probability of sand sedimentation conveyed by running water with alluvion at Irrigation Levees with calcium carbonate compounds. All of these materials are larger than clay separate. However, the sedimentation of suspension clay is abundant at the ends of basins and near drainages.

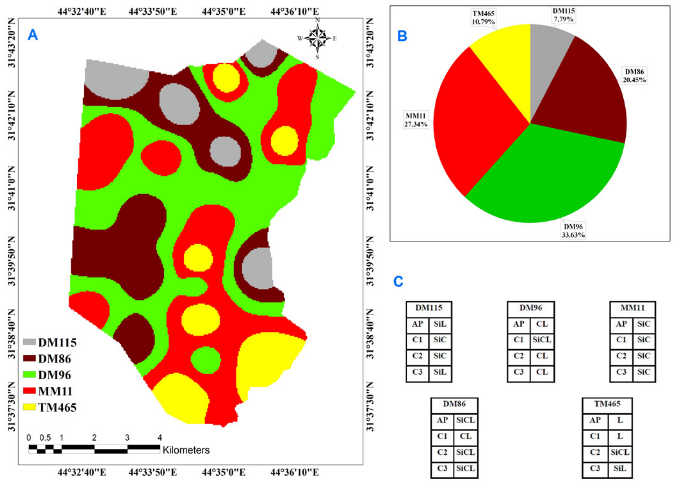

Figure 2: *A: Spatial distribution of the study area soil series. B: Graphic representation of the percentages of soils series areas. C: Graphic representation of textures Stratification within soil series profiles.*

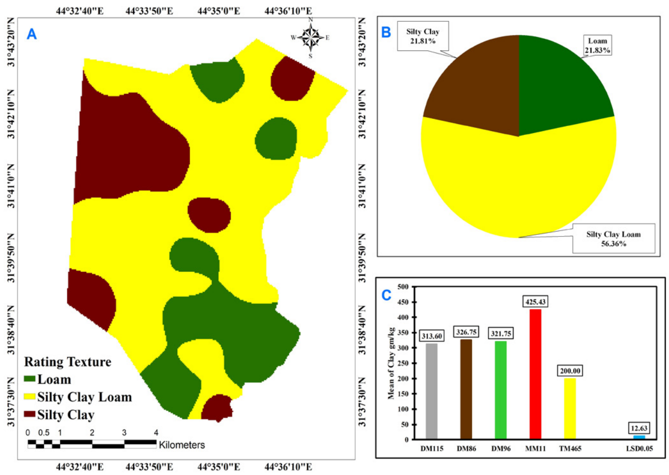

Figure 3: *A: Spatial distribution of study area soils textures. B: Graphic representation of the percentages of soil textures areas. C: Graphic representation of clay content averages in the study area soil series.*

The study of Ahmed *et al.* (2010) indicates that the variation of textures in lime-nature alluvial soils, calcium carbonate of coarse nature is positioned near Irrigation Levees and integrate significantly with sand separated and coarse alluvion. This integration continues with the small size of carbonate crystals directly with the appearance of clay separated in abundance, especially at the end of the river soils basin.

In Figure 3C It is observed that clay content in MM11 series is significantly superior to all study area series followed by the DM86 series, whose clay content surpassed the DM115 and TM465 series respectively. While the DM96 series significantly surpassed the series TM465. While DM115 series significantly surpassed the latter. This can be explained by the fact that the nature of the distribution of soil textures types is ranged from Silt Clay to Loam, as soft separates prevail in the load of water stream due to the constant reduction in the amount of energy and the length of Earth slope so the Irrigation Levees soils and the irrigation channels are with textures ranging from Loam to Silty Clay Loam. It causes differential sedimentation of separates resulting from the difference in speed, momentum, capacity and the quality of the carrier's load, which often results in the sedimentation of sand separate and a large portion of the coarse alluvion, as measured by soft alluvion and clay separate, which is positioned at river and irrigation basins. This is consistent with the results of Al-Waeli (2020).

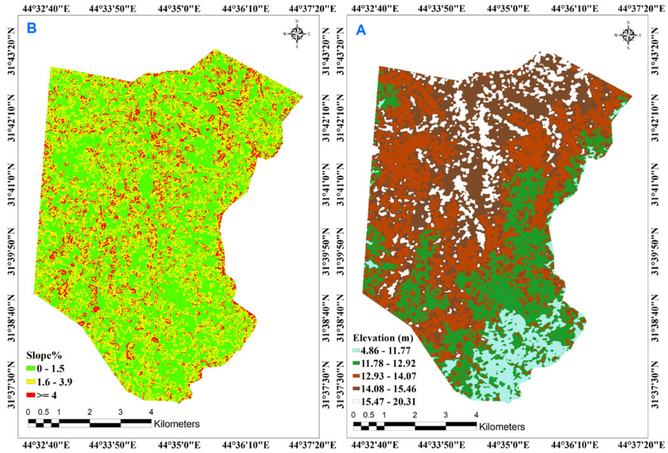

Figure 4: *A: study area elevations. B: study area inclinations.*

In Figure 4, it is observed that the topography and the physiography of the area belong to irrigation levees soils unit with coarse to moderate-texture and ranging to finish at the soft-texture irrigation basin unit. The pattern of physiographic units distribution is typical for the conditions of the area and the nature of its irrigation systems as an area subject to the influence of agricultural human activity since the evolution of the alluvial plain. The textures of Loam or Silt Loam ranging to Silt Clay Loam are often be adjusted to the main or sub-irrigation channels that located at the middle of the agricultural fields. Overall, they are among the rankings of low-slope flat topography (Al-Waeli, 2020). The descriptive statistics of soil separates, topography and land sloping is shown in Table 3 and support the explanations above.

As for the geochemistry of area soils, it has an original Calcareous Alluvium type, with a decrease in the amount of lime, most of which consists of secondary lime comes from irrigation operation carrying it with an abundance of calcium carbonate and which has a fundamental role in the physical and chemical behaviour of soil, it adversely affects the Cation exchangeable capacity and reduces the positive effect of soil organic matters and its abundance comes from the study area conditions of dry climate, poor natural vegetation and the absence of permanent cultivation, which are the same conditions that encouraged salinization of soil.

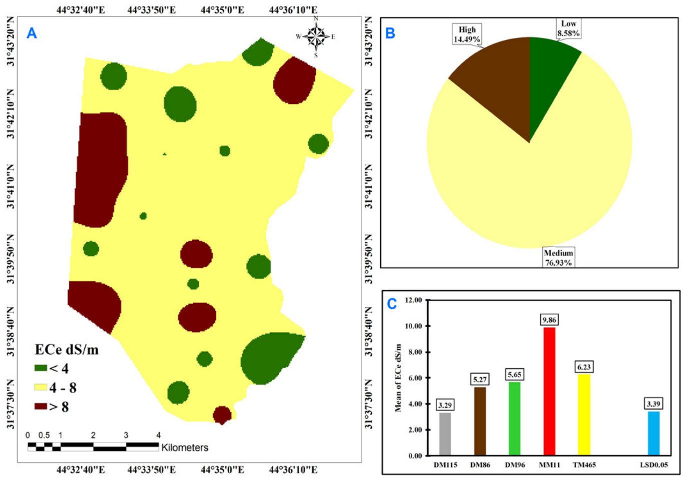

Figure 5: *A: Spatial distribution of salinity-affected soil in the study area. B: Graphic representation of percentage for areas of salinity-affected soils varieties in the study area. C: Graphic representation of electrical conductivity rates of the solution of the soil series of the study area.*

Figure 5A shows the soils saline state which indicates the recession of salinity-unaffected soils in limited areas, often adjacent to the beginning of irrigation canals. Figure 5B shows that Soils whose electrical conductivity is less than 4dS.m^{-1} occupies 8.58% of study area while because the area is subject to continuous cultivation, the soils with electrical connectivity between 4-8 dS.m^{-1} occupies 76.93% of the study area. The soil with electrical connectivity exceeds 8 dS.m^{-1} occupies 14.49% of the study area, whereas most soils with ESP are more than 15% which is an evidence of sodic salts accumulation, which cause shora soils more than other soils near areas of agricultural activity in conditions of climate drought and water resource shortage, which accelerates the deterioration of salinity-unaffected soils to more saline varieties, which is consistent with the results (Adamu *et al*., 2014). Al-Waeli *et al*. (2024) study indicates that the human factor is the basis for the deterioration of soils and the accumulation of salts. Landsat images in the 1990s showed a decrease in the salinity-affected soils due to continuous cultivation compared to the last 10 years, where the absence of wise management and land abandonment contributed to an increase in salinity soils and permanently. The descriptive statistics of chemical soil characteristics is included in Table 4.

Figure 5C shows that the impact of MM11 series significantly exceeded all the study area series. As for the other series, the increases among their rates are insignificant due to situational factors of increased clay content, which causes the reduction of drainage. Unplanned human activity is also one of the most significant deterioration factors of soil resource, which is evident in the complex chemical aspect of the agricultural environment and its open variables. Human use of unscientific methods of soil management raises the level of saline-carrying ground water to root system area and survives for a period that allows the prevalence of salt accumulations. In addition, farmers are forced by the prolonged dry season and the apparent decrease in water resources of suitable quality for agricultural purposes, leaving the cultivation of areas of land for long periods of time salting and this has become a prominent phenomenon in large areas of the Middle East (Wu *et al.*, 2014).

Figure 6A shows that the soil content of organic matter is among the intermediate, low and lowest varieties where, according to Figure 6B, it occupied 47.58%, 42.49% and 9.93% of the study area, respectively. The absence of higher varieties is an indicator of chemical deterioration in soil, which is accompanied by all negative changes in the chemical soil characteristics affecting plant growth and various soil uses (Ali and Taha, 2016).

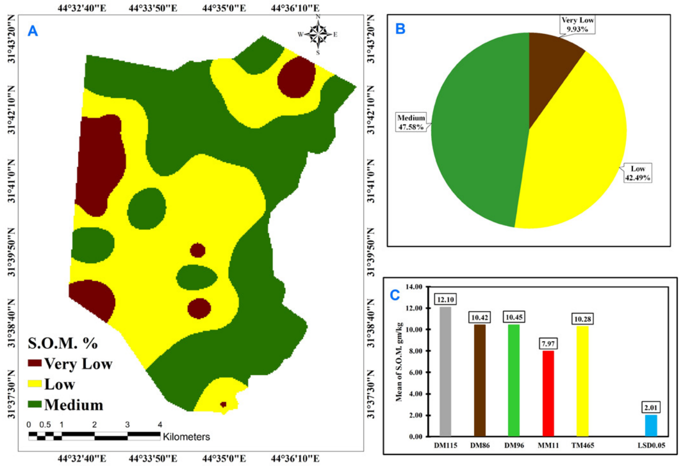

Figure 6: *A: Spatial distribution of soil content of organic matter in study area. B: Graphic representation of percentage for areas of soil content varieties of organic matter in study area. C: Graphic representation of organic matter rates in the study area soil series.*

Figure 6C shows that the content of organic matter in all series has achieved a significant increase in MM11 series. The differences between the rest of the series are insignificant due to similarity of agricultural procedures in all series in terms of non-adoption of organic compost accompanied by high temperatures,

Table 3: *The descriptive statistics of soil separates and topographical characteristics.*

Descriptive statistics							
	N	Range	Minimum	Maximum	Mean	Std. deviation	Variance
Sand(gm/kg)	30	356.00	61.00	417.00	194.37	103.76	10766.24
Silt(gm/kg)	30	155.00	401.00	556.00	484.73	41.75	1743.17
Clay(gm/kg)	30	255.00	178.00	433.00	320.90	75.95	5767.89
Elevation (m)	30	5.99	10.34	16.33	13.70	1.32	1.75
Slope (%)	30	4.75	0.00	4.75	1.39	1.53	2.34

Table 4: *The descriptive statistics of the most important chemical characteristics in study area.*

Descriptive Statistics							
	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
pH	30	0.84	7.13	7.97	7.58	0.22	0.05
ECe $dS.m^{-1}$	30	12.37	2.41	14.78	6.30	3.40	11.54
ESP	30	10.59	10.38	20.97	14.94	2.03	4.14
Lime ($gm.kg^{-1}$)	30	127.50	215.50	343.00	268.60	27.61	762.28
Gypsum ($gm.kg^{-1}$)	30	2.65	0.41	3.06	1.42	0.56	0.31
SOM ($gm.kg^{-1}$)	30	7.79	4.84	12.63	10.11	2.04	4.16
CEC $cmol.L^{-1}$	30	3.23	19.56	22.79	21.04	0.66	0.44

Table 5: *The descriptive statistics of soil suitability for spelt and barley in study area.*

Descriptive statistics						
	N	**Range**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Wheat	30	68.12	7.88	76.00	47.96	21.03
Rice	30	58.65	9.94	68.59	49.30	17.55

drought and lack of rain which cause declining vegetation, as Al-Waeli *et al.* (2021) referred to the soil content of organic matter is associated with climate, type of vegetation and followed cultivation technique. In this desert environment characteristic region, vegetation cover type is a fundamental morphological indicator in understanding site conditions that contribute to define the amount of soil organic matter which increase the environmental fragility that naturally increases the chances of soil erosion whose separates are conveyed with wind as dust.

The decrease in the soil content of organic matter with the dominance of calcium carbonate in the interactions of the central and southern Iraqi soil was discussed by Al-Waeli *et al.* (2024). The study showed that the accelerated rates of soil physical deterioration due to erosion is a direct result of these effects that with the deterioration of agricultural land management systems, large areas have become non-productive economically. The decrease in organic carbon and thus the poor soil content of organic matter in Iraq and according to the interpretation of Alhashimi *et al.* (2021) is caused by the effects of dry climate and the traditional non-scientific management method, which in its final result leads to a deterioration in the quality of Iraqi soils and a decrease in its productivity, leaving the earth to be prepared for a more harmful environmental disaster, which is the activity of salt accumulations, changing Iraq's soils into unproductive salt deserts. The descriptive statistical indicators in Table 4 show the tendency of soils to deteriorate chemically due to the high amount of calcium carbonate, salinity and low soil content of organic matter.

The suitability of study area soil series for cultivating spelt and rice

Both Figure 7A and Table 5 show the absence of highly suitable item (S1) while the rest of the items; moderately suitable (S2), marginally suitable (S3), currently not suitable (N1) and permanently not suitable (N2) occupied 14.46%, 67.27%, 14.21% and 4.06% of the study area, respectively, as shown in Figure 7B. It is reckoned in this study that the limited good suitability of spelt derived from the effects of drought in reducing the quantities of water available which has caused soil increased salinity and ESP as well as the decrease in soil content of organic matter as this condition causes chemical deterioration of any soil (Al-Mashreki *et al.*, 2011).

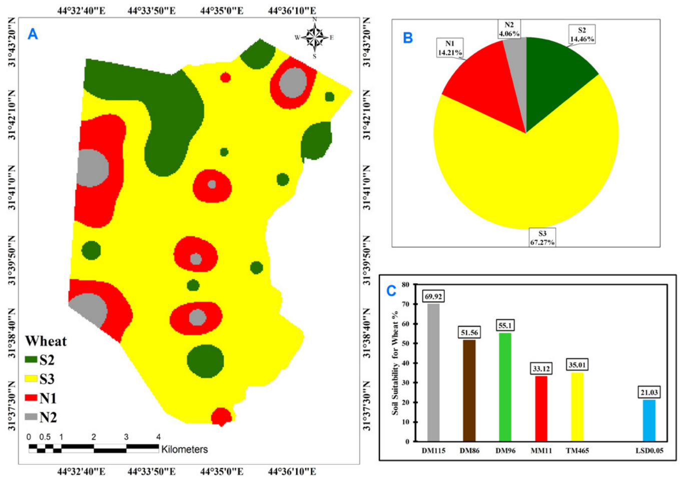

Figure 7: *A: Spatial distribution of soil suitability varieties for spelt in study area. B: Graphic representation of percentages of areas of soil suitability varieties for spelt in study area. C: Graphic representation of the rates of suitability of soil series for spelt in study area.*

Figure 7C also shows that the series DM115 has achieved significant increases on both series TM465 and MM11. The series DM96 has also achieved a significant increase on the series MM11. This is due to the neglected effects of the suitability of series textures MM11 with Silty Clay texture and TM465 with Loam texture to cultivate spelt in addition to poor organic carbon in it. In the study of (Al-Waeli *et al.*, 2020), the greatest and most prominent agent in poor soils suitability for Gramineae corps was the high soil salinity and sodium with apparent decrease in soil content of organic carbon with the abundance of calcium carbonate because of the fact that soils have a fertile material of *Calcareous alluvium* type.

Both Figure 8A and Table 5 show the absence of highly suitable item (S1) while the rest of the items; moderately suitable (S2), marginally suitable (S3), currently not suitable (N1) and permanently not suitable (N2) occupied 11.32%, 72.96%, 12.91% and 2.81% of the study area respectively as in Figure 8B.

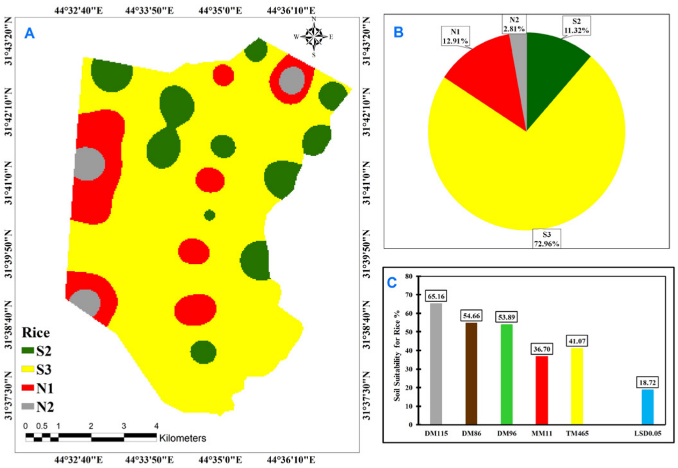

Figure 8: *A: Spatial distribution of soil suitability varieties for rice in study area. B: Graphic representation of percentage areas of soil suitability varieties for rice in study area. C: Graphic representation of the rates of suitability of soil series for rice in study area.*

The cultivation of rice plant in Ghammas is prevalent, yet the season of its cultivation with the period of drought has contributed to its decline in the physiographic units adjacent to water sources. The existence of a rational water policy is sufficient for this region to regain its place in achieving self-sufficiency from this crop which is highly consumed by Iraqi individual (Kadim and Al-Wasiti, 2022).

Figure 7C shows that the DM115 series has achieved a significant increase on both TM465 and MM11 series. The rest of soils' series increase insignificantly. It is reckoned that this result is due to the similarity of area conditions in terms of dependence on surface irrigation, which might be scarce leading to high salinity and the absence of typical growth status of rice, most of which requires continuous immersion in water, which is consistent with the findings of the (Al-Salihy and Al-Khafaji, 2019) study. The impact of chemical soil qualities specifically on the soil suitability of spelt plant was discussed in the study of Mubarakah and Al-Waeli (2019). The salinity and sodic of Iraqi sedimentary soil due to Stratification and the absence of good drainage all contribute to raising the salts concentrations and deteriorating the root growth of spelt plant.

Table 6: *The association of soil qualities affecting its suitability to spelt and barley in study area.*

		Correlations						
		Clay	**ECe**	**ESP**	**Lime**	**SOC**	**Wheat**	**Rice**
Clay	Pearson correlation	1	.350	.409*	.362*	-.384*	-.038	-.072
	Sig. (2-tailed)		.058	.025	.049	.036	.840	.705
	N	30	30	30	30	30	30	30
Ece	Pearson correlation	.350	1	.882**	.976**	-.985**	-.876**	-.883**
	Sig. (2-tailed)	.058		.000	.000	.000	.000	.000
	N	30	30	30	30	30	30	30
ESP	Pearson correlation	.409*	.882**	1	.947**	-.876**	-.772**	-.791**
	Sig. (2-tailed)	.025	.000		.000	.000	.000	.000
	N	30	30	30	30	30	30	30
Lime	Pearson correlation	.362*	.976**	.947**	1	-.964**	-.864**	-.863**
	Sig. (2-tailed)	.049	.000	.000		.000	.000	.000
	N	30	30	30	30	30	30	30
SOC	Pearson correlation	-.384*	-.985**	-.876**	-.964**	1	.865**	.844**
	Sig. (2-tailed)	.036	.000	.000	.000		.000	.000
	N	30	30	30	30	30	30	30
Wheat	Pearson correlation	-.038	-.876**	-.772**	-.864**	.865**	1	.935**
	Sig. (2-tailed)	.840	.000	.000	.000	.000		.000
	N	30	30	30	30	30	30	30
Rice	Pearson correlation	-.072	-.883**	-.791**	-.863**	.844**	.935**	1
	Sig. (2-tailed)	.705	.000	.000	.000	.000	.000	
	N	30	30	30	30	30	30	30

**: Correlation is significant at the 0.05 level (2-tailed). **: Correlation is significant at the 0.01 level (2-tailed).*

In this study, as can be shown in Table 6, the clay content did not affect the values of soil suitability for spelt and rice while a negative and highly significant correlation is clearly appeared with the values of ECe, ESP and Lime. It is reckoned that management is more influential factor in the values of soil suitability of these two plants than site conditions factor represented by texture. This is consistent with the study of Mohammed and Suliman (2023) which indicates that salinity and sodic soil adversely affected the growth of spelt as for lime, its effect was shown to be slight.

In this study, it is confirmed that although high calcium carbonate has a slight direct effect on soil suitability for spelt, it contributes to reduce soil content of organic carbon due to its impact on raising soil interaction, which in turn causes the sedimentation of many nutrients leaving the soil unprepared to cultivate plant and reduces the effectiveness of microbial activity in generating organic matters in soil. And the high correlation coefficient (r = -0.863 * *) in Table 6 confirms this opinion.

Likewise, the rice plant, although the condition and availability of water is the most fundamental factor to enhance soil suitability for rice.

In Gyekye *et al*. (2021) study, it was indicated that the suitability of soil for rice requires an abundance of water of a quality suitable for growth, and that soil textures do not allow water to leak away from the surface of the submersion, and in soil conditions of this study, the water factor is unfortunately not available in the season of rice growth coinciding with dry season and the very long summer season in Iraq.

The relation of soil suitability to normalized difference vegetation index (NDVI)

Through Figure 9A whose classifications based on field examinations that values of NDVI in spring and specifically in March more than + 0.3 represent areas cultivated with spelt crop and sometimes barley while NDVI values are from + 0.01 to less than + 0.3 of bushes and herbaceous plants. NDVI values below + 0.01 represent uncultivated lands. Thus, according to Figure 9B, it can be considered that 43.82% of study area is mostly cultivated with spelt plant. The bushes occupied 29.61% of study area and the rest of the area without vegetation. Figure 9C also shows that DM115 series has significantly surpassed MM11 series in containing a healthy vegetation and bright green growth of spelt.

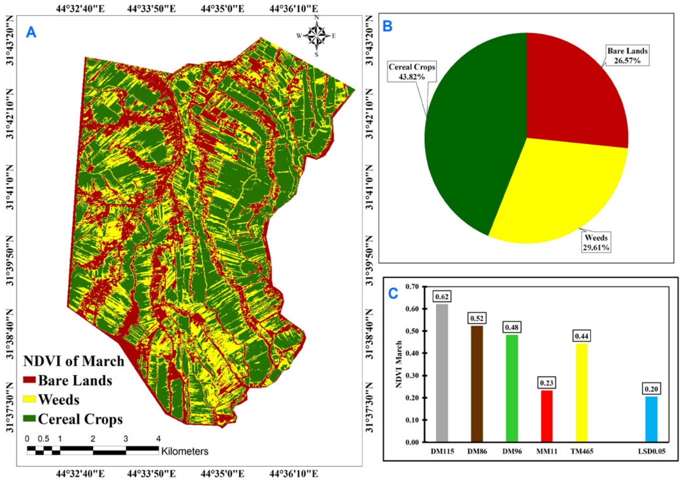

Figure 9: *A: Spatial distribution of land cover varieties in study area depending on NDVI values for March. B: Graphic representation of percentages of land cover varieties in study area based on NDVI values for July. C: Graphic representation of NDVI rates in study area soil series.*

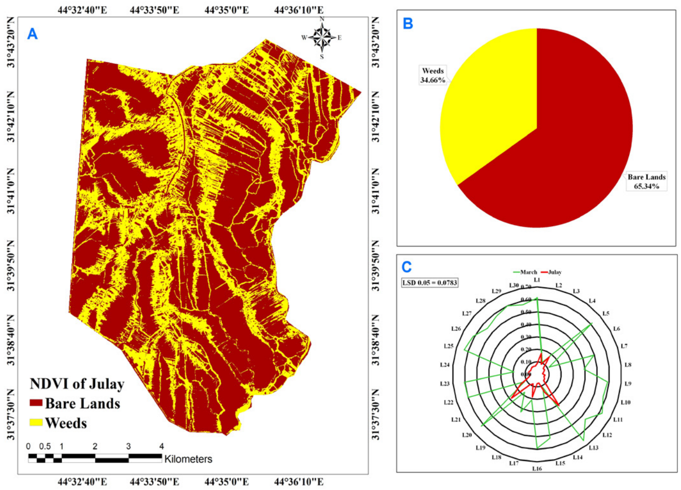

Figure 10: *A: Spatial distribution of land cover varieties in study area depending on NDVI values for July. B: Graphic representation of percentages of land cover varieties in study area based on NDVI values for July. C: Graphic representation of NDVI rates between March and July in study area.*

According to (Kadim and Al-Wasiti, 2022) study, Ghammas is one of the main rice cultivation territories in Iraq's central Euphrates region. However, it is observed through Figure 10A that NDVI values measured in July (Iraqi dry season) did not clearly indicate any agricultural activity in study area whereas Figure 10B Indicates effectively the absence of rice plant in study area. Figure 10C Indicates a highly significant difference between NDVI values in spring (spelt cultivation season) and its values in July (rice cultivation season) as also indicated by NDVI values in Table 7.

Table 7: *The Descriptive statistics of NDVI rates between March and July in study area.*

Descriptive statistics						
	N	**Range**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
NDVI of March	30	0.5491	0.1062	0.6553	0.4433	0.2038
NDVI of July	30	0.2632	0.0463	0.3095	0.1019	0.0658

Geomatics techniques provide valuable tools to assess soil suitability for cultivating grain crops in Ghammas. The integration of remote sensing and geostatistical analysis enables researchers to analyse soil characteristics and helps to make informed decisions regarding agricultural practices. By taking advantage of these techniques, farmers and landlords can improve grain crop production, promote sustainable agricultural practices and contribute to the region's food security.

The absence of water resource during rice cultivation period clearly caused the disappearance of its cultivation in one of the most prominent areas of rice cultivation in the Middle East.

In this study, a Sentinel2 data integration approach has been adopted with laboratory tests. NDVI values has been classified based on field investigations. Thus, the research is an early warning method for decision-makers to find alternatives such as by hybridizing local varieties with other rice varieties germinating without the need of water or providing suitable water after consultation with hydrogeologists to assess its usefulness for rice.

It is reckoned that an integrated agricultural environment survey tool has been provided to save money and effort soon to assess the deterioration of vegetation due to drought and, most importantly, the traditional management pattern that does not keep pace with sustainable management in adopting a rational agricultural policy that preserves the biodiversity of economic plants of the Mesopotamian region.

Conclusions and Recommendations

The Iraqi alluvial soils suitable for rice cultivation are deteriorating due to the activity of salinization processes, the interruption of rainfall for most days of the year, and the scarcity of water in the irrigation channels of the Euphrates River that runs through the study area. The last thirty years have not witnessed any clear rice cultivation in this area. Still, rather it has become a soil for growing wheat and barley crops, which threatens the biological diversity of economic plants in the Iraqi alluvial plain. Drought has negative effects on the organic matter content of the soil, as it leads to an increase in the rate of decomposition of organic matter in an alkaline environment due to the high amounts of calcium carbonate in the soil. In previous conditions, the abundance of water made this area similar to a marsh or a water swamp, with fresh supplies from the Euphrates River working to reduce salts continuously. However, drought with soils of a clayey nature contributed to the deposition of calcium compounds in a way that negatively affects soil fertility, in addition to the accumulation of salts due to the poor internal drainage conditions of the soil, which may have benefited rice, but undoubtedly causes great harm to wheat growth. The region has become more prepared not only for chemical deterioration due to salinization and calcification but also for physical deterioration, the rates of which are expected to increase unless effective management measures are taken to achieve the sustainability of the soils of the study area. In this study, we were able to monitor the nature of soil exploitation, as it was not planted with rice in the summer, but rather with wheat in the winter and until spring. We believe that sensor data is an important and effective means of monitoring the management pattern of agricultural systems in the fields and understanding the effects that affect the plant throughout the growing season. However, being satisfied with the monitoring situation may be ineffective unless a sustainable management approach is planned that adopts smart agriculture, one of the pillars of which is monitoring using remote sensing methods. Serious consideration of introducing remote sensing data as inputs for planning sustainable management is not useful in diagnosing production constraints, but it can be used to predict the most suitable soils that are suitable for growing an economic plant without losses due to current soil conditions resulting from drought. Remote sensing data may contribute to the benefit of diagnosing the grassy areas that are not grown in the summer in the study area as pastures for sheep and cattle or suggesting the cultivation of crops that are invested as fodder that tolerate soil conditions that seem to be completely desertified unless they are exploited sustainably.

1. Develop plans for soil sustainability based on the indicators provided by remote sensing data that show the pattern of soil management in agriculture.
2. Develop a periodic program to evaluate the suitability of soils for the cultivation of economic plants and find plant alternatives that are suitable for agricultural exploitation and in a way that achieves sustainable environmental balance.
3. Conduct a study to evaluate the sensitivity of soil to erosion and desertification, especially in periods that are left without agricultural exploitation.
4. Use organic fertilizers and leguminous plants as soil fertilizers instead of chemical fertilizers.
5. The most important thing, to preserve the identity of the study area in rice cultivation, is to derive genetic varieties that tolerate drought and are planted in the season of water availability in winter.

Novelty Statement

Using geomatics technologies as an early warning tool for agricultural and environmental efforts in the study area in order to adopt sustainable management at short range.

Author's Contribution

Aurass Muhi Taha Al Waeli: Conceptualization, data curation, formal analysis, methodology, visualization.
Fadia W. Al-Azawi: Resources, writing - original draft, writing - review & editing.

Code and data availability
All code and data in this study can be found in the body of manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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