RESEARCH ARTICLE

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Contribution of Different Land Evaluation Systems to Assess Land Capability and Suitability of Some Coastal Soils in Egypt

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Abstract

The objectives of this study were to assess the land capability using Storie Index and Cervatana model and to assess the land suitability by LUSET and Almagra model for some coastal soils in Egypt. Twenty-seven soil profiles were dug and morphologically described to represent all physiographic units. Landsat image, DEM, geological map, field and laboratory work were used to create physiographic-soil map relationship. Based on the modified Storie Index, soils were classified into four land capability grades (grade 2, 3, 4 and 5). The Cervatana model classified these soils into three capability classes, S2, S3 and N. Almagra model indicated that 4.71% of the area is highly suitable (S2) for wheat and citrus and 14.82% of the area is S2 for olives. About 31.78% of the soils is moderately suitable (S3) for wheat and citrus where-as 52% are S3 for olives. Based on LUST, about 5.85, 3.73 and 2.11% of soils are highly suitable (S1) for wheat, cotton and olives respectively. About 31% of the area is moderately suitable (S2) for citrus and peach where-as 63.86% is S2 for alfalfa and 85% of the area is S2 for wheat. Soil salinity, calcium carbonate, drainage and soil texture were the most common limiting factors of the soils. The study revealed that the MicroLEIS application either Cervatana or Almagra is not suited to predict the land suitability and land capability while the LUSET and Modified Storie index is recommended for Egyptian pedoenvironment.

Key words: Almagra, Cervatana, Land evaluation, LUSET, Storie index.

Introduction

Land capability and suitability assessment become a necessary process for defining the potential capabilities of the land under different uses for sustainable land management. Scientifically each specific land unit should be utilized for an application which is suitable for that application (FAO, 1976). Agricultural land suitability is a very significant piece of information in agriculture development and planning (Chiranjit and Kishore, 2018; Ramamurthy *et al*., 2019). Therefore, there is an intense need for land evaluation studies to select the superior land use (Zhang *et al*., 2015; Sabareeshwari *et al*., 2018). Combination of geographic information system with soil survey and land methods were developed and adopted to evaluate soil suitability for different crops (Bhaskar, *et al.,* 2015). Many systems have been designed and developed for land evaluation assessment such as Storie Index (Storie, 1973), land capability classification system (Klingebiel and Montgomery, 1961), FAO Framework for Land Evaluation (FAO 1976), Soil Productivity Index (Delgado 2003), Land Use Suitability Evaluation Tool (LUSET) (Yen *et al*., 2006), Modified Storie Index (UCDAVIS, 2008), Microcomputer Land Evaluation Information System (MicroLEIS) (De La Rosa *et al*., 2009) and the Agriculture Land Evaluation System (ALESarid and modified ALESarid-GIS) (Ismail *et al*., 2005). Land evaluation systems could be either qualitative or quantitative methods. The qualitative approach gives the results in qualitative terms where the quantitative approach involves more parametric techniques which allow various statistical analyses to be performed. This study focused on the comparison of modified Storie Index (UCDAVIS, 2008) and Cervatana model of MicroLEIS (De la Rosa *et al*., 2004) and also comparison between (LUSET) (Yen *et al*., 2006) and of Almagra model of MicroLEIS (De la Rosa *et al*., 2004) as land suitability evaluation systems. Many researchers used these systems or built up their own systems depend on the methodology of the soil science (Xingwu *et al*., 2015). Modified Storie Index was used in several studies to evaluate the land capability in the northwestern coast of Egypt and in many other areas (Sawy, *et al*., 2013; Abd El-Aziz, 2018; Yousif, 2018; Yousif and Ahmed, 2019). Cervatana and Almagra models of MicroLEIS were applied to assess the land capability and suitability evaluation in many areas in Mediterranean region (Abd El-Aziz, 2018; Abd-Elmabod *et al*. 2019; Mahmoud *et al*. 2019; Yousif, 2019). LUSET is a utility tool of land suitability Evaluation for multiple crops. It is programmed in Microsoft Excel and the calculation in

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LUSET was coded using Visual basic for Application (VBA), (Yen *et al.*, 2006) and depends on the land evaluation framework of the FOA (FAO, 1976). LUSET tool was used to assess land suitability evaluation in many different areas (Aldabaa, 2018; Yousif, 2018). The objectives of the current study were to (1) characterize the soils of the area extended from El-Kasaba village to Paghoush village and located at the east of Matrouh city, Egypt. (2) Assess land capability using modified Storie Index and Cervatana model of MicroLEIS. (3) Assess land suitability by LUSET and Almagra model of MicroLEIS.

MATERIALS AND METHODS

Study area

The study area is located in the east of Matrouh city by about 25 km and it is extended from El-Kasaba village to Paghoush village. It occupies an area of 197.22 km^2 (46957.14 Fadden) and located between longitudes 27° 25' 24" to 27° 47' 50" E and latitudes 31° 7' 26" to 31° 13' 41" N (Fig 1). The elevation ranged between 11-120 m ASL. Flat to nearly level, gently sloping and sloping are the dominant slope classes (Fig 2). Normalized Difference Vegetation Index (NDVI) showed that some areas covered by scattered vegetation with maximum value of 0.5 (Fig 3). The investigated area is characterized by dry hot summer where the mean monthly temperature ranged between 14.5 to 26.7°C and almost rainy winter where the annual rainfall ranged between 87.10 and 274.50 mm year^{-1} with an average of 145.06 mm year^{-1} (E.M.A., 2014). It is dominated by a sedimentary rock varying from Tertiary (Miocene) to Quaternary period (El Shazly *et al.*, 1975).

GIS and remote sensing

Using ArcGIS 10.5, Landsat 8 OLI image (path 179, row 38) captured in 2018 and 3D presentation created from digital elevation model (DEM) were used to distinguish and delineate the different physiographic units.

Field work and laboratory analysis

To represent all physiographic units, twenty-seven soil profiles were dug and morphologically described according to FAO (2006). Soil analyses were done according to USDA (2017). Soils were classified according to Soil Survey Staff (2014).

Land Evaluation Methods

Land capability classification

1. MicroLEIS Cervatana model, De la Roza, 2000 (Table 1).
2. Modified Storie Index Rating, UCDVVIS, 2008 (Table 2).

Land suitability classification

1. MicroLEIS, De la Roza (2000), Almagra model (Table 3).
2. Land Use Suitability Evaluation Tool (LUSET), Yen *et al.*, 2006 (Table 4).

RESULTS AND DISCUSSION

Each landform was represented by some soil profiles as shown in Fig 4 and Table 5 and soils were characterized as the following:

Soils of upper slope unit

This unit is located in the southern part of the studied area and occupies an area of 51.77 km^2 and represented by eight soil profiles (Table 5). Results reveled that most of soils are

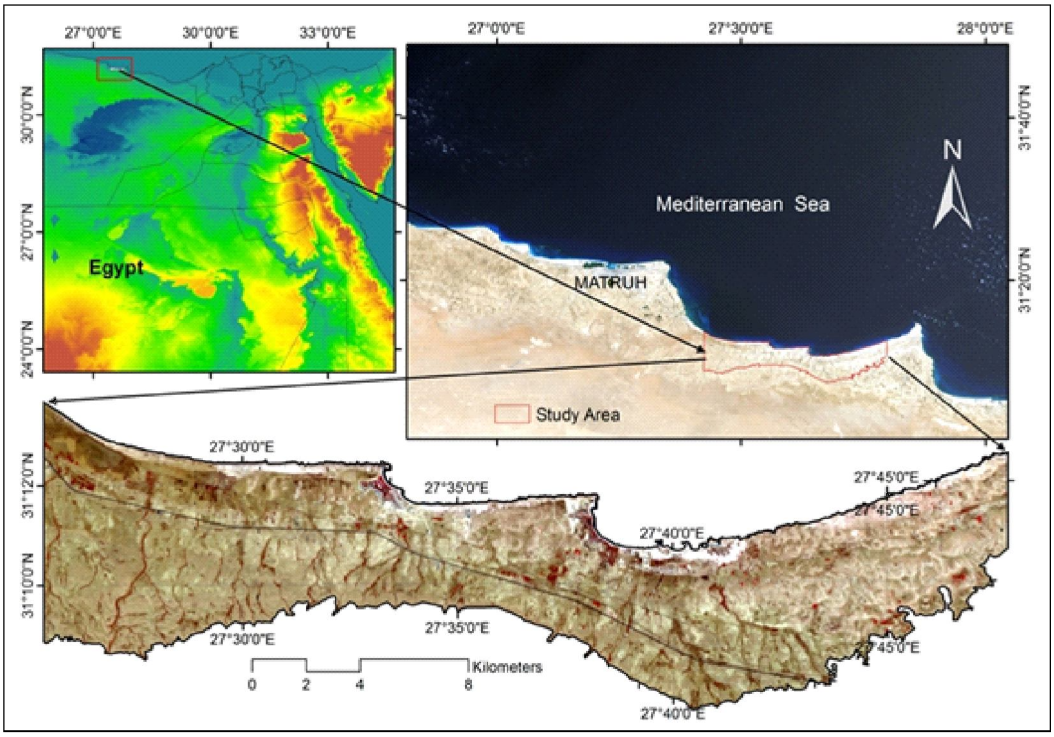

Fig 1: Location map of the investigated area.

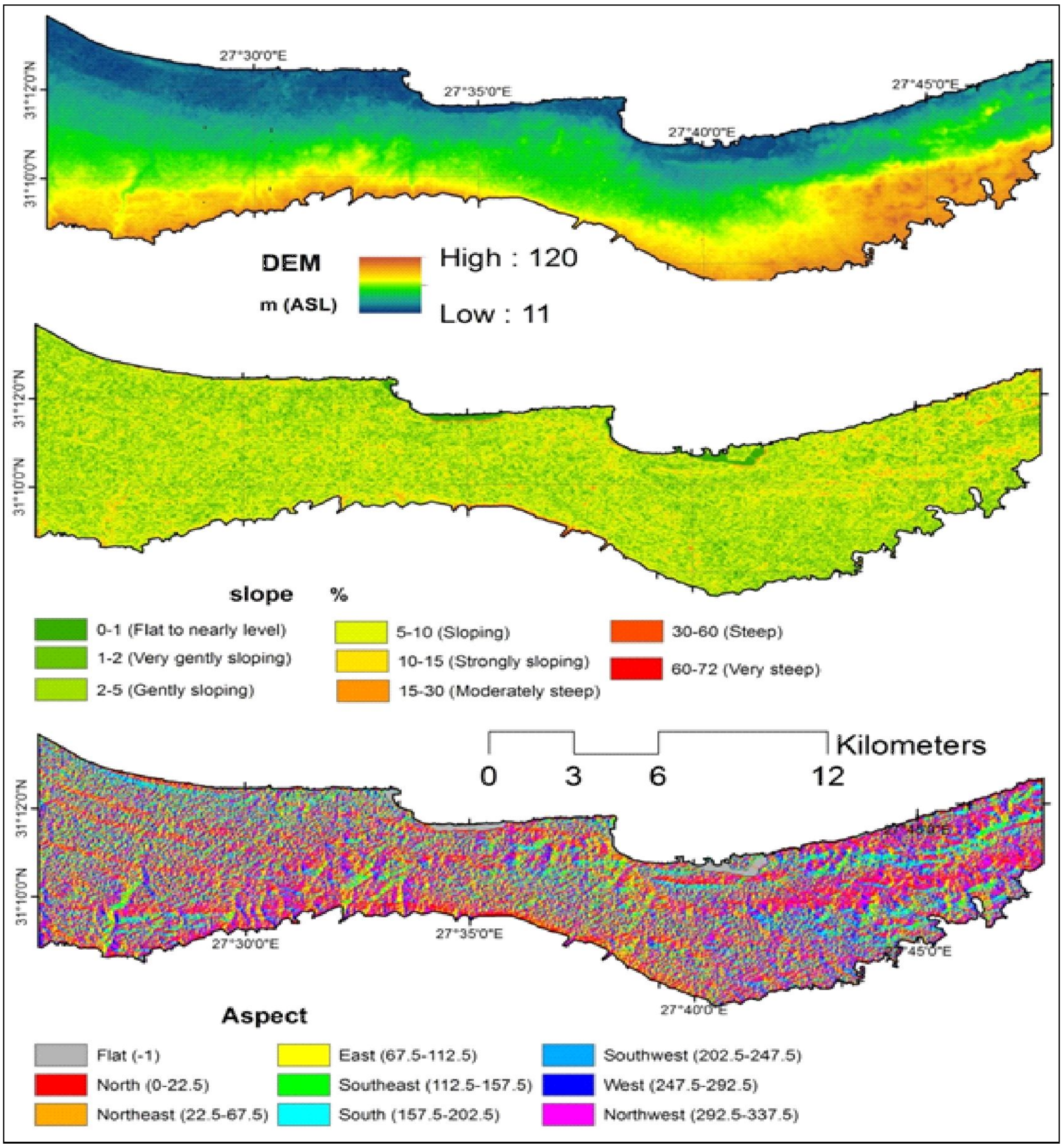

Fig 2: Topographical analysis of the investigated area.

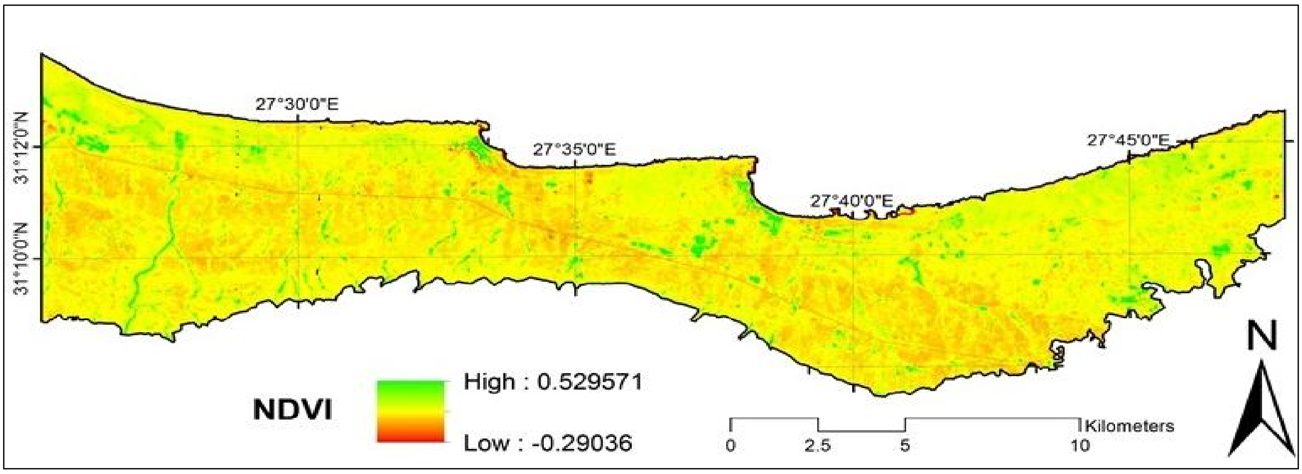

Fig 3: Normalized Difference Vegetation Index (NDVI).

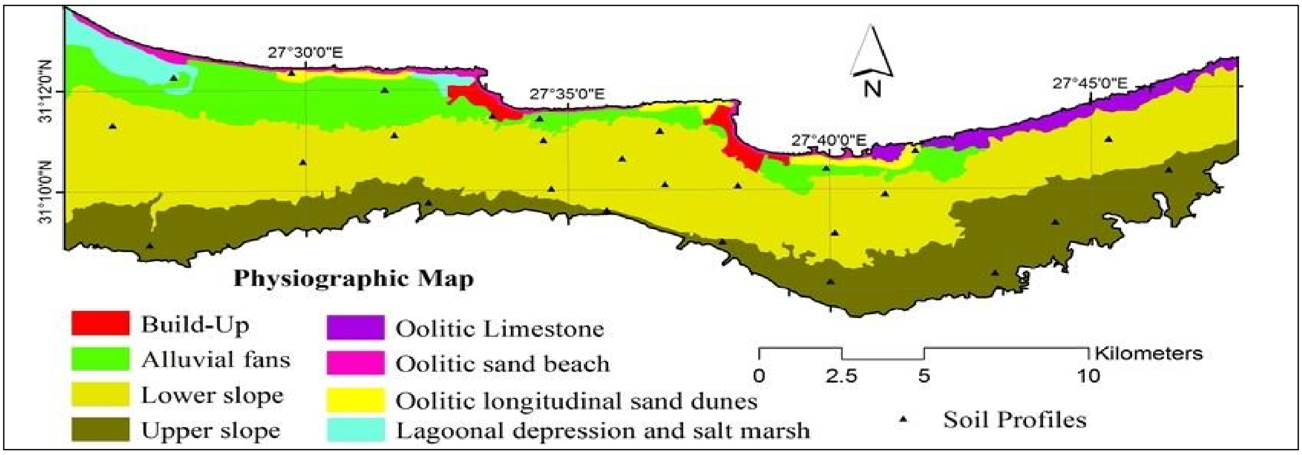

Fig 4: Physiographic soil map.

Table 1: Land capability according to Cervatana model De la Roza (2000).

Class	Description	Sub class	Limitation	
S1	Excellent use capability	Slope	t	Slope
S2	Good use capability.	Soil	l	Useful depth
S3	Moderate use capability.			Texture class
N	Marginal or non-productive			Stoniness and rockiness
				Drainage class
		Erosion risk	r	Soil Erodibility
				Slope gradient
				Vegetation density
		Bioclimatic deficiency	b	Aridity degree
				Frost risks

Table 2: Land capability classification according to revised Storie Index (2008).

Class	Description	Rate %	Limitation severity
1	Excellent	80 - 100	No limitation
2	Good	60 - 80	Slight limitation
3	Fair	40 - 60	Moderate limitation
4	Poor	10 - 40	Sever limitation
5	Non-agricultural	0 - 10	Very sever limitation

Table 3: Land suitability according to Almagra model De la Roza (2000).

Class	Description	Rate %	Sub class	Limitation
S1	highly suitable	100-80	p	Depth
S2	Suitable	80-60	t	Texture
S3	moderately suitable	60-40	d	Drainage
S4	marginal suitable	40-20	c	Carbonates calcium content
S5	not suitable	0-20	s	Salinity
			a	Sodium saturation
			g	Development of soil profile

Table 4: Land suitability classes according to Yen *et al.* (2006).

Class	Description	Rate %	Limitation severity
S1	Highly suitable	85-100	No limitation
S2	moderately suitable	60-85	Slight limitation
S3	marginally suitable	40-60	Moderate limitation
N	not suitable	0-40	Very sever limitation

Table 5: Some chemical and physical analysis of soil properties.

Landforms	Profile No.	Depth cm	Gravel g kg^{-1}	Particle size distribution Sand %	Silt %	Clay %	class	FC %	PWP %	AW %	OM g kg^{-1}	$CaCO_3$ g kg^{-1}	pH	EC dS m^{-1}	SAR %	ESP %	CEC cmol(p+) kg^{-1}soil
Upper slope	1	0-20	16.78	84.88	7.50	7.62	loamy sand	11.53	6.53	5.00	5.04	837.07	7.13	0.72	7.41	9.58	5.73
		20-80	7.48	84.88	5.00	10.12	loamy sand	11.50	6.51	4.99	3.64	939.26	7.00	0.59	7.35	9.52	6.44
		80-120	8.37	72.38	15.00	12.62	sandy loam	18.23	8.77	9.46	5.60	702.40	7.11	4.41	9.12	11.35	8.44
	5	0-40	2.52	74.88	10.00	15.12	sandy loam	16.92	8.28	8.64	5.60	276.72	7.29	8.14	10.85	13.13	9.69
		40-90	0.00	69.88	12.50	17.62	sandy loam	19.47	9.23	10.24	6.16	356.68	8.15	0.50	7.31	9.48	11.15
		90-120	0.73	67.38	10.00	22.62	sandy clay loam	20.57	9.62	10.96	12.61	433.63	7.92	0.52	7.32	9.49	16.10
	6	0-25	340.01	72.38	12.50	15.12	sandy loam	18.23	8.77	9.46	6.16	362.55	7.22	6.35	10.02	12.27	9.90
		25-50	75.67	67.38	15.00	17.62	sandy loam	20.72	9.74	10.98	5.32	507.71	7.45	5.76	9.75	11.99	10.83
	7	0-35	9.13	77.38	10.00	12.62	sandy loam	15.63	7.84	7.79	4.20	284.26	7.60	1.90	7.96	10.15	7.91
		35-65	0.72	79.88	10.00	10.12	sandy loam	14.29	7.40	6.90	6.16	213.54	7.40	2.15	8.07	10.27	7.40
	16	0-40	116.57	77.38	7.50	15.12	sandy loam	15.58	7.80	7.78	22.14	390.84	7.23	0.71	7.41	9.58	15.97
		40-80	148.00	69.88	12.50	17.62	sandy loam	19.47	9.23	10.24	4.76	550.71	7.11	1.06	7.57	9.74	10.62
		80-120	282.22	67.38	12.50	20.12	sandy clay loam	20.67	9.69	10.98	4.20	541.71	7.45	0.88	7.48	9.66	11.66
	19	0-30	250.00	73.96	10.42	15.62	sandy loam	17.40	8.45	8.95	7.00	191.90	7.33	3.40	8.65	10.86	10.47
		30-80	350.00	85.04	6.46	8.5	loamy sand	11.44	6.50	4.94	9.00	436.20	7.30	3.50	8.70	10.91	7.67
		80-130	0.00	79.76	12.01	8.23	loamy sand	14.35	7.41	6.94	3.20	69.80	7.11	2.60	8.28	10.48	5.33
	23	0-30	16.00	79.50	12.50	8.00	Loamy sand	14.48	7.45	7.04	4.80	273.00	8.70	0.98	7.53	9.71	5.82
		30-60	18.00	82.00	10.00	8.00	Loamy sand	13.13	7.02	6.11	2.50	176.00	7.78	9.48	11.48	13.77	4.95
		60-90	30.00	84.50	10.00	5.50	Loamy sand	11.73	6.58	5.15	1.90	199.00	7.80	10.22	11.82	14.12	3.47
		90-120	0.00	84.50	10.00	5.50	Loamy sand	11.73	6.58	5.15	1.90	211.00	7.66	8.35	10.95	13.23	3.47
		120-150	0.00	87.00	10.00	3.00	Sand	10.28	6.13	4.15	2.10	172.00	7.80	6.52	10.10	12.36	2.30
	25	0-45	322.10	76.00	10.00	14.00	Sandy loam	16.35	8.09	8.27	7.00	225.10	7.72	2.83	8.39	10.59	9.66
		45-100	152.60	76.00	7.50	16.50	Sandy loam	16.29	8.03	8.26	3.30	232.20	7.91	3.46	8.68	10.89	9.50
		100-150	31.80	81.00	5.00	14.00	sandy loam	13.61	7.13	6.47	3.30	225.10	7.97	3.81	8.84	11.06	8.25
Lower slope	2	0-35	4.99	69.88	12.50	17.62	sandy loam	19.47	9.23	10.24	1.68	526.83	7.20	0.76	7.43	9.60	9.45
		35-75	5.59	72.38	7.50	20.12	sandy clay loam	18.08	8.65	9.43	2.52	694.29	7.09	3.70	8.79	11.01	11.02
		75-115	3.85	62.38	15.00	22.62	sandy clay loam	23.05	10.70	12.35	2.24	440.17	7.24	4.58	9.20	11.43	12.16
	4	0-40	5.13	82.38	5.00	12.62	sandy loam	12.87	6.91	5.96	2.52	323.86	7.08	6.97	10.31	12.57	7.27
		40-80	1.42	74.88	12.50	12.62	sandy loam	16.95	8.30	8.64	2.80	241.77	7.79	5.99	9.86	12.10	7.37
		80-120	16.61	69.88	12.50	17.62	sandy loam	19.47	9.23	10.24	7.00	173.99	7.47	3.40	8.65	10.86	11.47
	8	0-10	144.97	74.88	10.00	15.12	sandy loam	16.92	8.28	8.64	2.80	524.61	7.26	1.08	7.58	9.76	8.62
		10-55	121.52	67.38	10.00	22.62	sandy clay loam	20.57	9.62	10.96	4.48	604.68	7.38	3.79	8.84	11.05	13.01
		55-80	145.10	64.88	15.00	20.12	sandy clay loam	21.91	10.22	11.69	1.96	464.61	7.31	5.49	9.62	11.86	10.80

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	9	0-35	15.49	74.88	10.00	15.12	sandy loam	16.92	8.28	8.64	10.65	375.45	7.82	1.01	7.54	9.72	11.61
		35-85	35.14	69.88	12.50	17.62	sandy loam	19.47	9.23	10.24	10.92	395.44	7.78	1.24	7.65	9.83	12.96
		85-105	101.39	69.88	10.00	20.12	sandy clay loam	19.40	9.17	10.22	5.60	435.79	7.59	1.02	7.55	9.72	12.19
	10	0-15	16.44	84.88	5.00	10.12	loamy sand	11.50	6.51	4.99	6.16	913.57	7.41	0.50	7.31	9.48	7.40
		15-75	13.33	74.88	7.50	17.62	sandy loam	16.85	8.22	8.62	4.20	804.26	7.48	0.81	7.45	9.63	10.41
	11	0-40	29.94	72.38	10.00	17.62	sandy loam	18.18	8.73	9.45	11.77	429.58	7.25	8.45	11.00	13.28	13.28
		40-80	22.37	69.88	12.50	17.62	sandy loam	19.47	9.23	10.24	4.48	385.06	7.93	3.37	8.64	10.85	10.51
		80-120	11.23	69.88	12.50	17.62	sandy loam	19.47	9.23	10.24	1.96	499.30	8.05	2.97	8.45	10.66	9.55
	14	0-35	27.79	74.88	7.50	17.62	sandy loam	16.85	8.22	8.62	7.85	315.22	8.05	7.84	10.71	12.99	11.79
		35-50	153.23	72.38	10.00	17.62	sandy loam	18.18	8.73	9.45	3.36	645.66	7.52	3.71	8.80	11.01	10.09
		50-85	54.93	87.38	2.50	10.12	loamy sand	10.05	6.06	3.98	3.08	236.41	7.62	2.69	8.32	10.52	6.23
		85-105	155.01	64.88	17.50	17.62	sandy loam	21.93	10.24	11.69	3.08	384.29	7.58	2.54	8.26	10.45	9.98
	15	0-20	46.79	87.38	2.50	10.12	loamy sand	10.05	6.06	3.98	5.60	704.27	7.75	1.12	7.60	9.77	7.19
		20-45	78.81	84.88	5.00	10.12	loamy sand	11.50	6.51	4.99	6.44	664.71	7.64	0.59	7.35	9.52	7.51
		45-85	16.24	82.38	7.50	10.12	loamy sand	12.92	6.95	5.96	6.44	586.51	7.61	0.44	7.28	9.45	7.51
		85-135	11.62	79.88	7.50	12.62	sandy loam	14.27	7.38	6.89	7.01	473.57	7.51	0.55	7.33	9.50	8.97
	17	0-10	103.54	69.88	17.50	12.62	sandy loam	19.47	9.23	10.24	8.13	262.57	7.88	1.35	7.70	9.88	9.40
		10-40	88.85	72.38	7.50	20.12	sandy clay loam	18.08	8.65	9.43	4.20	396.70	7.49	1.56	7.80	9.99	11.66
	22	0-20	0.00	37.53	45.03	17.44	Loam	32.60	15.73	16.87	7.70	277.40	8.20	68.30	38.77	41.88	11.65
		20-50	0.00	46.75	45.84	7.41	Loam	28.43	12.98	15.45	6.70	243.10	8.10	36.20	23.87	26.54	6.25
		50-85	0.00	48.98	44.85	6.74	Loam	27.62	12.54	15.07	5.70	240.20	8.10	22.70	17.61	20.09	5.54
		85-115	0.00	63.19	18.40	18.41	Sandy loam	22.74	10.58	12.15	3.60	182.20	8.10	23.30	17.89	20.37	10.57
	24	0-10	194.00	84.50	10.00	5.50	Loamy sand	11.73	6.58	5.15	7.70	364.00	8.05	5.29	9.53	11.77	5.68
		10-45	90.00	87.00	7.50	5.50	Loamy sand	10.32	6.17	4.16	7.70	447.00	8.16	8.42	10.98	13.26	5.68
		45-70	0.00	79.50	10.00	10.50	Sandy loam	14.50	7.46	7.04	2.60	381.00	8.17	6.73	10.20	12.46	6.24
	26	0-50	374.90	78.50	5.00	16.50	Sandy loam	14.91	7.54	7.37	3.00	275.10	7.82	2.66	8.31	10.51	9.39
		50-90	47.20	71.00	10.00	19.00	sandy loam	18.86	8.97	9.89	2.50	368.00	7.63	12.63	12.94	15.28	10.45
		90-150	165.40	68.50	10.00	21.50	Sandy clay loam	20.06	9.42	10.64	1.00	360.90	7.69	14.81	13.95	16.32	11.13
Alluvial Fans	3	0-15	8.80	72.38	2.50	25.12	sandy clay loam	17.74	8.37	9.37	14.29	696.72	7.18	12.59	12.92	15.26	17.99
		15-55	3.24	77.38	5.00	17.62	sandy loam	15.48	7.72	7.76	6.44	701.84	7.96	2.91	8.43	10.63	11.26
		55-95	2.11	72.38	5.00	22.62	sandy clay loam	17.93	8.53	9.41	4.20	748.65	7.80	3.64	8.77	10.98	12.91
		95-130	0.00	92.38	2.50	5.12	sand	7.17	5.29	1.87	4.20	860.62	7.94	0.82	7.46	9.63	4.16
	12	0-10	0.00	77.38	7.50	15.12	sandy loam	15.58	7.80	7.78	18.50	553.56	7.08	33.90	22.81	25.44	14.59
		10-100	0.00	67.38	15.00	17.62	sandy loam	20.72	9.74	10.98	8.97	359.39	7.59	9.24	11.36	13.66	12.22
		100-150	1.41	67.38	15.00	17.62	sandy loam	20.72	9.74	10.98	8.41	330.20	7.40	14.14	13.64	16.00	12.01
	13	0-15	1.61	67.38	12.50	20.12	sandy clay loam	20.67	9.69	10.98	10.09	365.80	7.76	2.58	8.27	10.47	13.89
		15-70	3.04	67.38	7.50	25.12	sandy clay loam	20.43	9.50	10.93	17.38	422.39	7.63	1.16	7.61	9.79	19.16
		70-130	0.00	67.38	7.50	25.12	sandy clay loam	20.43	9.50	10.93	5.04	333.51	8.17	1.17	7.62	9.80	14.48

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	20	0-15	250.00	63.9	15.45	20.65	sandy clay loam	22.38	10.42	11.96	4.00	183.20	7.05	1.40	7.73	9.91	11.85
		15-25	305.00	80.66	11.81	7.53	loamy sand	13.86	7.24	6.61	4.40	43.60	7.00	3.60	8.75	10.96	5.44
		25-60	285.00	83.68	6.22	10.1	loamy sand	12.19	6.72	5.47	3.90	274.80	7.12	1.90	7.96	10.15	6.53
	21	0-15	0.00	68.20	19.11	12.69	Sandy loam	20.29	9.55	10.74	7.70	231.90	8.40	62.50	36.08	39.11	9.27
		15-40	0.00	55.41	26.68	17.91	Sandy loam	26.18	12.16	14.02	6.70	288.80	7.90	27.50	19.84	22.38	11.50
		40-75	0.00	76.88	17.51	5.61	Loamy sand	15.77	7.82	7.94	5.10	509.30	8.00	13.19	13.20	15.54	4.74
		75-120	0.00	61.99	17.78	20.23	Sandy loam	23.29	10.82	12.47	5.80	648.10	8.10	9.79	11.62	13.92	12.32
		120-150	0.00	90.87	5.87	3.26	Sand	8.07	5.53	2.54	7.00	637.80	8.00	16.71	14.83	17.23	4.29
Oolitic	18	0-50	0.45	97.38	2.50	0.12	sand	4.52	4.13	0.39	1.12	997.10	7.95	0.59	7.35	9.52	0.49
longitudinal		50-100	0.59	97.38	2.50	0.12	sand	4.52	4.13	0.39	1.10	986.27	7.85	0.60	7.36	9.53	0.48
sand dunes		100-150	0.64	97.38	2.50	0.12	sand	4.52	4.13	0.39	1.10	997.49	7.90	0.59	7.35	9.52	0.48
	27	0-50	0.00	98.38	1.50	0.12	sand	5.25	4.38	0.87	0.70	977.10	8.05	0.49	7.31	9.48	0.33
		50-100	0.00	99.38	0.50	0.12	sand	4.80	4.23	0.57	0.60	956.27	8.15	0.55	7.33	9.50	0.29
		100-150	0.00	99.5	0.38	0.12	sand	7.75	4.21	3.54	6.00	987.49	8.35	0.35	7.24	9.41	2.34

very deep soil except profile 6 and 7 which have moderately depth with 50 and 65 cm respectively. EC ranged between 0.59 and 10.22 dSm^{-1}. Calcium carbonate ($CaCO_3$) content was to the tune of 939.26 g kg^{-1} and 93.93% the soils were considered as extremely calcareous. The soils were classified as Typic Torripsamments (12.50%), Typic Haplocalcids (25%), Typic Torriorthents (37.50%) and Lithic Torriorthents (25%) as shown in Table 6.

Soils of lower slope unit

This unit is the largest unit and located in the middle part of the area and occupies an area of 99.88 km^2 and represented by twelve soil profiles (Table 5). Soil depth varied from shallow to very deep (40 to 150 cm). EC values ranged between 0.44 and 14.81 dSm^{-1} except soil profile 22 with EC value of 68.3 dSm^{-1} (extremely saline). Soils are extremely calcareous where calcium carbonate reached up to 913.57 g kg^{-1} (91.36 %). Soils of this unit were classified as Typic Haplocalcids cover (50 %), Typic Torriorthents cover (33.34 %), Lithic Torriorthents cover (8.33 %) and Calcic Haplosalids cover (8.33 %) as illustrated in Table 6.

Soils of alluvial fans unit

This unit is located in the northern part of the area covers (26.07 km^2) and represented by five soil profiles (Table 5). Most of soils are very deep soil except profile 20 which is shallow (60 cm). EC ranged between 0.8 and 62.50 dSm^{-1}. $CaCO_3$ content reached up to 860.62 g kg^{-1} (86.06%). Soils of this unit were classified as Typic Haplosalids (20%), Typic Torriorthents (40%) and Typic Haplocalcids (40%) as shown in Table 6.

Soils of oolitic longitudinal sand dunes unit

This unit is located in the northern part of the investigated area parallel with shore line. It occupies an area of 3.32 km^2 and represented by two soil profiles (Table 5). Soils of this unit classified as a very deep soil. EC values varied between 0.46 and 0.60 dSm^{-1}. $CaCO_3$ content reached up to 997.50 g kg^{-1} (99.75 %). Soils of this unit were classified as Typic Torripsamments (Table 6).

Land Capability of investigated soils

Modified Storie Index

The area could be classified into four capability classes (Fig 5; Table 7). Grade 3 occupied an area of 98.98 km^2 (50.19%) while grade 4 had an area of 58.57 km^2 (29.70%) as illustrated in Table 8. The common limiting factors are soil salinity, shallow soil depth and coarse of texture class.

MicroLEIS Cervatana model

The studied area could be classified into three capability classes *viz* S2, S3 and N (Fig 6; Table 10). Lands with good capability (S2) have a topographic or climatic limitation which in turn restrict the choice for possible crops and their productivity. Land capability (S3) having the limitations of topographic or climatic factors cause limit of potential crops capability of productivity. S3 class includes three sub capability classes S3lr, S3r and S3l. Marginal land (N) as non-productive land is not recommended for cultivation and may be used for a

Table 6: Legend of the physiographic soil map of the study area.

Landform	Area Km^2	%	Main Soils	% of mapping unit	Represented Profiles	Kind of mapping unit
Upper slope	51.77	26.25	Typic Torripsamments	12.50	23	Complex
			Typic Torriorthents	37.50	5, 16, 25	
			Typic Haplocalcids	25	1, 19	
			Lithic Torriorthents	25	6, 7	
Lower slope	99.98	50.70	Typic Haplocalcids	50	2, 4, 8, 14, 15, 24	Association
			Typic Torriorthents	33.34	9, 10, 11, 26	
			Lithic Torriorthents	8.33	17	
			Calcic Haplosalids	8.33	22	
Alluvial fans	26.07	13.22	Typic Haplosalids	20	21	
			Typic Torriorthents	40	3, 12	
			Typic Haplocalcids	40	13, 20	
Oolitic longitu dinals and dunes	3.32	1.68	Typic Torripsamments	100	18, 27	Consociation
Build-up	2.60	1.32	No data	—	—	Miscellaneous
Lagoonal depression and salt marsh	4.61	2.34	No data	—	—	Miscellaneous
Oolitic Limestone	5.17	2.62	No data	—	—	Miscellaneous
Oolitic sand beach	3.70	1.88	No data	—	—	Miscellaneous
Total	197.22	100				

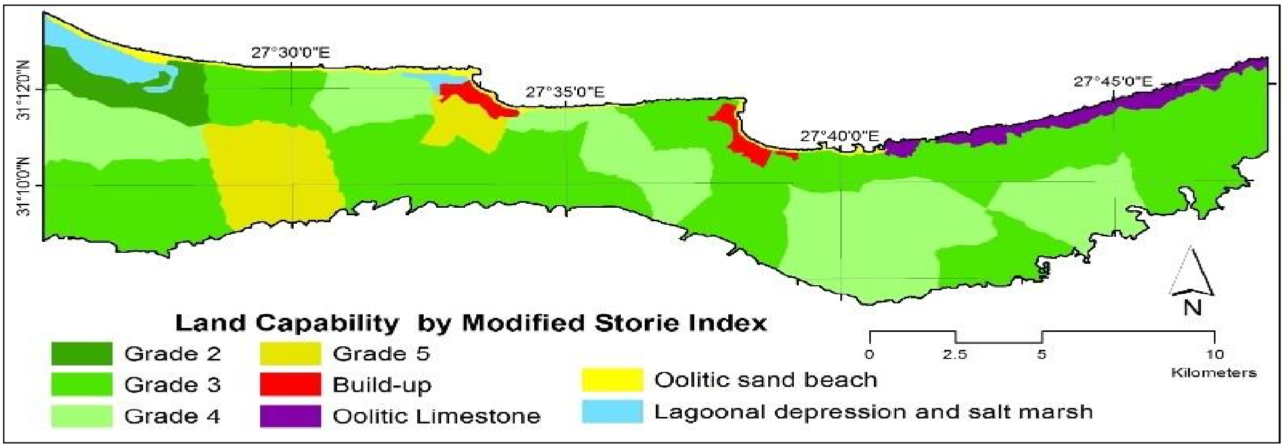

Fig 5: Land capability assessment by Modified Storie Index.

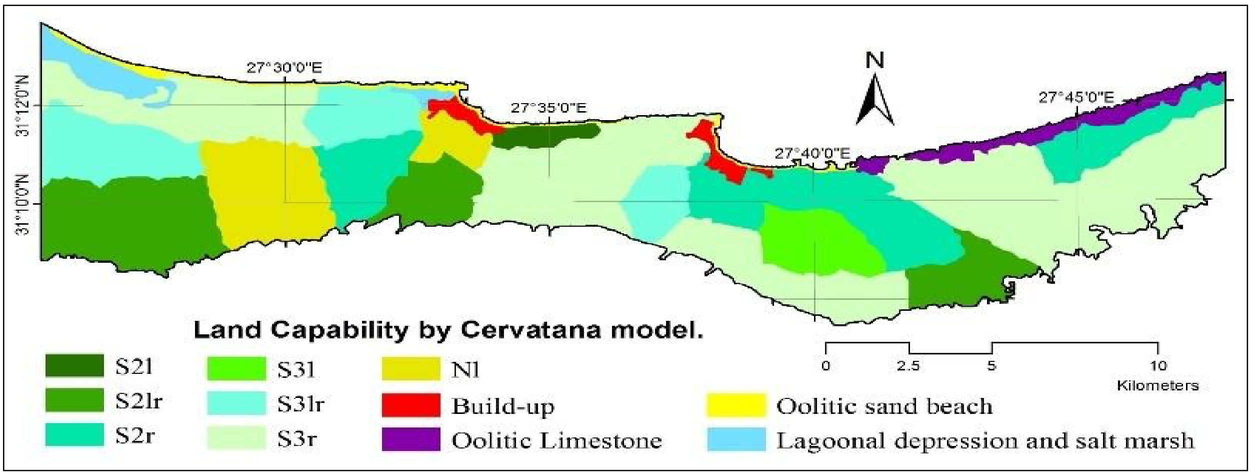

Fig 6: Land capability assessment by MicroLEIS Cervatana model.

Table 7: Land capability by modified Storie index.

Landforms	P.N.	RateDepth	Rategravel	RateSlope	RatepH	RateSAR	RateEC	Ratetexture	Finalrate	Class
Upper slope	1	84.0	99.1	89.9	100.0	87.9	92.6	80.0	48.73	Grade 3
	5	84.0	99.9	95.1	100.0	87.1	88.1	95.0	58.18	Grade 3
	6	44.1	81.5	91.0	100.0	85.1	76.7	95.0	20.28	Grade 4
	7	54.8	99.5	93.6	100.0	87.8	92.1	95.0	39.17	Grade 4
	16	84.0	83.7	96.4	100.0	88.5	96.5	95.0	54.98	Grade 3
	19	87.6	82.8	89.8	100.0	87.0	87.8	95.0	47.28	Grade 3
	23	93.3	98.8	91.0	100.0	84.4	72.8	80.0	41.26	Grade 3
	25	93.3	85.3	94.9	100.0	86.9	86.8	95.0	54.09	Grade 3
Lower slope	2	82.0	99.6	92.0	100.0	87.1	87.9	95.0	54.55	Grade 3
	4	36.3	99.3	89.8	100.0	85.5	79.0	95.0	20.77	Grade 4
	8	64.3	88.0	100.0	100.0	86.5	84.5	95.0	39.32	Grade 4
	9	77.6	96.2	94.9	100.0	88.4	95.6	95.0	56.83	Grade 3
	10	61.3	98.7	100.0	100.0	88.6	97.0	80.0	41.61	Grade 3
	11	84.0	98.0	94.9	100.0	85.9	80.9	95.0	51.58	Grade 3
	14	77.6	92.7	94.9	100.0	86.1	82.5	95.0	46.07	Grade 3
	15	89.2	97.2	96.4	100.0	88.7	97.6	80.0	57.87	Grade 3
	17	36.3	91.5	91.0	100.0	88.1	94.1	95.0	23.80	Grade 4
	22	82.0	100.0	96.4	100.0	68.7	10.6	80.0	4.59	Grade 5
	24	58.1	93.3	94.9	100.0	84.3	71.9	80.0	24.93	Grade 4
	26	93.3	81.8	94.9	100.0	82.5	61.8	95.0	35.09	Grade 4
Alluvial fans	3	87.6	99.8	91.0	100.0	86.7	85.6	95.0	56.05	Grade 3
	12	93.3	100.0	98.4	100.0	81.0	53.7	95.0	37.91	Grade 4
	13	87.6	99.9	93.6	100.0	88.2	94.8	95.0	65.03	Grade 2
	20	51.4	75.5	94.2	100.0	87.8	91.9	95.0	28.00	Grade 4
	21	93.3	100.0	96.4	100.0	76.4	28.7	95.0	18.72	Grade 5
Oolitic longitudinal	18	93.3	99.9	95.4	100.0	88.7	97.6	60.0	46.26	Grade 3
sand dunes	27	93.3	100.0	92.0	100.0	88.8	98.2	60.0	44.89	Grade 3

Table 8: Tabulate area between Storie capability and landforms km^2.

Landform	Upper slope	Lower slope	Alluvial fans	Oolitic longitudinal sand dunes	Total
Grade 2	0.00	0.82	6.32	0.00	7.13
Grade 3	29.79	54.78	11.63	2.79	98.98
Grade 4	17.92	33.15	6.98	0.53	58.57
Grade 5	4.06	11.24	1.15	0.00	16.45
Total	51.77	99.98	26.07	3.32	181.14

Table 9: Tabulate area between MicroLEIS capability and land form km^2.

Capability		Upper slope	Lower slope	Alluvial fans	Oolitic longitudinal sand dunes	Total
Class	Subclass					
S2	S2lr	17.91	11.36	0.00	0.00	29.27
	S2r	3.04	22.94	2.50	0.97	29.45
	S2l	0.00	0.67	1.48	0.00	2.15
S3	S3r	25.90	32.48	15.45	1.83	75.65
	S3l	0.74	6.62	0.00	0.00	7.36
	S3lr	0.11	14.68	5.50	0.53	20.81
N	Nl	4.06	11.24	1.15	0.00	16.45
Total		26.07	3.32	51.77	99.98	181.14

Good . S2 ; Moderate, S3; Marginal, N ; Soil, l ; Erosion risks, r.

Table 10: Suitability by Almagra model.

Landform	P.N	T	M	Me	P	S	A	G	Af	Me	C	O	Land capability
Upper slope	1	S4t	S4t	S4t	S4tc	S4t	S4t	S4t	S4t	S4c	S4c	S3c	S2r
	5	S3t	S3tc	S3tc	S3tc	S3t	S3tc	S3t	S3t	S3c	S3c	S2tcs	S2lr
	6	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3tcs	S3tcs	S3ts	S3r
	7	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tca	S2tca	S2ta	S3r
	16	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3tc	S3tc	S3t	S2lr
	19	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S3t	S3r
	23	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4s	S4s	S3s	S2lr
	25	S4ta	S5a	S4ta	S4ta	S4ta	S4ta	S4ta	S4ta	S4a	S4a	S4a	S3r
Lower slope	2	S3tc	S3tc	S3tc	S4c	S3tc	S3tc	S3tc	S3tc	S4c	S4c	S3c	S2r
	4	S3td	S3ta	S3ts	S3t	S3td	S3t	S3t	S3td	S4d	S4d	S4d	S3lr
	8	S3tc	S3tca	S3tc	S4c	S3tc	S3tc	S3tc	S3tc	S4c	S4c	S3c	S2r
	9	S3t	S3tc	S3tc	S3tc	S3t	S3tc	S3t	S3t	S3c	S3c	S2tca	S2r
	10	S3tc	S3tc	S3tc	S4c	S3tc	S3tc	S3tc	S3tc	S4c	S4c	S3c	S3r
	11	S3t	S3tca	S3tcs	S3tc	S3t	S3tc	S3t	S3t	S3cs	S3cs	S3s	S3r
	14	S3t	S3tca	S3tc	S3tc	S3t	S3tc	S3t	S3t	S3c	S3c	S2tcs	S3r
	15	S4t	S4t	S4t	S4tc	S4t	S4t	S4t	S4t	S4c	S4c	S3c	S2r
	17	S3td	S3tc	S3tc	S3tc	S3td	S3tc	S3t	S3td	S4d	S4d	S4d	S3lr
	22	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	NI
	24	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4s	S4s	S3s	S3r
	26	S5a	S5a	S5a	S5a	S5a	S5a	S5a	S5a	S5sa	S5sa	S5a	S3l
Alluvial Fans	3	S3c	S3ca	S3c	S4c	S3c	S3c	S3c	S3c	S4c	S4c	S3c	S3r
	12	S5s	S5s	S5s	S5s	S5s	S4s	S5s	S4s	S5s	S5s	S5s	S3lr
	13	S2ca	S3c	S3c	S3c	S2ca	S3c	S2ca	S2ca	S3c	S3c	S2tca	S3r
	20	S2t	S2tc	S3t	S3t	S2t	S3t	S2t	S2t	S3t	S3t	S4t	S2l
	21	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	NI
Oolitic longitudi-	18	S4t	S4t	S4t	S4tc	S4t	S4t	S4t	S4t	S4c	S4c	S3c	S3r
-nal sand dunes	27	S4t	S4ta	S4t	S4tc	S4t	S4t	S4t	S4t	S4c	S4c	S3ca	S3r

maize (M), melon (Me), potato (P), soybean (S), wheat (T), cotton (A), sunflower (G), alfalfa (Af), citrus (C), peach (Me), olive (O). optimum suitable (S1), high suitable (S2), moderate suitable (S3), marginal suitable (S4), not suitable (S5), Useful depth (p), Texture (t), Drainage (d), Carbonate(c), Salinity (s), Sodium saturation (a), Profile development (g), Slope (t), Soil (l), Erosion risks (r), Bioclimatic deficit (b).

pasture or forestry. NI sub-class occupied an area of 16.45 km^2 (8.34%) and affected by salinity and soil depth and some physical limitations (Table 9).

Land suitability assessment

MicroLEIS Almagra model

The investigated soils are classified into four suitability classes *vis* high suitable (S2), moderate suitable (S3), marginal suitable (S4) and not suitable (S5). Land suitability analysis indicated that 4.71% of the studied area is S2 for wheat, soya, sunflower, alfalfa and citrus whereas 14.82% of the study area is S2 for olives (Table 11). The common limitations in theses soils are calcium carbonate, salinity and soil texture. About 31.78% of the study area is S3 for wheat, maize, peach, citrus, cotton, sunflower and alfalfa. About 36.5% of the study area is S3 for watermelon and about 52% of the study area is S3 for olives. About 40% is S4 for most of crops evaluated. Soil salinity, excess of calcium carbonate, drainage and soil texture were the most common limiting factors in these soils (Fig 7; Table10).

LUST model

The investigated soils are classified into three suitability classes as highly suitable (S1), moderately suitable (S2) and marginally suitable (S3) (Table 12; Fig 8). Land suitability analysis indicated that 5.85, 3.73 and 2.11% of the area are S1 for wheat, cotton and olives respectively (Table 13). About 31% of the study area is S2 for citrus, peach and soya where 63.86% is moderately suitable for alfalfa and sunflower. About 85% of the area is moderately suitable for wheat and melon. Finally, about 55% of the study area is moderately suitable for potato and cotton while 75% is moderately suitable for maize and olives. About 30% of the area is S3 for most of the selected crops (Table 13). Soil salinity, excess of calcium carbonate, drainage and soil texture were the most common limiting factors in the studied soils.

CONCLUSION

It may be concluded that Storie Index categorized 50% of the area as S3. Cervatana model showed that 52.5% of the

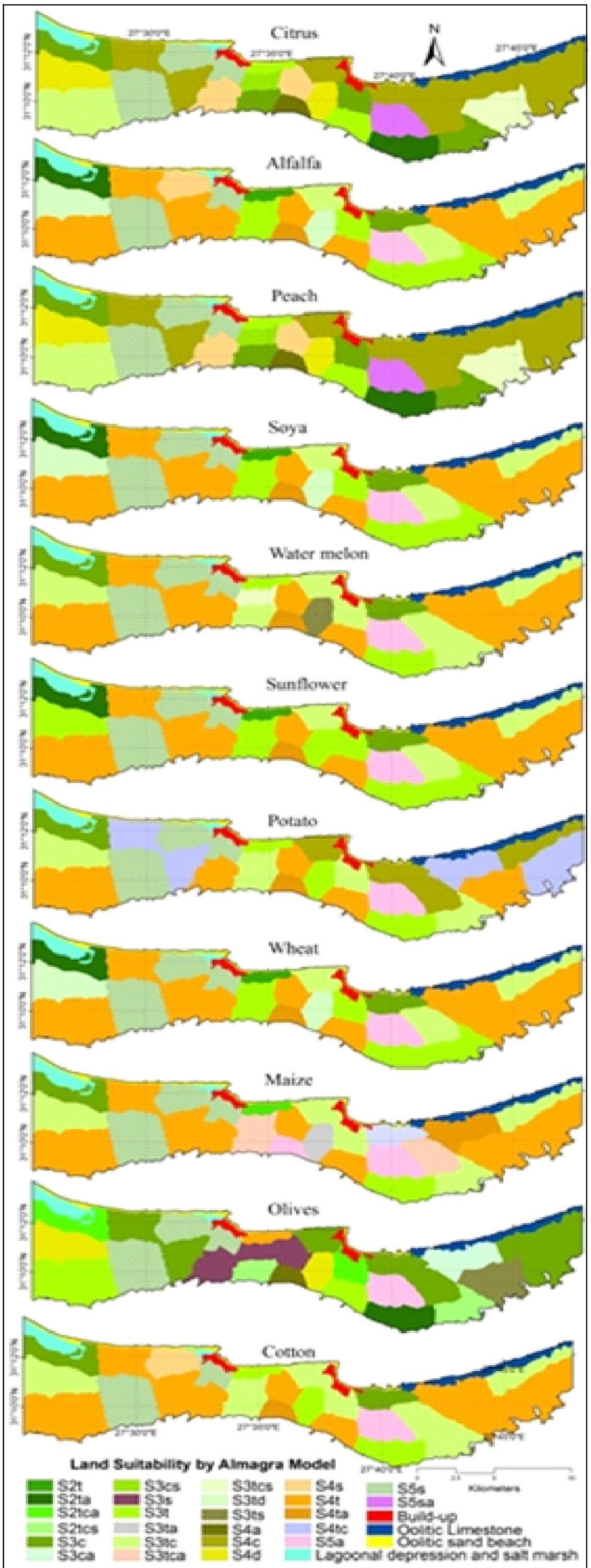

Fig 7: Suitability by Almagra.

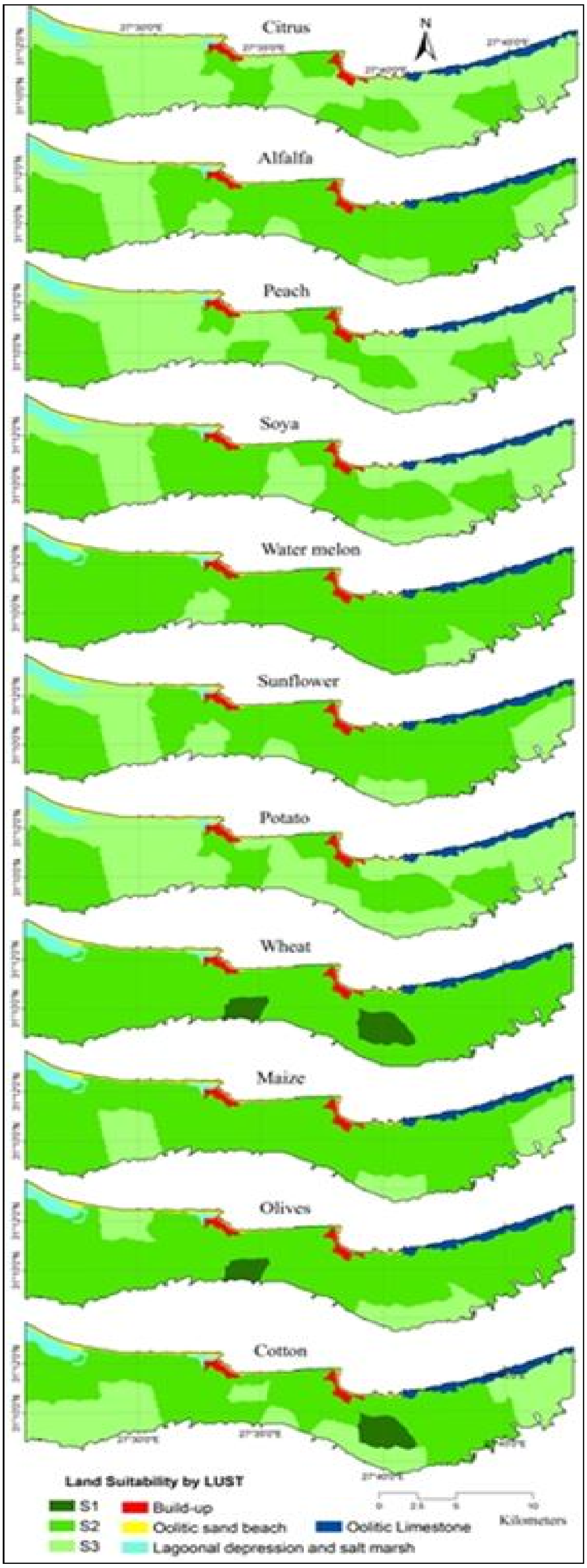

Fig 8: LUST suitability class.

Table 11: Tabulate area in km^2 between Microlies suitability and land form.

Crop	Class	Landform				Total
		Upper slope	Lower slope	Alluvial fans	Oolitic longitudinal sand dunes	
Wheat	S2	0.00	1.48	7.80	0.00	9.28
	S3	16.35	40.83	3.72	1.81	62.71
	S4	30.62	39.63	7.94	0.98	79.17
	S5	4.80	18.03	6.62	0.53	29.98
Maize	S2	0.00	0.67	1.48	0.00	2.15
	S3	16.35	41.65	10.04	1.81	69.85
	S4	30.08	37.47	7.94	0.98	76.46
	S5	5.34	20.19	6.62	0.53	32.68
Melon	S3	16.35	42.32	11.52	1.81	71.99
	S4	30.62	39.63	7.94	0.98	79.17
	S5	4.80	18.03	6.62	0.53	29.98
Potato	S3	14.88	26.04	8.18	0.00	49.10
	S4	32.08	55.91	11.28	2.79	102.07
	S5	4.80	18.03	6.62	0.53	29.98
Soya	S2	0.00	1.48	7.80	0.00	9.28
	S3	16.35	40.83	3.72	1.81	62.71
	S4	30.62	39.63	7.94	0.98	79.17
	S5	4.80	18.03	6.62	0.53	29.98
Cotton	S3	16.35	42.32	11.52	1.81	71.99
	S4	30.62	39.80	13.41	1.50	85.34
	S5	4.80	17.86	1.15	0.00	23.81
Sunflower	S2	0.00	1.48	7.80	0.00	9.28
	S3	16.35	40.83	3.72	1.81	62.71
	S4	30.62	39.63	7.94	0.98	79.17
	S5	4.80	18.03	6.62	0.53	29.98
Alfaalfa	S2	0.00	1.48	7.80	0.00	9.28
	S3	16.35	40.83	3.72	1.81	62.71
	S4	30.62	39.80	13.41	1.50	85.34
	S5	4.80	17.86	1.15	0.00	23.81
Peach	S2	6.93	0.24	0.00	0.00	7.18
	S3	27.45	23.40	8.15	0.00	59.00
	S4	12.58	58.31	11.30	2.79	84.99
	S5	4.80	18.03	6.62	0.53	29.98
Citrus	S2	6.93	0.24	0.00	0.00	7.18
	S3	27.45	23.40	8.15	0.00	59.00
	S4	12.58	58.31	11.30	2.79	84.99
	S5	4.80	18.03	6.62	0.53	29.98
Olives	S2	14.77	7.79	6.67	0.00	29.23
	S3	31.54	56.82	11.28	2.79	102.43
	S4	0.65	17.34	1.50	0.00	19.50
	S5	4.80	18.03	6.62	0.53	29.98

soils were classified as S3. The main land capability limitations were erosion risk, excess of soil salinity and shallow soil depth. Land suitability analysis by Almagra model showed that about 4.71% and 31.78% of the area are S2 for wheat and citrus respectively. Olives had an area of 14.82% and 52% as S2 and S3 respectively. LUST results showed that about 5.85, 3.73 and 2.11 % of the area are S1 for wheat, cotton and olives respectively. About 31% of the study area is S2 for citrus, peach and soya whereas 63.86% is S2 for alfalfa and sunflower and 85% of the area is S2 for wheat and melon. The main limitation factors were soil salinity, calcium carbonate, drainage and texture. Thus MicroLEIS application either Cervatana or Almagra to predict land suitability and land capability respectively is not

Table 12: LUST suitability class.

Landform	LU	T	M	Me	P	S	A	G	Af	Me	C	O
Upper slope	1	S2	S2	S2	S3	S3	S3	S2	S2	S3	S3	S2
	5	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2
	6	S2	S3	S2	S3	S3	S3	S3	S3	S3	S3	S3
	7	S2	S2	S2	S2	S2	S2	S2	S2	S3	S3	S2
	16	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2
	19	S2	S2	S2	S3	S2	S2	S2	S2	S3	S3	S2
	23	S2	S2	S2	S3	S3	S2	S2	S2	S3	S3	S2
	25	S1	S2	S2	S2	S2	S1	S2	S2	S2	S2	S2
Lower slope	2	S2	S2	S2	S3	S3	S2	S2	S2	S3	S3	S2
	4	S2	S2	S3	S3	S3	S2	S2	S2	S3	S3	S3
	8	S2	S2	S2	S2	S2	S2	S2	S2	S2	S3	S2
	9	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2
	10	S2	S2	S2	S2	S2	S3	S2	S2	S3	S2	S2
	11	S2	S2	S2	S3	S2	S2	S2	S2	S3	S3	S2
	14	S2	S2	S2	S3	S2	S2	S2	S2	S3	S3	S2
	15	S2	S2	S2	S2	S2	S3	S2	S2	S2	S2	S2
	17	S2	S2	S2	S3	S3	S2	S3	S3	S3	S3	S3
	22	S2	S2	S3	S3	S2	S2	S3	S3	S3	S3	S2
	24	S2	S2	S2	S3	S3	S3	S3	S3	S3	S3	S2
	26	S2	S2	S2	S3	S3	S2	S2	S2	S3	S3	S2
Alluvial fans	3	S2	S2	S2	S3	S3	S2	S2	S2	S3	S3	S2
	12	S2	S2	S2	S3	S3	S2	S3	S3	S3	S3	S2
	13	S1	S2	S2	S2	S2	S2	S2	S2	S2	S2	S1
	20	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2
	21	S2	S3	S2	S3	S3	S3	S3	S3	S3	S3	S2
Oolitic longitudinal sand dunes	18	S2	S2	S2	S3	S2	S3	S2	S2	S3	S2	S2
	27	S2	S3	S2	S3	S3	S3	S3	S3	S3	S3	S2

maize (M), melon (Me), wheat (T), potato (P), soybean (S), alfalfa (Af), cotton (A), sunflower (G), peach (Me), citrus (C) , olive (O), Highly suitable (S1), Moderately suitable (S2), Marginally suitable (S3), Not suitable (N).

Table 13: Tabulate area in km^2 between LUST suitability and landforms.

Crop	Class	Landform				Total
		Upper slope	Lower slope	Alluvial fans	Oolitic longitudinal sand dunes	
Citrus	S2	21.75	39.43	2.48	0.85	64.51
	S3	30.01	60.55	23.59	2.47	116.63
Alfalfa	S2	31.57	77.89	13.72	2.77	125.95
	S3	20.19	22.09	12.36	0.54	55.19
Peach	S2	19.96	37.18	2.83	0.85	60.82
	S3	31.81	62.80	23.24	2.47	120.31
Soybean	S2	27.14	58.52	9.90	1.37	96.94
	S3	24.62	41.46	16.17	1.94	84.20
Watermelon	S2	42.99	96.30	26.07	3.32	168.68
	S3	8.78	3.68	0.00	0.00	12.46
Sunflower	S2	31.57	77.89	13.72	2.77	125.95
	S3	20.19	22.09	12.36	0.54	55.19
Potato	S2	30.35	54.30	23.24	2.47	110.35
	S3	21.42	45.68	2.83	0.85	70.79
Wheat	S1	2.15	9.38	0.00	0.00	11.53
	S2	49.62	90.60	26.07	3.32	169.61
	S3	0.00	0.00	0.00	0.00	0.00
Maize	S2	34.46	85.07	26.07	3.32	148.91
	S3	17.31	14.91	0.01	0.00	32.23
Olives	S1	1.41	2.76	0.00	0.00	4.17
	S2	36.99	96.46	20.04	2.77	156.27
	S3	13.36	0.76	6.03	0.54	20.70
Cotton	S1	0.74	6.62	0.00	0.00	7.36
	S2	22.25	55.72	26.06	3.32	107.35
	S3	28.78	37.64	0.01	0.00	66.43

recommended as these applications evaluates the land based on the minimum limiting factor. LUSET application for land suitability or Modified Storie index for land capability is recommended where all soil parameters share together for assessing the soil suitability rate by calculating the average methods.

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