Evolution of land suitability and capability for some crops growth using LSSM model at Al-Gabbanah valley, Ibb, Yemen

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Abstract

This study aimed at finding the productivity of the land and its suitability for the growth of some agricultural crops (field crops, vegetable crops and fruits), namely sorghum, potatoes and figs. The study area was evaluated according to its production capacity according to Sys et al. 1991 for the first and second grades (S1, S2) using a special digital model to illustrate this cartography. These lands were also classified according to their suitability to grow three types of crops, vegetables and fruits according to Sys et al. 1993, and using a special digital model to illustrate this cartography. The studied crops were suitable for cultivation in the Al-Gabbanah valley, as the results showed that sorghum in the ground sectors (1, 4) is very appropriate (S1), while in the ground sectors (2.3) it is moderate suitability (S2). The potato yield showed very appropriate result (S1) in sectors (2,4) and moderate suitability in sectors (1,3). As for the fig crop, the results showed moderate suitability (S2) in all sectors.

Keywords: Land productivity, suitability of crop growth, sorghum, potatoes, figs, Ibb Governorate, Yemen.

Introduction:

Yemen occupies the southern end of the Arabian Peninsula. The country has many interior mountains separated by western and central highlands. The western highlands have peaks reaching to 3660 meters, with relatively fertile soil and sufficient plentiful rainfall. Although the central highlands are more like a plateau of about 2000- 3200 meters, with rolling hills, small knolls, and some very prominent peaks, they still relatively very high. Those regions have less rainfall, but they still receive sufficient rain in summer months for extensive cropping pattern Fig.(1)

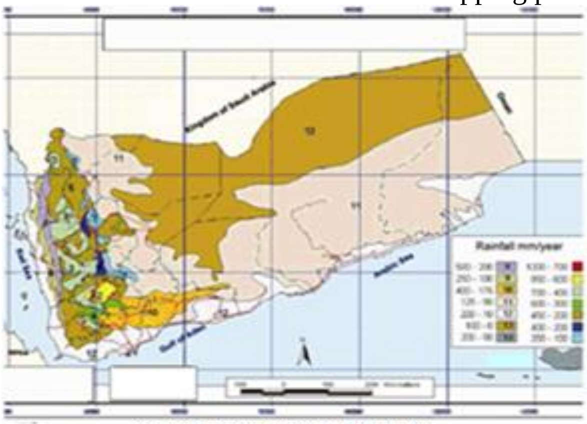

Fig. (1) : Average of Rainfall in Yemen
(Yemen International Information Center)

Only 2.9 % of Yemen is considered to be arable land, and less than 0.3 % of the land is planted with permanent crops. About 4900 km^2 of land are irrigated. According to the United Nations, Yemen has 19550 km of forests and other wood lands, which constitute almost 4 % of the total land area, (Wikipedia, (13).

Limited information are available on the soils of Yemen. Few soil surveys which were conducted previously were not sufficient or adequately correlated in national or international system to serve development needs. They varied in giving details and required complementary studies to respond to an increasing demand for soil resource information.

Ibb city is the capital of Ibb Governorate (the area under study). It is situated on mountain ridge, surrounded by fertile land and is known as "the green City". The region of Ibb has many notable mountains such as Ba'dan, which overlooks most of the city. Ibb Governorate has many famous valleys.

Dar AL- Handasah (2) described the four main stratigraphic units outcrop in the Ibb city. These are from younger to older as follows:

Quaternary deposits are represented by valley alluvium and terraces which unconformable overly the bedrock at the base of main valleys or on the slope terraces of the mountain ranges, respectively . The alluvial deposits are principally composed of gravel, sand boulders, and large detritus of volcanic rocks, while the terraces deposits are composed of loess with calcareous concentrations, alluvial fans, gravel, silt, loamy sands as well as sandy loam texture.

Ibb has a cool continental climate, varied in the mountainous highlands and mild in the central plains, while it is warm in the southern and western regions .it rains over most parts of the province. A summer seasonal rainfall in most districts reaches 800-1200 mm. The soil moisture regime for Ibb Governorate, according to the SOIL SURVEY Staff (9), is Ustic and/or Udic. The soil temperature regime is classified as Iso-thermic (Bruggeman, (1), fig.(2).

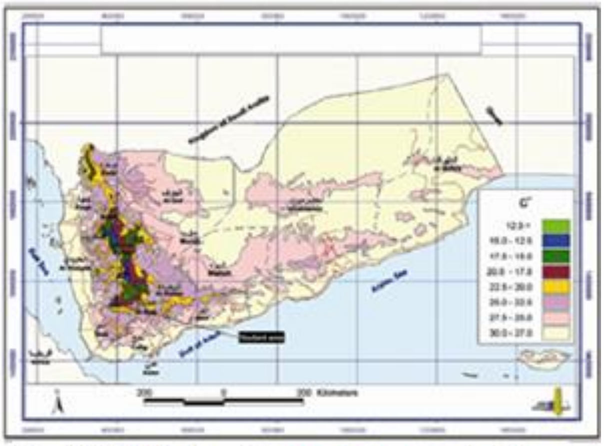

Fig. (2) : Distribution of Average Temperature in Yemen (Yemen International Information Center)

The aim of the current study is to investigate the characteristics and classification of the soils representing the four profile main valley AL-Gabbanah located at directorate Ibb from Yemen. This research could serve as a base management of these soils for sustainable agriculture. Therefore, this study aimes at finding the productivity of the land and its suitability for the growth of some agricultural crops (field crops, vegetable crops and fruits), namely sorghum, potatoes and figs.

Materials and methods:

The studied area is located at Ibb Governorate, Al-Makhader directorate, Yemen Republic, which is about 15 km from Ibb . Al-Gabbanah valley was chosen for the current study around the

Ibb city. The studied area is (about 15 km) bounded between latitude 14 04'40.00 N and longitude 44 10'05.00 E, as shown in Figs. (3) and. (4).

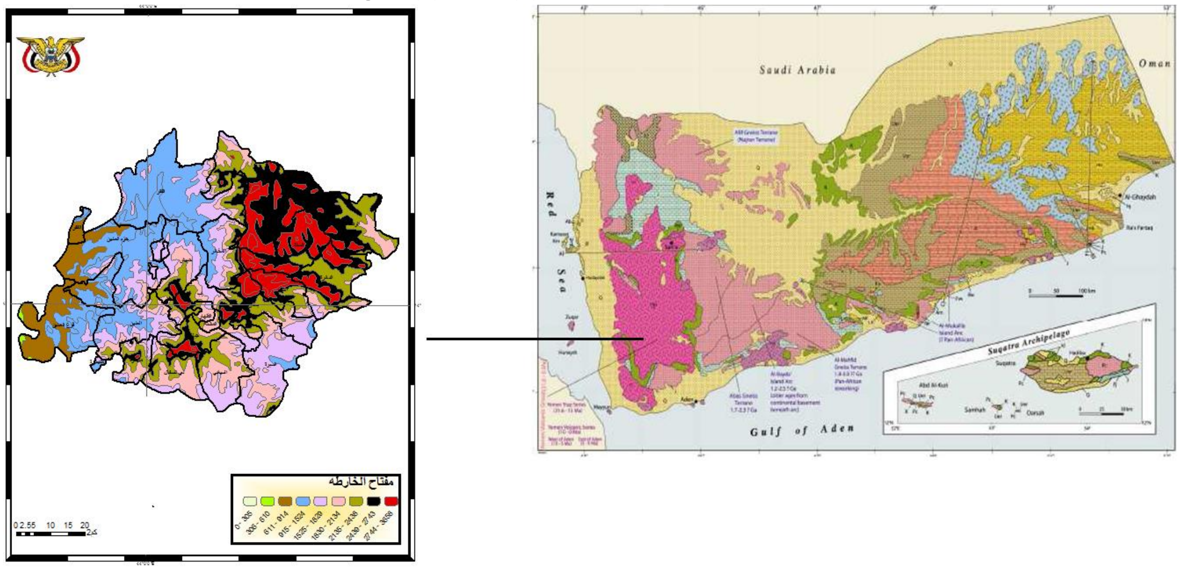

Fig. (3): Yemen and Ibb Governorate topographic map. (Yemen international information center)

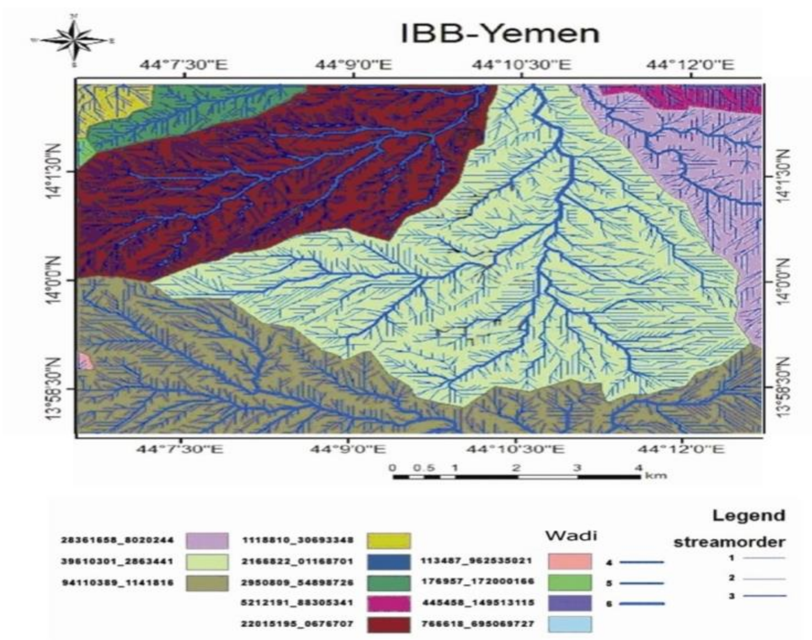

Fig. (4) : Ibb Valley
and Location of the studied profiles .

Geomorphology and soil mapping using GIS

Geomorphologic map was carried out using digital image processing of land Sat7.0 ETM+ image (Path/row 166/50) dated 2012, executed using ENVI software 5.0 (ITT, 2012) .Image was stretched using linear 2 %, smoothly filtered, and their histograms were matched according to

LilleSand and Kiefer (7). Image was atmospherically corrected using FLAASH module (ITT (6). GIS works were performed to produce geomorphologic and soil map for the studied area using Arc GIS software 10.1 (ESRI, (4).

Field Work

Four soil profiles were chosen representing the different valleys and geomorphologic units and morphologically described according to FAO (5). Soils were collected according to the vertical morphological variation and prepared for the different physical and chemical analysis.

Physio-chemical Analyses

Particle size distribution was carried out according to KLUT (3). Electrical conductivity (EC). pH, organic matter (OM), calcium carbonate ($CaCO_3$), gypsum, cation exchange capacity (CEC) and exchangeable Na percentage (ESP), were determined according to Page et al. (8).

Results and discussion

GIS works resulted in valley and stream order as well as geomorphologic figs of Al-Gabbanah valley Fig (4). Also, satellite images interpretation indicated that the investigated area includes three geomorphologic units, i.e. Low over flow valley , high decantation valley and low decantation valley, Fig. (5).

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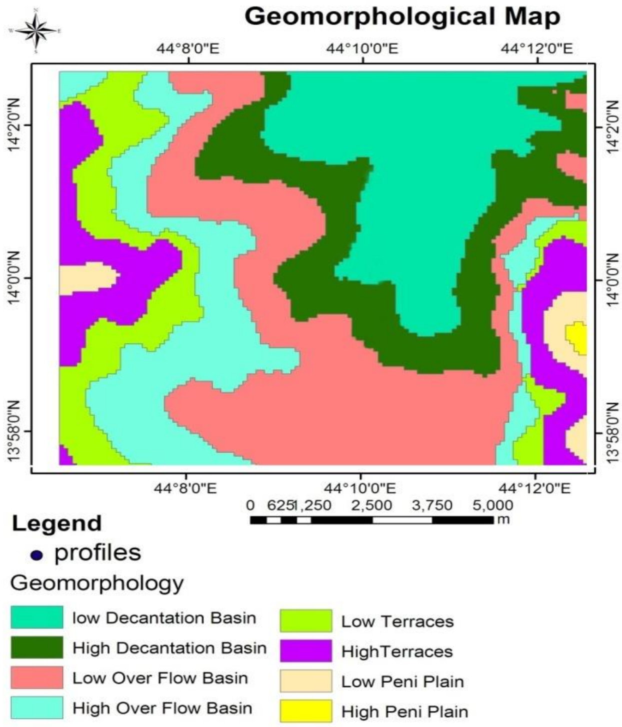

Fig. (5) : Geomorphologic map of the studied area .

Table (1) : Morphological description of the studied soil profiles

Wadi	Profile No.	Elevation m asl	Depth (cm)	Color		Texture	Structure	Consistence	
				Dry	Moist			Dry	Moist
Al-Gabbanah	1	1508	0 – 25	10 YR5/3	3/2	s.g. Sand Loam	2 m sbk	v.hard	Friable
			25-50	10 YR5/3	3/2	s.g. Sandy	1 m gr	s.hard	Friable
			50-70	10 YR5/3	3/2	s.g. Sandy L.	2 m bk	Hard	Firm
			70-85	10 YR5/3	3/2	g. Sandy L.	2 m pk	Hard	Firm
			85-125	10 YR5/3	3/2	g. Sandy L.	2 m pk	Hard	Firm
	2	1484	0-30	10 YR5/3	3/2	g.Sandy L.	2 m sbk	v.hard	Firm
			30-60	10 YR5/3	3/3	g.L.Sandy	2 m sbk	v.hard	Friable
			60-90	10 YR5/3	3/2	s.g. Sandy L.	2 m gr	ex.hard	Firm
			90-130	10 YR4/3	3/2	g.Sandy L.	2 c sbk	ex.hard	Friable
	3	1478	0-25	10 YR4/3	3/2	v.g. Sandy L.	2 m sbk	v.hard	Friable
			25-50	10 YR5/3	3/2	s.g. Loam	2 c gr	s.hard	Friable
			50-70	10 YR5/3	3/2	v.g. Loam	2 m gr	s.hard	v.friable
			70-85	10 YR5/3	3/3	v.g. Clay L.	2 m sbk	Hard	v.friable
			85-100	10 YR5/3	3/2	g. Clay L.	1 m sbk	Hard	v.friable
			100-130	10 YR5/3	3/2	g. Clay L.	1 m sbk	Hard	Friable
	4	1482	0-30	7.5 YR5/3	3/2	g.Sandy L.	2 m bk	Hard	Firm
			30-60	7.5 YR5/3	3/2	g.L. Sand	2 m sbk	Hard	Friable
			60-90	7.5 YR4/3	3/2	s.g. Sandy L.	2 c bk	ex.hard	Firm
			90-130	7.5 YR4/3	3/2	g. Sandy L.	2 m bk	v.hard	Firm

Abbreviations: Texture : s=slightly , g=gravelly , L=loam ; Structure: 1=weak, 2=moderate , f=fine, m=medium, co=coarse , gr=granular, sbk=sub-angular blocky ;Consistence: s=slightly ,v=very , ex= extremely

Table (2): Some physical and chemical properties of studied soil profiles

Wadi	profile No.	Depth (cm)	Gravels (%)	Particle size distribution (%)			Texture Class	pH 1:2.5	EC (dSm)	CEC meq/100g soil	Esp	CaCO (%)	Gypsum (%)	OM (%)
				Sand	Silt	Clay								
Al-Gabaanah	1	0-25	9.20	72.25	23.14	4.61	Sandy L.	8.00	0.50	6.10	5.27	7.51	2.01	1.59
		25-50	6.65	90.79	2.73	6.48	Sand	8.03	0.41	4.30	5.30	7.53	2.24	1.01
		50-70	10.30	78.01	8.50	13.49	Sandy L.	8.31	0.38	9.15	4.25	6.43	2.83	0.59
		70-85	21.50	77.00	11.37	11.63	Sandy L.	8.90	0.49	7.10	4.46	5.95	2.54	0.49
		85-125	11.40	80.86	1.58	17.56	Sandy L.	7.91	0.46	6.16	4.79	6.78	2.41	0.18
		W.P.M	79.11	58.81	9.46	10.75	Sandy L.	--	-	6.56	4.81	6.84	2.41	0.77
	2	0-30	24.00	78.00	03.33	18.67	Sandy L.	8.10	1.40	9.80	12.82	6.04	3.25	1.50
		30-60	18.32	87.17	2.43	10.40	L. Sand	8.16	1.90	5.93	13.21	6.80	1.59	1.49
		60-90	13.01	76.00	12.00	12.00	Sandy L.	8.36	1.20	10.01	14.40	6.42	2.78	0.89
		90-130	23.35	82.67	9.00	8.33	L. Sand	8.11	1.18	6.51	11.25	12.59	2.40	0.38
		W.P.M	67.19	96.80	69.6	35.12	Sandy L.	--	-	8.06	12.92	7.96	2.51	07.1
	3	0-25	44.01	48.90	44.80	6.30	Sandy L.	8.00	0.40	8.55	9.35	5.88	2.15	1.58
		25-50	8.012	51.90	36.80	11.30	Loam	8.01	0.55	16.40	11.50	4.22	2.59	1.00
		50-75	55.92	92.80	2.90	4.30	Loam	8.52	0.60	15.20	14.95	4.82	2.86	0.50
		75-85	61.60	28.70	43.50	27.80	Clay L.	8.30	0.41	17.30	10.20	1.01	4.06	0.36
		85-100	23.65	31.20	31.60	37.20	Clay L.	8.45	2.00	21.70	10.50	1.13	4.89	0.38
		100-125	24.44	32.00	30.10	37.90	Clay L.	8.56	1.95	22.00	11.45	1.19	4.95	0.29
		W.P.M	27.36	47.58	31.62	20.80	Loam	--	-	16.89	11.30	3.04	3.58	54.0
	4	0-30	13.22	78.00	4.00	18.00	Sandy L.	8.06	1.22	11.58	8.93	4.20	1.74	2.50
		30-60	29.00	86.00	6.00	8.00	L. Sand	8.15	1.50	8.30	8.90	5.06	2.09	2.00
		60-90	13.98	66.67	18.00	15.33	Sandy L.	8.36	1.30	12.78	10.22	8.42	2.95	1.01
		90-130	25.00	74.67	14.66	10.67	Sandy L.	7.79	1.76	8.89	9.01	7.80	2.67	0.49
		W.P.M	30.20	76.34	10.66	13.00	Sandy L.	--	-	10.39	9.27	6.37	2.39	50.1

w.p.m = whited profile mean

Land Evaluation:

Evaluating and classifying the soil according to its agricultural productivity is essential to narrow the gap between food production and consumption.

Evaluation of land capability:

Quantitative estimation of soil characteristics, namely slope, soil profile depth, drainage, erosion, texture, $CaCO_3$, gypsum, salinity and sodicity, were used for evaluating land capability index according to Sys *et al.*, (13). The mapping units were placed into grades according to their calculated capability indexes Table. (3).

Table (3): Classification of the soils to grades according to their capability rates according to Storie (10):

Grade	Soils	Rate
I	Excellent soils	100-80%
II	Good soils	79-60%
III	Fair soils	59-40%
IV	Poor soils	39-20%
V	Very poor soils	19-10%
VI	Nonagricultural soils	Less than 10%

Table (4) shows the values that were were used as a guide in rating the studied soils according to Sys et al (11).The ratings of soil characteristics, capability indexes and soil grades calculated for the mapping unites are presented in Table. (5) and Fig. (6).

Table (4): Soil properties rating.

Factor	Soil properties				Rating %
A	Availability and quality of irrigation water				
	Pure irrigation water				100
	Mixed irrigation with drains water 1000 ppm				90
B	Soil Texture				
	L., Si.L., S.C.L., S.L., SiC.L., C.L.				100
	Si.				95-90
	L.S., S.C.				85-80
	F.S., M.S., Si.C., C.				75-60
	C.S.				55-40
		Slight. Gr.	Gravelly	Very gr.	
	L., Si.L., C.L.	80	70	60	
	S.L.	70	60	50	
	L.S.	60	50	40	
	S	50	40	30	
C	Soil profile depth (cm)				
	> 120				100
	120-90				100-90
	90-60				90-70
	60-30				70-40
	< 30				< 40
D	Wetness (drainage conditions)				
	Well drained				100
	Moderately drained				95-85
	Imperfectly drained				85-75
	Poorly drained				75-45
	Very poorly drained				45-25
E	Salinity level (EC dS/m)				
	< 4				100
	4-8				95-85
	8-16				85-45
	> 16				< 45

Table (4): Cont.		
Factor	Soil properties	Rating %
F	Sodicity (ESP)	
	< 10	100
	10-15	95-85
	15-30	95-75
	30-50	75-55
	> 50	< 55
G	Carbonate as CaCO3 content %	
	< 5	100
	5-10	95-90
	10-20	90-75
	20-50	75-40
	> 50	< 40
H	Gypsum ($CaSO_4$-$2H_2O$) content %	
	< 3	95
	3-10	100
	10-15	95
	15-25	75
I	Slope %	
	Flat or Almost flat 0-20%)	100
	Undulating (2-8%)	95-90
	Rolling (8-16%)	90-85
	Hilly (16-30%)	95-70
	Steep (20-45%)	70-35
	Very steep (> 45%)	< 35
J	Erosion	
	Wind erosion :	
	Non	100
	Slightly	95-90
	Moderately	90-75
	Severe	75-20
	Water erosion :	
	Non	100
	Slightly	95-90
	Moderately	90-75
	Severe	75-40
	Very severe	40-10

Table (5): Capability index and soil capability grades for rating of the studied soil profiles

Studied Valley	Profile No.	Slope	Erosion	Irrigation Water	Soil Depth	Drainage	Texture	EC	ESP	CaCo	Gypsum	Capability Index ci	Grade
Al-Gabbanah	1	100	95	100	100	100	60	100	100	95	95	51.44	111
	2	100	95	100	100	100	60	100	95	95	95	48.88	111
	3	100	95	100	100	100	70	100	95	100	100	63.18	11
	4	100	95	100	100	100	60	100	95	95	95	48.87	111

The calculated soil capability index in Table. (5) reveals that the investigated soils can be classified into the following grades, Fig. (6).

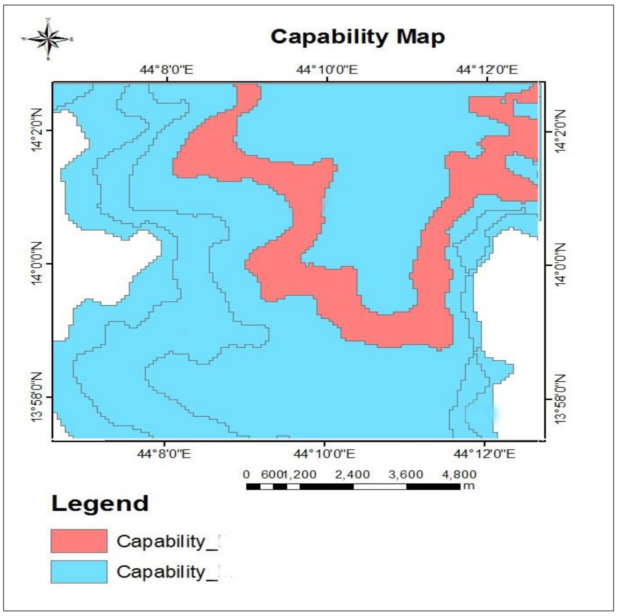

Fig. (6): Capability grades of the mapping units at the studied area .

Conventional methods of land evaluation assume that soil characteristics are homogenous within the land unit and hence it gives a suitability map of discrete value which does not represent the real situation. Therefore, there is a need to develop a method that takes the spatial variability of soil properties into account Fig. (7).

The evaluation of agricultural sustainability status helps in identifying specific indicators that constrain the achievement of sustainable agriculture.

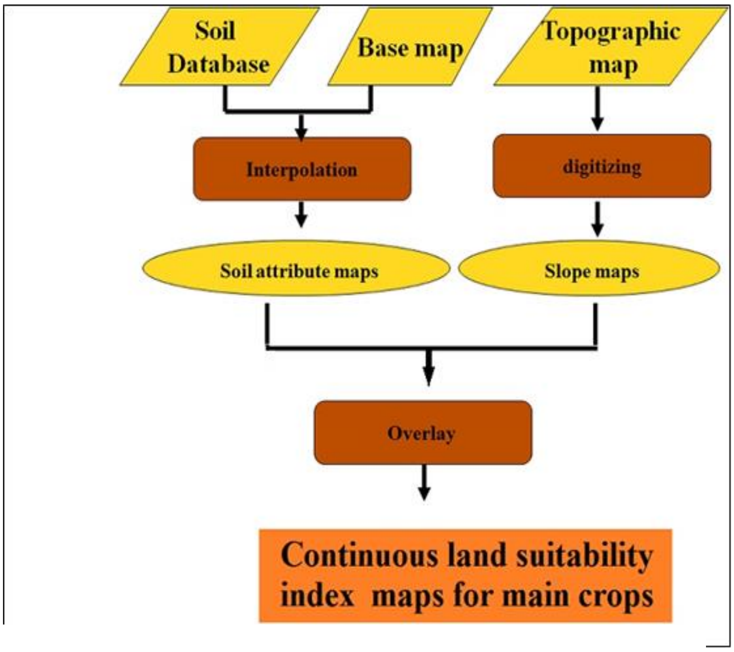

Fig. (7): Chart for the steps of land evaluation.

Land Sustainable Spatial Model (LSSM)

LSSM was built according to ESRI (4) as follows: File geo-database was created. Spatial model for environment settings was specified. A series of values for input criteria was calculated resulting in five datasets. Each derived dataset was reclassified to a common measurement scale, giving each range a discrete and integer value between 1 and 4. Higher values were given to attributes within each dataset that are more suitable for sustainability classes. Conditional expressions were used to get sustainability raster classes. Datasets were weighed through setting equal influence with different scale values. Sustainability raster classes were converted into sustainability polygons in the geo-database and Sustainability layers, then, were created. Four suitability classes were selected by attribute (values). Hence, the final layers that represent sustainability classes (I, II, III and N) were resulted Fig. (8).

Model verification

However, quantitative assessment was executed for SLMSM, it is very important to identify and measure the map errors derived from the model. In this assessments, map data were compared with ground truth data obtained from two sources: 1-from field measurements & observations on farming system level and 2- from laboratory analyses that assumed to be 100% correct. The overall accuracy assessment of thematic maps recorded 98.34%.

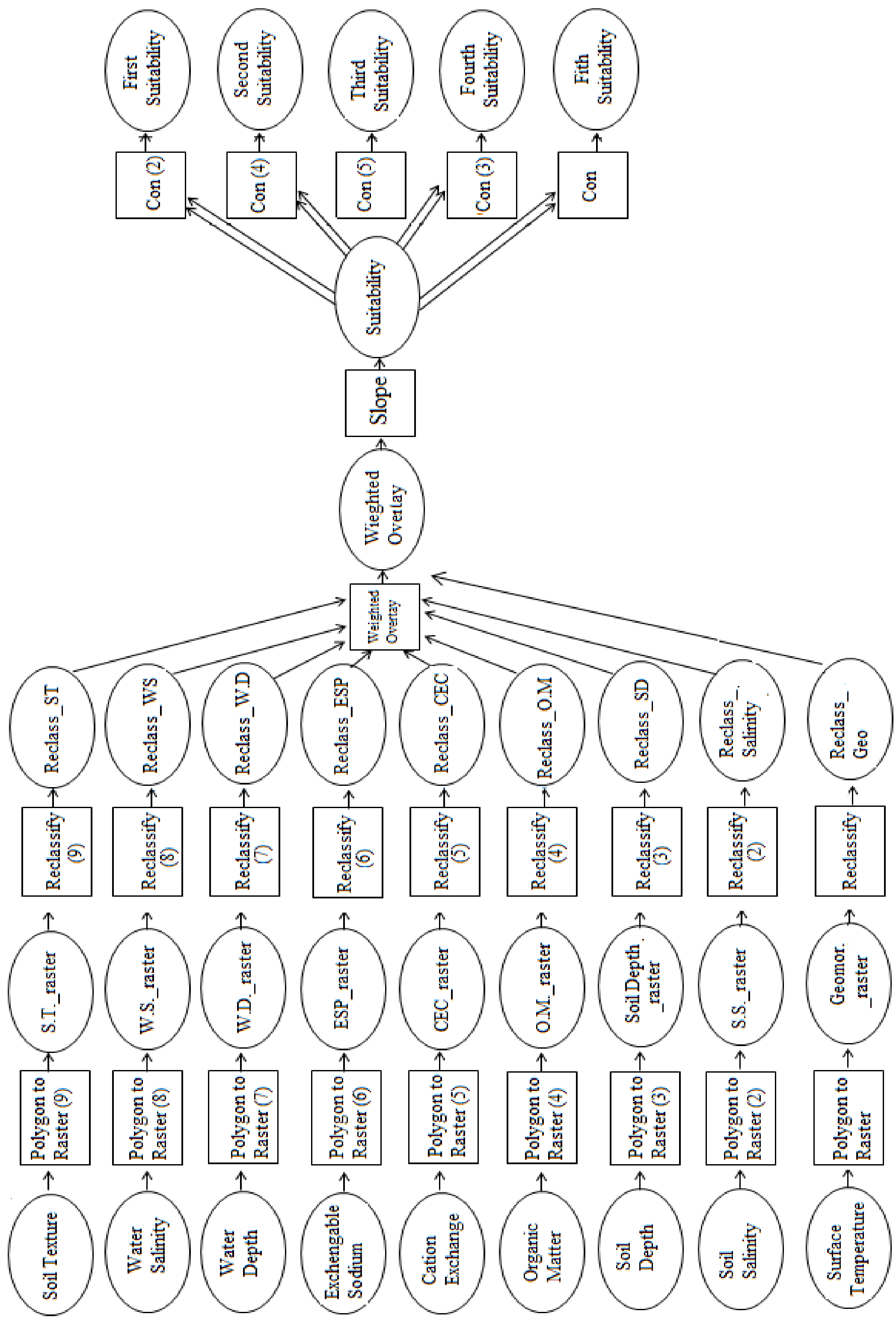

Fig.` (8): Land suitability spatial modeling Chart

-Grade II: (Good). These soils have slight limitations and their rates ranges from 60.0 to 79.000. They include mainly some locations represented by profiles No's 3 with capability index. They have mainly a slight limitation intensity of soil texture, sometimes erosion and both total carbonate and gypsum contents.

- Grade III: (Fair). These soils are affected by moderate limitations and have capability rates between 40.0 and 59.0%. They include some locations represented by soil profiles No's 1, 2 and 4. They have mainly a slight limitation intensity of, sometimes ,erosion, irrigation water and ESP, and both carbonate and gypsum for all soils where profiles belonging to grade III. Also, they have moderate limitation intensity of soil texture.

Evaluation of soil suitability for growing main crops:

Studied soil profiles were evaluated to determine their suitability for growing 15 field crops, vegetable and fruits according to Sys *et al.*, (12). The soil parameters used for estimating suitability index (Si) for the different crops were defined through matching climate condition, slope, soil profile depth, drainage, gravels, texture, $CaCo_3$, gypsum, salinity, alkalinity and soil fertility (PH, CEC and O.M) with crop requirements. Land suitability classes are defined according to the value of the suitability index (Si)Table. (6) suggested by Sys *et al.*, (13) as follow:

Table (6) : Land suitability classes

Symbols	Suitability classes	Soil index (Si)
S1	Suitability classes	100-75
S2	Very suitable	74-50
S3	Moderate suitable	49-25
N	Marginally suitable	<25

Suitability indexes and classes were estimated in the mapping units for the major field crops, vegetable and fruits which are shown in Table. (7) and represented in Figs. (9-11).

Suitability class of Al-Gabbanah Soils:

Data in Table (7) that illustrated in a Figs. (9-11) shows that the soils of this valley represented by profiles No's 1,2,3and 4 are very suitable S_1 and/or moderate suitable (S2) for growing sorghum, potato and figs from field crops. Also, the soils are disparately suitable from S_1 to S for growing vegetable and fruit crops. The suitability classes differ from site to another according to their parameters variations. From vegetables and from fruits at all sites of this valley are unsuitable. Also, it is considered as unsuitable at some sites.

Table (7) : Suitability index (Si) for Al-Gabbanah valey

Studied basin	Prof. No.	Suitability indices for different crops								
		Field crops			Vegetables			Fruits		
		Crop	Si	Class	Crop	Si	Class	Crop	Si	Class
Al-Gabbanah	1	Sorghum	75	S_1	Potato	58	S_2	Fig	58	S_2
	2	Sorghum	68	S_2	Potato	75	S_1	Fig	65	S_2
	3	Sorghum	68	S_2	Potato	62	S_2	Fig	60	S_2
	4	Sorghum	7 9	S_1	Potato	81	S_1	Fig	60	S_2

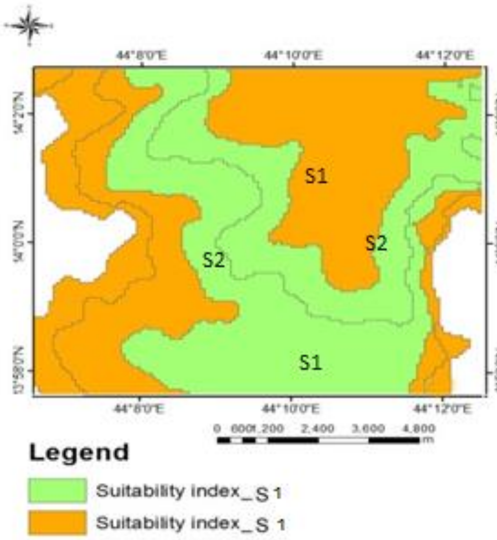

Fig. (9): Suitability classes for Sorghum in the studied area

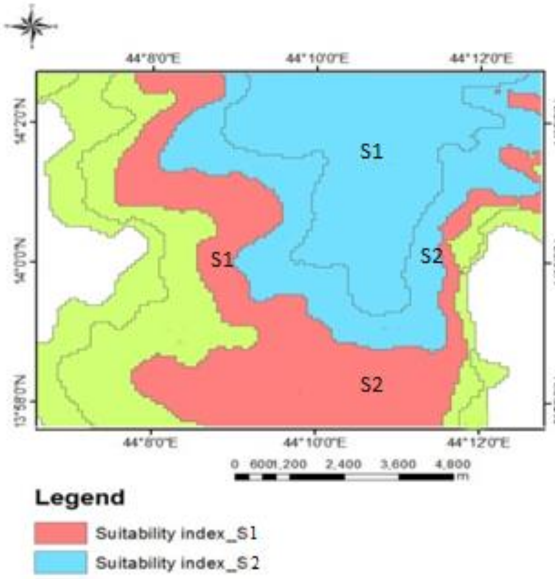

Fig. (10): Suitability classes for Potato in the studied area

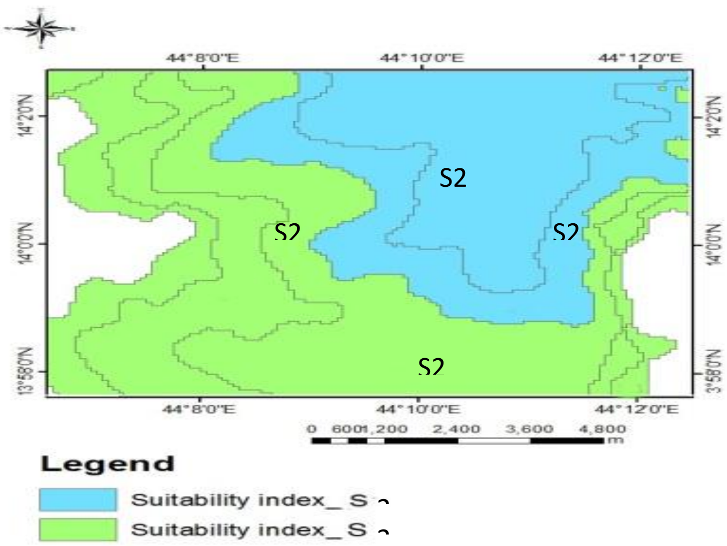

Fig. (11): Suitability classes for fig in the studied

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تقييم قدرة إنتاجية الأرض وملاءمتها لنمو بعض المحاصيل باستخدام موديل LSSM في وادي الجبانة، محافظة إب، اليمن

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الملخص

أجريت هذه الدراسة في وادي الجبانة، محافظة إب، مديرية المخادر، الجمهورية اليمنية، والذي يبعد حوالي 15 كم عن مدينة إب. وهدفت هذه الدراسة لمعرفة قدرة إنتاجية الأرض وملاءمتها لنمو بعض المحاصيل الزراعية (الحقلية، الخضروات والفواكه) وهي الذرة الرفيعة، البطاطس والتين. تم تقييم منطقة الدراسة حسب قدرتها الإنتاجية تبعاً لـ Sys et al.1991 للدرجات الأولى والثانية (S1, S2) واستخدام موديل رقمي خاص لتوضيح ذلك خرائطياً . كما صنفت تلك الأراضي حسب مدى ملاءمتها لزراعة ثلاثة أنواع من المحاصيل والخضر والفاكهة تبعاً Sys et al.1993، واستخدام موديل رقمي خاص لتوضيح ذلك خرائطياً. وقد كانت المحاصيل المدروسة ملائمة للزراعة في وادي الجبانة، كما أوضحت النتائج أن الذرة الرفيعة في القطاعات الأرضية (1،4) ملائمة جداً (S1)، بينما في القطاعات الأرضية (2،3) متوسط الملاءمة (S2)، أما محصول البطاطس فقد بينت النتائج ملاءمته الجيدة (S1) في القطاعات (2،4) ومتوسط الملاءمة في القطاعات (1،3) وبالنسبة لمحصول التين فقد أظهرت النتائج أنه كان متوسط الملاءمة (S2) في جميع القطاعات.

الكلمات المفتاحية: قدرة إنتاجية الأرض، مدى الملاءمة لنمو المحاصيل، الذرة الرفيعة، البطاطس، التين، مديريات إب، اليمن.