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A review on soil-site suitability evaluation for vegetable crops

Archana Sharma and JC Sharma

Abstract
Land evaluation procedure given by FAO for soil site suitability for various land utilization type has been used to access the land suitability for various vegetable crops. Soil suitability evaluation analysis allows identifying the limiting factor for production of vegetable crops and enables decision makers to develop crop management and able to increase land productivity. The results of earlier study showed that land evaluation is the process of predicting the use potential of land on the basis of its attributes. The results of earlier findings are intended to be used for land resource related decision making, both strategic land use planning by the direct land users, that is, the farmers.

Keywords: suitability, evaluation, vegetable crops, FAO

Introduction
India is blessed with diverse agro-climatic zone with distinct season due to which we are able to grow wide range of vegetable. Vegetables are a good source of nutrient, dietary fibre, phytochemical and vitamins. Instead of providing health benefits it provides fodder for animal. India is the second largest producer of vegetables next to China in the world. In India it is grown on an area of 9.575 million hectares with productivity of 17.7 mt/ha which contributes 14 % of the world population of vegetables. Among various states in India, West Bengal, Bihar, Uttar Pradesh, Madhya Pradesh, Odisha, Gujrat and Karnataka are the major vegetable producing states. During 2016-17 (2nd Adv Est), the area under vegetables is estimated at 10.3 million hectares with a production of 175 million tonnes in India. Per capita availability of vegetables in India id 357g/person/day, which helps in fighting malnutrition. India is an agricultural and populous country. About 70 per cent of people depend on agriculture. In order to grow food-crops and agricultural products in large quantities to feed the growing millions, intensive farming and rotation of crops are essential. Agriculture is one of the world's most important activities supporting human life. From the beginning of the civilization man has used the land resources to satisfy his needs. The land resources regeneration is very slow while the population growth is very fast, leading to an unbalance. On a global scale, agriculture has the proven potential to increase food supplies faster than the growth of the population (Davidson, 1992) [1]. Lack of wise and suitable agricultural practices results the degradation of natural habitats, ecosystems and agricultural lands round the globe. Therefore concept of land suitability evaluation was evolved. Soil suitability evaluation is carried out to estimate the fitness of land for a specific use, such as arable farming or irrigated agriculture. OR Assessment of land performance and its production potential. The principle purpose of agriculture land suitability evaluation is to predict the potential and limitation of land for crop production (Pan and Pan, 2012) [6]. It is essential to select crops for cultivation according to the soil suitability, so that maximum profit may be achieved while maintaining the ecological sustainability.

Methodology
The land suitability evaluation carried out by various workers according to the guidelines of FAO. This guideline has procedures to evaluate the suitability of the land for intended land use. Evaluation of land suitability is the most central part of land evaluation.

Diagnostic criteria for land evaluation
The land qualities such as moisture capacity, fertility or climatic parameters.

The process of evaluation for land suitability involves

1) Defining the land utilization type

A Land Utilization Type (LUT) is a use of land defined in terms of a product, or products, the inputs and operations required to produce these products, and the socio-economic setting in which production is carried out. (FAO, 1976). Attributes of land utilization types include data or assumptions on:

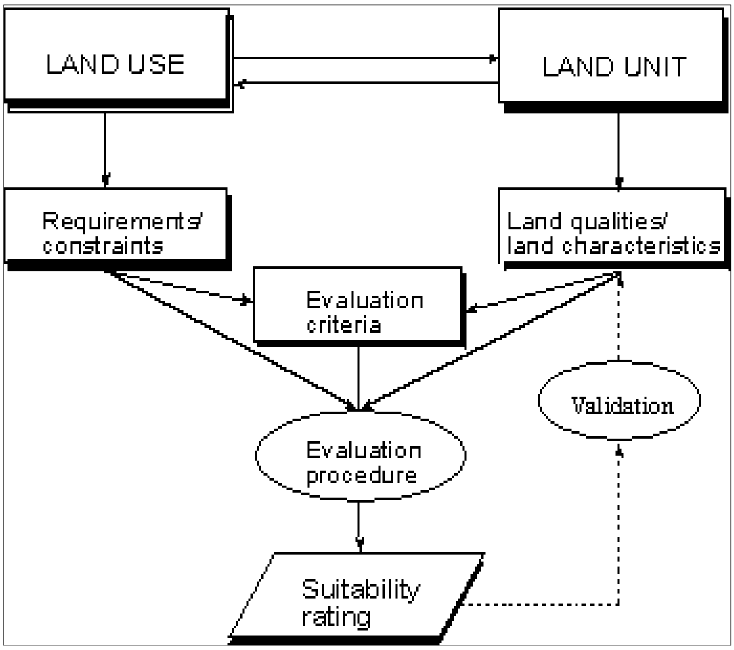
- Produce, including goods (e.g. crops, livestock timber), cervices (e.g. recreational facilities) or other benefits (e.g. wildlife conservation)
- Market orientation, including whether towards subsistence or commercial production
- Capital intensity
- Labour intensity
- Power sources (e.g. man's labour, draught animals machinery using fuels)
- Technical knowledge and attitudes of land users
- Technology employed (e.g. implements and machinery, fertilizers, livestock breeds, farm transport, methods of timber felling)
- Infrastructure requirements (e.g. sawmills, tat factories, agricultural advisory services)
- Size and configuration of land holdings, including whether consolidated or fragmented
- Land tenure, the legal or customary manner in which rights to land are held, by individuals or groups
- Income levels, expressed per capita, per unit of production (e.g. farm) or per unit area.

2) Defining the land use requirement

Land-use requirements are described by the land qualities needed for sustained production. A land quality is a complex attribute of land that has a direct effect on land use. Examples are the availability of water and nutrients, rooting conditions and erosion hazard. Most land qualities are determined by the interaction of several land characteristics, measurable attributes of the land. For example, the quality "availability of water" is determined by the balance between water demand and water supply. The demand is the potential evaporation from the surface of the crop and the soil; the supply is determined by rainfall, infiltration, storage of water in the soil and the ability of the crop to extract the stored water.

3) Matching land qualities with land use requirement

Compare land-use requirements with land qualities or characteristics to determine provisional land suitability classes, consider modifications to land-use types, in order that they become better suited to the land, consider land improvements that could make the land better suited to the land use.



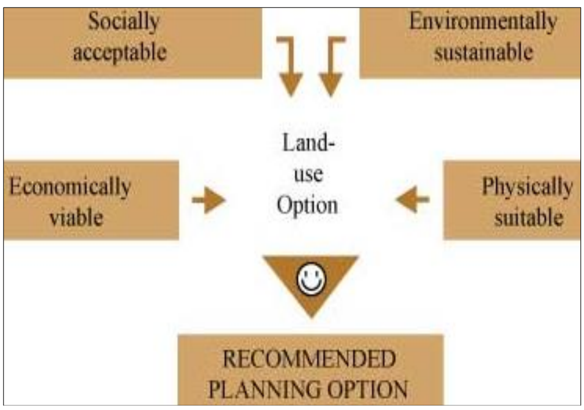
Structure of the Soil Suitability Classification

FAO panel for land evaluation (1976) defined the concept of land utilization types and suggested classification. There are four categories or levels of classification

i. **Soil suitability order:** Reflects kind of suitability
ii. **Soil suitability classes:** Reflects degree of suitability within orders
iii. **Soil suitability subclasses:** Reflects kind of limitation
iv. **Soil suitability unit:** Reflects minor differences in required management within subclasses

Appraisal of sustainability factors of land use option

Production could be met through systematic survey of the soils, evaluating their potentials for a wide range of land use options and formulating land use plans which were economically viable, socially acceptable and environmentally sound (Sathish and Niranjana, 2010).



Land evaluation consist of physical and socio-economic evaluation. Physical land evaluation involves interpretation of data concerning the physical environment and past and present land use in term of its resource potential. It is thus concerned with seeking solution problem such as possible long term degradation of land qualities as a result of current use, viability of alternate land uses, and extent to which management of existing land uses can be improved and impact of inputs on productivity and land quality.
Social impact the active participation of all stakeholders and their representatives in formulation of land use objective and a continued dialogue through procedure of land resource evaluation should ensure that proposed land use are socially accepted.

Environmentally sustainable: Sustainable land use is that which meet the needs of present while a same time conserving resources for future use or generation. This require both production and conservation.

Economically viable: Financial analysis look at profitability from point of view of farmer and other private investors by comparing producer revenue with their cost. Farmer will not practices a land use option unless from their point of view it pays.

1. Land suitability orders
There are two orders(S and N) which reflect the kind of suitability (S for suitable and N for unsuitable land).

Order "S" -Suitable land
Land on which sustained use of the kind under consideration is expected to yield benefits which justify the inputs, without unacceptable risk of damage to land resources.

Order "N"-Unsuitable land
Land having characteristics which appear to preclude its sustained use for the defined purpose in the defined manner or which would create production, upkeep and/or conservation problems requiring a level of recurrent inputs unacceptable at the time of interpretation.

Land may be classed as Not Suitable for a given use for a number of reasons. It may be that

- The proposed use is technically impracticable, such as the irrigation of rocky steep land.
- Due to severe environmental degradation, such as the cultivation of steep slopes.
- The another reason may be economic: that the value of the expected benefits does not justify the expected costs of the inputs that would be required.

2. Land Suitability Classes
There are 3 classes under order suitable(S) and 2 classes under order unsuitable (N).

Order S (suitable)

- ✓ Class S1 Highly Suitable
- ✓ Class S2 Moderately Suitable
- ✓ Class S3 Marginally Suitable

Order N (not suitable)

- ✓ Class N1 Currently Not Suitable
- ✓ Class N2 Permanently Not Suitable

Class S1 Highly Suitable
Land having no significant limitations, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level. It is shown by dark green color on map.

Class S2 Moderately
Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land. It is shown by yellow color on map.

Class S3 Marginally Suitable
Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified. It is shown by dark brown color on the map.

Class N1 Currently Not Suitable
Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner. It is shown by red color on map.

Class N2 Permanently Not Suitable
Land having limitations which appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner. It is shown by violet color on map.

3. Land suitability subclasses
Reflects the kind of limitations or the main kind of improvement measures required within a class.
The following Subclasses have been defined
C: climate limitation
T: topography limitation
W: wetness limitation
N: salinity limitation
F: soil fertility limitation
S: physical soil limitation (influencing soil/water relationship and management.

4. Land suitability units
This grouping is used to identify land development units having minor differences in management requirements. This can indicate the relative importance of land development works. It is indicated by Arabic numerals, enclosed in parenthesis, following the subclass symbol.

Example of total unit
The whole unit is indicated by a symbol; for example: S2w (2). Here "S" represents Order (Suitable); the number 2 after the letter S represents Class 2(moderately suitable); "w" represents Subclass w (wetness limitation); and (2) represents Unit 2.
Sys and Verheye (1975) [3] proposed the following capability index (Ci) based on nine parameters for crop production in the arid and semi-arid regions.

Ci =A.B.C.D.E.F.G.H.I.

Where, A = rating for soil texture (Taken as 100 for best texture, say loam)
B = rating for calcium carbonate
C = rating for gypsum
D = rating for salinity
E = rating for sodium saturation
F = rating for drainage
G = rating for soil depth
H = rating for epipedon and weathering stage
I = rating for profile development
B to I taken as a fraction of one (1).

Degree of limitation and Suitability class
Sys (1976) proposed the following scheme for evaluating the degree of limitation ranging from 0(suggesting no limitation and having Ci of 80 or more) to 4(suggesting very severe limitation with Ci of 30 or less.

Degree of Limitation	Suitabillity Class	Capability Index (Ci)	Equivalent Order and Class
0	Suitable	>80	S1
1	Moderately suitable	60–80	S2
2	Marginally suitable	45–60	S3
3	Not suitable (but potentially suitable)	30–45	N1
4	Not suitable (presently and potentially)	<30	N2

No limitation (0): The characteristics (quality) are optimal for plant growth (Ci 80 or more).

Slight limitation (1): The characteristics are nearly optimal for the land utilization type and Limitation affect productivity for not more than 20 per cent with regard to optimal Yield (Ci 60 to 80).

Moderate limitation (2): The characteristics have moderate influence on crop yield decline; Limitation however, benefits can still be made and the yield remain economical. (Ci 45 to 60).

Severe limitation (3): This adversely affect crop productivity and become uneconomical. (Ci 30-45).

Very severe limitation (4): Such limitations will not only decrease the yields below the Limitation profitable level, but may inhibit the use of the soil for the considered land utilization (Ci less than 30).

Criteria for determining suitability class based on kind, degree and number of limitations
S1: Limitation of 1 (upto 3 limitation)
S2: Limitation of 1 and/or of 2 (upto 3 correctable, or upto 1uncorrectable limit)
S3: Limitation of 2 and/or of 3 (upto 3 correctable or upto 1 uncorrectable limit)
N1: Limitation of 3 and/or of 4 (upto 3 correctable or upto 1 uncorrectable limit)
N2: Limitation of 4 (more than 3 correctable, or 2 uncorrectable limit)

Limitation levels of land characteristics and land suitability classes for vegetables

Soil	Wetness (w)	Soil physical characteristics (s)		Soil fertility characteristics (f)			Salinity/ Alkalinity (n)		suitability class
	Drainage	Texture	Calcium carbonate	Bs (%)	pH (1:2.5)	OC (g/kg)	EC (dS/m)	ESP	
Typic Haplustalfs	1	0	0	0	1	1	0	0	S1w
Typic Ustifluvents	1	0	0	0	1	1	0	0	S1w
Typic Ustorthents	0	1	0	1	1	1	0	0	S2f
Typic Haplustepts	0	1	0	0	2	1	0	0	S2s,f
Typic Haplustepts	0	1	1	0	0	1	0	0	S1s
Typic Haplustepts	2	1	1	0	2	1	0	0	S2s
Typic Ustipsamments	0	1	0	1	0	0	0	0	S1

***Source*:** Selvaraj and Naidu (2012) [10]

The soil site suitability evaluation study revealed that the major limitations of area were texture, base saturation, pH and organic carbon. The coarser texture can be improved by mixing the soil with tank silt whereas the fine texture can be improved by addition of organic matter. The soil fertility properties such as base saturation, pH and organic carbon can be improved by addition of organic matter through farm yard manure or compost or green manuring. Hence, judicious use of organic manures in combination with inorganic fertilizers in these soils not only paves the to achieve sustainable yield of crops but also sustains the soil fertility.

	Joshi and Singh (1975)	Muthu and Krishnan et al. (2002)	Hosmani (1982)	Bose et al. (2002)	Kaliappan and Raja Gopal (1970)
Rainfall	75-100 cm	Excessive rainfall rainfall cause defoliation			
Temperature			Optimum temperature of > 10°C to 20-35°C		
Soil				Fairly light fertile	
Drainage				Well drained	
Texture				Loam	
pH			pH 5 to 9	pH 6 to 7	7.6
EC					0.2

Soil suitability evaluation for chilli
(***Source*:** Naidu *et al.*, 2006) [3]

Several researchers studied the soil and climatic requirements of Chilli crop and showed that high temperature during summer accelerates flower and fruit drop. Rains in November result in the incidence of powdery mildew, which cause defoliation. The germination of Chilli crop is found satisfactory in soils with pH <7.6 and EC <0.2. Both highly acidic and alkaline soils are not suitable. Well drained, black soils are suitable for growing rainfed crop.

Soil-site suitability criteria for chillies

Soil-site characteristics			Rating			
		Unit	Highly suitable S1	Moderately suitable S2	Marginally suitable S3	Not suitable N
Climatic regime	Mean temperature in growing season	°C	25-32	33-35 20-24	36-38 <20	>38
	Total rainfall	mm	750-900	900-1200	500-600 >1200	-
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	>150	120-150	90-120	<90
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately to imperfectly drained	Poorly drained/ Excessively	Very poorly drained
Nutrient availability	Texture	Class	l, scl, cl, sil	sl, sc, sic, c(m/K)	c(ss), ls, s	
	pH	1:2.5	6-7	7.1-8.0	8.1-9.0, 5.0-5.9	>9
	OC	%	>0.75	0.5-0.75	<0.5	
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Coarse fragments	Vol %	<15	>15-35	>35	
Soil toxicity	Salinity (EC saturation extract)	dS/m	Non saline	1-2	2-4	<4
	Sodicity (ESP)	%	Non sodic	5-10	10-15	
Erosion hazard	Slope	%	<3	3-5	5-10	

Mineralogy: C(mIk.) = Clayey (mixed/ kaolinitic); C(ss) = Shrink- swell clay

Soil-site suitability criteria for potato

Soil-site characteristics			Rating			
		Unit	Highly suitable S1	Moderately suitable S2	Marginally suitable S3	Not suitable N
Climatic regime	Mean temperature in growing season	°C	16-25	26-30 13-15	31-32 10-12	>32 <10
Land quality	Land characteristics					
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately/ Imperfectly	Poorly drained	Very poorly drained
Nutrient availability	Texture- surface	Class	sl, l, ls	s, scl	sil, cl	Heavy c
	Sub-surface texture	class	scl, sil	s, sil	s	Heavy c
	pH	1:2.5	5.5-6.5	6.6-8.2 5.0-5.4	>8.2 <5.0	
	CEC	C mol (p+)/kg	>16	<16	<5	
	OC	%	High	Medium	Low	
Rooting conditions	Effective soil depth	cm	75-100	50-75	25-50	<25
	Stonnines	%	0-10	10-15	15-35	>35
Soil toxicity	Salinity (EC saturation extract)	dS/m	>16	<16		
	Sodicity (ESP)	%	Non Sodic	10-15	>15	
Erosion hazard	Slope	Hills %	<5	5-10	10-15	>15
		Plains %	<3	3-5	5-8	>8

Source: Reddy and Shivaprasad (1999)

Soil site criteria for cluster bean

Soil-site characteristics			Rating			
		Unit	Highly suitable S1	Moderately suitable S2	Marginally suitable S3	Not suitable N
Climatic regime	Mean temperature in growing season	°C	24-33	22-23 34-35	20-21 36-40	<20 >40
	Total rainfall	mm	750-1000	500-750	250-500	<250
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	>110	90-110	60-90	<60
Oxygen availability to roots	Soil drainage	Class	Well drained/ mod. Well drained	Imperfectly drained	Poorly drained	V.Poorly
Nutrient availability	Texture	Class	sl, l, scl, cl, sc	sic, sicl c, ls	Heavy clays (ss), s	-
	pH	1:2.5	6.0 -8.0	8.1-8.5 5.5-5.9	8.6-9.5 4.0-5.4	>9.5 <4.0
	$CaCO_3$ in root zone	%	<15	15-25	25-30	>30
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
Soil toxicity	Salinity (EC saturation extract)	dS/m	<1.0	1.0-2.0	2.0-4.0	>4
	Sodicity (ESP)	%	<10	10-15	15-20	>20
Erosion hazard	Slope	%	<5	5-10	10-15	>15

Source: Natarajan et al. (2002)

Soil site criteria for Field pea

Soil-site characteristics			Rating			
		Unit	Highly suitable S1	Moderately suitable S2	Marginally suitable S3	Not suitable N
Climatic regime	Mean temperature in growing season	°C	20-35	18-19 36-40	15-17 41-45	<15 >45
	Total rainfall	mm	750-900	600-750	500-600	<500
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	>120	90-120	70-90	<70
Oxygen availability to roots	Soil drainage	Class	Well drained/ Moderately well drained	Imperfectly drained	Poorly drained	Very poorly drained
Nutrient availability	Texture	Class	l, sl, scl, cl, sc	ls, sic, sicl c,ls	Heavy clays (>60%)	-
	pH	1:2.5	6.0-8.5	8.5-9.0 5.5-5.9	9.1-9.5 5.0-5.4	>9.5 <5.0
	$CaCO_3$ in root zone	%	<15	15-25	25-30	>30
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<24
Soil toxicity	Salinity (EC saturation extract)	dS/m	<1.0	1.0-2.0	2.0-4.0	>4
	Sodicity (ESP)	%	<10	10-15	15-20	>20
Erosion hazard	Slope	%	<5	5-10	10-15	>15

Soil site suitability for Pea

Soil site characteristics		Degree of limitation				
		0(None)	1(Slight)	2(Moderate)	3(Severe)	4(Very severe)
Rainfall (mm)		>1000	750-1000	500-750	<500	
Temp. (°C) during growing period		10 to 18	18-22	22-26	26-29	>29
Slope (%) -Plain irrigated		<1	1 to 3	3 to 5	5 to 10	>10
-Hilly unirrigated		<3	3 to 8	8 to 15	15-25	
Drainage		Well	Moderately well	Imperfect	Poor	Very poor
Flood hazards		Nil	Slight	Moderate	Severe	Very severe
Erosion		None	Slight	Moderate	Severe	Very severe
Soil depth (cm)		>80	50-80	30-50	15-30	<15
Soil texture		sil,l,sicl,fsl,cl	scl,sc,sl	sic,c,ls	fs	s
Surface stoniness (%)		<3	3 to 15	15-40	>40	
Relief		Normal	Flat	Concave	Concave	
NPK rating		HHH	MMM	MLL	LLL	
pH		5.8-6.5	6.5-7.0	7-7.5	>7.5	
Base saturation (%)		>70	50-70	35-50	<35	

(***Source*:** Sharma and Chaudhary, 2008) [11]

Soil site suitability for Tomato

Soil site characteristics	Degree of limitation				
	0(None)	1(Slight)	2(Moderate)	3(Severe)	4(Very severe)
Rainfall (mm)	>1000	750-1000	500-750	<500	
Temp. (°C) during growing period	18.5-26	26-30	30-33	33-40	>40
Slope (%) -Plain irrigated	<1	1 to 3	3 to 5	5 to 10	>10
-Hilly unirrigated	<3	3 to 8	8 to 15	15-25	
Drainage	well	Moderately well	Imperfect	Poor	Very poor
Flood hazards	Nil	Slight	Moderate	Severe	Very severe
Erosion	None	Slight	Moderate	Severe	Very severe
Soil depth (cm)	>100	80-100	50-80	30-50	<30
Soil texture	sil,l,sicl,fsl,cl	scl,sc,sl	sic,c,ls	fs	s
Surface stoniness (%)	<3	3 to 15	15-40	>40	
Relief	Normal	Flat	Concave	Concave	
NPK rating	HHH	MMM	MLL	LLL	
pH	5.5-6.5	6.5-7.5	7.5-8.0	>8	
Base saturation (%)	>70	50-70	35-50	<35	

(***Source*:** Sharma and Chaudhary, 2008) [11]

Soil site suitability criteria for cabbage

Land quality/soil-site characteristics		Unit	Suitability rating			
			S1φ	S2§	S3Φ	Nq
Climate (c)	Mean temperature in growing season	°C	25-28	29-32 / 20-24	33-36 / 15-19	<15 / >36
Climate (c)	Total rainfall	mm	600-750	500-600 / 750-1000	450-500 / >1000	
Climate (c)	Rainfall in growing season	mm	>150	120-150	90-120	
Climate (c)	Length of growing season	Days	>150	120-150	90-120	
Topography (t)	Slope	%	1-3	3-5	5-10	>10
Wetness (w)	Soil drainage	Class	Well drained	Moderate	Imperfect	Poor
Soil physical properties (s)	Texture	Class	sl, l, cl, scl, sil	ls, sicl, sic, sc, c(m/k)	c(ss)	S
Soil physical properties (s)	Coarse fragments	vol (%)	<15	15-35	>35	
Soil physical properties (s)	Effective soil depth	cm	>75	50-75	25-50	<25
Fertility (f)	pH	1-2.5	6.0-7.5	5.0-5.9; 7.6-8.5	<5 / >8.5	
Fertility (f)	CEC	cmol(p+)/kg	>15	10-15	<10	
Fertility (f)	$CaCO_3$ in root zone	%	Non-calcareous	Slightly calcareous	Strongly calcareous	
Soil toxicity (n)	Salinity (EC saturation extract)	dS m^{-1}	Non-saline	Slightly saline	Strongly saline	
Soil toxicity (n)	Sodicity (ESP)	%	Non-sodic	Slightly sodic	Strongly sodic	

φ = Highly suitable (IP = 100-75%), Moderately suitable (IP = 74-50%); Φ = Marginally suitable (IP = 49-25); q = Not suitable (24-0%).

(***Source*:** NBSS & LUP, 1994) [5]

Conclusion

Soil suitability studies provide information on the choice of crop to be grown on best suited soil unit for maximizing crop production per unit of land, labour and input.

The evaluation process, provides information on the major constraints and opportunities for the use of land for particular use types which will guide decision makers on how resources are optimally utilized.

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