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A Computerised Approach for Physical Suitability Evaluation of Lands of Singhik Sub-Watershed, Sikkim

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Abstract : *Physical suitability evaluation of lands at project level was attempted in this study using ALES software. A 'knowledge base' describing the proposed land uses in terms of physical requirement and a 'database' describing the land characteristics of the mapping units were interacted in the ALES framework to infer the physical suitability of lands of Singhik sub-watershed. It revealed that the physical suitability sub- classes of the mapping units for different land utilization types ranged from highly suitable to marginally suitable with limitations due to nutrient retention capacity, water availability and rooting condition. Citrus plantation was found to be most suitable followed by maize and paddy cultivation on those lands.*

Land evaluation, the process of assessment of land performance used for specified purposes (FAO 1976), is an exercise to match the land areas, termed as 'Land units' (LU) with land use, termed as 'land utilization types' (LUT) for determining the relative suitability of each area for each use. Of the two kinds of suitabilities, the 'physical suitability' expresses the degree to which the sustained implementation of the LUT on a certain land unit is feasible without unacceptable risk to the ecosystem. The 'economic suitability' is based on the calculation of economic returns which may be expected if the LUT in question is implemented on the land (Rossiter and Van Wambeke 1989 a,b). FAO's framework provides guidelines for both physical and economic evaluations. However, this procedure involves many repetitive calculations, construction, comparisons and matching of tables which are tedious, time consuming and error prone. Hence, there was a need to have an automated system. Wood and Dent (1983) and Purnell (1987) developed automated systems for land evaluation, but there were certain limitations for universal application. These limitations were overcome by introducing 'Automated Land Evaluation System' (ALES), (Rossiter & Wambeke 1989b), a computerised realisation of the FAO methodology for ascertaining the physical and economic suitability of lands for different LUTs.

An attempt has been made in this study to

TABLE 1. Description of soils of the Singhik area

Soil series/ classification	Mapping unit	Brief description	Area (ha)
Very steep to steep upper hill slopes			
Rimick (RM) Typic Udorthent		Very deep, well drained dark grey to dark greyish brown, loam to clay loam on 25-50% slopes, severely eroded.	
	RMhG3	Same as above with clay loam surface on 25-33% slopes, severaly eroded.	9.57 (1.8)*
	RMhH3	Same as above with clay lqam surface on 33-50% slopes, severely eroded.	32.25 (6.0)
	RMiH3	Same as above with sandy clay loam surface on 33-50% slopes, severely eroded.	3.76 (0.7)
Moderately steep to steep hill slopes			
Ringi (R) Umbric Dystrochrept		Moderately deep, mod. well drained, yellow to yellowish brown, sandy loam to clay on 10-50% mid hill slopes, moderately to severely eroded.	
	ReH3	Same as above with sandy loam surface on 33-50% slopes, severely eroded.	10.41 (1.9)
	RhG2	Same as above with clay loam surface on 25-33% slopes, moderately eroded.	41.97 (7.8)
	RiF2	Same as above with sandy clay loam surface on 15-20% slopes, moderately eroded.	46.54 (8.7)
Moderately steep hill slopes			
Singhik (s) Umbric Dystrochrept		Deep, mod. well drained, very dark greyish brown, sandy clay loam on 15-50% slopes, moderately to severely eroded.	
	SiF2	Same as above with sandy clay loam surface on 15-25% slopes, moderately eroded.	4.07 (1.6)
	SiH3	Same as above with sandy clay loam surface on 33-50% slopes, severely eroded.	4.07 (0.8)

(* Percentage of total area)

evaluate the physical suitability of land units of the Singhik sub-watershed of Sikkim for different LUTs using ALES software.

MATERIALS AND METHODS

The soil data needed for building the 'model' for evaluation were obtained from the detailed soil survey report of the water-1 shed (NBSS&LUP 1991). The area was surveyed by following the procedure outlined in the Soil Survey Manual (AIS&LUS 1970) using 16" = 1 mile (1:3960) scale cadastral map, and final map was prepared at phase level on 8" = 1 mile (1:7920) scale. The description of the mapping units, their occurrence and extent are given in Table 1. The land use requirements for different LUTs were worked out based on the approach of Dent and Young (1981). The physical suitability evaluation of the land units for four proposed LUTs was done using an IBM personal computer.

Watershed Characteristics and Soils: The surveyed area is located between 27°33'15" to 27°36'15" N latitudes and 88°35' to 88°37'15" E longitudes covering about 460 ha. The general physiography is highly sloping (15 to 50% slope). The elevation ranges from 1150 to 1400 m above MSL. The annual rainfall is about 3250 mm of which major portion is received during May to August. The mean annual maximum and minimum air temperatures are 19.9°C and 11.4°C, respectively. The terraced area is cultivated to paddy, maize, vegetables and horticultural crops. The unterraced area is partly under cardamom cultivation and partly under forest.

Model Building: Building 'model' is the most essential component of ALES. A preliminary version of it, is built by selecting a few LUTs, expressing them in terms of their most important land use requirements (LURs), determining the basis of evaluation by choosing the land characteristics (LCs), and constructing decision procedures to relate these two. After the preliminary model is built, the data pertaining to the LCs are entered into the ALES-database and the evaluation results are computed.

Four LUTs considered for evaluation in this study are (i) rainfed paddy cultivation (ii) maize cultivation (iii) maize (ear-corn) and paddy cultivation and (iv) citrus (mandarin) plantation on terraced hill slope under rainfed condition.

The LURs alongwith their diagnostic LCs are listed below:

LURs	LCs
Nutrient availability (na)	pH
Nutrient availability-nitrogen (nan)	Av-N
Nutrient availability-potassium (nak)	Av-K
Nutrient availability-phosphorous(nap)	Av-P
Nutrient retention capacity (nrc)	CEC, base saturation
Oxygen requirement (ox)	Drainage class
Rooting condition (rc)	Soil depth,coarse fragment

Soil workability (sw)	Consistency, coarse fragment, structural grade
Water availability (wa)	Permeability, texture

The LCs data of different land mapping units used are shown in table 2.

In physical land evaluation the 'expert knowledge' to be entered in the ALES is a set of severity levels of limitations of the land qualities (LQs) imposed on the performance of the LUTs. These severity levels are the consequences of interactions between land characteristics that create unfavourable condition for the LUTs. The 'expert knowledge' is entered by means of 'decision trees'. The physical suitability sub-class decision trees for different LUTs for computing the suitability are described below:

Physical suitability sub-class decision trees for different LUTs:

Rainfed paddy cultivation (rpd)

Wa (water availability)

1. (No limitation > sw (soil workability)
   1 (easy) > nrc
   1 (high) 1
   2 (med) ..... 2 nrc
   3 (low) ..... 3 nrc
   4 (v. low) ..... 4 nrc
2 (mod) 1

TABLE 2. Land characteristic values of the Singhik watershed

Map units	Soil depth	Surface texture	Structure	Consistency	Permeability	Coarse fragment (Moist)	Drainage Class	pH	Org-C%	CEC me/100g	BS %	Available N	P	K
TmG2	vd	c	2m sbk	vfi	ms	f	m	4.5	5.9	9.8	53	h	l	m
ThH3	d	cl	lf sbk	fi	ms	f	w	4.5	5.9	8.8	52	h	l	m
TeH3	vd	l	lf sbk	fr	mr	f	w	4.5	5.9	8.8	52	h	l	m
RiF2	vd	scl	lf sbk	fi	ms	c	m	4.9	1.0	9.6	58	l	m	l
ReH3	vd	l	lm sbk	fr	r	c	m	4.9	1.0	9.6	58	l	m	l
RhG2	vd	cl	lm sbk	fi	mr	c	m	4.9	1.0	9.7	58	l	m	l
RMhH	3d	cl	lm sbk	gi	ms	c	w	4.6	3.7	8.8	54	h	l	m
RMhG1	d	cl	lm sbk	fi	ms	f	w	4.6	3.7	8.9	55	h	l	m
RMiH3	d	scl	2m sbk	fi	mr	f	w	4.6	3.7	8.8	54	h	l	m
SiF2	vd	scl	2m sbk	fi	mr	f	m	4.6	5.8	17.6	57	h	m	l
SiH3	vd	scl	2m sbk	fi	ms	f	m	4.6	5.8	17.6	57	h	m	l
THhG2	md	cl	2m sbk	fi	s	f	m	4.9	2.8	17.5	53	m	m	m
SiH3	vd	sd	2msbk	h	ms	f	m	4.6	5.8	17.6	57	h	m	l
THhG2	md	d	2m sbk	fi	s	f	m	4.6	2.8	17.5	53	m	m	m

* h = high; l = low; m = medium

3 (diff) .....2 sw
4 (v. diff) .....4 sw
2 (slight stress) .....2 wa
3 (mod. stress) .....3 wa
4 (severe stress) .....4 wa

Maize (maz) and Maize and Paddy cultivation (hmp)

Wa (water availability)

1. (No limitation) > ox
1. (No limitation) > nrc

1 (high) 1
2 (med) .....2 nrc
3 (low) .....3 nrc
4 (v. low) .....4 nrc
2 (slight stress) > nrc
1 (high) .....2 ox
2 (med) .....3 ox/nrc
3 (low) .....3 ox/nrc
4 (v. low) .....4 nrc
3. (mod. stress) .....3 ox
4 (severe stress) .....4 ox
2. (slight stress) ..... 2 wa
3. (mod. stress) .....3 wa
4. (severe stress) .....4 wa

Citrus (ctr) rc (Rooting condition)

1. (No limitation) > nrc
1 (high) > wa
1 (no limitation) 1
2 (slight stress) .....2 wa
3 (mod. stress) .....3 wa
4 (severe stress) .....4 wa

2. (Medium) > wa
1 (No limitation) ....2 nrc
2 (slight stress) ....3 nrc/wa
3 (mod. stress) .... 3 nrc/wa
4 (severe stress) .... 4 nrc/wa
3 (low) .... 3 nrc
4 (v. low) .... 4 nrc
2. (slightly impeded) ..... 2 rc
3. (mod. impeded) .... 3 rc
4. (severely impeded) ..... 4 rc

Final ratings:1= highly suitable; 2= moderately suitable; 3= marginally suitable; 4 = currently not suitable.> denotes connection to a sub-tree.

RESULTS AND DISCUSSION

After completion of the 'model', the results were computed to get the physical suitability sub-class ratings (Table 3) of each unit for different LUTs.

TABLE 3. Physical suitability sub-class ratings of soils

	Land unitilization types			
Map Units	rpd	maz	hmp	ctr
ReH3	3 wa	3 wa	3 wa	3 nrc/wa
RhG2	2 wa	3 ox/nrc	2 wa	2 nrc
RiF2	2 wa	3 ox/nrc	2 wa	2 nrc
RMhG3	3 nrc	2 nrc	3 nrc	2 rc
RMhH3	3 nrc	2 nrc	3 nrc	2 rc
RMiH3	3 wa	2 nrc	3 wa	2 rd
SiF2	3 wa	2 ox	3 wa	1
SiH3	2 wa	2 ox	2 wa	1
TeH3	2 wa	2 wa	2 wa	3 nrc/wa
ThH3	3 nrc	2 nrc	3 nrc	2 rc
TmG2	3 nrc	2 nrc	3 nrc	3 rc
THhG2	3 nrc	2 nrc	3 nrc	2 nrc

* 1 = highly suitable, 2 = moderately suitable, 3 = marginally suitable.

The physical suitability of different map unit for LUT-rpd ranked from 2 (moderately suitable) to 3 (marginally suitable) with water availability and nutrient retention capacity as limiting factors. The map units, RhG2, RiF2, SiH3 and TeH3 ranked 2 and ReH3, RMiH3 and SiF2 ranked 3 for limitations due to water availability, lighter surface texture and rapid to moderately rapid permeability. On the other hand, the map units RMhG3, RMhH3, ThH3, TmG2 and THhG2 were found to be marginally suitable for paddy cultivation due to severe limitation imposed by nrc which depends on the CEC and base saturation of the soils.

For LUT-maz also nrc remained a major limiting factor. The map unit RMhG3, RMhH3, RMiH3, ThH3, TmG2 and THhG were rated as moderately suitable. TeH3 and ReH3 counted for 2 and 3, respectively, due to restricted water availability. Singhik soils (SiF2, SiH3) are moderately suited as ox is limiting due to moderate drainage condition of the soils. CEC, base saturation and drainage class of the soil units RhG2 and RiF2 posed severe problem to rate as 3 ox/nrc.

When the same map units were assessed for maize (upto ear-corn stage) and paddy rotation, the suitability ratings were changed from moderate to marginal as compared to LUT-maz. However, the map units RhG2 and RiF2 showed a reverse trend and ReH3 and TeH3 remained unchanged. Interestingly, the physical suitability of all the soil units for LUT-rpd and LUT-hmp were similar even though the physical suitability sub-class decision trees were different.

While considering the implementation of the LUT-ctr on these map units, it is observed that Singhik soils (SiF2 and SiH3) are moderately suitable with slight limitations of rooting condition, whereas RhG2, Rif2 and THhG2 had same suitability class with nrc as a constraint. ReH3 and TeH3 were classified as marginally suitable as nrc and wa are limiting factors.

It can be concluded from the study that citrus plantation is most suitable on the soils of this terraced sloping hilly region followed by maize, paddy and maize-paddy rotation. Proper water management and addition of fertilizer and liming to these highly acidic soils may improve the suitability for better performance of paddy and maize.

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