Considerations for an Integrated Land Evaluation System for Tanzania

Lessons from the Land Suitability Assessment of Mbulu District

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1. Abstract

The demands on soil survey and land evaluation in Tanzania are changing from the former research-oriented approach to client-driven. The consequence of this shift in demand is requirement for speed, reliability and versatility in land evaluation. Manual methods of land evaluation can be very time consuming especially in cases of many combination of land utilization types and land evaluation units, as can easily be for districts or regions with a wide range of agro-ecological variability. In this study Mbulu district was used to test the automation of land evaluation in Tanzania.

The study area, covering about 6,700 sq. km., was mapped at the scale of 1:100,000. The land evaluation (soil mapping) units were established on the basis of land(scape) units, parent material, relief types and soils. Ten land(scape) units, five parent material types were identified. Their combination with relief types and soils resulted in 115 land evaluation units. The altitude ranges from about 1,100 m to 2,250 m above sea level with annual rainfall ranges between about 400 and 1,100 mm. The main land use alternatives include mechanized rainfed cultivation with medium to high inputs, smallholder rain-fed cultivation, extensive grazing and afforestation. Major crops grown in the district include beans, coffee, maize, pigeon pea, sorghum and wheat.

The land suitability assessment in this study was carried out using SISTAN version 2 as the source of the land mapping unit data base for ALES version 2 which was used to create a land evaluation expert system. To correct the incompatibility between the data type generated and used by the two programs an ad hoc program was written primarily to classify the attribute data. The resultant mapping unit data files were re-structured using text editor macros and data fields for climatic attributes were added manually for each mapping unit.

The Tanzanian SISTAN database can be linked to the ALES land evaluation system in an integrated land evaluation system with significant payoffs in terms of shortened time required for completion of such studies. The problem encountered in this study which interfered with integration of the two software packages was the inadequacy of SISTAN to provide a complete database of physical land resources as inputs into the ALES land evaluation expert system. The second problem was the need to classify the attribute data generated by the data base system prior to importation into the land evaluation system.

The recommendation of this study is that the SISTAN project should be expanded in order to develop an integrated land evaluation system for Tanzania including SISTAN and ALES to start with. Possibilities for spatial analysis should also be foreseen.

2. Introduction

The demands on soil survey and land evaluation technology in Tanzania are changing. Formerly, soil survey and land evaluation was carried out along research lines with government as the main client. For this reason, the soil surveyors could set their own work plan for specific soil survey activities. Several district and regional land evaluation studies such as the ones for Geita and Sengerema [3], Dodoma Capital City [4], Morogoro (NSS, in preparation) were executed along these lines. Typically, these district studies took five to seven years to complete.

With a decrease in government budget for soil survey activities and the increasing awareness among land users for proper land management, land evaluation studies are now being carried out more along consultancy lines. Land evaluators no longer enjoy the luxury of setting their own work plan. They have to deliver results within a limited time frame, set by the client. In 1994, for example, almost all requests to the National Soil Service (NSS) for soil survey and land evaluation specified a waiting period. And in all cases, the time limits of the clients were much shorter than a data processing to fieldwork time ratio, which had come to be standard. (At NSS a data processing to field work time ratio of about 4 was considered achievable i.e. one week field work required 4 weeks office work [10]).

With the spreading knowledge among land use planners of the possibilities and flexibility offered by computerized methods of presentation of land evaluation results (i.e. using geographic information systems) the demand for computer processed land suitability is on the increase. Examples in this regard include a study in the Western Cotton Growing Areas for the identification of suitable locations for cotton ginneries [12] and the environmental impact studies carried out in Mbulu and Monduli districts.

Computerized land evaluation methods have been tried before in Tanzania on a small-scale [6]. However, the *SISTAN* database system has not been used for land evaluation purposes before. The main purpose of this study was to establish the potential and efficiency of an integrated land evaluation system involving the local soil data base system and a land evaluation software system by applying them in the land suitability assessment of a district with a high agro-ecological variability. The specific objectives of the study were:

- to identify the required processing on the outputs of *SISTAN* before they can be used as input for the *ALES* land evaluation system;
- to carry out the land suitability assessment of Mbulu district using *SISTAN* and *ALES*;
- to assess the potential of integrating *SISTAN* and the *ALES* land evaluation system in a computerized land evaluation system for Tanzania in order to increase the efficiency of land evaluation reporting.

3. General Description of the Study Area

Mbulu district is bounded by Lake Manyara in the east and Lake Eyasi in the west, stretching from the Ngorongoro Conservation area down to Hanang District in the south. It occupies an area of approximately 7,695 square km, including Lake Eyasi. The area of land is approximately 6,700 square km. The district administrative centre is Mbulu town. Figure 1 shows the location of Mbulu district.

The altitude of Mbulu district ranges from 1,000 m at the level of both Lake Manyara and Lake Eyasi, to nearly 2,400 m in the southeastern part of the district. Due to these large differences in elevation there is a wide range of climatic conditions in the district. Table 1 lists the location, altitude and rainfall statistics for a number of stations in the district. Table 2 gives mean annual temperatures and moisture availability indices (rainfall to evaporation ratio) for a number of stations in Mbulu district.

The geology of the district comprises Neogene volcanic rocks in the north, basalt of variable mineralogy and texture being the common rock type. Metamorphic rocks of the Usagaran underlie most of the central part of the district. They are a varied group of gneisses, schists, amphibolites and quartzites. The rocks have undergone permeation and injection to various degrees and this has culminated in the formation of granitoid gneisses. The gneisses are variable; the granitoid gneisses are more uniform. Granites underlie the southern part of the district.

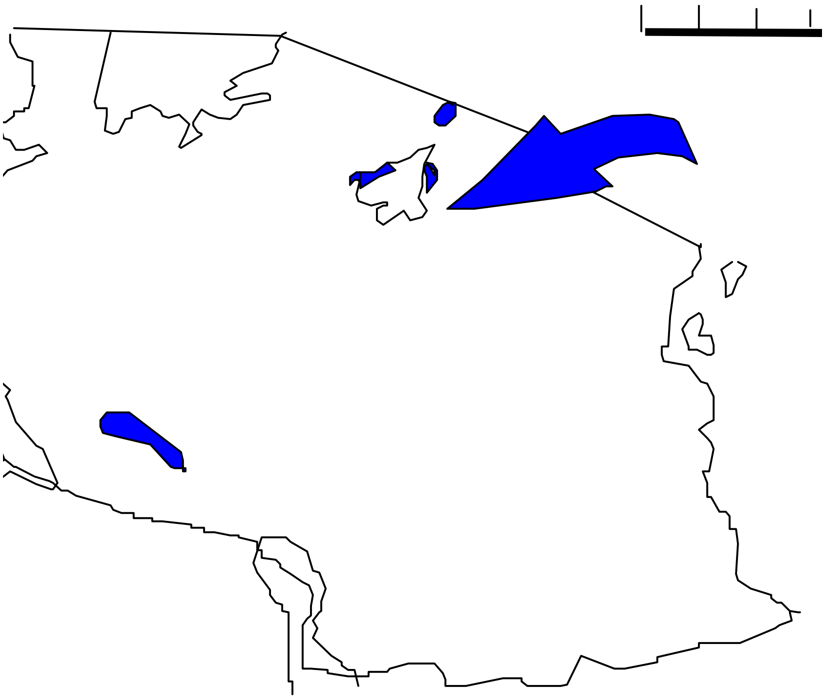

Figure 1. Location of Mbulu district in Tanzania.

The landscapes in Mbulu district are highly contrasting, ranging from highly dissected hilly and mountainous areas to extended alluvial and lacustrine plains. In the northern part of the district volcanic mountains rise to an altitude of about 3,650 m, often with smaller volcanic cones on their slopes. At the foot of these mountains are broad, gently dissected piedmonts.

The central part of Mbulu district is a broad plateau bounded by the Manyara escarpment to the east and the Yaeda escarpment to the west. Elevations on this plateau reach 2,400 m. Below the Yaeda escarpment a gentle dipslope leads to the salt pans of Lake Eyasi.

The southern and south-western part of the district is a slightly dissected peneplain at an elevation of 1,600 - 1,900 m. This peneplain is characterized by bare granitic hills and chains of hills rising to between 1,830 and 2,125 m. Extensive mbuga systems are common on this peneplain.

Detailed descriptions of geology and climate are found in Magoggo, Brom and Van der Wal [8], descriptions of landforms in Brom and Van der Wal [1; 2].

The soils are described by Magoggo, Brom and Van der Wal [8]. The main factors, which control variations in soil characteristics in Mbulu district, are parent rock and topographic position. There are four main parent rocks to be distinguished, viz.: granite, gneiss, schist (all belonging to the Basement Complex) and undifferentiated volcanic rocks (basalt, lavas, scoriae, ignimbrite etc). As a first approximation, the soils of the district can be distinguished on the basis of parent rock. Topographic position and other factors give rise to variants of the main characteristics as determined by parent rock. Table 3 gives a summary of the salient characteristics of the soils according to parent rock.

Table 1a. Rainfall Stations in Mbulu District

Station	Latitude	Longitude	Altitude (m)	No. rec. yrs
Mbulumbulu	3°15'S	35°47'E	1830	20
Mbulumbulu school				21
Gibb	3°17'S	35°40'E	1700	20
Gurland	3°18's	35°33'E	1700	10
Rhode	3°18'S	35°36'E	1700	23
Rhode's Estate	3°19'S	35°36'E	1675	31
Francke	3°18'S	35°37'E	1700	12
Ben Dhu	3°19'S	35°38'E	1700	13
Ben Dhu Estate	3°19'S	35°36'E	1705	21
Pflug	3°19'S	35°37'E	1550	7
Kongoni	3°20'S	35°34'E	1650	20
Kongoni Estate	3°20'S	35°34'E	1675	28
Jaeckel	3°20'S	35°34'E	1600	6
Schulze	3°20'S	35°34'E	1600	7
Karatu	3°20'S	35°40'E	1500	15
Karatu	3°20'S	35°41'E	1370	29
Karatu Agr. Office				30
Karatu Agr. Office				9
Karatu Parish				7
Karatu Shangrila				5
Braunschweig	3°21'S	35°31'E	1700	21
Bergfrieden Est.	3°21'S	35°31'E	1675	29
Dehrmann	3°22'S	35°33'E	1500	7
Ndamakai Est.	3°23'S	35°28'E	1850	25
Ndamakai Est.	3°23'S	35°28'E	1770	33
Ndamakai Est.	3°23'S	35°28'E	1770	34
Ugenini	3°24'S	35°34'E	1450	10
Mbulu	3°52'S	35°33'E	1770	44
Tlawi	3°55'S	35°29'E	1920	21
Tlawi				12
Kainam	3°56'S	35°35'E	1880	9
Kainam Pr. Court				53
Nou	4°07'S	35°32'E	2200	4
Bashay-Dongobesh			1980	10
Dongobesh Miss.	4°03'S	35°23'E	2040	28
Dongobesh	4°05'S	35°21'E	1950	22
Haidom	4°12'S	35°01'E	1750	4
Haidom Hospital				7
Haidom Hospital				8
Yaeda chini	3°58'S	35°10'E	1311	9
Yaeda chini vill.				17
Yaeda chini				34
Yaeda chini			1320	16
Mang'ola				7

Table 1b. Mean Rainfall for a Number of Stations in Mbulu District

Station	Mean rainfall (mm)												
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Year
Mbulumbulu	5	28	89	117	71	81	124	262	127	10	5	3	922
Mbulumbulu school	6	28	85	123	75	80	130	268	128	10	5	3	940
Gibb	7	24	70	101	92	92	123	250	134	12	7	4	916
Gurland	11	15	65	88	105	86	147	360	170	25	6	3	1081
Rhode	8	24	70	107	96	95	136	268	162	15	5	4	990
Rhode's Estate	5	3	86	119	94	94	152	282	145	18	5	3	1006
Francke	5	27	110	118	98	87	135	209	164	17	14	7	991
Ben Dhu	3	35	70	115	101	97	152	221	169	14	10	7	994
Ben Dhu Estate	5	30	94	122	99	99	165	244	142	18	8	8	1034
Pflug	5	6	77	83	83	74	121	265	131	13	1	0	859
Kongoni	4	17	59	92	94	84	114	214	112	10	6	4	810
Kongoni Estate	5	18	74	102	94	86	127	224	102	13	5	3	853
Jaeckel	13	8	75	84	131	58	108	215	98	8	3	1	802
Schulze	7	8	67	68	104	60	111	234	105	9	1	1	775
Karatu	6	23	80	84	73	76	109	178	102	6	6	4	747
Karatu	10	25	89	89	84	91	142	239	122	13	8	5	917
Karatu Agr. Office	9	26	86	86	82	91	138	239	120	12	7	4	899
Karatu Agr. Office	1	30	110	99	119	68	152	156	60	12	1	1	799
Karatu Parish	5	28	91	85	71	53	143	217	95	6	3	7	804
Karatu Shangrila	0	30	106	54	51	49	142	200	56	1	0	10	706
Braunschweig	7	20	66	105	121	103	136	251	166	18	10	7	1010
Bergfrieden Est.	8	25	76	114	114	112	150	257	150	19	8	8	1040
Dehrmann	5	7	46	60	90	65	67	233	74	3	2	0	652
Ndamakai Est.	5	18	61	114	132	98	158	212	124	14	4	4	944
Ndamakai Est.	5	15	66	112	127	112	160	208	114	15	3	5	952
Ndamakai Est.	5	16	65	113	124	110	157	209	114	15	3	4	935
Ugenini	3	8	61	60	91	69	108	146	60	3	1	1	611
Mbulu	4	26	82	122	104	87	150	164	65	4	2	2	811
Tlawi	4	26	78	117	107	94	145	184	77	5	2	0	839
Tlawi	2	26	84	117	166	58	208	194	70	7	0	4	936
Kainam	8	70	116	223	101	141	183	197	121	38	12	11	1221
Kainam Pr. Court	4	25	90	124	99	92	152	176	63	5	2	2	832
Nou	0	71	125	152	150	104	156	176	52	17	6	0	1009
Bashay-Dongobesh	0	3	14	79	100	172	96	183	119	12	11	2	791
Dongobesh Miss.	5	13	57	121	134	111	156	115	32	6	0	0	750
Dongobesh	5	14	48	122	130	101	153	111	34	6	2	0	726
Haidom	4	28	90	115	123	95	166	96	30	5	0	0	752
Haidom Hospital	7	10	94	143	132	100	110	110	22	15	0	0	743
Haidom Hospital	8	5	100	157	134	105	110	121	25	4	0	0	769
Yaeda chini	6	5	26	137	79	74	129	61	17	6	3	1	544
Yaeda chini vill.	5	7	47	126	72	82	128	76	23	4	2	0	572
Yaeda chini	5	8	44	122	76	83	112	80	20	4	1	1	556
Yaeda chini													598
Mang'ola	0	1	18	30	88	116	57	3	0	0	0	0	374

The results of the land suitability assessment [9] in this study are summarized in Figure 2. Of the total land area of the district (about 6,700 sq. km.) about 23% of the district can be used sustainably for smallholder cultivation and about 7% for mechanized agriculture. A large part of the district (38%) is moderately or highly suitable for afforestation and about 17% is moderately suitable for extensive grazing. By the definition of the suitability classes used in this analysis, there is virtually no land which is *highly* suitable for the above land use alternatives, except for afforestation.

Table 2. Moisture Availability Indices and Mean Annual Temperatures for Selected Rainfall Stations in Mbulu District

Station	Latitude	Longitude	Altitude (m)	r/Eo	Tmean (°C)
Mbulumbulu	3°15'S	35°47'E	1830	0.53	18.3
Gibb	3°17'S	35°40'E	1700	0.51	19.2
Gurland	3°18'S	35°33'E	1700	0.60	19.2
Rhode's Est.	3°19'S	35°36'E	1675	0.55	19.3
Ben Dhu Est.	3°19'S	35°36'E	1705	0.57	19.1
Kongoni Est.	3°20'S	35°34'E	1675	0.47	19.3
Karatu Mission	3°20'S	35°40'E	1485	0.40	20.5
Karatu Agr. Off.	3°20'S	35°41'E	1370	0.48	21.3
Bergfrieden Est.	3°21'S	35°31'E	1675	0.57	19.3
Dehrmann	3°22'S	35°33'E	1500	0.35	20.5
Ndamakai Est.	3°23'S	35°28'E	1770	0.52	18.7
Ugenini	3°24'S	35°34'E	1450	0.32	20.8
Mbulu	3°52'S	35°33'E	1770	0.46	18.7
Tlawi	3°55'S	35°29'E	1920	0.48	17.7
Kainam, near Nou			1840	0.70	18.2
Nou	4°07'S	35°32'E	2200	0.62	15.9
Dongobesh Miss.	4°03'S	35°23'E	2040	0.44	16.9
Dongobesh	4°05'S	35°21'E	1950	0.42	17.5
Haidom Hospital	4°12'S	35°01'E	1750	0.43	18.8
Yaeda chini	3°58'S	35°10'E	1320	0.29	21.6
Mang'ola			1050	0.18	23.4

r/Eo = mean annual rainfall/potential evaporation
Tmean = mean annual temperature

Table 3 Summary of the Characteristics of the Main Soils of Mbulu District

Parent rock	Soil characteristics					
	drainage	color	texture	fertility	AWC	others
Granite	excessive	dark brown, greyish brown and dark red	loamy sands to sandy clays	low	Low	frequently compact, iron pan common at depth
Gneiss	well to excessive	reddish brown and dark red	Sandy loams to clays	low	Moderate	thick dark topsoil where under forest
Schist	well	red	clays	Moderate	Moderate	
Volcanic	well	dark reddish brown	clays	Moderate to high	High	thick dark topsoil at high elevations

The most suitable areas (i.e. highly and moderately suitable) for smallholder cultivation and mechanized agriculture include some river terraces and flood plains, gently undulating terrain, sheetwash plains, concave valley slopes, broad ridge crests and feet of rocky hills. In general, the same lands that are suitable for arable agriculture are also suitable for afforestation. For afforestation, suitable lands include even more dissected terrain. These areas have only slight or moderate limitations to sustained application of these land use alternatives.

Approximately 35% of the district is not suitable for sustained arable agriculture, afforestation, and grazing. More or less the same lands are non-suitable for arable farming and afforestation, but for grazing a larger proportion (about 58%) of the district is non-suitable. Non-suitable lands are mainly (eroded) hills and steeply sloping footslopes and escarpments.

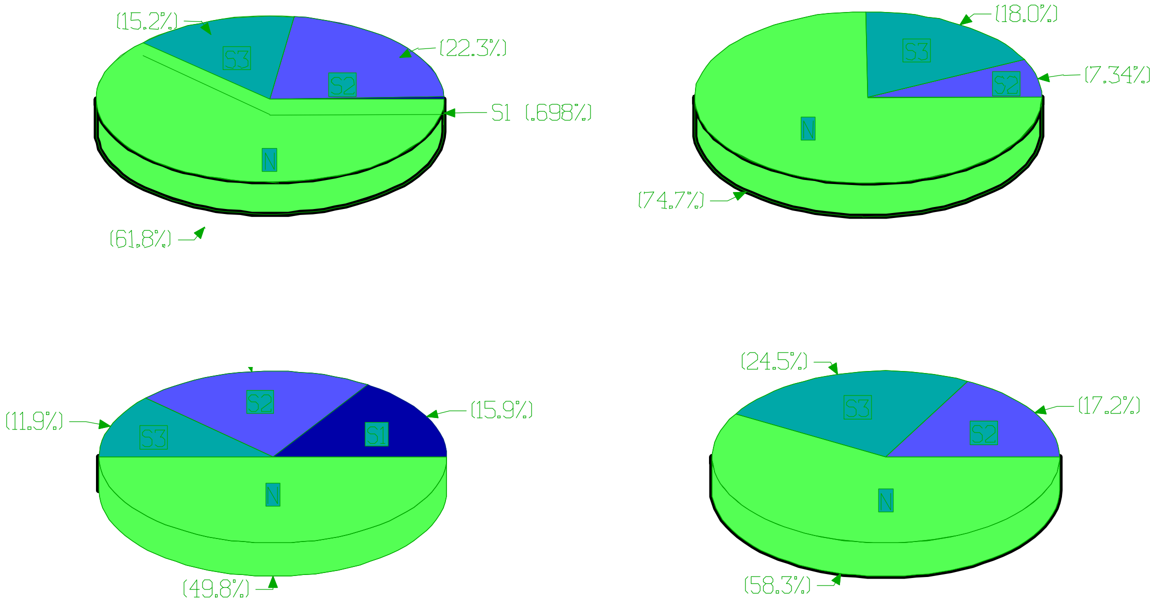

Figure 2. Summary of Land Suitability Classification for Major Land Use Alternatives in Mbuku District.

The major limitations to the sustained application of the considered land use alternatives are varying degrees of present erosion or erosion hazard and moisture availability (especially in the western part of the district). In a large part of the district (most areas except the Oldeani-Mbulumbulu highlands, the Maghang-Datlaa-Kainam highlands) the soil fertility status is low or only moderate.

4. The Contribution of *SISTAN* and *ALES* to the Land Suitability Assessment of Mbulu District

Terrain and soils data from a total of 117 sites were entered into *SISTAN* [7]. On the basis of land(scape) units, parent material, relief types and soils, 115 land evaluation units were established.

The land suitability assessment in this study was carried out using *SISTAN* version 2 as the source for part of the land mapping unit database and *ALES* version 2 [11] as the basis for the land evaluation expert system. The procedure followed is shown schematically in Figure 3. Following in the next paragraphs is a brief description of the two software systems.

4.1 SISTAN

SISTAN is a compiled computer program developed in Tanzania for the input, validation, storage, processing and retrieval of standard soil survey field and laboratory data. It runs independently under the DOS environment.

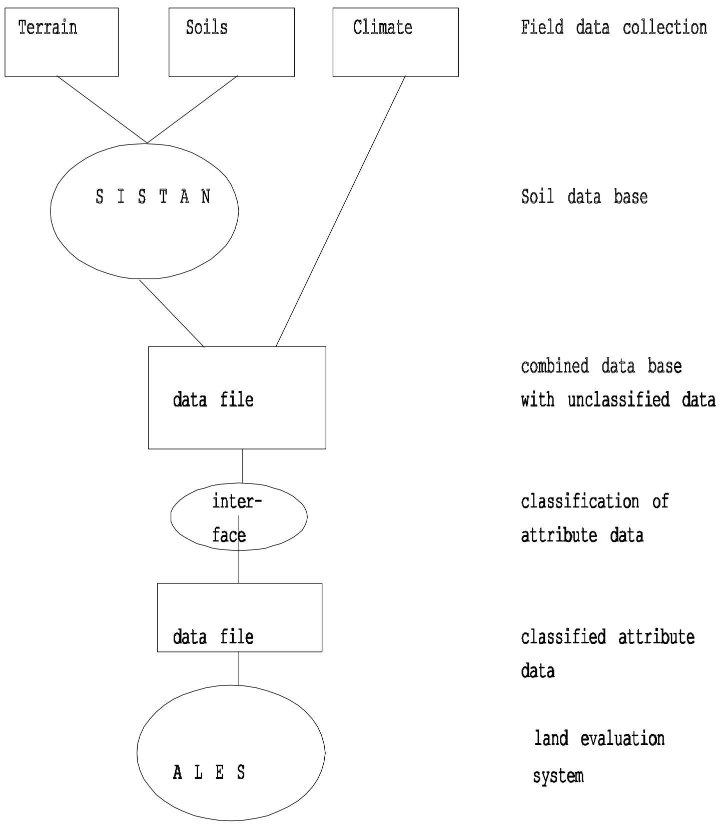

Figure 3. Schematic representation of the integration method for SISTAN and ALES in the land evaluation study of Mbulu district.

Terrain and soil data are stored in separate data files. One set of files is for geo-referencing and terrain data, one for soil profile data and another for laboratory analytical data. The defined data attributes for each file are according to the minimum data set in the Tanzania guidelines for soil survey [10]

Some of the data that are entered into the geo-referencing and terrain data file are dependent on scale. Examples are descriptions of landforms or parent material. Flexibility is allowed by the presence of a number of dictionary files that can be updated interactively within the program.

The screen forms for entering and editing the field and laboratory data are identical to the analogue forms actually used in the field by National Soil Service (NSS) soil survey staff.

SISTAN offers three possibilities for retrieval of data and information:

- conversion of (selected part of) the contents of the analytical data file into ASCII for export to software systems with more numeric or graphics processing capability such as spreadsheets;
- generation and retrieval of soil profile description text and analytical data tables for direct use in soil survey reports or through a word processor;
- generation and retrieval of attribute data ranges for spatial units such as land mapping units for export to systems designed for analysis of spatial data such as land evaluation systems or geographic information systems. Table 4 shows an extract of the output file for land mapping unit attribute data for this study that was created by *SISTAN*.

Table 4. Extract of the SISTAN Output File for Land Mapping Unit Attribute Data of Mbulu District

```
"A1","TS",1520,1700,120,175,0.5,2.0,7.8,8.1,4.0,4.5,0.23,0.45,19,23,0.10,0.50,6.0,16.0
"A1","SS",1520,1700,120,175,0.5,2.0,7.9,8.2,0.2,1.5,0.04,0.12,3,8,0.10,1.80,?,?
"A2","TS",1360,1440,130,180,0.0,2.0,7.3,8.0,3.4,4.9,0.34,0.45,6,13,0.40,0.50,26.0,36.0
"A2","SS",1360,1440,130,180,0.0,2.0,8.2,8.7,0.1,0.8,0.24,0.25,4,7,0.10,1.80,30.0,38.0
```

The contents of the fields for this file are as follows:

Map_unit	TS/SS	Altitude		depth		slope		pH (water)		Org. C %		Total N%		P (B/O)		K(me/100g)		CEC(me/100g)	
		MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX

Note:

- TS = topsoil; SS = subsoil.
- Each mapping unit has two records for topsoil and subsoil data respectively.
- For each attribute the minimum and maximum values are given.
- Question marks by *SISTAN* mean data was incomplete or missing.

4.2 ALES

ALES is a highly interactive computer program that allows land evaluators to build expert systems to evaluate land, in terms of land mapping units, according to the FAO framework for land evaluation [5]. The database building module allows flexibility in the attributes of land which may be used in the analysis as well as the structure of the input file in terms of the order in which the data attributes are arranged per record. There are options for entering the mapping unit database (i.e. the file with attribute data for each land-mapping unit) manually or from an ASCII file produced by an external database. One condition of the data in this file is that the attribute data should be classified; *ALES* does not use actual measured data. Table 5, an extract of the file used in this study, shows the structure of the land mapping unit input file for *ALES*.

Table 5 Extract of land mapping unit data base file used by ALES

```
"A1","af","vd","pd","sic","none","sodic","mb","vh","m","h","l","l","s","vl"
"A2","af","vd","pd","sic","none","sodic","sb","m","l","h","h","h","vs","vl"
"A3","af","vd","mwd","cl","none","sodic","mb","m","l","h","h","vh","vs","l"
"A4","af","vd","mwd","cl","none","none","mb","m","l","h","h","h","vs","vl"
"A5","af","vd","mwd","c","none","none","n","h","l","h","h","h","m","m"
"A6","af","vd","wd","sl","none","none","sa","l","l","l","l","vl","vs","m"
"A7","af","vd","mwd","scl","none","sodic","n","l","vl","h","l","m","vs","m"
"A8","af","vd","mwd","l","none","none","n","m","m","m","m","m","vs","h"
"A9","af","vd","pd","sl","none","none","sla","m","m","m","m","m","vs","h"
"A10","af","vd","wd","sc","none","none","n","m","vl","h","m","h","s","m"
"A11","gu","d","mwd","scl","none","none","sla","m","l","m","m","l","se","h"
"A12","af","vd","mwd","sc","none","sodic","n","m","l","m","m","vl","vs","h"
"A13","gu","vd","pd","sc","none","none","sla","m","l","m","m","m","s","l"
"B1","af","vd","pd","c","none","sodic","mb","m","l","h","vh","m","se","m"
"B2","af","vd","pd","sc","none","sodic","","","","","","","s","h"
"B3","af","vd","pd","c","none","sodic","ma","m","vl","l","m","m","se","m"
"B4","af","vd","pd","c","none","sodic","n","m","l","l","h","h","s","h"
"B5","af","vd","wd","c","none","sodic","mb","h","m","m","h","h","s","m"
```

Apart from the data base module, the program has five other components, two of which are described in the manual as follows:

- a framework for a knowledge base describing proposed land uses, in both physical and economic terms;
- an inference mechanism to relate [the data base and the knowledge base], thereby computing physical and economic suitability of a set of map units for a set of proposed land use."

The other two components are for explaining the results obtained: a query facility and a report generator.

The fields in this file are: "Map unit", "slope", "soil depth", "drainage class", "soil texture", "stoniness", "sodicity", "pH", "OC", "N", "P", "K", "CEC", "erosion", "moisture availability index"

4.3 Interfacing SISTAN to ALES

The data generated by *SISTAN* for the mapping unit attributes are ranges on a continuous scale. *ALES* requires the attribute data to be organized into discrete classes upon input. An *ad hoc* and simple program was written which compared the minimum and maximum values for each attribute for a land mapping unit against a classification scheme currently used at NSS. The classification scheme for the attribute data was included as part of the program. Thus, this scheme is fixed and cannot be varied. The program developed allowed for user intervention in cases where a range fell outside the established classes. For example, in mapping unit A1 where the CEC range was between 6 and 16 (falling in both low and medium NSS classes), the program would halt and return a question mark with a pick-list containing both classes. The user intervention was then to select one of the two classes with a combination of the cursor control and return keys. The main menu of the interface program is shown in Figure 4.

Classification of Attribute Data for Use in ALES

With this program you can now read the land characteristics ASCII file and classify the data according to the "NSS classification for general soil fertility" and the "FAO guidelines for soil profile description".
Caution: The source file should be in SISTAN format!

1. Add data fields
2. Process
0. Exit

Select your choice (0 - 2) 0

Figure 4. Main Menu of Interface Program for Classification of the Land Mapping Unit Attribute Data.

5. Results and Discussion

The *SISTAN* outputs for the description of mapping units gives absolute values on a continuous scale for numeric attributes for the following land characteristics: elevation, slope gradient, soil depth, pH, organic carbon, nitrogen, phosphorus, potassium, CEC. This list of land characteristics is not complete for the definition of the important land qualities used in this study. Land characteristics related to climate are not part of version 2 of the *SISTAN* database.

The attribute data for the land mapping units have to be classified (according to the scheme provided in the Tanzania NSS classification for general soil fertility evaluation and the Tanzania guideline for soil survey) upon input into *ALES*. The *SISTAN* database is not equipped to provide this facility.

The classification of the attribute data for input into the *ALES* land mapping unit data base calls for heavy use of look-up tables. This process is subject to errors and, for a large project as was the case in this study, tedious. The program contributed in saving input time into *ALES* and reducing possibilities for input errors. Although no attempts were made to quantify the time saved in using the computerized methods described in this paper compared to a purely manual approach, considering the combination of land evaluation units, land characteristics and land use alternatives used in this study, the time saving was tremendous.

6. Conclusions

ALES is likely to be adopted in Tanzania as a tool for land evaluation for three reasons: (a) it follows the FAO framework for land evaluation which is nationally accepted; (b) it allows the land evaluator to use local knowledge base much in the same manner as with non-computerized methods and (c) the experience so far gained in the test areas of Kilosa and in Mbulu district is encouraging. However, for large projects such as a country study, regions or districts with many land mapping units and land use alternatives the data entry task can be formidable. In view of the fact that the national digital database is growing, there will be cases where the data to be processed in a particular land evaluation project already exist in digital form. In these cases the manual entry of the same data into the *ALES* database is an unnecessary waste of time.

The experience of the land suitability assessment of Mbulu district shows that *SISTAN* can be integrated with *ALES* in a computerized land evaluation system for Tanzania.

Using the lessons learned in this study a new version of *SISTAN* is in the stage of being finalized. Apart from a multitude of new features, this new version will include climatic data to its databases. It will have modules for the classification (rating) of individual land characteristics according to the scheme used at NSS. The modules include options for interactively developing a project-specific classifying scheme for land characteristics.

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