PROPOSALS FOR RATING OF LAND QUALITIES

(subject to revision)

* Note: Land qualities are classified in terms of grade of availability of conditions or of grade of absence of risk, required.

1. Very high grade of availability/absence of risk
2. high grade " " "
3. medium grade " " "
4. low grade " " "
5. very low grade " " "

a) CLIMATE

Due to the widely different climatic conditions in Kenya (e.g. bimodal and monomodal rainfall, temperature and evaporation differences) and the lack of climatic data in many areas, the best way to indicate climatic conditions on a country-wide basis is at present the ratio r/E_o. The seven classes of this ratio are called the ecological zones. As each ecological zone is characterised by certain plant species the delineation of boundaries between the zones can be done on the basis of a vegetation survey. The ecological zones will be used in the land evaluation tables. For each survey area a climatic study will be done in order to determine the climatic characteristics of each zone: average annual rainfall and evaporation, seasonal rainfall and evaporation, probability of seasonal rainfall and moisture deficits or surplusses, temperature regime, rainfall intensity). In tabular form these statistics will appear in each report.

Ecological zones

Ecological zone I is determined by temperature and thus by altitude; the other ecological zones are determined by the ratio of rainfall over evaporation (r/E_o). This ratio is simple to calculate and has no clear disadvantages over Woodhead's (1970) Annual Index of Available Water, or Pratt et al's (1966) Moisture Index, both of which are difficult to calculate.

...../2

Ecolog.zone	r/E_o	annual r	annual E_o	physiognomy	indicator species
I		altitude more than 3000 m		Alpine moorland	Erica arborea (?)
II	> 63%	900–2600	1200–2200	Moist Forest	
IIIa	55–63%	800–1300	1700–2300	Dry forest Moist Woodland	Juniperus procera Acacia abyssinica " lahai Croton macrostachyus " megalocarpus
IIIb	48–55%			Interm. woodl. (semi-moist)	Combretum molle
IVa	40–48%	600–1000	1800–2400	Semi-dry woodland	Combretum zeyheri " collinum
IVb	33–40%			Dry woodland	Combretum zeyheri Acacia tortilis Croton dichogamus
V	18–33%	350–700	2000–2600	Bushland	Commiphora africana Acacia mellifera Delonix elata
VI	< 18%	150–450	2600–2800	Scrubland-bushland	Acacia reficiens

Another system is that of Trapnell et al, maps sheets 1 & 3 Vegetation & Vegetation and Climate, 1966-1970, who give maps of the zonal groupings of vegetation types together with climatic information of the Western part of Kenya. Their relation between climate and vegetation has not been worked out in tables.

b) "AVAILABILITY OF SOIL MOISTURE STORAGE"

A generally accepted method for study of soil moisture availability is the determination of a so-called moisture tension or pF curve of an undisturbed soil sample (core sample). The difference between the so-called fieldcapacity (FC) and the wilting point percentage (WP) is then taken to represent the available water storage capacity in the samples (AM value). The FC value is the maximum amount of moisture that can be stored in the freely draining soil, the WP value

the amount of moisture held by the soil particles with a force larger than the maximally possible suction by the plant roots. This maximum suction is generally taken to be at about 15 atmosphere (pF 4.2). Less agreement consists over the suction value of the field capacity.

It is variously taken to be 0.1 atm (pF 2.0), 0.2 atm (pF 2.3) or 0.33 atm. (pF 2.5). Also the ratings of the AM values varies. Those mentioned by Unger (1972) seem the most appropriate, they are as follows:

Total available soil moisture storage per horizon (AM value) over pF range 2.3-4.2

> 15 vol %	:	abundant
12-15 vol %	:	sufficient
8-12 vol %	:	medium
5-8 vol %	:	insufficient
0-5 vol %	:	unfavourable

No ratings are available in literature on the total storage capacity over the whole rooting zone (TAM).

To arrive at the total available moisture in the rootable zone (TAM value), the depth of the soil has to be taken into account. Depth classes used at present by KSSP are as follows:

Soil depth classes:

> 180 cm	:	extr. deep
120-180 cm.	:	very deep
80-120 cm.	:	deep
50-80 cm.	:	moderately deep
25-50 cm.	:	shallow
0-25 cm.	:	very shallow

A single combination of AM classes and depth classes would yield the following total available moisture storage (TAM) classes:

Total available soil moisture storage over rootable depth (TAM)

> 150 mm	:	very high
90-150 mm	:	high
60-90 mm	:	moderate

..../4

30-60 mm : low

< 30 mm : very low

The above rating is however not satisfactory, for several reasons:

— 1) for any rating to be geared towards production rather than survival of the plants, the WP percentage (pF 4.2) cannot well be applied. An upper limit of pF 3.7 would be more realistic (see also .....)
The ratio between the vol % in the range pF 2.3 and 3.7 (PAM)
and the total AM (pF 2.3-4.2) depends on the form of the pF curve.
This varies per type of soil, but no sufficient data are available to establish these ratios. For the moment therefore, an average ratio of 0.8 is taken, unless individual pF 3.7 data are available.

The productive moisture storage (PAM) in a soil layer of 20 cm. with AM value of 15 vol % would therefore be $\frac{20 \times 15}{10} \times 0.8 = 24$ mm

— 2) In deeper horizons the rooting intensity is less, which implies that not all available moisture can be taken up. This has to lead to the concept of TRAM (see USBR.): total readily available moisture. (TRAM)
In irrigation projects with undifferentiated soils it is often taken to be 2/3 to 3/4 of the total available moisture (TAM).
The rooting pattern varies however per type of crop (notably arable versus tree crops), the consistency ("compactness") of the various soil horizons, and the smoothness of their transition.
The influence of the average rooting patterns of crops can be dealt with at the definition of land utilization types: for those crops that have deep rooting patterns the land quality "availability of soil moisture storage" is more important in relation to other land qualities than for shallowly rooting crops.
The influence of the soil horizon sequence has however to be dealt with at the level of subratings for the land quality under consideration.
Ideally it should be done by extensive in-situ research on the differential rooting pattern of a representative crop on different soils (root-counting studies) and determination of pF curves for all horizons followed by a

...../5

weighted calculation of the readily available moisture per horizon and ultimately a summation till TRAM value.

In the absence of such in-situ research, an alternative method for the rating of the moisture storage capacity in the rootable zone has been devised, consisting of the summing up of sub ratings on soil depth, productive available moisture storage of the topsoil (0-50 cm) and profile hindrance (root development).

Soil depth 0. > 180cm.	Average PAM in topsoil (pF 2.3 - 3.7)	Profile hindrances to root development
1. > 120 cm.	1. > 15 Vol %	1. none: e.g. oxic. horizons
2. 120 - 80 cm.	2. 15 - 12 vol %	2. slight: e.g. cambic argillic transitional horizons
3. 80 - 50 cm.	3. 12 - 8 vol %	3. moderate: e.g. cambic horizon, distinct sedimentary stratification
4. 50 - 25 cm.	4. 8 - 5 vol %	4. strong: e.g. pronounced argillic horizon, pronounced sed. stratification
5. < 25 cm.	5. < 5 vol %	5. very strong: eg. planic and sodic horizons

Final rating:

0.	Exceptionally high	2
1.	very high	3 - 4
2.	high	5 - 6
3.	moderate	7 - 8 - 9
4.	low	10 - 11 - 12
5.	very low	13 - 14 - 15

...../6

These ratings may be equivalent to the following values of "total productive and readily available moisture storage in the rootable zone (TPRAM)

exc. high	:	>180 mm
very high	:	180 - 130 mm
high	:	130 - 90 mm
moderate	:	90-60 mm
low	:	60 - 35 mm
very low	:	<35 mm

Note:1:This method has the "charm" that it gives full weight to genetically and morphometrically determined soil classification units.

Note 2: If subsequent research would prove this approach to be valid, then there will be no further need to determine pF curves for subsoils during the routine survey analysis (sparing the soil physics laboratory a lot of these time consuming determinations).

Note 3: The actual moisture availability depends moreover on:

1 -) the rainfall (total and frequency) which is already included in the land quality climate/ecological zones (see a))

2 -) the runoff/infiltration rate, which is determined by slope and sealing; this aspect is included in the land quality: "tilth" (see c)

3 -) ground water reserve; this can be treated as a separate land quality if needed.

o) CHEMICAL SOIL FERTILITY

Components for rating:

I). CEC of the topsoil II). Base saturation, exchangeable aluminium, available P and K, total carbon content of the topsoil III) total nutrient content i.e. P, K, Ca and Mg. of topsoil.

...../7

Sub-ratings:

I CEC in me% (pH 8.2)	II. Available nutrients
Ratings	Ratings
1 -> 28	1
2 - 16 to 28	2
3 - 9 to 16	3
4 - 4 to 9	
5 - < 4	

Ratings	B% S.	Al. me%	P+ ppm	K+ * m.eq.	C++ %
1	70-100	0	> 50	> 0.6	> 2.5
2	35-70	0-1	20-50	0.2-0.6	1.5-2.5
3	< 35	> 1	< 20	<0.2	< 1.5

III. Mineral Reserve (total mineral content soil)

ratings	P ppm	K ppm	Ca ppm	Mg ppm
1.	> 500	> 750	> 5000	> 1000
2.	150-500	250-750	1500-5000	150-1000
3.	< 150	< 250	< 1500	< 150

Final rating:

For group II, the sub-ratings are summed from left to right.

For the sum in the range 5-8 the group rating is 1

" " " " 9-12 " " 2

" " " " 12-15 " " 3

In the same way for group III:

If the sum is 4-7, the rating is 1

" " 8-10 " " 2

" " 10-12 " " 3

For the final rating, the ratings of the three groups are combined, with the understanding that group I has a rating in 5 classes and groups II and III in three classes (1, 2 and 3).

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\+ Mehlig analysis

* Exchangeable K should be more than 5% of the CEC

++ The C/N ratio should not be more than 12.

...../8

The combinations of the sub-ratings are arbitrarily chosen.

1 = very high chemical fertility
↓ ↓
5 = very low chemical fertility

Rating	combinations									
1	111									
	112									
2		211								
	113	212								
3	121	213	311	321						
	122	221	312							
4		222	313	323	411	413				
	123	223	322		412	421				
						422				
5		231	233 331	333	423	432	511	521	531	
	132 133	232	332		431	433	512	522	532	
	131						513	523	533	

Remarks:

1. Saline and alkaline soil conditions are on purpose excluded and should be regarded as separate from soil fertility.
2. For the above rated characteristics, the topsoil of 0-30 cm is taken.
3. The possibility of entering weatherable minerals in the B/C horizons and the availability of micro nutrients in the A horizon, into the ratings are still under consideration.
4. (W.G. Sombroek) The subratings for CEC of the topsoil were derived by comparing a number of genetically and morphometrically defined soil classification units, over a range from known very rich to known very poor soils. Factors taken into account at this subrating were: chemical activity of the clay fraction, amount of organic matter (%C) and perc. of clay, as follows:

...../9

CEC at pH 8.2 per 100 g topsoil (A1 + A3/AB horizons in meq)

(* refers to CEC at pH 7)

1. Very good: CEC > 24 (20*)

Examples:

- soils with activity of the clay > 72(60*) meq, > 2.5. % C and > 15% clay: Humic Gleysols, Vertisols, Chernozems, Kastanozems, Black-Brown Phaeozems, Humic Andosols, etc.
- soils of 2) with > 4% C or > 25% clay

2. Good: CEC 16-24 (12-20*)

Examples:

- soils of 1) with lower % C or lower % clay
- soils with activity of the clay 47-72 (35-60*) meq, > 1.7% C and > 15% clay: Brown-Red Luvi/Phaeozems, Humic Planosols, Orthic Luvisols, Chromic Luvisols, Nitosols (?)
- soils of 3) with > 3% C or > 35% clay

3. Moderate: CEC 9-16 (6 - 12*)

Examples:

- soils of 2) with lower % C or lower % clay
- soils with activity of the clay 30-47 (20-35*) meq, > 1% C and > 15% clay: Ferric Luvisols, Ochric Planosols, Orthic and Chromic Acrisols.
- soils of 4) with > 2% C or > 50% clay

4) Low: CEC 4 - 9 (2-6*)

Examples

- soils of 3) with lower % C or lower % clay
- soils with activity of the clay 10-30 (5-20*) meq, > 0.5% C and > 15% clay: Ferric Acrisols, Intergrades Ferralsols/Acrisols/Luvisols, Ferralsols.
- soils of 5) with > 1% C (or > 80% clay).

5) Very low: CEC < 4 (< 2*)

Examples:

- soils of 4) with < 0.5% C or < 15% clay
- soils with activity of clay < 10 (5*) meq, 0.5% C and/or 15% clay: Arenosols, Acric Ferralsols, Xanthic Ferralsols, Dystric Regosols. etc

(can be elaborated in tables and graphs)

d) POSSIBILITIES FOR THE USE OF AGRICULTURAL IMPLEMENTS

This depends on a. steepness of slope

b. slope length c.q. slope complexicity (less important)

c. strongness and rockiness of the soil surface or shallowness of the bedrock

d. "workability" of the soil.

1. Subrating for steepness of slope

(major effect, therefore "heavy" subrating)

			rating
slope classes A, B and C	< 8%	:	1 - tractors possible
D	8-16%	:	3 - tractors possible, but not easy
E	16-30%	:	5 - lighter implements (e.g. oxen-pulled) only.
F	30-70%	:	7 - hand tools only
G	> 70%	:	9 - hand tools only (cumbersome)

2. Subrating for slope length:

(minor effect, therefore "light" subrating

> 200m	:	1
50 - 200m	:	2
< 50m	:	3

3. Subrating for stoniness/rockiness/shallowness of the soil

(classes for stoniness and rockiness: see SSM; for shallowness: see map).

non-stony, non-little rocky and not shallow:	1
fairly stony, fairly rocky and/or shallow:	3
stony - rocky and/or shallow:	5
very stony, very rocky and/or very shallow:	7
exceedingly stony, and/or very rocky:	9

4. Subrating for "workability" of the soil

(tentative, based on lab. simulation of harrowing (Koenigs).

4a. moisture range at which tillage (harrowing) can be carried out.

Expressed as the difference in vol% of moisture between upper tillage limit (UTL) and lower tillage limit (LTL).

moisture UTL - LTL		Rating
> 12 vol% moisture	:	1 very wide range

moisture UTL - LTL	Rating	
12–8 vol% moisture	: 2 wide range	See table 1 of Koenigs
8–4 vol% "	: 3 moderate range	
4–2 vol% "	: 4 small range	
< 2 vol% "	: 5 very small range	

4b. Easiness of plowing (early) in dry season

Expressed as the pF value at the lower tillage limit (LTL)

pF at LTL		Rating
> 4.2	:	1
4.2–3.75	:	2
3.75–3.30	:	3
3.30–2.85	:	4
< 2.85	:	5

4c. Resistance to plowing

(expressed in gram forces (gf) needed to move the plowsimulator through the soil sample)

		Rating
< 10 gf	:	1
10–25gf.	:	2
25–50gf.	:	3
50–100gf.	:	4
> 100gf	:	5

See table 6 of Koenigs

4d. Need for moistening before dry-season plowing

expressed in vol% moisture to be added to get from air-dry condition (pF6.0) to the condition at lower tillage limit (LTL); considered less important than 4a to c, therefore only subdivision in three classes:

Moisture between pF 6.0 and LTL

< 5 vol%	:	1
5–20 vol%	:	2
> 20 vol%	:	3

See table 5 of Koenigs

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The combination of the class given under 4a to d gives the total subrating for "soil workability", as follows:

sum of 4a - 4d classes	subrating for "workability"	examples
< 5 :	1 - very high	sandy basement
5-7.5 :	2 - high	clayey Ferrasols, Nitosols
7.5-10 :	3 - moderate	↕
10-12.5 :	4 - poor	intergrades
> 12.5 :	5 - very poor	black cotton

Combined, on the four subratings as mentioned under 1) to 4) give the following rating for the possibilities for the use of implements:

final rating

1. very high: combined ratings : 4-5
2. high: combined ratings:6,7
3. moderate: combined ratings: 8, 9, 10
4. slight: combined ratings: 10, 11, 12, 13
5. very slight: combined ratings: 14, 15, ... 22.

e) RESISTANCE TO EROSION (if used for agriculture)

sheet erosion:

susceptibility to sheet erosion depends on:

1. slope class
2. susceptibility to sealing
3. climate
4. slope length (not yet included in this proposal for rating)

1. Slope classes: subrating

rating:	slope class
1	A + AB
3	B + BC + C
5	CD + D
7	E + F

...../13

2. Susceptibility to sealing: subrating

rating based on silt/clay ratio in A horizon and infiltration measurements

silt/clay	infiltration (4 inch cylinder)	susceptibility to sealing	rating	examples
silt in A < 10% clay in A/B < 15% silt/clay ratio: variable	uncult. < 15 min/ 10cm. cult. < 15 min/ 10cm.	nil	1	sandy topsoils,
silt in A < 10% clay in A > 15% silt/clay in A: 0.20 in B 0.10	uncult. 20-50min/ 10cm. cult. < 15min/ 10cm.	little	2	ferralitic soils
silt in A 10-20% clay in A > 15% silt/clay in A: 0.20-0.30 silt/clay in B: 0.10-0.25	uncult. 30-80min/ 10 cm cult. > 15min/10cm.	moderate	3	intergrades Ferralsols/ Acrisols/ Luvisols
silt in A 20-30% clay in A > 15% silt/clay in A: 0.40-0.70 silt/clay in B: 0.25-0.50	uncult.: 50-120min/ 10 cm. cult. : > 15min/10cm.	strong	4	intergrades
silt in A: > 30% clay in A: silt/clay in A: > 0.70 silt/clay in B: > 0.50		very strong	5	sodic soils

...../14

3. Climate subrating

Ecological zone	rating
I and II	-
III	1
IV and V	2

Combined the three characteristics give the following rating for resistance to sheet erosion.

rating final		combined subratings
1	very high resistance	3, 4, 5
2	high	6, 7
3.	moderate	8, 9
4.	slight	10-11
5.	very slight	12-13-14

Note: susceptibility to gully erosion (high infiltration rate + unstable subsoil) still to be elaborated.

f) HINDRANCE BY VEGETATION:

	rating	vegetation type
very high :	5	bushland thicket (Bt), wooded bushland thicket (WBt)
high :	4	dense bushland (Bd), dense wooded bushland (WBd) dense bushed woodland (BWd), dense woodland (Wd)
moderate :	3	bushland (B), wooded bushland (WB), bushed woodland (BW), woodland (W)
slight :	2	bushed grassland (BG), wooded bushed grassland (WBG)
very slight :	1	grassland (G), bushed wooded grassland (BWG), wooded grassland (WG)

Note: For percentages tree/scrub cover in vegetation types see "Guidelines" "Soil Profile Description Form", Stencil S202/3/1/82W - 9/1/74

...../15

g) RECEPTIVITY OF THE SOIL AS A SEEDBED ("tilth")

Suitability of tilled topsoil for germination, emergence and initial root development.

This depends on:

1) moisture conditions of the topsoil after tillage for seedbed preparation

2) "crumbiness" of the soil after such tillage

3) susceptibility of the soil to surface sealing (capping).

1. Subrating for "moisture conditions in topsoil"

(based on l.b. simulation of harrowing of topsoils (Koenigs)

1a) Waiting-period for sowing, due to waiting for drying-up of topsoil to allow tillage, after onset of rains (negative time-of-planting effect) due to lowering of soil temperature and/or shortage of moisture during total growing season). Expressible in the difference in % moisture in topsoil between FC and UTL, as follows:

moisture % FC-UTL	rating
< 1 vol% :	1
1-6 vol% :	2
6-11 vol% :	3
11-16 vol% :	4
> 16 vol% :	5

FC = Field capacity
UTL = Upper tillage limit
WP = Wilting point.

see: (table 3 of Koenigs)

1b) Moisture-stress at germination: suction of the soil moisture in the topsoil right after tillage for seedbed preparation (harrowing*) soonest after onset of rains, i.e. at upper tillage limit, UTL.

*) plowing itself preferably be done directly after cropping c/q at the start of the dry season.

...../16

Expressable in the pF values at UTL:

	rating
pF < 2.2 :	1
" 2.2-2.7 :	2
" 2.7-3.2 :	3
" 3.2.-3.7 :	4
" ≥ 3.7 :	5

see: (table 2 of Koenigs)

1c) Available moisture in topsoil, after earliest tillage for seedbed preparation, for initial plant development.

Expressable in the difference in % moisture between UTL and WP:

moisture % UTL - WP	rating
> 11 vol%	1
11-9 vol%	2
9-7 vol%	3
7-5 vol%	4
< 5 vol%	5

see: (table 4 of Koenigs)

The combination of the ratings as given in 1a - 1c gives the following rating for "moisture condition after tillage"

subratings added	rating
≤ 4	1 very good
4-7	2 good
7-10	3 moderate
10-13	4 poor
≥ 13	5 very poor

...../17

2. Crumbiness of topsoil after tillage for seedbed preparation

A fine crumbiness is needed for proper germination. Subrating to be based on observations on field structure (see profile descriptions), and/ the degree of crumbling of agregates (e.g. easiness of such crumbing). under tillage for seedbed preparation (as expressed in the crumbling-factor at lab testing - Koenig's table 7).

rating		field structure	Koenigs m.w.d* factor (table 7)
very good	1	single grains, fine crumby, or moderate fine subangular blocky	⩾1.8
good	2	medium to coarse crumby or medium subangular blocky	1.8-1.6
moderate	3	coarse subangular blocky, massive and slightly hard	1.6-1.4
poor	4	hard and massive	1.4-1.2
very poor	5	platy, prismatic or coarse strong angular blocky	⩽ 1.2

* mean weight diameter.

3. Susceptibility of the soil to surface sealing/capping

Resealing soon after tillage has two main effects on tilth: 1) mechanical hindrance to emergence due to crust formation (possibly also hindrance to germination due to local shortage of oxygen) and 2) lower availability of moisture due to run-off before and during the growing season.

Tendency to (re-)sealing to be established from a) visual observations in the field, b) infiltration rate determinations, c) bulk density and pore-volume, d) silt/clay ratios and org. matter content, e) climate. (for details see land quality: resistance to erosion).

...../18

Rating:

1 non susceptable to surface sealing

2 little "

3 moderate "

4 strongly "

5 very strongly "

Combined, the three subratings 1, 2 and 3 give the following rating for "tilth":

rating		combined subratings	examples
very good	1	$\leq$ 4	sandy (top) soils
good	2	4-7	clayey Ferralsols Nitisols
moderate	3	7-10	intergradesFerralsols/Acrisols/ Luvisols
poor	4	10-13	intergrades, well structured blac cotton soils
very poor	5	$\geq$ 13	planosols, solonetzes

h) PRESENCE OF OVERGRAZING

(by visual observation)

rating:

1 no to very slight overgrazing

2 slight "

3 moderate "

4 strong "

5 very strong "

...../19

j) PRESENCE/HAZARD OF WATERLOGGING

ratings	soils
1: No	Well to excessively drained soils
2: Slight	Mod. well drained soils
3: Moderate	Imperfectly drained soils
4: High	Poorly drained soils
5: Very high	Very poorly drained soils

Other land qualities not taken into account for this area: (sheet 136)

1) absence or risk for salinization/alkalinization

2) " " for inundation

3) occurrence of diseases/pests