LAND EVALUATION

PART II

METHODS IN LAND EVALUATION

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1. GENERAL INTRODUCTION

At present most systems of land evaluation are interpretative classifications. They present an evaluation in different categories, each corresponding to a certain level of detail. At each level the interpretation differs in precision, objectives, requirements and assumptions. These successive steps may help the user in a better understanding of the system.

A first distinction is made between **qualitative and quantitative classifications.** Quantitative is reserved to inform the user that the interpretative groupings are distinguished in precise numerical economic terms. Classifications which do not meet this requirement would be described as qualitative although they may be based on varying amounts of quantitative data on yields and required inputs.

Actual and potential suitability classifications are two other concepts in land evaluation. Actual suitability classification is related to the present condition of the land and is based on direct observations; potential suitability classification reflects a future situation, after the land has been changed by major land improvements. Since major improvements are assumed to require heavy capital expenditure, it is proposed to further subdivide the potential suitability classification in "with or without amortization" depending upon whether or not the amortization of this capital expenditure has been taken into account in evaluating suitability.

The introduction of the concept of actual and potential suitability implies the set-up of criteria for the estimation of land improvement requirements. The land improvement requirements to evaluate are mostly related to drainage works, flood control, levelling and grading, salt and alkali control.

For each of these multiple improvement works a uniform scale of estimation can be suggested for appreciation. This scale is best related to the rate of land limitations defined and can be expressed as follows :

0 : no improvements are necessary, when no limitations have been mentioned;
1 : low requirements to improve slight limitations;
2 : moderate requirements to improve moderate limitations;
3 : high requirements to improve severe limitations;
4 : very high requirements to improve very severe limitations.

If land improvement requirements have to be defined in terms of capital input we suggest to use the criteria of the **F.A.O. publication 17** "Land evaluation for rural purposes" (table 1).

Table 1. Classification of land improvement requirements

Level	Technical services	Cost
Low	some technical advisory services	can in general be born by the landowner
Moderate	requires important technical services	can be born by the landowner with credit facilities
High	need intervention of specialists for planning and execution	requires government funds or long-term credit to the landowner
Very high	id. + special equipment	large government funds

In these notes different systems are given, illustrating each a specific methodology.

A general evaluation, based on limitations of land characteristics, is best illustrated in the U.S.D.A. capability classification (**Klingebiel and Montgomery, 1966**). A detailed outline of this method has been described.

The system of **Riquier et al.** (**1970**) is an example of a parametric approach for general evaluation; with however specific reference to arable land, pasture, forest and tree crops.

The suitability for irrigation can be achieved through different methods. The system elaborated by the **U.S.B.R.** and adapted to F.A.O. standards, illustrates a methodology based on limitations of land characteristics. While the system of **Sys and Verheye** (**1974**) is an illustration of a parametric approach.

Finally the principles of the F.A.O. classification, as presented in the framework for land evaluation, are given. A methodology is suggested to apply this classification system for evaluation for specific land utilization types.

2. LAND EVALUATION METHODS FOR RAINFED AGRICULTURE

2.1. General land evaluation methods

2.1.1. CLIMATIC EVALUATION ACCORDING TO PAPADAKIS

2.1.1.1. Generalities

In the complex of the various factors that determine the agricultural potentialities of a region climate is certainly the most important. There is a general consensus that conventional agroclimatology can do little to predict the agricultural potentialities of a country, or to help the transfer of crops, varieties or experience from one part of the world to another; all these questions were hitherto solved by trial and error without any help, and sometimes in spite of conventional science.

The climatic classification of **Papadakis (1970)** is a system in which a classification of climates and an ecologic classification of crops fit one another, and has been prepared with special reference to agricultural potentialities. On the basis of elemental climatic data - average daily maximum, average daily minimum and average of the lowest temperatures, vapour pressure and rainfall, month by month - climatic diagnostics are computed, and the climate is classified; to each classification unit corresponds definite agricultural potentialities; the classification points out automatically the possibilities and limitations of the climate for each crop, and type of agriculture.

Papadakis' system has been used by a great number of scientists in various parts of the world and it has always given satisfactory results.

2.1.1.2. **Determination of diagnostics**

As stated before, five sets of monthly normals are sufficient : **average of the lowest, average daily minimum and average daily maximum temperatures, vapour pressure and rainfall.** Average monthly temperatures are necessary to determine the coldest month.

As shown by table 2, potential evapotranspiration, water storage and humidity index, as well as other diagnostics have to be computed.

(1) **POTENTIAL EVAPOTRANSPIRATION**

The monthly potential evapotranspiration in mm can be calculated by using the following formula :

$$PET = 5.625\ (ea_{tmax} - ed)$$

ea_{tmax} : saturation vapour pressure that corresponds to average daily maximum. This value can be found in standard table 3.

ed : actual vapour pressure. This value is not always given in meteorologic statistics; but it may then be computed on the basis of relative humidity and temperature :

$$ed = \frac{ea_{tmean} \times RH_{mean}}{100}$$

ea_{tmean} : read from standard table 3.

Monthly potential evapotranspiration corresponds to 365/12 days.

*Table 2. How to determine potential evapotranspiration; water balance; water storage; monthly and annual humidity indices; humid, intermediate and dry seasons; leaching rainfall; drought stress; average, available and minimum frost-free seasons for the station of **BUENOS AIRES** in **ARGENTINA**.*
(All figures in centigrades, millibars or millimeters)

MONTHS	J	F	M	A	M	J	J	A	S	O	N	D	An.
Average monthly temp.	23.4	23.2	20.1	17.2	13.7	11.1	10.3	11.4	13.9	16.7	19.7	22.3	
Average of the lowest temp.	10.4	10.1	7.9	4.4	1.3	-1.0	-1.2	-0.1	1.2	3.2	6.1	8.9	
Average daily minimum temp.	17.6	17.3	15.3	11.9	8.6	5.8	5.8	6.4	8.2	10.6	13.3	15.6	11.4
Average daily maximum temp.	29.5	28.7	26.1	22.2	18.1	14.7	14.5	15.9	18.0	20.9	24.5	27.8	21.7
Vapour pressure (ed)	19.3	19.6	18.0	15.2	12.5	10.4	10.3	10.3	11.6	13.5	15.6	17.9	14.5
5.625 ea_{tmax}	232	222	190	150	117	94	93	101	116	139	173	210	1837
5.625 ed	109	110	101	85	70	59	59	59	65	76	88	101	982
Rainfall	84	78	111	103	75	54	55	64	82	87	90	98	981
Potential evapotranspiration	**123**	**112**	**89**	**65**	**47**	**35**	**34**	**42**	**51**	**63**	**85**	**109**	**855**
Water storage	**50**	**16**	**22**	**60**	**88**	**100**	**100**	**100**	**100**	**100**	**100**	**89**	
Humidity index	**1.00**	**1.00**	**1.25**	**1.58**	**1.60**	**1.55**	**1.61**	**1.52**	**1.61**	**1.38**	**1.06**	**1.00**	**1.15**

Average of the lowest temp. : average of all the coldest days of all the years
Average daily minimum temp. : average of all the minimum temp. of all the days
ea_{tmax} : saturation vapour pressure that corresponds to average daily maximum
Water storage : water stored in the soil from previous rains

*Table 3. Saturation vapour pressure (ea) in mbar as function of air temperature (T) in °C (**Doorenbos and Pruitt,, 1977**)*

T	ea	T	ea	T	ea	T	ea
0	6.1	10	12.3	20	23.4	30	42.4
1	6.6	11	13.1	21	24.9	31	44.9
2	7.1	12	14.0	22	26.4	32	47.6
3	7.6	13	15.0	23	28.1	33	50.3
4	8.1	14	16.1	24	29.8	34	53.2
5	8.7	15	17.0	25	31.7	35	56.2
6	9.3	16	18.2	26	33.6	36	59.4
7	10.0	17	19.4	27	35.7	37	62.8
8	10.7	18	20.6	28	37.8	38	66.3
9	11.5	19	22.0	29	40.1	39	69.9

(2) **WATER STORAGE**

Water storage in the soil is the difference **rainfall - PET**, when positive; it is cumulative; the excess of a month is added algebraically to that of the following one, and so on; but it cannot exceed **100 mm**; it cannot be negative (if deficit, the water storage is zero).

The computation of the water storage begins with the **first month of the humid season** (R > PET). For Buenos Aires, this is the month of March.

Computation of the water storage for Buenos Aires :

MONTH	RAINFALL (min)	-	PET (mm)	=	EXCESS (mm)
March	111		89		**22**
April	103 + **22** = 125		65		**60**
May	75 + **60** = 135		47		**88**
June	54 + **88** = 142		35		107 → **100**
July	55 + **100** = 155		34		121 → **100**
August	64 + **100** = 164		42		122 → **100**
September	82 + **100** = 182		51		131 → **100**
October	87 + **100** = 187		63		124 → **100**
November	90 + **100** = 190		85		105 → **100**
December	98 + **100** = 198		109		**89**
January	84 + **89** = 173		123		**50**
February	78 + **50** = 128		112		**16**

Water storage at the end of February is 16 mm

(3) HUMIDITY INDEX

Humidity index is equal to **rainfall/PET**; but in months in which stored water is used we add this water (the part consumed in the month); **rainfall + used stored water/PET**

Based on the humidity index, we can define :

- **Humid month** : month with humidity index greater than **1.0** (R > PET);
- **Dry month** : month with humidity index lower than **0.5**; and
- **Intermediate month** : month with humidity index between **1.0** and **0.5**.

Computation of humidity index for Buenos Aires :

MONTH	RAINFALL (mm) :	PET (mm) =	HUMIDITY INDEX
March	111	89	1.25
April	103	65	1.58
May	75	47	1.60
June	54	35	1.55
July	55	34	1.61
August	64	42	1.52
September	82	51	1.61
October	87	63	1.38
November	90	85	1.06
December	98 (+11)	109	**1.00**
January	84 (+39)	123	**1.00**
February	78 (+34)	112	**1.00**

In Buenos Aires rainfall exceeds potential evapotranspiration in March, April, May, June, July, August, September, October, November; this is the humid season.

In no month, the humidity index is lower than 0.50, as a consequence, there is no dry season.

The **annual humidity index** is annual rainfall/annual PET; 981/855 = **1.15.**

(4) **LEACHING RAIN (Ln)**

Ln = rainfall of humid months - PET of humid months.
Rainfall during the humid season (March ⟶ November, both included) is equal to :

111 + 103 + 75 + 54 + 55 + 64 + 82 + 87 + 90 = 721 mm;

PET : 89 + 65 + 47 + 35 + 34 + 42 + 51 + 63 + 85 = 511 mm;
Ln = 721 - 511 = 210 mm (seasonal excess of rainfall).

(5) DROUGHT STRESS (S)

Drought stress is the difference between PET and rainfall during the non-humid months. The non-humid months in Buenos Aires are December, January and February.

- PET during the non-humid season is 109 + 123 + 112 = 344 mm;
- rainfall during the non-humid season is 98 + 84 + 78 = 260 mm; and
- drought stress is 344 - 260 = 84 mm.

(6) FROST-FREE SEASONS

Definitions of frost-free seasons are based on the average of the lowest temperature (average of the absolute minimum temperature). Three types of frost-free seasons are defined :

- **average frost-free season :**
  period during which the average of the lowest temperature exceeds 0°C
- **available frost-free season :**
  period during which the average of the lowest temperature exceeds 2°C; and
- **minimum frost-free season :**
  period during which the average of the lowest temperature exceeds 7°C.

The length of these periods can be determined graphically (months in the X-axis and T°C in the Y-axis (fig. 1). We have to start with the month after the coldest one (August) or with the month where the average of the lowest temperature is minimal (July). We assume that the average of the lowest temperature corresponds to the first of the month, when temperatures are ascending, and to the last day when descending and the variation from month to month is linear.

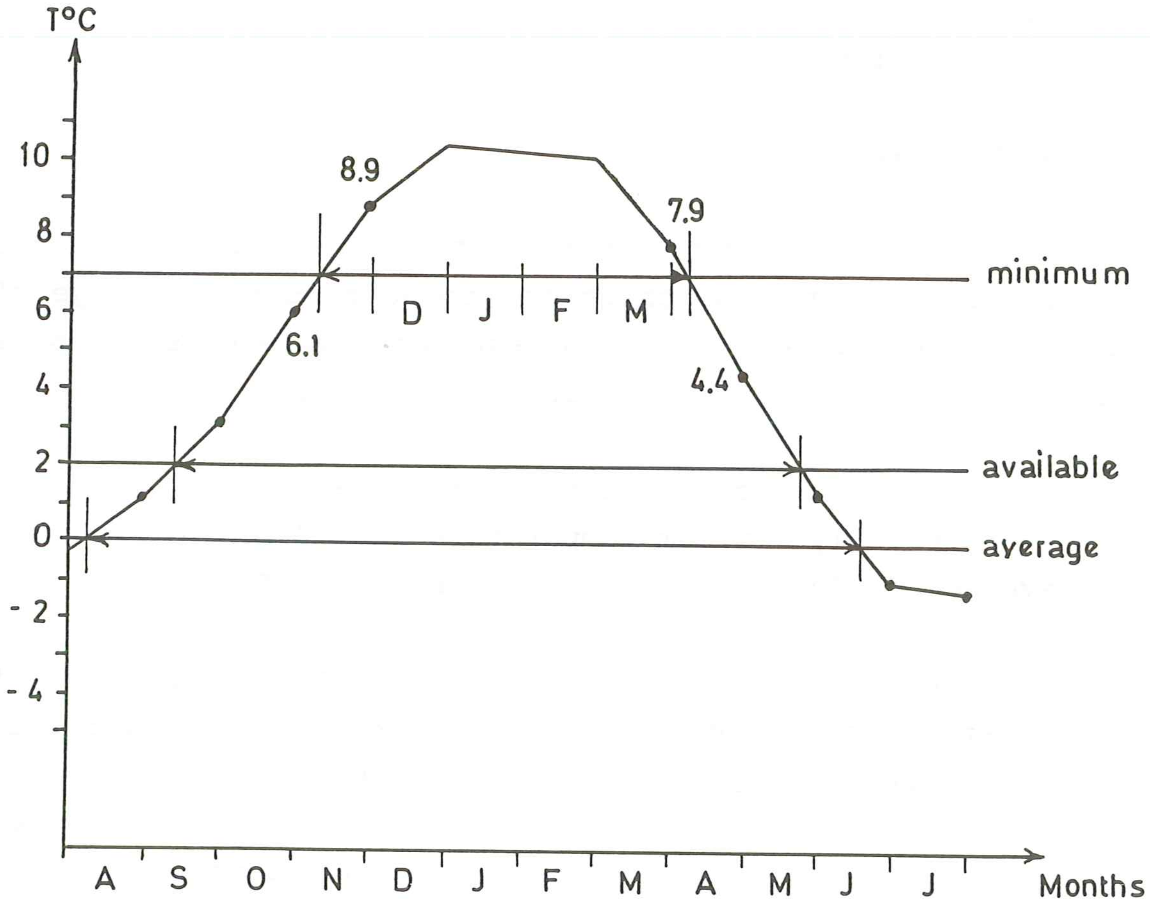

Fig. 1 *Graphical determination of the length of the frost-free seasons.*

The **minimum frost-free season** includes **(8.9-7.0)/(8.9-6.1) = 0.68 or 68%** of November, all December, all January, all February, all March and **(7.9-7.0)/(7.9-4.4) = 0.26 or 26%** of April; total **4.94 months.**

2.1.1.3. **Classification of climate**

The classification of climate requires the determination of :

- winter type;
- summer type;
- temperature regime; and
- humidity regime

(1) **WINTER TYPE**

Definition of the winter type (table 4) is based on the temperature characteristics of the coldest month (average of the lowest temperature). The coldest month in Buenos Aires is July (average monthly temperature is 10.3°C).

July average of the lowest temperature is **- 1.2°C**;
average daily minimum temperature is **5.8°C**;
average daily maximum temperature is **14.5°C**.

Table 4 : the average daily minimum is < 18°C; the average of the lowest of the coldest month is > - 2.5°C, but lower than 7°C; the average daily maximum of the coldest month is 14.5, higher than 10°C; as a consequence, winter type is citrus (Ci or Ct); the average daily maximum of the coldest month is 14.5, lower than 21°C; as a consequence winter is **Ci**.

(2) **SUMMER TYPE**

Definition of the summer type (table 5) is based on average daily minimum and maximum temperature of all months, including the type and the length of the frost-free season.

Table 5 : the minimum frost-free season > 4.5 (Buenos Aires : 4.94 months); the average of the average daily maxima of the

Table 4. Definitions of winter type

Equatorial zone (sufficiently warm for equatorial crops)
Ec Average daily minimum of the coldest month > 18°C

Tropical zone (entirely frostless, but not equatorial)
Tp Average of the lowest of the coldest month > 7°C average daily minimum of the coldest month between 13°C and 18°C

tP Idem; but average daily minimum of the coldest month between 8°C and 13°C; average daily maximum of the coldest month > 21°C

tp Idem, but average daily maximum of the coldest month < 21°C

Citrus zone (sufficiently mild for citrus, but not entirely frostless)
Ct Average of the lowest of the coldest month between - 2.5°C and 7°C; average daily minimum of the coldest month > 8°C; average daily maximum of the coldest month > 21°C

Ci Idem; but average daily maximum of the coldest month between 10°C and 21°C; average daily maximum of the coldest month may be > 21°C if the average daily minimum of the coldest month is < 8°C

Avena (winter oat) zone (sufficiently mild for winter oat, but not for citrus)
Av Average of the lowest of the coldest month between - 10°C and - 2.5°C; average daily minimum of the coldest month > - 4°C; average daily maximum of the coldest month > 10°C

av Idem; but average daily maximum of the coldest month between 5°C and 10°C; when the average daily minimum of the coldest month is < 4°C, the average daily maximum of the same month may be > 10°C

Triticum (winter wheat) zone (sufficiently mild for winter wheat, but not for winter oat)

Tv Average of the lowest of the coldest month between - 29°C and - 10°C; average daily maximum of the coldest month > 5°C

Ti Idem; but average daily maximum of the coldest month between 0°C and 5°C

ti Idem; but average daily maximum of the coldest month < 0°C

Primavera (Spring crops) zone
Pr Average of the lowest of the coldest month < - 29°C; average daily maximum of the coldest month > - 17.8°C

pr Idem; but average daily maximum of the coldest month < - 17.8°C

Table 5. Definitions of summer types

<u>Gossypium (cotton) zone</u> (sufficiently warm for cotton; climate not good for arabica coffee)

G Minimum frost-free season > 4.5 months; average of the average daily maxima of the 6 warmer months > 25°C; average daily maximum of the warmest month > 33.5°C

g Idem; but average daily maximum of the warmest month < 33.5°; it cannot be c

<u>Coffee zone</u> (thermic climate good for arabica coffee)

c All months are included in the minimum frost-free season; average of the average daily maxima of the 6 warmest months > 21°C; average daily minimum of all months < 20°C; average daily maximum of all months < 33.5°C; the highest monthly pot.evapotranspiration happens in the month of summer solstice, or 1-6 months before

<u>Oryza (rice) zone</u> (sufficiently warm for rice, but not for cotton)

O Minimum frost-free season > 3.5 months; average of the average daily maxima of the 6 warmest months > 21°C; average daily maximum of the warmest month > 25°C; summer cannot be c, g or G

<u>Maize zone</u> (sufficiently warm for maize, but not for rice)

M Available frost-free season > 4.5 months; average of the average daily maxima of the 6 warmer months > 21°C; summer is not O, c, g or G.

<u>Triticum (wheat) zone</u> (sufficiently warm for wheat, but not for maize)

T Available frost-free season > 4.5 months; average of the average daily maxima of the 4 warmer months between > 17°C; summer is not M, O, c, g or G

t Idem; but available frost-free season between 2.5 and 4.5 months

<u>Polar (taiga) zone</u> (sufficiently warm for forest, but not for wheat)

P Average of the average daily minima of the 2 warmer months > 5°C; average of the average daily maxima of the 4 warmer months > 10°C; summer is not t, T, M, O, c, g or G

<u>Andine-Alpine zone</u> (sufficiently warm for grassland, but not for forest)

A Average daily maximum of the 4 warmer months > 10°C; average frost-free season > 1 month; summer is not P, t, T, M, O, c, g or G

a Idem; but average frost-free season < 1 month

<u>Polar (tundra) zone</u> (sufficiently warm for tundra, but not for forest or grassland)

p Average of the average daily maxima of the 2 warmer months > 6°C; summer is not a, A, P, t, T, M, O, c, g or G

<u>Frigid zone</u> (too cool for tundra)

F Average daily maximum of the warmest month < 0°C; summer is not p, P, t, T, M, O, c, g or G, it cannot be A or a

f Average daily maximum of the warmest month < 0°C

6 warmer months (January, February, March, April, November and December : (29.5 + 28.7 + 26.1 + 22.2 + 24.5 + 27.8)/6 = 26.5) is > 25°C; the average daily maximum of the warmest month (January : 29.5°C) is < 33.5°C; as the consequence summer is sufficiently long warm for cotton (**g**), it cannot be coffee (c), because the minimum frost-free season does not cover all the year.

(3) **TEMPERATURE REGIME**

The definition of temperature regime (table 6) is based on the combination of winter type, summer type and some special diagnostics.
Buenos Aires : winter type **Ci** and summer type **g**

Table 6 : Looking for a combination of Ci and g, we will find two possibilities :

Temperature regime	Winter type	Summer type	Special diagnostics
TF :	**Av** or **Ci** or **Ct**	**g**	**1** and **3**
Su :	**Ci**	**g**	**4** and/or **2**

For the determination of the temperature regime, we have to check the special diagnostics (table 6).

1. The highest monthly potential evapotranspiration happens in the month of summer solstice or 1-6 months earlier. Buenos Aires : highest monthly PET in January (123 mm) Month of summer solstice : Buenos Aires is in the southern hemisphere (**21st of December**). In the northern hemisphere : **21st of June.** The first diagnostic is not fulfilled for Buenos Aires.

Table 6. Definitions of temperature regimes

The table gives winter type, summer type, special diagnostics (characteristics) and an example (place). Special diagnostics are explained at the end of the table.

Equatorial

EQ : Ec, G Madras, India
Eq : Ec, g Jakarta, Indonesia

Tropical

TR : Tp, G. Cocanada, India
tR : tP, g Rio d. Janeiro, Brasil
tR : tP, g-G Nagpur, India
tr : tp, 0-g, 2 Lima, Peru

Tierra Templada

Tt : tp-tP-Tp, c, 1 San José, Costa Rica
tt : tp, T, 1 Tjividej, Indonesia

Tierre Fria

TF : Av-Ci-Ct, g,1, 3 Salisbury, Rhodesia
Tf : Tv-av-av-Ci, M-O, 1, 3 Quito, Ecuador
tf : Tv-av-Av, Ci, t-T, 1 Darjeeling, India

Andine

An : Tv-av-Av, A, 1 Puno, Peru
an : Ti-tv-av-Av, a, 1 Chuquibambilla, Peru
aP : Ti-Tv-av-Av-Ci, P, 1 Pangerango, Indon.
ap : Ti-Tv, p, 1 High Andes, Peru
aF : Ti-Tv, F, 1 High Andes, Peru

Subtropical

Ts : Ct, g-G, 4 Asuncion, Paraguay
SU : Av-Ci, G Lahore, Pakistan
Su : Ci, g, 4 and/or 2 Hong Kong, China

Marine

Mm : Ci, T, 2 Wellington, N. Zealand
MA : Ci, M-O, 2 Auckland, N. Zealand
Ma : av-Av, T. 2 London, U.K.
ma : Ti-tv-av, P, 2, 6 Juneau, Alaska
mp : Ti, p, 2 Hasselbough Bay, Macquiarie island
mF : Ti, F, 2 Heard isl., South Indian Ocean

Temperate

TE : av-Av, M-O, 2, 10 Bordeaux, France
Te : ti-Ti, T, 2 Berlin, Germany
te : ti-Ti, t, 2 Helsinki, Finland

Pampean-Patagonian

PA : Av, M-O, 2, 9 Nueve d. Julio, Argentina
Pa : Tv-av-Av, t, 2 Trelew, Argentina
pa : Ti-Tv-av-Av, P, 2, 5 Rio Gallegos, Argentina

Continental

CO : Pr-Ti-Tv-av, g-G Oklahoma City, USA
Co : Pr-ti-Tv, M-O New York, USA
co : pr-Pr, t Quebec, Canada

Polar

Po : pr-Pr-ti, P Berezovo, Soviet Union
po : pr-Pr-ti, p Nizhne Kolymsk, Soviet Union
Fr : pr-Pr-ti, F Wrangel isl., Soviet Union
fr : pr-Pr-ti, f Eismitte, Greenland

Alpine

Al : Pr-ti-Ti, A, 2 Miena, Tasmania
al : Pr-ti-Ti, a, 2 St. Moritz, Switserland

Explanation of special diagnostics

1. The highest monthly potential evapotranspiration happens in the month of summer solstice or 1-6 months earlier
2. The highest monthly potential evapotranspiration happens after the month of summer solstice, but not later than 4 months after it.
3. Average daily minimum of all months < 20°C
4. Average daily minimum of one or more months > 20°C; it is not necessary when summer is G
5. Available frost-free season < 2.5 months
6. Available frost-free season > 2.5 months
7. Average of the average daily maxima of the 6 warmer months > 25°C
8. Average of the average daily maxima of the 6 warmer months < 25°C

2. For Buenos Aires the highest monthly PET happens after the month of summer solstice.

3. Average daily minimum of all months < 20°C.

4. Average daily minimum of one or more months > 20°C; it is not necessary when summer is G. This is not the case for Buenos Aires.

For Buenos Aires, two of the four diagnostics (2 and 3) are fulfilled and as a consequence the temperature regime is **Su (subtropical)**.

(4) **HUMIDITY REGIME**

The humidity regime can be determined according to table 7. We have to check first the fundamental regimes (general classification), before going to the more detailed classification.

<u>Table 7</u> : Humid (HU, Hu); ex. London, U.K.; no month is dry : annual humidity index > 1.00; Ln > 20% of annual PET.

Buenos Aires :

no month is dry (humidity index always > 0.50); annual humidity index = 981/855 = 1.15 > 1.00;
Ln = 210 mm > 855 x 20/100 = 170 mm

For Buenos Aires, the fundamental regime is **humid.**

<u>Subdivision of humid regimes</u> (table 7) :
HU (ever-humid); all months are humid
Hu (humid); 1 or more months are non-humid

For Buenos Aires, three months are non-humid (January, February and December) and as a consequence the humidity regime is **Hu (humid)**.

Table 7. Definition of humidity regimes

GENERAL CLASSIFICATION

Fundamental regimes
Humid (HU, Hu); ex. London, U.K.; no month is dry; annual humidity index > 1.00; Ln > 20% of annual pot. evapotranspiration.

Mediterranean (ME, Me, me); ex. Athens, Greece; neither humid, nor desertic; winter (Dec.-Jan.-Febr.) rainfall > than summer (Jun.-Jul.-Aug.) rainfall; on the basis of rainfall/pot. evapotranspiration ratio spring (Mar.-Apr.-May) is more humid than summer (Jun.-Jul.-Aug.); when 2 or more months are dry, one of them is July.

Monsoon (MO, Mo, mo); ex. Bombay, India; neither humid nor desertic; on the basis of rainfall/pot. evapotranspiration ratio summer (Jun.-Jul.- Aug.) is more humid than both spring (Mar.-Apr.-May) and winter (Dec.-Jan.-Febr.).

Steppe (St); ex. Bucarest, Romania; neither mediterranean nor monsoon; too dry for humid; the combined rainfall of the 3 spring months (Mar.-Apr.-May) covers more than half of their combined potential evapotranspiration.

Semiarid isohygrous (si); ex. Gen. Acha, Argentina; too dry for steppe; too humid for desertic; neither mediterranean nor monsoon.

Desertic (da, de, di, do); ex. Cairo, Egypt; all months with average daily maximum > 15°C are dry; annual humidity index < 0.22.

MORE DETAILED CLASSIFICATION

Subdivision of humid regimes
HU (ever-humid); ex. Valentina, Ireland, all months are humid

Hu (humid); ex. London, England; 1 or more months are non-humid

Subdivision of Mediterranean regimes
ME (rainy mediterranean); Ln > 20% of annual pot. evapotranspiration and/or annual humidity index > 0.88.

Me (dry mediterranean); Ln < 20% of annual pot. evapotranspiration; annual humidity index between 0.22 and 0.88; in 1 or more months with average daily maximum > 15°C, available water covers entirely pot. evapotranspiration; the dry season begins with May or later.

me (semiarid mediterranean); ex. Fresno, California; too dry for Me.

Subdivision of monsoon regimes
MO (rainy monsoon); ex. Saigon, Vietnam; Ln > 20% of annual pot. evapotranspiration and/or annual humidity index > 0.88.

Mo (dry monsoon); ex. Tientsin, China; Ln < 20% of annual pot. evapotranspiration; annual humidity index between 0.44 and 0.88.

mo (semiarid monsoon); ex. Bellary, India; annual humidity index < 0.44.

Subdivision of desertic regimes
da (absolute desert); ex. Lima (Peru); all months with average daily maximum > 15°C have humidity indices < 0.25; annual humidity index < 0.09.

de (mediterranean desert); ex. Phoenix, Arizona. Less dry than da; winter (Dec.-Jan.-Febr.) rainfall > than summer (Jun.-Jul.-Aug.) rainfall.

di (isohygrous desert); ex. Ain Sefra, Algeria. Neither da, nor de or do.

do (monsoon desert); ex. Timbuktu, Mali; on the basis of rainfall/pot. evapotranspiration ratio summer (Jun.-Jul.-Aug.) is more humid than spring (Mar.-Apr.-May) and winter (Dec.-Jan.-Febr.).

N.B. The months mentioned correspond to the northern hemisphere; for the southern hemisphere Jan. = Jul.; Febr. = Aug. and so on.

2.1.1.4. **Definition of climatic groups**

The final classification of the climate is done by using table 8. Winter of Buenos Aires is Ci; the climate cannot be 1 (tropical). Maximum monthly PET takes place in January, after summer solstice; the climate cannot be 2 (tierra fria). Humidity regime is not da-de-di-do (desertic); the climate cannot be 3 (desertic). Winter is Ci; summer is g; humidity regime is Hu; the highest monthly PET happens after the month of summer solstice; it combines summer g with winter Ci; the climate is **4 (subtropical)**.

To what subdivision of 4.1 does it belong ? Humidity regime is not HU; the climate cannot be 4.11. Average daily minimum of all months is below 20°C; the climate cannot be 4.12; humidity regime is not HU, the climate cannot be 4.13. Winter is Ci, summer g; humidity regime Hu, maximum monthly PET takes place after summer solstice; all months have average daily minimum below 20°C; the climate is **4.14 (humid subtropical)**.

Classification is rapid, because once the climate cannot be 1., 2. or 3., it cannot belong to whatever of their subdivisions; once it cannot be 4.12, it cannot belong to whatever of its subdivisions; in this way, entire blocks of entries are eliminated; and very few are tried. Moreover, one usually knows approximately the group to which belongs the climate; he only desires to confirm his opinion or choose between two or few groups.

It is to be noted that for the lowest subdivisions, table 8 gives a complete definition. So that if the climate has been erroneously classified in 4. or 4.1, the classification will not find a subdivision of 4. or 4.1 that fits the diagnostics of the climate, and he will check his error.

Table 8. Definitions of climatic groups

For each group, high or low, the table gives the type of winter, type of summer, humidity regime, and special diagnostics (96, 99, etc.), which are explained at the end of the table. The lowest subdivisions can be naturally further subdivided, but whatever subdivision that is not important should be avoided; however it would be probably useful to subdivide some ever-humid (HU) groups, according to the annual humidity index (1-2; 2-3; 3-4; more than 4); and some humid groups according to the number of non-humid months (1; 2; 3; 4 or more).

tp-tP-Tp-Ec, T-O-c-g-G, HU-Hu-MO-Mo-mo means that winter may be tp, tP, Tp or Ec; summer T, O, c, g, or G; humidity regime HU, Hu, MO, Mo, or mo; the definitions of these symbols, in meteorlogic figures, are given in tables .. (winter types), (summer types), and (humidity regimes).

1. *(TROPICAL)*

1. tp-tP-Tp-Ec, T-O-c-g-G, HU-Hu-MO-Mo-mo

1.1 *(Humid Equatorial)*

1.1 Ec, g, HU-Hu-MO, 96
1.11 Ec, g, HU Singapore, Malaya
1.12 Ec, g, Hu
1.121 Ec, g, Hu, 99, 101 Belem, Brasil
1.122 Ec, g, Hu, 99, 102 Abidjan, Ivory C.
1.123 Ec, g, Hu, 100 Douala, Cameroons
1.13 Ec, g, MO, 53, 96
1.131 Ec, g, MO, 44, 53, 96, 97, 101 Kumasi, Ghana
1.132 Ec, g, MO, 44, 53, 96, 98 Benin, Nigeria
1.133 Ec, g, MO, 44, 53, 96, 100 Freetown, S. Leone
1.134 Ec, g, MO, 53, 96, 97, 102 Gagnoa, Ivory C.
1.135 Ec, g, MO, 41, 53, 96 Cotonou, Dahomey
1.14 Ec, g, MO, 59, 96
1.141 Ec, g, MO, 44, 59, 96 Conacry, Guin.
1.142 Ec, g, MO, 42, 59, 96 Mangalore, India
1.143 Ec, g, MO, 40, 59, 96 Analalava, Madag.
1.144 Ec, g, MO, 38, 59, 96 Bombay, India

1.2 *(Humid Tropical)*

1.2 Tp, g, HU-Hu-MO, 4, 96
1.21 Tp, g, HU, 4 Santos, Brasil
1.22 Tp, g, Hu, 4
1.221 Tp, g. Hu, 4, 97 Habana, Cuba
1.222 Tp, g. Hu, 4, 98 Cairns, Austr.
1.23 Tp, g, MO, 4, 53, 96 Kinshasa, Congo
1.24 Tp, g, MO, 4, 59, 96
1.241 Tp, g, MO, 4. 44. 59. 96 Akyab, Burma
1.242 Tp, g, MO, 4, 42, 59, 96 Heng-ch'un, Taiwan
1.243 Tp, g, MO, 4, 40, 59, 96 Acapulco, Mex.
1.244 Tp, g, MO, 4, 38, 59, 96 Townsville, Austr.

1.3 *(Marine Savanna Tropical)*

1.3 Tp-Ec, g, MO-Mo, 4, 95
1.31 Tp-Ec, g, Mo, 4, 61 Accra, Ghana
1.32 Tp-Ec, g, Mo, 4, 63 Willemstad, W, Ind.
1.34 Tp-Ec, g, Mo, 4, 55, Gr. Turc, Bahamas
1.35 Tp-Ec, g, MO, 4, 55, 95 Lomé, Togo
1.36 Tp-Ec, g, MO, 4, 61, 95 Lindi, Tanz.
1.37 Tp-Ec, g, MO, 4, 63, 95 Guayaquil, Ecuad.

1.4 *(Continental Savanna Tropical)*

1.4 Tp-Ec, G, MO-Mo
1.41 Tp-Ec, G, Mo, 57
1.411 Tp-Ec, G, Mo, 57, 101 Bouake, Ivory C.
1.412 Tp-Ec, G, Mo, 57, 102 Akuse, Ghana
1.42 Tp-Ec, G, Mo, 64 Tamalé, Ghana
1.46 Tp-Ec, G, MO, 59, 96
1.461 Tp-Ec, G, MO, 58, 96 Rangoon, Burma
1.462 Tp-Ec, G, MO, 64, 96 Boké, Guinea
1.47 Tp-Ec, G, MO, 53, 96
1.471 Tp-Ec, G, MO, 53, 96, 97 Ho, Ghana
1.476 Tp-Ec, G, MO, 53, 96, 98 Manila, Philipp.
1.48 Tp-Ec, G, MO, 95
1.481 Tp-Ec, G, 44, 95, 97 Ejura, Ghana

1.482 Tp-Ec, G, MO, 42, 95, 97 Yendi, Ghana
1.483 Tp-Ec, G, MO, 40, 95, 97 Luang Prabang, Laos
1.484 Tp-Ec, G, MO, 38, 95, 97 Port Darwin, Austr.
1.485 Tp-Ec, G, MO, 36, 95, 97 Madras, Ind.
1.486 Tp-Ec, G, MO, 95, 98 Zinguinchor, Sen.

1.5 *(Semiarid Tropical)*

1.5 Tp-Ec, g-G, mo, 4
1.53 Tp-Ec, G, mo, 34
1.531 Tp-Ec, G, mo, 38 Yola, Nigeria
1.532 Tp-Ec, G, mo, 36 Sokoto, Nigeria
1.533 Tp-Ec, G, mo, 35 Ibipetuba, Brasil
1.534 Tp-Ec, G, mo, 33 Niamey, Niger
1.54 Tp-Ec, G, mo, 32
1.541 Tp-Ec, G, mo, 32, 79 Paratiuga, Brasil
1.542 Tp-Ec, G, mo, 32, 76, Mopti, Mali
1.543 Tp-Ec, G, mo, 32, 74 Sennar, Sudan
1.544 Tp-Ec, G, mo, 32, 72 Galcayu, Somal.
1.57 Tp-Ec, g, mo, 4, 34
1.571 Tp-Ec, g, mo, 4, 38
1.572 Tp-Ec, g, mo, 4, 36
1.573 Tp-Ec, g, mo, 4, 35 St. Louis, Sen.
1.574 Tp-Ec, g, mo, 4, 33 Luanda,Angola
1.58 Tp-Ec, g, mo, 4, 32
1.581 tp-Ec, g, mo, 4, 32, 79 Mahukoma, Hawaii
1.582 Tp-Ec, g, mo, 4, 32, 76 Voi, Kenya
1.583 Tp-Ec, g, mo, 4, 32, 74 Tulear, Madag.
1.584 Tp-Ec, g, mo, 4, 32, 72 S. Vicente, C. Verde

1.6 *(Cool Tropical)*

1.6 tp, O-g, HU-Hu-MO-Mo, 2
1.61 tp, g, HU, 2 Hamilton, Berm.
1.62 tp, g, Hu, 2 Pascua isl., Chile
1.63 tp, g, MO, 2
1.64 tp, O, HU, 2 Norfolk isl.
1.65 tp, O, Hu, 2 P. Delgada, Azores

1.7 *(Humid Tierra Templada)*

1.7 tp-tP-Tp, T-c, HU-Hu-MO
1.71 Tp, c, HU, Fort d. Cock, Indon.
1.72 Tp, c, Hu Kampala, Uganda
1.73 Tp, c, MO, 57 San José, Costa Rica
1.74 Tp, c, MO, 64
1.741 Tp, c, MO, 60 Jos, Nigeria
1.742 Tp, c, MO, 63 Marrupa, Moz.
1.75 tp-tP, c, HU Tjipodas, Indon.
1.76 tp-tP, c, Hu F. Portal, Uganda
1.77 tp-tP, c, MO Nairobi, Kenya
1.78 tp, T, HU-Hu-MO Tjividej, Indon.

1.8 *(Dry Tierra Templada)*

1.8 tp-tP-Tp, T-c, Mo-mo
1.81 Tp, c, Mo
1.811 Tp, c, Mo, 55 Caracas, Ven.
1.812 Tp, c, Mo, 61 Tabora, Tanz.
1.813 Tp, c, Mo, 63 Moyale, Ken.
1.82 Tp, c, mo, 34 Makindu, Ken.
1.83 Tp, c, mo 32 Monte Santo, Brasil
1.84 tp-tP, c, Mo
1.841 tp-tP, c, Mo, 53 Nakuru, Ken.
1.842 tp-tP, c, Mo, 61 F. Jameson, Zamb.
1.843 tp-tP, c, Mo, 63 Cazombo, Angola
1.85 tp-tP, c, mo, 34 Dodoma, Tanz.
1.86 tp-tP, c, mo, 32

1.9 *(Cool-winter Tropical)*

1.9 tP, g-G, HU-Hu-MO-Mo-mo, 4
1.91 tP, G, MO-Mo-mo
1.911 tP, G, MO-Mo, 44 Comilla, Pak.
1.912 tP, G, MO-Mo, 42 Jessore, Pak.
1.913 tP, G, MO-Mo, 40 Cuttack, India
1.914 tP, G, MO-Mo-mo, 38 Jamsedpur, India
1.915 tP, G, MO-Mo-mo, 36 Kano, Nigeria
1.916 tP, G, mo, 35 Katherine, Austr.
1.917 tP, G, mo, 33 Karachi, Pak.
1.918 tP, G, mo, 32, 77 Betroky S., Madag.
1.919 tP, G, mo, 32, 73 Guaymas, Mex.
1.92 tP, g, Hu-MO-Mo-mo, 4
1.921 tP, g, Hu-MO, 4, 47 Dibrugarh, India
1.922 tP, g, Hu-MO-Mo, 4, 44 Macquay, Austr.
1.923 tP, g, Hu-MO-Mo, 4, 42 Mt Edgecome, Sudafr.
1.924 tP, g, MO-Mo-mo, 4, 40 Tres Lagôas, Brasil
1.925 tP, g, MO-Mo-mo, 4, 38 Gladston, Austr.
1.926 tP, g, Mo-mo, 4, 36 Lour. Marqués, Moz.
1.927 tP, g, Mo-mo, 4, 35
1.928 tP, g, Mo-mo, 4, 33 Mambone, Moz.
1.929 tP, g, Mo-mo, 4, 32
1.9291 tP, g, Mo-mo, 4, 32, 77 Otobotini, Sudafr.
1.9292 tP, g, mo, 4, 32, 73

2. *(TIERRA FRIA)*

2. Ti-Tv-av-Av-Ci-Ct, f-F-p-P-a-A-t-T-M-O-g, HU-Hu-MO-Mo-mo, 1, 3, 22

2.1 *(Semitropical Tierra Fria)*

2.1 Ct, g, HU-Hu-MO-Mo-mo, 1, 3
2.11 Ct, g, HU-Hu, 1, 3 Tshibinda, Congo
2.12 Ct, g, MO, 1, 3, 57 Catalao, Brasil
2.13 Ct, g, MO, 1, 3, 64 Lusaka, Zamb.
2.14 Ct, g, Mo, 1, 3 Ihosi, Madag.
2.15 Ct, g, mo, 1, 3, 34 Bulawayo, Rhod.
2.16 Ct, g, mo, 1, 3, 32 Tsumeb, S. W. Afr.

2.2 *(Low Tierra Fria)*

2.2 Av-Ci, g, HU-Hu-MO-Mo-mo, 1, 3
2.21 Av, g, Mo, 1, 3 Salta, Arg.
2.22 Av, g, mo, 1, 3, 34 Cor. Moldes, Arg.
2.23 Av, g, mo, 1, 3, 32 Chihuahua, Mex.
2.24 Ci, g, HU-Hu, 1, 3 Cordoba, Mex.
2.25 Ci, g, MO, 1, 3, 57 Tananarive, Madag.
2.26 Ci, g, MO, 1, 3, 64 Elisabethv., Congo
2.27 Ci, g, Mo, 1, 3 Nanyuki, Ken.
2.28 Ci, g, mo, 1, 3, 34, Aguas Cal., Mex.
2.29 Ci, g, mo, 1, 3, 32 Pietersburg, Sudafr.

2.3 *(Medium Tierra Fria)*

2.3 Av-Ci, M-O, HU-Hu-MO-Mo-mo 1, 3
2.31 Av-Ci, O, HU-Hu, 1, 3 Cherrapunji, India
2.32 Av-Ci, O, MO, 1, 3, 57 Addis Ababa, Ethiop.
2.33 Av-Ci, O, MO, 1, 3, 64 Mexico C., Mex.
2.34 Av-Ci, O, Mo, 1, 3 Cuenca, Ecuad.
2.35 Av-Ci, O, mo, 1, 3, 34 Erigawo, Somal.
2.36 Av-Ci, O, mo, 1, 3, 32 Bloomfontein, Sudafr.
2.37 Av-Ci, M, MO, 1, 3 Quito, Ecuad.
2.38 Av-Ci, M, Mo, 1, 3 Cuzco, Peru
2.39 Av-Ci, M, mo 1, 3 Grootfontein, Sudafr.

2.4 *(High Tierra Fria)*

2.4 Tv-av-Av-Ci, t-T, HU-Hu-MO-Mo-mo, 1
2.41 Tv-av-Av-Ci, t-T, HU-Hu, 1
2.411 Ci, T, HU-Hu, 1 Bogotá, Colomb.
2.412 av-Av, t-T, HU-Hu, 1 Darjeeling, India
2.413 Tv, t, Hu, 1 Yatung, Tibet
2.42 Tv-av-Av-Ci, t-T, MO, 1
2.421 Ci, T, MO, 1 Sucre, Boliv.
2.422 av-Av, t-T, MO, 1 Nottingh. Rd., Sudafr.
2.423 Tv, t, MO, 1
2.43 Tv-av-Av-Ci, t-T, Mo, 1
2.431 Ci, T, Mo, 1 La Paz, Boliv.
2.432 av-Av, t-T, Mo, 1 Barkly, Sudafr.
2.433 Tv, t, Mo, 1
2.44 Tv-av-Av-Ci, t-T, mo, 1, Potosi, Bol.

2.5 *(Low Andine)*

2.5 Tv-av-Av, A, HU,Hu-MO-Mo-mo, 1
2.51 Tv-av-Av, A, MO, 1 Puno, Peru.
2.52 Tv-av-Av, A, mo, 1 Oruro, Bol.

2.6 *(High Andine)*

2.6 Tv-av-Av, a, HU-Hu-MO-Mo-mo, 1
2.61 Tv-av-Av, a, HU, 1 Cerro d. Pasco, Peru
2.62 Tv-av-Av, a, MO, 1 Imata, Peru
2.63 Tv-av-Av, a, mo, 1 Abra Pampa, Arg.

2.7 *(Subandine)*

2.7 Ti-Tv-av-Av, P, HU,Hu-MO-Mo-mo, 1
2.71 Ti-Tv-av-Av, P, HU-Hu, 1 Pangerango, Indon.
2.72 Ti-Tv-av-Av, P, mo, 1 La Quiaca, Arg.

2.8 *(Andine Tundra)*

2.8 Ti-Tv-av-Av, p, HU-Hu-MO-Mo-mo, 1 High Andes

2.9 *(Andine Subglacial Desert)*

2.9 Ti-Tv-av-Av, F, HU-Hu-MO-Mo-mo, 1 High Andes

3. *(DESERT)* [1]

3. pr-Pr-ti-Ti-Tv-av-Av-Ci-Ct-tp-tP-Tp-Ec, a-A-p-P-t-T-M-O-g-c-G, da-de-di-do

3.1 *(Hot Tropical Desert)*

3.1 tP-Tp-Ec, G, da-de-di-do
3.11 Tp-Ec, G, da Assab, Ethiop.

[1] The concept of desert in my classification has a wider range than usual, including climates in which not irrigated and not flooded land has appreciable vegetation, and some livestock carrying capacity; but no crops can be grown without irrigation or flooding.

3.12 Tp-Ec, G, do, Djibouti, Fr. Somal.
3.13 tP, G, da
3.14 tP, G, do Piura, Peru
3.15 Tp-Ec, G, de Quseir, Egypt
3.16 tP, G, de Sharjah, Arab.
3.17 tP, G, do Zeidab, Sudan

3.2 *(Hot Subtropical Desert)*

3.2 Av-Ci-Ct, G, da-de-di-do
3.21 Ct, G, da Reggan, Alger.
3.22 Ct, G, do Timbuktu, Mali
3.23 Ci, G, da Farina, Austr.
3.24 Ci, G, de Biskra, Alger.
3.25 Ci, G, di Wilcania, Austr.
3.26 Ci, G, do La Rioja, Arg.
3.27 Av, G, da-de-di-do
3.271 Av, G, da San Juan, Arg.
3.272 Av, G, de Bidelt, Morocco
3.273 Av, G, di Ain Sefra, Alger.
3.274 Av, G, do El Paso, Tex., USA

3.3 *(Marine Tropical Desert)*

3.3 tp-tP-Tp-Ec, O-g, da-de-di-do, 2
3.31 Tp-Ec, g, da, 2, 9 Daedalus, Egypt
3.33 Tp-Ec, g, do, 2, 9 Georgetown, Ascens.
3.34 tp, g, da, 2, 9 Lima, Peru
3.35 tp, g, de, 2, 9 Bahrain, Arab.
3.36 tp, O, da, 2, 10 Antofagasta, Chile
3.37 tp, g, do, 2, 9 Mossamedes, Angola
3.38 tp, O, de, 2, 10 Cape Juby, Sahara

3.4 *(Marine Subtropical Desert)*

3.4 Ci, T-M-O-g, da-de-di-do, 2
3.41 Ci, g, da, 2 Cook, Austr.
3.42 Ci, g, di, 2 Raulina, Austr.
3.43 Ci, g, de, 2 Garies, Sudafr.
3.44 Ci, M-O, da-de-di-do, 2 Walvis Bay, S. W. Afr.
3.45 Ci, T, da-de-di-do, 2 Alexanderbaai, Sudafr.

3.5 *(Highland Desert)*

3.5 Tv-av-Av-Ci-Ct-tp-tP-Tp, a-A-T-M-O-g, da-de-di-do, 1, 3
3.51 tp-tP-Tp, O-g, da-do, 1, 3 Las Anod, Somal.
3.52 Av-Ci-Ct, g, da, 1, 3 Moquegua, Peru
3.53 Av-Ci-Ct, g, do, 1, 3 Gobabis, S. W. Afr.
3.54 Tv-av-Av-Ci, M-O, da-do, 1, 3 Victoria W., Sudafr.
3.55 Tv-av-Av-Ci, t-T, da-do, 1, 3 Potrerillos, Chile
3.56 Tv-av-Av, a-A, da-do, 1, 3 Uyuní, Bol.

3.7 *(Continental Desert)*

3.7 pr-Pr-Ti-Tv-av, a-A-t-T-M-O-g-G, da-de-di-do, 2, 21
3.71 Ti-Tv-av, g-G, da-de-di-do, 2 Krasnov., Russ.
3.72 Ti-Tv, M-O, da-de-di-do, 2 Kazalinsk, Russ.
3.73 pr-Pr-ti, t, da-dedi-do, 2 Leh, Kashmir
3.75 ti-Ti, t, da-de-di-do, 2 Toponah, Nev., USA

3.8 *(Pampean Desert)*

3.8 Av, M-O-g, da-de-di-do, 2
3.82 Av, M, da-de-di-do, 2, 8, 9 Mendoza, Arg.
3.83 Av, M, da-de-di-do, 2, 7, 9 Cipolletti, Arg.
3.85 Av, M, da-de-di-do, 2, 10 P. Madryn, Arg.
3.86 Av, g, da-de-di-do, 2 V. Fertil, Arg.
3.87 Av, O, da-de-di-do, 2 Jachal, Arg.

3.9 *(Patagonian Desert)*

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3.91 Av, t, da-de-di-do, 2, 9 Trelew, Arg.
3.92 Tv-av-Av, t, da-de-di-do, 2, 10, 11 Col. Sarmiento, Arg.
3.93 Tv-av-Av, t, da-de-di-do, 2, 12 Cañ. León, Arg.
3.94 Tv-av, P, da-de-di-do, 2, 11 Maquinchao, Arg.
3.95 Tv-av, P, da-de-di-do, 2, 12 Gob. Costa, Arg.
3.96 Tv-av, t, da-de-di-do, 2, 9 Reno, Nev., USA
3.97 Tv-av-Av, T, da-de-di-do, 2 Dos Pozos, Arg.

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4.2212 Ci, G, mo, 33, 152 Lahore, Pak.
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4.26 Ci, G, MO, 2 and/or 4, 152 Katuta, Pak.
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4.32 Ct, G, mo, 34
4.321 Ct, G, mo, 33 Jodhpur, India
4.322 Ct, G, mo, 35 Kaipur, India
4.323 Ct, G, mo, 36 Baroda, India
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4.34 Ct, G, MO
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5.125 Av, M-O, St, 2, 9, 65, 117, 133 Rio Cuarto, Arg.
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5.82 Tv-av-Av, t, St, 2 Waipiata, N. Zeal.
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5.951 Tv-av-Av, t, me, 2, 9 Las Lajas, Arg.
5.952 Tv-av-Av, t, me, 2, 10 San Julián, Arg.
5.96 Ti-Tv-av-Av, P, me, 2, 5 Lago Argent., Arg.
5.97 av-Av, T, me, 2 P. Deseado, Arg.
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6.3 av-Av, T, ME Seattle, Wash., USA

6.4 *(Tropical Mediterranean)*

6.4 tp, O-g, ME-Me
6.41 tp. g, ME Dasseneiland, Sudafr.
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6.43 tp, O, ME Rettnest isl., Austr.
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6.441 tp, O, Me, 172 Funchal, Madeira
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6.6 Pr-ti-Ti-Tv-av-Av, P-t-T, ME-Me
6.61 ti-Ti-Tv-av, T, ME Montalegre, Port.
6.62 ti-Ti-Tv-av-Av, t, ME Erzurum, Turkey
6.63 ti-Ti-Tv-av-Av, t, Me, 94 Flagstaff, Ariz., USA
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6.65 Pr-ti, P, ME-Me Yellowst. Park, Wyo., USA
6.66 Ti-Tv-av-Av, P, ME, 5, 12, 13 Esquel, Arg.
6.67 Ti-Tv-av-Av, P, Me, 5 Cressy, Austr.
6.68 Ti-Tv-av-Av, P, ME 5, 11 Blue Can., Cal., USA
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6.713 Av, g-G, ME, 53, 171 Shkoder, Alban.
6.714 Av, g-G, ME, 53, 172 Ioannina, Greece
6.72 av-Av, g-G, ME, 59
6.721 av, g-G, ME, 59 Trikkala, Greece
6.722 Av, g-G, ME, 59, 173 Limnos, Greece
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6.78 ti-Ti-Tv, M-O, 'Me, 93 Ankara; Turkey
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6.791 Pr, t, ME Port Hill, Idaho, USA
6.792 Pr, t, Me Ashton, Idaho, USA

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6.931 av, M-O, me, 175 Albacete, Spain
6.932 av, M-O, me, 176 Miraieda, Spain
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6.941 ti-Ti, t, me, 179 Baker, Oreg., USA
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7.1 Ci, T-M-O, HU-Hu, 2
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7.12 Ci, M-O, Hu, 2
7.121 Ci, M-O, Hu, 2, 81
7.122 Ci, M-O, Hu, 2, 82 Nelson, N. Zeal.
7.123 Ci, M-O, Hu, 2, 83 Gisborne, N. Zeal.
7.124 Ci, M-O, Hu, 2, 84 Yallourn, Austr.
7.13 Ci, T, HU, 2, Wellington, N. Zeal.
7.14 Ci, T, Hu, 2
7.141 Ci, T, Hu, 2, 81 Valdivia, Chile
7.142 Ci, T, Hu, 2, 82 Apollo B., Austr.
7.143 Ci, T, Hu, 2, 83 Stanley, Austr.
7.144 Ci, T, Hu, 2, 84 Portland, Austr.
7.15 Ci, P, Hu, 2 Eureka, Cal., USA

7.2 *(Cool Marine)*

7.2 av-Av, T, HU-Hu, 2
7.21 av, T, HU, 2 Ostend, Belg.
7.22 av, T, Hu, 2
7.221 av, T, Hu, 2, 81 Birmingham, U. K.
7.222 av, T, Hu, 2, 82 Limpne, U. K.
7.223 av, T, Hu, 2, 83 Oxford, U. K.
7.224 av. T, Hu, 2, 84 Greenwich, U. K.
7.23 Av, T, HU, 2 Zeeha, Austr.
7.24 Av, T, Hu, 2
7.241 Av, T, Hu, 2, 81 Hythe, Austr.
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7.244 Av, T, Hu, 2, 84 St. Helens, Austr.

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7.32 av, P. Hu, 2, 6 North Head, Wash., USA
7.33 Ti-Tv, P, HU, 2, 6 Juneau, Alaska
7.34 Ti-Tv, P, Hu, 2, 6 Punta Arenas, Chile

7.4 *(Polar Marine)*

7.4 Ti-Tv-av, F-p, HU-Hu, 2
7.41 av, p, HU-Hu, 2 Kerguelen isl.
7.42 Ti-Tv, p, HU-Hu, 2
7.421 Ti-Tv, p, HU, 2 Grimsey, Icel.
7.422 Ti-Tv, p, Hu, 2
7.43 Ti, F, HU-Hu, 2 Heard isl.

7.5 *(Warm Temperate)*

7.5 av-Av, M-O, HU-Hu-MO, 2
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7.52 av-Av, M-O, Hu, 2
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7.522 av-Av, M-O, Hu, 2, 82 Bayonne, France
7.523 av-Av, M-O, Hu, 2, 83 Trabzon, Turkey
7.524 av-Av, M-O, Hu, 2, 84 Bordeaux, France
7.53 av-Av, O, MO, 2 China-Japan Mount.

7.6 *(Cool Temperate)*

7.6 ti-Ti-Tv, T, HU-Hu, 2
7.61 Ti-Tv, T, HU, 2 Bruxelles, Belg.
7.62 ti, T, HU, 2 Minsk, Russ.
7.63 Ti-Tv, T, Hu, 2, Berlin, Germ.
7.65 ti, T, Hu, 2 Stockholm, Sweden

7.7 *(Cold Temperate)*

7.7 ti-Ti, t, HU-Hu, 2
7.71 ti, t, HU, 2 Halifax, Can.
7.72 Ti, t, HU, 2 Yarmouth, Can.
7.73 ti, t, Hu, 2 Helsinki, Finland
7.74 Ti, t, Hu, 2 Luneburg, Germ.

7.8 *(Humid Patagonian)*

7.8 Ti-Tv-av-Av, P-t, HU-Hu, 2, 19, 20
7.81 Tv-av-Av, t, HU-Hu, 2 Gore, N. Zeal.
7.82 Ti-Tv-av, P, HU-Hu, 2, 5
7.821 Ti-Tv-av, P, HU-Hu, 2, 5, 18 b Bariloche, Arg.

7.822 Ti-Tv-av, P, HU-Hu, 2, 5, 18 c Ushuaia, Arg.

8. *(HUMID CONTINENTAL)*

8. pr-Pr-ti-Ti-av-Av, t-T-M-O-g-G, HU-Hu-MO, 21

8.1 *(Warm Continental)*

8.1 Ti-tv-av-Av, g-G, HU-Hu
8.11 Ti-Tv-av-Av, g, HU Tokyo, Japan
8.12 Ti-Tv-av-Av, g, Hu, 143, 158 Maebashi, Japan
8.13 Ti-Tv-av-Av, g, Hu, 122, 131 Osaka, Japan
8.14 Ti-Tv-av-Av, g, Hu, 131, 159
8.141 av-Av, g, Hu, 131, 159 Atlanta, Georg., USA
8.142 Ti-Tv, g, Hu, 131, 159 Little Rock, Ark., USA
8.15 Ti-av-Av, g-G, Hu, 123, 131, 160
8.151 av-Av, g-G, Hu, 123, 131, 160 New Orleans, La., USA
8.152 Ti-Tv, g-G, Hu, 123, 131, 160 Raleigh, N. Car., USA
8.16 Ti-Tv-av-Av, g, Hu, 143, 161, 162 Nanking, China
8.17 Ti-Tv-av-Av, g, Hu, 132, 162, 163 I-Ch'ang, China
8.18 Ti-Tv-av-Av, g, Hu 132, 162, 164 Chefoo, China
8.19 Av, G, Hu Alexandria, La., USA

8.2 *(Semi-warm Continental)*

8.2 Pr-ti-Ti-Tv, M-O, HU-Hu-MO
8.21 Pr-ti-Ti-Tv, M-O, HU Kyoto, Japan
8.22 Pr.ti-Ti-tv, M-O, Hu, 124, 131, 165
8.221 Ti-Tv, M-O, Hu, 124, 131, 165 Strasbourg, France
8.222 ti, M, Hu, 124, 131, 165 Lansing, Mich., USA
8.223 Pr, M, Hu, 124, 131, 165 Green Bay, Wisc., USA
8.23 Pr-ti-Ti-Tv, M-O, Hu, 143, 161 Mito, Japan
8.24 Pr-ti-Ti-Tv, M-O, Hu, 125, 131
8.241 Pr-ti-Ti-Tv, M-O, Hu, 125, 128, 131 New York, N. Y., USA
8.242 Pr-ti-Ti-Tv, M-O, Hu, 125, 126, 131 Bristol, Tenn., USA
8.243 Pr-ti-Ti-Tv, M-O, Hu, 111, 131 Asheville, N. C., USA
8.25 Ti-tv, M, Hu, 126, 131, . 166 Dijon, France
8.26 Pr-ti-Ti-Tv, M-O, MO Mukden, Mandchur.
8.27 Pr-Ti-Tv, M-O, Hu, 143, 164 Wei-Hai-Wei, China
8.28 Pr-Ti-Tv, M-O, Hu, 132, 164 Dairen Manchuria

8.3 *(Cold Continental)*

8.3 pr-Pr, t, HU-Hu-MO
8.31 pr-Pr, t, HU Goose Bay, Can.
8.32 pr-Pr. t. Hu Tobolsk, Russ.
8.33 pr-Pr, t, MO Ch'ang Ch'un, Mandch.

9. *(STEPPE)*

9. pr-Pr-ti-Ti-Tv-av, P-t-T-M-O-g-G, St-si-Mo-mo, 2, 29, 31

9.1 *(Warm Steppe)*

9.1 Ti-Tv-av, g-G, St
9.11 Ti-Tv-av, g-G, St, 51 Watts, Okla., USA
9.12 Ti-Tv-av, g-G, St, 53 Oklohoma C., Okla., USA
9.13 Ti-Tv-av, g-G, St, 59 Altus, Okla., USA

9.2 *(Semi-warm Steppe)*

9.2 Pr-ti-Ti-Tv, M-O, St
9.21 Pr-ti-Ti-Tv, M-O, St, 51
9.211 Ti-Tv, M-O, St, 51 Debrecen, Hung.
9.212 ti, M, St, 51 Des Moines, Iowa, USA
9.213 Pr, M, St, 51 Minneapolis, Minn., USA
9.22 Pr-ti-Ti-Tv, M-O, St, 69
9.221 Ti-Tv, M-O, St, 69 Sofiya, Bulg.
9.222 ti, M, St, 69 Saratov, Russ.
9.223 Pr, M, St, 69 Voronezh, Russ.
9.23 Pr-ti-Ti-Tv, M-O, St, 68
9.231 Ti-Tv, M-O, St, 68 Odessa, Russ.
9.232 ti, M, St, 68 Rostov n. D., Russ.
9.233 Pr, M, St, 68 Pierre, S. Dak., USA

9.3 *(Cold Stappe)*

9.3 pr-Pr, t, St
9.31 Pr, t, St, 51 Saskatoon, Can.
9.32 Pr, t, St, 69 Fargo, N. Dak., USA
9.33 Pr, t, St, 68
9.331 Pr, t, St, 68, 182 Lusk, Wyo., USA
9.332 Pr, t, St, 68, 183 Akmolinsk, Russ.
9.34 pr, t, St, 51 Omsk, Russ.
9.35 pr, t, St, 69 Fairbanks, Alaska

9.4 *(Temperate Steppe)*

9.4 ti-Ti, t-T-M, St
9.41 ti-Ti, t, St, 70 Tambov, Russ.
9.42 ti-Ti, t, St, 68 Cheyenne, Wyo., USA

9.43 ti-Ti-Tv, T, St
9.431 ti-Ti-Tv, T, St, 51 Praha, Chech.
9.432 ti-Ti-Tv, T, St, 53 Stavropol, Russ.
9.44 av, M, St, 70 Solsona, Spain
9.45 av, M, St, 68 Zaragoza, Spain

9.5 *(Polar Steppe)*

9.5 Pr-ti-Ti, P, St, 31 White Horse, Can.

9.7 *(Semiarid Continental)*

9.7 pr-Pr-ti-Ti-Tv-av, P-t-M-O-g-G, si, 29, 31
9.71 Ti-Tv-av, g-G, si Lubbock, Tex., USA
9.72 Pr-ti-Ti-Tv, M-O, si Astrakhan, Russ.
9.73 pr-Pr, t, si Medic. Hat, Can.
9.74 ti-Ti, t, si Modena, Utah, USA
9.75 Pr-ti-Ti, P, si Meeker, Colo., USA

9.8 *(Monsoon Continental)*

9.8 pr-Pr-ti-Ti-Tv-av, t-T-M-O-g-G, Mo-mo, 29
9.81 pr-Pr, t, Mo Ulan Bator, Mong.
9.82 Pr-ti-Ti-Tv, M, Mo Grodekovo, Russ.
9.821 Ti-Tv, M, Mo Lhasa, Tibet
9.822 Pr-ti, M, Mo Harbin, Mandch.
9.83 Pr-ti-Ti-Tv, M, mo
9.84 Pr-ti-Ti-Tv, O, Mo Hsi-Wan, China
9.85 Pr-ti-Ti-Tv, O, mo Lanchow, China
9.87 Ti-Tv-av, g-G, Mo Tientsin, China
9.88 Ti-Tv-av, g-G, mo Sian, China
9.89 Ti-Tv, t, mo Cyantse, Tibet

10. *(POLAR ALPINE)*

10. pr-Pr-ti-Ti-Tv, f-F-p-P-a-A, HU-Hu-MO-Mo-mo-ME-Me-me, 2, 185, 186

10.1 *(Taiga and Subalpine)*

10.1 pr-Pr-ti, P, HU-Hu-MO,Mo-St 2, 185
10.11 Pr-ti, P, HU, Fogo, Can.
10.12 Pr-ti, P, Hu Archangelsk, Russ.
10.13 Pr-ti, P, MO Arschan, Russ.
10.14 Pr-ti, P, Mo Irkutsk, Russ.
10.16 pr, P, HU Trout Lake, Can.
10.17 pr, P, Hu Okhotsk, Russ.
10.18 pr, P, Mo Chita, Suss.
10.19 pr, P, St F. Yukon, Alaska

10.2 *(Tundra)*

10.2 pr-Pr-ti, p-a, HU-Hu-MO-Mo-St, 31 b
10.21 pr-Pr-ti, p, HU, Nanortalik, Greenl.
10.22 pr-Pr-ti, p, Hu, Mare Sale, Russ.
10.23 pr-Pr-ti, p, MO, Baker Lake, Can.
10.24 pr-Pr-ti, p, St, Thule, Greenl.
10.25 pr, a, St High Centr. Asia mount.

10.3 *(Subglacial Desert)*

10.3 pr-Pr-ti, F Orcadas d. S., Arg.

10.4 *(Ice Cap)*

10.4 pr-Pr-ti, f Eismitte, Greenl.

10.5 *(Alpine)*

10.5 pr-Pr-ti-Ti-Tv, a-A, HU-Hu-MO-Mo-mo-ME-Me-me-St-si, 2
10.51 pr-Pr-ti-Ti-Tv, A, HU-Hu, 2 Miena, Austr.
10.52 Pr-ti-Ti-Tv, a, HU, 2 St. Moritz, Switz.
10.53 Pr-ti-Ti-Tv, a, 'Hu, 2 S. Europe mount.
10.54 Pr-ti-Ti-Tv, a-A, St, 2 Centr. Asia mount.
10.55 Pr-ti-Ti-Tv, a-A, si, 2 Irketshan, Russ.
10.56 Pr-ti-Ti-Tv, a-A, Mo, 2 Centr. Asia mount.
10.57 Pr-ti-Ti-Tv, a-A, mo, 2, Okinski Stan, Russ.
10.58 Pr-ti-Ti-Tv, a-A, ME-Me-me, 2 Cristo Redentor, Arg.

EXPLANATION OF SPECIAL DIAGNOSTICS

Summer Tenperature Conditions

1 The highest monthly potential evapotranspiration happens in the month of summer solstice or 1-6 months before.

2 The highest monthly potential evapotranspiration happens after the month of summer solstice, but not later than 4 months after it.

3 Average daily minimum of all months $< 20°$ C.

4 Average daily minimum of one or more months $> 20°$ C; it is not necessary when summer is G.

5 Available frost-free season < 2.5 months.

6 Available frost-free seanson > 2.5 months.

7 Available frost-free season < 6 months.

8 Available frost-free season > 6 months.

9 Average of the average daily maxima of the 6 warmer months $> 25°$ C.

DEFINITIONS OF CLIMATIC GROUPS

10 Average of the average daily maxima of the 6 warmer months < 25° C.
11 Average of the average daily maxima of the 6 warmer months > 21° C.
12 Average of the average daily maxima of the 6 warmer months < 21° C.
13 Average of the average daily maxima of the 4 warmer months > 17° C.
14 Average daily maximum of the warmest month > 30° C.
15 Average daily maximum of the varmest month < 30° C.
16 Average daily maximum of the warmest month < 25° C.
17 Average daily maximum of the warmest month > 25° C.
18 Average of the average daily maxima of the 4 warmer months < 17° C.
18b Average daily maximum of the warmest month > 17° C.
18c Average daily maximum of the warmest month < 17° C.

Continentality etc.

19 If winter is Ti, summer cannot be t.
20 If summer is P available frost-free season is < 2.5 months.
21 When winter is av summer should be g or G; when winter is Tv, Ti or ti, summer should be M or warmer.
22 Conditions specified in 21 are not filled.
23 When summer is g, winter should be *Ci*.
24 When summer is *G* and humidity regime *HU* or *Hu*, winter cannot be Av.
25 When summer is T and humidity regime me, winter should be Ci.
26 Average of the lowest of the coldest month < 7° C.
27 Average of the lowest of the coldest month > 7° C.
28 When winter is Tv or av, summer should be P, t or T.
29 When winter is Tv or av, and humidity regime me, St, Mo or mo, summer should be M, O, g or G.
30 When summer is T, and humidity regime me, winter should be av.
31 When summer is P, winter cannot be pr.
31b When summer is a, winter should be pr.

Humid months

32 No month is humid.
33 1 humid month.
34 1 or more humid month.
35 2 humid months.
36 3 humid months.
38 4 humid months.
40 5 humid months.
41 6 or less humid months.
42 6 humid months.
43 5-7 humid months.
44 7 humid months.
47 8 or more humid months.
48 2 or more humid months.
49 1 or less humid months.

Dry months

51 No month is dry.
53 1-3 dry months.
55 0-3 dry months.
57 4 or less dry months.
58 4 dry months.
59 4 or more dry months.
60 5 dry months.
61 4-5 dry months.
63 6 or more dry months.
64 5 or more dry months.
65 1-5 months are dry.
66 All months are dry.
67 9 or more dry months.
68 3 or more dry months.
69 1-2 dry months.
70 2 or less dry months.

Non-dry months

72 1 non-dry month.
73 2 or less non-dry months.
74 2 non-dry months.
75 1 or more non-dry months.
76 3 non-dry months.
77 3 or more non-dry months.
79 4 or more non-dry months.

Non-humid Months

81 1 non-humid month.
82 2 non-humid months.
83 3 non-humid months.
84 4 non-humid months.

Annual Humidity Index, Ln, etc.

91 Annual humidity index < 0.22.
92 Annual humidity index > 0.22.
93 Annual humidity index < 0.44.

94 Annual humidity index > 0.44.
95 Annual humidity index < 1.00.
96 Annual humidity index > 1.00.
97 Ln < 1,000 mm.
98 Ln > 1,000 mm.
99 Ln < 2,000 mm.
100 Ln > 2,000 mm.
101 The humid months form one continuous humid season.
102 The humid season is divided in two or more segments.
105 If humidity regime is St, it should combine with winter Ct.
106 Humidity regimes MO, Mo, mo should combine with summer g.

Summer Humidity Conditions

111 The 3 summer months are humid.
112 The 3 summer months are non-humid.
113 1-2 summer months are humid.
114 The only dry month is July.
115 2-3 summer months are dry.
116 The 3 summer months are dry.
117 No summer month is dry.
119 2-5 summer months are dry.
120 1 or more summer months are dry.
121 1 or more summer months are non-dry.
122 August is the only month of the year that is non-humid.
123 If August is non-humid, it is not the only non-humid month of the year.
124 July and August are non-humid.
125 July and/or August are humid.
126 June and July are non-humid.
128 June and July are the only months that are non-humid.
129 June and/or July are humid.

Ns B. These months correspond to the northern hemisphere; for southern hemisphere July corresponds to January, August to February and so on; 2-5 summer months means that the dry season is continuous and includes at least 2 summer months; summer includes June, July and August in the northern hemisphere. December, January and February in the southern one.

Winter Humidity Conditions

131 The 3 winter months are humid.
132 The 3 winter months are non-humid.
133 4-5 winter months are dry.
134 1-3 winter months are dry.
135 2 winter months are humid.
136 1 or more winter months are humid.
137 The 3 winter months are neither dry non humid.
138 7 or more winter months are humid.
139 3-6 winter months are humid.
140 1 or more winter months are non dry.
141 In 1 or more months with average daily maximum > 15° C available water covers entirely pot. evapotranspiration.
142 In no month with average daily maximum above > 15° C available water covers entirely pot. evaprotranspiration.
143 1 or more winter months are not humid.
144 0-1 winter months are humid.
145 Winter is humid.
146 Winter is not humid.
147 The number of dry months is not higher in winter than in summer.
148 The number of dry months is higher in winter than in summer.

N. B.: Winter includes December, January and February in the northern hemisphere; June, July and August in the southern one; 4-5 or 3-6 winter months means that the dry or humid season is continuous and includes the 3 winter months. "Winter is humid" means, that the combined rainfall of the 3 winter months is higher than the corresponding potential evapotranspiration.

Spring and Atumn Humidity Conditions

151 Available water covers more than 50 % of potential evapotranspiration in spring.
152 Available water covers less than 50 % of potential evapotranspiration in spring.
153 April and/or March are humid.
154 April and May are non-humid.
155 1 or more winter-spring months are dry.
156 2 or more spring months are humid.
157 1 or more spring or autumn months are non-dry.
158 October is humid.
159 August, September and October are not humid.

160 1 or more of the 3 months August, September and October are humid.
161 The 3 spring months are humid.
162 October is non-humid.
163 1-2 spring months are not humid.
164 The 3 spring months are non-humid.
165 April is humid.
166 April and May are non-humid.

N. B.: Spring includes March, April and May; autumn September, October and November; the months mentioned correspond to the northern hemisphere; in the southern hemisphere March corresponds to September, April to October and so on.

The dry season begins

171 The dry season begins with August.
172 The dry season begins with July.
173 The dry season begins with June.
174 The dry season begins with May.
175 The dry season begins with April or later.
176 The dry season begins with March or earlier.
177 The dry season begins with April.
178 The dry season begins with April or earlier
179 The dry seasons begins with May or later.
180 When summer is M and humidity regime me, the dry season begins with February.
182 The dry season begins with July or later.
183 The dry season begins with June or earlier.

N. B. These months correspond to the northern hemisphere; for southern hemisphere August = February, July = January, June = December, May = November, April = October, March = September. February = August.

Miscellaneous

184 It cannot belong to 4.
185 When winter is Pr or ti, humidity regime cannot be St.
186 Ti-Tv can only combine with summer A or a.

2.1.1.5. Determination of suitability and limitations for important crops

The tables (9 to 20) give information about the suitability and the limitations of world climates for important crops :

table 9	winter cereals (wheat, rye, barley, oat);
table 10	mid-season crops (sugar beet, potato);
table 11	summer cereals (maize, sorghum, tropical millet, temperate millet, rice);
table 12	cotton;
table 13	citrus;
table 14	sugar cane;
table 15	coffee;
table 16	tea;
table 17	banana;
table 18	equatorial crops (coconut, oilpalm, hevea, cocoa);
table 19	forage resources
table 20	grapes and olives

The climatic group for Buenos Aires is **4.14.** For this group you can find information about suitability and limitations for important crops.

<u>For example table 9</u> :

4.14 Winter cereals grow well, but "actual" fertility is low, and fertilizers are necessary; the same conditions favour weeds and diseases.

Table 9. Suitability and limitations of world climates for winter cereals (wheat, rye, barley, oat)

Climate	*Suitability*
	1. *Tropical*
1.1	Too warm for winter cereals; it may be the invention of vernalizants and moderators of respiration will permit to grow them under these climates; but growth retardants and better methods of controlling diseases will also be necessary.
1.2-1.5	Same as 1.1; but winter is less warm; and in some areas with average daily minimum of the colder month approaching 13° wheat begins to appear.
1.6	See 7.1, but climate is warmer and more favourable to diseases.
1.71-1.74	Same as 1.1; but winter is less warm and in the cooler parts, some wheat begins to appear.
1.75-1.77	Same as 1.84-1.86; but climate is more humid, irrigation is sometimes unnecesary, while diseases are more favoured.
1.81-1.83	Too warm for winter cereals; they appear a little on the limit with 1.84-1.86.
1.84-1.86	Marginal for winter cereals; but they are grown a little; winter is dry in these climates and irrigation is necessary; growth retardants could help.
1.911-1.913	Same as 1.914; but winter is less dry and in many subdivisions the crops can be grown without irrigation; on the other hand, diseases cause greater damages.
1.914-1.919	Marginal for winter cereals; they are a little grown, but yields are low; growth retardants and fertilizers permit to obtain rather good yields; irrigation or flooding is necessary.
1.921-4	Same as 1.914-1.919; but winter is less dry and in many subdivisions these crops can be grown without irrigation; on the other hand diseases cause greater damages.
1.925-9	Same as 1.914-1.919.
	2. *Tierra Fria*
2.1	Same as 1.914-1.919; but winter is less warm, and consequently conditions are better; in some subdivisions winter is sufficiently humid to grow these crops without irrigation.
2.2	Same as 4.2; but in some subdivisions winter is less dry and these crops can be grown without irrigation.
2.3	Winter cereals can be sown either in spring or in autumn; but in many subdivisions irrigation is necessary for the winter crop; in some of them aven the crop sown in spring needs irrigation; irrigated and well fertilized crops yield well.
2.4	Same as 2.3.
2.5	Too frosty for winter cereals; some barley is grown, but it is often damaged by frosts.
2.6-2.9	Too cold for winter cereals.

3. *Deserts*

3.11-3.12	Analogous to 3.2; but winter is too warm for winter cereals and yields considerably lower; growth retardants could be helpful.
3.13-3.14	Winter is a little cooler than in 3.11-3.12, but still unfavourable.
3.15	Same as 3.11-3.12.
3.16-7	Same as 3.13-3.14.
3.2	Varieties with low cold requirements well fertilized and irrigated give high yields; growth retardants might still increase them.
3.3-4	Same as 3.2.
3.51	Same as 1.84-6, but irrigation is always necessary.
3.52-3	Same as 2.2; but irrigation is always necessary.
3.54	Same as 2.3; but irrigation is always necessary.
3.55	Same as 2.4; but irrigation is always necessary.
3.56	Same as 2.5; but irrigation is always necessary.

4. *Subtropical*

4.11-2	Same as 4.14, but nights are warmer and the need for growth retardants greater; in 4.121 winter is less humid and "actual" fertility higher; in 4.11 rains are frequent at harvest.
4.13	Same as 4.14, but weather is often rainy at harvest.
4.14	Winter cereals grow well, but "actual" fertility is low, and fertilizers are necessary; the same conditions favour weeds and diseases.
4.15, 4.18	Same as 4.14, but varieties with lower cold requirements are necessary and growth retardants more useful. In 4.18 "actual" fertility is usually higher in winter; winter cereals are often followed by rice in the same soil.
4.2	Adequate varieties with low cold requirements well fertilized and irrigated give high yields. which night still be increased by growth retardants; winter cereals are often grown with water stored in the soil from previous rains and/or irrigation, and they suffer from drought.
4.3-4	Same as 4.2, but winter is warmer and yields lower; the need for growth retardants is also greater; in 4.36 and 4.44-5 irrigation is not necessary.
4.5	Same as 4.2, but irrigation is not necessary, it is only desirable.

5. *Pampean*

5.11-5.12	This is one of the best regions of the world for growing winter cereals without irrigation and without fertilizers; the quality of wheat is also good due to high "actual" fertility and drought. The higher yields are obtained in 5.113; "actual" fertility is a little lower in 5.111, 5.112, 5.121-2 and 5.128; drought causes some little damages in 5.121-2, 5.128 and 5.129; and more in 5.123-7.
5.13	Winter cereals suffer considerably from drought; some years they are pastured instead of being havested; but in good years yields are high and compensate for failures; due to high "actual" fertility and drought wheat quality is still better than in 5.11-5.12.
5.14	Same as 5.113 (see 5.11), but "actual" fertility is lower and non-fertilized crops yield lower yields.
5.2	Same as 5.128 (see 5.11), but late frosts and drought cause some damages.
5.31	Same as 5.113 (see 5.11).
5.32	Same as 5.113 (see 5.11), but "actual" fertility is lower and non-fertilized crops yield lower yields; varieties with lower cold requirements are ncessary.

5.33-4 Same as 5.113 (see 5.11), but the crop suffers more from drought; varieties with lower cold requirements are necessary, and yields are lower.

5.35-6 Non-irrigated non-fertilized crops suffer from drought and/or low "actual" fertility; winter is also too warm; fertilizers and growth retardants might permit to obtain good yields.

5.37 Analogous to 5.35-6; it suffers more from drought, but "actual" fertility is higher.

5.381-2 Same as 5.35.

5.383 Same as 5.35-6, but is suffers more from drought.

5.39 Same as 5.125, but varieties with lower cold requirements are necessary; in 5.393 wheat suffers more from drought than in 5.125 and yields are lower.

5.41-2 Non-irrigated well fertilized crops yield well, but "actual" fertility is often low.

5.43 Non irrigated crops yield well; irrigation permits high yields.

5.44-6 Same as 5.41.

5.6-7 Too dry for winter cereals; they are a little grown on the limits with 5.1.

5.81 Too frosty for winter cereals, except on the limits with 5.46.

5.82 Same as 5.41-2; "actual" fertility is higher but drought more frequent.

5.83 Same as 5.81.

5.9 Too dry and/or frosty for winter cereals; in 5.92, 5.95, 5.97 and 5.98 good yields can be obtained with irrigation.

6. *Mediterranean*

6.1 Low cold requirements varieties, well fertilized give high yields; but "actual" fertility is often low, more especially in 6.12, 6.14, 6.18; drought causes some damages in 6.1312, 6.1322, 6.152, 6.163, 6.171, 6.1913 and 6.1922.

6.2 Adequate varieties, well fertilized give high yields, but "actual" fertility is often low, more especially in 6.21-2 and 6.25; drought causes serious damages in 6.24. Irrigated well fertilized crops yield very high yields.

6.3 Well fertilized crops yield high yields, but "actual" fertility is often low.

6.4 Low cold requirements varieties yield well without irrigation; fertilizers should be combined with growth retardants.

6.5 Fertilized crops yield well without irrigation, but "actual" fertility is often low, more especially in 6.51-2; drought causes sometimes damages in 6.542.

6.61-4 Fertilized crops yield well without irrigation, but "actual" fertility is often low, more especially in 6.61-2; drought causes some damages in 6.64.

6.65-9 Rather too frosty for winter cereals; they yield well as forage crops.

6.7 Well fertilized crops yield well without irrigation; "actual" fertility is often low, more especially in 6.71-2; drought causes damages in 6.723, 6.74 and 6.78.

6.8 Too dry for winter cereals; in 6.831-3, 6.835, 6.836, 6.838, 6.871 and 6.881, they are a little grown without irrigation, but failures are frequent. Irrigated and fertilized crops yield very well, when adequate varieties are used.

6.9 Too dry for winter cereals; in 6.911, 6.921 and 6.941 winter cereals are grown without irrigation, but failures are frequent. Irrigated well fertilized crops yield very well.

7. *Marine*

7.1 Same as 7.2; but winter is milder, and consequently more favourable for Ophiobolus graminis and other diseases; crops grown for forage grow better. In 7.11 and 7.13 rainy weather is frequent at harvest.

7.2 Well fertilized crops yield very well; "actual" fertility is often low; Ophiobolus and other diseases are favoured; rains are frequent at harvest in 7.21 and 7.23; in 7.23-4 crops grown for forage yield very well.

7.3 Too cool for winter cereals; oat and barley are grown on the limits with 7.2.

7.4 Too cool for winter cereals.

7.5 Same as 7.2; in 7.51 and 7.53 rains are frequent at harvest.

7.6, 7.7 Well fertilized crops yield very well; "actual" fertility is often low; winter is too severe for oat, which is sown in spring; in 7.62, 7.65, 7.71 and 7.73 barley also and part of wheat are sown in spring; but rye resists well the winter; in 7.61-2, 7.71 and 7.72 rains are frequent at harvest.

7.81 Analogous to 7.6.

7.82 Rather too frosty for winter cereals; crops grown for forage yield well.

8. *Humid Continental*

8.1 Well fertilized crops yield well; "actual" fertility is low in 8.11 and 8.13-8.15; in 8.141 and 8.151 varieties with low cold requirements are necessary and some diseases are favoured by the mild humid winters; crops grown for forage yield well; in 8.142 and 8.152 oat is sown in spring.

8.2 Winter cereals yield well; winter is too severe for oat, which is sown in spring barley also and part of wheat are sown in spring in 8.222; in 8.223 all species are sown in spring. "Actual" fertility is often low in 8.21-2 and 8.24-5, but as the crop is usually sown after maize, this is not so important; rains are frequent at harvest in 8.21, 8.23 and 8.26.

8.3 Winter cereals are sown in spring; well fertilized they yield well; "actual" fertility is often low in 8.31-2; rains are frequent at harvest in 8.31 and 8.33.

9. *Steppe*

9.1 Winter cereals yield well without irrigation; drought causes damages in 9.13; crops grown for forage yield well.

9.2 Winter cereals yield well without irrigation; this is one of the more important wheat regions of the world; good quality wheat is produced ("hard winter" and "hard spring"); winter is too severe for oat, which is sown in spring; barley and part of wheat are also sown in spring in 9.212, 9.222 and 9.232; in 9.213, 9.223 and 9 233 all species are sown in spring; drought causes damages in 9.23.

9.3 Winter cereals are sown in spring and yield well without irrigation; good quality wheat is produced ("hard spring"); drought causes damage in 9.33, more especially 9.332, and 9.35.

9.4 Winter cereals yield well; drought causes some damages in 9.42 and 9.45; in 9.41-3 winter is too severe for oat, which is sown in spring; much barley is also sown in spring.

9.5 Too frosty for winter cereals; some barley is grown on the limit with 9.3.

9.7 Too dry for winter cereals; but irrigated crops yield well; winter is too severe for oat, which is sown in spring; wheat also is always sown in spring in 9.72-5; for irrigated crops spring sowing is preferred in 9.72-4; 9.75 is too frosty for winter cereals grown for grain.

9.81	Winter cereals sown in spring yield well without irrigation, but some areas suffer from drought; oat is little grown.
9.82	Same as 9.81, but drought is more frequent; oat is little grown.
9.83	Too dry for winter cereals, but irrigated crops yield well.
9.84	Winter cereals suffer often from drought; oat is little grown.
9.85	Too dry for winter cereals, but irrigated crops yield well.
9.87	Winter cereals suffer frequently from drought; oat is little grown.
9.88	Too dry for winter cereals; irrigated crops yield well.
9.89	Barley sown in spring yields rather well.

10. *Polar, Alpine*

10.1	Too cold for winter cereals; some oat and barley are grown on the limit with 9 or 8.
10.2-4	Too cold for winter cereals.
10.5	Too cold for winter cereals; some oat and barley is grown on the limit with 7.3, 7.7, 8.3 or 9.3.

Table 10. Suitability and limitations of world climates for mid-season crops (sugar beet and potato)

Climate	*Suitability*
	1. (*Tropical*)
1.	Nights are too warm for these crops, and yields are low. It is only in 1.75-8, 1.84-1.86 and 1.9 climates that a little potato is grown in winter; in 1.6 and 1.78 conditions are fairly good for these crops.
	2. (*Tierra Fria*)
2.1-2.2	Potato is grown in winter in practically frost-free areas; but in 2.1 nights are too warm for good yields; and in 2.21-3 winter is too severe. Irrigation is usually needed. Sugar beet could be grown, using varieties with high cold requirements, but irrigation is needed and production would be probably too costly.
2.3-4	Potato yields well; depending on climate and time of planting irrigation is often needed; sugar beet could be grown, but it would be probably costly.
2.5	Potato is frequently damaged by frosts, but it is grown; irrigation is indispensable in 2.52. Sugar beet could be grown with varieties that do no bolt easily and resist frosts.
2.6-2.9	Too frosty for potato and sugar-beet. Some bitter potato (S. acaule) is grown in 2.6.
	3. (*Deserts*)
3.1	Nights are too warm in these climates and these crops yield low yields.
3.2	Potato is grown as spring or autumn crop; in practically frostless areas it could be also grown in winter. Sugar-beet could be grown in winter, but production would be costly; varieties that do no bolt easily are required.
3.31-3	Analogous to 3.1.
3.34-8	Potato grown in winter yields well; 3.36 and 3.38 are especially favourable; sugar beet could also be grown, but it would be costly.
3.4	See 3.2; 3.44 and 3.45 are especially favourable for potato; sugar beet could also be grown, but it would be costly.
3.51	See 1.7-1.8; but irrigation is indispensable.
3.52-3	See 2.1 and 2.2; but irrigation is indispensable.
3.54-5	See 2.3 and 2.4, but irrigation is indispensable.
3.56	See 2.5; but irrigation is indispensable.
3.71	Potato can be grown in spring or autumn; in the case of sugar beet the two crops interlap.
3.72	Same as 3.71; but the two crops of potato interlap.
3.73	Potato is grown in summer.
3.8	Potato is grown during the frost-free season; good yields can be obtained from healthy well fertilized and irrigated crops. Sugar beet can also be grown, but it would be costly.
3.9	Same as 3.8, but the growing season is shorter.

4. *(Subtropical)*

4.1 Potato is grown as spring or autumn crop; and where winter is practically frostless, as winter crop too; sugar beet can be grown in winter.

4.2-3 Same as 4.1, but irrigation is needed more especially in winter and spring.

4.4-5 Same as 4.1, but irrigation is needed in 4.41-4.43 and 4.52.

5. *(Pampean)*

5.111 Non-irrigated potato and sugar beet yield well; they grow in summer.

5.112 Same as 5.111 but conditions are less favourable (drier climate, warmer nights).

5.113 Same as 5.31, but conditions are less favourable (sowing of the spring crop is later, and that of the autumn crop earlier; winter is more frosty).

5.121 Same as 5.31, but the crop suffers considerably more from drought.

5.122-9 Too dry fro potato and sugar beet; they could be grown with irrigation.

5.31 Potato is grown in spring or autumn, and yields well without irrigation, sugar beet could be grown as winter crop.

5.32 Same as 5.31, but these crops suffer more from drought.

5.33-4 Too dry for potato and sugar beet.

5.35 Same as 5.31, but these crops suffer more from drought and long-warm nights.

5.36-7 Too dry for these crops.

5.381 Same as 5.31, but drier more especially for the autumn potato crop.

5.382-3 Too dry and frosty for these crops.

5.391 Same as 5.31, but these crops suffer more from drought.

5.392-3 Too dry for these crops.

5.41 Same as 5.111.

5.42 Too dry for these crops.

5.43-6 Analogous to 5.111.

5.6-7 Too dry for these crops.

5.8 Potato yields well without irrigation; but the drier parts of 5.81 are too dry for this crop, the growing season is rather too short for sugar beet.

5.9 Too dry for these crops; potato can be grown with irrigation.

6. *(Mediterranean)*

6.1 Potato can be grown in spring or autumn; sugar beet could be grown in winter; but irrigation is necessary except perhaps for the winter and/or spring crop of 6.121-2 and 6.181-2.

6.2 Potato and sugar beet yield well with irrigation; in 6.21 and 6.25 irrigation is not indispensable for the spring crop of potato and the winter crop of sugar beet (that sown in autumn-winter).

6.3 Irrigated potato and sugar beet yield well; irrigation is not indispensable, but desirable.

6.4 Potato and sugar beet can be grown in winter; irrigation is necessary except in 6.41 and 6.43, where it is desirable.

6.5 Potato and sugar beet yield well with irrigation.

6.6 Potato and sugar beet yield well with irrigation; 6.69 is too cool for sugar beet.

6.71-4 Same as 6.5, but the growing season is shorter or warmer and conditions less favourable; irrigation is necessary, except for the pring crop of 6.711.

6.75-9 Irrigated potato and sugar beet yield well.

6.8 Potato is grown in spring or autumn; and where the climate is almost frostless in winter too; sugar beet can be grown in winter. With irrigation, which is indispensable, good yields are obtained.

6.9 Potato and sugar beet yield well with irrigation.

7. *(Marine)*

7.1-7.2	Potato and sugar beet yield very well without irrigation; this is one of the best climates for these crops.
7.3-4	The growing season is too short for these crops, but potato is grown near to the limit with 7.2.
7.5	Same as 7.1-7.2, but 7.523-4 are drier.
7.6	Same as 7.1-7.2.
7.7-8	Same as 7.1-7.2, but the growing season is rather too short for sugar beet.

8. *(Humid Continental)*

8.1	These crops are grown either in spring or in autumn; but they suffer from drought and/or long-warm nights.
8.2-8.3	Potato and sugar beet grow well without irrigation; in 8.3 the growing period is rather too short for sugar beet.

9. *(Steppe)*

9.1	Too dry for potato and sugar beet.
9.21	Potato and sugar beet can be grown without irrigation, but they suffer from drought.
9.22-3	Too dry for potato and sugar beet.
9.31	Potato can be grown without irrigation, but suffers from drought; the growing season is rather too short for sugar beet.
9.32-3	Too dry for potato and sugar beet.
9.41-2	Same as 9.32-3.
9.43	Same as 7.6.
9.5	Too cool for sugar beet, potato is grown.
9.7	Too dry for potato and sugar beet; they are grown with irrigation in 9.72-4.
9.8	Too dry for potato and sugar beet; they are grown with irrigation in 9.81-5 and 9.89.

10. *(Polar - Alpine)*

10.1	Too cool for potato and sugar beet; some potato is grown near to the limit with 8.3 or 9.3.
10.2-4	Too cool.

Table 11. *Suitability and limitations of world climates for summer cereals (maize sorghum, tropical millet ("Pennisetum cinereum"), temperate millet ("Panicum milliaceum"), rice)*

Climate	*Suitability*
	1. *(Tropical)*
1.1-1.4	The chief handicaps are: 1) warm long nights that favour leaf-shoot growth, accelerate respiration, and produce tall-leafy crops with low grain yields; 2) when the crop is sown to be harvested during the humid season, the grain is difficult to store; and when the crop is sown to be harvested during the dry season, it is often damaged by drought; 3) "actual" fertility is low during the humid season and the best time of sowing, in this respect, is the beginning of the humid season, but crops sown at this time are often harvested under rainy weather. For all these reason yields are low in these climates; and the best season to grow them, from a temperature point of view, is the dry one (low minimum temperatures). En 1.1 and 1.2 maize is preferred to sorghum and millet, but it is not extensively grown because it is often harvested under rainy weather; sorghum and millet are very little grown except in 1.14 and 1.24, where the dry season is longer. In 1.3 maize is extensively grown; the long intermediate seasons of these climates are not too dry for this crop and permit to harvest under reasonably good weather. In 1.4 maize is sown at the beginning of the humid season; sorghum and millet are sown later to be harvested during the dry season; and since the grain harvested during the dry season is easier to be stored, sorghum and millet are more extensively grown. Naturally preference depends also on dietary habits; in South America sorghum and millet are little grown. Rain-fed rice can be grown wherever the dry season is > 5 months; but to avoid drought the whole period of growth should be included in the humid season, harvesting is done under rainy weather, and the grain is difficult to store. Irrigated rice is grown everywhere; but only that harvested during the dry season is easy to store; from a temperature point of view the dry season (low minimum temperatures) is the best; but usually irrigation water is scarce during it. The use of fertilizers, growth retardants, and grain-dryers permit to overcome many of the fore-mentioned difficulties and obtain high yields of summer cereals in the tropics (Papadakis 1966, 1968).
1.5	Sorguhm and millet are grown without irrigation in 1.531 - 1.533, 1.541, 1.571 - 1.573 and 1.581; millet is grown even in 1.534, 1.542, 1.574 and 1.582; in 1.543-4 and 1.583-4 the non-dry season is too short even for millet; Principal handicaps long-warm nights and drought. Maize is little grown. With irrigation rice, maize and sorghum yield well; the best yields are obtained when the crop is grown during the dry season; (cooler nights); but irrigation water is usually scarce during it. Growth retardants and fertilizers will permit to increase yields considerably (Papadakis 1966, 1968).
1.6	Same as 1.1, but nights are cooler permitting better yields. Maize and rice are preferred to sorghum and millet, which are very little grown.
1.7, 1.8	The cooler nights of these climates make them better than 1.1 - 1.5 for summer cereals; naturally, the best season to grow these crops from a temperature point of view is winter; but irrigation is usually needed and water is scarce during this season. Maize is preferable in 1.7, 1.81 and 1.84; sorghum and millet in 1.82 and 1.85; in 1.83 and 1.86 even sorghum and millet fail frequently. Rain-fed rice can be grown in 1.71 - 1.73 and 1.75 - 1.76; irrigated rice everywhere. 1.78 is too cool for summer cereals.

1.9 Same as 1.1, but winter is cooler, and when hydric conditions or irrigation permit to grow these crops in winter, yields are better; however the bulk of the crop is grown during the humid season and suffers from long warm nights. Sorghum and millet are extensively grown in 1.914-8 and 1.925 - 1.9291; 1.919 and 1.9292 are too dry even for them. Rain-fed rice could be grown in 1.911-3 and 1.921-4; maize could be grown without irrigation in 1.911-4 and 1.921-5; but the grain would be harvested under rainy weather and storage would be difficult; that is why it is little grown. Irrigated rice is grown everywhere.

2. *(Tierra Fria)*

2.1-2.2 The cool nights of these climates make them good for summer cereals, which are grown during the frost-free season. Maize can be grown without irrigation in 2.11-4, 2.21 and 2.24-7. In 2.15, 2.22 and 2.28 sorghum and millet yield better; 2.16, 2.23 and 2.29 are too dry even for them. Rain-fed rice is possible in 2.11-2 and 2.24-5; irrigated rice everywhere.

2.3 This climate is still better for maize than 2.1 - 2.2 (cooler nights); but rice can only be grown in 2.31-6. Maize is preferable to sorghum in 2.31-4 and 2.37-8; 2.36 and 2.39 are too dry for summer cereals; 2.37-9 are too cool for sorghum.

2.4-9 Too frosty-cool for summer cereals; maize is grown a little on the limit with 2.3.

3. *(Deserts)*

3.1 Irrigated summer cereals can be grown all the year round, but nights are usually too warm, and yields rather low. The best season to grow them is winter (lower night temperatures), when naturally irrigation water is available; the climates with the cooler winters are 3.13-4 and 3.16-7.

3.2 The relatively cool nights of these climates make them very good for irrigated summer cereals, more especially when the crop is grown in autumn. Fertilizers permit to obtain very high yields. Sorghum is only grown where irrigation water is scarce. Maize is preferably grown in autumn when nights are cooler and potential evapotranspiration lower at tasseling. Rice is extensively grown.

3.3-4 Same as 3.2; potential evapotranspiration is lower and this fact permits to economize water; 3.45 is rather too cool for them.

3.51 Same as 1.7 - 1.8, but irrigation is always necessary.

3.52-3 Same as 2.1-2, but irrigation is always necessary.

3.54 Same as 2.3, but irrigation is always necessary.

3.55-6 Too frosty for summer cereals; they are a little grown with irrigation on the limit with 3.54.

3.71-2 Irrigated summer cereals are grown during the frost-free season and yield well, when adequately fertilized; some parts of 3.72 are too cool for rice and sorghum.

3.73-5 Too cool for summer cereals.

3.8 Irrigated maize yields well in these climates; but 3.82-5 are too cool for rice.

3.9 Too cool for summer cereals.

4. *(Subtropical)*

4.1	Non-irrigated summer cereals yield well. Maize is preferred to sorghum and millet; irrigated rice is often the most important crop, and rain-fed rice could also be grown. Nights are rather too warm for maize in 4.11-2; but they are sufficiently cool for rice and sorghum. Rains are frequent at harvest in 4.11 and 4.13, 4.122-3, 4.14 and 4.15 are too dry for rain-fed rice.
4.2-3	Non-irrigated sorghum and irrigated rice are very important crops in these climates; however nights are too warm in summer. Fertilizers combined with growth retardants permit high yields. Maize is little grown (short dry season or rainy weather at harvest); 4.25 and 4.34 are the best subdivisions for it; 4.2211-2, 4.31 and 4.321 are too dry even for sorghum.
4.4	Same as 4.1, but nights are warmer. Maize is preferred in 4.44-5, but weather is often rainy at harvest; rice also can be grown without irrigation in 4.43. Irrigated rice can be grown everywhere.
4.5	Same as 4.2; 4.51 is better for maize and 4.52 for sorghum.

5. *(Pampean)*

5.11-2	Same as 5.113, but the crop suffers more from drought and it is harvested under more rainy weather; moreover, "actual" fertility is usually lower. Too cool for rice.
5.113	This is one of the best climates for maize in the world; nights are cool, spring is humid, winter is dry and "actual" fertility at sowing high. But drought causes serious damages some years. Maize is preferred to sorghum.
5.121	Same as 5.113, but drought makes maize rather hazardous, too cool for rice.
5.122	Summer is too dry for maize, rather too cool for sorghum; too cool for rice.
5.123	Too dry for maize; rather too cool and too dry for sorghum; too cool for rice.
5.125	Rather too dry for maize; good for sorghum.
5.126-7	Rather too dry for maize; good for sorghum; too cool for rice.
5.128	Rather too dry for maize, rather too cool for sorghum; too cool for rice.
5.129	Good for maize, but less than 5.113; good for sorghum.
5.13	Too dry for maize; sorghum yields well some years, but fails in others; too cool for rice.
5.14-5	Too dry for maize; rather too dry for sorghum.
5.2	Too frosty for summer cereals.
5.31	Same as 5.113; irrigated rice yields well.
5.32-3	Rather too dry for maize; good for sorghum and irrigated rice.
5.34	Good for maize, sorghum and irrigated rice.
5.35-7	Nights are rather too warm for summer cereals, more especially maize; growth retardants would be helpful; sorghum yields better than maize; irrigated rice is extensively grown.
5.381	Same as 5.35-7; but sufficiently humid for maize.
5.382-3	Same as 5.35-7.
5.39	5.891 is analogous to 5.381, 5.392 to 5.33 and 5.393 to 5.611.
5.611	Too dry for maize; good for sorghum and irrigated rice.
5.612	Rather good for maize; too cool for rice.
5.621	Too dry for maize; even sorghum can hardly be grown without irrigation; good for irrigated rice.
5.622	Same as 5.621, but too cool for rice.
5.7	Summer cereals need irrigation; climates with M summer are too cool for rice.
5.8, 5.91-7	Too cool for summer cereals.
5.98	Maize could be grown with irrigation; too cool for sorghum and rice.

6. *(Mediterranean)*

6.11-6.17	Maize needs irrigation; it is a little grown without irrigation in flooded lowlands; sorghum behaves a little better, but it is little grown because it reduces "actual" fertility and wheat gives low yields after it; irrigated rice yields well, but nights are a little warmer than optimum.
6.18-9	Same as 6.11 - 6.17, but nights are cooler and consequently more favourable; maize can be grown without irrigation in 6.181-2.
6.21-6.24	Same as 6.11 - 6.17, but nights are cooler. Irrigated summer cereals give very high yields; in the less dry parts of 6.21 maize can be grown without irrigation.
6.25-6.26	Too cool for summer cereals.
6.27	Maize is grown; but too cool for rice and sorghum.
6.28	Too cool for summer cereals.
6.3	Too cool for summer cereals.
6.4	Winter sown maize is a little grown without irrigation, but it is little grown; irrigated summer cereals yield well.
6.5	Maize is a little grown in 6.51; but 6.52-4 are too dry for it. Sorghum behaves a little better but it is little grown because of its effect on "actual" fertility; irrigated summer cereals yield well, but many of these climates are too cool for rice.
6.6	Too cool for summer cereals. Some temperate millet is grown on the limit with 6.5 or 6.2.
6.7	Maize is grown a little in 6.711-2 and 6.75; but the remaining climates are too dry for it; sorghum behaves a little better, but it is little grown because of its effect on "actual" fertility; irrigated summer cereals yield well; but some areas of 6.76-7, and 6.78-9, are too cool for rice; and 6.79 is too cool for summer cereals; some temperate millet is grown in the warmer areas of 6.79.
6.8-9	Summer cereals cannot be grown without irrigation, but when irrigated they give high yields; 6.92 is too cool for rice; and 6.94-5 is too cool for all summer cereals.

7. *(Temperate)*

7.1-7.4	Too cool for summer cereals.
7.5	Good for maize; however on the limits with 7.2 and 7.6 summer is rather cool for it. Sorghum is little grown. Too cool for rice; temperate millet grows well on the limits with 7.6.
7.6-8	Too cool for summer cereals. Some temperate millet is grown on the limits with 7.5 or 8.2.

8. *(Humid Continental)*

8.1	Nights are a little too warm for maize; maize yields rather well and it is preferred to sorghum; irrigated rice yields very well.
8.21	Same as 8.22, but weather is rainy at harvest; moreover "actual" fertility is lower; continuous rains favour rice growing, but it is harvested under rainy weather.
8.22	This is the eastern part of the American "corn belt", one of the best regions of the world for non-irrigated and fertilized maize; the crop suffers only exceptionnally from drought; moreover there is an interruption of rains (indian summer) that permits better ripening and harvest; "actual" fertility is rather low, because winter is humid, but this difficulty is overcome by adequate rotations and fertilizers. Sorghum is little grown; too cool for rice, except on the limit with 8.1.

8.23-4	Same as 8.22 but more rainy. O subdivisions are good for rice.
8.25	Same as 8.22 but maize suffers from drought some years.
8.26	Same as 8.22, but rains are less sure, that is why sorghum is preferred to maize.
8.3	Too cool for summer cereals. Some temperate millet is grown on the limits with 8.2.

9. *(Steppe)*

9.1	Maize suffers from drought, more especially in 9.12 and 9.13; moreover nights are warmer than optimum; sorghum and irrigated rice yield well.
9.21	This is the western part of the American "corn belt". Same as 8.22, maize suffers a little more from drought; on the other hand "actual" fertility is higher and soils better. Sorghum is little grown. Too cool for rice, except on the limits with 9.1.
9.22-3	Too dry for maize; sorghum is preferred; however 9.223 and 9.233 are too cool for it; rice is not grown except on the limits with 9.1; in 9.223 and 9.233 temperate millet could be grown.
9.3-5	Too cool for summer cereals; some temperate millet is grown on the limit with 9.2.
9.7	Summer cereals cannot be grown without irrigation; some sorghum can be grown without irrigation on the limits with 9.2. Irrigated rice yields well in 9.71; 9.73-5 are too cool for summer cereals.
9.81	Too cool for summer cereals. Some millet is grown on the limit with 9.82.
9.82	Maize suffers from drought; sorghum is grown; rather too cool for rice.
9.83	Too dry for sorghum, except on the limits with 9.82; too cool for rice.
9.84	Too dry for maize; sorghum is preferred; irrigated rice yields well.
9.85	Even sorghum suffers from drought; irrigated rice yields well.
9.87	Maize suffers from drought, sorghum is grown; irrigated rice yields well.
9.88	Even sorghum suffers from drought; irrigated rice yields well.
9.89	Too cool for summer cereals. Some millet is grown with irrigation on the limit with 9.82.

10. *(Polar)*

10.	Too cool for summer cereals.

Table 12. *Suitability and limitations of world climates for cotton*

Climate	Suitability
	1. *(Tropical)*
1.1, 1.2	Too humid for cotton; it is a little grown in the drier subdivisions of 1.14 and 1.24; but the phytosanitary problems are serious; it may be advances in pest and disease control will change the situation.
1.3	Cotton is grown a little without or with irrigation; but the phytosanitary problems are serious; 1.32 and 1.37 have the drier long seasons and are consequently the best, more especially when irrigation is given.
1.4	1.46, 1.47, 1.481 and 1.482 are too humid for cotton; it is a little grown in 1.41, 1.42, 1.481-3; and more in 1.484 and 1.485. But the phyto-sanitary problems are serious.
1.5	Cotton is grown without irrigation in 1.531-2, and 1.571-2; and with irrigation everywhere: Phyto-sanitary problems are serious but less than 1.1 - 1.4.
1.6	Too humid for cotton.
1.7-8	1.71 - 1.73 and 1.75 - 1.76 are too humid for cotton; 1.78 is too cool; some cotton is grown without irrigation in 1.74, and more in 1.8; but in 1.83, 1.86 and the drier parts of 1.82 and 1.85 irrigation is necessary; the phyto-sanitary problems are less serious than in 1.1 - 1.5.
1.9	1.911-2 and 1.921-3 are too humid for cotton. In 1.913-5 and 1.924-7 cotton is grown without irrigation; and in 1.916-9, 1.927-9 with irrigation; the phyto-sanitary problems are less serious than in 1.1 - 1.5.
	2. *(Tierra Fria)*
2.1-2.2	2.11-2, 2.24-5 are too humid for cotton; in the remaining irrigation is indispensable or highly desirable; the phytosanitary problems are less serious than in 1.
2.3-2.9	Too cool for cotton.
	3. *(Deserts)*
3.1	Same as 3.2, but the phyto-sanitary problems are more serious.
3.2	Irrigated cotton is one of the principal crops of this climate and long staple cotton (egyptian) is produced.
3.31-5, 3.37	Irrigated cotton is one of the principal crops of this climate and long staple cotton (Tanguis) is produced.
3.36	Rather too cool for cotton.
3.41-3	Same as 3.31-5.
3.44-5	Too cool for cotton.
3.51	Same as 1.83 and 1.86.
3.52-3	Same as 2.1 - 2.2, but irrigation is indispensable, and the phyto-sanitary problems less serious.
3.54-6	Too cool for cotton.
3.71	Irrigated cotton is one of the principal crops of this climate.
3.72-5, 3.8, 3.9	Too frosty or cool for cotton.

4. (*Subtropical*)

4.1	Cotton can be grown, but it rains at harvest, more especially in 4.11 and 4.13; 4.121 is the best.
4.2-4.3	Cotton is extensively grown with or without irrigation; in 4.2211-2 and 4.31 irrigation is indispensable.
4.42-3	Cotton is grown with or without irrigation.
4.44-5	Rather too humid for cotton.
4.51-2	Cotton is grown with or without irrigation.

5. (*Pampean*)

5.1-5.2	Too frosty for cotton.
5.31-36	Autumn is too rainy for cotton.
5.37-39	Cotton is grown extensively, chiefly without irrigation, but in some areas it is irrigated; irrigation is indispensable in the drier areas of 5.383; autumn is rather too rainy in 5.392.
5.4	Too cool for cotton.
5.6	Irrigated cotton can be grown in 5.611 and 5.621; 5.612 and 5.622 are too frosty for cotton.
5.71-4	Too frosty for cotton.
5.76-8	Irrigated cotton is extensively grown.
5.79, 5.8-9	Too cool for cotton.

6. (*Mediterranean*)

6.1	Irrigated cotton yields well; but in some subdivisions autumn is too rainy; growing cotton without irrigation is difficult.
6.2-3	Too cool for cotton.
6.41-2	Analogous to 6.1.
6.43-4	Too cool for cotton.
6.5-6	Too cool for cotton.
6.71	Autum is rather too rainy for cotton.
6.72-3	Irrigated cotton grows well; growing cotton without irrigation is difficult; autumn is rather too rainy.
6.74	Irrigated cotton grows well; irrigation is practically indispensable.
6.75-9	Too cool or frosty for cotton.
6.81-4	Irrigated cotton yields well; irrigation is indispensable; long staple cotton can be grown.
6.85	Too cool for cotton.
6.86-7	Same as 6.81-4.
6.88	Too cool for cotton.
6.89	Same as 6.81-4.
6.91	Irrigated cotton yields well; irrigation is indispensable.
6.92-5	Too cool for cotton.

7. (*Marine*)

7.	Too cool for cotton.

8. *(Humid Continental)*

8.11	Too humid for cotton.
8.12	Analogous to 8.14, but autumn is more rainy.
8.13	Too humid for cotton.
8.14	This is the eastern part of the American "cotton belt", one of the best climates of the world for non-irrigated cotton; autumn is non-humid; winter is cold.
8.15	Analogous to 8.14, but autumn is more rainy.
8.16-7	Same as 8.14.
8.18	Same as 8.14.
8.19	Same as 8.14.

9. *(Steppe)*

9.1	This is the western part of the American "cotton belt", one of the better climates of the world for cotton; harvest is done under dry weather and winter is cold; the crop suffers often from drought, but irrigated cotton yields very well.
9.2-5	Too cool for cotton.
9.71	Irrigated cotton yields very well.
9.72-5	Too cool for cotton.
9.81-5	Too cool for cotton.
9.87	Cotton is grown without irrigation; it yields very well with irrigation.
9.88	Same as 9.87, but irrigation is almost indispensable.
9.89	Too cool for cotton.

10. *(Polar-Alpine)*

10.	Too cool for cotton.

Table 13. *Suitability and limitations of world climates for citrus*

Climate	*Suitability*
	1. *(Tropical)*
1.1-2	High humidity favours diseases. Citrus can be grown without irrigation in 1.11-1.13 and 1.21-3; in 1.14 and 1.24 irrigation is necessary.
1.3	Diseases are less favoured than in 1.1-2; citrus can be grown without irrigation in 1.34-5; in the other subdivisions irrigation is more or less necessary.
1.4	Citrus can be grown without irrigation in 1.412 and 1.47; in the other subdivisions irrigation is necessary.
1.5	Citrus can be grown with irrigation.
1.6	Citrus are grown without irrigation.
1.7	Citrus can be grown without irrigation in 1.71-1.73 and 1.75-6; in the other subdivisions irrigation is more or less necessary; 1.78 is too cool.
1.8	Citrus can be grown without irrigation in 1.811 and 1.841; in the other subdivisions irrigation is necessary.
1.9	Citrus can be grown without irrigation in 1.911 and 1.921-2; in the other subdivisions irrigation is necessary.
	2. *(Tierra fria)*
2.1-2	Citrus can be grown without irrigation in 2.11-2 and 2.24-5; in the remaining subdivisions irrigation is more or less necessary. Diseases cause less damages and the colour of oranges is better in 2.2 than in 2.1 or 1. Av climates are too frosty.
2.3	Rather too cool for citrus.
2.4-2.9	Too cool for citrus.
	3. *(Deserts)*
3.1-4	Irrigated citrus yield well in these climates; however 3.27 is too frosty for them; the colour of oranges is better in 3.2, 3.34-8 and 3.4.
3.5	These climates are usually too frosty for citrus; but where the winter is *Ci* and summer *O* or warmer, they yield well.
	4. *(Subtropical)*
4.1	Citrus yield well without irrigation; the colour of oranges is good.
4.2-3	Citrus require irrigation; it is only in 4.36 that are grown without irrigation; the colour of oranges is good.
4.4	Citrus can be grown without irrigation in 4.44-5; they require irrigation in 4.42-3; the colour of oranges is a little deficient.
	5. *(Pampean)*
5.1-2	Too frosty for citrus.
5.3	Citrus van be grown without irrigation in 5.31-6, 5.381 and 5.391; in the other subdivisions irrigation is more or less indispensable; the colour of oranges is good.
5.4	Rather too cool.
5.6-9	Too frosty for citrus.

6. *(Mediterranean)*

6.1	Irrigated citrus yield fruits of excellent quality; color of oranges is very good.
6.2	Similar to 6.1, but ripening is often deficient, except for lemon.
6.3	Too frosty for citrus.
6.4	Same as 6.1.
6.5-6.7	Too frosty for citrus.
6.8	Same as 6.1; *Av* subdivisions are too frosty; and *O-M-T* rather cool or too cool.
6.9	Too frosty for citrus.

7., 8., 9., 10. *(Other climates)*

7., 8., 9., 10	Too cool for citrus.

Table 14. Suitability and limitations of world climates for sugar cane

Climate	*Suitability*
	1. *(Tropical)*
1.11-2	Similar to 1.23 - 1.24; but nights are warmer and less favourable for sugar accumulation; moreover, weather at harvest is often rainy.
1.13-4	Similar to 1.23-4; but nights are warmer and less favourable for sugar accumulation; growth retardants permit now to overcome this difficulty.
1.21-2	Similar to 1.23-4; but weather at harvest is often rainy.
1.23-4	One of the best climates of the world for non-irrigated sugar-cane; winter is cool and dry.
1.3-5	Similar to 1.23-4, but nights are a little too warm in some parts; and the crop requires irrigation in most of them to give high yields.
1.6	Rather too cool and rainy for sugar cane.
1.7-1.9	Same as 1.23-4; but weather is rainy at harvest in some parts, and irrigation is needed in others.
	2. *(Tierra Fria)*
2.1-2	Where winter is practically frostless sugar cane yields high hields; it is harvested every winter; in some parts weather is a little rainy at harvest.
2.3-9	Too frosty for sugar cane.
	3. *(Deserts)*
3.1	Similar to 3.34, but nights are a little too warm; growth retardants permit to overcome this difficulty.
3.2	One of the best climates for irrigated sugar cane; but it should be harvested every year; 3.27 is too frosty; practically frostless areas are preferable.
3.31-3.33	Similar to 3.34, but nights are warmer.
3.34-5, 3.37	The best climate for irrigated sugar cane; nights are cool and the climate practically rainless; harvest may be done at whatever period of the year. Potential evapotranspiration is low and consequently water consumption is low.
3.36-8	Rather cool for sugar cane.
3.4-3.9	Too cool and/or frosty for sugar cane.
	4. *(Subtropical)*
4.1	Sugar cane is grown in practically frost-free areas.
4.2-3	Irrigated sugar cane yields well in practically frost-free areas; it is harvested every winter; irrigation is necessary, except in 4.25 and 4.36; 4.21 and 4.222 are too frosty.
4.4-4.5	Irrigated sugar cane yields well in practically frost-free areas; irrigation is needed in 4.42 and 4.52.

5. *(Pampean)*

5.	Too frosty for sugar cane.

6. *(Mediterranean)*

6.1-6.3	Too frosty for sugar cane; it is grown a little in practically frost-free areas of 6.1.
6.4	Irrigated sugar cane yields well in 6.41-2; 6.43-4 are too cool.
6.5-7	Too frosty for sugar cane.
6.8	Irrigated sugar cane can be grown in practically frost-free areas; *M-O* climates are rather too cool.
6.9	Too frosty for sugar cane.

7., 8., 9., 10. *(Other Climates)*

7., 8., 9., 10	Too frosty for sugar cane.

Table 15. *Suitability and limitations of world climates for coffee*

Climate	*Suitability*
	1. *(Tropical)*
1.1-1.5	Too warm for arabica coffee; robusta and liberica are grown; but 1.31-2, 1.36-7, 1.42, 1.462, 1.482-1.485, 1.5 are too dry for it.
1.6	Sufficiently cool and humid for arabica coffee.
1.71-2	Same as 1.73, but flowering is distributed over a longer season, and this fact makes harvesting more difficult.
1.73	Typical arabica coffee climate.
1.74	Rather too dry for coffee.
1.75-6	Same as 1.73, but flowering is distributed during a longer season and this fact makes harvesting more difficult.
1.77	Same as 1.73; shading is not used.
1.78	Too cool for coffee.
1.8	Too dry for coffee.
1.9	Too warm for arabica coffee; robusta and liberica could be grown in 1.911-2 and 1.921-2.
	2. *(Tierra Fria)*
2.1-2.2	Too frosty for coffee. Arabica coffee is grown in practically frost-free areas of 2.11-2.12 and 2.24-5, but occasional frosts cause considerable damages.
2.3-2.9	Too cold for coffee.
	3. *(Deserts)*
3.1-2,3.31-2	Too warm and/or frosty for arabica coffee.
3.34-5	Irrigated arabica coffee could be grown
3.4	Too frosty for coffee.
3.51	Irrigated arabica coffee could be grown.
3.52-6,3.7-9	Too cold for coffee.
	4. *(Subtropical)*
4.1	Too warm and/or frosty for coffee. Some arabica coffee is grown in practically frost-free areas of 4.13; but occasional frosts cause considerable damages.
4.2-4.5	Too frosty for coffee.
	5. *(Pampean)*
5.	Too cold for coffee.
	6. *(Mediterranean)*
6.1-6.3	Too cold for coffee.
6.4	Irrigated coffee could perhaps be grown.
6.5-6.9	Too cold for coffee.
	7., 8., 9., 10., *(Other climates)*
7., 8., 9., 10.	Too cold for coffee.

Table 16. Suitability and limitations of world climates for tea

Climate	Suitability
	1. *(Tropical)*
1.1-2	Rather too warm for tea.
1.3-5	Too dry for tea.
1.6	Good for tea.
1.71-3	Good for tea.
1.75-8	Good for tea.
1.74, 1.8	Too dry for tea.
1.9	Rather too warm for tea; it is also too dry, except 1.921-2.
	2. *(Tierra Fria)*
2.11-2	Good for tea, a little too warm.
2.13-6	Too dry for tea.
2.21-3	Too dry for tea.
2.24	Good for tea.
2.25-9	Too dry for tea.
2.31	One of the best climates for high quality tea.
2.32	Rather good for tea.
2.33-9	Too dry for tea.
2.411	One of the best climates for high quality tea.
2.42-4	Too dry for tea.
2.5-2.9	Too frosty for tea.
	3. *(Deserts)*
3.	Too dry for tea.
	4. *(Subtropical)*
4.11	Good for tea.
4.121	Rather good for tea.
4.122-3	Rather too dry for tea.
4.13	Good for tea.
4.14-5	Too dry for tea.
4.18	Rather good for tea.
4.2-3	Too dry for tea.
4.41-4	Too dry for tea.
4.45	Rather good for tea.
4.5	Too dry for tea.

5. *(Pampean)*

5.	Too dry for tea.

6. *(Mediterranean)*

6.	Too dry for tea.

7. *(Marine)*

7.11	Good for tea.
7.12	Too dry for tea.
7.13	Rather too cool for tea.
7.14	Too dry for tea.
7.2-4	Too frosty for tea.
7.51-2	Too cool for tea.
7.53	Rather good for tea.
7.6-8	Too cold for tea.

8., 9., 10. *(Other climates)*

8., 9., 10.	Too cold for tea.

Table 17. Suitability and limitations of world climates for banana

Climate	Suitability
	1. (*Tropical*)
1.1-2	Good for banana. In 1.13-4 and 1.23-4 irrigation is desirable.
1.3	Good for banana, irrigation is desirable everywhere, it is neecssary in 1.36 and 1.37.
1.4	Good for banana; it can be grown without irrigation in 1.47; but in 1.42, 1.462 and 1.483-5 irrigation is necessary.
1.5	Good for irrigated banana.
1.6	Good for banana; 1.65 is too cool.
1.7	Good for banana; irrigation is desirable in 1.73; it is necessary in 1.74 and parts of 1.77; 1.78 is too cool.
1.8	Good for banana; irrigation is desirable everywhere; it is necessary in 1.813, 1.82-3, 1.843 - 1.86.
1.9	Good for banana; irrigation is everywhere desirable; it is necessary in 1.913-19 and 1.924-9.
	2. (*Tierra Fria*)
2.1-2	Banana can be grown in practically frost-free areas; irrigation is necessary in 2.13 - 2.16, 2.21-3 and 2.26 - 2.29.
2.3-2.9	Too frosty for banana.
	3. (*Deserts*)
3.1	Good for banana.
3.2	Banana is grown in practically frost-free areas.
3.3	Good for banana; 3.36-7 are rather too cool.
3.4	Banana is grown in practically frost-free areas.
3.51	Good for banana.
3.52-6	Too frosty for banana.
3.7-3.9	Too frosty for banana.
	4. (*Subtropical*)
4.1	Banana is grown in practically frost-free areas.
4.2-3	Irrigated banana is grown in practically frost-free areas.
4.4-5	Banana is grown in practically frost-free areas; irrigation is necessary in 4.41 - 4.43 and 4.52.

5. *(Pampean)*

5.	Too frosty for banana.

6. *(Mediterranean)*

6.1	Irrigated banana can be grown in practically frost-free areas.
6.2-3	Too frosty for banana.
6.4	Good for irrigated banana.
6.5-7	Too frosty for banana.
6.8	Irrigated banana can be grown in practically frost-free areas.
6.9	Too cold for banana.

7., 8., 9., 10. *(Other climates)*

7.,8., 9.,10.	Too cold for banana.

Table 18. Suitability of world climates for equatorial crops

Climates	*Suitability*
	1. *(Tropical)*
1.11	Good for coconut, oil palm and hevea; too humid for cocoa.
1.121	Same as 1.11, but cocoa is grown where Ln is < 1,000 mm.
1.122	Good for all including cocoa.
1.123	Same as 1.11.
1.131	Typical cocoa climate; good for coconut, oil palm and Hevea.
1.132-3	Same as 1.11.
1.134	Same as 1.131.
1.135	Rather too dry for cocoa and rubber; coconut and oil palm can still be grown in soils with high water holding capacity.
1.141-2	Same as 1.135.
1.143-4	Too dry for equatorial crops; some coconut is grown in coast sands.
1.2	Too cool for these crops; some coconut is grown in coast sands.
1.3	Too dry for these crops. Some coconut is grown in coast sands.
1.41-1.46	Too dry for these crops; some coconut is grown in coast sands of 1.46.
1.47	Good for equatorial crops; they suffer from dry spells; 1.476 is too humid for cocoa.
1.48	Too dry for equatorial crops. Some coconut and oil palm is grown in 1.481; coconut etxends into coastal sands of climates drier than 1.481.
1.5	Too dry for equatorial crops.
1.6	Too cool for equatorial crops.
1.7-1.8	Too cool for equatorial crops; cocoa advances a little into 1.7-1.8 when the climate is sufficiently, but not too humid; sometimes it is grown with irrigation.
1.9	Too cool for equatorial crops. Some coconut is grown in coastal sands.
	2. - 10. *(Other Climates)*
2.-10.	Too cool and frosty for equatorial crops.

Table 19. *Forage resources according to climate*

Climate	Forage Resources
	1. (Tropical)
1.1-2	Natural vegetation is forest and does not provide grazing; but in many areas it has been open by cropping and burning; however the quality of grazing is poor. Due to warm-long nights, grasses grow rapidly and are not nutritive; there are not legumes. It may be legumes (centrosema, etc.) could be introduced in pasturelands; but fertilization and adequate management would be necessary. The true solution will be nitrogen fertilizers and forage crops. Natural pasturelands, when well fertilized with nitrogen combined with minerals and growth retardants give abundant and nutritive forage; but if abundant fertilizers are used, it will be probably preferable to give them to forage crops and sown grairies. Many forage crops (maize, sorghum, Stizolobium, cowpea, Stylosanthes, Centrosema, etc.) are possible; their alternation with food crops increases the yield of the later. Many pluriannual grasses (Panicum, Pennisetum, Brachyaria, Hyparrhamia) and a few legumes grow well. Moreover, with grains that are easy to produce with fertilizers, poultry and swines could be raised. However, such intensive practices cannot extend until the standard of life of people has sufficiently rised to pay for costly animal food.
1.3-4	Same as 1.1-2, but vegetation is more open and provides more grazing; on the other hand, the dry season creates many problems (see 1.5); not only grass is scarce during the dry season, but it is poor in proteins, and livestock looses weight. So that the problem is analogous to that of 1.1-2. Stylosanthes, pluriannual grasses and other forage crops mentioned for 1.1-2 grow well in this climate.
1.5	The open savannah of these climates permits to have more livestock, and livestock is more important than in 1.1-1.4. But the long dry season creates many problems; grazing is not only scarce during it, but it is poor in proteins, and livestock looses weight. The answer is stored food (including grains). So that the necessity for forage crops is still greater than in 1.1-2. Maize, sorghum, cowpea, grow well in 1.531-2 and 1.541-2; many pluriannual legumes and grasses do not resist the high drought stress of this climate.
1.6	Native vegetation is forest; but it is easily transformed in relatively nutritive grassland, more especially when mineral fertilizers are added. Moreover, the solutions mentioned for 1.1-2 are also adequate, and easier, in 1.6.
1.7-8	Nights are cooler in these climates (more especially in 1.75-8 and 1.84-6), and grass is more nutritive; moreover, in 1.8, vegetation is open savannah; for all these reasons, these climates are better for livestock than the lowlands 1.1-1.5 and 1.9). The solutions mentioned for 1.1-2 are adequate and easier in 1.7-8. Irrigated alfalfa (non pastured) and winter cereals are possible in 1.85 - 1.86; more especially when growth retardants and fertilizers are used; but they require irrigation; clovers are possible in 1.78.
1.9	1.911-4 and 1.921-5 are similar to 1.3-4; 1.915-9 and 1.826-9 are similar to 1.5.

2. *(Tierra Fria)*

2.1-2	Analogous to 1.7-8; but some species very sensitive to frosts cannot be grown. Winter cereals and non-pastured alfalfa, are possible, more especially in 2.21-3 and 2.27-9; but they need irrigation.
2.31-2	Adequately fertilized cryophilous grasses and legumes yield well without irrigation, which is desirable in the drier parts. Winter and summer cereals yield well. That is why this is an excelent climate for livestock production.
2.33-9	Same as 2.31-2, but the dry season is longer; cryophilous grasses and legumes need irrigation or the choice of species and yields are considerably limited; stored food and/or irrigated land is needed for intensive livestock production. 2.37 is analogous to 2.32.
2.41-2	Same as 2.31-2.
2.43-4	Same as 2.33-9.
2.51	Same as 2.31, but yields are considerable lower. Sheep are extensively raised.
2.52	Same as 2.33-9, but yields are considerably lower. Sheep are extensively raised.
2.61-2	Same as 2.31-2, but yield are considerably lower. Sheep and alpaca are extensively raised.
2.7	Same as 2.31-2, but yields are lower. Sheep and alpacas are raised.
2.8-9	Very low carrying capacity; alpacas are raised in the moister areas.

3. *(Deserts)*

3.1	The carrying capacity of native vegetation is extremely low; some goats are raised in 3.12 and 3.14-7. The answer is irrigated sown prairies and forage crops with tropical grasses, tropical legumes, summer cereals and summer legumes.
3.2	Carrying capacity is extremely low; some grass grows in 3.24 and 3.272 in winter and in 3.26 and 3.274 in summer, and some livestock is raised in them. But the true answer is irrigated forage and pasture crops. Not only non-cryophilous, but also cryophilous crops (Trifolium alexandrinum, winter vereals, alfalfa) are possible in 3.23-7.
3.31, 3.33	Analogous to 3.1.
3.34-8	Carrying capacity is practically nil in 3.34 and 3.36; some goats are raised in 3.35 and 3.37-8. The true answer is forage and pasture crops. Not only non-cryophilous but cryophilous crops (alfalfa, winter cereals and legumes) are possible too.
3.41	Analogous to 3.2.
3.51	Analogous to 1.7-8; but irrigation is needed, and irrigated alfalfa grows better; carrying capacity of non irrigated land is extremely low.
3.52-3	Analogous to 3.2.
3.54-5	Irrigated alfalfa, winter cereals and many other forage crops grow well. Carrying capacity of non-irrigated land is extremely low.
3.56	Analogous to 3.54-5, but yields are lower; sheep are raised.
3.71-2	Carrying capacity is extremely low without irrigation. Irrigated alfalfa yields well. Stored feed is necessary for winter, more especially in 3.72.
3.73	Same as 3.71; but clovers compete with alfalfa. And the need of stored feed is still greater than in 3.72.
3.8	Carrying capacity of non-irrigated land is very low; summer cereals, alfalfa and winter cereals yield well.
3.9	Analogous to 3.8; yields are lower; sheep are raised.

4. *(Subtropical)*

4.1 Vegetation is forest, but it is easily transformed into grassland; however, carrying capacity is rather low. Fertilizers with growth retardants and forage crops (winter and summer cereals and legumes) can improve the situation.

4.2-3 The carrying capacity of non-sown pastures is low; irrigated Trifolium alexandrinum and forage crops (winter and summer cereals and legumes) yield well. Irrigated alfalfa yields well in the drier parts of 4.2. Summer crops can be grown without irrigation in the less dry climates.

4.41-3 Analogous to 4.2-3.

4.44-5 Analogous to 4.1, but carrying capacity is a little lower; conditions are less propicious for winter cereals and legumes.

4.5 Analogous to 5.393.

5. *(Pampean)*

5.1-2 Carrying capacity is rather high; moreover, grazing is possible all the year round. Alfalfa and winter cereals yield well without irrigation. For all these reasons, and because of the fertility of its soils, this is one of the best livestock regions of the world. The replacement of nature pasturelands by sown prairies and forage crops increases greatly production. Cryophilous grasses and clovers grow without irrigation in 5.11, but in 5.122-3 and 5.14-5 even alfalfa withstands with difficulty the dry summer. In 5.13 drought often causes great damages. Sorghum may be grown everywhere; and maize in 5.11, 5.121 and 5.125-9.

5.31 Analogous to 5.1, more especially 5.11.

5.32 Analogous to 5.1, but carrying capacity a little lower; alfalfa and winter cereals yield less. Sorghum and raize grow well.

5.33 Analogous to 5.32.

5.35-6 Analogous to 5.32; but carrying capacity is still lower; summer is rather too humid for alfalfa; less propicious for winter cereals.

5.37 Analogous to 5.36, but drier.

5.381-2 Analogous to 5.32, but carrying capacity is lower; alfalfa and winter cereals yield less.

5.383 Carrying capacity is low; alfalfa needs irrigation.

5.391-3 5.391 es analogous to 5.32; 5.392 to 5.129; 5.393 to 5.125.

5.4 Analogous to 5.1, but soils are usually less fertile; "actual" fertility is in many subdivisions lower, because winter is more humid.

5.6 Vegetation is shrub with grasses; pasturelands are easily invaded by shrubs; carrying capacity is rather low in 5.61, very low in 5.62; alfalfa and winter cereals cannot be grown without irrigation.

5.7 Vegetation is shrub with grasses; carrying capacity is very low; alfalfa and winter cereals cannot be grown without irrigation, some rye is grown for grazing in 5.71 and Eragrostis curvula grows well.

5.8 Carrying capacity is rather low; growth is interrupted in winter. Winter cereals, cryophilous grasses and clovers yield well, but clovers need irrigation in the drier parts.

5.9 Vegetation is low shrub, with grasses; carrying capacity very low; sheep are raised. Winter cereals and alfalfa cannot be grown, without irrigation.

6. *(Mediterranean)*

6.1	Natural pasturelands provide more or less good grazing in winter, but dry out in summer; sheep transhume to the mountains. Winter cereals, Trifolium alexandrinum and other winter legumes yield well, but irrigation is necessary for alfalfa, and summer cereals. Increase of livestock production depends chiefly on these crops.
6.2	Similar to 6.1; but Trifolium subterraneum and some cryophilous grasses can be grown without irrigation in 6.211, 6.25, 6.274-5 and 6.278; clovers compete with alfalfa as irrigated crops.
6.3	Similar to 7.2, but it suffers more from drought.
6.4	Analogous to 6.1.
6.5	Analogous to 6.1; but winter is colder and the need to store forage greater. In 6.511, some cryophilous grasses and alfalfa can be grown without irrigation.
6.6	Similar to 6.1; but winter is very cold and forage should be stored for winter; excepting 6.64 and 6.67, the carrying capacity of natural pasturelands is good in summer; but the growing season is short.
6.711-2	Carrying capacity of nature pastureland is good. Alfalfa can be grown without irrigation; and yields very well with it; ladino clover yields also well. Very good livestock region, but it is necessary to store forage for the winter.
6.713-4, 6.72-4	Similar to 6.1, but winter is longer and the need for stored forage greater.
6.75	Similar to 6.711-2.
6.76-8	Nature pasturelands provide good grazing for a short season in spring. The need for stored forage is great. Irrigated alfalfa grows well.
6.79	Nature pastureland provides good forage for a more or less short season in summer. Irrigated alfalfa and clovers yield well; need for stored forage is great.
6.8	Natural pastureland gives grazing for a very short period in winter. Irrigated alfalfa yields well; winter cereals yield well with irrigation, but their yield without irrigation varies enormously from year to year; some years they are a complete failure. In 6.811, 6.821, 6.831-3, 6.835-6, 6.838, 6.871, 6.881, 6.884, they are often sown for grain and used as forage when spring is dry.
6.9	Similar to 6.78-9, but the season natural pastureland provides grazing is still shorter; in 6.911, 6.921, 6.941, winter cereals are often sown for grain and used as forage when spring is dry.

7. *(Marine)*

7.1	This climate es excellent for grazing; which continues all the year round. Adequately fertilized, natural pastureland, cryophilous grasses and clovers, winter and summer forages yield well.
7.2	Similar to 7.1, but winter is colder and the need for forage storage greater; summer forage crops are little used; 7.23-4 are similar to 7.1.
7.3	Vegetation is forest and the growing season short; near to the limits with 7.2, conditions are fairly good for livestock production.
7.5	Analogous to 7.1, but winter is colder and the need for stored forage greater. Alfalfa competes with clover.
7.6	Analogous to 7.7, but the growing season is longer and the need for stored forage lower.
7.7	Natural pasturelands, cryophilous grasses and clovers yield well, but the growing period is short and the need for stored forage high; winter resistant grasses and clovers are used.
7.8	Analogous to 7.1; but winter is colder and the need for stored forage greater; summer forage crops are little used.

8. *(Humid Continental)*

8.1 Climax vegetation is forest and natural pastureland is not so nutritive; cryophilous grasses, clovers and alfalfa do no yield well. The main forage crops are winter cereals and legumes, summer cereals and legumes, lespedeza, etc. Well fertilized they yield well.

8.2 Cryophilous grasses and legumes yield very well, but winter is cold, the growing season short and the need for stored forage high. One of the best regions for livestock industry in the world.

8.3 Similar to 8.2, but the growing period is shorter, the need for stored forage greater, and winter resistant varieties are used.

9. *(Steppe)*

9.11 Similar to 8.1, but drier.

9.12-3 The carrying capacity of native pastureland is low. Irrigated alfalfa and summer cereals yield well.

9.21 Similar to 8.2, but drier.

9.22-3 Natural pastureland provides rather nutritive forage, but depending on the length of the non-dry season, carrying capacity is low. Irrigated alfalfa and summer cereals yield well.

9.31 Similar to 8.3, but drier.

9.32-3 Similar to 9.22-3, but the growing season is shorter and winter more severe. Winter creals, sown in spring and clovers are preferable to summer cereals and alfalfa.

9.34-5 The growing season is extremely short; winter is too severe for the most important cryophilous grasses and clovers.

9.41 Analogous to 7.7.

9.42 Analogous to 9.22-3, but the growing season is shorter.

9.43 Analogous to 7.7.

9.44-5 Analogous to 9.22-3, but winter is milder.

9.5 Analogous to 9.31, but the growing season is still shorter.

9.7 Carrying capacity of native pastureland is low; moreover, the growing season is more or less short. Irrigated alfalfa grows well in 9.71-4; and irrigated clovers in 9.73-5.

9.8 Carrying capacity of native pastureland is low; moreover, the growing period is more or less short. Irrigated alfalfa and summer cereals could yield rather abundant forage in 9.82-8.

10. *(Polar - Alpine)*

10. The growing period is very short; vegetation varies from forest to shrub, tundra or desert; that is why this climate is not propicious for livestock industry except on the limit with warmer climates.

10.5 Natural pasturelands provide good grazing in summer and are used during this period; 10.51-4 are good grassland regions; but livestock transhumes to lowlands in winter. 10.55-8 have lower carrying capacity.

Table 20. *Suitability and limitations of world climates for grapes and olives*

Climates	Suitability
	1. (Tropical)
1.1-1.5	Too warm for these crops.
1.6	Summer is too humid for these crops.
1.71-4	Too warm for these crops, although less than 1.1-1.5.
1.75-7	Analogous to 1.84-6; fungicides are more needed; it is more difficult to regulate the time of flowering by irrigation.
1.78	Too cool for these crops.
1.81-3	Too warm for grapes and olives.
1.84-6	Vine and olive can be grown but summer is too humid; fungicides (more important for vine) and growth retardants (more important for olive) permit to turn this difficulty; the plant can flower at various seasons, but rains, defoliation, and irrigation regulate flowering; two crops of vines are usually obtained; irrigation is needed during the dry season; and with irrigation the drier subdivisions are preferable.
1.9	Grapes and olives could be grown, but summer is too humid and long; fungicides and growth retardants permit to control diseases, detain growth and overcome to a certain extent the difficulty; irrigation is necessary during the dry season.
	2. (Tierra Fria)
2.1-2.2	Analogous to 1.84-6, but winter is cooler and consequently more favourable.
2.3	Vine can be grown, but humid summers favour diseases, late frosts cause damages and irrigation is needed during the dry season in many subdivisions; with irrigation the drier subdivisions are preferable; too cool for olive, and sweet grapes.
2.4-2.9	Too cool for these crops.
	3. (Deserts)
3.1	Too warm for these crops.
3.2	Grapes and olives can be grown.
3.31-3	Too warm for these crops.
3.34-8	Good for grapes and olives.
3.4	Good for grapes and olives.
3.51	Same as 1.84-6; more irrigation is needed; the problem of diseases and excessive leaf-shoot growth is less serious.
3.52-3	Same as 2.1-2, more irrigation is needed; the problem of diseases and excessive leaf-shoot growth is less serious.
3.54	Same as 2.3; more irrigation is needed; the problem of diseases and excessive leaf-shoot growth is less serious. Good for irrigated vines.
3.55-6	Too cool for these crops.
3.71-2	Olive can be grown where winter is *Av*, and grapes where the winter is *Ti* or milder.
3.73	Too cold for these crops.
3.82	Good for these crops.
3.83	Rather too frosty for grapes; too frosty for olive.
3.85	Same as 3.82.
3.9	Too cold for these crops.

4. *(Subtropical)*

4.1	Summer is too humid for these crops; american grapes are grown; fungicides (more important for grapes) and growth retardants (more important for olive), permit to turn this difficulty; subdivisions with non-humid summer are preferable.
4.2	Grapes and olives can be grown with irrigation; where one or more summer months are humid, the problem of diseases and excessive shoot growth become serious.
4.3	Similar to 4.2, but winter is warmer and consequently less favourable.
4.4	Same as 4.2, but winter is warmer and consequently less favourable; the problem of diseases and excessive leaf-shoot growth is very serious in 4.42-4.45.

5. *(Pampean)*

5.1	Grapes and olives suffer from late and early frosts; moreover, summer is often too humid for them; and winter too dry for olive in many subdivisions. Some areas of 5.123, less exposed to early and late frosts (near to the sea) and 5.14, are the best subdivisions.
5.2	Too frosty for these crops.
5.3	Depending on the subdivision, summer is too humid and/or winter too dry for these crops; American grapes are grown in 5.31; some olive in 5.32 and 5.35. Irrigated grapes and olive are grown in 5.393; in 5.38 the danger of early and late frosts is too great for these crops.
5.41-3	Summer is too humid for these crops; fungicides (more important for grapes) and growth retardants (more important for olives) permit to turn the difficulty; American grapes can be grown in 5.43; 5.44 and 5.46 are too cool.
5.6	Good for these crops; summer is rather too humid in 5.61; it is rather too cool for olive in 5.612 and 5.622; irrigation is indispensable.
5.7-9	Too frosty for these crops.

6. *(Mediterranean)*

6.1	Typical climate of grapes and olives.
6.21-4	Same as 6.1; very good for table wine.
6.25-6	Too cool for these crops.
6.271-5	Too cool for olives; rather too humid for grapes.
6.276-8	Same as 6.21-4, but cooler.
6.28	Too cool for these crops.
6.3	Too cool for these crops.
6.4	Same as 6.1; varieties with low cold requirements are necessary.
6.5	Same as 6.1; but 6.511, 6.521 and 6.541 are too cool for olives.
6.6	Too cool for these crops.
6.71-4	Good for grapes and olives; but 6.711-2, 6.721 and 6.731 are too cold for olives.
6.75-8	Good for grapes; too cold for olive; late frosts cause damages in many areas.
6.8	Good for irrigated grapes and olives; in the less dry subdivisions they are grown without irrigation, but yields are low.
6.91-3	Good for grapes; too cold for olives; late frosts cause damages in many areas.

7. *(Marine)*

7.1-4 Too cold for these crops.

7.51 Too humid for these crops; too cold for olives.

7.52 Grapes are grown and very good table wine is produced, but summer favours diseases; 7.524 is better than the others; too cold for olive.

7.53 Same as 7.51.

7.6-8 Too cold for these crops.

8. *(Humid Continental)*

8. In many subdivisions, winter is too severe for olive, or both; late and early frosts cause serious damages; in many subdivisions, summer is too cool for olives or both. Some table-wine grapes are grown in 8.221, in areas less exposed to late frosts; 8.25 is good for grapes, and excellent table wine is produced, but the crop suffers from late frosts and diseases. Where summer is humid American grapes are grown.

9. *(Steppe)*

9. Same handicaps as in 8; 9.211, 9.221, and 9.231 are good for grapes; winter is not so severe and summer not so humid.

10. *(Polar - Alpine)*

10. Too cool for these crops.

2.1.2. USDA LAND CAPABILITY CLASSIFICATION

2.1.2.1. General principles

The USDA capability classification (**Klingebiel and Montgomery, 1966**) is one of a number of interpretative groupings made primarily for agricultural purposes.

The following principles are adopted :

(1) the criteria used in assessing a land unit are the physical land properties made available after a soil survey;

(2) the seriousness of a limitation is a function of the severity with which crop growth is inhibited;

(3) the capability of a land unit for crop growth is better when a wide range of crops can be cultivated on it than on an other land unit.

Therefore the system is one of a general appraisal and not related to a specific land utilization type. However, the preferential utilization type and land use is reflected in the classes. As such the arable soils are grouped according to their potentialities and limitations for sustained production of the common cultivated crops that do not require specialized site conditioning or site treatment. Non-arable soils are grouped according to their potentialities and limitations for the production of permanent vegetation and according to their risk of soil damage if mismanaged.

2.1.2.2. Major categories of soil groupings

The capability classification provides three major categories of soil groupings : **classes, subclasses** and **units.**

(1) **CAPABILITY CLASSES**

Capability classes are groups of land units that have the same degree of limitation. The risks of soil damage or limitation become progressively greater from class I to class VIII.

The classes show the general suitability of a land unit for agricultural use.

(2) **CAPABILITY SUBCLASSES**

Capability subclasses are defined on the basis of major conservation problems, such as :

e - erosion and runoff
w - excess water
s - root-zone limitations
c - climatic limitations

The capability subclass provides information as to the kind of conservation problem or limitation involved. Class and subclass together provide the map user information about both the kind of problem involved and the degree of this limitation.

(3) **CAPABILITY UNITS**

A capability unit is a subdivision of subclasses on the basis of potential productivity. All soils within a sub-class having comparable potential productivity belong to the same capability unit.

This means that soils in a capability unit are sufficiently uniform to :

a) produce a similar kind of cultivated crops and pasture plants with similar management practices;

b) require similar conservation treatment and management;

c) have comparable potential productivity.

2.1.2.3. **Capability classes**

The criteria used at the level of the capability classes are:

(1) Range of crops that can be cultivated
The soil is better when a wide range of crops can be cultivated; when this range of crops becomes narrower the suitability of the land decreases at class level.

(2) Importance of conservation practices required
- to prevent soil deterioration (chemical and physical)
- to improve air- and water relation

The application of these criteria requires the definition of some "management levels" :

(a) Ordinary management; may include the use of one or more of the following :
- fertilizer and lime, as to compensate the output by the crops
- cover- and green manure crops
- conservation of crop residue
- animal manure

(b) Careful management; moderate conservation practices :
- slight drainage as to improve air and water relations

- contour tillage
- strip cropping
- crop rotations that include grasses and legumes
- slight salt- and alkali control
- more intense application of items under a

(c) <u>Very careful management</u>; special conservation practices:
- important drainage
- flood protection
- terracing or other intense protection against erosion (mulching)
- important salt- and alkali control
- more intense application of items under a and b

The classes, based on the climatic, erosion (topography), wetness (flooding, drainage), physical- and fertility requirements of the crops are defined in table 21.

Following considerations can be added to these definitions :

(1) **CLASS I**

Soils of class I are nearly level, have deep rooting zones, have favourable permeability and water-holding capacity, and are easily maintained in good tilth. In irrigated areas some of the soils may require initial conditioning including levelling to the desired grade, leaching of a slight accumulation of soluble salts, or lowering of the seasonal water table. Where limitations due to salts, water table, overflow, or erosion are likely to recur, the soils are regarded as subject to permanent natural limitations and are not included in class I.

Soils that are wet and have slowly permeable subsoils are not placed in class I. Some kinds of soil in class I may be drained

Table 21. USDA classification - Principles for the definition of the classes

PARAMETERS	ARABLE LAND CLASSES			
	CLASS I	CLASS II	CLASS III	CLASS IV
Definition	Few limitations restrict their use	Moderate limitations reduce choice of plants or require moderate conservation practices	Severe limitations reduce choice of plants or special conservation practices are required	Very severe limitations restrict choice of plants; special conservation practices are required
Range of crops or preferential use	All climatologically adapted crops give nearly optimal yields	Most climatologically adapted crops can be cultivated and give nearly optimal yields	Highly demanding crops do not yield satisfactorily	Use limited to 2-3 of the common crops and harvest may be low(marginal)
erosion (e)	Level to nearly level, no or low erosion hazard	Gentle slopes, moderate susceptibility to wind- or water erosion	Moderate steep slopes, high susceptibility to water- or wind erosion	Steep slopes, very high susceptibility to water- and wind erosion
Wetness (w)				
- flooding	Not subject to damaging overflow	Occasional damaging overflow	Frequent overflow accompanied by some crop damage	Frequent overflow accompanied by severe crop damage
- drainage	Well drained	Wetness correctable by drainage, but moderate permeability limitation	Somewhat continuing waterlogging after drainage, due to very slow permeability of the subsoil	Excessive wetness with continuing hazard of waterlogging after drainage
Physical soil conditions (s)	Hold water well Good workability Deep (+ 100 cm)	Somewhat unfavourable soil structure and workability Less than ideal depth (50-100 cm)	Low moisture holding capacity Shallow depth (25-50 cm)	Low moisture holding capacity Very shallow depth (-25 cm)
Fertility	Well supplied with plant nutrients or highly responsive to input of fertilizers	id.	Low fertility - not easy to be corrected	id.
Salinity and alkalinity	No or slight easy to be corrected	Slight to moderate, easy to be corrected but likely to return	Moderate salinity or sodium hazard	Severe salinity or sodium hazard
Management requirement	Ordinary management	Carefull management	Very carefull management	Very carefull management

PARAMETERS	PASTURE		FOREST	RECREATION - WILDLIFE
	CLASS V	CLASS VI	CLASS VII	CLASS VIII
Definition	Not suited to cultivation, little to no erosion hazard, but limitations that limit their use to pasture;....	Severe limitations that make them generally unsuitable for agriculture and limit their use to pasture and range	Very severe limitations make them unsuitable for cultivation and restrict their use to :	Unsuitable for any commercial plant production
Range of crops or preferential use	Pasture; can be improved	Pasture or range	Woodland	Recreation, wildlife.
erosion (e)	Nearly level	Very steep slopes; severe erosion hazard	Very steep slopes. Erosion	Erosion or erosion hazards
Wetness (w)				
- flooding	Frequent overflow that eliminates arable land farming	-	-	-
- drainage	Drainage for arable land not feasible	-	too wet soils for improved grasland	too wet soils
Physical soil conditions (s)	Stony or rocky Too shallow for arable land farming	Stoniness low moisture capacity Too shallow for arable land farming	Stoniness Too shallow	Low moisture holding capacity. Stoniness Too shallow
Fertility	-	-	-	-
Salinity and alkalinity		Severe salinity or sodium hazard	Severe salt and sodium hazard	
Management requirement	Pasture can be improved	Pasture can be improved. Common crops need unusual intensive management. Special crops grow with usual management	Pasture can not be improved. No common crops can be grown. Special crops need unusual intensive management	

as an improvement measure for increased production and ease of operation.

(2) **CLASS II**

The soils of class II provide the farm operator less latitude in the choice of either crops or management practices than soils in class I.
These land units will require careful management as defined above.

(3) **CLASS III**

Soils in class III as defined in table 21 have more restrictions than those in class II and conservation practices are more difficult and need very careful management.

When cultivated, many of the wet, slowly permeable but nearly level soils in class III require drainage and a cropping system that maintains or improves the structure and tilth of the soil. To prevent crust formation and to improve permeability it is commonly necessary to supply organic material to such soils and to avoid working them when they are wet. In some irrigated areas, part of the soils in class III have limited use because of high water table, slow permeability, and the hazard of salt or sodic accumulation. Each distinctive kind of soil in class III has one or more alternative combinations of use and practices required for safe use, but the number of practical alternatives for average farmers is less than that for soils in class II.

(4) **CLASS IV**

The restriction in use for soils in class IV are greater than those in class III and the choice of plants is limited to only two or three of the common crops or the harvest produced is marginal. Soils in class IV may be well suited to one or more of the special crops, such as fruits and ornamental plants, but this suitability itself is not sufficient to place a soil in class IV.

(5) **CLASS V**

In practice soils of class V are level or nearly level areas, such as poorly drained valleys, saturated with water in winter but dry in the summer; stony level terraces not suited for arable land, lateritic peneplains in the tropics.

Important is that pasture land can be improved by sowing artificial grasses mixed with clover, use of fertilizers, some drainage and flood protection, removal of stones.

(6) **CLASS VI**

Soils of class VI are upland soils with pronounced topography which however permits installation of grassland that can be improved.

For cultivation of the common crops unusual intensive management is required. The soils are however adapted to special crops such as orchards, ornamental plants etc. ...

(7) **CLASS VII**

The soils of class VII should be preferentially used as forest. Some of these soils however can be used as natural grassland, pasture cannot be improved by seeding and fertilizers.

They are not suited for the common crops but some of these soils may be used for special crops under unusual management practices.

Some areas of class VII may need seeding or planting to protect the soil and prevent damage to adjoining areas.

(8) **CLASS VIII**

These lands unsuitable for any form of commercial plant production may include badlands, rock outcrop, sandy beaches, some sand dunes, river wash, mine tailings and other nearly barren lands. Also very steepland under natural forest where topography prevents any commercial exploitation. A quantification of the class criteria, for the sub-humid tropics is given in table 22.

2.1.2.4. Capability subclasses

Subclasses are groups of capability units within classes that have the same kinds of dominant limitations for agricultural use as a result of soil and climate. Some soils are subject to erosion if they are not protected, while others are naturally wet and must be drained if crops are to be grown. Some soils are shallow or droughty or have other soil deficiencies. Still other soils occur in areas where climate limits their use. The four kinds of limitations recognized at the subclass level are : risks of erosion, designated by the symbol (**e**); wetness, drainage, or overflow (**w**); rooting-zone limitations (**s**); and climatic limitations (**c**). Capability class I has no subclasses.

The subclass provides the map user information about both the degree and kind of limitation :

(1) **SUBCLASS (e)** is made up of soils where the susceptibility to erosion is the dominant problem or hazard in their use.

Table 22. Land capability classification - quantification of the criteria for tropical savannah areas (Zambia) - (USDA system)

CHARACTERISTICS	CLASS I	CLASS II	CLASS III	CLASS IV	CLASS V	CLASS VI	CLASS VII	CLASS VIII
Topography (t)								
Slope (%)	< 2	< 6	< 12	< 25	< 2	< 25	< 55	< 55
Wetness (w)								
Flooding	no (F0)	no (F0)	no (F0)	no to slight (F1)	no to severe (F3)	no to severe (F3)	no to very severe (F4)	no to very severe (F4)
Drainage (1)	good	moderate or better	somewhat imperfect or better	imperfect or better	poor or better	poor or better	very poor or better	very poor or better
Physical soil conditions (s)								
Surface texture	SL to Co	LfS to C-60s	fS-C-60v	cS to C+60v	cS to Cm	cS to Cm	cS to Cm	cS to Cm
Surface coarse fragments (vol.%)	none	< 15	< 35	< 55	< 55	< 55	< 75	≷ 75
Surface stoniness (%)	none	< 0.01	< 0.1	< 0.3	< 15	< 15	< 75	≷ 75
Rockyness (%)	none	< 2	< 10	< 25	< 50	< 50	< 75	< 75
Subsurface texture	L to C-60s	SCL to C-60v	LfS to C+60v	fS to C+60v	cS to Cm	cS to Cm	cS to Cm	cS to Cm
Subsurface coarse fragments	< 15	< 35	< 55	< 75	< 75	< 75	≷ 75	≷ 75
Soil depth (m)	> 1.5	> 1	> 0.50	> 0.25	> 0.25	> 0.25	> 0.10	≷ 0.10
Fertility (f)								
Apparent CEC	> 16	≷ 16, net(-)ch.	≷ 16, net(+)ch.					
Base saturation	> 80	> 50	> 35	> 15	> 15	> 15	≷ 15	≷ 15
O.C. (0-15 cm)	> 1.5	> 1.0	> 0.6	> 0.4	> 0.4	>0.4	≶ 0.4	≶ 0.4

TEXTURAL RANGE

Cm : clay, massive; **SiCm** : silty clay, massive; **C+60,v** : clay, more 60% 0-2µ, vertisol structure; **C+60,s** : clay, more 60% 0-2µ, blocky structure; **C-60,v** : clay, less 60% 0-2µ, vertisol structure; **C-60,s** : clay, less 60% 0-2µ, blocky structure; **SiCs** : silty clay, blocky structure; **Co** : clay, oxisol structure; **SiCL** : silty clay loam; **CL** : clay loam; **Si** : silt; **SiL** : silt loam; **SC** : sandy clay; **L** : loam; **SCL** : sandy clay loam; **SL** : sandy loam; **LfS** : loamy fine sand; **LmS** : loamy medium sand; **LcS** : loamy coarse sand; **fS** : fine sand; **mS** : medium sand; **cS** : coarse sand

Erosion susceptibility and past erosion damage are the major soil factors for placing soils in this subclass.

(2) **SUBCLASS (w)** excess water is made up of soils where excess water is the dominant hazard or limitation in their use. Poor soil drainage, wetness, high water table, and overflow are the criteria for determining which soils belong in this subclass.

(3) **SUBCLASS (s)** soil limitations within the rooting zone includes, as the name implies, soils that have such limitations as shallowness of rooting zones, stones, low moisture-holding capacity, low fertility difficult to correct, and salinity or sodium.

(4) **SUBCLASS (c)** climatic limitation is made up of soils where the climate (temperature or lack of moisture) is the only major hazard or limitation in their use[1].

Limitations imposed by erosion, excess water, shallow soils, stones, low moisture-holding capacity, salinity or sodium can be modified or partially overcome and take precedence over climate in determining subclasses. The dominant kind of limitation or hazard to the use of the land determines the assignment of capability units to the (e), (w) and (s) subclasses. Capability units that have no limitation other than climate are assigned to the (c) subclass.

Where two kinds of limitation that can be modified or corrected

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1 Especially among young soils such as alluvial soils, although not limited to them, climatic phases of soil series must be established for proper grouping into capability units and into other interpretative groupings. Since the effects result from interactions between soil and climate, such climatic phases are not defined the same in terms of precipitation, temperature, and so on, for contrasting kinds of soil

are essentially equal, the subclasses have the following priority : **e, w, s**. For example, we need to group a few soils of humid areas that have both an erosion hazard and an excess water hazard; with them the e takes precedence over the w. In grouping soils having both an excess water limitation and a rooting-zone limitation the w takes precedence over the s.

In grouping soils of subhumid and semi-arid areas that have both an erosion hazard and a climatic limitation the e takes precedence over the c, and in grouping soils with both rooting-zone limitations and climatic limitations the s takes precedence over the c.

Where soils have two kinds of limitations, both can be indicated if needed for local use; the dominant one is shown first. Where two kinds of problems are shown for a soil group, the dominant one is used for summarizing data by subclasses.

2.1.2.5. Capability units

The capability units provide more specific and detailed information than the subclass for application to specific fields on a farm or ranch. A capability unit is a grouping of soils that are nearly alike in suitability for plant growth and responds to the same kinds of soil management. That is, a reasonable uniform set of alternatives can be presented for the soil, water, and plant management of the soils in a capability unit, not considering effects of past management that do not have a more or less permanent effect on the soil. Where soils have been so changed by management that permanent characteristics have been altered, they are placed in different soil series. Soils grouped into capability units respond in a similar way and require similar management although they may have soil characteristics that put them in different soil series.

Soils grouped into a capability unit should be sufficiently uniform in the combinations of soil characteristics that influence their qualities to have similar potentialities and continuing limitations or hazards. Thus the soils in a capability unit should be sufficiently uniform to :

(a) produce similar kinds of cultivated crops and pasture plants with similar management practices;
(b) require similar conservation treatment and management under the same kind and condition of vegetative cover, and
(c) have comparable potential productivity. (Estimated average yields under similar management systems should not vary more than about 25 percent among the kinds of soil included within the unit).

2.1.2.6. **Form for practical use and example**

A form as represented in table 23 can be used in practice. This table has to be filled in by using information that is available in the soil survey report. If nothing is mentioned about a particular characteristic, you have to consider it as not limitative.

Table 24 summarized the degree of limitation of the considered characteristics for the different capability classes.

EXAMPLE : SOIL SURVEY, Ventura area in California. Description of a soil series available in the soil survey report

<u>Metz Series</u>

The Metz series consists of somewhat excessively drained, cal-

Table 23. Form - USDA Land Capability Classification

	SLOPE	WIND OR WATER EROSION	OVERFLOW	DRAINAGE	MOISTURE HOLDING CAPACITY	DEPTH	STONINESS	STRUCTURE AND WORKABILITY	PERMEABILITY OF SUBSOIL	SALINITY AND ALKALINITY	FERTILITY	CLIMATE	
SOIL UNIT :													
I													
II													
III													
IV													
V													
VI													
VII													
VIII													
								CLASSIFICATION :					

Table 24. Degree of limitation of the characteristics for the different capability classes

SUBCLASSES		e		w			s						c
LIMITATIONS / CLASSES		SLOPE	WIND OR WATER EROSION	OVERFLOW	DRAINAGE	MOISTURE HOLDING CAPACITY	DEPTH	STONINESS	STRUCTURE AND WORKABILITY	PERMEABILITY OF SUBSOIL	SALINITY AND ALKALINITY	FERTILITY	CLIMATE
ARABLE LAND	I	no	no slight	no	no	no	no	[no]	no	no	no	no slight	no
	II	slight	moderate	slight	slight moderate	slight moderate	slight	[slight]	slight	slight	slight moderate	slight moderate	slight
	III	moderate (mod. steep slopes)	severe	moderate	moderate (imperfectly drained)	moderate severe	moderate severe (shallow)	-	-	moderate severe (very low)	moderate	severe	moderate
	IV	severe	very severe	severe	severe (poorly)	severe	severe	-	-		severe	severe	moderate
NON ARABLE LAND	V	no	[no]	frequent	ponded areas	-	-	severe (stony)	-	-	-	-	severe
	VI	severe (very steep)	severe	-	severe (excessively drained)	severe	severe (shallow)	- (strong)	-	-	-	-	severe
	VII		very severe	-	excessively drained	-	shallow	severe	-	-	-	-	unfavourable climate
	VIII	One or more of following limitations (x) can not be corrected	x		x	x		x			x		x

careous, loamy sands and loamy fine sands 60 inches or more deep. These soils formed on alluvial plains and fans, in stratified alluvium derived predominantly from sedimentary rocks. They have slopes of 0 to 9 per cent. Elevations range from 25 to 1,000 feet. The annual rainfall ranges from 14 to 18 inches, and the frost-free season from 300 to 340 days. The average annual air temperature is 62°F. The vegetation is annual grasses.

Metz soils occur with Anacapa, Corralitos, Hueneme, and Pico soils. They are used for vegetables, strawberries, walnuts, avocados, citrus crops, and field crops, and for urban development. Small areas are used for range.

Metz loamy sand, 0 to 2 per cent slopes (**MeA**)

This is a level to nearly level soil of the alluvial plains and fans.

The surface layer is pale-brown, calcareous loamy sand about 7 inches thick. Below this is stratified light brownish-gray, calcareous sand and sandy loam.

Representative profile located about 1,600 feet south and 1,300 feet east of NW corner of sec. 9, T. 2 N., R. 19 W, SBB&M.

A--0 to 7 inches, pale-brown (10YR 6/3) loamy sand, dark grayish brown (10YR 4/2) moist; massive; slightly hard, very friable, nonsticky and nonplastic; common micro roots; many fine irregular pores; moderately alkaline (pH 8.0) and slightly effervescent; lime disseminated; abrupt, wavy boundary.

C1--7 to 24 inches, light brownish-gray (2.5Y 6/2) sand, grayish brown (2.5Y 5/2) moist; single grain; loose, nonsticky and nonplastic; many fine irregular pores; moderately alkaline (pH 8.0) and slightly effervescent; lime disseminated; abrupt, smooth boundary

C2--24 to 31 inches, light brownish-gray (2.5Y 6/2) sandy loam, dark grayish brown (2.5Y 4/2) moist; massive; slightly hard, very friable, nonsticky and slightly plastic; many fine irregular pores; moderately alkaline (pH 8.0) and slightly effervescent; lime disseminated; abrupt, smooth boundary

C3--31 to 36 inches, light brownish-gray (2.5Y 6/2) sand, grayish brown (2.5Y 5/2) moist; single grain; loose, nonsticky and nonplastic; many fine irregular pores; moderately alkaline (pH 8.0) and strongly effervescent; lime disseminated; abrupt, smooth boundary

C4--36 to 46 inches, light brownish-gray (2.5Y 6/2) sand, grayish brown (2.5Y 5/2) moist; single grain; loose, nonsticky and nonplastic; many fine irregular pores; moderately alkaline (pH 8.0) and slightly effervescent; lime disseminated; abrupt, smooth boundary

C5--46 to 60 inches, light brownish-gray (2.5Y 6/2) sand, grayish brown (2.5Y 5/2) moist; single grain; loose, nonsticky and nonplastic; many fine irregular pores; moderately alkaline (pH 8.0) and strongly effervescent; lime disseminated

The A horizon ranges from light brownish gray through grayish brown, or from pale brown through brown in hues of 10YR and 2.5Y. It is loamy sand or fine sand in texture and ranges from 7 to 10 inches in thickness. It ranges from mildly alkaline to moderately alkaline. The C horizon ranges from light brownish gray through light yellowish brown or from grayish brown through yellowish brown or light olive brown in hues of 10YR and 2.5Y. This horizon is stratified; in texture it ranges from sand and loamy sand to sandy loam that has thin lenses of silty material. It is mildly alkaline to moderately alkaline. The Metz soil is typically calcareous throughout the profile, but in a few places the uppermost few inches of the surface layer and the coarser textured strata are noncalcareous. Buried horizons of unrelated soils are common. Below a depth of 42 inches are strate that are as much as 25 per cent gravel and cobble-stones.

Included with this soil in mapping were areas of Anacapa sandy loam; Corralitos loamy sand; Hueneme sand loam; Pico sandy loam; Metz loamy sand, loamy substratum; and Metz loamy fine sand, 0 to 2 per cent slopes.

Permeability is rapid. Surface runoff is very slow, and there is no erosion hazard. The available water holding capacity is 4 to 5 inches in the 60 inches of effective rooting depth. Inherent fertility is low.

Metz loamy sand, 2 to 9 per cent slopes **(MeC)**

This is a gently sloping to moderately sloping soil of the alluvial plains and fans. It differs from Metz loamy sand, 0 to 2 per cent (MeA), mainly in having steeper slopes.

Included with this soil in mapping were areas of Anacapa sandy loam; Corralitos loamy sand; Cortina stony sandy loam; Metz loamy fine sand; Metz loamy sand, 0 to 2 per cent slopes; and Pico sandy loam.

Surface runoff is slow, and the erosion hazard is slight.

This soil is used mainly for field crops, citrus crops, and walnuts, and for urban development. Vegetables and strawberries are grown on the more gentle slopes. Small areas are used for range.

Metz loamy sand, loamy substratum, 0 to 2 percent slopes **(MfA)**

This is a nearly level soil of the alluvial plains and fans. In contrast with Metz loamy sand, 0 to 2 percent slopes (MeA), this soil is typically stratified with silt loam to loamy very fine sand below a depth of 40 inches.

Included with this soil in mapping were areas of Anacapa sandy loam; Corralitos loamy sand; Hueneme loamy sand, loamy substratum; Metz loamy sand; Metz loamy fine sand; and Pico sandy loam.

Permeability is moderately rapid. The available water holding capacity is 5 to 6 inches in the 60 inches of effective rooting depth. In the loamy substratum, permeability decreases and the available water holding capacity increases. In places a temporary perched water table forms after a rain or a heavy application of irrigation water.

This soil is used mainly for vegetables, field crops, citrus crops, walnuts, and strawberries, and for urban development. Small areas are used for range.

Table 25. USDA Land Capability Classification of these soil units corresponding to the Metz Series

	SLOPE	WIND OR WATER EROSION	OVERFLOW	DRAINAGE	MOISTURE HOLDING CAPACITY	DEPTH	STONINESS	STRUCTURE AND WORKABILITY	PERMEABILITY OF SUBSOIL	SALINITY AND ALKALINITY	FERTILITY	CLIMATE	
SOIL UNIT : **MeA**													
I	+	+			+	+		+	+	+			
II				+	+					+			
III				+							+		
IV													
V													
VI													
VII													
VIII													
													CLASSIFICATION : **IIIws**
SOIL UNIT : **MeC**													
I		+			+	+		+	+	+			
II	+	+		+	+					+			
III				+							+		
IV													
V													
VI													
VII													
VIII													
													CLASSIFICATION : **IIIws**
SOIL UNIT : **MfA**													
I	+	+			+	+			+				
II				+	+				+		+		
III				+									
IV													
V													
VI													
VII													
VIII													
													CLASSIFICATION : **II-IIIws**

2.1.3. PARAMETRIC SYSTEM FOR GENERAL EVALUATION PURPOSES

2.1.3.1. General principles

In 1970, a parametric method for land evaluation has been proposed by **Riquier et al. (1970)**.

They claim that limitations are a negative and complex concept and that present and future capability are better expressed in terms of productivity.

The system avoids economic and sociological considerations which lie outside the province of the soil scientist. Soil productivity, or known yields, moreover, provide the best grounds for understanding between the soil scientist and the economist.

The system suggests the calculation of a productivity index considering nine factors as determining soil productivity, viz. : moisture (H), drainage (D), effective depth (P), texture/structure (T), base saturation (N), soluble salt concentration (S), organic matter content (O), mineral exchange capacity/nature of clay (A), and mineral reserve (M).

$$\text{PRODUCTIVITY INDEX} = H \times D \times P \times T \times \begin{matrix} N \\ \text{or} \\ S \end{matrix} \times O \times A \times M$$

An attempt has thus been made to evolve a mathematic formula expressing productivity as a resultant of the various factors, considered, following STORIE's method of calculation. Each factor is rated on a scale from 0 to 100, the actual percentages being multiplied by each other. The resultant index of productivity, also lying between 0 and 100, is set against a scale placing the soil in one or other of five productivity classes.

When calculating the actual productivity index the value of the ratings refer to the present day situation.

The index of potentiality refers to the potential productivity with ratings according to the situation after soil management.

Therefore it is first necessary to determine which management practices are necessary, then evaluate what their repercussions are on potentiality.

Two groups of managements are considered :

(1) management imposed by limiting factors

- **H** (dryness) - requires irrigation
- **D** (poor drainage) - requires drainage
- **P** (shallowness) - requires deepening
- **T** (poor texture or structure) - requires stone removal or mechanical working
- **N** (low nutrient content) - requires application of fertilizers
- **S** (salinity) - requires desalting
- **O** (low organic matter content) - requires application of organic matter

(2) management imposed by physiographic conditions and environment (situation, climate, vegetation)

- control of wind erosion
- control of water erosion
- land clearance

The coefficient of improvement of a soil is expressed by the ratio index or potentiality/productivity index.

2.1.3.2. Soil characteristics used to determine productivity

(1) SOIL MOISTURE CONTENT - H

H1 Rooting zone below wilting point all the year round

H2 Rooting zone below wilting point for 9 to 11 months of the year
- H2a 11 months
- H2b 10 months
- H2c 9 months

H3 Rooting zone below wilting point for 6 to 8 months of the year
- H3a 8 months
- H3b 7 months
- H3c 6 months

H4 Rooting zone below wilting point for 3 to 5 months and wet below field capacity for over 6 months of the year
- H4a 5 months
- H4b 4 months
- H4c 3 months

H5 Rooting zone wet above wilting point and below field capacity for most of the year

Note : 1. If data on actual soil moisture is not available, it is possible to use instead the number of dry months per year calculated from weather intelligence (Gaussen's ombrothermic diagramme for instance) at least for small scale maps.

2. For cold countries, the months during which frost occurs as also the months of average temperature < 10°C (threshold of productivity) are considered as dry months.

(2) **DRAINAGE-D**

D1a Marked waterlogging, water table almost reaches the surface all year round (Hydromorphic horizon at a depth of 0 to 30 cm)

D1b Soil flooded for 2 to 4 months of the year

D2a Moderate waterlogging, the water table being sufficiently close to the surface to harm deep rooting plants (hydromorphic horizon at a depth of 30 to 60 cm)

D2b Total waterlogging of profile for 8 days to 2 months

D3a Good drainage, water table sufficiently low not to impede crop growing (hydromorphic horizon at a depth of 60 cm below the surface)

D3b Waterlogging for brief periods (flooding), less than 8 days each time

D4 Well drained soil, deep water table (hydromorphic horizon at over 120 cm depth); no waterlogging of soil profile.
In this case see H

<u>Note</u> : 1. If the hydromorphic horizon is not recognizable from morphological characteristics, the height of the water table is the only point to be considered. If, on the other hand, it is fossilized, it should be ignored all together.

2. In some instances soils are both too dry in the summer and too wet in the winter, in which case the two functions H and D are combined.

(3) **EFFECTIVE DEPTH OF SOIL-P**

P1 Rock outcrops with no soil cover or very shallow cover

P2 Very shallow soil, less than 30 cm deep

P3 Shallow soil, 30-60 cm deep

P4 Fairly deep soil, 60-90 cm deep

P5 Deep soil, 90-120 cm deep

P6 Very deep soil, over 120 cm deep

Note : By effective depth is meant the rooting zone. The latter extends to the horizon where the roots can no longer penetrate, whether it be parent rock, hardpan, claypan or gypseous layer (> 10-25 per cent gypsum).

(4) **TEXTURE AND STRUCTURE OF ROOT ZONE-T**

T1	Pebbly, stony or gravelly soil
T1a	Pebbly, stony or gravelly > 60 per cent by weight
T1b	Pebbly, stony or gravelly from 40 to 60 per cent
T1c	Pebbly, stony from 20 to 40 per cent
T2	Extremely coarse-textured soil
T2a	Pure sand, of particle structure
T2b	Extremely coarse-textured soil (> 45 per cent coarse sand)
T2c	Soil with non-decomposed raw humus (> 30 percent organic matter), and fibrous structure
T3	Dispersed clay of unstable structure (often Na/T > 15 per cent)
T4	Light-textured soil, fine sand, loamy sand or light sandy loam, or coarse sand and silt
T4a	Unstable structure
T4b	Stable structure
T5	Heavy-textured soil : clay or silty clay
T5a	Massive to large prismatic structure
T5b	Angular to crumb structure or massive but highly porous (e.g. soils with a high sesquioxide content)
T6	Medium-heavy soil : heavy sandy loam, sandy clay, clay loam, silty clay loam or silt
T6a	Massive to large prismatic structure
T6b	Angular to crumb structure (or massive but porous)
T7	Soil of average, balanced texture : loam, silt loam and sandy clay loam.

Note : Texture should preferably be judged by touch in this way taking micro-aggregation into account. Otherwise reference to the texture triangle is necessary. This chart is based on the U.S. Department of Agriculture's Soil Survey Manual, but the surface "sandy loam" has been further subdivided into T4 ("light") and T6 ("heavy").

(5) AVERAGE NUTRIENT CONTENT OF A HORIZON-N

N1	Soil with base saturation V = S/T less than 15 per cent
N2	V from 15 to 35 per cent
N3	V from 35 to 50 per cent
N4	V from 50 to 75 per cent
N5	V over 75 per cent
N6	Soil excessively calcareous (> 20 to 30 per cent)

(6) SOLUBLE SALTS CONTENT-S

S1	Total soluble salts less than 0.2 per cent
S2	Total soluble salts between 0.2 and 0.4 per cent
S3	Total soluble salts between 0.4 and 0.6 per cent
S4	Total soluble salts between 0.6 and 0.8 per cent
S5	Total soluble salts between 0.8 and 1.0 per cent
S6	Total soluble salts over 1 per cent
	If sodium carbonate is present in the soils (alkali soils):
S7	Total soluble salts (including sodium carbonate) 0.1 to 0.3 per cent
S8	Total soluble salts from 0.3 to 0.6 per cent
S9	Total soluble salts over 0.6 per cent

(7) ORGANIC MATTER IN A1 HORIZON-O

O1	Very little organic matter, less than 1 per cent
O2	Little organic matter, 1 to 2 per cent
O3	Average organic matter content, 2 to 5 per cent
O4	High organic matter content, over 5 per cent

O5 Very high content, but C/N over 25

Note : Place in one category lower if the organic matter is raw, of mor or moder type

(8) MINERAL EXCHANGE CAPACITY AND NATURE OF THE CLAY IN THE B-HORIZON-A

A0 Exchange capacity of clay less than 5 cmol(+).kg^{-1}

A1 Exchange capacity of clay less than 20 cmol(+).kg^{-1} (probably kaolinite and sesquioxides)

A2 Exchange capacity of clay from 20 to 40 cmol(+).kg^{-1} (probably a mixture of clays or illite)

A3 Exchange capacity of clay over 40 cmol(+).kg^{-1} (probably montmorillonite or amorphous clay)

(9) RESERVES OF WEATHERABLE MINERALS IN B-HORIZON-M

M1 Reserves very low to nil

M2 Reserves fair

M2a Minerals derived from sands, sandy materials or ironstone

M2b Minerals derived from acid rocks

M2c Minerals derived from basic or calcareous rocks

M3 Reserves large

M3a Sands, sandy materials or ironstone

M3b Acid rocks

M3c Basic or calcareous rocks

The following information has to be used only where certain characteristics are missing and which can be replaced by close, though not entirely interchangeable, equivalents. These are listed below by way of guidance and have no rigid value :

T

T1a Stones and pebbles : 30 per cent by volume

T1b	Stones and pebbles : 20 to 30 per cent
T1c	Stones and pebbles : 10 to 20 per cent
T2a	HE : equivalent moisture < 10 per cent
T2b	HE : equivalent moisture < 10 per cent
T3	A + L < 40 per cent and pH 8.5 or Na/T > 15 per cent (A = clay; L = silt)
T4	HE : from 10 to 15 per cent
T5	HE > 30 per cent
T6	HE : from 25 to 35 per cent
T7	HE : from 15 to 25 per cent

N

N1	pH (in water 1:1) from 3.5 to 4.5
N2	pH (in water 1:1) from 4.5 to 5.0
N3	pH (in water 1:1) from 5.0 to 6.0
N4	pH (in water 1:1) from 6.0 to 7.0
N5	pH (in water 1:1) from 7.0 to 8.5

Note : The use of pH instead of base saturation is advisable in cases of very sandy soils with a low cation exchange capacity. In such cases base saturation given by analysis is often unreliable.

S	Content of salts in % of soil	Conductivity in millimho of saturation extract	Conductivity in micromho of saline extract 1/5	Conductivity in micromho of saline extract 1/10
	0	0	0	0
S1 ↕				
	0.2	2	1000	500
S2 ↕				
	0.4	6	1750	875
S3 ↕				
	0.6	8	2500	1250
S4 ↕				
	0.8	12	3000	1625
S5 ↕				
	1.0	16	3500	2000
S6 ↕				

Note : These figures cannot be taken for an exact correspondence between the different conductivities, as they may vary according to the water capacity in the soil, and the degree of solubility of salts, thus according to their nature. However, these figures give an order of extent available in the proposed formula. In column 2 the American classification limits of Riverside have been chosen.

O Organic matter content = carbon x 1.7 = nitrogen x 20

O1 Thickness of the humus-forming horizon : < 10 cm

O2 Thickness of the humus-forming horizon : from 10 to 20

O3 Thickness of the humus-forming horizon : from 20 to 30

O4 Thickness of the humus-forming horizon : > 30

A Exchange capacity of clay

$$\frac{(\text{Tcmol}(+).\text{kg}^{-1}\text{ of soil} - K \times \%\text{ organic matter}) \times 100}{\%\text{ clay}}$$

and K = 2,50 for very humic soils, peaty soils or soils of cold or high regions

K = 2,00 for soils of temperate regions

K = 1,50 for tropical soils with little humus

M

M1 Sum of total bases determined by treating with hot nitric acid: Total bases < 10 meq

M2 Sum of total bases determined by treating with hot nitric acid : Total bases 10-50 meq

M3 Sum of total bases determined by treating with hot nitric acid : Total bases 50-300 meq

2.1.3.3. Tentative ratings of the characteristics

Tentative ratings of different characteristics are given in table 26.

Table 26. Tentative ratings of different characteristics

	FOR CROP GROWING			FOR PASTURE			FOR FOREST AND NON-FOREST TREE CROPS		
H									
H1		5			5			5	
H2	H2a10	H2b20	H2c40	20	20	30		10	
H3	H3a50	H3b60	H3c70	30	40	60	10	20	40
H4	H4a80	H4b90	H4c100	70	80	90	70	90	100
H5		100			100			100	
D	H4 H5	H2	H3						
D1		10-40			60			5	
D2		40-80			100			10	
D3		80-90			90			40	
D4		100			80			100	
P									
P1		5			20			5	
P2		20			60			5	
P3		50			80			20	
P4		80			90			60	
P5		100			100			80	
P6		100			100			100	
T									
T1a		10			30			50	
T1b		30			50			80	
T1c		60			90			100	
	H4H5H6AB	H3	H1H2						
T2a	10	10	10	(same ratings as for crop growing)			(same ratings as for crop growing)		
T2b	30	20	10						
T2c	30	30	30						
T3	30	20	10						
T4a	40	30	30						
T4b	50	50	60						
T5a	50	60	20						
T5b	80	80	60						
T6a	80	80	60						
T6b	90	90	90						
T7	100	100	100						

Remark : rating for H2a is 10; when the soil is irrigated the rating becomes 100

Table 26. (Cont'd)

	FOR CROP GROWING	FOR PASTURE	FOR FOREST AND NON-FOREST TREE CROPS
N			
N1	40	60	80
N2	50	70	80
N3	60	80	90
N4	80	90	100
N5	100	100	100
N6	80	90	100

S	T1 T2 T4	T5 T6 T7
S1	100	100
S2	70	90
S3	50	80
S4	25	40
S5	15	25
S6	5	15
S7	60	90
S8	15	60
S9	5	15

O	H1H2H3 D3D4	H4H5 D1D2 AB
O1	85	70
O2	90	80
O3	100	90
O4	100	100
O5	70	70

A	
A0	85
A1	90
A2	95
A3	100

M	H1H2H3	H4H5 AB
M1	85	85
M2a	85	90
M2b	90	95
M2c	95	100
M3a	90	95
M3b	95	100
M3c	100	100

2.1.3.4. **Classes of productivity**

Five classes of productivity (actual and potential) are considered and are defined by the productivity index (overall rating calculated following Storie's method) (table 27).

Table 27. Classes of productivity (P) and potentiality (P')

P	CLASSES	RATING	P'
1	excellent	100-65	I
2	good	64-35	II
3	average	34-20	III
4	poor	19-8	IV
5	extremely poor to nil	7-0	V

2.1.3.5. **Improvement of soil characteristics by management**

The following land improvement can be necessary for development :

A : Irrigation (essential) and drainage (usually required)
B : Supplementary irrigation : B1 by sprinkling
B2 by flood or furrow irrigation
C : Excess water removal : by reclamation, ridging, drainage or protection against floods
D : Deepening of top soil : by ridging, deep plowing or breaking up of soil crust
E : Improvement of texture and structure :
E1 by stone or rock removal

E2 by mechanical working of soil (difficult and costly - requiring heavy machinery)

E3 by improvement of organic soils

F : Fertilizers, amendments, liming in large quantities (application of fertilizers - particularly those containing nitrogen - is considered indispensable for all soils)

G : Desalting

G1 by irrigation and drainage

G2 by irrigation and drainage + application of gypsum ($CaSO_4$) to eliminate sodium salts ($NaCO_3$)

H : Enriching and maintenance of organic matter content, application of manure, green manure, mulching, crop rotation, forest fallow, etc.; also improvement of humic condition of peat and semi-peat soils.

J : Measures to control wind erosion : windbreaks, mulching

K : Measures to control severe water erosion : construction of banquettes, terraces, etc.

L : Measures to control mild water erosion : digging of ditches, planting of hedgerows, etc.

M : Large scale land clearance.

Table 28 summarized the effect of management practizes on soil characteristics or properties.

2.1.3.6. **Soil suitability depending on its characteristics**

Table 29 illustrates the soil suitability for different uses depending on its characteristics.

Table 28. Improvement of soil characteristics or properties by management

Management practices	A	B_1B_2	C	D	E_1	E_2	E_3	F+H (with A_0)	F(with A_1 or A_2)	F(with A_3)*	G_1	G_2	H	J	KL	M
Initial soil properties	H_1H_2	H_3H_4	D_1D_2	$P_1P_2P_3$	T_{1bc}	$T_{5a}T_{6a}$	T_{2c}	N_1N_2	$N_1N_2N_3$	$N_1N_2N_3N_4$	S_3S_4	S_9	$O_1O_2O_5$	H_1H_2 + $T_1T_2T_4$		
Improved soil properties	H_5	H_5	D_3	$P_2P_3P_4$	T of fine soil materials	$T_{5b}T_{6b}$	T of sub-soil	N_3	N_4	N_5	S_1S_2	S_7	O_4 Add 10% to final index O_4 (T_{2c}T of subsoil)	Add 10% to final index	Add 20% to final index (10% if improvement of organic matter (H) has already been taken in consideration	0%
											For T_6 and T_7 For T_2 improvement of 4 soil classes rated according to salinity. For T_5 improvement of a single soil class rated according to salinity					

* Note : $A_0A_1A_2A_3$ refer to CEC data

<u>Incompatible management practices and characteristics</u>

A and B_2 with P_{12}, P_3 + T_{1247}, P_4 + T_{1a} T_2 T_3

B_1 with P_1 and T_3

C with T_3 (C and T_3 are compatible if G_2 is used)

S with T_1

E_1 with T_{1a} T_{1b}

E_2 with T_3

F with A_0; However F + H is compatible with A_0

L with P_{12}, T_3, T_{5a}

K with P_{123}, T_3, T_{5a}

Table 29. Illustration of soil suitability for different uses depending on its characteristics

Envisaged land use	Rice growing	Tree crops	Coconuts	Pasture
Soil characteristics permitting the proposed use	H_4 to H_5 or H_1 to H_3 and A or B	H_5 or H_1 to H_4 and A or B	N_4 to N_5 H_1 to H_3 and A or B	N_4 to N_5 H_1 to H_3 and A or B
Other characteristics preclude or considerably hamper the proposed use)	D_1 to D_2 D_3 to D_4 and/or B P_4 to P_6 T_5 T_6 T_7 N_1 to N_5 S_1 to S_5 and G O_1 to O_5 A_1 to A_3 M_1 to M_3	D_3 to D_4 or D_1 to D_2 and C P_5 to P_6 T_{10} T_4 T_6 T_7 N_3 to N_5 S_1 O_3 to O_4 A_1 to A_3 M_1 to M_3	D_3 to D_4 P_4 to P_6 T_{2ab} T_4 T_7 N_1 to N_5 S_1 to S_5 and G O_2 to O_4 A_1 to A_3 M_1 to M_3	D_2 to D_3 P_2 to P_6 T_{10} 5 6 7 N_1 to N_5 S_1 O_2 to O_4 A_1 to A_3 M_1 to M_3

2.1.4. LAND CAPABILITY CLASSIFICATION FOR THE HUMID TROPICS

2.1.4.1. General principles

The land capability classification for the humid tropics is a parametric system for general evaluation developed by **Sys and Frankart (1971)** and can be considered as an adapted application of the parametric system of **Riquier et al. (1970)**.

In this method a **capability index (Cs)**, being the product of ratings attributed to 6 soil characteristics, has to be calculated :

$$Cs = A \times \frac{B}{100} \times \frac{C}{100} \times \frac{D}{100} \times \frac{E}{100} \times \frac{F}{100}$$

in which **Cs** = capability index
A = rating for profile development
B = rating for texture
C = rating for soil depth
D = rating for color/drainage conditions
E = rating for pH/base saturation
F = rating for the development of the A horizon

The capability or soil index is an expression of the natural fertility and can therefore be correlated with crop production under natural conditions, without use of fertilizers or soil improvement works.

2.1.4.2. **Soil characteristics**

(1) PROFILE DEVELOPMENT

It has been generally accepted that the profile development in the tropics is a good expression of the stage of chemical weathering of the soil; therefore this field characteristic is very suitable for evaluation purposes. Table 30 gives the ratings as used in the system.

(2) TEXTURE (PARENT MATERIAL)

The parent material of a soil can be defined by its texture and mineralogical composition. In tropical areas the mineralogical composition is function of the weathering stage and as such expressed in the profile development. This implies that the rating for texture joined to the rating for profile development will fully evaluate the parent material. Texture will be rated with regard to its influence on the hydromorphic and physico-chemical properties (table 31).

The textural rating of the profile is the weighted average rating calculated over a depth of 1 m.

(3) SOIL DEPTH

The depth of a lateritic crust or a gravel layer with more than 90 weight % coarse fragments may influence considerably the suitability for crop production. There is however a different reaction to soil depth, whether annual crops with superficial root system are involved, or whether perennial crops with a deeper root system are considered. The ratings used are given in table 32.

Table 30. Ratings for profile development

PROFILE DEVELOPMENT	RATING
(1) absence of diagnostic subsurface horizons (A-C profiles), or profiles with cambic or argillic horizon but with a CEC > 24 cmol(+)kg^{-1} clay	100
(2) cambic or argillic horizon with a CEC < 24 cmol (+)kg^{-1} clay and a Munsell chroma ≤ 4	95
(3) argillic horizon with a good structure, a CEC < 24 cmol(+)kg^{-1} clay, a Munsell chroma > 4 and > 50% clay cutans on ped faces	90
(4) argillic horizon with a good structure, a CEC < 24 cmol(+)kg^{-1} clay, a Munsell chroma > 4 and < 50% clay cutans on ped faces	85
(5) oxic horizon with some (good) structure and some patchy clay skins	80
(6) oxic horizon with weak structure and almost without patchy clay skins	75
(7) oxic horizon with a very weak structure but having a net negative charge	65
(8) oxic horizon with a very weak structure, a bleached A2(E) horizon and/or a positive charge	55

Remark : At the time the method was developed, the kandic horizon was not yet considered as a diagnostic horizon

Table 31. Ratings for soil texture of fine earth

TEXTURAL CLASS	RATING						
	-15% coarse fragments (*)	more than 15% coarse fragments					
		rock fragments		laterite gravel		quartz	
		gravelly (1)	very gravelly (2)	gravelly	very gravelly	gravelly	very gravelly
Clay (0-2μ) + 75	75	85	60	80	60	-	-
Clay 60-75	90	100	65	95	60	-	-
C-60, SiC	100	90	75	85	60	-	-
SiCL	95	85	70	80	60	70	50
CL	90	80	65	75	55	65	50
SiL, Si	85	75	65	70	50	60	50
SC	80	70	60	65	50	55	50
L	75	70	60	65	50	55	50
SCL	70	65	55	60	50	50	45
SL	60	55	50	50	45	45	40
LS	50	45	40	40	35	35	30
S	40	35	30	30	25	25	20

(1) 15-40% coarse fragments
(2) 40-90% coarse fragments
(*) coarse fragments expressed in weight percentages

Table 32. Rating of soil depth

DEPTH (cm)	RATINGS	
	Perennials with deep rooting system	Annuals with superficial root system
+120	100	100
80-120	85	100
50- 80	70	85
20- 50	50	70
- 20	30	50

(4) **DRAINAGE**

In tropical areas the influence of the permanent or temporarily watertable affects particularly the soil color; for this reason color-drainage classes have been introduced and rated (table 33).

(5) **BASE SATURATION**

The natural fertility of a tropical soil is for a great deal a function of the base status of the profile. Base status is further well related to pH and is rated with regard to the situation in the A and the B horizon (table 34).

(6) **DEVELOPMENT OF ORGANIC TOPSOIL**

The development of the organic topsoil (A-horizon) has been rated with regard to the ecological conditions. As humiferous topsoil one considers :

- **under savannah** : Munsell colors with values of 3 or less, associated with chromas of 2 or less;

Table 33. Rating of color - drainage classes

COLOR*-DRAINAGE CLASS	RATINGS	
	ANNUAL CROPS	PERENNIAL CROPS
(1) red, well drained; (5YR and redder)	100	100
(2) yellow, well drained; (yellower than 5YR and no mottling in upper 120 cm)	95	95
(3) moderately well drained; (whatever the color, mottling between 80 and 100 cm)	90	80
(4) imperfectly drained; (mottling between 40 and 80 cm)	75	60
(5) poorly drained; (mottling between 0 and 40 cm)	60	40
(6) very poorly drained; (reduced horizon in upper part)	50	25

* colors : moist

Table 34. Rating of pH and Ca saturation

pH AND Ca SATURATION	RATING
(1) pH 5.8 and higher in A and B (Sat. > 50%)	100
(2) pH less than 5.8 in B (Sat. < 50%)	
(a) topsoil more than 5.8 (Sat. > 50%)	95
(b) topsoil 5.2-5.8 (Sat. 35-50%)	90
(c) topsoil 4.6-5.2 (Sat. 15-35%)	75
(d) topsoil less than 4.6 (Sat. < 15%)	60

- **under forest and under cultivation** : Munsell colors with values of 4 or less and chromas of 3 or less.

Ratings for the development of the organic topsoil are given in table 35; look first to the color and than to the thickness.

Table 35. Ratings for the development of the humiferous topsoil

THICKNESS CLASSES (in cm) OF THE DARK COLORED TOPSOIL			RATING
SAVANNAH	FOREST	CULTIVATED	
-	> 10	-	125
> 20	5-10	-	120
10-20	-	> 20	110
5-10	2- 5	10-20	100
2-5 (continuous)	-	5-10	80
2-5 (discontinuous)	-	< 5	60
< 2	-	-	40

2.1.4.3. Capability classes

Capability classes with regard to the value of the soil index have been defined for three groups of crops. For each group a reference crop was used to study the relation between soil index and yield.

- exacting crops : cocoa
- moderately exacting crops : cotton
- less exacting crops : rubber

Table 36. Suitability classes for different groups of crops

SUITABILITY CLASSES	VALUE OF THE SOIL INDEX		
	Exacting crops	Moderately exacting crops	Less exacting crops
Excellent suitability	> 90	> 85	> 75
Very suitable	70-90	65-85	50-75
Suitable	50-70	45-65	35-50
Moderately suitable	35-50	30-45	25-35
Slightly suitable	25-35	15-30	10-25
Unsuitable	< 25	< 15	< 10

With regard to the suitability for various crops the land capability classes are defined as follows :

CLASS I : soil index > 90. These soils are excellent for all crops.

CLASS II : soil index between 70 and 90. The soils are very suitable for exacting crops, excellent to very suitable for moderately exacting crops and excellent for less exacting crops.

CLASS III : soil index between 50 and 70. These soils are suitable for exacting crops, suitable to very suitable for moderately exacting crops and very suitable for less exacting crops.

CLASS IV : soil index between 35 and 50. The soils are moderately suitable for exacting crops, moderately suitable to suitable for moderately exacting crops and suitable for less exacting crops.

CLASS V : soil index between 20 and 35. These soils are only slightly suitable for exacting crops, slightly to moderately suitable for moderately exacting crops and moderately suitable for less exacting crops.

CLASS VI : soil index < 20. The soils are unsuitable for exacting crops, unsuitable or slightly suitable for moderately exacting crops and less exacting crops.

2.1.4.4. Form for practical use and example

LAND CAPABILITY EVALUATION IN THE HUMID TROPICS
PARAMETER SYSTEM OF SYS AND FRANKART (1971)

REFERENCES : Country :
Survey Area :

SOIL CHARACTERISTICS	PROFILE DEVELOPMENT	PARENT MATERIAL (TEXTURE + MINERAL COMPOSITION)	SOIL DEPTH	COLOUR-DRAINAGE	pH-BASE SATURATION	EPIPEDON DEVELOPMENT	CAPABILITY INDEX
Soil unit :							
Annual crops							Capability class :
Perennial crops							Capability class :

EXAMPLE : moderately well drained soil under savannah in the Bafia survey area in Cameroon (Soil Unit AB1)

Brief profile description :

A 0-18 cm : 5YR 2/1; clay, with less than 60% clay; no coarse fragments; well developed crumb structure;

Bt1 18-42 cm : 5YR 4/5; clay, clay content between 60 and 75%; no coarse fragments; well developed angular blocky structure; less than 50% clay cutans on the ped faces;

Bt2 42-82 cm : 5YR 4/5; clay, clay content between 60 and 75%; no coarse fragments; well developed angular blocky structure; less than 50% clay cutans on the ped faces;

Cg 82-110 cm : 5YR 5/6; silty clay; 20% rock fragments; weak developed angular blocky structure; mottling;

R 110+ : hard bedrock.

Some chemical characteristics

HOR.	DEPTH (cm)	O.C. (%)	pH H_2O	pH KCl	CEC (cmol(+).kg^{-1} clay)	Ca Sat. (%)
A	0-18	2.42	5.7	5.1	22	48
Bt1	18-42	0.20	5.4	4.9	12	39
Bt2	42-82	-	5.3	4.9	13	38
Cg	82-110	-	5.5	5.0	15	40
R	110+	-	-	-	-	-

Problem :

Capability class for annual and perennial crops

Solution :

Determination of the ratings for the different soil characteristics

(1) **PROFILE DEVELOPMENT** : argillic horizon with a good structure, a CEC < 24 cmol(+)kg^{-1} clay, a Munsell chroma > 4 and < 50% clay cutans on ped faces ⇒ rating : 85.

(2) **TEXTURE** : textural rating is the weighted average rating calculated over a depth of 1 m.

A 0-18 cm : C-60, no coarse fragments ⇒ rating : 100
Bt1 18-42 cm : C 60-75, no coarse fragments ⇒ rating : 90
Bt2 42-82 cm : C 60-75, no coarse fragments ⇒ rating : 90
Cg 82-110 cm : SiC, 20% rock fragments ⇒ rating : 90

Weighted average rating : 18 x 100 = 1800
24 x 90 = 2160
40 x 90 = 3600
18 x 90 = 1620

Sum : 9180 : 100 = 92

(3) **SOIL DEPTH** : the profile has a depth of 110 cm;
rating for annual crops : 100;
rating for deep rooting perennial crops : 85.

(4) **DRAINAGE** : moderately well drained, mottling between 80 and 100 cm;
rating for annual crops : 90;
rating for perennial crops : 80.

(5) **SATURATION** : pH topsoil is between 5.2 and 5.8, with a saturation between 35 and 50% ⇒ rating : 90.

(6) **DEVELOPMENT OF ORGANIC TOPSOIL** :

A horizon 0-18 cm, 5YR 2/1 : value less than 3 and chroma less than 2; thickness 18 cm (savannah)⇒ rating : 110.

LAND CAPABILITY EVALUATION IN THE HUMID TROPICS
PARAMETER SYSTEM OF SYS AND FRANKART (1971)

REFERENCES : Country : **Cameroon**
Survey Area : **Bafia**

SOIL CHARACTERISTICS	PROFILE DEVELOPMENT	PARENT MATERIAL (TEXTURE + MINERAL COMPOSITION)	SOIL DEPTH	COLOUR-DRAINAGE	pH-BASE SATURATION	EPIPEDON DEVELOPMENT	CAPABILITY INDEX
Soil unit : **AB1**							
Annual crops	85	92	100	90	90	110	70
				Capability class : **II-III**			
Perennial crops	85	92	85	80	90	110	53
				Capability class : **III**			

A capability index of 70 (capability class : II-III) means :
- suitable to very suitable for exacting annuals;
- very suitable for moderately exacting annuals; and
- very suitable for less exacting annuals.

A capability index of 53 (capability class III) means :
- suitable for exacting perennials (e.g. cocoa);
- suitable for moderately exacting perennials; and
- very suitable for less exacting perennials (e.g. rubber).

2.2. Crop specific land evaluation method - FAO land suitability classification

2.2.1. GENERAL PRINCIPLES

The systems of land capability (or suitability) classification of which we have discussed only some examples are diverse in form and in concept. Most of these systems can be considered as general land evaluation methods; with only some reference to general utilization (e.g. USDA land capability classification : arable land, pasture, forest).

The first FAO panel for land evaluation (**Wageningen, 1973**) has defined the concept of land utilization types and suggested the classification of land for a specific use.

The FAO system also considers a quantitative and a qualitative classification and recommends to make a choice between both methods according to the data available. The system refers to current and potential suitability classifications as defined earlier.

The FAO land suitability classification is presented in different categories : orders, classes, subclasses and units.

(1) **LAND SUITABILITY ORDERS**

At the origin three orders were defined : suitable (S), conditionally suitable (CS) and unsuitable (N).

The purpose of classification at the order level is to minimize the risk of misunderstanding by establishing the basic meaning of more detailed interpretations. The order should always be quoted in the classification symbol, therefore, even when only one order of land is represented in the survey area.

At a later stage (**Rome, 1975**), it was stated that there was a need to diminish the emphasis put on the order "conditionally suitable, CS" which had been the subject of misunderstanding and misuse. Therefore it was recommended to use 2 orders.

ORDER 'S' - Suitable land : land on which sustained use for the defined purpose in the defined manner is expected to yield benefits that will justify required recurrent inputs without unacceptable risk to land resources on the site or in adjacent areas.

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 the interpretation.

(2) **LAND SUITABILITY CLASSES**

The framework at its origin permits complete freedom in determining the number of classes within each order. However, it has been recommended to use only 3 classes within order S and 2 classes within order N.

The class will be indicated by an Arabic number in sequence of decreasing suitability within the order; and therefore reflects degrees of suitability within the orders.

S1 : suitable
S2 : moderately suitable
S3 : marginally suitable
N1 : actually unsuitable but potentially suitable
N2 : actually and potentially unsuitable

No firm criteria are given for defining the classes which permits complete freedom in the choice of the criteria in order to elaborate the degrees of suitability within the orders.

For each specific case a specific method has to be suggested. Appraisal can be done according to an evaluation of land limitations or even through a parametric method.

(3) LAND SUITABILITY SUBCLASSES

The subclasses are reflecting kinds of limitations, or main kinds of improvement measures required, within classes. They are indicated in the symbol using lower case letters with mnemonic significance.

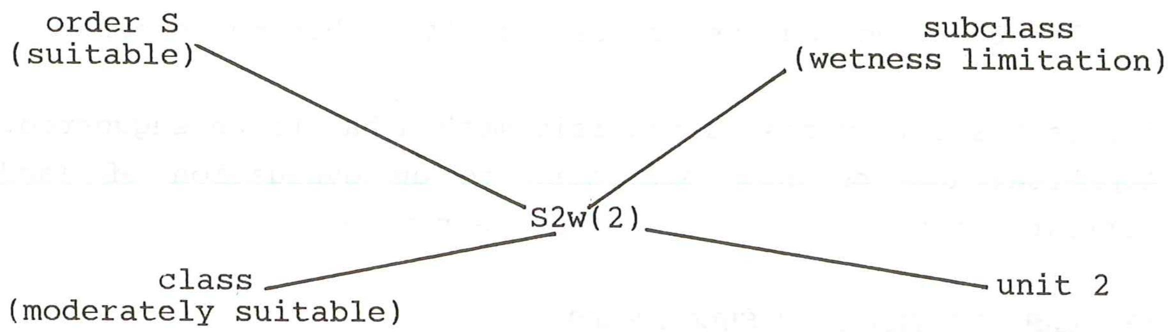
The following subclasses have been defined :

c : climatic limitations
t : topographic limitations
w : wetness limitations
s : physical soil limitations (influencing soil/water relationship and management)
f : soil fertility limitations not readily to be corrected
n : salinity (and/or alkalinity) limitations

(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 improvement works. It is suggested to indicate them by Arabic numbers, enclosed in brackets.

Example



2.2.2. EVALUATION PROCEDURE

The evaluation procedure consists of 3 phases :

(1) collection of the necessary characteristics or qualities;

(2) determination of the requirements of the land utilization types; and

(3) the evaluation sensu stricto by comparing characteristics or qualities with the requirements of the land utilization types.

2.2.2.1. Phase I : collection of the necessary characteristics or qualities

This phase consists of the characterization of the land units in terms of land characteristics or land qualities. It is absolutely necessary to deal with all characteristics or qualities having an influence on the production capacity of the considered land utilization type.

The characterization of the climate and the other characteristics or qualities is done separately. The study of the climate includes a selection of climatic characteristics which have an influence on the behaviour of the considered land utilization type.

Data collection for an evaluation of a land unit for a specific crop in terms of characteristics :

(1) **CLIMATIC CHARACTERISTICS**

The collection of data for a climatic evaluation of annual crops (e.g. grain maize) groups all parameters (latitude and altitude of the climatic station, height of the wind vane, data on rainfall, temperature, insolation, relative humidity and windspeed) necessary for a preliminary determination of :

- the growing period (see PART I);
- the planting or sowing date; and
- the crop variety with well known crop cycle.

It is usually recommended to start sowing as early as possible in the growing period. **FAO (1983)** recommends to start planting in the first decade that receives 30 mm of rainfall.

The climatic characteristics (insolation, temperature, rainfall and relative humidity) necessary for the determination of the climatic suitability of annual crops have to be considered only during the crop cycle. Average values for the length of the crop cycle have to be calculated.

For perennial crops, no preliminary determinations are needed and monthly averages on a yearly base are used for the evaluation.

(2) **LANDSCAPE AND SOIL CHARACTERISTICS**

Some data such as **slope**, **drainage** and **flooding** can be used as they are indicated in the soil profile descriptions, others have to be recalculated over a certain depth (upper 25 cm, depth of the rooting system), sometimes by using weighting factors for the different profile sections.

For cereals, pasture and annual root crops, the soil parameters are calculated over a depth of 100 cm, while for deep rooting perennial crops a depth of 150 cm is considered.

Soil profiles are subdivided into equal sections and to each section a weighting factor is attributed (table 37).

Table 37. Number of sections and weighting factors for different depths

DEPTH (cm)	NUMBER OF EQUAL SECTIONS	WEIGHTING FACTORS
125-150	6	2.00-1.50-1.00-0.75-0.50-0.25
100-125	5	1.75-1.50-1.00-0.50-0.25
75-100	4	1.75-1.25-0.75-0.25
50- 75	3	1.50-1.00-0.50
25- 50	2	1.25-0.75
25	1	1.00

PHYSICAL SOIL CHARACTERISTICS

Texture/structure : if the soil horizons have different textural classes and/or structure, a new textural class for the depth of rooting zone has to be calculated using the weighting factors. If one fraction (clay, silt or sand) is constant throughout the profile, only one other fraction (clay, silt or sand) has to be recalculated, using the weighting factors, because two fractions are enough to determine a textural class in the textural triangle.

Coarse fragments : the data needed are a function of the evaluation method that will be used :

- In a limitation approach, the content of coarse fragments in vol. % has to be recalculated over the depth of the rooting zone by using the weighting factors.

- In a parametric approach, the presence of coarse fragments is evaluated together with texture. This is achieved by a downgrading of the fine earth texture rating for coarse fragments according to the criteria given in table 38.

Table 38. Particle size rating of gravelly soils

Coarse fragments Volume %	% of fine earth rating for		
	quartz	Fe-oxide concretions	rock fragments
5	90	95	-
15	80	88	95
35	62	68	75
55	45	50	55
75	25	30	35

It is recommended to differentiate three groups of coarse fragments : rock fragments, laterite gravel and quartz gravel.

A graphical determination of the downgrading can be done by fig. 2. In a parametric approach, the percentage of the fine earth rating can be calculated using equations.

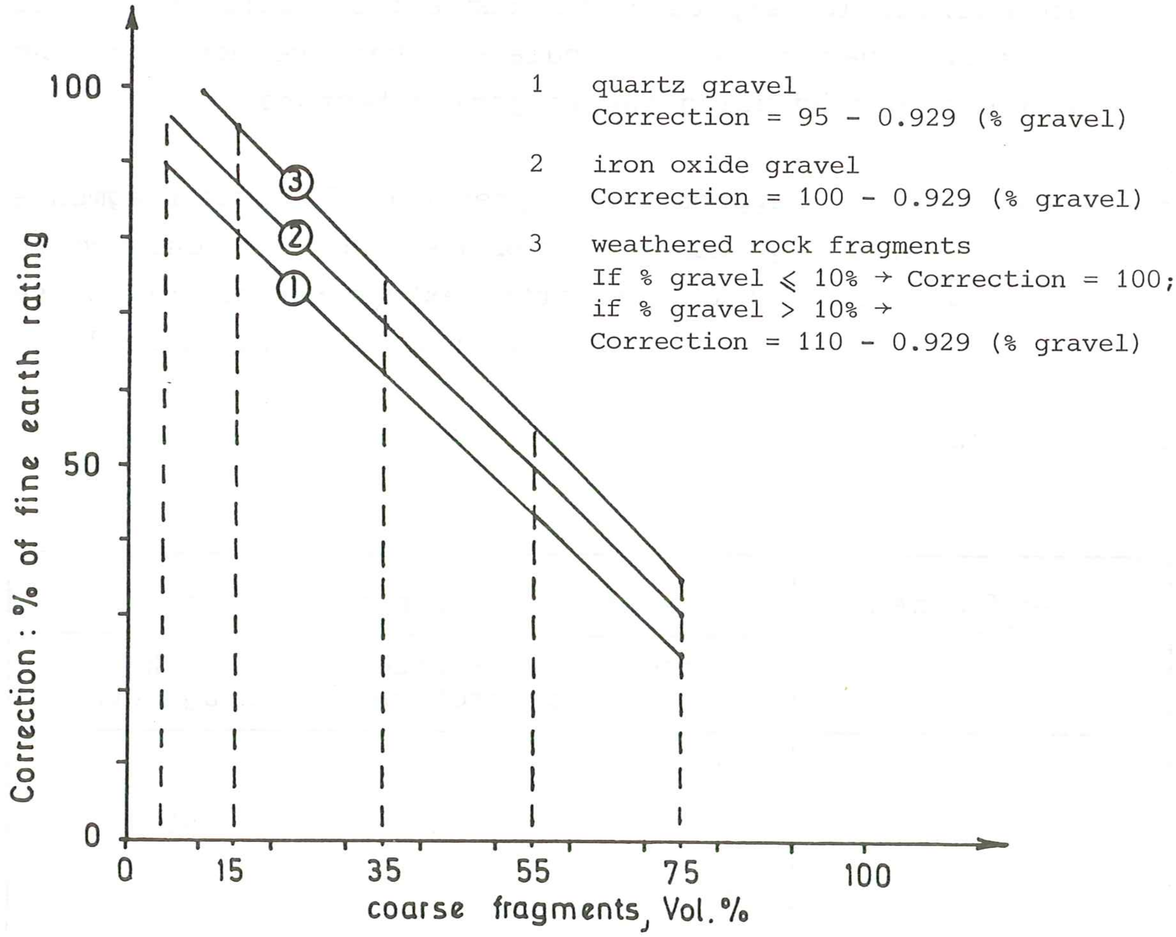


Fig. 2 *Particle size rating of gravely soils as expressed in percent of fine earth rating.*

Soil depth : information from profile description.

If the soil depth is not optimal, it will be evaluated together with texture (and coarse fragments) in the parametric evaluation method. This is achieved by attributing a rating of 0 to a limiting impermeable layer.

Remark : when coarse fragments (gravel) are present and the soil depth is not optimal, the 3 characteristics texture/structure, coarse fragments and depth are evaluated together in the parametric approach and represented only by one rating.

Calcium carbonate : the adapted $CaCO_3$ content is calculated, using weighting factors for the different profile sections.

Gypsum : the adapted $CaSO_4$ content is calculated, using weighting factors for the different profile sections.

FERTILITY CHARACTERISTICS

Apparent CEC : the CEC of the clay fraction ($cmol(+)kg^{-1}$ clay) in the B horizon or at a depth of 50 cm is calculated, without correction for organic matter.

Sum of basic cations : the weighted average of Ca + Mg + K expressed in $cmol(+)kg^{-1}$ soil is calculated for the upper 25 cm of the mineral soil.

Acidity (pH-H_2O) : the weighted average is calculated for the upper 25 cm. This characteristic is not considered for Low Activity Clay (LAC) soils.

Organic carbon : the weighted average expressed in % is calculated for the upper 25 cm.

SALINITY AND ALKALINITY

Salinity : the adapted electric conductivity (Ec) expressed in dS/m is calculated, using weighting factors for the different profile sections.

Alkalinity : the alkalinity of the horizon presenting the highest ESP value within a depth of 100 cm is used for the evaluation.

2.2.2.2. Phase II : determination of the requirements of the land utilization types

This consists of the study of climatic and soil requirements for the considered land utilization types. This is done separately for climate at one hand, landscape and soil at the other hand. There are, of course, different ways to present the requirement data. For our use we have prepared requirement tables for the different crops (part III). We should realize that these criteria have been elaborated in a specific agro-ecological zone. Production functions which may work adequately in one region may be unreliable in an other. **Therefore these tables have to be considered as a guideline.** The class, or limitation levels for the different characteristics should be adapted to local conditions and sometimes to crop varieties.

In some places texture is more important for soil-water relationships (xeric) than in other places with permanent rainfall (udic).

2.2.2.3. Phase III : the evaluation sensu stricto

The evaluation sensu stricto is realized by comparing the land characteristics (or qualities) with the requirements of the land utilization type. The land class can be determined following different methods :

(1) **SIMPLE OR MAXIMUM LIMITATION METHOD**

In this method the land characteristics (or qualities) are compared with the requirements and the land class is attributed according to the less favourable characteristic (or quality).

The methodology suggests in the first place an evaluation of the climatic characteristics with as ultimate aim the determination of one class level to be introduced in the total evaluation.

The relation between land classes (suitability classes) and limitations is given in table 39.

Table 39. Relation between suitability classes and limitations

LIMITATIONS	SUITABILITY CLASSES (LAND CLASSES)
0 : no	**S1** : very suitable
1 : slight	**S1** : very suitable
2 : moderate	**S2** : moderately suitable
3 : severe	**S3** : marginally suitable
4 : very severe	**N1** : unsuitable but susceptible for correction **N2** : unsuitable and non-susceptible for correction

(2) LIMITATION METHOD REGARDING NUMBER AND INTENSITY OF LIMITATIONS

This method defines the land classes according to the number and the intensity of limitations. The methodology suggests in the first place an evaluation of the climate, whereby the climatic characteristics are regrouped in 4 groups (radiation, temperature, rainfall and relative air humidity). For each group of climatic characteristics the most severe limitation will be considered to determine the climatic suitability class as well as the corresponding limitation level to be used in the total land evaluation (table 40).

Table 40. Criteria for the determination of the climatic suitability class and the corresponding limitation level

CLASS	CRITERIA	LIMITATION
S1	Climate has no limitations; or Climate with max. 3 slight limitations	**0** **1**
S2	Climate with 4 slight limitations and/or max. 3 moderate limitations	**2**
S3	Climate with 4 moderate limitations and/or one or more severe limitations	**3**
N	Climate with one or more very severe limitations	**4**

The land suitability classes are defined according to the criteria given in table 41.

Table 41. Criteria for the determination of the land suitability classes

LAND CLASSES	CRITERIA
S1 : very suitable	land units with no, or only 4 slight limitations
S2 : moderately suitable	land units with more than 4 slight limitations, and/or no more than 3 moderate limitations
S3 : marginally suitable	land units with more than 3 moderate limitations, and/or one or more severe limitation(s)
N1 : actually unsuitable and potentially suitable	land units with very severe limitations which can be corrected
N2 : unsuitable	land units with very severe limitations which can not be corrected

(3) **PARAMETRIC METHOD**

In the parametric method a numeral rating is attributed to each characteristic (or quality). If a land characteristic (or quality) is optimal for the considered land utilization type the maximum rating of 100 is attributed; if the same land characteristic (or quality) shows a limitation a lower rating will be applied. The individual ratings will be used to calculate an index.

The methodology suggests in the first place an evaluation of the climate, whereby the climatic characteristics are regrouped into 4 groups (characteristics related to radiation, temperature, rainfall and relative air humidity). The climatic index will be calculated using the lowest rating of each group. This index is transferred into a climatic rating that will be used in the total land evaluation. This is carried out according the relations expressed in table 42 and fig. 3.

Table 42. Key for determination of climatic rating from climatic index

CLIMATIC CLASSES	LIMITATION LEVELS	CLASS INDICES	CORRESPONDING RATINGS
S1	no to slight	100-75	100-85
S2	moderate	75-50	85-60
S3	severe	50-25	60-40
N	very severe	25-12.5 12.5-0	40-20 20- 0

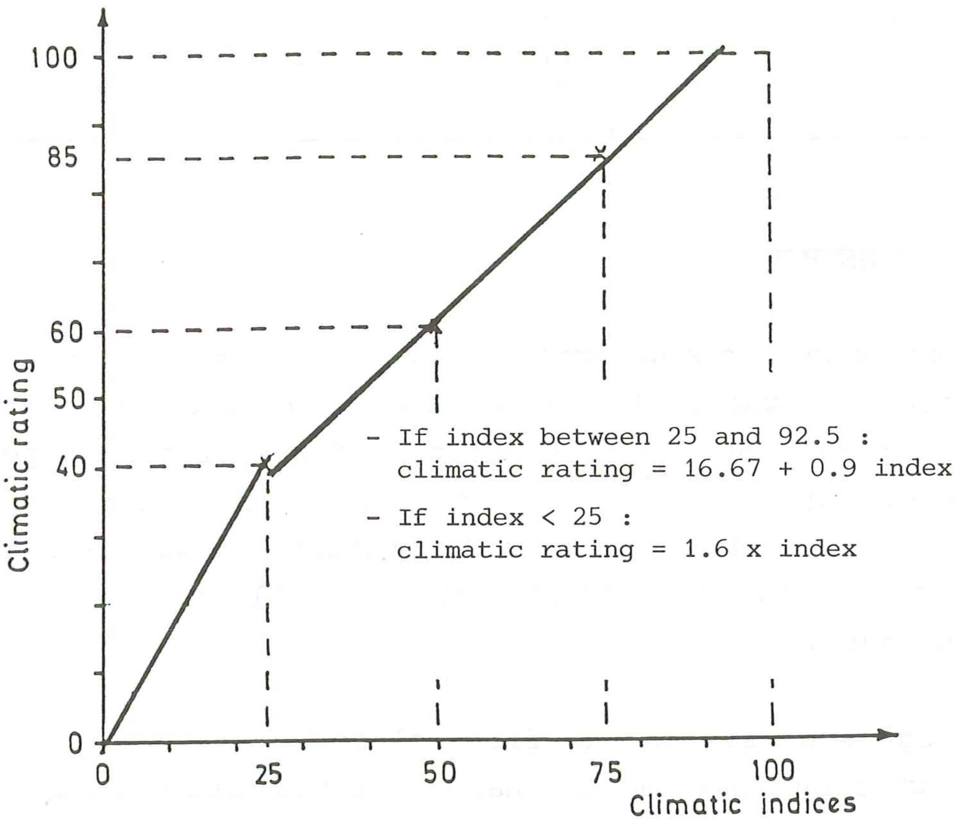


Fig. 3 Relation climatic indices and ratings.

The indices (climatic index and land index) are calculated from the individual ratings and this can be done following two procedures :

(1) **STORIE METHOD**

$$I = A \times \frac{B}{100} \times \frac{C}{100} \times \ldots$$

(A, B, C... : ratings)

(2) **SQUARE ROOT METHOD (Khiddir, 1986)**

$$I = R_{min} \times \sqrt{\frac{A}{100} \times \frac{B}{100} \times \ldots}$$

I : index
Rmin : minimum rating
A, B... : other ratings besides the minimum rating

The suitability classes are defined according to the value of the index (table 43).

Table 43. Index values for the different suitability classes

INDEX	SUITABILITY CLASS
100-75	**S1** : very suitable
75-50	**S2** : moderately suitable
50-25	**S3** : marginally suitable
25-0	**N** : unsuitable

2.2.2.4. **Example**

As an example we will proceed to the evaluation for grain maize (low level of management) of a **Kanhaplic Haplustalf, fine loamy, kaolinitic, isohyperthermic (Haplic Lixisol)** developed on sandstone (Grès de Garoua); a representative soil for the area of Ndjola (9°05'57"N, 13°30'24"E; altitude : 330 m), 25 km south of Garoua (North Cameroon).

PHASE I : DATA COLLECTION

(1) CLIMATIC CHARACTERISTICS

The climatic of Ndjola is comparable to that of Garoua, so that the climatic data of Garoua will be used (Ndjola has no meteorological station) (table 44)

Preliminary determinations

- Determination of growing period (as explained in Part I) : analysis of rainfall and ETo data reveals that the growing period is stretched over 180 days, starting on May 3rd until November 3rd (end of the rains is on October 14th). This means that a maize variety with a crop cycle of maximum 180 days can be fit into the growing period.

- Determination of the sowing date : it is usually recommended to start sowing as early as possible in the growing period. FAO further recommends to start planting in the first decade that receives 30 mm of rain. For the station of Garoua, both conditions are fulfilled in the first decade of May (1st-10th) (table 45).

- Determination of the maize variety : since the mean daily temperatures during the growing season are greater than 20°C, both early and medium varieties can be grown. Temperature requirements, expressed as sum of mean daily temperatures, for medium varieties are 2,500 to 3,000 degree days, while early varieties require about 1,800 degree days (**Doorenbos and Kassam, 1986**).

Table 44. Climatic characteristics of the station of Garoua (9.2 N, 13.23 E; altitude 244 m)

CHARACTERISTICS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Insolation												
- n	9.07	9.57	8.46	7.89	8.16	7.60	6.18	5.47	6.46	8.83	9.60	9.62
- N	11.63	11.82	12.08	12.33	12.55	12.67	12.62	12.43	12.19	11.93	11.71	11.59
- n/N	0.78	0.81	0.70	0.64	0.65	0.60	0.49	0.44	0.53	0.74	0.82	0.83
TEMPERATURE (°C)												
- Tmax	35.00	37.20	39.50	38.50	36.00	32.10	30.50	30.00	30.70	33.50	36.00	35.30
- Tmin	18.00	21.10	24.50	26.00	24.50	22.10	22.00	21.70	21.50	21.70	19.70	17.70
- Tday	29.58	31.06	34.69	34.48	32.29	28.87	27.76	27.33	27.75	29.73	30.80	29.69
- Tnight	23.60	26.33	29.27	29.89	28.01	25.12	24.58	24.56	24.40	25.50	25.04	23.52
- Tmean	26.50	29.15	32.00	32.25	30.25	27.10	26.25	25.85	26.10	27.60	27.85	26.50
RAINFALL												
- rainfall (mm)	0	1	5	38	122	155	178	224	214	75	1	1
- frequency (days)	20	20	20	15	8	3	4	2	3	15	20	20
RELATIVE AIR HUMIDITY												
- mean relative air hum. (%)	24.9	21.2	26.5	40.9	59.0	74.2	77.5	79.1	79.1	68.4	45.1	24.9
Wind speed (m/sec)	1.6	2.0	2.6	3.0	2.9	2.7	2.6	2.5	2.1	2.2	2.1	1.8
Calculated ETo (mm) (**Frère and Popov, 1979**)	158.89	199.37	235.49	216.55	178.63	141.37	126.75	121.15	124.51	147.11	177.14	163.65

Table 45. Interpolated climatic data (normal value per decade) - (for calculation see Part I)

NUMBER	PERIOD	P (mm)	ETo (mm)
1	jan1	0.00	51.26
2	jan2	0.00	52.40
3	jan3	0.00	55.23
4	feb1	0.06	62.17
5	feb2	0.30	66.51
6	feb3	0.63	70.69
7	mar1	0.00	77.20
8	mar2	1.10	79.18
9	mar3	3.90	79.11
10	apr1	6.48	75.23
11	apr2	12.04	72.42
12	apr3	19.48	68.91
13	may1	33.85	63.72
14	may2	41.30	59.53
15	may3	46.85	55.37
16	jun1	48.49	50.14
17	jun2	51.79	46.84
18	jun3	54.72	44.38
19	jul1	55.64	43.43
20	jul2	59.05	42.14
21	jul3	63.31	41.18
22	aug1	72.32	40.56
23	aug2	75.36	40.27
24	aug3	76.32	40.31
25	sep1	78.81	40.18
26	sep2	72.93	41.27
27	sep3	62.26	43.06
28	oct1	37.23	46.16
29	oct2	24.20	48.94
30	oct3	13.57	52.01
31	nov1	1.00	57.86
32	nov2	0.00	59.59
33	nov3	0.00	59.70
34	dec1	0.38	55.62
35	dec2	0.35	54.44
36	dec3	0.27	53.59

For early varieties, with a crop cycle between 80 and 110 days, the 1,800 degree days necessary to reach maturity are already reached after 64 days in Garoua :

May	: 29 days	x 30.25°C	= 877.25	degree days
June	: 30 days	x 27.10°C	= 813.00	degree days
July	: 5 days	x 26.25°C	= 131.25	degree days
	64 days		1,821.50	degree days

Medium varieties have a crop cycle of 110 to 140 days and require 2,500 to 3,000 degree days to maturity. In Garoua, 3,000 degree days are reached after 110 days :

May	: 29 days	x 30.25°C	= 877,25	degree days
June	: 30 days	x 27.10°C	= 813.00	degree days
July	: 31 days	x 26.25°C	= 813.75	degree days
August	: 20 days	x 25.85°C	= 517.00	degree days
	110 days		3,021.00	degree days

Since the early variety will show the tendency to develop too fast (maturity reached after 64 days compared to a crop cycle of 80 to 110 days, it seems appropriate to choose a medium variety with a crop cycle of about 110 days.

Data used in the evaluation

Crop cycle : 110 days, medium grain maize variety; ripening period: 10 days.

INSOLATION

May	: 29 days x 8.16	=	236.64
June	: 30 days x 7.60	=	228.00
July	: 31 days x 6.18	=	191.58
August	: 20 days x 5.47	=	109.40
	110 days		765.62 : 110 = 6.96

TEMPERATURE

May	: 29 days x 30.25°C	=	877,25
June	: 30 days x 27.10°C	=	813.00
July	: 31 days x 26.25°C	=	813.75
August	: 20 days x 25.85°C	=	517.00
	110 days		3,021.00 : 110 = 27.46°C

RAINFALL

May : 29 days : $\frac{122 \times 29}{31}$ = 114 mm

June : 30 days : = 155 mm

July : 31 days : = 178 mm

August : 20 days : $\frac{224 \times 20}{31}$ = 145 mm

110 days 592 mm

Using the interpolated rainfall data per decade; the total rainfall during the crop cycle (from May 1 to Aug 2, table 45) will be 603 mm (each month here is considered as 30 days).

RELATIVE AIR HUMIDITY

- Pre-ripening period : 100 days

May	: 29 days	x 59.0%	=	1,711.0
June	: 30 days	x 74.2%	=	2,226.0
July	: 31 days	x 77.5%	=	2,402.5
August	: 10 days	x 79.1%	=	791.0
	100 days			7,130.5 : 100 = 71.3%

Ripening period (only considered for grain maize) : 10 days
August : 79.1%.

(2) **LANDSCAPE AND SOIL CHARACTERISTICS**

The considered area is almost flat (slope = 1%) and has never been flooded. The soils have a weak medium angular to subangular blocky structure throughout the solum and they are well to somewhat excessively drained; no watertable has been observed (very deep). The soils are completely free of salts and the exchangeable sodium is almost zero.

Table 46 gives the most important physico-chemical characteristics

Data used in the evaluation

SLOPE : 1% (low level of management)
FLOODING : Fo
DRAINAGE : g (good) - loamy soil
TEXTURE/STRUCTURE : the structure is weak medium angular to subangular blocky throughout the solum. The soil horizons have different textural classes, which implies that a new textural class for the depth of the rooting zone has to be calculated using the weighting factors.

Table 46. Analytical characterization of the reference profile

HORIZON	DEPTH (cm)	TEXTURE (%)			TEXT. CLASS	COARSE FRAGMENTS (vol. %)	pH		O.C. (%)	ADSORPTION COMPLEX (cmol(+)kg^{-1} soil)				
		CLAY	SILT	SAND			H_2O	KCl		CEC	Ca	Mg	K	Na
A	0-16	10	13	77	SL	-	6.0	4.8	0.62	2.2	1.65	0.39	0.04	0.01
BA	16-38	10	14	76	SL	-	5.5	4.4	0.58	2.9	1.59	0.49	0.04	0.02
Bt	38-75	24	14	62	SCL	-	5.7	4.6	0.10	4.2	2.19	0.49	0.06	0.02
Cr	75-90	15	13	72	SL	15, quartz	6.8	5.7	0.03	3.8	2.64	1.04	0.10	0.02
R	90+	-	-	-	-	-	-	-	-	-	-	-	-	-

For the example of grain maize the reference depth is 100 cm; but the reference soil profile has a rock substratum at 90 cm, so that we have to use 4 equal sections (4 x 22.5 cm) with weighting factors : **1.75-1.25-0.75-0.25.**

- Recalculation of the clay content :
  We have to consider 4 equal sections of (90:4) 22.5 cm

Section 0 -22.5 cm	: 0 - 16	: 16 x 1.75 x 10	= 280.00
	16 - 22.5	: 6.5 x 1.75 x 10	= 113.75
Section 22.5-45 cm	: 22.5- 38	: 15.5 x 1.25 x 10	= 193.75
	38 - 45	: 7 x 1.25 x 24	= 210.00
Section 45 -67.5 cm	: 45 - 67.5	: 22.5 x 0.75 x 24	= 405.00
Section 67.5-90 cm	: 67.5- 75	: 7.5 x 0.25 x 24	= 45.00
	75 - 90	: 15 x 0.25 x 15	= 56.25
		sum	1,303.75

The recalculated clay content of the profile is :
1,303.75 : 90 = 14.5%

- Recalculation of the silt content :

Section 0 -22.5 cm :	0 - 16	: 16 x 1.75 x 13 =	364.00
	16 - 22.5	: 6.5 x 1.75 x 14 =	159.25
Section 22.5-45 cm :	22.5- 45	: 22.5 x 1.25 x 14 =	393.75
Section 45 -67.5 cm :	45 - 67.5	: 22.5 x 0.75 x 14 =	236.25
Section 67.5-90 cm :	67.5- 75	: 7.5 x 0.25 x 14 =	26.25
	75 - 90	: 15 x 0.25 x 13 =	48.75
		sum	1,228.25

The recalculated silt content of the profile is :
1,228.25 : 90 = 13.6%

Recalculated texture : SL

If one fraction (e.g. silt) is constant throughout the profile, only one other fraction has to be recalculated.

COARSE FRAGMENTS : 15 vol. % of quartz gravel between a depth of 75 to 90 cm. For the limitation approach, the content of coarse fragments has to be recalculated over the depth of the rooting zone by using equal sections and weighting factors.

- Recalculation of the gravel content

Section 0 -22.5 cm :	0 - 16	: 16 x 1.75 x 0 =	0
	16 - 22.5	: 6.5 x 1.75 x 0 =	0
Section 22.5-45 cm :	22.5- 38	: 15.5 x 1.25 x 0 =	0
	38 - 45	: 7 x 1.25 x 0 =	0
Section 45 -67.5 cm :	45 - 67.5	: 22.5 x 0.75 x 0 =	0
Section 67.5-90 cm :	67.5- 75	: 7.5 x 0.25 x 0 =	0
	75 - 90	: 15 x 0.25 x 15 =	56.25
		sum	56.25

The recalculated gravel content is :
56.25 : 90 = 0.6%

DEPTH : 90 cm

$CaCO_3$ CONTENT : 0%

$CaSO_4$ CONTENT : 0%

APPARENT CEC : select the CEC (cmol(+)kg^{-1} soil) of B horizon or at 50 cm depth and calculate the apparent CEC (cmol(+)kg^{-1} clay), without correction for organic material.

$$\frac{4.2 \times 100}{24} = 17.5 \text{ cmol(+)kg}^{-1} \text{ clay}$$

SUM OF BASIC CATIONS (0-25 cm) : weighted average of Ca + Mg + K expressed in cmol(+)kg^{-1} soil

A : 0-16 cm : Ca + Mg + K = 1.65 + 0.39 + 0.04 = 2.08 cmol(+)kg^{-1} soil

BA : 16-38 cm : Ca + Mg + K = 1.59 + 0.49 + 0.04 = 2.12 cmol(+)kg^{-1} soil

Weighted average (0-25 cm)

0-16 cm : 16 x 2.08 = 33.28

16-25 cm : 9 x 2.12 = 19.08

---

sum 52.36 : 25 = 2.09 cmol(+)kg^{-1} soil

ACIDITY (pH-H_2O : 0-25 cm) : weighted average

A : 0-16 cm : 16 x 6 = 96.0

BA : 16-25 cm : 9 x 5.5 = 49.5

---

sum 145.5 : 25 = 5.82

ORGANIC CARBON (0-25 cm) : weighted average

A : 0-16 cm : 16 x 0.62 = 9.92

BA : 16-25 cm : 9 x 0.58 = 5.22

---

sum 15.14 : 25 = 0.61%

SALINITY : Ec = 0 dS/m

ALKALINITY : ESP = 0

PHASE II : REQUIREMENTS

The crop requirements for maize are given in tables 47 and 49, respectively climatic requirements and landscape-soil requirements. These tables can be considered as multi-methodologic and allow to use the limitation method as well as the parametric system. For each characteristic, the tables indicate the class gradients, the limitation levels and the different ratings. The ratings to be attributed to each characteristic can be calculated by using the equations given in tables 48 and 50.

Table 47. Climatic requirements for maize

CLIMATIC CHARACTERISTICS OF THE MAIZE CROP CYCLE	LANDCLASS, DEGREE OF LIMITATION AND RATING SCALE					
	S1			S2	S3	N
	0		1	2	3	4
	100	95	85	60	40	25
Insolation						
mean n	8.5+	8.1	7.3	5.2	3.5	2.3-
Temperature						
mean temperature (°C)						
opt. day temp. range 20-30°C	22-26	21.4 28.0	20.3 32.0+	17.3	15.0-	
opt. day temp. range 25-35°C	27-31	26.4 33.0	25.3 37.0+	22.3	20.0-	
Rainfall						
total rainfall (mm)						
early var.	450+	428	383	270	180-	
medium var.	500+	475	425	300	200-	
late var.	600+	570	510	360	240-	
Relative Air Humidity						
mean RH (%) pre-ripening	75-	83	100			
mean RH (%) ripening (grain maize only)	60-	64	71	90+		

Table 48. Criteria for the determination of the ratings for the climatic characteristics of maize

CLIMATIC CHARACTERISTICS OF THE MAIZE CROP CYCLE	RATING (R)
Insolation mean n	if n > 8.5 then R = 100 if n =< 8.5 then R = 100-12* (8.5-n)

Temperature
mean temperature (°C)
opt. day temp.
range 20-30°C
	if temp >= 22 and temp =< 26 then
	R = 100
	if temp < 22 then
	R = 100-8.57* (22-temp)
	if temp > 26 then
	R = 100-2.5* (temp-26)

opt. day temp.
range 25-35°C
	if temp >= 27 and temp =< 31 then
	R = 100
	if temp < 27 then
	R = 100-8.57* (27-temp)
	if temp > 31 then
	R = 100-2.5* (temp-31)

Rainfall total rainfall (mm) early var. medium var. late var.	 R = 100-0.22* (450-rain) R = 100-0.20* (500-rain) R = 100-0.167* (700-rain)

Relative Air Humidity
mean RH (%) pre-ripening
	if RH =< 75 then
	R = 100
	if RH > 75 then
	R = 100-0.6* (RH-75)

mean RH (%) ripening
(grain maize only)
	if RH =< 60 then
	R = 100
	if RH > 60 then
	R = 100-1.33* (RH-60)

Table 49. Landscape and soil requirements for maize

LANDSCAPE AND SOIL CHARACTERISTICS FOR MAIZE	LANDCLASS, DEGREE OF LIMITATION AND RATING SCALE					
	S1			S2	S3	N
	0		1	2	3	4
	100	95	85	60	40	25
Topography						
Slope (%)						
High level management	0	1.3	3.8	10.0	15.0	19.0+
Low level management	0	2.5	7.5	20.0	30.0	38.0+
Wetness						
Flooding (x)	F0			F1		F2+
Drainage (x)				(xx)		
Clayey and loamy soils	g	m	i	pa	p	vp
Sandy soils	i	m	g	pa	p	vp
Physical Soil Characteristics						
Texture/structure (x)	C-s, Co,CL, SiCs, SiCL, SiL,Si	C+s, C-v, SC, SCL, L	C+v, SL, LS	LcS, fS		Cm, S
Coarse fragments (vol.%)						
Quartz	0	0	11	38	59	
Iron oxides	0	5	16	43	35	
Rock fragments	10-	15	25	50	70	
Depth (0%)	100+	93	80	47	20	
$CaCO_3$ content (%)	5-	8	15	23	30	35
$CaSO_4$ content (%)	0	2	5	13	20	25
Fertility characteristics						
Apparent CEC at 50 cm ($cmol(+)kg^{-1}$ clay)	24+	21	16(-)	16(+)		
Sum of basic cations (0-25 cm) ($cmol(+)kg^{-1}$ soil)	6+	5.6	4.9	3.0	1.5	
pH H_2O (0-25 cm)	5.8-6.5	6.7 5.7	7.1 5.6	8.2 5.2	9.7 4.7	
Organic carbon (%) (0-25 cm)						
Kaolinitic mat.	2.0+	1.9	1.6	1.0-		
Calcareous mat.	0.8+	0.7	0.6	0.4-		
Other materials	1.2+	1.1	1.0	0.6-		
Salinity and Alkalinity						
EC (dS/m) mean 0-100 cm	1.7-	2.1	3.0	5.0	6.7	8.0
ESP (%) max. 0-100 cm	0	5	15	20	25	

(x) signification of symbols - see Part I

(xx) pa : poor drainage, aeric (subgroup - Soil Taxonomy)

Table 50. Criteria for the determination of the ratings for the landscape and soil characteristics of maize

LANDSCAPE AND SOIL CHARACTERISTICS FOR MAIZE	RATING (R)
Topography	
Slope (%)	
Low level management	R = 100-2* (slope)
High level management	R = 100-4* (slope)
Wetness	
Flooding	-
Drainage	
Clayey and loamy soils	-
Sandy soils	-
Physical Soil Characteristics	
Texture/structure	-
Coarse fragments (vol.%)	
Quartz	if cfv = 0 then R = 100 if cfv > 0 then R = 95-0.929* (cfv)
Iron oxides	R = 100-0.929* (cfv)

Rock fragments	if cfv =< 10 then
	R = 100
	if cfv > 10 then
	R = 110- (cfv)

Depth (cm)	if depth > 100 then
	R = 100
	if depth =< 100 then
	R = 100-0.75
	(100-depth)

$CaCO_3$ content (%)	if $CaCO_3$ =< 5 then
	R = 100
	if $CaCO_3$ > 5 and
	$CaCO_3$ =< 15 then
	R = -1.5* ($CaCO_3$-5)
	if $CaCO_3$ > 15 then
	R = 85-3* ($CaCO_3$ - 15)

$CaSO_4$ content (%)	R : 100-3* ($CaSO_4$)

Table 50. Continued

Fertility characteristics	
Apparent CEC (cmol(+)/kg clay)	if ACEC > 24 then R = 100 if ACEC =< 24 and ACEC >= 16 then R = 100-1.875* (24-ACEC) if ACEC < 16 and pH KCl < 5 then R = 85 if ACEC < 16 and pH KCl >= 5 then R = 60

Sum of basic cations
(cmol(+)/kg soil)
	if sum > 6 then
	R = 100
	if sum =< 6 then
	R = 100-12.3* (6-sum)

pH H_2O	if pH < 5.8 and
	pH < 6.5 then
	R = 100
	if pH =< 5.8 then
	R = 100-66.67* (5.8-pH)
	if pH >= 6.5 then
	R = 100-23.53* (pH-6.5)

Organic carbon (%)	

Kaolinitic mat.	if O.C. > 2 then
	R = 100
	if O.C. =< 2 and
	>= 1 then
	R = 100-40* (2-OC)
	if O.C. < 1 then
	R = 60

Calcareous mat.	if O.C. > 0.8 then
	R = 100
	if O.C. =< 0.8 and
	>= 0.4 then
	R = 100-100* (0.8-OC)
	if O.C. < 0.4 then
	R = 60

Other materials	if O.C. < 1.2 then R = 100 if O.C. =< 1.2 and >= 0.6 then R = 100-66.7* (1.2-OC) if O.C. < 0.6 R = 60
Salinity and Alkalinity	
EC (dS/m) mean 0-100 cm	R = 100-11.91* (EC-1.7)

ESP (%) max 0-100 cm	if ESP < 15 then
	R = 100-ESP
	if ESP >= 15 then
	R = 85-4.5* (ESP-15)

PHASE III : EVALUATION SENSU STRICTO

Phase III is realized by comparing land characteristics with the crop requirements. The suitability classes can be determined according to different methods : limitation method or parametric method.

(1) **SIMPLE OR MAXIMUM LIMITATION METHOD**

The land characteristics are compared with the crop requirements and the land class is attributed according to the less favourable characteristic.

- EVALUATION OF CLIMATE (Compare data with table 47)
  Evaluation of climate for the medium variety of grain maize with an optimal day temperature range between 25 and 35°C.

Climatic characteristics of crop cycle	**Data**	**Max. land class**
Mean n (hrs)	6.96	S2
Mean temperature (°C)	27.46	S1
Total rainfall (mm)	592	S1
Mean RH (%) pre-ripening	71.3	S1
Mean RH (%) ripening	79.1	S2

Climatic evaluation : S2

- <u>EVALUATION OF LANDSCAPE AND SOIL</u> (compare data with table 49)

Characteristics	Data	Max. land class
Topography (t)		
- Slope (%) - low level management	1	S1
Wetness (w)		
- Flooding	F0	S1
- Drainage (loamy soils)	g	S1
Physical soil characteristics (s)		
- Texture/structure	SL	S1/S2
- Coarse fragments (vol. %) - quartz	0.60	S1
- Depth (cm)	90	S1
- $CaCO_3$ content (%)	0	S1
- $CaSO_4$ content (%)	0	S1
Fertility characteristics (f)		
- ACEC (cmol(+)/kg clay)	17.5	S1
- Sum of basic cations (cmol(+)/kg soil)	2.09	S3
- pH H_2O	5.82	S1
- Organic carbon (%) - kaolinitic mat.	0.61	S3
Salinity and alkalinity (n)		
- EC (dS/m)	0	S1
- ESP (%)	0	S1

Landscape and soil evaluation : S3

- <u>TOTAL LAND EVALUATION</u>

Climate	S2
Landscape and soil	S3

Total land evaluation : S3

The actual land suitability subclass : **S3f,c,s**
The potential land suitability subclass : **S2c,s** (after correction of the fertility limitations.

(2) LIMITATION METHOD REGARDING NUMBER AND INTENSITY OF LIMITATIONS

In this method we refer to the limitation levels of the land characteristics : no (**0**), slight (**1**), moderate (**2**), severe (**3**) and very severe (**4**).

- EVALUATION OF CLIMATE (compare data with table 47)

Climatic characteristics of crop cycle	Data	Limitation level
Insolation		
- Mean n (hrs)	6.96	2
Temperature		
- Mean temperature (°C)	27.46	0
Rainfall		
- Total rainfall (mm)	592	0
Relative air humidity		
- Mean RH (%) pre-ripening	71.3	0*
- Mean RH (%) ripening	79.1	2

(*) The limitation level for the mean RH of the pre-ripening will not be considered in the determination of the climatic suitability class, because we will consider only the most severe limitation of each group. In the group of relative air humidity, the limitation level will be 2.

The climatic limitations are characterized by two moderate limitations. The climatic suitability class (table 40) is S2.

- <u>EVALUATION OF LANDSCAPE AND SOIL</u> (compare data with table 49)

Characteristics	**Data**	**Limitation level**
Topography (t)		
- Slope (%) - low level management	1	0
Wetness (w)		
- Flooding	F0	0
- Drainage (loamy soils)	g	0
Physical soil characteristics (s)		
- Texture/structure	SL	1/2*
- Coarse fragments (vol. %) - quartz	0.6	0/1*
- Depth (cm)	90	0
- $CaCO_3$ content (%)	0	0
- $CaSO_4$ content (%)	0	0
Fertility characteristics (f)		
- ACEC (cmol(+)/kg clay)	17.5	1
- Sum of basic cations (cmol(+)/kg soil)	2.09	3
- pH H_2O	5.82	0
- Organic carbon (%) - kaolinitic mat.	0.61	3
Salinity and alkalinity (n)		
- EC (dS/m)	0	0
- ESP (%)	0	0

(*) For texture/structure and coarse fragments we will consider the lowest limitation level : texture/structure (1) and coarse fragments (0).

Landscape and soil conditions are characterized by two slight and two severe limitations. The landscape and soil suitability class (table 41) is **S3**.

- TOTAL LAND EVALUATION

  Climate : S2 (moderate limitation : 2 - table 40)

  Landscape and soil : two slight and two severe limitations

The land suitability class (table 41) remains **S3**
The actual land suitability subclass : **S3f,c,s.**
The potential land suitability subclass : **S2c,s** (after correction of the fertility limitations).

(3) **PARAMETRIC METHOD**

In the parametric method a numeral rating is attributed to each characteristic and an index is calculated. The suitability class will be determined by the value of the index.

- EVALUATION OF CLIMATE (compare data with table 47 and use the criteria given in table 48)

Climatic characteristics of crop cycle	**Ratings**
Insolation	
- Mean n (6.96 hrs). . . . . .R = 100 - 12 (8.5 - 6.96) =	82
Temperature	
- Mean temperature (27.46°C)	100
Rainfall	
- Total rainfall (592 mm)	100
Relative air humidity	
- Mean RH pre-ripening (71.3%)	100
- Mean RH ripening (79.1%). . . R = 100 - 1.33 (79.1 - 60) =	75

For the calculation of the climatic index, the lowest rating (75) of the relative air humidity characteristics will be used.

Climatic index (Ic)
Storie method :

$$Ic = 82 \times \frac{75}{100} = 62$$

Suitability class (table 42) : **S2**

The climatic rating to be used in the total evaluation has to be calculated (table 42, fig. 3) :

$$R = 16.67 + 0.9 \times 62 = \mathbf{72}$$

Square root method :

$$Ic = 75 \times \sqrt{\frac{82}{100}} = 68$$

Suitability class (table 42) : **S2**
The climatic rating to be used in the total evaluation has to be calculated : R = 16.67 + 0.9 x 68 = **78**

- EVALUATION OF LAND CHARACTERISTICS (compare data with table 49 and use criteria given in table 50)

Characteristics	**Ratings**
Topography (t)	
- Slope (1%) - low level management R = 100 - 2 (1)	98
Wetness (w)	
- Flooding (F0)	100
- Drainage (good) - loamy soils	100
Physical soil characteristics (s)	

When coarse fragments are present and the soil depth is not optimal, the 3 characteristics (texture/structure, coarse fragments and soil depth) are evaluated together and represented by only one rating.

Horizon	Depth (cm)	Fine earth texture	Rating fine earth texture (table 49)
A	0-16	SL	85
BA	16-38	SL	85
Bt	38-75	SCL	95
Cr	75-90	SL	85
R	90+	impermeable	0

Horizon Cr contains 15 vol.% quartz gravel. The rating of the fine earth texture of the Cr horizon has to be downgraded using the criteria given in table 38 of fig. 2 :

15 vol.% quartz : 80% of the fine earth rating

$$\frac{85 \times 80}{100} = 68$$

The calculation of the overall rating using sections and weighting factors is as follows :

Section 0- 25 cm :	0- 16 :	16 x 1.75 x 85 =	2,380
	16- 25 :	9 x 1.75 x 85 =	1,338.75
Section 25- 50 cm :	25- 38 :	13 x 1.25 x 85 =	1,381.25
	38- 50 :	12 x 1.25 x 95 =	1,425
Section 50- 75 cm :	50- 75 :	25 x 0.75 x 95 =	1,781.25
Section 75-100 cm :	75- 90 :	15 x 0.25 x 68 =	255
	90-100 :	10 x 0.25 x 0 =	0
		8,561.25 : 100 =	86

- Texture/structure
- Coarse fragments 86
- Depth

- $CaCO_3$ content (0%) 100

- $CaSO_4$ content (0%). 100

Fertility characteristics (f)

- ACEC (17.5 cmol(+)/kg clay) R = 100 - 1.875 (24 - 17.5) 88

- Sum of basic cations
  (2.09 cmol(+)/kg soil) R = 100 - 12.3 (6 - 2.09). 52

- $pH\text{-}H_2O$ (5.82) 100

- Organic carbon (0.61%)
  kaolinitic materials. 60

Salinity and alkalinity (n)

- EC (0 dS/m) 100

- ESP (0%). 100

LAND INDEX (I)

Storie method

Climatic rating = 72

$$I = 72 \times \frac{98}{100} \times \frac{86}{100} \times \frac{88}{100} \times \frac{52}{100} \times \frac{60}{100} = 17$$

Actual suitability subclass (table 43) : **N1f,c,s**

Square root method

Climatic rating = 78

$$I = 52 \times \sqrt{\frac{78}{100} \times \frac{98}{100} \times \frac{86}{100} \times \frac{88}{100} \times \frac{60}{100}} = 31$$

Actual suitability subclass (table 43) : **S3f,c,s**

2.2.3. APPROACH TO A QUANTITATIVE EVALUATION

The methodology as described under 2.2.2. is a qualitative classification. A quantitative meaning to these classes can be achieved. However as collection of data on inputs and outputs for all crops and on all land units is often an impossible task, it is suggested to select a limited number (10 to 15) of representative land units covering about 50 to 60 percent of the survey area.

The qualitative evaluation is realized and land indices are attributed to each land unit. If the parametric method was used these land indices are immediately available. If an other method is used indices are arbitrary attributed.

The qualitative classes with the indices of the reference soils are transferred on the X-axis (fig. 4).

The yield data required are :

- yield on the representative soils;
- optimal yield; and
- marginal yield.

The land classes are next defined on a basis of quantitative yield data. The S1 class refers to optimal yields (more than 75 percent of optimal), the S3 class to marginal yields (yields between 40 per cent over and 10 per cent below marginal), S2 has intermediary yields and N has lower yields.

These quantitative classes and yield data of the reference soils are plotted on the Y-axis (fig. 4).

The land index values on the X-axis and the yield on the Y-axis determine the points in the graph.

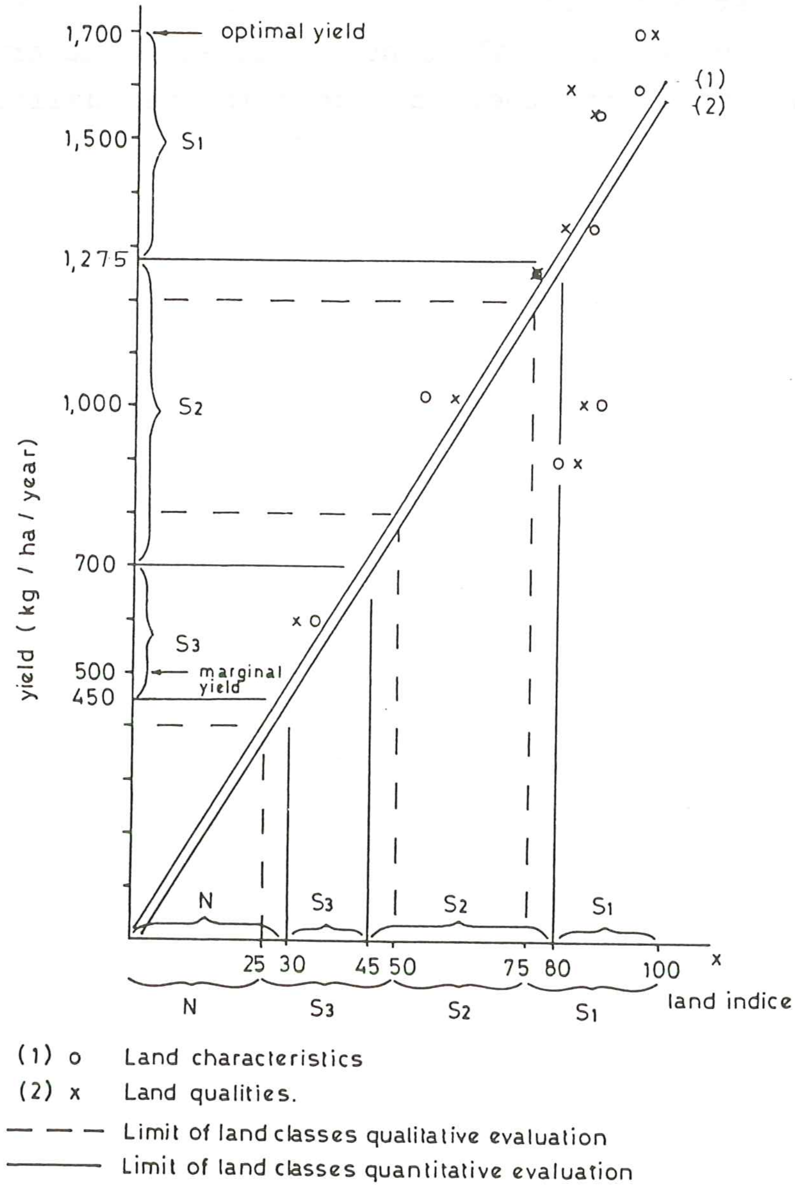


Fig. 4 *Relationship between land indices and rubber yield of RRIM 600 (**Yew, 1982**).*

The correlation is calculated between land indices and yields. The correlation line is used as a bridge to transfer the quantitative classes of the y-axis to the x-axis where they are defined in terms of land indices.

It is suggested to extend this definition elaborated for the representative soils to all other soils after determination of their land index from their characteristics/qualities.

3. LAND EVALUATION METHODS FOR IRRIGATED AGRICULTURE

3.1. General evaluation methods for irrigation

3.1.1. EVALUATION SYSTEM FOR IRRIGATION DEVELOPED BY FAO IN IRAN

3.1.1.1. General principles

This general evaluation system for irrigation developed for FAO by the **Soil Institute of Iran (1970)** in co-operation with FAO is based on an evaluation of different land characteristics and their appraisal for irrigation purposes.

The suitability classification groups at the first level the land development units in six classes :

CLASS I-III : suitable for irrigated agriculture;
CLASS IV : not irrigable, except under special conditions;
CLASS V : undetermined suitability for irrigation; and
CLASS VI : non-irrigable.

At the second level of the classification (except for class I), four subclasses are distinguished, indicating the nature of the limitation or hazard, such as :

S-soil limitations : subsoil permeability, subsoil stoniness, topsoil texture, topsoil stoniness, soil depth and depth-limiting layer;

A-salinity and alkalinity limitations : soil salinity and soil alkalinity;

T-topographic limitations : overall slope, maximum transversal slope, micro-relief and present erosion status (erosion is also considered as topographic limitation because of its relation to slope).

W-drainage limitations : groundwater depth, other drainage limitations such as permeability of underlying strata, ponding and flooding hazard.

The subclasses indicated by one symbol following the class number are showing one or the most severe limitation of the soil; soil classes defined by two limitations of equal degree are indicated by adding the two limitation symbols after the class number.

For example, a land with salinity limitations of class II and a topographic limitation of class III are noted III T, whereas lands with soil limitation and drainage limitation of class III level are noted III SW.

Each limitation, when present, is rated separately and given a rating symbol. Some basic land characteristics which may or may not be limiting are also rated in all cases : the top soil texture, the subsoil permeability, slope and microrelief. These symbols are placed in a rating formula according to a standard sequence with the soil limitations and salinity limitation in the numerator and the topography and drainage limitations in the denominator (fig. 5).

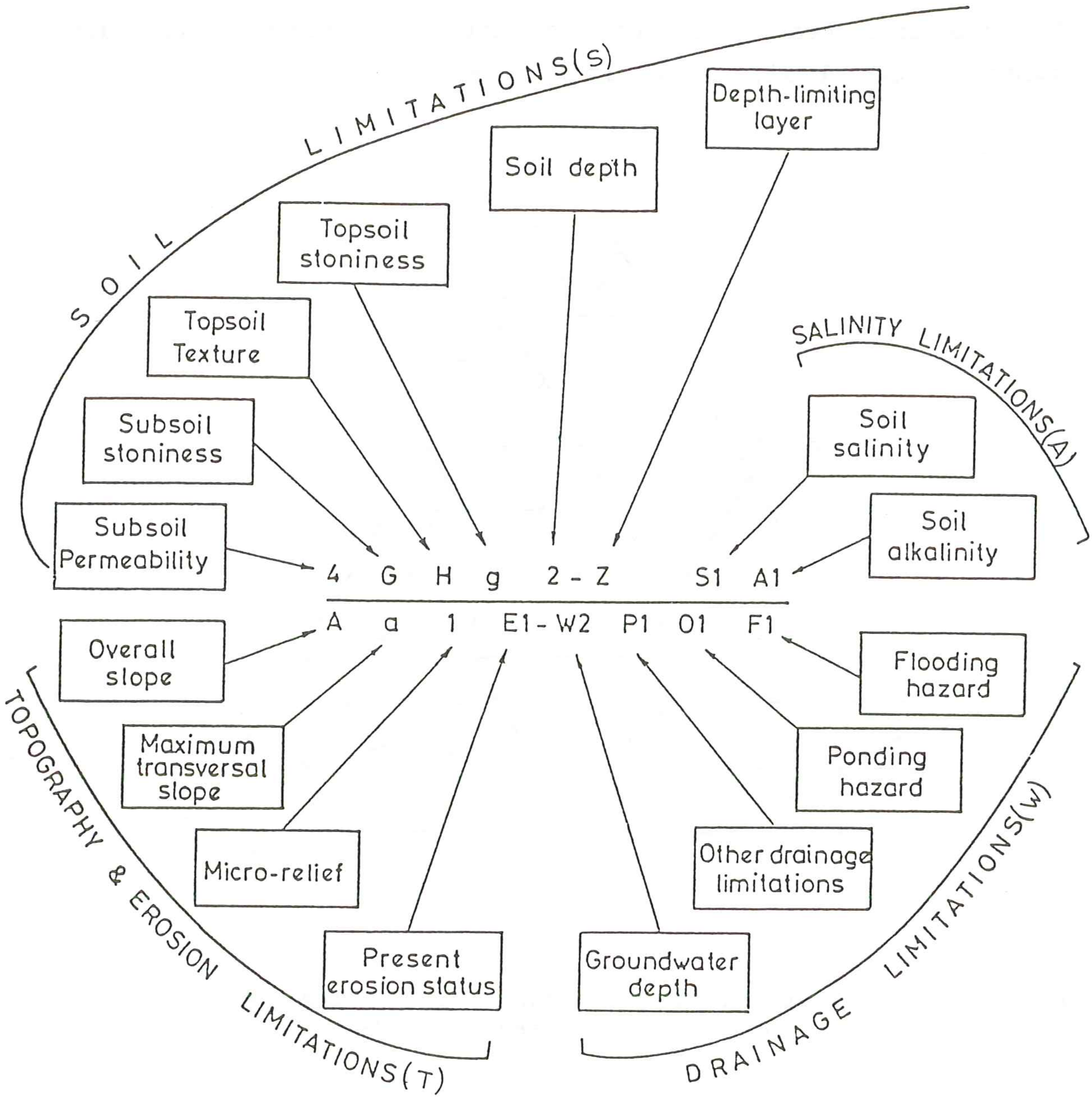


Fig. 5 Limiting symbol formula.

3.1.1.2. **Soil limitations**

(1) **TOPSOIL TEXTURE**

The texture of the fine earth of the upper 20 cm is considered. The textural fractions are indicated according to the **U.S. system (USDA, 1951)**, shown in fig. 6.

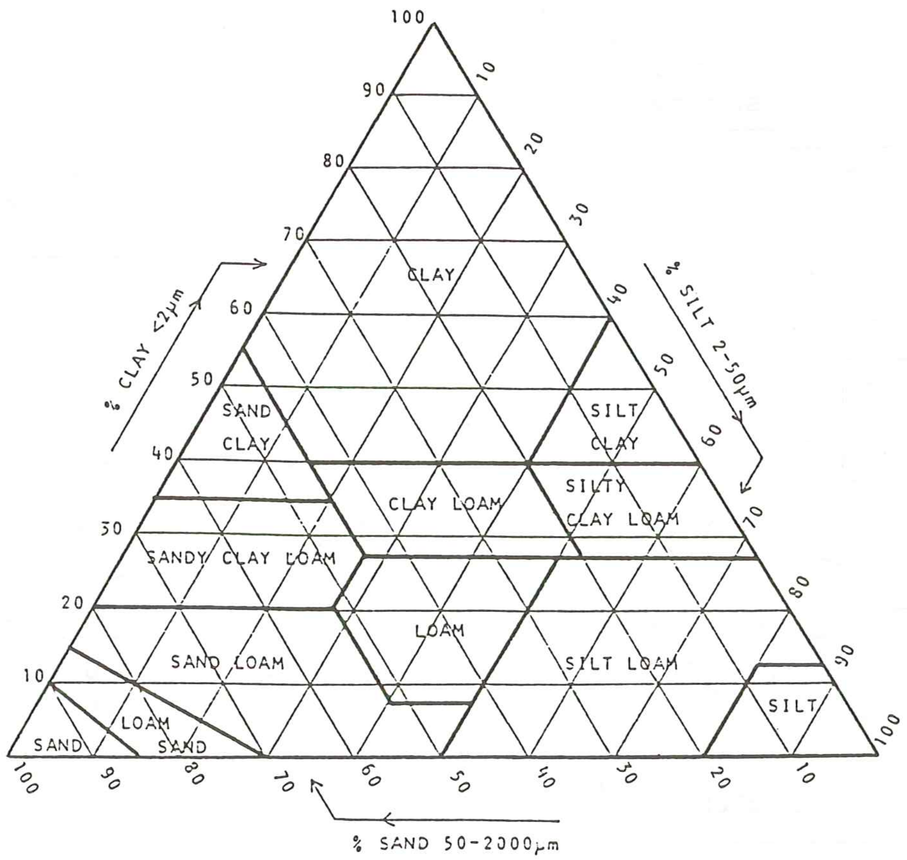


Fig. 6 *U.S. Dept. Agriculture textural classes (**USDA, 1951**), taken over by Soil Taxonomy (**Soil Survey Staff, 1975**).*

The standards for rating average surface texture of the fine earth are given in table 51.

Table 51. Rating symbols and maximum land classes for topsoil texture

SYMBOL	DEFINITION	MAXIMUM LAND CLASS
Z	very coarse - sand (coarse sand)	**IV**
C	coarse - loamy coarse sand, fine sand	**III**
L	light - coarse sandy loam, loamy fine sand	**II**
M	medium - loam, fine sandy loam, silt loam, silt	**I**
H	heavy - clay loam, silty clay loam, sandy clay loam	**I**
V	very heavy - sandy clay, silty clay, clay	**II**

(2) TOPSOIL STONINESS

The stoniness of the top soil is rated by the percentage of total coarse fragments in volume in the top 20 cm of the soil. When coarse fragments of different sizes occur, the average size is taken into account for the rating. However, if the percentage of the coarse fragments lead to a more severe rating with respect to the maximum land class, this rating is considered for the classification.

The following classes of coarse fragments are distinguished :

- **fine gravels** : size between 0.2 and 2.5 cm;
- **coarse gravels** : size between 2.5 and 7.5 cm;
- **stones** : size between 7.5 and 25 cm; and
- **boulders** : size above 25 cm

Topsoil stoniness is rated tentatively as indicated in table 52.

Table 52. Rating symbols and maximum land classes for topsoil stoniness

VOL. (%)	FINE GRAVELS	COARSE GRAVELS	STONES	BOULDERS
3-15	**(f) - I**	**(g) - II**	**(s) - II**	**b - III**
15-40	**f - II**	**g - III**	**s - III**	**B - IV**
40-75	**F - III**	**G - IV**	**S - IV**	**B - IV**
> 75	**Z - IV**	**Z - VI**	**Z - VI**	**Z - VI**

(3) **SUBSOIL STONINESS**

Subsoil stoniness is rated on the basis of the (average) percentage (vol.%) of coarse fragments between 0.20 and 0.80 m or to the depth of a limiting layer. Size of the coarse fragments is not distinguished. The rating symbols are given in table 53.

Table 53. Rating symbols and maximum land classes for subsoil stoniness

SYMBOL	VOL.% COARSE FRAGMENTS	MAXIMUM LAND CLASS
g	15-40	**II**
G	40-75	**III**
Z	> 75 (limiting layer)	**IV**

(4) SUBSOIL PERMEABILITY

The rating is based upon the lowest permeability rate between 0.20 and 1.20 or between 0.20 m and the depth of a limiting layer, when the soil is less than 1.20 m deep. The rating symbols are given in table 54.

Table 54. Rating symbols and maximum land classes for subsoil permeability

SYMBOL	PERMEABILITY RATE (cm/h)	MAXIMUM LAND CLASS
1	very rapid : > 12	III
2	rapid : 12-6	II
3	moderate : 6-0.5	I
4	slow : 0.5-0.1	II
5	very slow : < 0.1	III

If the same textural classes defined for the top soil are applied to the subsoil (when not gravelly or stony), the following tentative rules can be used for a first approximation (table 55).

(5) SOIL DEPTH AND DEPTH-LIMITING LAYER

The soil depth is defined as the thickness of the soil above a limiting layer (if any) and it is shown by a symbol made of the number indicating the soil depth class. The soil depth classes are given in table 56.

Table 55. Permeability rating according to the subsoil heaviest texture

TEXTURE CLASS OF THE SUBSOIL HEAVIEST HORIZON	TENTATIVE SUBSOIL PERMEABILITY RATING
C - coarse	1 - very rapid
L - light	2 - rapid
M - medium	3 - moderate
H - heavy	3 - moderate
V - very heavy	4 - slow : for non-massive structure 5 - very slow : for massive structure

Table 56. Symbols for the soil depth classes

SYMBOL	DEPTH CLASSES (cm)	
no symbol	very deep	: > 120
1	deep	: 120-80
2	moderately deep	: 80-50
3	shallow	: 50-25
4	very shallow	: 25-10

When the soil depth is less than 10 cm, the land classification symbol is replaced by those of miscellaneous land types.

When a soil depth limitation occurs, it will be indicated by a letter indicating the kind of limiting layer, that follows the symbol for the soil depth class. The types of limiting layers considered are given in table 57.

Table 57. Symbols for the depth-limiting layers

SYMBOL	DEPTH - LIMITING LAYERS
Z	Unconsolidated gravels, stones and coarse sands, with at least 75 per cent of the volume of the layer made of stones and gravels, and layer thickness at least 30 cm
S	Soft weathered rock, more than 30 cm thick or soft, continuous, whitish secondary lime, more than 30 cm thick (with more than 50 per cent $CaCO_3$ equivalent) or a gypsiferous layer
H	Unweathered hard rock or calcareous hard pan, more than 10 cm thick

Rating of the soil depth :

-When the average soil texture below 20 cm is fine sandy loam or finer, table 58 will be used.

Table 58. Maximum land classes for soil depth and a texture of fine sandy loam or finer

DEPTH LIMITING LAYER	SOIL DEPTH (in cm)				
	> 120	120-80	80-50	50-25	25-10
Z or S	**I**	**I**	**II**	**III**	**IV**
H	**I**	**II**	**III**	**IV**	**IV**

-When the average soil texture below 20 cm is coarser than fine sandy loam, the maximum land class will be one class lower than those given in table 58, for any land class higher than IV (table 59).

Table 59. Maximum land classes for soil depth and a texture coarser than fine sandy loam

DEPTH LIMITING LAYER	SOIL DEPTH (in cm)				
	> 120	120-80	80-50	50-25	25-10
Z or S	II	II	III	IV	IV
H	II	III	IV	IV	IV

3.1.1.3. Salinity and alkalinity limitations

(1) SOIL SALINITY

The salinity classes are expressed by the electric conductivity of the saturation extract (table 60).

(2) SOIL ALKALINITY

Limitations due to alkalinity are rated on the basis of the maximum **E**xchangeable **S**odium **P**ercentage (**ESP**) found within the first 75 cm of the soil (table 61).

Table 60. Rating symbols and maximum land classes for soil salinity

SYMBOL	ELECTRIC CONDUCTIVITY (mmhos/cm)	MAXIMUM LAND CLASS
S0	< 4 : no or very slight limitation	I
S1	4- 8 : slight limitation	II
S2	8-16 : moderate limitation	III
S3	16-32 : severe limitation	V
S4	> 32 : very severe limitation - if permeability class < 4 - if permeability class 4 or 5	 V VI

Table 61. Rating symbols and maximum land classes for soil alkalinity

SYMBOL	ESP (%)	MAXIMUM LAND CLASS
no symbol	< 10 (pH < 8.5) : no limitation	I
A1	10-15 (pH > 8.5) : slight limitation	II
A2	15-30 (pH : 8.5-9) : moderate limitation	III
A3	30-50 (pH : 9-9.5) : severe limitation	V
A4	> 50 (pH > 9.5) : very severe limitation	VI

3.1.1.4. **Topographic limitations**

(1) **OVERALL SLOPE**

For the overall slope, we have to consider the longest slope of the mapping unit. The following slope classes are given in table 62.

Table 62. Rating symbols and maximum land classes for overall slope

SYMBOL	SLOPE CLASS (%)	MAXIMUM LAND CLASS
A	0- 2 : level to very gently sloping	**I**
B	2- 5 : gently sloping	**II**
C	5- 8 : sloping	**III**
D	8-12 : strongly sloping	**IV**
E	12-25 : moderately steep, according to other characteristics (e.g. texture, permeability, depth, etc.)	**IV/VI**
F	25-40 : steep	**VI**
G	40-70 : very steep	**VI**
H	> 70 : extremely steep	**VI**

(2) **MAXIMUM TRANSVERSAL SLOPE**

In most cases, the undulations are observed in a direction perpendicular to the one of the overall slope. Complex slopes are shown in two symbols : the first one applies to the overall slope as above, the second applies to the maximum transversal slope. The same slope classes are used for rating the maximum transversal slope as for the overall slope (table 63).

Table 63. Rating symbols for maximum transversal slope

SYMBOL	SLOPE CLASS (%)
no symbol	< 1
a	1-2
b	2-5
c	5-8
d	8-12
e	12-25
f	25-40

Maximum land classes for complex slopes (combination of overall slope and maximum transversal slope) are given in table 64.

(3) **MICRO-RELIEF**

By microrelief is meant relief irregularities and undulations found within less than 100 m distances and due to neither active erosion by wind or water run-off nor to existing irrigation or drainage systems. Four microrelief classes are distinguished (table 65).

Table 64. Maximum land classes for complex slopes

SLOPE CLASS	A	B	C	D	E	F,G,H
a	I	II	III	IV	IV/VI(*)	VI
b	II	III	III	IV	VI	VI
c	III	III	IV	IV	VI	VI
d	IV	IV	IV	IV	VI	VI
e	IV	IV	IV/VI(*)	IV/VI(*)	VI	VI
f,g,h	VI	VI	VI	VI	VI	VI

(*) Maximum land class to be determined according to local specifications

Table 65. Rating symbols and maximum land classes for micro-relief

SYMBOL	MICRO-RELIEF	MAXIMUM LAND CLASS
0	none or very slight	I
1	slight	II
2	moderate	III
3	strong	IV

(4) PRESENT EROSION STATUS

Two types of erosion are considered : water erosion (table 66) and wind erosion (table 67).

Table 66. Rating symbols and maximum land classes for water erosion

SYMBOL	WATER EROSION	MAXIMUM LAND CLASS
E0	no apparent erosion	I
E1	slight erosion	II
E2	moderate erosion	III
E3	severe erosion	IV
"E"	land destroyed by gully erosion Miscellaneous land type	VI

Table 67. Rating symbols and maximum land classes for wind erosion

SYMBOL	WIND EROSION	MAXIMUM LAND CLASS
(E1)	slight erosion	II
(E2)	moderate erosion	III
(E3)	severe erosion	IV

3.1.1.5. Drainage limitations

(1) GROUNDWATER DEPTH

The limitations due to the depth of the groundwater table are rated according to the salinity of the groundwater (table 68).

Table 68. Rating symbols and maximum land classes for groundwater depth

SYMBOL	GROUNDWATER DEPTH (m)		MAXIMUM LAND CLASS
	SALINE GROUNDWATER EC > 1,500 micromhos/cm	SWEET GROUNDWATER EC < 1,500 micromhos/cm	
W1	3-2 : slight limitation	2-1.20 : slight limitation	**II**
W2	2-1.20 : moderate limitation	1.20-0.75 : moderate limitation	**III**
W3	< 1.20 : severe limitation	< 0.75 : severe limitation	**V**

(2) OTHER DRAINAGE LIMITATIONS

The other drainage limitations are due to :

- temporary waterlogging as reflected in the soil profile colour (hydromorphy), such as mottling, gley or pseudogley horizons; and
- impermeable layer in the underlying material (below 120 cm depth)

Table 69. Rating symbols and maximum land classes for other drainage limitations

SYMBOL	OTHER DRAINAGE LIMITATIONS	MAXIMUM LAND CLASS
P1	Between 1.20 and 2 m presence of : 1) mottling bluer than 10YR; 2) or soil colour matrix bluer than 10YR; 3) or a clay pan or a horizon with permeability lower than 0.1 cm/h	II
P2	Same features except for permeability, observed between 0.75 and 1.20 m	III
P3	Same as P2, observed between 0.20 and 0.75 m	V

(3) **PONDING HAZARD**

Ponding means inondation in a closed basin, out of a flood plain. Symbols and maximum land classes for ponding hazard are given in table 70.

Table 70. Rating symbols and maximum land classes for ponding hazard

SYMBOL	PONDING HAZARD	MAXIMUM LAND CLASS
01	slight limitation	II
02	moderate limitation	III
03	severe limitation	V

(4) **FLOODING HAZARD**

Symbols and maximum land classes for flooding hazard are given in table 71.

Table 71. Rating symbols and maximum land classes for flooding hazard

SYMBOL	FLOODING HAZARD	MAXIMUM LAND CLASS
F1	slight flooding hazard	**II**
F2	moderate flooding hazard	**III**
F3	severe flooding hazard	**V**

3.1.1.6. **General characteristics and definitions of land classes**

CLASS I - Arable : "Lands without apparent hazards or limitations of soil, salinity, topography or drainage, for irrigation farming, under present conditions".

CLASS II - Arable : "Lands with slight hazards and/or limitations of soil, salinity or topography, for irrigation farming under present conditions".

CLASS III - Marginal arable : "Lands with moderate hazards and/or limitations of soil, or topography for irrigated farming under present conditions".

CLASS IV - Restricted arable : "Lands with severe limitations of soil or topography for irrigated farming under present conditions, except for special crops or with special conditions of management which can cope with these limitations".

CLASS V - Undetermined arable : "Lands with severe hazards and/or limitations of salinity or drainage for any type of irrigated farming under present conditions, but whose limitations might be reduced or removed if further studies prove it possible and feasible economically".

CLASS VI - Non arable : "Lands with severe hazards and limitations for any type of irrigation farming under present conditions and whose reclamation is not technically and/or economically feasible at present".

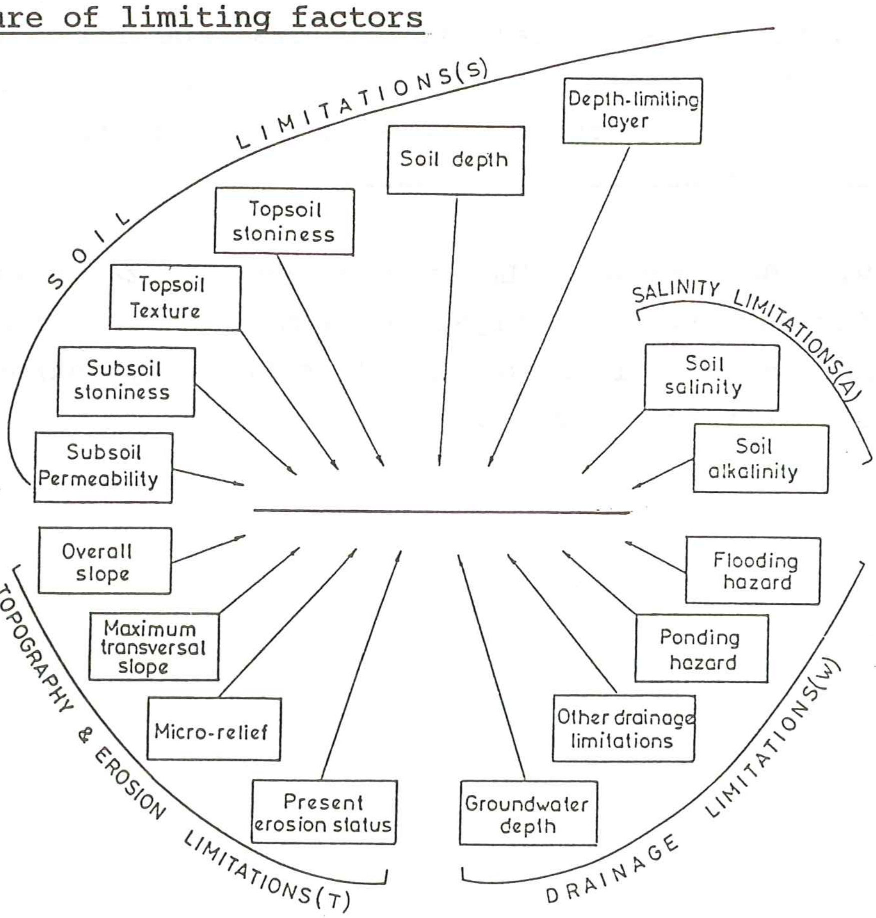
3.1.1.7. Form for practical use and example

The form as represented below can be used for practical purposes.

LAND EVALUATION FOR IRRIGATION SYSTEM DEVELOPED BY FAO IN IRAN (1970)

1. References : Country :
   Survey area :
   Soil unit :

2. Nature of limiting factors



3. Land classification formula (maximum land classes)

.. ..

.. ..

4. Land classification symbol

- Land class :
- Land subclass :

EXAMPLE : SEMI-DETAILED SOIL SURVEY IN IRAN

(1) General information

The Bojnurd survey area consists of an inter-mountain basin, located in Khorassan province (NE-Iran), and situated at about 280 km NW of Meshed. The mean altitude is about 985 m.

The climate is semi-arid with warm and fairly dry summers and cold winters. The annual precipitation amounts to 254 mm, of which most is recorded during the period January-May. The mean temperatures range from 24.2°C in July (mean max. : 31.6°C) to 1.3°C in January (mean min. : -7.3°C).

The area, which covers about 7.900 ha, was investigated in order to assess the relative suitability of the land for irrigated agriculture, mainly in the prospect of a proposed irrigation project. Most of the area on the piedmont plains, the lowlands, the valleys and the lower plateau is at present under cultivation, i.e. summer crops, such as sugar beets and vegetables, or winter crops like wheat and barley or alternatively fallow. The land on the alluvial and colluvial fans is largely used for grazing, whereas the higher plateaus or plateau remnants are generally wasted due to the very uneven topography and often very shallow and/or gravelly soils. Some orchards have been established at various places near the villages.

The soil survey and land classification study was carried out at a semi-detailed level. It was conducted by Khavaran and Taheri, and supervised by Ochtman. The basic information on this study is compiled in Publication n° 235 of the Soil Institute of Iran.

(2) **Information of two selected mapping units**

-**RUSTAMI SERIES - ORTHOTYPE (RU).** Reference profile n° **P14**
Deep (> 120 cm), yellowish brown loam to silt loam, often with few lime and/or gypsum (mostly mycelia); frequently gravelly throughout : often underlain by slightly gypsiferous, very gravelly substratum; well drained; slope 0-2%.

-**RUSTAMI SERIES - VERY GRAVELLY PHASE (RU-Vq).** Reference profile n° **P3**
As orthotype, but with appreciably more gravel, common stones and boulders especially on the surface, occasionally shallow to moderately deep soil; well drained; slope 2-5%.

Some basic soil properties of the two mapping units are given in table 72.

Table 72. Basic soil properties of the two mapping units

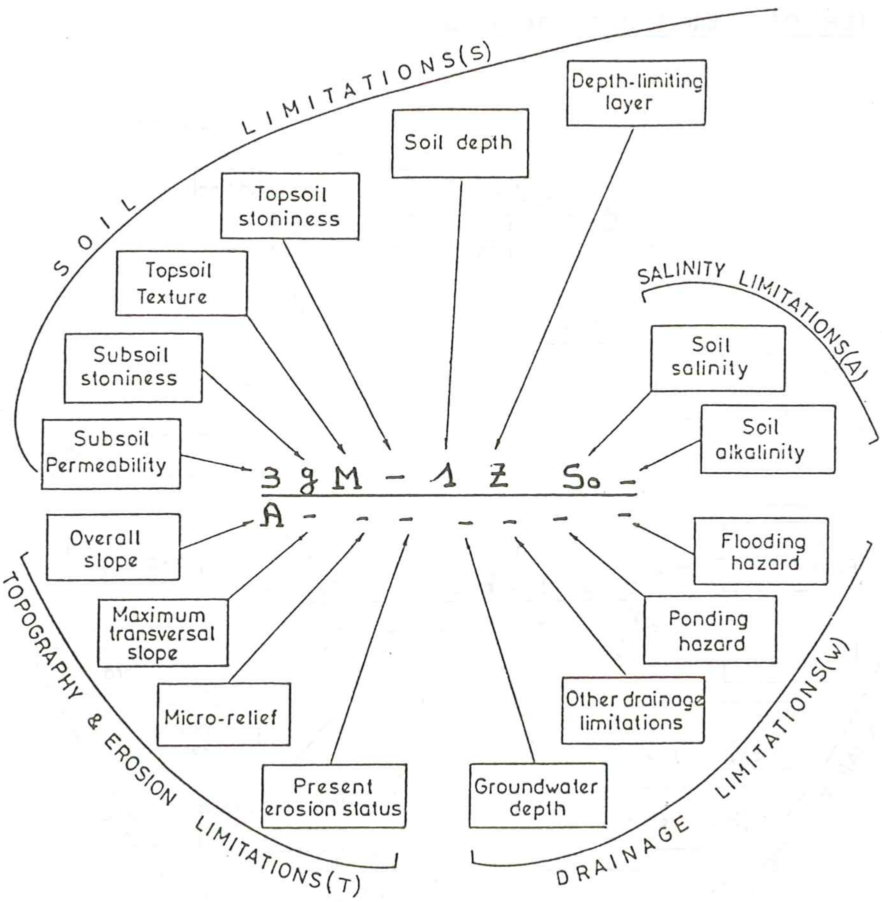
Profile number	Depth (cm)	Texture + gravel (%)	$CaCO_3$ (%)	$CaSO_4$ (%)	ESP (%)	Salinity (mmhos/cm)	Epipedon (or OC %)	Weathering stage
P14	0- 20	SiL	31	(1.2)	2	0.6	-	Entic
	20- 45	L+16	42	(1.6)	4	0.4	-	
	45-120	L>75	39	(2.0)	8	4.7	-	
P3	0- 20	L+41	39	(1.2)	1	0.4	-	Entic
	20- 60	L+41	51	(1.7)	3	0.4	-	
	60-110	L+41	53	(2.1)	3	0.3	-	

(3) **Evaluation**

LAND EVALUATION FOR IRRIGATION
SYSTEM DEVELOPED FOR FAO IN IRAN (1970)

1. References : Country : **Iran**
   Survey area : **Bojnurd**
   Soil unit : **Rustami series - orthotype (RU)**

2. Nature of limiting factors



3. Land classification formula (maximum land classes)

I II I - I I I -

I - - - - - - -

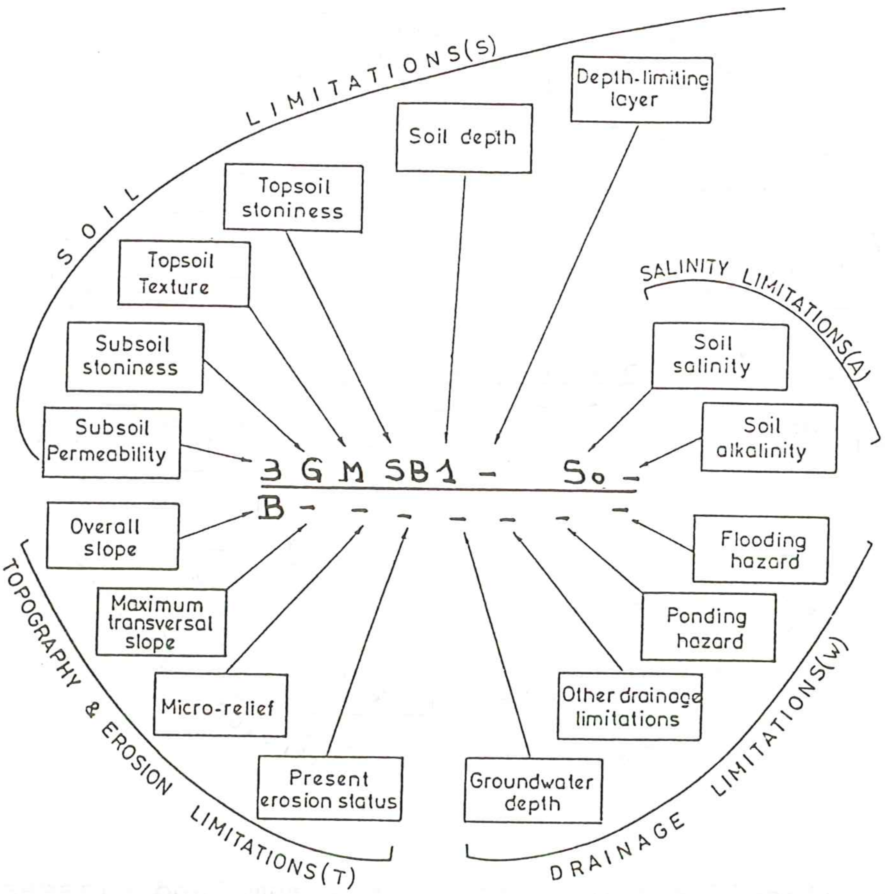
4. Land classification symbol

- Land class : **II**
- Land subclass : **IIs**

LAND EVALUATION FOR IRRIGATION SYSTEM DEVELOPED FOR FAO IN IRAN (1970)

1. References : Country : **Iran**
   Survey area : **Bojnurd**
   Soil unit : **Rustami series - very gravelly phase (RU-Vq)**

2. Nature of limiting factors



3. Land classification formula (maximum land classes)

I	III	I	IV	I	-	I	-
II	-	-	-	-	-	-	-

4. Land classification symbol

- Land class : IV

3.1.2. PARAMETRIC EVALUATION SYSTEM FOR IRRIGATION PURPOSES

3.1.2.1. General principles

The aim of this parametric evaluation system (**Sys and Verheye, 1974**) is to provide a method that permits evaluation for irrigation purposes, and that is based on the standard granulometrical and physico-chemical characteristics of a soil profile.

It has been estimated that the soil as a medium for plant growth under irrigation should in the first place provide the necessary water and plant nutrients in an available form, and in the most economic way.

The factors influencing the soil suitability for irrigation can therefore be subdivided in the following four groups :

(1) **PHYSICAL PROPERTIES**, that determine the soil-water relationship in the solum such as permeability and available water content both related to texture, structure and soil depth, also $CaCO_3$ status and gypsum status could be considered here;

(2) **CHEMICAL PROPERTIES**, that interfere in the salinity/alkalinity status, such as soluble salts and exchangeable Na;

(3) **DRAINAGE PROPERTIES**; and

(4) **ENVIRONMENTAL FACTORS**, such as slope.

The different land characteristics that influence the soil suitability for irrigation are rated and a **CAPABILITY INDEX FOR IRRIGATION (Ci)** is calculated according to the formula :

$$Ci = A \cdot \frac{B}{100} \cdot \frac{C}{100} \cdot \frac{D}{100} \cdot \frac{E}{100} \cdot \frac{F}{100} \cdot \frac{G}{100}$$

whereby :

Ci = capability index for irrigation
A = rating of soil texture
B = rating of soil depth
C = rating of $CaCO_3$ status
D = rating of gypsum status
E = salinity/alkalinity rating
F = drainage rating
G = slope rating

The capability **classes** are defined according to the value of the capability (or suitability) index (Ci) (table 73).

Table 73. Capability indices for the different capability classes

CAPABILITY INDEX	CLASS	DEFINITION
> 80	I	excellent
60-80	II	suitable
45-60	III	slightly suitable
30-45	IV	almost unsuitable
< 30	V	unsuitable

The classes II to V can have following **subclasses** with regard to the nature of the limiting factors :

s - limitations due to physical soil properties (A, B, C, D);
n - limitations due to salinity/alkalinity (E);
w - wetness limitations (F)
t - topographic limitations (G)

3.1.2.2. **Factors influencing the soil suitability for irrigation**

(1) **TEXTURE - A**

Texture is rated (table 74) with regard to permeability and available water content, and weighted average is calculated for the upper 1 m.

(2) **SOIL DEPTH - B**

Soil depth is defined as the thickness of the loose soil above a limiting layer, which is impenetrable for roots or percolating water. The most common types of such limiting layers are:

- an unconsolidated gravelly or stony horizon with at least 75% coarse fragments (by weight);
- a continuous, more or less consolidated, calcium carbonate or gypsiferous layer with a minimum thickness of 30 cm, and containing at least 75% calcium carbonate or gypsum (or both together); and
- a continuous hard rock or hardpan more than 10 cm thick.

Table 75 gives the depth ratings used for the suitability classification for irrigation.

Table 74. Rating of textural classes for irrigation

TEXTURAL CLASS	RATING				
	-15% gravel	Fine gravelly		Coarse gravelly	
		15-40%	40-75%(*)	15-40%	40-75%
CL+SiCL	100	90	80	80	50
SCL	95	85	75	75	45
L+SiL+Si	90	80	70	70	45
SiC+C-60%	85	95	80	80	40
SC	80	90	75	75	35
SL	75	65	60	60	35
C+60%	65	65	55	55	30
LS	55	50	45	45	25
S	30	25	25	25	25

(*) weight percentages

Table 75. Rating of depth for irrigation

SOIL DEPTH (in cm)	RATING
< 20	30
20-50	60
50-80	80
80-100	90
> 100	100

(3) CALCIUM CARBONATE STATUS - C

The presence of free lime in the soil has not only an effect on the structural arrangement of the soil mass, interfering thus directly on water infiltration rate and evaporation processes, but plays also a role in the soil reaction and the physico-chemical constitution of the solum as a whole. The calcium carbonate status influences thus at the same time the soil-water relationship of the soil and its available nutrient supply for plant growth.

A moderate $CaCO_3$ content has a favourable effect on soil suitability for irrigation. Table 76 gives the $CaCO_3$ ratings used in the system. The $CaCO_3$ content of the profile represents the weighted average over the superficial 100 cm.

Table 76. Rating for $CaCO_3$ content

$CaCO_3$ (%)	RATING
> 50	80
25-50	90
10-25	100
0.3-10	95
< 0.3	90

(4) GYPSUM STATUS - D

The influence of gypsum can broadly be compared to that of $CaCO_3$, interfering thus as well on water-intake as on the availability of the nutrient balance. As the result of its salinity dissolution depressions could be created under irrigation. For this reason soils with high gypsum content have been graded down considerably.

Ratings are suggested in table 77. The gypsum content represents the weighted average for the upper 100 cm.

Table 77. Rating for gypsum content

GYPSUM (%)	RATING
> 50	30
25-50	60
10-25	85
0.3-10	100
< 0.3	90

(5) **SOIL SALINITY/ALKALINITY - E**

The unfavourable effect of combined salinity and alkalinity hazards depends on soil texture. Ratings are given in table 78. The values for exchangeable sodium percentage (ESP) and electric conductivity (Ec) are weighted averages for the upper 100 cm.

(6) **DRAINAGE - F**

Imperfect or poor drainage is an evident limiting factor. The drainage problems for irrigation are related to soil texture and to the depth and salinity status of the groundwater. Ratings are given in table 79.

Table 78. Ratings for salinity and alkalinity

ESP (%)	ELECTRIC CONDUCTIVITY (Ec) (in mmhos) (on sat. extr.)				
	0-4	4-8	8-16	16-30	30+
0-8	100 100(*)	95 90(*)	90 80(*)	85 70(*)	80 60(*)
8-15	95 90(*)	90 80(*)	85 70(*)	80 60(*)	75 50(*)
15-30	90 80(*)	85 70(*)	80 60(*)	75 50(*)	70 40(*)
30+	85 70(*)	80 60(*)	75 50(*)	70 40(*)	65 30(*)

(*) Clay, silty clay, sandy clay

Table 79. Ratings for drainage classes as related to texture and salinity of groundwater

DRAINAGE CLASS	RATING			
	Clay, silty clay, sandy clay, silty clay loam		Other textures	
	non saline	saline groundwater	non saline	saline groundwater
Well drained soils				
gley at > 3 m	100	100	100	100
2-3 m	95	85	100	100
1.2-2 m	90	75	95	95
Moderately well drained with gley at 80-120 cm	80	50	90	70
Imperfectly drained with gley at 40-80 cm	70	35	80	60
Poorly drained soils with gley at < 40 cm	60	30	65	40
Very poorly drained reduction horizon at < 40 cm	40	20	65	30

(7) **SLOPE - G**

The dominant topographic factor that influences on the irrigation suitability, concerns the slope. Rating the overall slope can be considered as sufficient. It is also estimated that a difference should be made between terraced and non-terraced slopes. Ratings are given in table 80.

Table 80. Rating of slopes

SLOPE CLASS (%)	RATING	
	Non-terraced	Terraced
0-1	100	100
1-3	95	95
3-5	90	95
5-8	80	95
8-16	70	85
16-30	50	70
> 30	30	50

3.1.2.3. **Form for practical use and example**

The form as presented below can be used for practical purposes.

EVALUATION FOR IRRIGATION IN ARID AND SEMI-ARID AREAS
PARAMETER SYSTEM OF SYS AND VERHEYE (1974)

REFERENCES : Country
Survey area :

FACTORS	TEXTURE	SOIL DEPTH	$CaCO_3$ STATUS	GYPSUM STATUS	SALINITY-ALKALINITY	DRAINAGE	SLOPE	CAPABILITY INDEX
Soil unit :								
Ratings								
								Capability class : Capability subclass :
Soil unit :								
Ratings								
								Capability class : Capability subclass :

EXAMPLE : SEMI-DETAILED SOIL SURVEY IN IRAN

(1) **General information** (similar to example of proceeding method)

The Bojnurd survey area consists of an inter-mountain basin, located in Khorassan province (NE-Iran), and situated at about 280 km NW of Meshed. The mean altitude is about 985 m.

(2) **Information of two selected mapping units** (table 81)

Table 81. Basic soil properties of two mapping units for the Bojnurd semi-detailed soil map

PROFILE N°	DEPTH (cm)	TEXTURE + GRAVEL (%)	$CaCO_3$ (%)	$CaSO_4$ (%)	ESP	SALINITY (mmhos/cm)	EPIPEDON (or OC %)	WEATHERING STAGE
Ali Abad Series (Ac) - shallow (50-60 cm), dark yellowish brown, coarse gravelly loam with lime accumulation over gravel (unconsolidated gravelly layer, 80-90% gravel) with lime and gypsum; well drained; slope 5-8%								
P20	0-15	SiL+20%	29	< 0.3	(< 5)	0.5	Erod.	
	15-65	L+20%	45	< 0.3	(< 5)	0.7	-	Entic
Rustami Series - Orthotype (Ru) - deep (> 120 cm) yellowish brown loam to silt loam, often with few lime and/or gypsum (mostly mycelia); frequently gravelly throughout; often underlain by slightly gypsiferous, very gravelly substratum; well drained; slope 0-2%								
P14	0- 20	SiL	31	(1.2)	2	0.6	-	
	20- 45	L+16%	42	(1.6)	4	0.4	-	Entic
	45-120	L>75%	39	(2.0)	8	4.7	-	

(3) **Evaluation**

EVALUATION FOR IRRIGATION IN ARID AND SEMI-ARID AREAS
PARAMETER SYSTEM OF SYS AND VERHEYE (1974)

REFERENCES : Country : **Iran**
Survey area : **Bojnurd**

FACTORS	TEXTURE	SOIL DEPTH	$CaCO_3$ STATUS	GYPSUM STATUS	SALINITY-ALKALINITY	DRAINAGE	SLOPE	CAPABILITY INDEX
Soil unit : **Ali Abad Series**								
Ratings	70	80	90	90	100	100	80	36
								Capability class : **IV** Capability subclass : **IVst**
Soil unit : **Rustami Series, Orthotype**								
Ratings	85	100	90	100	95	100	95	69
								Capability class : **II** Capability subclass : **IIs**

3.1.3. USBR EVALUATION METHOD FOR IRRIGATION CORRELATED WITH THE FAO LAND CLASSIFICATION

3.1.3.1. General principles

A general system for land evaluation for irrigation has been elaborated by the USBR (**United States Bureau of Reclamation, 1951**). The system does not use a rigid or fixed methodology. Instead general principles are applied to fit land classification to the economic, social, physical and legal patterns existing in a project area. The classification is quantitative and requires a multidisciplinary team approach.

The system uses 6 classes. Four classes are suitable for surface irrigation (classes 1, 2, 3 and 4), one class is potentially suitable (class 5) and one class is unsuitable (class 6).

3.1.3.2. Definition of land classes

CLASS 1 : represents land units which have a relatively high payment capacity under irrigated agriculture.

CLASS 2 : land units with intermediate payment capacity.

CLASS 3 : land units with the lowest suitability for surface irrigation and marginal payment capacity.

CLASS 4 : land units no more suitable for surface irrigation because of some excessive deficiencies for irrigated farming, except for special crops (paddy rice) or with special conditions of management (sprinkler, drip). This results in restricted or special use which has been shown to be of limited suitability for irrigation.

CLASS 5 : under the existing conditions, the land units are not suitable for irrigation. However after improvement of some limitations they are potentially suitable.

CLASS 6 : land units are actually and potentially unsuitable for any type of irrigation. They have severe limitations for any type of irrigated farming and their reclamation is technically and/or economically not feasible.

3.1.3.3. Quantification of class criteria

For the quantification of the limitation/class levels suggested here, classes 1, 2 and 3 are considered suitable for any type of irrigation. They are particularly suitable for surface irrigation.

The criteria used to attribute classes 1, 2, 3 are :

(1) The range of climatologically adapted crops that can be cultivated. When this range of crops becomes narrower the suitability of the land decreases.

(2) The suitability of the land to support irrigation, with particular reference to soil/water relationship.

(3) The importance of land improvement works and conservation practices required :
- to improve soil-air-water relationship;
- to prevent soil deterioration (crust formation); and
- to prepare land in optimal conditions for irrigated agriculture (levelling and grading, clearing of surface stoniness).

FAO (**1979**) has suggested land classes for irrigation farming, related to the USBR classes (table 82).

Table 82. Correction between USBR and FAO land classification

FAO	CLASS DEFINITION	USBR
S1	Highly suitable	Class 1
S2	Moderately suitable	Class 2
S3	Marginally suitable	Class 3
Sc	Special use	Class 4
N1	Not suitable at present but potentially suitable	Class 5
N2	Actually and potentially unsuitable	Class 6

Resler (**1979**) has suggested a quantification of most land characteristics for defining classes 1, 2 and 3.

We have extended these criteria for the classes S1, S2, S3, Sc, N1 and N2 according to the scheme normally used in our methodology.

Table 83 provides information with regard to the quantification of class criteria for general irrigation farming.

This evaluation does not include climatic factors, therefore the climate has to be evaluated separately according to principles described earlier, and assuming that a rainfall limitation is fully corrected by irrigation.

Table 83. Criteria for the definition of land classes for irrigation

	S1	S2	S3	Sc	N1	N2
Topography (t)						
- slope - micro-relief : pm	< 2 %	<5 %	< 8 %	< 12 %	< 25 %	< 25 % and more
Wetness (w)						
- Flooding	slight or less	considerable or less				
- Internal drainage	moderate	slow to somewhat rapid	slow to rapid	slow to very rapid	very slow to very rapid	very slow to very rapid
- Natural drainage	good	moderate or better	Imperfect or better	imperfect or better	poor or better	very poor or better
Physical soil conditions (s)						
- Topsoil texture (0 - 25 cm)	SL to perm CL	LS to C – 60 v	S to C + 60 v	S to C + 60 v	Sc to Cm	Sc to Cm
- Subsoil texture (25 - 100 cm)	fSL to CL	LfS to C – 60 v	LmS to C + 60 v	S to C + 60 v	Sc to Cm	Sc to Cm
- Surface stoniness : (%)	none	< 0.1	< 3	< 3	< 15	< 15 or more
- Surface coarse fragments (0 - 25 cm)	e < 3 %	< 15 %	< 35 %	< 35 %	< 35 %	< 35 % or more
	g < 15 %	< 35 %	< 55 %	< 55 %	< 55 %	< 55 % or more
- Subsurface coarse fragm. (25 - 100 cm)	<15 %	< 35 %	< 55 %	< 75 %	< 75 %	< 75 % or more
- Rockiness	0 %	< 2 %	< 10 %	< 10 %	< 25 %	< 25 % or more
- Depth to solid rock or hardpan	> 2 m	>1.5 m	> 1 m	>50 cm	>25 cm	> 25 cm or less
- Depth to gravel substratum or to soft weathered rock or clean sand	> 1 m	>75 cm	> 50 cm	> 25 cm	>10 cm	> 10 cm or less
- Lime content	<15 %	< 25 %	< 40 %	< 40 %	< 75 %	< 75 % or more
- Gypsum content	< 5 %	< 15 %	< 30 %	< 30 %	< 30 %	< 30 % or more
Salinity and alkalinity (n)						
- EC mmhos/cm (average 0 - 100 cm)	< 4	< 8	< 16	< 16	< 30	< 30 or more
- ESP (maxim 0 - 100 cm)	< 5	<15	< 25	< 25	< 45	< 45 or more

INTERNAL DRAINAGE (infiltration rate)				LAND CLASS
moderate	optimal	0.8 - 3.5 cm/h	SCL to CL	1
	nearly optimal	0.5 - 0.8 cm/h 3.5 - 7 cm/h	CL to SiCL SCL to fSL	
rather slow somewhat rapid		0.2 - 0.5 cm/h 7 - 10/11 cm/h	SiCL to C-60 V fSL to LfS	2
slow rapid		0.1 - 0.2 cm/h 10 - 12.5 cm/h	C-60V to C+60V LmS to LcS	3
Very slow		– 0.1 cm/h	C+60V to Cm	4
Very rapid		> 12.5 cm/h	LcS to cS	5

TEXTURAL RANGE	
Cm	SiL
SiCm ---- 0,1 cm/h	SCs
C 60,v	L
C 60,s ---- 0.2 cm/h	SCL ---- ± 3.5 cm/h
C 60,v	fSL
C 60,s	cSL ------ 7 cm/h
SiC,s	Lfs
Co ------- 0.5 cm/h	LmC
SiCL	LcS ---- 11 cm/h
CL ---- ± 0.8 cm/h	Sf ------ 12.5 cm/h
Si	Sm
	Sc

3.2. Specific evaluation methods for irrigation

3.2.1. EVALUATION FOR SURFACE IRRIGATION

3.2.1.1. General principles

The land utilization type considered here consists in irrigation of crops normally cultivated under rainfed farming when sufficient precipitation is present. In arid areas rainfall is replaced by irrigation. Paddy rice cultivation is not included because it represents a special type of irrigation.

The system that we have developed, considers landscape and soil criteria directly related to surface irrigation and particularly the soil/water relationship.

Such an evaluation has to be associated with an evaluation for crop production where the specific crops are evaluated according to the procedure described under 2.2.2.

Surface irrigation is practiced in basins; according to the method of providing water one may consider :

- basin flush irrigation, whereby water enters in the basin and flows equally over the surface;

- basin furrow irrigation, whereby the water distribution in the basins is done according to a furrow system

Although a quantitative land evaluation is desired for irrigation, it may be useful to suggest criteria for an evaluation of the physical environment. Indeed, such data can be used for a qualitative evaluation in the pre-project, reconnaissance and even detailed phase of the survey. It will further help to select the most suitable lands for irrigation, for which the economic land evaluation has to be made during the feasibility study.

Evaluation of the physical environment can be done in terms of land characteristics or land qualities :

(1) **LAND CHARACTERISTICS**

The land characteristics important for surface irrigation purposes are the following :

- topography;
- wetness :
  - flooding;
  - drainage;
- physical soil characteristics :
  - texture including surface and subsurface stoniness;
  - soil depth;
  - calcium carbonate status;
  - gypsum status;
- salinity and alkalinity.

The fertility criteria are not directly considered indeed, as weathering stage of arid lands is always in a recent stage the apparent cation exchange capacity is high to medium. Base saturation is always high and a disturbed cation balance is going to be considered by other characteristics. As a result of common levelling and grading organic layers are mostly disturbed and therefore not considered for the specific irrigation suitability.

(2) **LAND QUALITIES**

The land qualities important for evaluation of an irrigation scheme are the following :

- Internal qualities :
  - ability for drainage and aeration;
  - capacity for water retention;
  - absence of more or less saline groundwater table;
  - resistance to alkalinization and structural deterioration;
  - absence of salinity and alkalinity;

- External qualities :
  - ability for lay-out of field plan;
  - flooding hazard;
  - workability;
  - stability of fields and irrigation infra-structure.

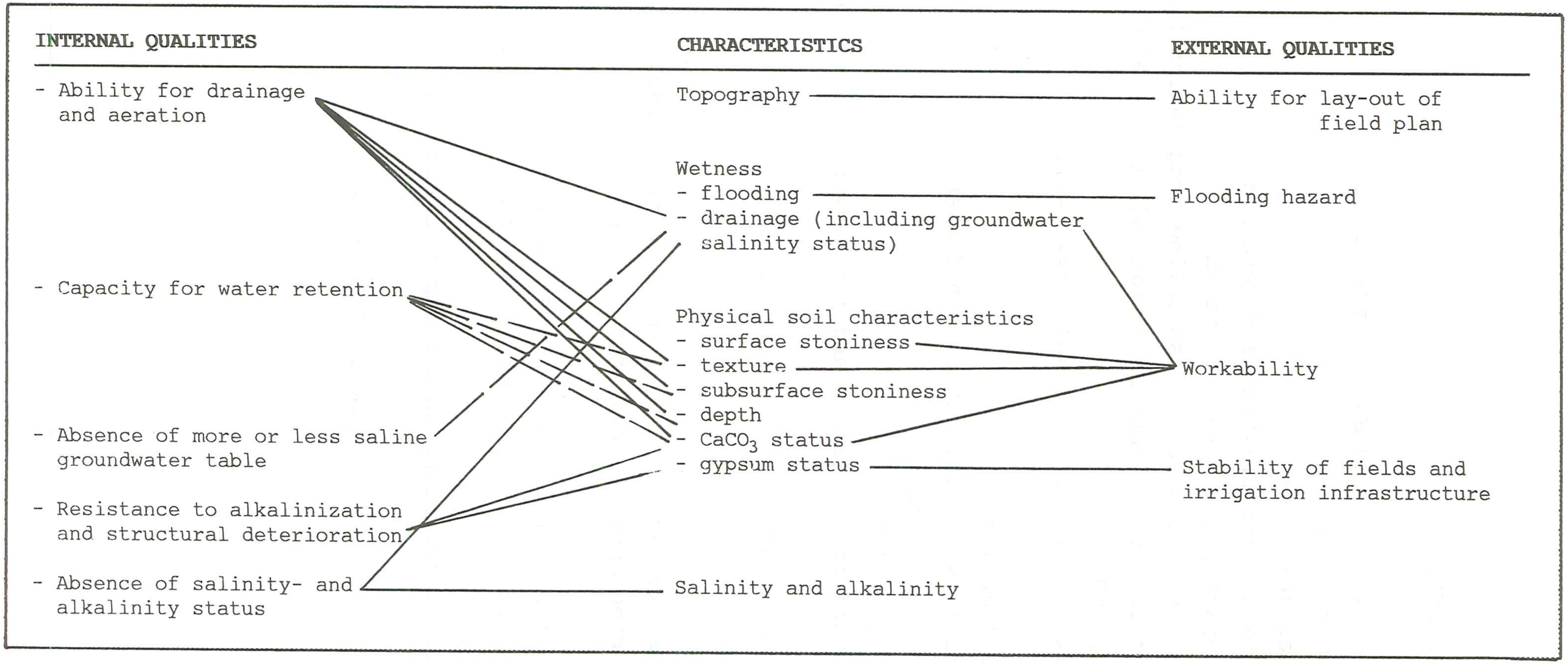
The relations between characteristics and qualities are given in table 84.

LAND CLASSES for surface irrigation can be defined according to the selected methodology; this can include :

- definition by the lowest class characteristic/quality;
- definition according to number and intensity of limitation levels;
- definition according to a parametric method.

SUBCLASSES deal with the kind of limitation.

Table 84. Relation between land characteristics and land qualities when used for the evaluation for irrigation



3.2.1.2. Evaluation of land characteristics

(1) **TOPOGRAPHY**

The dominant topographic factor that influences the irrigation suitability of an area concerns slope and microrelief (gilgai a.o.).

The application of basin flush irrigation requires horizontal basins, while for basin furrow irrigation a slight slope of the basins is permitted.

We consider that a slope up to 2 per cent can be levelled for basin-flush irrigation. At the other hand slopes of 6% can be considered as marginal for basin furrow irrigation. Levelling and grading are considered as ordinary management practices up to slopes of 6 per cent (table 85).

(2) **FLOODING**

Flooding is evaluated as follows :

F0 : no limitation....................................S1
F1 : moderate limitation..............................S2
F2 : severe limitation................................S3
F3 + F4 : very severe limitations.........................N

(3) **DRAINAGE**

The effect of drainage will also depend on the depth and quality of a possible groundwater table. Impeded drainage conditions are limiting, particularly when saline groundwater is present.

Table 85. Evaluation of slope for basin furrow irrigation

SLOPE %	DEGREE OF LIMITATION AND RATING (-)			
	Gilgai + other forms of micro-relief			
	No	Slight	Moderate	Strong
0-1	0 (S1) (100)	1 (S1) (95)	2 (S2) (80)	3 (S3) (65)
1-2	1 (S1) (90)	2 (S2) (80)	2-3 (S3) (65)	3 (S3) (55)
2-4	2 (S2) (75)	2-3 (S3) (65)	3 (S3) (55)	3 (S3) (50)
4-6	3 (S3) (60)	3 (S3) (55)	3 (S3) (50)	4 (N1) (40)
6-10	4 (N1) (40)	4 (N1) (35)	4 (N1) (30)	4 (N1) (30)
> 10	4 (N2) (20)	4 (N2) (20)	4 (N2) (20)	4 (N2) (20)

Table 86 suggests criteria for a combined evaluation of drainage conditions and possible presence of groundwater, saline or non-saline.

(4) **TEXTURE**

For irrigation texture has to be evaluated with regard to the waterholding capacity and the infiltration rate.

The most common surface irrigation system is furrow irrigation. Long-furrow irrigation is a logical development of the short furrow method used in small holdings. Since hand labour,

Table 86. Evaluation of drainage for surface irrigation

DEPTH OF GROUNDWATER (cm)	DRAINAGE CLASS	MAXIMUM LAND CLASS	LIMITATION LEVEL	RATING
A. No or non-saline groundwater (Ec < 1,500 micromhos)				
> 200	well	S1	0	100
100-200	well	S1	1	90
	(x) →	S2	2	80
50-100	moderate	S2	2	70
	(x) →	S2/3	2/3	60
25- 50	imperfect	S3	3	50
	(x) →	N1	4	40
< 25	poor	N1	4	40
	(x) →	N2	4	30
	very poor	N2	4	30
	(x) →	N2	4	20
B. Presence of saline groundwater (Ec > 1,500 micromhos)				
> 300	well	S1	0	100
200-300	well	S1	1	90
	(x) →	S1	1	85
100-200	well	S1	1	85
	(x) →	S2	2	70
50-100	moderate	S3	3	50
	(x) →	N1	4	40
25-50	imperfect	N1	4	30
	(x)	N2	4	20
< 25	poor	N2	4	20
	(x) →	N2	4	10
	very poor	N2	4	10
	(x) →	N2	4	5

(x) : Fine textured soils (clay, silty clay, sandy clay)
no mark : other textural classes

necessary for irrigation management, has become scarce the long furrow method was introduced in mechanized farming.

The long furrow method requires land levelling and grading. It saves in effort and waste of land, but water is still wasted through deep percolation, surface evaporation and runoff.

Hanna and El Awady (1970) have noted that the length of furrows depends on soil texture and slope of the furrow (table 87).

*Table 87. Furrow length with regard to slope and texture (**Hanna and El Awady**, 1970)*

FURROW SLOPE	FURROW LENGTH in m					
	Silty clay	Clay	Clay-loam	Loam	Sandy loam	Sand
1/10,000	60	30	20	45	-	-
1/1,000	200	90	70	40	15	-
1/100	-	300	200	150	50	10

This indicates that in irrigation management we have advantage to increase the furrow slope when soil texture becomes coarser.

The ratings of the textural classes for normally structured soils are represented in fig. 7. When we consider broad structural classes and an adaptation to fine-coarse sandy textures we may determine textural evaluation criteria as suggested in table 88.

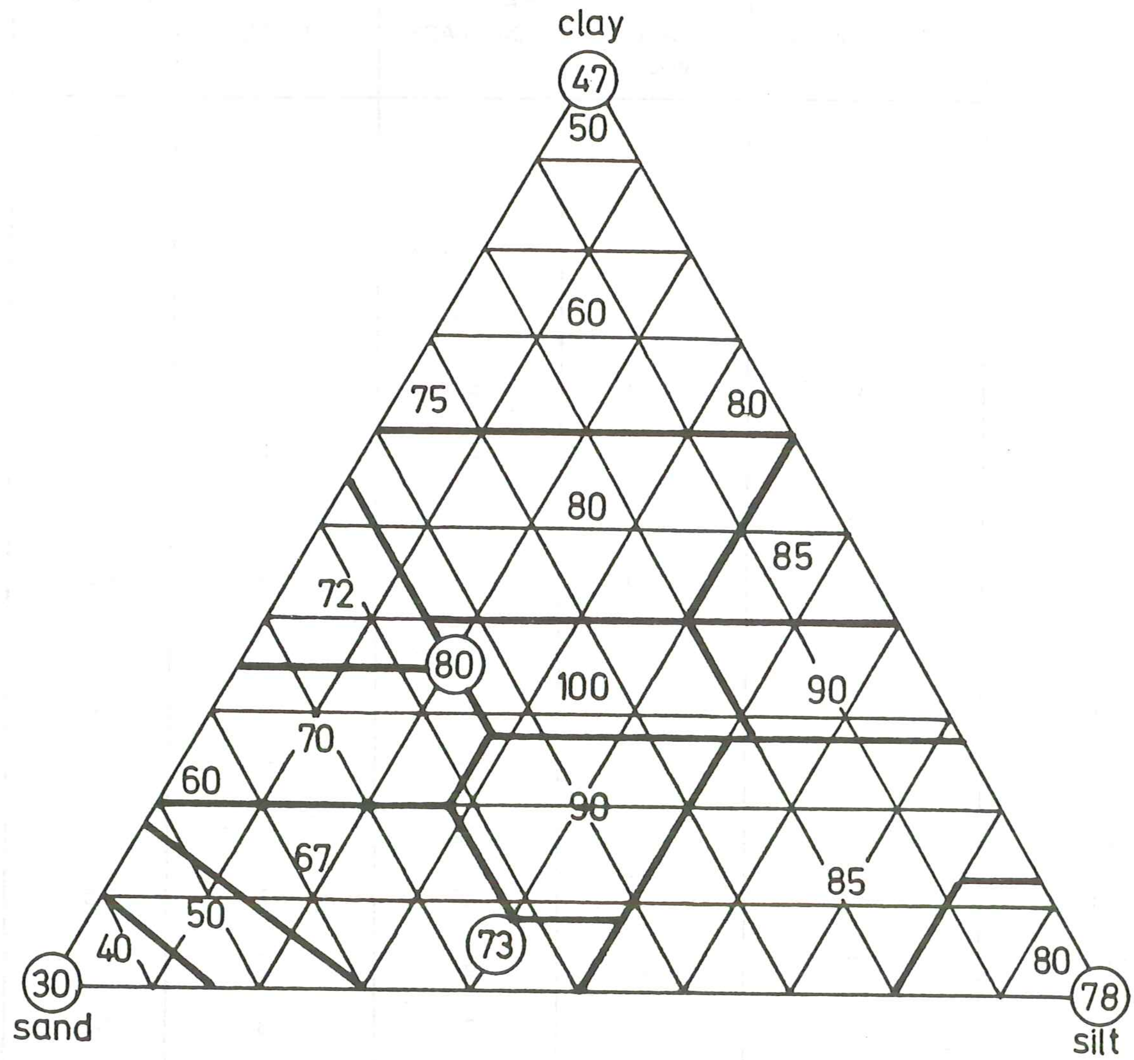


Fig. 7 Rating of textural classes for surface irrigation.

Table 88. Guidelines for the evaluation of textural classes for surface irrigation for the profile section 0 to 100 cm depth

TEXTURAL CLASS	INFILTRATION RATE (cm/h)	AVAILABLE WATER vol.%	MAXIMUM LANDCLASS	LIMITATION LEVEL	RATING
Cm			N2	4	20
C+60V			S3	3	50
C+60s	< 0.1	15	S3(2)	3(2)	55
C-60V			S2	2	75
C-60s	0.2	20	S2	2	75-80
SiC		21	S1	1	85
SiCL	0.5		S1	1	90
CL	0.8	19	S1	0	100
L		16	S1	1	90
SiL			S1	1	85
SC		15	S2	2	72
SCL	3.5		S2	2	70
fSL			S2	2	70
SL	7	12.5	S2	2	65
cSL			S3	3	60
LfS			S3	3	60
LS	11	8-9	S3	3	50
LcS			S3	3	40
fS	12		S3	3	40
S			N2	4	30
cS		4	N2	4	20

The evaluation of particle size classes for gravelly soils requires a downgrading of the fine earth textural evaluation as follows :

- one land class per 20 volume per cent coarse fragments;
- one limitation level per 20 volume per cent coarse fragments;
- for parametric method downgrading of fine earth textural rating using line (1) of fig. 2.

For surface irrigation texture is evaluated to a depth of 2 m.

The first section of the profile from the surface to 1 m depth is evaluated with regard to its capacity to retain water and its capacity for drainage. The criteria of table 88 are used. However, for stratified profiles with horizons of different texture, the texture of the 0 to 100 cm section is recalculated using 4 sections of 25 cm with weighting factors : 1.75 - 1.25 - 0.75 - 0.25. This is done for clay and silt and the recalculated textural class is used for evaluation when we use the limitation method.

For gravelly soils we use the mean gravel content of 0-100 cm.

If we use the parametric method, and in the case of gravelly soils, a downgrading is done of the fine earth texture and the rating of the profile is calculated as explained earlier (under 2.2.2.). In this case depth is also integrated.

The profile section from 1 to 2 m depth is evaluated with regard to its capacity for drainage.

For this we use groups of textural classes regrouped according to the family criteria of Soil Taxonomy.

The evaluation is suggested in table 89.

Table 89. Guidelines for the evaluation of texture for surface irrigation for the section 100-200 cm depth

TEXTURAL CLASS	MAXIMUM LAND CLASS	LIMITATION LEVEL	RATING
Sandy and coarse loam	S1	0	100
Fine loamy	S1	1	80
Fine clayey	S2	2	70
Very fine clayey	S2	2	60
Gravelly > 75% coarse fragments	S1	0	100

Gravel contents of less than 75% are not considered unless they influence the infiltration rate. If they do so the evaluation is upgraded according to the improvement of drainage conditions.

The evaluation of the deep subsoil (100-200 cm) in heterogeneous profiles is done from 100 cm to the depth of the lower limit (base) of the least permeable horizon. In any case the calculated mean of the considered horizons is used.

(5) **SOIL DEPTH**

The soil depth is defined as the thickness of the loose soil above a limiting layer, which is impermeable for roots and/or percolating water. The most common types in arid areas are :

- an unconsolidated gravelly or stony horizon with at least 75% coarse elements;

- a continuous, consolidated calcium carbonate layer with a minimum thickness of 30 cm and more than 60% calcium carbonate;

- a continuous gypsiferous layer with more than 25% gypsum and a minimum thickness of more than 30 cm;

- a continuous hard rock, or hardpan of more than 10 cm thick.

Evaluation of soil depth for these materials is suggested in table 90.

(6) **CALCIUM CARBONATE STATUS**

Calcium carbonate can favour soil structure, may influence waterholding capacity and becomes a serious limitation for surface irrigation.

For evaluation we consider the recalculated lime content to a depth of 100 cm or up to a limiting layer (lithic contact, horizon with more than 60% $CaCO_3$ or more than 25% gypsum).

The weighting factors used are :

- for profiles deeper than 100 cm : 4 sections of 25 cm with weighting factors : 1.75 - 1.25 - 0.75 - 0.25;

- for profiles 75-100 cm deep : 4 equal sections with weighting factors : 1.75 - 1.25 - 0.75 - 0.25;

Table 90. Evaluation of soil depth for irrigation (cm)

DEPTH OF LOOSE SOIL (cm) OVER	MAXIMUM LANDCLASS AND DEGREE OF LIMITATION				
	S1		S2	S3	N2
	0	1	2	3	4
Gravel layer + 75% coarse fragments	> 100	75-100	50-75	30-50	< 30
Calcium carbonate (+ 60%) as more or less consolidated layer	> 150	100-150	75-100	50-75	< 50
Gypsum layer, permeable	> 300	200-300	150-200	100-150	< 100
Hard rock or hardpan	> 300	200-300	100-200	50-100	< 50

- for profiles 50-75 cm deep : 3 equal sections with weighting factors : 1.5 - 0.9 - 0.6;

- for profiles 25-50 cm deep : 2 equal sections with weighting factors : 1.2 - 0.8;

- for profiles < 25 cm : no weighting factors.

Evaluation criteria are suggested in table 91. They depend on soil texture as a large amount of lime is more favorable for fine textured soils.

Table 91. Evaluation of the calcium carbonate status

ADAPTED $CaCO_3$ CONTENT (%)	MAXIMUM LAND CLASS	DEGREE OF LIMITATION	RATING
35-60	S2 (S1)	2 (1)	80 (90)
10-35	S1 (S1)	1 (0)	90 (100)
1-10	S1 (S1)	0 (1)	100 (90)
< 1	S1 (S2)	1 (2)	90 (80)

Indications between () are for clayey families

(7) **GYPSUM STATUS**

As gypsum in a soil influences the stability of an irrigation infrastructure it is most important for irrigation. However gypsum contents over 25 per cent are considered separately under depth criteria. For adapted gypsum contents of the horizons, with less than 25 per cent gypsum, obtained by using the weighting factors as suggested for lime, the evaluation criteria are suggested in table 92.

Table 92. Evaluation of gypsum contents of < 25%

ADAPTED $CaSO_4$ CONTENT (%)	MAXIMUM LAND CLASS	DEGREE OF LIMITATION	RATING
15-20	S2	2	75
10-15	S1	1	90
3-10	S1	0	100
< 3	S1	1	90

(8) SALINITY AND ALKALINITY STATUS

For salinity we use the average weighted parameter from 0 to 100 cm.

For alkalinity the highest value between 0 and 100 cm or to a lithic contact.

Table 93 suggests the evaluation criteria.

Table 93. Evaluation of salinity and alkalinity

SODIUM SATURATION %	ELECTRICAL CONDUCTIVITY, SATURATION EXTRACT IN mmhos/cm					
	0-4	4-8	8-16	16-30	>30	
DEGREE OF LIMITATION	0 S1		1 S1	2 S2		
0-8	100 / 100 (x)	98 / 90 (x)	90 / 80 (x)	85 / 70 (x)	80 / 60 (x)	
8-15	96 / 90 (x)	90 / 80 (x)	85 / 70 (x)	80 / 60 (x)	75 / 50 (x)	3 S3
15-30	90 / 80 (x)	85 / 70 (x)	80 / 60 (x)	75 / 50 (x)	30 (x)	
> 30	85 / 70 (x)	80 / 60 (x)	75 / 50 (x)	58 / 30 (x)	30 / 20 (x)	4 N

(x) : fine textured soils (clay, silty clay, sandy clay).
no mark : all other textural classes.

Some of these values may appear too high for direct cultivation. These are indeed no values for crop production but values which can be improved up to the evaluation standards of the table using the normal irrigation management with use of the required leaching of salts.

3.2.1.3. **Evaluation of land qualities**

(1) **ABILITY FOR DRAINAGE AND AERATION**

The land quality "ability for drainage and aeration" is related to natural drainage conditions, texture, subsurface stoniness, presence of impermeable layers and calcium carbonate status. We believe that it is best expressed by the infiltration rate of the soils.

When using irrigation water of good quality optimum infiltration rates are situated between 0.8 and 3.5 cm/hour, while soils with an infiltration rate of less than 0.1 cm/hour or more than 12.5 cm/hour are considered to present very severe limitations.

Infiltration rates of 0.1 to 0.2 cm/hour and 11.0 to 12.5 cm/hour are considered as marginal for gravity irrigation.

The limitation levels in function of infiltration rate are given in table 94.

The presence of impermeable substrata may influence the ability for drainage and aeration. When such substratum is present we recommend to apply a downgrading of this land quality (table 95).

Table 94. Limitation levels and maximum land classes for infiltration rate

INFILTRATION RATE (cm/hour)	LIMITATION LEVEL	MAXIMUM LAND CLASS
0.8 - 3.5	no limitation	S1
0.5 - 0.8 3.5 - 7.0	slight limitation	S1
0.2 - 0.5 7.0 -11.0	moderate limitation	S2
0.1 - 0.2 11.0 -12.5	severe limitation	S3
< 0.1 > 12.5	very severe limitation	N2

Table 95. Guidelines for the evaluation of the land quality "Ability for drainage and aeration" with downgrading for impermeable substratum and impeded drainage

INFILTRATION RATE (cm/h)	DEPTH IMPERMEABLE SUBSTRATUM OR WATERTABLE (m)				
	> 3	2-3	1-2	0.5-1	< 0.5
0.8-3.5	S1 0(100)	S1 1(92)	S2 2(82)	S3 3(60)	N2 4(20)
0.5-0.8 3.5-7.0	S1 1(92)	S1 1(85)	S2 2(70)	S3 3(50)	N2 4(15)
0.2-0.5 7.0-11.0	S2 2(80)	S2 2(70)	S3 3(50)	S3 3(40)	N2 4(10)
0.1-0.2 11.0-12.5	S3 3(55)	S3 3(45)	N1 4(35)	N2 4(20)	N2 4(10)
< 0.1 > 12.5	N2 4(10)	N2 4(10)	N2 4(10)	N2 4(10)	N2 4(10)

Figure 8 shows the evaluation of infiltration rate for gravity irrigation.

(2) **CAPACITY FOR WATER RETENTION**

The capacity for water retention of a soil depends on the texture of the fine earth, the subsurface stoniness, the depth and the calcium carbonate status.

The water hold by the specific horizons is important; however, a good picture of all the characteristics will be included in the concept available water in the rooting zone. This means to a depth of 1 m or to an impermeable layer. As such the effect of depth is integrated together with waterholding capacity of the soil horizons situated above an impermeable layer.

The criteria suggested are given in table 96 and fig. 9.

Table 96. Suggestions for the evaluation of the capacity for water retention

DEGREE OF LIMITATION	MAXIMUM LAND CLASS	cm OF AVAILABLE WATER THAT CAN BE STORED FROM TOP TO 100 cm OR TO IMPERMEABLE LAYER
0	S1	> 16
1	S1	14-16
2	S2	9-14
3	S3	5- 9
4	N	< 5

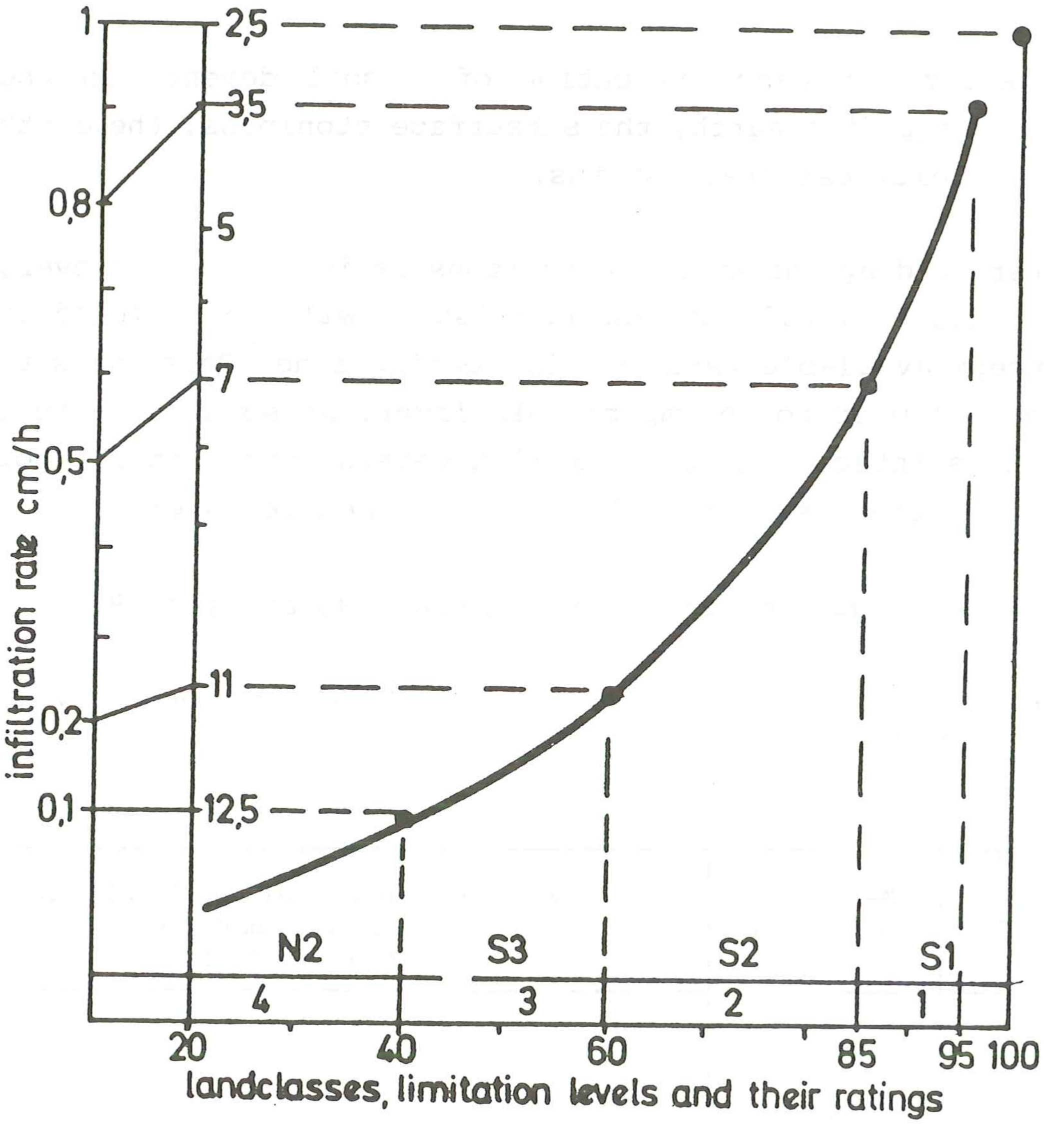


Fig. 8 Evaluation of infiltration rate for gravity irrigation

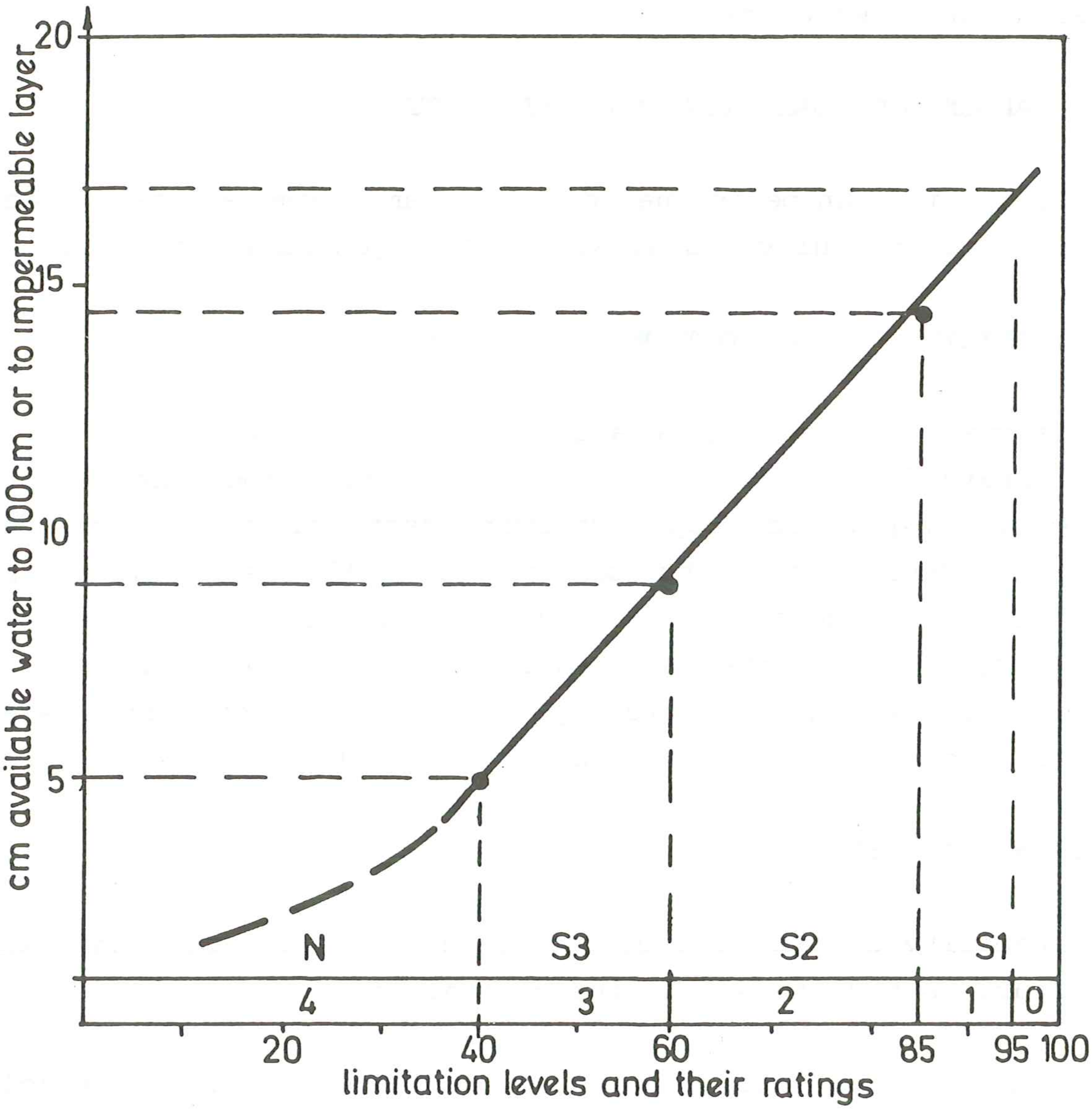


Fig. 9 *Evaluation of water holding capacity of the profile for surface irrigation.*

(3) **ABSENCE OF A MORE OR LESS SALINE GROUNDWATER TABLE**

Suggestions for the evaluation of drainage conditions with regard to the salinity status and position of the groundwater table have been stated in table 86. The same table can be used for the evaluation of the quality "absence of more or less saline groundwater table".

(4) **ABSENCE OF SALINITY AND ALKALINITY**

This quality can be evaluated in the same terms as the characteristics "salinity and alkalinity" suggested in table 93.

(5) **ABILITY FOR LAY-OUT OF FIELD PLAN**

This quality is mainly related to levelling and grading works necessary for gravity irrigation. The most important factors are topography and slope. However, depth of calcic horizons which undesirably can be exposed during the levelling works, could also be considered. We suggest to use table 85 related to slope limitations as a base for the evaluation of this quality. However, downgradings have to be considered when calcic horizons are exposed as a result of levelling.

(6) **WORKABILITY**

Workability of the land depends mainly on surface stoniness, texture, structure and drainage conditions.

We assume that under irrigation drainage is under control. Structure is related to macroporosity and therefore to infiltration rate. Both drainage and infiltration rate are evaluated as the quality "Ability for drainage and aeration".In order to avoid interactions between qualities, a second evaluation should not be considered; therefore, workability can be evaluated with regard to surface stoniness and texture of the surface horizon.

For surface stoniness the following classes of coarse fragments are distinguished :

- fine gravels : size between 2 mm and 2.5 cm
- coarse gravels : size between 2.5 and 7.5 cm
- cobbles : size between 7.5 and 25 cm
- stones : size above 25 cm.

The stoniness of the top soil is rated by the percentage of total coarse fragments in volume in the top 20 cm of the soil. When coarse fragments of different sizes occur, the average size is taken into account for the rating. However, if the percentage of the coarsest fragments leads to a more severe limitation, this situation is considered for the evaluation.

The evaluation of workability with regard to stoniness in the top soil, associated with a medium or coarse textured fine earth or a well structured clay, is suggested in table 97. For massive fine textured clays, sandy and silty clays, a down-grading of 20% could be applied.

Table 97. Limitations and maximum land classes for workability with regard to surface coarse fragments

SURFACE COARSE FRAGMENTS (vol.%)	FINE GRAVELS		COARSE GRAVELS	COBBLES
3-15	0	S1	1-S1	1-S1
15-35	1		2-S2	2-S2
35-55	2	S2	3-S3	3-S3
55-75	3	S3	4-N1(?)	4-N1(?)
above 75	4	N2	4-N2	4-N2

The workability with regard to surface stoniness can be evaluated using the criteria given in table 98.

Table 98. Limitations and maximum land classes for workability with regard to surface stoniness

SURFACE STONINESS (vol.%)	DEGREE OF LIMITATION	MAXIMUM LAND CLASS
none	0	S1
< 0.01	1	S1
0.01-0.1	2	S2
0.1-3	3	S3
3-15	4	N1
> 15	4	N2

(7) **STABILITY OF THE FIELDS AND IRRIGATION INFRASTRUCTURE**

The stability of the fields and irrigation infrastructure can present serious limitations when important amounts of gypsum are present or when peat occurs in the subsoil.

For the evaluation of this quality we refer to criteria on gypsum as discussed under land characteristics and to table 99.

The evaluation with regard to the presence of peat in the subsoil will depend on the type of irrigation infrastructure : depth of canals, depth of drainage system a.o. as well as on the depth and thickness of the peat itself.

Table 99. Stability of fields and irrigation infrastructure with regard to gypsum content

DEPTH (cm) GYPSUM LAYER (> 30% GYPSUM)	GYPSUM CONTENT OVER GYPSIC MATERIAL (> 30%)			
	< 3	3-5	5-15	15-30
> 300	0	0	1	2
200-300	1	1	2	3
150-200	2	2	3	4
100-150	3	3	4	4
< 100	4	4	4	4

3.2.2. EVALUATION FOR SPRINKLER IRRIGATION

Sprinkler irrigation is a kind of artificial rainfall whereby the water requirement can be ideally satisfied. Indeed as irrigation is fully under control, frequency of irrigation and amount of water to be applied per irrigation can be adapted to the soil conditions.

The suitability of the land to cultivate a specific crop under sprinkler irrigation will essentially depend on the requirements of the crop.

Considering that the water control is in hands of the manager less severe criteria can be used for characteristics related to the water balance.

As such light textured soils, unsuitable under rainfed farming, because of water availability limitations, may become suitable when sprinkler irrigation is used.

Also the depth requirements have to be adapted to the possibilities of a controlled water balance.

3.2.3. EVALUATION FOR RICE CULTIVATION

3.2.3.1. Different types of rice cropping

If we make an analysis of rice cultivation techniques, we realize that rice can be cultivated according to different broad land utilization types :

- rainfed upland rice;
- bunded rice;

- rice cultivation under natural floods; and
- irrigated rice.

(1) RAINFED RICE

Rainfed rice consists in the cultivation of rice, mostly as upland crop under dry land conditions, without any flooding. The crop grows as any other cereal.

(2) BUNDED RICE

Bunded rice is a form of upland paddy cultivation on bunded fields. The land is perfectly levelled; therefore, terraces are built and bunded. The floodwater comes for a great deal from rainfall accumulated on the puddled fields, but this water can be supplemented by water caught from small inland rivers and springs. This type of rice cultivation in terms of landform, as described by **Moormann and van Breemen (1978)**, is the main cultivation pattern in inland valleys. The general relief of the land system can vary from mountainous, hilly, rolling to undulating. A similar cultivation pattern is also practiced on some alluvial terraces, alluvial fans and piedmont plains. In all these cases cultivation starts most often on lower slopes and it goes up sometimes on moderate slopes where the bunded terraces become very narrow.

(3) RICE CULTIVATION UNDER NATURAL FLOODS

Rice cultivation under natural floods is another widespread type of rice farming in many tropical countries. It is practiced in floodplains where farmers benefit from the natural floods to cultivate paddy rice. This type of rice farming, in terms of landform, is the main cultivation pattern in meander floodplains, lacustrine floodplains and marine floodplains. Cultivation under natural floods can also be practiced on some parts of alluvial terraces where floodwater, as a result of run-off from higher landforms, accumulates during the monsoon period.

(4) **IRRIGATED RICE**

Irrigated rice cultivation is the cultivation of paddy rice under fully controlled irrigation. This utilization type can also be introduced in warm dry climates, where irrigation water is available.

These main utilization types are adapted to specific hydrologic conditions and, therefore, specific crop requirements have to be suggested for each, particularly with regard to landform, flooding and physical soil characteristics. **Sys** (**1986**) has elaborated land requirements for rice cultivation and these criteria are useful for soil survey interpretation as part of the land evaluation procedure.

The crop requirements are set up to use the FAO-system (**FAO, 1976**), whereby land characteristics are quantified. The class is attributed to the most important limitation level. The suggested requirements are therefore a basis for a qualitative evaluation.

The frame of the system (suitability classification) is as follows :

ORDER S : suitable land
- **CLASSES S1** : suitable
- **S2** : moderately suitable
- **S3** : marginally suitable

ORDER N : non-suitable land
- **CLASSES N1** : actually unsuitable but potentially suitable
- **N2** : actually and potentially unsuitable.

3.2.3.2. Climatic requirements

Rice production is restricted to areas having warm temperatures and sufficient water supply. The principal rice producing countries lie between 30°N and 30°S. Exceptions are Japan and Korea. In these tropical and subtropical regions, rice is by far the most productive cereal that can be grown. Rice is cultivated in Asia from below sea level to an elevation of 2,500 m.

Although it is considered as a tropical crop, rice is grown on an extensive scale in subtropical and low temperature latitudes. It can be cultivated in almost any region having 4 to 6 months an average temperature of at least 20 to 25°C and a minimum of 10°C. Rice needs ample rainfall; however, in warm dry areas rainfall can be replaced by irrigation.

(1) RAINFALL

In many tropical countries rice is grown with high rainfall. Under these conditions rice can be cultivated as an upland crop without maintaining water at the surface, or on levelled bunded fields submerged by natural precipitation during most of the season if good yields have to be obtained. Under such conditions rice is grown where annual rainfall is 1,000 mm or more. It is, however, considered that a good water supply requires 1,400 mm of rainfall during the growing season, while 800 to 1,000 mm is considered as marginal.

However, rice thrives in dry hot regions where there is ample irrigation water. The water requirement for rice varies from 200 to 900 mm per month, according to the rate of evapotranspiration.

Where rice is grown on flooded lowlands or under irrigation supply, rainfall has not to be considered if full irrigation water is present.

(2) **TEMPERATURE**

Most information related to the effect of temperature on rice growing is from experiments in glass-houses, where conditions are artificially under control. For natural conditions, few information is available. A comparative study of temperature characteristics of rice growing areas indicates that in the temperature range below optimal conditions, the results obtained in an artificial environment can be reasonably extrapolated to natural conditions. However, for temperatures above optimal conditions, we realize that results obtained in natural conditions do not necessarily coincide with those obtained in glass-houses. This is most likely due to the fact that the open air temperature in a sunny rice field is higher than the registered temperatures measured under thermometer-house.

It is generally considered that rice grows successfully when the mean temperature of the growing season varies from 20 to 38°C.

The germination of rice seeds at warm temperatures promotes earlier flowering because of an increased rate of growth during the early stages of plant development.

The mean temperature during the crop development stage, from germination to flowering, is ideally 30 to 32°C, but there is no important limitation in the temperature range from 24 to 36°C. Marginal conditions are 10 to 18°C and 42 to 45°C. The climate is considered unsuitable when the mean temperature of this crop development stage is lower than 10°C or higher than 45°C.

Studying the relation between the temperature and the percentage of ripened grains under natural conditions it has been stated that, when the maximum, mean and minimum temperatures are lower than 25-26°C, 21-22°C and 17°C respectively, the percentage of ripened grains decreases rapidly. On the other hand, at higher temperatures such as 30°C, 26.5°C and 23°C respectively, no decrease in the percentage of ripened grains is recognized.

Ideally, the mean temperature of the ripening stage (last 2 weeks) can be considered as 30 to 33°C, but in the temperature range from 25 to 38°C, no important impact on the ripening has been noted. On the other hand, 17 to 20°C and 42 to 45°C are considered as marginal ranges for the most common varieties. With regard to the main minimum temperature of the ripening stage the temperature range 17 to 25°C seems to be ideal. The marginal minimum temperature ranges during ripening are considered as 7 to 10°C and 28 to 30°C.

In optimal conditions, the average daily maximum of the warmest month may fluctuate between 30 and 40°C. Marginal conditions are 21 to 26°C and 45 to 50°C.

(3) **RELATIVE HUMIDITY**

Relative humidity may affect the sensitivity to diseases, the formation of the grains after the milky stage and the ripening of the crop.

In the early stage of crop growth and during the whole vegetative stage, it is considered that high relative humidity levels favour crop development.

During the formation of the grain a too low relative humidity may cause shrinkage of the grains and too high levels will favour diseases; this is particularly applicable in rainfed rice where low relative humidity levels coincide with periods of drought stress and high levels with excessive rain.

At harvest low relative humidity levels are desired.

(4) **DURATION OF SUNSHINE**

The intensity of radiation will influence the climatic potential yield and can be evaluated in terms of number of sunshine hours as expressed by the n/N ratio.

Taking into account the different climatic characteristics the evaluation of the climate is represented in table 100.

3.2.3.3. Landform requirements

The evaluation of the landform for rice cultivation will depend on the land utilization type.

For upland rice the slope criteria are similar to those of other cereals. The requirements however may still depend on the level of management.

Under intensive farming with a high level of management, ideally the land should be flat or have long, regular, smooth slopes of up to 2 to 4 per cent, the higher value being more acceptable with heavier soils. This permits the widest choice of field lay-out design and the most economical cultivation and harvesting techniques. Slopes of 8 to 16 per cent are considered to present severe limitations and are marginal.

Table 100. Agro-climatic evaluation for rice cultivation

CLIMATIC CHARACTERISTICS	AGRO-CLIMATIC LAND CLASS				
	S1	S2	S3	N1	N2
Rainfall growing season (*) in mm	> 1,400	> 1,000	> 800	< 800	< 800
Mean T°, crop development stage °C	24-36	18-42	10-45		any
Mean T°, ripening stage	25-38	20-42	17-45		any
Mean minimum T°, ripening stage	17-25	10-28	7-30		any
Average daily maximum, warmest month	30-40	26-45	21-50		any
Relative humidity, tillage stage	55-90	any			
Relative humidity, vegetative stage	50-90	any			
Relative humidity after milky stage (*)	40-70	> 30	≷ 30		
Relative humidity harvest stage (**)	< 60 (< 75)	< 80 (≷ 75)	≷ 80		
Sunshine duration, growing season, n/N	> 75	> 45	≷ 45		

(*) Only for rainfed rice; (**) Depending on severity of interpretation

At a low level of management, where only small fields are cultivated, optimal conditions may extend to slopes up to 8 per cent, while 16 to 30 per cent is considered as a marginal situation.

For bunded rice all irregularities in the topography, as gilgai and slope, constitute a limitation and will require levelling and grading works. Slopes up to 4 per cent permit to elaborate basins of 10 to 20 m wide on deep soils, and can be considered as optimal. Slopes of 8 to 12 per cent can be considered as marginal. In any case slope will be interrelated to soil depth as cuts may expose impermeable substrata. Presence of such substrata may cause land-sliding and solifluction. Such possibilities have to be studied carefully.

Rice cultivation under natural floods requires a flat terrain for optimal situation. Even slight slopes require some bunding for flood control and maintenance of a uniform equal water cover on the fields. In most cases this utilization type is only practiced in flood plains with flat topography where slope is not a problem.

For full irrigated intensive rice farming the land should ideally be flat with less than 1 per cent slope. In these conditions one can easily maintain a uniform water depth on large fields, while the nearby flat topography will satisfy the necessity, on irrigated schemes, of establishing a slight slope for water distribution purposes.

Slopes up to 4 per cent remain suitable for irrigated rice; however, optimal yields require levelling and grading, and therefore an adaptation of the water distribution system associated with some restrictions on field design. This results in a pattern with smaller basins.

Slopes of 4 to 6 per cent are very marginal; they could only be used after intensive levelling and grading but an increasing economic penalty is paid in terms of greater costs of land levelling, restriction in the choice of the field lay-out and some constrains on mechanical harvest methods.

3.2.3.4. **Wetness requirements**

The wetness conditions are determined by flooding and drainage. The drainage situation determines the oxido-reduction potential of the soil and this affects growth and yield of rice. Generally some degree of drainage or some lateral movement of water is desirable in preventing excessive reduction of the soil and consequent undesirable chemical changes that may occur. Heavy soils become strongly reduced; at the other hand, somewhat lighter, better drained soils may retain an oxidizing rootzone for long periods. In this respect some sandy soils are reported to give superior yields. However, excessively drained paddy soils are also undesirable, because they require too much water and an excessive use of fertilizers.

Flooding will influence the redox potential in the soils. It will depend on depth, organic matter content and ionic balance. Sometimes an oxidized horizon may occur at some depth due to the trapping of air in the soil on flooding. After flooding, nitrate is the first soil nutrient to become reduced and denitrification is the main mechanism whereby nitrate is lost from the soil.

The wetness requirements as determined by flooding and drainage are essentially different for the various types of rice cultivation.

A first need for evaluation is to define flood classes in terms of the duration and depth of flooding and adapted to the specific requirements of the rice crop.

With regard to the **duration of flooding** one may define classes according to the optimal length of the growing season :

1 : time of flooding is less than the marginal flood conditions of a growing season (less than 2 months);

2 : time of flooding is near but above marginal conditions as compared to the length of the growing season (2 to 3 months);

3 : time of flooding corresponds or is near to the optimal length of the growing period (3 to 4 months);

4 : time of flooding exceeds the optimal length of the growing period, so that harvesting has to be done under flooded conditions (more than 4 months).

With regard to **depth of the floods**, 5 classes are considered:

1 : depth of flooding is less than ideal (less than 10 cm);

2 : depth of flooding is ideal (10 to 20 cm);

3 : depth of flooding is more than ideal, but still permits cultivation of the common rice varieties (20 to 40 cm);

4 : depth of flooding becomes marginal for cultivation of the common varieties and use of floating rice could be considered (40-80 cm);

5 : depth of flooding is too important for any form of normal rice cultivation and requires use of floating rice (more than 80 cm).

In addition to depth of flooding, the irregular sudden increase in flood level may influence the suitability.

Table 101 summarizes the possible flood classes and indicates the maximum land class for the different types of paddy cultivation.

Upland rice and bunded rice are considered here as upland crops on land not susceptible for flooding.

The drainage situation has also to be commented with regard to the rice technology.

Table 102 suggests maximum land classes for drainage classes as related to the rice technology.

For upland rice cultivation the evaluation of drainage classes is similar to that used for other cereals.

For paddy rice cultivation important information is available (**Dudal, 1958; Dudal and Moormann, 1968**) for south-east Asia.

From these studies we may conclude that the cultivation of bunded rice, as defined here, starts at the border of the valleys and at the lower footslopes, where drainage is often imperfect; it is considered that this situation is optimal. For higher lands, suitability will depend on the possibility to make the surface soil impermeable for water by using puddling, rather than on the natural drainage class.

Table 101. Flood classes for rice cultivation with maximal land class for rice cultivation under natural floods (A) and irrigated rice (B)

DEPTH OF FLOODS	DURATION OF FLOODING (1-2-3-4) AND MAXIMUM LAND CLASS FOR RICE CULTIVATION UNDER NATURAL FLOODS (A) AND IRRIGATED RICE (B)											
	1 MAXIMUM LAND CLASS			2 MAXIMUM LAND CLASS			3 MAXIMUM LAND CLASS			4 MAXIMUM LAND CLASS		
		A	B		A	B		A	B		A	B
1	F11	N2	S1	F21	S3	S1	F31	S1	S1	F41	S2	S2
2	F12	N2	S1	F22	S3	S1	F32	S1	S1	F42	S2	S2
3	F13	N2	S2	F23	S3	S2	F33	S2	S2	F43	S3	S3
4	F14	N2	S3	F24	S3	S3	F34	S3	S3	F44	N2	N1
5(*)	F15	N2	N1	F25	N2	N1	F35	N2	N2	F45	N2	N2
5(**)					S3	S3					S3	

F0 : no floods
(*) : evaluation for normal varieties
(**) : floating rice cultivation, considered as marginal practice, is possible

Table 102. Maximum land classes for the drainage classes

DRAINAGE CLASSES	MAXIMUM LAND CLASSES				
	DRY UPLAND RICE (1)	DRY UPLAND RICE (2)	BUNDED RICE	NATURAL FLOODS	IRRIGATED
Good	S1	S3	S2/S1	N2	S2
Moderate	S2	S2	S1/S2	S3	S1
Imperfect	S3	S1	S1	S2	S1
Poor	N1	N1	S2	S1	S2
Very poor	N1	N2	N2	S2	S3

(1) fine loamy and clayey families;
(2) coarse loamy and sandy families.

The evaluation of drainage classes for rice cultivation under natural floods is also tentative and done with regard to the possible relation between drainage and the most common flood classes.

For irrigated rice the imperfect class seems to be in an ideal situation together with the moderately well drained soils. Water uplift will be slight and drainage at harvest time becomes easy. The very poorly drained soils are considered marginal as maximum land class. However, some of these soils, due to difficulties for flood control and drainage associated with possible secondary salinization,are N1 or N2 according to their possible improvement or not.

3.2.3.5. **Physical soil conditions**

For paddy rice cultivation the water has to be maintained on the fields. The capacity to hold water at the surface will not only depend on the soil texture and structure, but also on the presence of superficial groundwater.

Rice grown on natural floods has most likely a high groundwater table during the flood period and can therefore be cultivated on a wider textural range than irrigated rice on soils without superficial groundwater, for which the infiltration rate is only influenced by textural and structural conditions.

It is also to be noted that surface texture is more important than subsurface texture.

An important amount of coarse fragments in the surface makes the soil unsuitable for paddy rice. Surface stoniness will prevent any mechanization and has to be evaluated according to severe standards. The evaluation criteria for the different types of rice cultivation are suggested in tables 103 to 106.

Soil depth has also to be considered. It should be interpreted carefully in the case of bunded rice, where cuttings may expose impermeable substrata of barren saprolite on steeper slopes and may cause a danger for land-sliding and solifluction.

The presence of calcium carbonate in soils of arid areas affects both the physical and the chemical characteristics of a soil. High lime concentration may not severely restrict water movement but may prevent root penetration. Rice is considered as a moderately tolerant crop to calcium carbonate; 25 to 30% are considered as marginal.

When in dry hot areas gypsum is present, it will affect the cation balance of the soil; through its easy solubility it releases Ca and may disturb Ca/Mg and Ca/K ratios. It also affects soil physical properties; it improves the soil structure and prevents sodium saturation.

A small amount of gypsum up to 3% is favourable for rice cultivation because it serves as a plant nutrient. Based on practical observations, it is concluded that rice growth is strictly limited when the gypsum content in the root zone is higher than 15 per cent.

3.2.3.6. **Fertility status**

The most important soil characteristics related to natural fertility are weathering stage as expressed by the apparent cation exchange capacity, sum of basic cations, pH and organic matter content. All these characteristics can, at a certain level of generalization, be deduced from a taxonomic soil classification at family level.

It has been stated that many rice soils have a pH between 4.5 and 6, but some may also include alkali conditions. However, attention must be drawn to the fact that the pH of paddy rice soils, measured on a dried sample, is most misleading. As soon as the land is flooded, the soil solution is in equilibrium with the flood water and takes its pH.

Sys and Riquier (1979) suggest an optimal pH-range from 5.5 to 7.5 for rice; as marginal values they accept a lower range down to 5.2 and an upper limit of 8.2.

3.2.3.7. **Salinity and alkalinity**

Rice is sensitive to salinity, less than 2 mmhos is considered optimal. A conductivity of the saturation extract of 4-6 mmhos/cm is considered marginal and rice will not develop when salinity is higher than 6 mmhos/cm (conductivity on saturation extract).

At the other hand the rice crop supports a high alkalinity status. Up to 10-20% sodium saturation no yield reductions have been observed. Sodium saturation levels from 30 to 40 per cent are marginal.

The land classes for the different rice land utilization types are summarized in tables 103 to 106.

Table 103. Land classes for rainfed upland rice

SOIL AND TERRAIN CHARACTERISTICS	LAND CLASSES				
	S1	S2	S3	N1	N2
Climate (c)	According to separate evaluation				
Topography (t)					
% slope (1)	< 4	< 8	< 16	< 25	> 25
(2)	< 8	< 16	< 30	< 30	< 30
Wetness (w)					
Flooding	no	no	no to slight	no to slight	any
Drainage (3)	good	moderate or better	imperfect or better	poor or better	very poor or better
(4)	imperfect	imperfect or moderate	good, moderate or imperfect	poor or better	very poor or better
Physical soil characteristics (s)					
Surface texture/structure (**)	C-60v to L	C+60v to LfS	C+60v to S	C+60v to S	Cm to Sc
Surface coarse fragments	< 15	< 35	< 55	< 55	> 55
Subsurface texture (**)	C+60v to fLS	C+60v to Sc	C+60v to Sc	C+60v to Sc	Cm to Sc
Subsurface coarse fragments	< 35	< 55	< 55	< 55	> 55
Depth to impermeable layer	> 90	> 50	> 20	> 20	< 20
$CaCO_3$ (%)	< 6	< 15	< 25	< 25	> 25
Fertility status (f)					
Apparent CEC at 50 cm (cmol(+)/kg clay)	> 16	> 0 (-)	> 0 (+)		
Sum of basic cations (0-25 cm) (cmol(+)/kg soil)	> 5	> 2	< 2		
pH H_2O (0-25 cm)	3.5-7.5	7.5-8.2 5.5-5.2	8.2 5.2	> 8.2 < 5.2	
Organic carbon (0-25 cm) (%)					
(5)	> 1.5	> 0.8	< 0.8		
(6)	> 0.8	< 0.8			

(1) Intensive fully mechanized agriculture; (2) Primitive farming; (3) Fine loamy or clayey families; (4) Coarse loamy and sandy families; (5) Non-calcareous soils; (6) Calcareous soils.

(**) Textural sequence : **Cm** : massive clay; **SiCm** : massive silty clay; **C+60v** : very fine clayey, vertic; **C+60s** : very fine clayey, blocky; **C-60v** : clay, vertic; **C-60s** : clay, blocky; **SiCs** : silty clay, blocky; **Co** : clay, oxic; **SiCL** : silty clay loam; **CL** : clay loam; **Si** : silt; **SiL** : silt loam; **SC** : sandy clay; **L** : loam; **SCL** : sandy clay loam; **SL** : sandy loam; **LfS** : loamy fine sand; **LS** : loamy sand; **LcS** : loamy coarse sand; **fS** : fine sand; **S** : sand; **cS** : coarse sand

Table 104. Land classes for bunded rice

SOIL AND TERRAIN CHARACTERISTICS	LAND CLASSES				
	S1	S2	S3	N1	N2
Climate (c)	According to separate evaluation				
Topography (t)					
% slope (1)	0-4	4-8	8-12	12-25	< 25
Wetness (w)					
Flooding	under control				
Drainage	imperfect	poor to moderate	poor to good	poor to good	very poor to good
Physical soil characteristics (s)					
Surface texture (**)	Cm to SiCs	Cm to Si	Cm to SC	Cm to SC	Cm to Sc
Surface coarse fragments	no	< 15	< 35	< 35	< 35
Subsurface texture (**)	Cm to Si	Cm to SC	Cm to LSf	Cm to LSf	Cm to Sc
Subsurface coarse fragments	no	< 15	< 35	< 35	< 35
Depth	to be considered with regard to levelling and grading and possibilities for landsliding				
$CaCO_3$ (%)	< 6	< 15	< 25	< 25	> 25
Fertility status (f)					
Apparent CEC at 50 cm (cmol(+)/kg clay)	> 16	> 0 (-)	> 0 (+)		
Sum of basic cations (0-25 cm) (cmol(+)/kg soil)	> 5	> 2	< 2		
pH H_2O (0-25 cm)	3.5-7.5	7.5-8.2 5.5-5.2	8.2 5.2	> 8.2 < 5.2	
Organic carbon (0-25 cm) (%)					
(1)	> 1.5	> 0.8	< 0.8		
(2)	> 0.8	< 0.8			

(1) Non-calcareous soils; (2) Calcareous soils.

(**) Textural sequence : **Cm** : massive clay; **SiCm** : massive silty clay; **C+60v** : very fine clayey, vertic; **C+60s** : very fine clayey, blocky; **C-60v** : clay, vertic; **C-60s** : clay, blocky; **SiCs** : silty clay, blocky; **Co** : clay, oxic; **SiCL** : silty clay loam; **CL** : clay loam; **Si** : silt; **SiL** : silt loam; **SC** : sandy clay; **L** : loam; **SCL** : sandy clay loam; **SL** : sandy loam; **LfS** : loamy fine sand; **LS** : loamy sand; **LcS** : loamy coarse sand; **fS** : fine sand; **S** : sand; **cS** : coarse sand.

Table 105. Land classes for rice cultivation under natural floods (floating rice is excluded)

SOIL AND TERRAIN CHARACTERISTICS	LAND CLASSES				
	S1	S2	S3	N1	N2
Topography (t) % slope	no	< 2	< 4	< 6	< 6
Wetness (w) Flooding	F32-F31	F32 to F42	F32 to F24	F32 to F24	F32 to F0
Drainage	poor	very poor to imperfect	very poor to moderate	very poor to moderate	very poor to good
Physical soil characteristics (s) Surface texture/structure	Cm to SiCs	Cm to SCL	Cm to Sf	Cm to Sf	Cm to Sc
Surface coarse fragments	< 15	< 35	< 55	< 55	< 55
Subsurface texture	Cm to LSf	Cm to Sc			
Subsurface coarse fragments	< 35	< 55	< 55		
Depth to impermeable layer	> 90	> 50	> 20	> 20	< 20
$CaCO_3$ (%)	< 6	< 15	< 25	< 25	< 25
Gypsum (%)	< 3	< 10	< 15	< 15	< 15
Fertility status (f) Apparent CEC at 50 cm (cmol(+)/kg clay)	> 16	> 0 (-)	> 0 (+)		
Sum of basic cations (0-25 cm) (cmol(+)/kg soil)	> 5	> 2	< 2		
Organic carbon (0-25 cm) (%) (1) (2)	> 1.5 > 0.8	> 0.8 < 0.8	< 0.8		
Salinity and alkalinity (n) EC (dS/m on sat. extr.)	< 2	< 4	< 6	< 6	< 6
ESP (%)	< 20	< 30	< 40	< 40	< 40

(1) Non-calcareous soils; (2) Calcareous soils.
Textural sequence : **Cm** : massive clay; **SiCm** : massive silty clay; **C+60v** : very fine clayey, vertic; **C+60s** : very fine clayey, blocky; **C-60v** : clay, vertic; **C-60s** : clay, blocky; **SiCs** : silty clay, blocky; **Co** : clay, oxic; **SiCL** : silty clay loam; **CL** : clay loam; **Si** : silt; **SiL** : silt loam; **SC** : sandy clay; **L** : loam; **SCL** : sandy clay loam; **SL** : sandy loam; **LfS** : loamy fine sand; **LS** : loamy sand; **LcS** : loamy coarse sand; **fS** : fine sand; **S** : sand; **cS** : coarse sand.
Flood sequence : F32-F31-F33-F41-F42-F34-F22-F21-F23-F43-F44-F35-F25-F45-F11-F12-F13-F14-F15-F0 (for definition of flood classes : see page 234).

Table 106. Land classes for irrigated rice

SOIL AND TERRAIN CHARACTERISTICS	LAND CLASSES				
	S1	S2	S3	N1	N2
Topography (t) % slope	< 1	< 2	< 4	< 6	< 6
Wetness (w) Flooding	F0 to F32	F0 to F42	F0 to F43	F0 to F44	F0 to F45
Drainage	moderate to imperfect	good to poor	good to very poor		
Physical soil characteristics (s) Surface texture (1) (2)	Cm to SiCs Cm to SiCs	Cm to Si Cm to SCL	Cm to SC Cm to Sf	Cm to SC Cm to Sf	Cm to Sc Cm to Sc
Surface coarse fragments (1) (2)	no < 15	< 15 < 35	< 35 < 55	< 35 < 55	< 35 < 55
Subsurface texture (1) (2)	Cm to Si Cm to LSf	Cm to SC Cm to Sc	Cm to LSf	Cm to LSf	Cm to Sc
Subsurface coarse fragments (1)	no < 35	< 15 < 55	< 35 < 55	< 35	< 35
Depth to impermeable layer	> 90	> 50	> 20	> 20	< 20
$CaCO_3$ (%)	< 6	< 15	< 25	< 25	< 25
Gypsum (%)	< 3	< 10	< 15	< 15	< 15
Fertility status (f) Apparent CEC at 50 cm (cmol(+)/kg clay)	> 16	> 0 (-)	> 0 (+)		
Sum of basic cations (0-25 cm) (cmol(+)/kg soil)	> 5	> 2	< 2		
Organic carbon (0-25 cm) (%) (3) (4)	> 1.5 > 0.8	> 0.8 < 0.8	< 0.8		
Salinity and alkalinity (n) EC (dS/m on sat. extr.)	< 2	< 4	< 6	< 6	< 6
ESP (%)	< 20	< 30	< 40	< 40	< 40

(1) soils without groundwater table within a depth of 30 cm from the surface (id. as banded); (2) soils with groundwater near or at the surface (id. as under natural floods); (3) Non-calcareous soils; (4) Calcareous soils.

Textural sequence : **Cm** : massive clay; **SiCm** : massive silty clay; **C+60v** : very fine clayey, vertic; **C+60s** : very fine clayey, blocky; **C-60v** : clay, vertic; **C-60s** : clay, blocky; **SiCs** : silty clay, blocky; **Co** : clay, oxic; **SiCL** : silty clay loam; **CL** : clay loam; **Si** : silt; **SiL** : silt loam; **SC** : sandy clay; **L** : loam; **SCL** : sandy clay loam; **SL** : sandy loam; **LfS** : loamy fine sand; **LS** : loamy sand; **LcS** : loamy coarse sand; **fS** : fine sand; **S** : sand; **cS** : coarse sand.

Flood sequence : F0-F11-F12-F21-F22-F31-F32-F13-F23-F33-F42-F14-F24-F34-F43-F15-F25-F44-F35-F45.

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