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SOIL SURVEY DATA FOR IRRIGATION DEVELOPMENT

A COOPERATIVE PROJECT OF THE GOVERNMENT OF ETHIOPIA,
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TABLE OF CONTENTS

LIST OF FIGURES

GRAPHS

LIST OF TABLES

ETHIOPIAN VALLEYS DEVELOPMENT STUDIES AUTHORITY

STUDIES FOR INTEGRATED IRRIGATION SYSTEMS

(Project ETH/88/001)

Addis Ababa, Ethiopia

To: National Project Coordinator
Project Soil Survey Staff

From: L.A. van Sleen
FAO Soil Surveyor

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INTRODUCTION

In this technical guide emphasis is given to soil- and land characteristics which are of importance to irrigated agriculture. However, full documentation of all the land- and soil characeristics is necessary, because it is useful to other disciplines concerned with project planning and design and may be needed to consider alternative development possibilities if irrigation is shown to be unfeasible.

Topography and cover of the soil surface, such as vegetation, stones, termite mounds and flooding features, are very important aspects in considering the feasibility of irrigation development, since they influence the cost and/or physical possibility of land improvement.

Knowledge of soil physical characteristics helps to create a favourable environment for plant growth.Understanding of soil-water-plant relations will lead to better irrigation water management..

Aquisition of soil chemical data provides awareness about plant nutrient availability which helps in efficient fertilizer management.

The accuracy of soil data depends upon proper and representative sampling. The selection of representative sampling sites (soil profile pits) depends upon many considerations. Since it is mainly based on a good understanding of soil-landscape relationships (including the past and present land-and soil forming processes), it can be done most accurately by means of aerial photo-interpretation. In practice, areas will be selected, which are uniform in respect of landform, relief, drainage(condition), soil type and vegetation cover type or crop growth. The sampling soil profile pit will then be dug in the middle of such units.

The intensity of sampling depends upon the level of development planned, and on the complexity of the soil pattern that has to be mapped.

This technical guide, includes 6 chapters:
Topography and other surface characteristics, determining land development requirements and limitations and their relationship to the cost and feasibility of their improvement for irrigation development are dealt with in chapter 1, while the physical and chemical properties of soils, important from the irrigation point of view are dealt with in chapters 2 and 3, respectively. Chapter 4 covers soil testing and its objectifs and chapter 5 deals with water quality appraisals. Criteria to select irrigation method are presented in chapter 6.

I - TOPOGRAPHY AND OTHER SURFACE FEATURES

This chapter mainly concerns with surface features effecting the physical feasibility and/or related cost to develop the land for irrigated agriculture, such as topography (slope, micro-, macro relief and position), vegetation, stoniness-rockiness , termite mounds and flooding features.

Table 1.1 gives a review of these properties and the purpose of their determination (why needed?) and where and how to be obtained.

A Topographical Considerations

Topography is discussed in terms of 4 of its aspects which have a special bearing on irrigation suitability: slope, micro-relief, macro-relief and position.

A.1 Slope

The acceptable degree of slope depends on factors such as:

- intended method of irrigation,
- rainfall intensity,
- risk of erosion and
- planned cropping pattern.

Observation of cultivated slopes indicate the limit of slope for rainfed crops which is the same for sprinkler irrigation, the latter being adaptable to the infiltration capacity of the soil.

The safe limit for gravity irrigation is usually about half that for rainfed farming; in some regions erosion by rainfall may dictate the limit of slope.

In general, erosion is less under irrigation than it is under rainfed because land smoothing and grading minimizes local contributary causes of erosion, but poor water management can cause needless erosion. The maximum allowable stream flow is related to slope.

In furrow irrigation, for example, Cridle (1956) suggested that this value (Q_{max}) can be roughly estimated in litres per second by dividing 0.63 by the percentage slope.
Thus:

$$Q_{max} = \frac{0.63}{\text{slope } \%} \text{ litres per second}$$

This formula applies to soil of average erodibility. Actual field tests should give more accurate estimates, even if variable because of the degree of soil compaction and type of land use at the time of the test.
Table 1.2 gives a general review of slope classes and the possible irrigation method, crops and/or problems.

Table 1.1: Inventory and Purpose of Soil Surface Characteristics effecting Land Development Feasibility and Costs.1(see next page)

Data Required	Why Needed?	Where and How Obtained?
A Topography	-Influences choice of irrigation method -Labour requirements -Irrigation efficiency -Drainage -Erosion -Range of possible crops -Cost of land development -Size and Shape of fields	-Field observations (Slope meters) -Aerial photos -(detailed) Topo sheets
B Vegetation cover	-Influences bush clearing costs -Labour requirements -Clearing equipment needed -Possible returns(sale of timber) -Cost of land grading (afterwards)	-Field observations -Aerial photo-interpretation -Vegetation cover maps
C Surface Stones, Boulders, Rock outcrops	-Limit the use of mechanized agricultural equipment -Interfere with tillage -Restrict suitable land surface -Reduce rootability -Reduce soil moisture availability	-Field observations (and measurements) -Topo sheets and/or -Geo(morpho) logical maps
D Termite mounds	-Interfere with cultivation -Restrict suitable land surface -Influence labour requirement for removal and -Cost for chemicals (to kill ants)	-Field observations and measurements
E Flooding features	-Influence the use and management -Costs of protective works	-Field observations (surface debris, injuries to trees) -Interview local people -Topo sheets

Table 1.2

Slope Classes	Possible Irrigation methods, Crops and/or Problems
0 - 0.5 %	-On slowly permeable soil and where heavy rainfall is frequent, possibility of scalding by ponded water and waterlogging, particularly in a hot climate. -However, if infiltration rates are moderately good and large flows of water available to push the water across the field, such slopes are conducive to high irrigation efficiency.
0.1 - 2 %	Usually regarded as ideal for gravity irrigation under average topographic conditions. In contrast to steeper land, such slopes reduce costs for ditches, torrent structures and labour to a minimum and do not restrict the choice of climatically adapted crops.
2 - 7 %	Progressively lower crop yields on gravity irrigated land of increasing steepness, attributed to poorer water penetration. Contour bench terraces can be used for slope modification and erosion control. They are excellent for slopes upto 3 %, but less useful on steeper slopes because of loss of productive land to berms.
Above 17 %	Rarely suited for gravity irrigation. But sprinkler irrigation of arable crops may be acceptable on slopes not exceeding 20%, but tree crops are commonly grown on slopes of 35 and occasionally 45%(in western USA). Elsewhere, allowance must be made for the erosive effect of heavy rainstorms of short duration by reducing the permissible slope to 8 or even 2%, or growing more erosion resistant crops, e.g. grass.

A.2 Micro-relief

The term micro-relief applies to minor surface undulations and irregularities of the surface, with differences in height between crest and trough of 4 - 5 cm. in flat lake plain areas or 4 - 5 m. in areas of windblown sand.

Irregularities of the soil surface may be formed by differrent processes, such as erosion or deposition by water, wind or gravity; solution (sinkholes);soil swelling and shrinkage (gilgai and cracks);or man (contour terracing, dikes,ditches etc).

Evaluation of irrigation suitability requires an estimate of levellling requirements.

Land grading is the most common development requirement. It is often expressed in terms of cut and fill, assuming that an average half of the area is cut and half is fill. The total volume of earth so moved is not the sole determinant of cost. Other factors include depth of cut, distance of land, soil conditions, desired precision of the final grading and type of equipment available.

It should be noted that subsoil quality must always be evaluated by the soil surveyor, since it may limit the amount of grading advisable or greatly increase the cost if it is possible to conserve and later respread the topsoil.
Coarse sands, gravels, or layers rich in lime or gypsum or exchageable aluminium may never respond to irrigation after severe cutting.

Table 1.3 shows the amount of earth to be moved at various depths of cut and fill which together with local unit costs can be used to calculate grading costs.

Table 1.3 Grading Estimates in Terms of Cut and Fill
(From:FAO,Soils Bulletin 42)

Type of Grading	Light	Medium	Heavy
Average Cut and Fill (cm.)	7.5	15	30
Earth moving (m^3/ha.)	375	750	1500

A.3 Macro-relief and Field size

In contrast to the correctible deficiencies of land with a smooth, uniform slope are the non-correctible deficiencies of complex topography where slopes change frequently in gradient and direction. The more complex the topography the less desirable is gravity irrigation. Sprinkler irrigation is better suited to this type of terrain.

For maximum production with a minimum labour requirement, irrigated fields should be large and the irrigation runs long and straight. Therefore, field size and shape need to be considered as criteria in evaluating land for gravity irrigation.

Table 1.4 shows an evaluation of field size and shape in relation to suitability for mechanized farming. Field size and shape are less important when machinery is not used.

Table 1.4 : Evaluation of Irrigated Field Size

(From:FAO,Soils Bulletin 42)

	Very Favourable	Favourable	Moderately Favourable	Unfavourable
Minimum Field Size	8.0 ha	3.6 ha	2 ha	1 ha
Minimum Length of Run *	390 m.	120 m.	100 m.	50 m.
Dimensions(m)	390X200	120X300	100X200	50X20

)* consideration must be given to intake rates, when assessing the length appropriate for a given soil.

A.4 Position and Accessibility

Small tracks of land, regardless of quality, are frequently found uneconomic to include in an irrigation scheme if they are remote from the source of water or suitable drainage outlet. They are usually excluded after completion of the initial land classification.

Areas of land rising several metres above adjacent land should be delineated on the map for ease of identification and location. Any decision to exclude them from the project would be made by the engineers and economists in consultation with the soil surveyor. Normally areas under 0.5 ha. would be disregarded.

Any very low land, likely to present drainage problems or to become too wet for certain crops should be assessed with the help of the drainage engineer. In pumping schemes, well drained lands at a lower level than the water source can sometimes be served advantageously by a gravity diversion.

B - REMOVAL OF VEGETATION

Removal costs depend on size and type of vegetation, local labour costs, equipment available and area involved. Costs rise steeply as the size of the individual bushes and trees and density of stand increases and sandy soils tend to cost less to clear than fine-textured soils.

Clearing large trees with bulldozers tends to leave large holes where the tree stood, and soil clinging to the roots is carried away for burning. Land grading is therefore usually necessary.

Ground cover that is salable reduces the net clearing costs.

C - REMOVAL OF ROCKS AND STONES

Rock outcrops are difficult and expensive to remove and blasting is the usual method if their removal is essential.

When soil and drainage conditions are favourable occasional outcrops or large boulders (diameter > 25 cm.) may be disregarded unless they restrict the productive area or field size and shape. In the latter event, the land suitability class should be downgraded.

Stones (20-40 cm in diameter) and cobbles (7-20 cm in diameter) are usually removed from the tillage zone although some crops, e.g. pasture and orchard, suffer little loss of production. Removal costs should be a consideration in assigning land classes.

A method of estimating the cost of stone removal used by the US Bureau of Reclamation is to remove and pile all stones or cobbles from the surface and upper 20 cm depth from an area of 10m X 10m (0.01 ha.) and then to measure or estimate the volume of the stone heap.

In the Yadot area (Ethiopia) some 10 manhours per cubic metre was required for manual picking of stones and boulders from the surface upto 20 cm depth.

D - <u>TERMITE MOUNDS</u>

In the case of termite mounds that are sufficiently large and compact to interfere with cultivation the suitability of the land unit will have to be downgraded.

A coverage of 2% or less of the surface may be disregarded but more than 2% coverage will not only restrict the productive area,but also hinder the cultivation practices and sometimes also the field layout.
Costs of their destruction and for chemicals to kill the termites must considered in the evaluation of the land.

E - <u>FLOODING</u>

Overflow hazards from rivers or drainage ways, or surface run-off from higher uplands, often influence the use, management and development costs of affected portions of an irrigation project.
Evidence of frequent flooding is often provided by surface debris (stones, cobbles, vegetative debris) and observable injuries to trees.

However, very often flood damage observable at the time of soil survey, will not recur because of upstream dam construction for the irrigation project.This is frequently a benefit of large-scale irrigation projects. Therefore, the flooding evidence has to be discussed with the project hydrologist and engineer who will be able to estimate the effect of proposed project works on future flooding.

II - SOIL PHYSICAL PROPERTIES

For a better understanding of soil-water relations, it is very important to determine or estimate the soil physical properties which are of importance from the irrigation point of view.

Table 2.1 gives a review of these properties and reasons why needed and where and how to be obtained.

A - SOIL DEPTH

This is an important soil property in selecting land for irrigation, because it affects water storage capacity.

Soil Depth	Remarks
150 cm	Ideal in well drained friable soils
90 cm	Excellent for most crops
60 cm	Close attention for crop management required
30 cm	Suitable for grass and rice with proper management, better use with sprinkler irrigation

Soil depth determines also the available rootroom.

Table 2.1:Inventory and Purpose of Soil Physical Data

Data Required	Why Needed?	Where and How to be obtained
A Soil Depth	-Effect on Root development -Effect on Earthmoving and land levelling and on alignment of canals,drainage channels etc. -Perched watertables and subsequent Salinity.	-Soil pits and augering -Substratum drilling
B Soil Texture	-Important in establishing the homogeneity of land units and for the above purposes plus nutrient retention prediction	-Field observations backed up by laboratory analysis
C Soil Structure	-Effects on root development -Ability to puddle soils for rice cultivation -Workability -Erosivity -Tilth for Crop establishment	-Field observations -Laboratory
D Bulk Density	-Soil aeration and Root Penetration.	-Laboratory
E Porosity	-Storage and movement of available water	-Laboratory
F Infiltration	-Leaching and Salinity control, -Choice of irrigation method -Erosivity -Field Shape and Size	-Field scale tests -Basin tests -Ring tests -Sprinkler tests
G Permeability	-Potential drainage Problems after irrigation -Leaching and salinity controll	-Auger hole method -Ring Permeameters with manometers -Piezometers -Laboratory tests
H Available Water	-Growth on residual moisture, -Irrigation Interval and -Method of Irrigation	-Field Measurements of field Capacity -Laboratory

B - SOIL TEXTURE

Soil texture refers to the relative proportions of the various particle sizes, i.e. Sand, Silt and Clay.

Soil texture is the most basic soil characteristic and it influences a number of other soil properties such as: soil moisture, infiltration rate, run-off, internal drainage, erosion, root penetration.

Soil of all textural classes, except coarse sand, are irrigable if proper methods are adopted.

The soil particles are divided in three main groups (called soil separates) according to their size: SAND, SILT and CLAY.

Table 2.2 gives the most important properties of the soil separates.

Table 2.2: Important Properties of Soil Separates

Property	Unit	Sand	Silt	Clay
Size	mm	2 - 0.02	0.02 -0.002	< 0.002
Shape	-	Spherical or Cubical		Platy
Density	kg dm^{-3}	2.65	2.60	2.60
Sp.Surf.Area	m^2 kg^{-1}	5	<1000	15000-800.000
C.E.C.	m.e./100 g	nil	small	5 - 120
Feel	-	Gritty	powderlike	Cloddy/hard

Table 2.3: Composition of different Textural classes (%)

Class	Sand	Silt	Clay	Remarks
Sand	> 85	< 15	< 10	Very poor,very dry
Loamy sand	70-90	< 30	< 15	Very poor,very dry
Sandy loam	45-85	< 50	< 20	Poor water retention
Loam	< 52	28-50	8-28	Good water retention Good drainage,fertile and productive, good for
Clay loam	< 45	15-52	28-40	Irrigation.
Silty clay	< 20	40-60	40-60	Difficult to cultivate, Poorly drained, fertile and good for dry crops.
Clay	< 45	< 40	> 40	

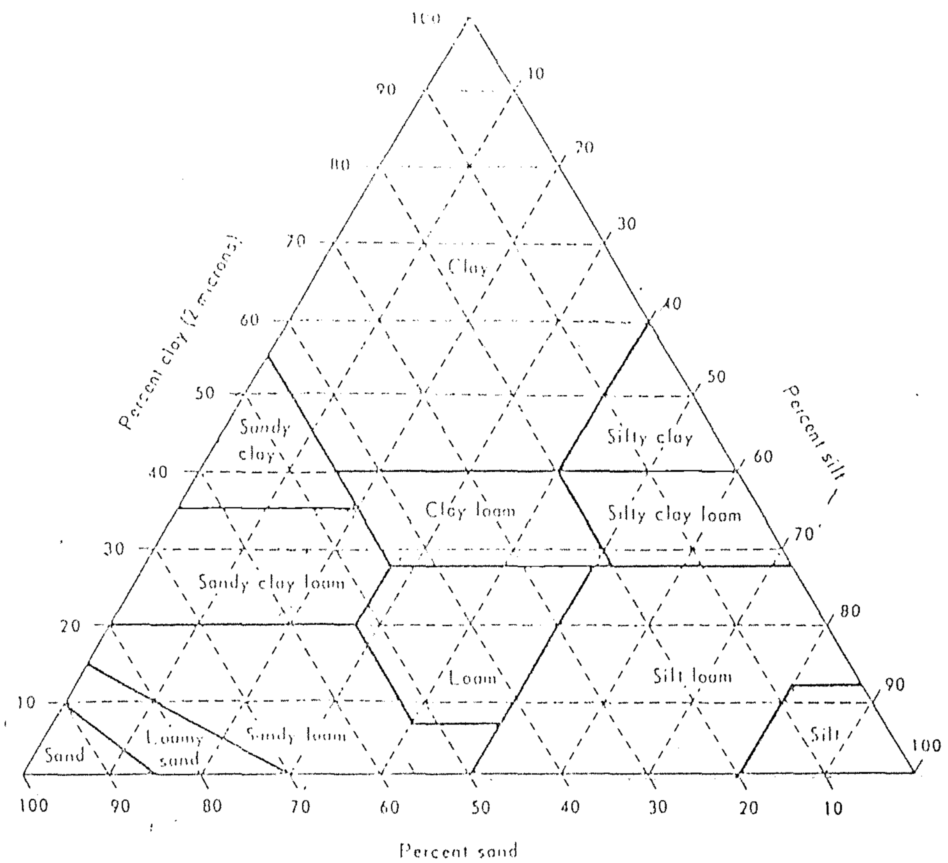


Figure 2.1: Textural diagramme

In using the diagramme, the points corresponding to the percentages of silt and clay present in the soil under consideration are located on the silt and clay lines, respectively. Lines are then projected inward, parallel in the first case to the clay side of the triangle and in the second case parallel to the sand side. The name of the compartment in which the two lines intersect is the class name of the soil in question.

Field Classification of Soil textural Classes

Textural classes are based on combinations of sand, silt and clay. Three types of textural classes are easily recognized.

1-Coarse textured or light soils: Sand and Loamy sand.

2-Medium textured soils: Sandy loam, Loam and Clay loam.

3-Fine textured or heavy soils: Sandy clay, Silty clay, Clay.

PROCEDURE (See Figure 2.2)

Take a spoonful of a soil sample. Try to make a ball. Now add water slowly until the soil starts to stick to the hand. Try to make a ribbon. The shape it takes indicates the textural class as follows:

A. Sand: the soil remains loose and single grained. It can be only heaped into a pyramid.

B. Loamy sand: It is somewhat cohesive and can be shaped into a ball, which easily falls apart.

C. Sandy loam: Forms a ball under pressure, which breaks when pressure is released. Soil can be rolled into a cylinder 5 cm. in length.

D. Loam: the soil can be rolled into a cylinder about 15 cm long that breaks when bent.

E. Clay loam: the soil can be bent into a U, but not further without breaking.

F. Silty clay: The soil can be bent innto a circle which shows cracks immediately.

G. Clay: the soil can be bent into a circle without any cracks.

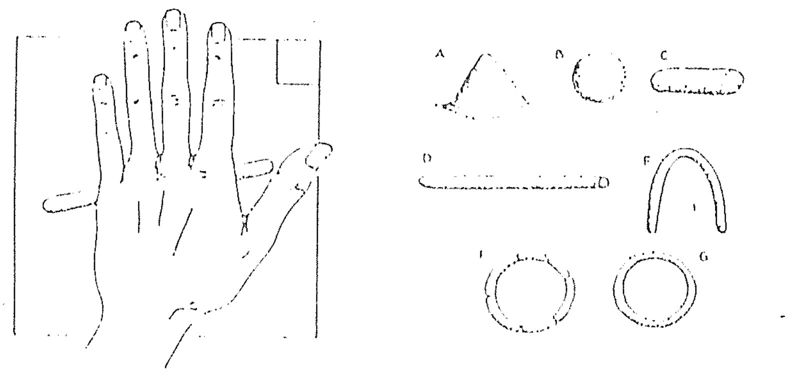


Figure 2.2: Manual test to estimate the textural class.

C - SOIL STRUCTURE

Soil structure refers to the arrangement of primary and secondary (aggregates) particles.

Soil structure influences soil air and moisture regimes and hydraulic conductivity.

Good soil structure allows plant growth factors to function at optimum efficiency, but a poor soil structure may limit the plant growth.

Soil structure is modified by soil texture, organic matter, cementing agents and ratios between cations present in the soil.

The desirable soil structure is one which has:

- Waterstable aggregates
- Sand and Gravel size aggregates
- Vertical axis of aggregates longer than horizontal axis
- Aggregates having round edges
- Soil should be friable: very loose soil has excessive aeration and poor root contact; massive and compact soil restricts aeration and root spread.

Measurement of Soil Structure

Expose a soil profile in the field and study the size of aggregates and their shapes.

Put some aggregates in water and observe their stability. Pour a bucket of water on top of the soil and observe its porosity.

- The distribution of aggregates according to size can be estimated by dry sieving. This is important for wind erosion control studies and can be done in the laboratory.

- Stability and distribution of waterstable aggregates can be estimated by wet sieving.This is also possible in the laboratory. It helps to understand water erosion problems.

Management of Soil Structure

The purpose of soil structure management is to create optimum conditions up to sufficient depth, so that most of the crop roots find favourable conditions to obtain maximum yields under a given climate and plant nutrition.

Another purpose is to decrease detachability and tranportability of soil by wind or water and to increase its infiltration and percolation to keep run-off and erosion at a minimum level.

How to obtain a desirable Soil Structure?

- Add Organic Matter by green manuring, compost, farm yard manure.
- By Mulching.
- Cultivation at proper moisture with proper implements.
- Deep ploughing and chiseling to break hard pans.
- Proper water management practices e.g. irrigation & drainage.
- Use of soil conditioners (on small scale only)
- P.V.A. (Poly Vinyl Acetate).

D - BULK DENSITY

Bulk density refers to mass per unit of total volume of dry soil. The volume includes both solids and pores. the units of B.D. are g/cm^3 or $kg\ dm^{-3}$.

The B.D. of clay, clay loam and silt loam soils ranges from 1.0 - 1.6 $kg\ dm^{-3}$.

The B.D. of sandy soils ranges from 1.2 - 1.8 kg dm¯3.

A very compact subsoil may have B.D. of 2.0 $kg\ dm^{-3}$.

Average values of B.D. are taken as 1.65 $kg\ dm^{-3}$.

Bulk density increases with compactness and decreases with looseness. Compact soils have lower water holding capacity, poor aeration and restricted root growth. Very loose soils have poor root contact and excessive aeration.

The specific weight (S.W.) of mineral soils (Specific weight of the solid material) varies between 2.60-2.70 kg dm^{-3}.
The relation between B.D., S.W. and porosity is given by the following formula:

Porosity = (1 - B.D./S.W.)x100%

E - <u>POROSITY</u>

The percentage of total volume not occupied by solids is referred to as porosity. The range is 30 - 60-%.

Three sizes of soil pores are generally recognized in soils:

- <u>Micro-pores</u>, small < 0.01 mm diameter for storage of available water.
- <u>Medium pores</u> 0.01 - 0.06 mm diameter for movement of water.
- <u>Macro-pores</u>, large > 0.06 mm diameter for aeration and infiltration.

In high rainfall areas large pores are important.
In dry farming areas, small and large pores are needed for adequate infiltration and storage.
In humid areas, large, medium and small pores should occupy about equal volumes.

Porosity in coarse textured soils does not vary too much, but in clay soils it is highly variable, due to swelling and shrinkage, aggregation, dispersion, compaction and cracking.

F - INFILTRATION

Infiltration rate is the rate at which water enters the soil surface and hydraulic conductivity (see next section) is the rate at which water will move through a unit cross section of soil under a unit hydraulic gradient.They are generally not identical.

Usually, in an infiltration test, the infiltration rate will be greater in the initial stage than the hydraulic conductivity rate, because of some lateral movement, and a head of surface water greater than zero must be maintained. There is also a downward capillary pull which initially is significant. As the wetting front moves downward, lateral and vertical capillary movement becomes negligeable, the hydraulic gradient will approach unity and the infiltration rate will approach the hydraulic conductivity rate.

Although the drainage engineer is mainly concerned with the hydraulic conductivity of the soil, the infiltration rate is also important in determining the deep percolation and runoff that must be carried by the drains.

The reduction in infiltration rate with time, after the initiation of infiltration is partly controlled by factors operating at the soil surface. They include swelling of soil colloids and the closing of small cracks which progressively seal the soil surface. Compaction of the soil surface by raindrop action is also considered important, where it is not mitigated by crop cover. Field data indicate a decreasing infiltration rate for 2 or 3 hours after the initiation of storm run-off. The infiltration rate eventually approaches a constant value, which is often somewhat smaller than the saturated permeability of the soil. Air entrapment and incomplete saturation of the soil are assumed to be responsible for this latter finding.

The basic infiltration rate (I_{bas}), is another quantity, which deserves consideration, because of its importance in irrigation design. According to the US Department of Agriculture, Soil Conservation Service, the basic infiltration rate is the instantaneous value, when the rate of change of intake for a standard period of 1 hour is 10% or less of its value. The time at which $I = I_{bas}$ is found by equating the first derivate of equation(1) to 0.1 I for a period of 1 hour.

$$dI/dt = -0.1\ I$$

(1) $I = at^{b}$,

where I=the instantaneous infiltration rate (cm/min)

t=infiltration time (min)

a= coefficient

b= dimensionless coefficient (between 0 and -1.0)

$$dI/dt = -0.1\ at^{b} = a\ bt^{b-1}$$

$$-0.1\ t^{b}/t^{b-1} = b \quad = -0.1\ t \longrightarrow t_{bas} = -10b \text{ (hour)}$$

If t_{bas} = - 10b is substituted in equation (1) and t expressed in hours, we have:

$I = at^b$---->$I= a\ (-10b)^b$

Or $I = a(60 \times 10b)^b = a(-600b)^b$ (cm/min)

Or $I = 60a(-600b)^b$ (cm/hour)

Infiltration capacity is a function of soil texture and vegetation as shown below.

Texture	Infiltration capacity cm/hour	
	Vegetated Soil	Bare Soil
Loamy sand	5.0	2.5
Loam	2.5	1.3
Silt loam	1.5	0.8
Clay	0.5	0.3

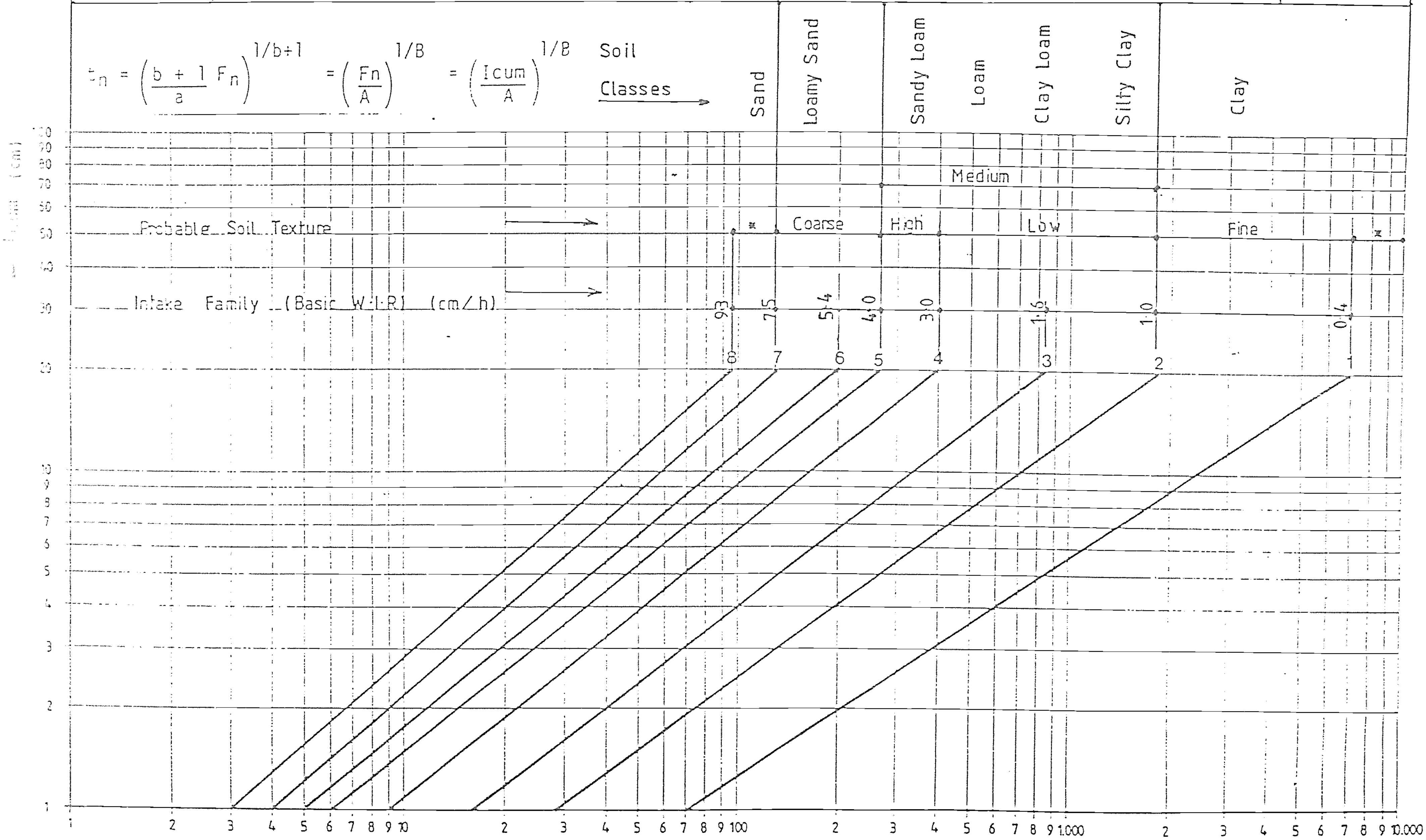
Infiltration capacity of coarse and muck and peat soils changes very little with time.

Infiltration rates

< 0.1 cm/hour	The soils are generally considered non-arable (except for rice). On cracking clays (vertisols), the infiltration rate is very rapid at first, but soon decreases to about zero. Such soils are more favourable than non-crackding clays, but irrigation may be hazardous with poor quality water.
0.1 - 0.2 cm/hour	Surface waste of water may become excessive, or ponding may reduce yields, crops may be damaged by scalding in hot weather, and leaching my be difficult.
0.7 - 3.5 cm/hour	Optimum infiltration rate.
< 7.5 cm/hour	Gravity irrigation not practicable, because of difficulties with water distribution and excessive percolation losses.

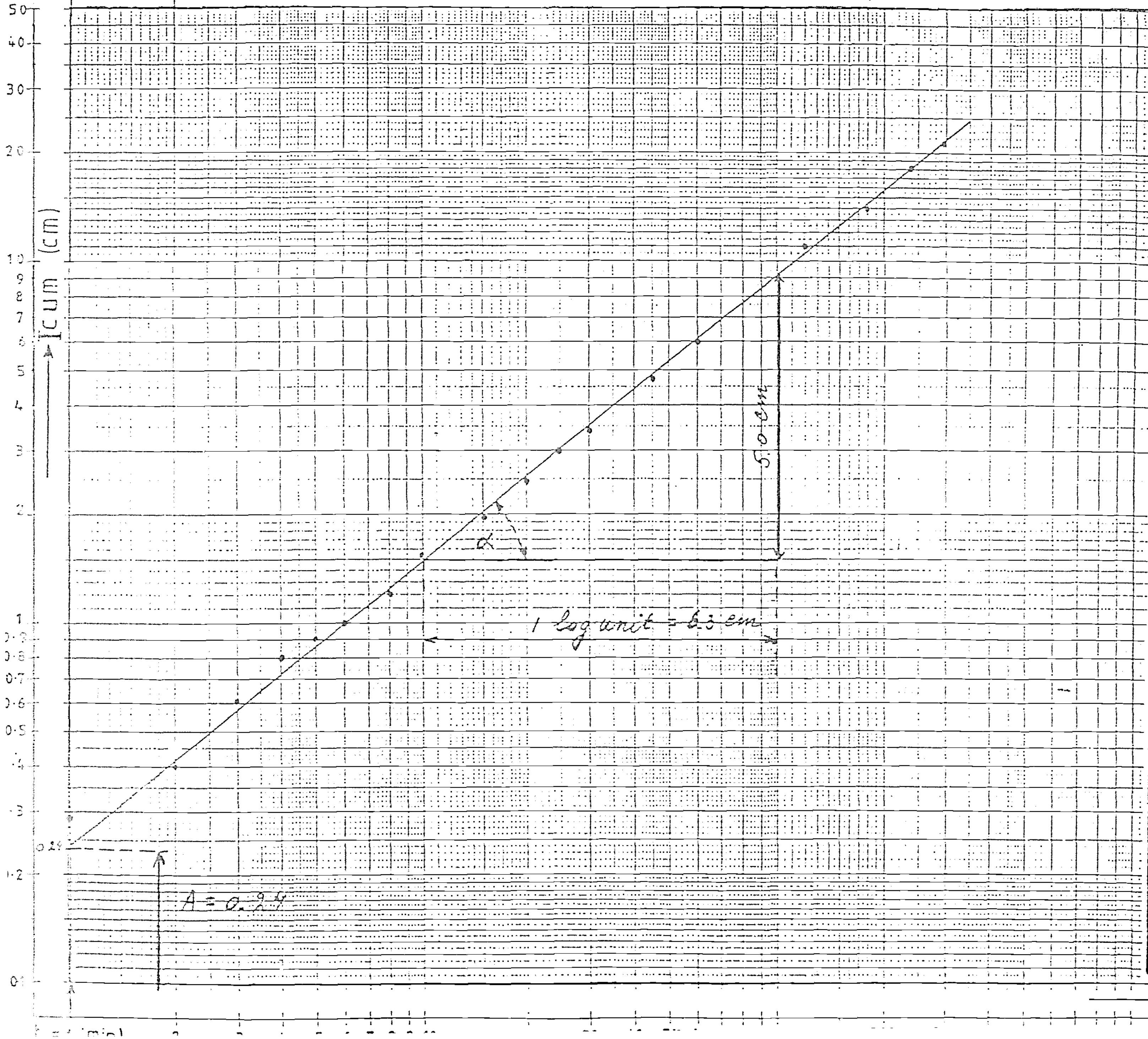
Graph.1 shows a graphically presentation of the 8 intake families, with probable soil textures and probable soil textural classes.

EVDSA | Graph 1: **Intake Characteristics of Different Soils (Intake Family)** | ETH



* Furrow irrigation is not ordinarily recommended for soil having a 7·5 < W·I·R ≤ 0·4 (cm/h)

EVDSA | Graph 2: **Determination of Intake Family** | ETH



t	Drop W. Head	Icum
min	Cm	Cm
0	25.5	0
1	25.2	0.3
2	25.1	0.4
3	24.9	0.6
4	24.7	0.8
5	24.6	0.9
6	24.5	1.0
8	24.3	1.2
10	24.0	1.5
15	23.5	2.0
20	23.0	2.5
30	22.	3.5
45	21.0	4.5
60	19.5	6.0
120	14.5	11.0
180	11.5	14.0
240	7.5	18.0
300	4.0	21.5

$Icum = At^{B}$

$\log Icum = \log A + B \log t$

$t = 1$ min $\rightarrow$ $A = Icum = 0.24$

$B = \tan \alpha = 5.0/6.3 = 0.8$

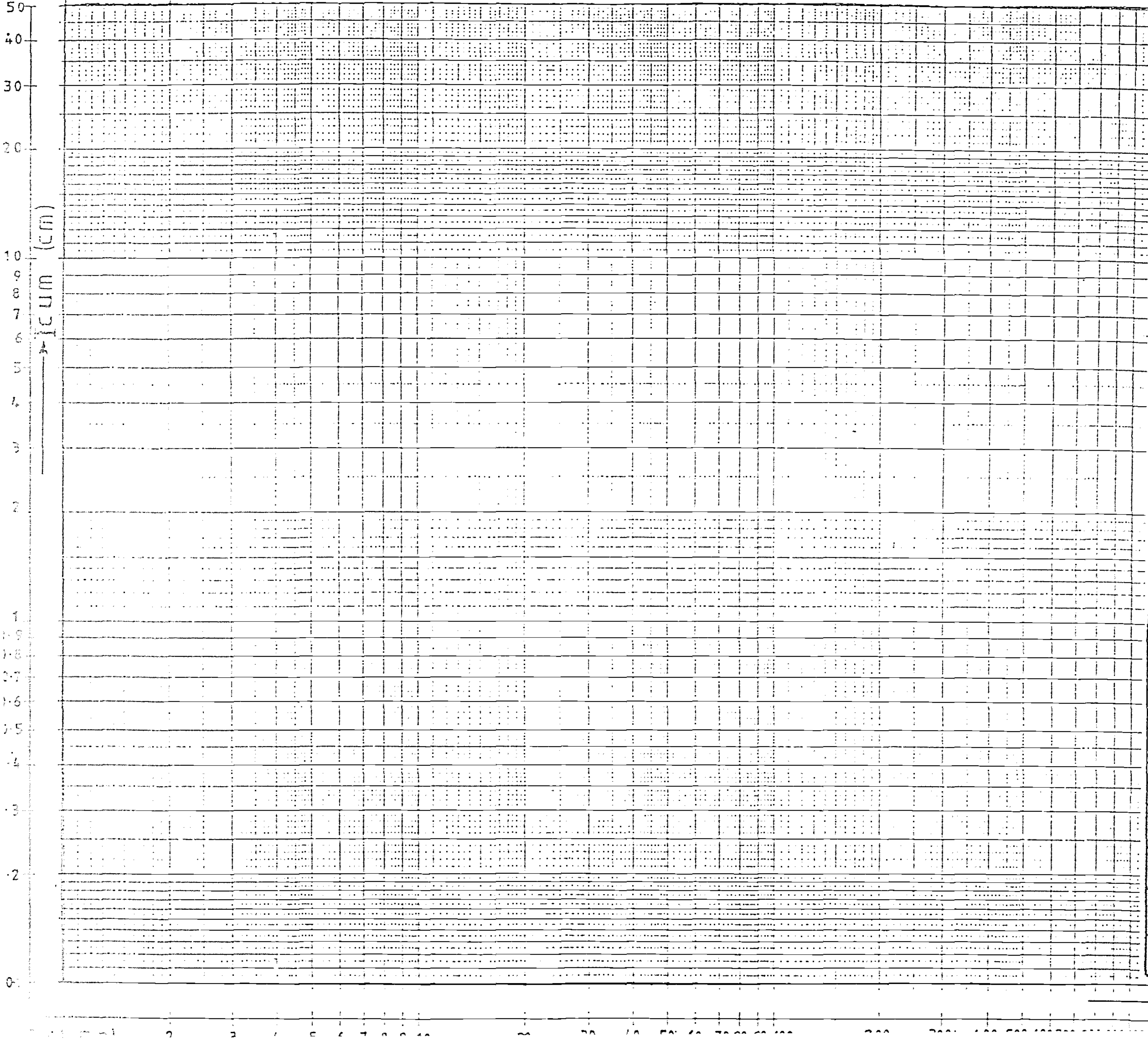
$a = A \times B = 0.24 \times 0.8 = 0.19$

$b = B - 1 = 0.8 - 1 = -0.2$

$I_{bas} = 60a(-600b)^{b} = 4.3$ cm/h

→ Intake Family ≃ 5

E.V.D.S.A | Graph 3: **Determination of Intake Family** | ETH



t	Drop W· Head	Icum
min	Cm	Cm

Icum = At^B

Log Icum = log A + B log t

t = 1 min → = A = Icum= ·

B = tan ∝ = · / · = ·

a = A ∗ B = · ∗ · = ·

b = B − 1 = · − 1 = ·

$I_{bas} = 60a(-600b)^b$ = · cm/h

→ Intake Family = ·

INFILTRATION TEST

PRINCIPLE:

Infiltration rate is measured by recording the fall of water in a ring driven into the soil surface. The use of a double ring infiltrometer reduces the error due to lateral movement. The outer ring can be made by earth if metal rings are unavailable.

MATERIALS REQUIRED:

- Infiltrometer rings 40 cm high with diameter of 30cm and 50 cm.
- Driving plates
- Hard wood
- Hammer with a handle
- Shear of scissors
- A ruler or a graduated cylinder
- Stopwatch or watch
- Shovel
- Graph paper (double log paper)
- Cloth piece

PROCEDURE:

Select a representative site, remove the vegetation or grass by clipping. Drive infiltrometer rings into the soil about 15 cm deep with the help of a driving plate and a hammer by keeping hard wood on the driving plate.Uniform vertical penetration of rings should be ensured by rotating the hard wood after a few blows. Tap the soil firm from inside and outside of the rings. Place a cloth over the soil to reduce turbidity while putting water.

Fill both the rings to a depth of 10 cm and note the time and height of water in the inner ring with a ruler. Repeat the measurement after 1, 2, 3, 4, 5, 10, 20, 30, 45, 60, 90, 120, 180, 240, 300 and 360 minutes. Do the same for 3 - 5 replicates.

Care should be taken that the soil within the cylinder has not been compacted or sealed. Infiltration rates for virgin soil will not be indicative of the infiltration rate of a cultivated soil. Therefore, if the area has never been cultivated, the soil in the test site should be turned over to a depth of 20 to 25 cm, then leveled, and all large clods broken up and worked into the soil before the cylinder is installed.

The water in the outer ring should remain at the same level as that within the inner ring. Measure the distance of the water surface from the top of the ring before and after topping it up, with a ruler. The other way is to measure the amount of water required for topping it up to a fixed hook gauge with a measuring cylinder (707 ml of water equal to 1 cm depth in 30 cm cylinder).

After recording the observation, the average hourly rates be calculated. Plot the curves of cumulative infiltration versus time on double log. graph paper.(See Graph.3).

From the graph, cumulative infiltration rate and the basic rate can be obtained.(See Graph.2).

Table 2.5 shows a review of intake characteristics of different soils (intake families) and the time required for a certain infiltration depth I_{cum}.

The basic infiltration rate is classified in 8 intake families.

Table 2.4 gives the family number, the corresponding I_{bas} and the suitability for gravity irrigation.

Table 2.4

Intake Family	I_{bas} (cm/hour)	Suitability for gravity irrigation
1	0.4	Unsuitable, except for rice.
2	1.0	Suitable, except for rice.
3	1.6	Suitable.
4	3.0	Optimum suitable.
5	4.0	Optimum suitable
6	5.4	Moderately suitable.
7	7.5	Marginally suitable.
8	9.3	Unsuitable (may be used for sprinkler irrigation.

As we have already seen above, the infiltration into the soil can be described by the following formula:

$I = at^b$ (cm/min) (1)

Where, I = the instantaneous infiltration rate (cm/min)

t = infiltration time (min)

a = coefficient

b = dimensionless coefficient (betweeen 0 and - 0.1)

The coefficients a and b are evaluated from experimental data. By integrating equation (1) between the limits t=0 and t=t, the cumulative intake I_{cum} can be obtained.

Table 2.5 | **Intake Characteristics of Different Soils** | ETH

Intake Family	Basic W·I·R $I_{bas}=60a(-600b)^b$ (cm / hour)		Basic Time $t_{bas}=-10b$ (hour)	Infilth. Rate $I=at^b$ (cm/ min) a	b	Cum. Infiltration $I_{cum}=F_n=At_n^B$ (cm) A	B	1/B
1	0·4	slow	3·4	0·04	−0·34	0·06	0·66	1·52
2	1·0	mod. slow	2·8	0·067	−0·28	0·09	0·72	1·39
3	1·6	mod. slow	2·4	0·09	−0·24	0·12	0·76	1·32
4	3·0	moderate	2·15	0·14	−0·215	0·18	0·785	1·27
5	4·0	moderate	2·0	0·18	−0·20	0·23	0·80	1·25
6	5·4	mod. rapid	1·9	0·22	−0·19	0·27	0·81	1·23
7	7·5	mod. rapid	1·85	0·30	−0·185	0·37	0·815	1·23
8	9·3	rapid	1·8	0·36	−0·18	0·44	0·82	1·22

Time Required for Infiltration of $I_{cum}=F_n$ (cm): $t_n=(\frac{b+1}{a}F_n)^{1/b+1} \doteq (F_n/A)^{1/B}=(I_{cum}/A)^{1/B}$ (min) — minutes

Intake Family	1cm	2	3	4	5	6	7	8	9	10	11	12	13	14	15cm
1	72	206	382	592	831	1096	1386	1698	2031	2384	2755	5145	5551	3975	4414
2	28	74	131	195	266	343	425	512	602	697	796	899	1004	1124	1220
3	16	41	70	102	137	175	214	256	299	343	389	437	485	535	58[illegible]
4	9	21	36	51	68	86	104	124	144	164	186	207	229	252	275
5	6	15	25	36	47	59	71	84	98	112	126	140	155	170	185
6	5	12	19	28	36	45	55	65	75	85	95	106	117	129	140
7	4	8	13	19	24	31	37	44	51	58	65	72	80	87	93
8	3	6	10	15	19	24	29	34	40	45	51	56	62	68	71

$$I_{cum} = a/b+1 + t^{b+1} = A\ t^B \text{ (cm)} \text{------>} t = (I_{cum}/A)^{1/B} \text{ (min)}$$

Where, I_{cum} = the cumulative infiltration depth during t minutes.

A = a/b+1, and represents the cumulative intake at t= 1 minute.

B = b+1, is a dimensionless coefficient (between 0 and +1.0)

t = Intake time (min) required for a infiltration depth I_{cum}.

G - PERMEABILITY

The property of the soil to transmit water down through it, i.e. readiness with which soil allows downward movement of water through it, is termed as permeability.

Considering soil moisture movement, permeability is the hydraulic conductivity of saturated soil.

Permeability of soil is determined mainly by size and continuity of the pores. A soil having high porosity due to coarse texture has high permeability.

Permeability is estimated in the field by the augerhole method and in the laboratory from undisturbed soil samples

Table 2.6: Classification of soil permeability rates

Augerhole Soil Permeabilities			
DESCRIPTION	cm/day	mm/hour	Classification
Extremely slow	< 5	< 2	Very poor
Very slow	5- 12	2- 5	Poor
Slow	12- 20	5- 8	Fair
Moderately slow	20- 40	8- 15	Good
Moderately rapid	40- 80	15- 25	Excellent
Rapid	80-156	25- 65	Good
Very rapid	156-240	65-100	Fair
Extremely rapid	240-360	100-150	Poor
Immeasurably rapid	>360	>150	Very poor

Downward movement of water takes place under pressure. Harmful salts are leached with percolation.

Depth of water percolating down decreases with soil depth because evaporation utilizes most of the water infiltrated into upper layer of the soil.

Moderate percolation rates are desirable: if the jpermeability is very rapid then water is lost through deep percolation and is not stored in the root zone of the soil.

Permeability of a soil is used to determine the need for subsurface drainage.

In-Place Permeability tests

- The Auger-hole method measures the average horizontal permeability of the soil profile from the static water table to the bottom of the hole, when an impermeable layer is at the bottom of the hole, or to a few cm or dm below the bottom of the hole.

- The Inversed Auger-hole method, measures the average permeability above the water table.It is described in French literature as the Porchet method and consists of boring a hole to a given depth, filling it with water, and measuring the rate of fall of the water level.

If it is valuable to know the the variation in permeability with depth or the permeability of individual strata within a soil profile the auger-hole method may be executed in the same hole but at different depths.

MATERIALS REQUIRED:

- Auger with extensions (Dutch type)
- Recorder board
- Recording tape
- Tripod
- Float apparatus
- Measuring rod or tape
- Hole scratcher
- Bailer or pump

- Stopwatch
- Inside calipers
- Computation sheets and clip board
- Burlap
- Perforated casing or wire-wound screen when and as required
- Mirror or strong flashlight
- Windshield

PROCEDURE:

The test should be performed by a two-man team.

The hole should be augered as straight as possible to the required depth, which depend on the soil strata to be tested, then the sides of the hole should be scratched to break up any sealing effect caused by the auger. The burlap is then forced to the bottom of the hole and tamped lightly to prevent any materials from entering the bottom.

the tripod with the float apparatus is placed near the hole so the float can be centered over the hole and move freely into it. the hole is filled with water to a certain level, which will be recorded and maintained at regular time intervals.

The stopwatch is started at the first moment of topping the water to this level and should be run continuously until the test has been completed.

Calculations

Upon completion of the (inversed) auger-hole field test, the time intervals and the corresponding distances between tick marks on the recorder tape are transferred to the compution sheet. Sample computations are shown in FAO Soils Bulletin 42, page 165 onward and also in IILRI, 1974, pages 292 -294. (See figure 2.3)

Example:

K = 1.15 r tan a

Where K = permeability to be determined (cm/sec)

r = radius of the augerhole (cm)

$h(t_i)$ = water level in the hole at time i (cm)

By plotting $(h(t_i) + r/2)$ against t_i on semilogarithmic paper we obtain a straight line with a tangent a (See Figure 2.4).

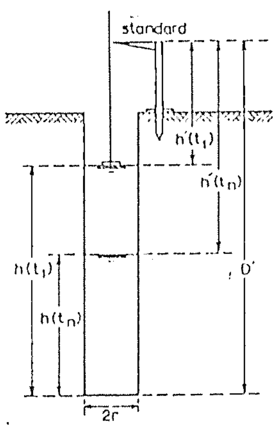


Figure 2.3: Inversed Auger-hole Method

Example: r = 4 cm

D^1 = 90 cm.

i	t_i	$h'(t_i)$	$h(t_i)$	$h(t_i)+r/2$	t_i	$h'(t_i)$	$h(t_i)$	$h(t_i)+r/2$
	sec	cm	cm	cm	sec	cm	cm	cm
1	0	73	17	19	0	71	19	21
2	40	74	16	18	140	72	18	20
3	80	75	15	17	300	73	17	19
4	150	76	14	16	500	74	16	18
5	250	77	13	15	650	75	15	17
6	350	78	12	14	900	76	14	16
7	550	79	11	13	1090	77	13	15
8	750	80	10	12	1300	78	12	14
9	975	81	9	11	1520	79	11	13

$\tan a_1 = \frac{2.0}{10} \times \frac{1}{1200}$ sec^{-1} $\tan a_2 = \frac{2.7}{10} \times \frac{1}{2000}$ sec^{-1}

K=1.15 x 4 x 0.000167 cm/sec K=1.15 x 4 x 0.000135 cm/sec

= 0.66 m/day = 0.54 m/day

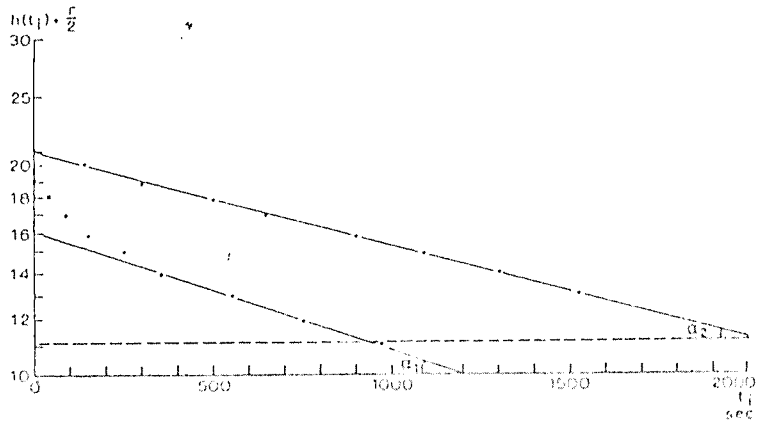


Figure 2.4: Plots of $h(t_i)$ + r/2 in the calculation of K.

Discussion

In general measurement should be made 1 to 3 times in loam and clay soils, depending upon the moisture content of the soil and its hydraulic conductivity. It may be necessary to repeat the measurement 3 to 6 times in sandy soils. By gradually deepening the auger hole and filling it with water over the corresponding depth, the hydraulic conductivity of successive layers can be measured in the same hole.

H - AVAILABLE WATER CAPACITY (Available Moisture AM)

Available water capacity (AM) is defined as the volume of water retained between Field Capacity and Permanent Wilting Point.

However, all available moisture is not accessible to plants due to imperfect drainage, hydraulic conductivity of soil, rooting depths, root concentrations at different depths and stage of plant growth. So , 50 - 75% of available moisture is considered readily available water (RAM).

As a rule of thumb readily available moisture (RAM) is considered 0.66 of total available water (See Table 2.6).

Table 2.7: SOIL TEXTURE AND AVAILABLE WATER

TEXTURE	SOIL PROPERT.	FIELD CAPACITY	WILTING POINT	AVAILABLE WATER	RATIO: RAM/AM	RAM	BULK DENSITY	TOT.PORE SPACE
		mm/m	mm/m	mm/m	-	mm/m	g/cm^3	% Volume
SANDY	Average	150	70	80		55	1.65	38
	Range	100-200	40-100	60-100	0.7	45- 70	1.55-1.75	36-40
LOAMY	Average	180	80	100		70	1.60	40
SAND	Range	130-230	50-110	70-130	0.7	50- 90	1.50-1.70	38-42
SANDY	Average	210	90	120		80	1.50	43
LOAM	Range	150-270	60-120	90-150	0.65	60-100	1.40-1.60	41-45
LOAM	Average	310	140	170		100	1.40	47
	Range	250-360	110-170	140-200	0.6	85-120	1.30-1.50	45-49
CLAY	Average	360	170	190		105	1.35	49
LOAM	Range	310-410	150-200	160-220	0.55	90-120	1.25-1.45	47-51
SILTY	Average	400	190	210		110	1.30	51
CLAY	Range	350-460	170-230	180-230	0.55	100-125	1.20-1.40	49-53
CLAY	Average	440	210	230		115	1.25	53
	Range	390-490	190-240	200-250	0.5	100-125	1.20-1.30	50-55

Calculation of the Irrigation Interval:

For irrigation scheduling, the paramaters needed are Field Capacity, Wilting Point, Readily Available Moisture (See Table 2.6), Plant Characteristics and Climatic Data (See Table 2.7).

After selecting the irrigation interval, irrigation efficiency is considered to arrive at the time of application.

Table 2.8: IRRIGATION INTERVAL

PROJECT:____________________ CROP:____________

CODE:______________________ REGION:__________

CODE	DESIGNATION	SYMBOL	REFERENCE	UNIT	EXAMPLE
1	Month	-	-	-	
2	Crop Stage	N	Station	-	
3	Irrigation method	-	Station	-	
4	Type of Soil		Text.Anal.	Fig.	
5	Field Capacity	F.C.	Lab.	mm/m	
6	Wilting Point	W.P.	Lab.	mm/m	
7	Available Moisture	A.M	5-6	mm/m	
8	Ratio RAM/AM	-	Table 2.6	-	
9	Readily Available Moisture	RAM	7x8	mm/m	
10	Root zone depth	D	field	m	
11	Available Effective Storage	S_e	9x10	mm	
12	Allowance for rain storage	S_{rain}	Station	mm	
13	Storage for irrigation	S	11-12	mm	
14	Crop Evapotranspiration	ET_{crop}	Station	mm/day	
15	Effective Rainfall	P_e	Station	mm/day	
16	Net Irrigation Requirement	I_n	14-15	mm/day	
17	Max. Possible Irr. Interval	i_{max}	13/16	days	
18	Chosen Irr. Interval	i	$i < i_{max}$	days	
19	Net Application	I_{cum}	16x18	mm	
20	Application Efficiency	e_a	Station	-	
21	Gross Application	I_{gros}	19/20	mm	
22	Flow rate at farm delivery	Q	Station	l/s,ha	
23	Time of Application	h	$I_{gros}/Q/3.6$	h/ha	

III - SOIL CHEMICAL PROPERTIES

This chapter deals with soil chemical properties which significantly influence the performance of plants. The importance of theses data, together with the acquisition methods and the range of values are presented in Table 3.1, while in the last column remarks are given for a better understanding of the situation.

The chemical properties covered in this chapter are shown in Table 3.1, which gives their importance, the method of acquisition and their ranges.

The properties discussed are:

A: Soil Reaction (pH)

B: Cation Exchange Capacity (CEC)

C: Base Saturation Percentage (BSP)

D: Exchangeable Sodium Percentage (ESP)

E: Salinity (EC_e)

F: Leaching Fraction (LR)

G: Gypsum Content (G.C.)

H: Organic Matter (O.M.)

I: Toxic Elements

J: Micro Nutrients

Table 3.1: INVENTORY OF SOIL CHEMICAL DATA

DATA REQUIRED	IMPORTANCE	ACQUISITION	VALUE RANGES	REMARKS
A SOIL REACTION (pH)	Identification Potential Sodicity or Acid Sulphate problem Crop requirem. Nutrient	Field meter Laboratory Special method for calcareous soils	< 5.5	Acidic,Toxicity Liming needed
			5.5-7.0	Preferred for most crops.
			7.0-8.5	Limited availability micro-nutrients
			> 8.5	Sodicity problems Addition of Gypsum required
B CATION EXCHANGE CAPACITY (CEC)	Nutrient retention fertility	Laboratory	<15 me/100g	Low nutrient reserve, marginal for irrigation
			15-25 me/100g	Satisfactory agricultural production with additional fertilizers use
			> 25 me/100g	Good agricultural production. Potassic fertilizer and liming needed.
C BASE SATURATION PERCENTAGE BSP	Index of soil fertility and estimation of lime requirem.	Calculation tot.exchang. bases/CEC	< 20%	Low fertility
			20-60%	Medium fertility
			> 60%	High fertility
D EXCHANGEABLE SODIUM PERCENTAGE (ESP)	Identification of sodicity & assoc.future physical probl ems through clay deflocculation	Laboratory determination of exchang able Na & CEC	< 15%	Normal soils,no amendment required
			15-25%	Alkaline or Sodic soils, 50% yield reduction for sensitive & semi-tolerant Crops. Gypsum application compulsory
			25-35%	50% yield reduction for salt tolerant crops and Gypsum application required
E SALINITY ECE	Salt effect on cropgrowth and yield.	Electrical conductivity saturation extracts or soil/water suspensions	<4.0 $mScm^{-1}$	Nonsaline soils. Good for all crops
			4-8 $mS\ cm^{-1}$	Saline soils. Reduced crop growth ,leaching necessary for raising successful crops

		Salinity probe	8-16 $mScm^{-1}$	Only salt tolernt crops may be grown.
			> 16 $mScm^{-1}$	Very salt tolerant crops can be raised.
F LEACHING FRACTION LR	Amount of water required for primary leaching of of salts and annual leaching ing requirement under irrigation	Field tests and desk estimates	< 10%	Low for keeping rootzone free of salt
			10-20%	Medium for keeping root zone free of salt.
			> 20 %	High for keeping rootzone free of salt.
G GYPSUM CONTENT	Amount of Gypsum re- quired to prevent sodification and structure deflocculation	Laboratory test of soil gypsum content Field and desk estimate of gypsum application.	< 2%	Favours crop growth.
			2-25%	No adverse effect if powdery.
			> 25%	Substantial yield reduction may be due to calcium imbalance.
H ORGANIC MATTER	Total Nitrogen	Laboratory tests	< 2%	Low fertility
			2.0-3.0%	Medium fertility
			3.0-5.0%	High fertility
			> 5.0%	Very high fertility
I TOXIC ELEMENTS LIKE BORON	Handling of toxicity problems	Soil and Leaf analys is in Labor atory.	< 3.0 ppm	Non toxic to most crops.
			3.0-6.0 ppm	Toxic to sensitive crops.
			> 6.0 ppm Hot water extractable Boron	Toxic to most crops.
J MICRO NUTRIENTS	Corrections of deficiencies especially Zinc in rice soils and sodic and calcareous soils	Soil and Plant analysis in laboratory	DTPA extrac table Zinc < 0.5 ppm in soil.	Deficient needs application of Zinc for most crops.

A - <u>SOIL REACTION (pH) (See figure 3.1)</u>

Soil pH determinations done on extracts from saturated soil pastes or 1:5 soil/water suspension serve as a guide to nutrient availability.

The pH tolerance limits of different plants vary greatly but for general crops, neutral range (pH 6.5 - 7.5) is most suitable.

At lower (<5.5) pH values, availability of some nutrients like phosphorus decreases, while those of others like aluminium and micronutrients increase to toxic levels.

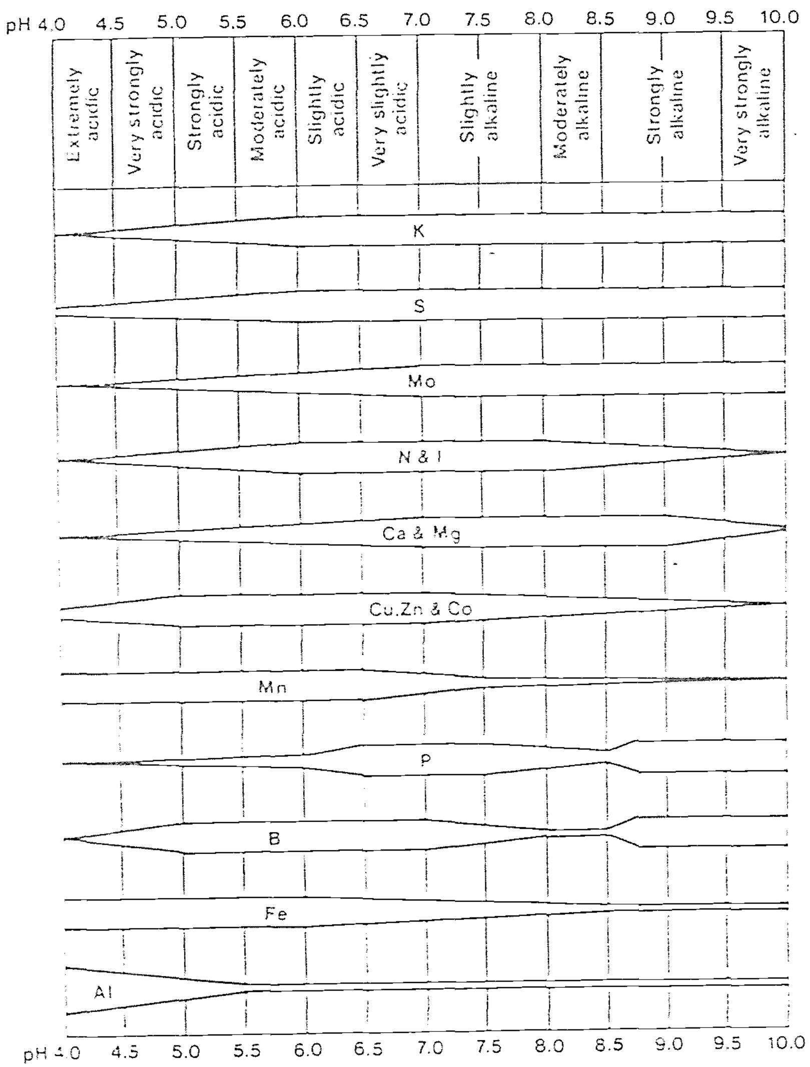
At higher pH (> 8.5) values, availability of phosphorus also decreases in the presence of Calcium.

Boron toxicity is common in Sodic soils (pH > 9.0).

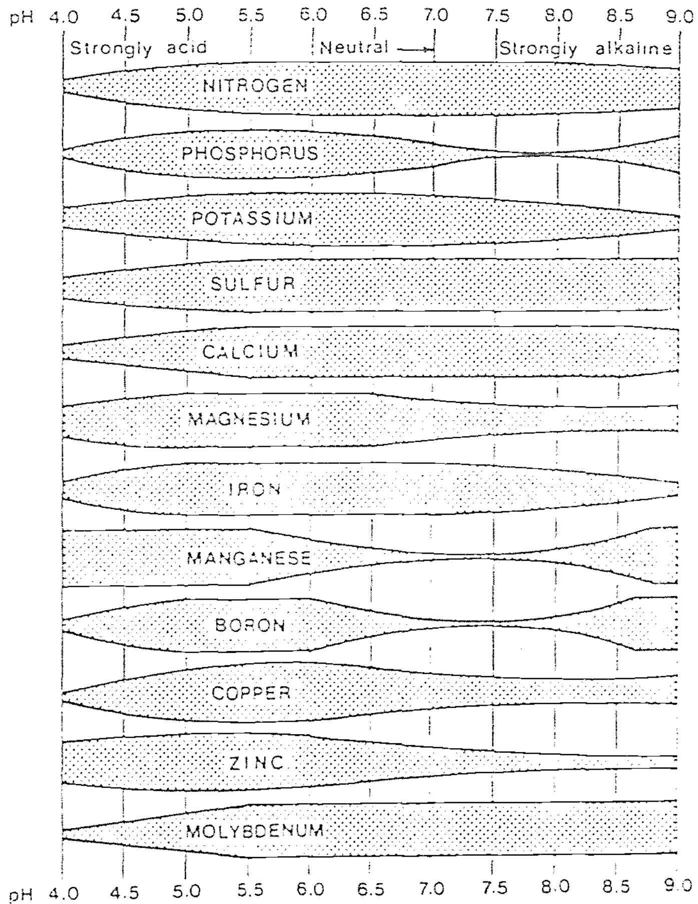
Availability of micronutrients except molybdenum decreases with increasing pH.

Figure 3.1: Effect of pH on availability of common elements in soils.

(Source: After Truog,1949)



1. Relative availability of common elements in mineral soils with pH (after Truog 1948)



2. Organic soils (after Lucas and Davis 1961)

General trend of the influence of reaction (pH) on the availability of plant nutrients (widest part of the bar indicates maximum availability)

B - CATION EXCHANGE CAPACITY (CEC)

Measurement of CEC helps to assess potential fertility status and nutrient retention of a soil and responses to fertilizer application. CEC values ranging between 15 - 25 me/100g are considerred optimum for normal agricultural crops. The CEC estimates also indicate the type of clay minerals present in a given soil.

Soils with lower CEC (< 15 me/100 g) values are considered marginal for irrigation as these soils are poor in nutrient reserve.

C - BASE SATURATION PERCENTAGE (BSP)

The proportion of the CEC accounted by exchangeable bases (Ca, Mg, K and Na) is considered an index of soil fertility. However, BSP does not distinguish between different bases. BSP is also used in calculating lime requirements of acid soils.

Base saturation less than 20% is considered low, 20 - 60% medium and more than 60% as high.

BSP is calculated as:

$$BSP = \frac{\sum Ex(Ca, Mg, K \text{ and } Na)}{CEC} \times 100$$

D - EXCHANGEABLE SODIUM PERCENTAGE (ESP)

The measurement of ESP is carried out to assess the sodicity problems. In general, soils having ESP < 15 are regarded nonsodic, requiring no amendments. However, ESP > 15 indicate the need for amendments without which yield reductions are observed.

Mathematically :

$$ESP = \frac{\text{Exchangeable Sodium}}{CEC} \times 100$$

E - SALINITY (EC)

Soil salinity is an index of total soluble salts present in soils. Salinity of soil modifies the plant growth and yield to a great extent. Normally soils having salinity of saturation extract (ECe) less than 4.0 mS cm^{-1} are regarded non-saline and considered suitable for all crops. Soils having ECe > 4.0 mS cm^{-1} need special treatment like leaching or growing salt tolerant crops to offset the effect of excessive salts present in the soil solution.

F - LEACHING FRACTION (LR)

Amount of water required for primary leaching of salts in addition to normal irrigation is calculated to determine leaching fraction.

The purpose of LR is to keep root zone free of salts.

Values of LR < 10% are considered low, whereas > 20% are considered high.

G - GYPSUM CONTENT

Amount of gypsum in soil is important to prevent sodification and deflocculation.

Gypsum content <1.0% favours crop growths and amounts > 25% cause substantial yield reductions due to calcium imbalance.

H - ORGANIC MATTER (OM)

Level of organic matter in soil indicates the total Nitrogen content in soil. OM is an index of soil fertility.

Organic matter < 2.0% indicates low fertility and > 5% shows high fertility.

I - TOXIC ELEMENTS

Some elements if present in excessive amounts become toxic to plants and cause yield reductions. Aluminium causes toxicity problems in highly acidic soils.

Similarly Boron content > 6.0 ppm is toxic to most crops and between 3 - 6 ppm causes damage to sensitive crops.

J - MICRO NUTRIENTS

Areas under intensive cultivation are likely to show deficiencies of some micronutrients like Zinc, Copper and Iron.

However, Zinc deficiency is widespread in rice soils and sodic and calcareous soils.

In general, soils with Zinc content < 0.5 ppm are considered deficient and need Zinc applications for normal growth and yield.

Soil Colour:

Soil colour is an indicative property of certain trends. Vertisols, have normally black colour with cracking tendency, low infiltration and restricted drainage.

Soils high in organic matter are also black in colour having good physical and chemical properties.

The red soils rich in Iron compounds are usually well drained.

Grey, white and light coloured soils are because of quartz, kaolin, lime and salts.

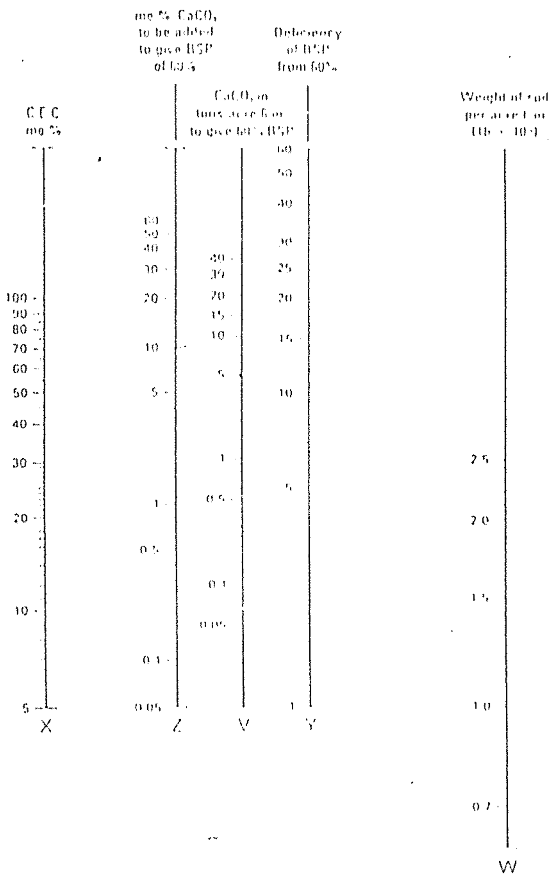
Blue colour of soil is indicative of a water-logged situation.

Lime requirement:

Improvement of excessive acidic soils involves calculation of lime requirement. One indirect method of estimating lime requirement is by making use of data on Cation Exchange Capacity (CEC) and Base Saturation Percentage (BSP). With the help of a nomogram (See figure 3.2), BSP is the proprtion of CEC accounted by exchangeable bases Viz. Ca, Mg. K, and Na.

Figure 3.2: Nomogram for estimation of lime requirement from CEC data.

(Source: Adapted from Melson, 1961)



Nomogram for estimation of lime requirement from CEC data

Note: Factors for conversion to metric units are

1 lb = 0.45 kg   1 acre 6 in = 4.1 × 10^{-3} m^2 15 cm
1 ton = 1,016 kg   = 4.1 × 10^{-1} ha 15 cm
1 ton per acre 6 in = 2 490 kg per ha 15 cm

Example:

CEC = 40 me 100g (from ammonium acetate method)

BSP = 35%

Deficiency of BSP from 60% = 25%

Soil density = 2.2 × 10^{6} lb per acre 6 in (= 2.4 × 10^{6} kg per ha 15 cm)

Align the number 40 of scale X and the number 25 of scale Y and read the $CaCO_3$ to be added on scale Z (10 me 100 g). Then align this 10 on scale Z with 2.2 on scale W, and read the lime requirement on scale V (5 tons per acre 6 in = 12.4 t per ha 15 cm)

Source: Adapted from Metson (1961)

IV - SOIL TESTING

Soil Testing and its objectives

Soil testing is an analysis of a soil sample to estimate its physico-chemical characteristics like texture, bulk density,particle density, porosity, available water, pH, electrical conductivity, CaCO3, organic Carbon, exchangeable ions and available nutrients for crops.

Soil testing helps to assess the plant nutrients status in the soil and its capacity to supply these to crops.

Soil testing also aids in identifying the existence of other problems like acidity, alkalinity or salinity. It also helps in planning and maintaining a sound soil management programme.

Purpose of soil sampling

Apart from sampling soils for their taxonomic classification and identification soil samples are collected generally for the following objectives:

- for fertilizer recommendations
- for reclamation of salt affected soils
- for horticultural plantations

Soil sampling tools

The following tools are normally required for collecting soil samples in the field.

- Soil auger
- small hand shovel
- spade
- mixing bowl
- polythene or cloth bags
- copying pencils
- tags
- measuring tape

Soil Sampling for Fertilizer Recommendations

- Separate uniform fields should be selected after considering slope, drainage, soil type and crop growth, for collecting each sample.
- Select 5 - 6 spots at random in zigzag fashion in a field.
- Clean the surface to remove any debris if present.
- Collect a uniform soil sample from 0-15 cm depth, with the help of soil auger. If soil auger is not available, make a V-shap cut up to 15 cm depth, with a shovel or spade and take a thick, uniform slice of soil from top to bottom.
- Make a composite sample of samples collected from 5-6 spots. In a standing crop, sample should be collected between the row of plants. Avoid taking samples from a fertilized band, old fence or places where manure was piled earlier.
- Each sample must have field number and address of the farmer. One label may be put inside the sample bag for better identification. Labels may be written with a copying pencil to reduce the effect of moisture present in the soil sample.

The soil testing of a field should be done at least once in a crop rotation. The preferable time of soil sampling should be before sowing or after harvesting of a crop

Information to be sent with a soil sample

The cropping history of the field sample should be sent to the laboratory along with the soil samples for getting better recommendations.

The following information is generally required:

- date of sampling
- address of the farmer
- field number
- type of farming (irrigated or dry farming)
- source of irrigation (canal or underground)
- Crops being raised
- Manures if applied
- slope of land (level, sloping, undulating)
- likelihood of flooding
- any problem faced by the farmer.

Soil Sampling for Reclamation of Salt Affected Soils:

For this purpose, soil sampling can be done either by a soil auger or digging a 90 cm deep pit.

Usually, sampling depths are from 0-15, 15-30, 30-60 and 60-90 cm. In addition a sample of the surface crust should be collected separately.

Depth and thickness of any hardpan or concretion should be noted and a separate sample of this be collected.

Each sample may be labelled properly, indicating the depth of the soil layer sampled.

Soil samples should have the folling information:

- source and frequency of irrigation
- depth of water table and natural drainage conditions
- crop rotation in practice
- soil management history, if known
- causes and sources of salinity/alkalinity, if known
- colour of soil under natural conditions
- condition and stand of the crops grown.

Soil Sampling for Horticultural Plantation

The roots of trees penetrate deep in the soils, to meet their nutritional requirement and for firm support. Soil samples are therefore taken upto a depth of 180 cm.

the soil samples can be taken either by an auger or by digging a 2 meter deep pit. The samples should be collected from 0-15, 15-30, 30-60, 60-90, 90-120, 120-150 and 150-180 cm.

Depth and thickness of a hardpan or concretion if present, should be noted and a separate sample may be collected from this. Each sample should be packed separately, indicating the depth of the sampled layer.

Table 4.1: Soil Categorization according to Soil Testing in Ethiopia

SOIL PARAMETER	SYMBOL	UNIT	SOIL CATEGORIES				
ACIDITY	pH	-log(H+)	H. Acid	Acidic	Neutral	Alkaline	H.Alkal
	range		< 5.5	5.5-6.5	6.5-7.5	7.5-8.5	>8.5
SALINITY	ECe	mS cm-1	Low	Slight	Medium	High	V.high
	range		< 4	4-6	8-12	12-16	>16
CALCAREOUS	CaCO3	%	Low	Slight	Medium	High	V.high
	range		< 8	8-10	10-15	15-25	>25
ORG.MATTER	O.M.	%	Low	Slight	Medium	High	V.high
	range		< 1	1-2	2-3	3-5	> 5
TOT.NITROG.	T.N.	%	Low	Slight	Medium	High	V.high
	range		<0.05	0.05-0.10	0.1-0.15	0.15-0.2	>0.20
AVAIL.PHOS	B.E.	Kg/ha	Low	Slight	Medium	High	V.high
PHORUS(BI-Carbon.extr)	range		<10	10-20	20-30	30-50	> 50
AV.PHOSPH.	A.E.	kg/ha	Low	Slight	Medium	High	V.high
(Acid extr)	range		<10	10-20	20-50	50-180	>180
AV.POTASSIUM	A.P.	kg/ha	Low	Slight	Medium	High	V.high
	range		<50	50-100	100-250	250-450	>450

V - WATER QUALITY APPRAISALS

V.1 - COLLECTION OF WATER SAMPLES

Ground and surface water contain variable amounts and kinds of soluble salts. Therefore it is essential to get these waters tested before using for irrigation.

The water sample should be taken in a well cleaned bottle. The bottle should be rinsed before filling. The well or tube well should be run 15020 minutes before collecting the water sample. In the canal the water sample should be collected at the mouth of the discharge. The bottle should be sealed properly and should carry the following information:

- Name and address of the farmer
- Location of the well or tube well
- Depth of the tube well cavity
- Soil type to be irrigated with this water
- Crops to be raised
- Availability of water from other sources.

It is advisable to send along with the water sample, a representative sample of soil to be irrigated.

V.2 - ASSESSMENT OF IRRIGATION WATER QUALITY

Suitability of irrigation water depends on the interaction of many factors which are discussed in the succeeding paragraphs.

A - Ionic Composition of Water:

The proportion and concentration of different ions present in water, determine its quality. An immportant criterion used in estimating water quality is Sodium Adsorption Ratio (SAR), which is defined as:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

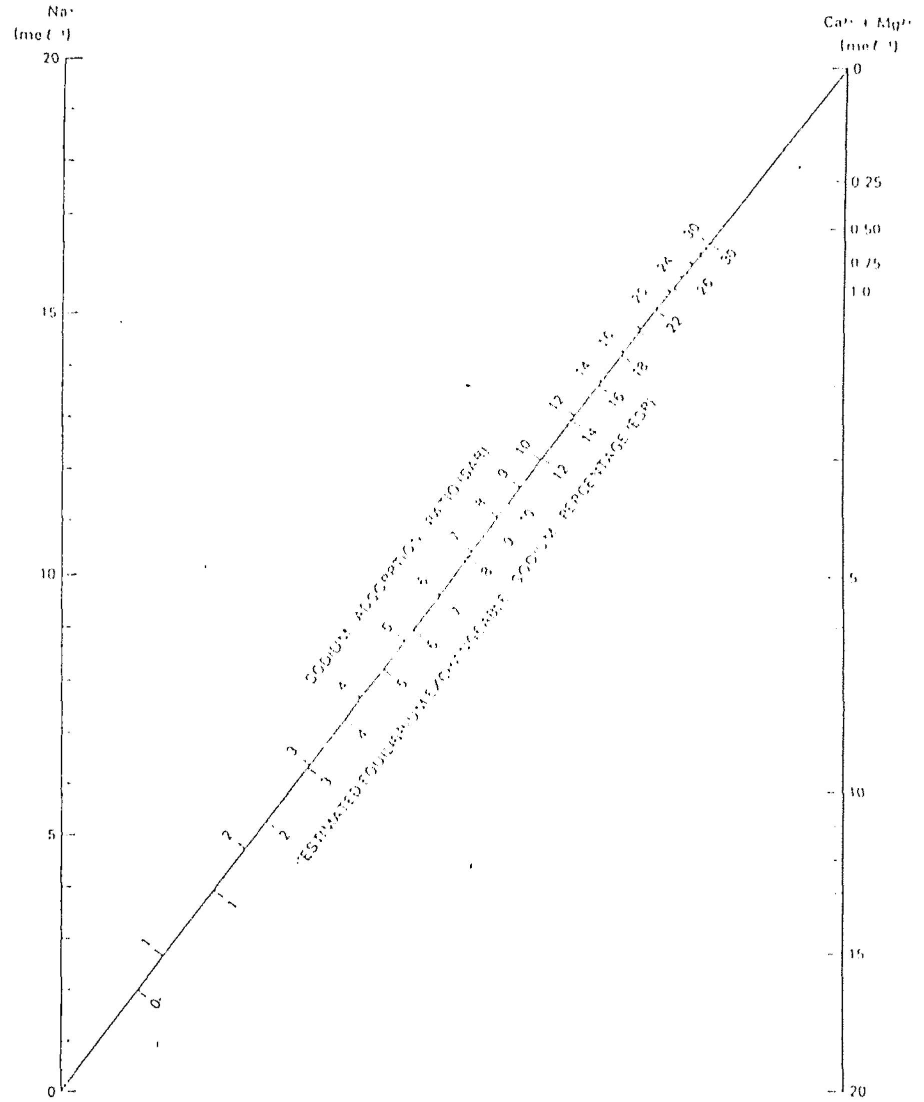
Where Na^{+}, Ca^{2+} and Mg^{2+} are ionic concentrations in me/l of solution. To determine SAR value of irrigation water and for estimating corresponding soil ESP (Exchangeable Sodium Percentage) values, the nomogram prepared by Richards (1954) as given below is quite helpful.

Figure 5.1: Nomogram for determining the SAR value of irrigation water and for estimating the corresponding soil ESP values.
(Source: Richards, 1954)

The ratings based on SAR concept are as under:

SAR < 10	Suitable for most crops
SAR 10-18	Suitable for coarse textured soils
SAR 18-26	May be used with special amendments like gypsum
SAR > 26	Generally unfit for irrigation.

Nomogram for determining the SAR value of irrigation water and for estimating the corresponding soil ESP values



Note: Recent work suggests that these values hold good only for total cation concentrations between 30 and 110 me ℓ⁻¹; other regression equations apply outside this range (see Doering et al, 1982).

Source: Richards (1954).

Another parameter used in assessing water quality is <u>Residual Sodium Carbonate (RSC)</u>, which is defined as:

$$RSC = (CO_3^{2-} + HCO_{3-}) - (Ca^{2+} + Mg^{2+})$$

Where all the ions are expressed in me/l, the following ratings are used for indicating the suitability of the irrigation water.

RSC < 1.25 me/l	Safe for irrigation
RSC 1.25-2.5 me/l	Marginally suitable for irrigation
RSC > 2.5 me/l	Unsuitable for irrigation.

Irrigation water <u>salinity</u> is another criterion employed for assessing the water quality.
<u>Chloride</u> dominant salinity is more harmful than <u>Sulphate</u> dominant salinity.

In general the following ratings of salinity are used to classify the irrigation water:

EC range (mS cm^{-1})	Rating
< 250	Suitable for all situations. No risk of soil salinization.
250-750	Suitable for semi-salt tolerant crops with moderate leaching.
750-2250	May be used with adequate drainage and for salt tolerant crops.
> 2250	Not suitable for ordinary conditions. May be used sparingly in coarse textured soils, having adequate drainage with considerable leaching for extremely salt-tolerant crops.

B - Water Table Depths and its Fluctuations:

A given quality of irrigation water may be found suitable when the groundwater table depth is quite deep, but when the water table depth rises to close vicinity (< 1 meter) of the surface, the same water might become unfit for use because it is not possible to provide any leaching allowance in such a situation. A rise of the water table may create silinity in the soil profile, which thus reduces the possibility of using saline/sodic water in such soils.

C - Soil Texture:

Marginally suitable water can be used successfully in light textured soils, but the same water is considered unfit in heavy textured soils, due to low permeability and restricted drainage e.g. irrigation water having SAR value of 15 may be managed in coarse textured (loamy sand), but it is found unfit for fine textured (clay loam) soils.
Hardpans if present, further reduce the chance of using water having salinity or sodicity hazards.

D - Soil Structure:

In a structureless state observed in puddled soil or in a soil having platy structure, it is difficult to manage water having medium salinity or sodiçity because of low permeability, whereas in a soil having macro-aggregates with large sized pores (>0.06 mm diameter) it is easy to manage marginal waters (medium salinity and sodicity).

E - Soil pH:

The normal pH range of soils in which most irrigation waters can be used is 6.0-8.5.

However, pH values of higher or lower magnitude than this range amy cause imbalance of nutrients by dissolving or precipitating certain nutrients, e.g. at pH more than 9.0 soluble Sodium present in water converts soil Phosphorus into Sodium Phosphate, which is highly soluble but unavailable to plants.

F - Clay Content and its Nature:

The higher the clay content in a soilk, the lower is the upper permissible limit of saline irrigation water. The adverse effect of saline water is more on Montmorillonitic than on Illitic or Kaolinitic clays.

G - Initial Soil Salinity and Sodicity:

Initial soil salinity and sodicity decreases the upper permissible limit of salinity of irrigation water. It is because of the fact that a soil having higher initial salinity or sodicity will reach a stage sooner where it will not be feasible to grow normal crops. So it is safer to use waters having low salinity/sodicity hazards in soils having initial salinity and sodicity problems.

H - Soil Fertility and Fertilizer Use:

Saline water can be used in fertile soils, particularly rich in Organic Matter. The adverse effect of saline/sodic water can be reduced by proper dozes of fertilizer. Saline water causes imbalance of nutrients but if sufficient level of nutrients is maintained in the soil by the application of fertilizers, the negative effect of saline water can be offset. So, it is possible to make use of marginal water by applying proper doses of fertilizers to maintain the fertility of the soil.

I - Crops and Agronomic Practices:

The crops which are relatively more tolerant to salinity, may be selected from table 5.1.

Table 5.1: Relative Salinity Tolerance of Important Crops.

Tolerant (Upto ECe of 15 mS cm^{-1})	Semi-Tolerant (Upto 7.5 mS cm^{-1})	Sensitive (Upto 3.75 mS cm^{-1})
Date Palm	Wheat	Red Clover
Barley	Tomato	Peas
Sugarbeet	Oats	Beans
Cotton	Alfalfa	Sugarcane
Asparagus	Rice	Orange
Spinach	Maize	Plum
	Flax	Peach
	Potatoes	
	Carrots	
	Onion	
	Cucumber	
	Pomegranate	
	Fig	
	Olive	
	Grapes	

Germination, seedling and flowering are the critical stages from salinity point of view.

Frequent irrigations to maintain low moisture stress and leach out the salts is essential.

Row crops should be grown near furrow bottom, where salt concentration is low.

The plant population should be increased by higher seed-rate and less spacing to compensate for the poor performance of individual plants.

J - Climatic factors:

The adverse effect of saline irrigation water is more in arid and semi-arid than humid regions.

Normally there are no changes of salt balance in the soil profile in regions where rainfall is more than 700 mm during the main rainy season.

Areas with higher evapotranspiration (ET) rates are likely to be salinized faster than areas with lower ET rates, when irrigated with saline water. Therefore it is suggested that marginal waters be used during the winter season when ET of crops is quite low.

From the foregoing discussion it becomes evident that by understanding the interaction of different factors which influence the suitability of irrigation water, it will be possible to make use of saline/sodic water more judiciously and efficiently.

VI - SELECTION OF IRRIGATION METHOD

GENERAL APPROACH

The choice of irrigation method depends upon so many factors, viz topography, soil, source of water supply, availability of funds, machinery and crops to be raised.

However, in general soil texture, infiltration rate, topography and stream size are taken into consideration (see Table 6.1), while selcting a particular method of irrigation.

OVERALL GRADE POINT METHOD

It becomes difficult sometimes, to choose a method of irrigation if one does not have a proper understanding of all the factors to be considered. To solve this problem, "Overall Grade Point Method" is proposed to see the suitability of different irrigation methods.

In this technique, each irrigation method is alloted certaqin points for each factor under consideration. Points for all the factors for each irrigation method are added.

Overall grade Point for each method is determined as under:

$$\text{Overall Grade Point (OGP)} = \frac{\text{Sum of all points of all factors}}{\text{number of factors}}$$

The irrigation method scoring the highest OGP is the best for the given set of factors under consideration. The irrigation method getting zero points for any of the factors, should not be included in the calculation of OGP.

If more than one irrigation methods have the same OGP, the one having lower standard deviation is better.

Table 6.1: General Guidelines for Selection of Irrigation Method.

Method of Irrigation	Soil Texture	Basic Infiltr (cm/hr)	Topography & landslope (%)	Stream Size (l/s)	Crops	Remarks
CHECK BASIN	Medium to Heavy	0.5-1.0	Levelled land 0.1	15-25	All crops except those sown on ridges & susceptible to water logging.	Less suited to mechanized cultivation. Wastage of land in channels/ ridges. Labour requirement high. Problem of drainage.
BORDER STRIP	Medium	1.0-2.0	Uniformly graded 0.1-0.3	12-30	All crops, except rice.	Need precise grading. Long fields are better. Labour saving.
FURROW	light to moderately heavy	0.5-2.5	0.3-0.6	1.0-2.0	Row crops except vegetables	Good for crusting soils. Provides better aeration and drainage. Leaching not possible.
SPRINKLER	Very Light and heavy	2.5	Rolling and Undulating	5.0	All crops except rice.	Less suited to canal system. Needs regular power for running pumps. Initial cost high.
DRIP	Light and heavy	0.5-2.5	Level to Sloping	5.0	Vegetables and Perennial fruit crosp.	Less suited to canal system. Needs highly skilled operator. Labour requirements low.

Table 6.2: Assessment of Suitability of Different Irrigation methods.

FACTORS OF COMPARISON		IRRIGATION METHODS				
		CHECK BASIN	BORDER STRIP	FURROW	SPRINKLER	DRIP
SURFACE TOPOGRAPHY	Level land	5	0	0	5	5
	Mod.slope	3	4	5	5	5
	Steep slope	3	3	3	4	4
	Undulating	2	0	2	5	4
SOIL	Light	4	3	3	5	5
	Heavy	5	4	4	4	5
	Erosive	0	2	3	1	0
	Salinity prone	2	2	4	2	2
WATER APPLICATION	Small depth	0	0	0	5	5
	Large depth	5	4	3	5	3
	Controlled rate	3	3	3	5	5
	Loss in water	4	3	3	4	5
	Use in saline water	3	1	3	2	4
WATER SUPPLY	Canal	5	5	3	2	2
	Tube well	4	3	4	5	5
CROPS	Grain crops	3	4	0	5	0
	Rice	5	3	0	1	0
	Sugar cane	3	3	5	4	1
	Tuber crops	3	4	5	5	1
	Cotton	4	4	5	4	3
	Vegetables	3	2	4	4	5
	Fodder	5	5	2	5	1
	Pastures	5	5	0	5	0
	Vine yard	3	3	4	5	5
LABOUR & TECHNOLOGY	Human labour requirements	2	3	3	4	4
	Technical understanding	4	4	4	2	3
	Possibility of automation	1	1	1	5	5
	Versatility	1	1	1	5	3
	Requirements of machines	4	3	3	2	2
LAYOUT & MANAGEMENT	Loss of land	1	2	3	4	4
	Requirement of Material	4	4	4	2	2
	Requirement of Energy	4	4	4	1	2
	Cost of Maintenance	4	4	4	1	2
	Cost of Installation	3	3	3	2	1
	Operation cost	4	4	4	1	2
	TOTAL					