

## A Study on Agricultural Drainage Systems

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**Abstract:** Integration of remote sensing data and the Geographical Information System (GIS) for the exploration of groundwater resources has become an innovation in the field of groundwater research, which assists in assessing, monitoring, and conserving groundwater resources. In the present paper, groundwater potential zones for the assessment of groundwater availability in Salem and Namakkal districts of TamilNadu have been delineated using remote sensing and GIS techniques. The spatial data are assembled in digital format and properly registered to take the spatial component referenced. The namely sensed data provides more reliable information on the different themes. Hence in the present study various thematic maps were prepared by visual interpretation of satellite imagery, SOI Top sheet. All the thematic maps are prepared 1:250,000, 1:50,000 scale. For the study area, artificial recharge sites had been identified based on the number of parameters loaded such as 4, 3, 2, 1 & 0 parameters. Again, the study area was classified into priority I, II, III suggested for artificial recharge sites based on the number of parameters loaded using GIS integration. These zones are then compared with the Land use and Land cover map for the further adopting the suitable technique in the particular artificial recharge zones.

**Key Word:** Study, Agricultural, Drainage, Systems

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### I. Introduction

#### General

In geomorphology, a drainage system is the pattern formed by the streams, rivers, and lakes in a particular drainage basin. They are governed by the topography of the land, whether a particular region is dominated by hard or soft rocks, and the gradient of the land. Geomorphologists and hydrologists often view streams as being part of drainage basins. A drainage basin is the topographic region from which a stream receives runoff, through flow, and groundwater flow. Drainage basins are divided from each other by topographic barriers called a watershed. A watershed represents all of the stream tributaries that flow to some location along the stream channel. The number, size, and shape of the drainage basins found in an area varies and the larger the topographic map.

Agricultural drainage criteria can be defined as criteria specifying the highest permissible levels of the water table, on or in the soil, so that the agricultural benefits are not reduced by problems of water logging. If the actual water levels are higher than specified by the criteria, an agricultural drainage system may have to be installed, or an already installed system may have to be improved, so that the water logging is eliminated. If, on the other hand, a drainage system has lowered water levels to a depth greater than specified by the criteria, we speak of an over-designed system. Besides employing agricultural drainage criteria, we also employ technical drainage criteria (to minimize the costs of installing and operating the system, while maintaining the agricultural criteria), environmental drainage criteria (to minimize the environmental damage), and economic drainage criteria (to maximize the net benefits).

#### Drainage patterns

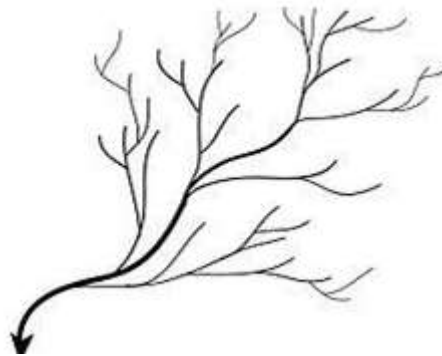
According to the configuration of the channels, drainage system can fall into one of several categories known as drainage patterns. Drainage patterns depend upon topography and geology of the land.

#### Accordant Drainage Patterns

A drainage system is described as accordant if its pattern correlates to the structure and relief of the landscape over which it flows.

#### Dendritic Drainage Pattern

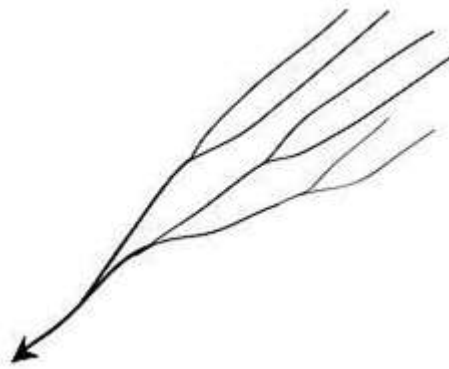
Dendritic drainage systems are the most common form of drainage system. In a dendritic system, there are many contributing streams (analogous to the twigs of a tree), which are then joined together into the tributaries of the main river (the branches and the trunk of the tree, respectively). They develop where the river channel follows the slope of the terrain. Dendritic systems form in V-shaped valleys; as a result, the rock types must be impervious and non-porous Fig 1.1



**Figure. 1.1** Dendritic Drainage Pattern

**Parallel Drainage Pattern**

A parallel drainage system is a pattern of rivers caused by steep slopes with some relief. Because of the steep slopes, the streams are swift and straight, with very few tributaries, and all flow in the same direction Fig 1.2

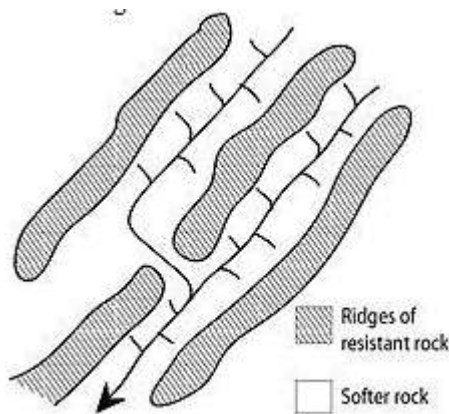


**Figure. 1.2** Parallel Drainage Pattern

Parallel drainage patterns form where there is a pronounced slope to the surface. A parallel pattern also develops in regions of parallel, elongate landforms like outcropping resistant rock bands. Tributary streams tend to stretch out in a parallel-like fashion following the slope of the surface. A parallel pattern sometimes indicates the presence of a major fault that cuts across an area of steeply folded bedrock. All forms of transitions can occur between parallel, dendritic, and trellis patterns.

**Trellis Drainage Pattern**

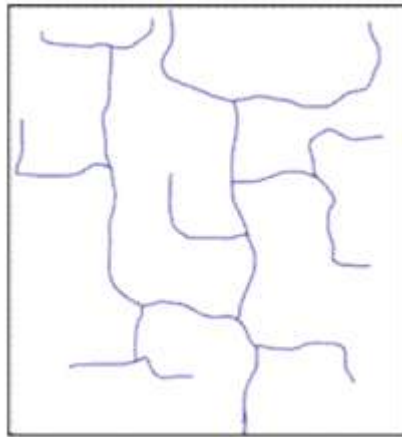
The geometry of a trellis drainage system is similar to that of a common garden trellis used to grow vines. As the river flows along a strike valley, smaller tributaries feed into it from the steep slopes on the sides of mountains. These tributaries enter the main river at approximately 90 degree angle, causing a trellis-like appearance of the drainage system. Trellis drainage is characteristic of folded mountains Fig 1.3



**Figure.1.3** Trellis Drainage Pattern

### **Rectangular Drainage Pattern**

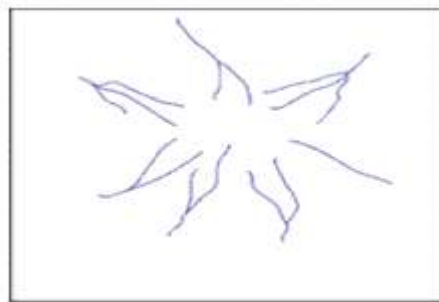
Rectangular drainage develops on rocks that are of approximately uniform resistance to erosion, but which have two directions of jointing at approximately right angles. The joints are usually less resistant to erosion than the bulk rock so erosion tends to preferentially open the joints and streams eventually develop along the joints. The result is a stream system in which streams consist mainly of straight line segments with right angle bends and tributaries join larger streams at right angles Fig 1.4



**Fig 1.4** Rectangular Drainage Pattern

### **Radial Drainage Pattern**

In a radial drainage system, the streams radiate outwards from a central high point. Volcanoes usually display excellent radial drainage. Other geological features on which radial drainage commonly develops are domes and laccoliths. On these features the drainage may exhibit a combination of radial patterns Fig 1.5



**Figure.1.5** Radial Drainage Pattern

### **Deranged Drainage Pattern**

A deranged drainage system is a drainage system in drainage basins where there is no coherent pattern to the rivers and lakes. It happens in areas where there has been much geological disruption. The classic example is the Canadian Shield. During the last ice age, the topsoil was scraped off, leaving mostly bare rock. The melting of the glaciers left land with many irregularities of elevation, and a great deal of water to collect in the low points, explaining the large number of lakes. The watersheds are young and are still sorting themselves out. Eventually the system will stabilize

### **Annular Drainage Pattern**

In an annular drainage pattern streams follow a roughly circular or concentric path along a belt of weak rock, resembling in plan a ring like pattern. It is best displayed by streams draining a maturely dissected structural dome or basin where erosion has exposed rimming sedimentary strata of greatly varying degrees of hardness, as in the Red Valley.

### **Angular Drainage Pattern**

Angular drainage patterns form where bedrock joints and faults intersect at more acute angles than rectangular drainage patterns. Angles are both more and less than 90 degrees

### Discordant Drainage Patterns

A drainage pattern is described as discordant if it does not correlate to the topology and geology of the area. In antecedent drainage, a river's vertical incision ability matches that of land uplift due to tectonic forces. Superimposed drainage develops differently: initially, a drainage system develops on a surface composed of 'younger' rocks, but due to denudative activities this surface of younger rocks is removed and the river continues to flow over a seemingly new surface, but one in fact made up of rocks of old geological formation.

### Reason For Artificial Drainage

Wetland soils may need drainage to be used for agriculture. In the northern United States and Europe, glaciations created numerous small lakes which gradually filled with humus to make marshes. Some of these were drained using open ditches and trenches to make muck lands, which are primarily used for high value crops such as vegetables. The largest project of this type in the world has been in process for centuries in the Netherlands. permitted drainage of some of the marginal land, but the final drainage of the lake had to await the design of large, steam powered pumps and agreements between regional authorities. The elimination of the lake occurred between 1849 and 1852, creating thousands of km<sup>2</sup> of new land.

## II. Study Area

Namakkal District is an administrative district in the state of Tamil Nadu, India. The district was bifurcated from Salem District with Namakkal town as Headquarters on 25-07-1996 and started to function independently from 01-01-1997. The district has 4 taluks (subdivisions); Tiruchengode, Namakkal, Rasipuram, Velur and KolliHills(in descending order of population) and has two Revenue Divisions; Namakkal and Tiruchengode. It was ranked second in a comprehensive Economic Environment index ranking of districts in Tamil Nadu not including Chennai prepared by Institute for Financial Management and Research in August 2009.(Figure2.1)



Figure.2.1 Namakkal District Map

## III. Classification Of Agriculture Drainage System

### General

Agriculture drainage is mainly of two types.. (1). Surface drainage (2). Sub Surface Drainage. However there are some other drainage systems also. Figure 1 classifies the various types of drainage systems. It shows the field (or internal) and the main (or external)systems. The function of the field drainage system is to control the water table, whereas the function of the main drainage system is to collect, transport, and dispose of the water through an outfall or outlet. In some instances one makes an additional distinction between collector and main drainage systems. Field drainage systems are differentiated in surface and subsurface field drainage systems. Some times (e.g. in irrigated, submerged rice fields), a form of temporary drainage is required whereby the drainage system is allowed to function on certain occasions only (e.g. during the harvest period). If allowed to function continuously, excessive quantities of water would be lost. Such a system is therefore called a checked, or controlled, drainage system. More usually, however, the drainage system is meant to function as regularly as possible to prevent undue water logging at any time and one employs a regular drainage system. In literature, this is sometimes also called a "relief drainage system". The main drainage systems consist of deep or shallow collectors, and main drains or disposal drains. Deep collectors are required for subsurface field drainage

systems, whereas shallow collectors are used for surface field drainage systems, but they can also be used for pumped subsurface systems. The terms deep and shallow collectors refer rather to the depth of the water level in the collector below the soil surface than to the depth of the bottom of the collector. The bottom depth is determined both by the depth of the water level and by the required discharge capacity. The deep collectors may either discharge their water into deep main drains (which are drains that do not receive water directly from field drains, but only from collectors), or their water may be pumped into a "disposal drain". Disposal drains are main drains in which the depth of the water level below the soil surface is not bound to a minimum, and the water level may even be above the soil surface, provided that embankments are made to prevent inundations. Disposal drains can serve both subsurface and surface field drainage systems. Deep main drains can gradually become disposal drains if they are given a smaller gradient than the land slope along the drain. The final point of a main drainage system is the gravity outlet structure or the pumping station.

### **Surface Drainage Systems**

The regular surface drainage systems, which start functioning as soon as there is an excess of rainfall or irrigation applied, operate entirely by gravity. They consist of reshaped or reformed land surfaces and can be divided into: Bedded systems, used in flat lands for crops other than rice; Graded systems, used in sloping land for crops other than rice. The bedded and graded systems may have ridges and furrows. The checked surface drainage systems consist of check gates placed in the embankments surrounding flat basins, such as those used for rice fields in flat lands. These fields are usually submerged and only need to be drained on certain occasions (e.g. at harvest time). Checked surface drainage systems are also found in terraced lands used for rice. In literature, not much information can be found on the relations between the various regular surface field drainage systems, the reduction in the degree of water logging, and the agricultural or environmental effects. It is therefore difficult to develop sound agricultural criteria for the regular surface field drainage systems. Most of the known criteria for these systems concern the efficiency of the techniques of land leveling and earthmoving. Similarly, agricultural criteria for checked surface drainage systems are not very well known.

### **Subsurface Drainage Systems**

Like the surface field drainage systems, the subsurface field drainage systems can also be differentiated in regular systems and checked (controlled) systems. When the drain discharge takes place entirely by gravity, both types of subsurface systems have much in common, except that the checked systems have control gates that can be opened and closed according to need. They can save much irrigation water. A checked drainage system also reduces the discharge through the main drainage system, thereby reducing construction costs. When the discharge takes place by pumping, the drainage can be checked simply by not operating the pumps or by reducing the pumping time. In northwestern India, this practice has increased the irrigation efficiency and reduced the quantity of irrigation water needed, and has not led to any undue salinization. The subsurface field drainage systems consist of horizontal or slightly sloping channels made in the soil; they can be open ditches, trenches, filled with brushwood and a soil cap, filled with stones and a soil cap, buried pipe drains, tile drains, or mole drains, but they can also consist of a series of wells. Modern buried pipe drains often consist of corrugated, flexible, and perforated plastic (PE or PVC) pipe lines wrapped with an envelope or filter material to improve the permeability around the pipes and to prevent entry of soil particles, which is especially important in fine sandy and silty soils. The surround may consist of synthetic fibre (geotextile). The field drains (or laterals) discharge their water into the collector or main system either by gravity or by pumping. The wells (which may be open dug wells or tube wells) have normally to be pumped, but sometimes they are connected to drains for discharge by gravity. Subsurface drainage by wells is often referred to as vertical drainage, and drainage by channels as horizontal drainage, but it is more clear to speak of "field drainage by wells" and "field drainage by ditches or pipes" respectively. In some instances, subsurface drainage can be achieved simply by breaking up slowly permeable soil layers by deep plowing (sub-soiling), provided that the underground has sufficient natural drainage. In other instances, a combination of sub-soiling and subsurface drains may solve the problem.

### **Main Drainage Systems**

The main drainage systems consist of deep or shallow collectors, and main drains or disposal drains. Deep collector drains are required for subsurface field drainage systems, whereas shallow collector drains are used for surface field drainage systems, but they can also be used for pumped subsurface systems. The deep collectors may consist of open ditches or buried pipe lines. The terms deep collectors and shallow collectors refer rather to the depth of the water level in the collector below the soil surface than to the depth of the bottom of the collector. The bottom depth is determined both by the depth of the water level and by the required discharge capacity. The deep collectors may either discharge their water into deep main drains (which are drains that do not receive water directly from field drains, but only from collectors), or their water may be pumped into a disposal drain. Disposal drains are main drains in which the depth of the water level below the soil surface is

not bound to a minimum, and the water level may even be above the soil surface, provided that embankments are made to prevent inundation. Disposal drains can serve both subsurface and surface field drainage systems.(Figure.3.1)



**Figure. 3.1** Deep collector drain

Deep main drains can gradually become disposal drains if they are given a smaller gradient than the land slope along the drain. The technical criteria applicable to main drainage systems depend on the hydrological situation and on the type of system.

#### **IV. Applications**

Surface drainage systems are usually applied in relatively flat lands that have soils with a low or medium infiltration capacity, or in lands with high-intensity rainfalls that exceed the normal infiltration capacity, so that frequent water logging occurs on the soil surface. Subsurface drainage systems are used when the drainage problem is mainly that of shallow water tables. When both surface and subsurface water logging occur, a combined surface/subsurface drainage system is required. Sometimes, a subsurface drainage system is installed in soils with a low infiltration capacity, where a surface drainage problem may improve the soil structure and the infiltration capacity. On the other hand, it can also happen that a surface drainage system diminishes the recharge of the groundwater to such an extent that the subsurface drainage problem is considerably reduced or even eliminated.

The choice between a subsurface drainage system by pipes and ditches or by tube wells is more a matter of technical criteria and costs than of agricultural criteria, because both types of systems can be designed to meet the same agricultural criteria and achieve the same benefits. Usually, pipe drains or ditches are preferable to wells. However, when the soil consists of a poorly permeable top layer several meters thick, overlying a rapidly permeable and deep subsoil, wells may be a better option, because the drain spacing required for pipes or ditches would be considerably smaller than the spacing for wells. When the land needs a subsurface drainage system, but saline groundwater is present at great depth, it is better to employ a shallow, closely spaced system of pipes or ditches instead of a deep, widely spaced system. The reason is that the deeper systems produce a more salty effluent than the shallow systems. Environmental criteria may then prohibit the use of the deeper systems.

#### **V. Analysis Of Agricultural Drainage Systems**

##### **Objectives And Effects**

The objectives of agricultural drainage systems are to reclaim and conserve land for agriculture, to increase crop yields, to permit the cultivation of more valuable crops, to allow the cultivation of more than one crop a year, and/or to reduce the costs of crop production in otherwise waterlogged land. Such objectives are met through two direct effects and a large number of indirect effects. The direct effects of installing a drainage system in waterlogged land are A reduction in the average amount of water stored on or in the soil, inducing drier soil conditions and reducing water logging;

A discharge of water through the system. The direct effects are mainly determined by the hydrological conditions, the hydraulic properties of the soil, and the physical characteristics of the drainage system. The direct effects trigger a series of indirect effects. These are determined by climate, soil, crop, agricultural practices, and the social, economic, and environmental conditions. Assessing the indirect effects (including the extent to which the objectives are met) is therefore much more difficult, but not less important, than assessing the direct effects. The indirect effects, which can be physical, chemical, biological, and/or hydrological, can be

either positive or negative. Some examples are: - Positive effects owing to the drier soil conditions: increased aeration of the soil; stabilized soil structure; higher availability of nitrogen in the soil; higher and more diversified crop production; better workability of the land; earlier planting dates; reduction of peak discharges by an increased temporary storage of water in the soil; Negative effects owing to the drier soil conditions: decomposition of organic matter; soil subsidence; acidification of potential acid sulphate soils; increased risk of drought; ecological damage;

The indirect effects of drier soil conditions on weeds, pests, and plant diseases: these can be both positive and negative; the net result depends on the ecological conditions;

Positive effects owing to the discharge: removal of salts or other harmful substances from the soil; availability of drainage water for various purposes;

Negative effects owing to the discharge: downstream environmental damage by salty or otherwise polluted drainage water; the presence of ditches, canals, and structures impeding accessibility and interfering with other infrastructural elements of the land.

Owing to its variation in time and space, a criterion factor can be specified in different ways. A chosen specification can be called a "criterion index". Examples of such indices are: The average depth of the water table during the cropping season; The average depth of the water table during the off-season; The exceedance frequency of the water table over a critically high level; Seasonal average salinity of the root zone; Salinity of the topsoil at sowing time; Average, minimum, or maximum number of days that the soil is workable during a critical period.

The relationship between an object factor and an index can be called "object function of the index" and is also known as "response function" or "production function".

### **Critical Duration, Storage Capacity, And Design Discharge**

The maximum permissible length of the period (the critical duration) to be used for the water table index, and the degree to which this index explains the yield, are influenced by the storage capacity of the drainage system. The critical duration and storage capacity determine the design discharge, as will be explained below. Reducing the surface or subsurface water logging by drainage creates a potential for the storage of water during periods of peak recharge. Thus the drainage system creates a buffer capacity in the soil, ensuring that the discharge is steadier than the recharge. A large buffer capacity permits the adoption of a longer period of critical duration and the use of average recharge and discharge rates over this period. In contrast, a small buffer capacity needs an assessment of the infrequent, extreme, recharge and discharge rates and the adoption of shorter periods of critical duration. Tube well drainage systems, which can lower the water table to a great depth (5 to 10 m), create a large buffer capacity. For these systems, the seasonal or yearly average depth of the water table can be used as a criterion factor. In the water balance over the corresponding long period of time, the change in storage can be ignored. Consequently, one can calculate the design discharge from the average net recharge over a full season or year, and can apply steady-state well-spacing formulas. Field drainage systems by pipes or ditches create a medium storage capacity. In regions with low rainfall intensities (say less than 100 mm/month) and in irrigated lands in arid or semi-arid regions, one can base the drainage design on average monthly or seasonal water levels, taking into account the month or season with the highest net recharge. As the change in storage over such periods is still small, the design discharge can be calculated from the average net recharge over the corresponding critical period. In regions having seasons with high rainfall (say more than 100 mm per month), it is likely that the problem is one of surface drainage (i.e. water logging on the soil surface) rather than of subsurface drainage. Here, a subsurface system would not be appropriate, or it could be combined with a surface system. In a combined system, the design discharge of the subsurface system has to be calculated from a water balance after the discharge from the surface system has been deducted. A surface field drainage system, consisting of beddings in flat lands or mildly graded field slopes in undulating lands, creates only small capacities for storage. Critical periods are therefore short (say 2 to 5 days). The design discharge must then be based on the recharge over the same short period, taking into account a recharge rate that is exceeded once or only a few times a year, or even once in 5 to 10 years. Surface systems that are able to cope with such rare recharges will also considerably reduce crop damage from any water logging that results from even more intensive, though more exceptional, recharges. The use of the water-level index as a criterion factor for surface field drainage systems is not common. This is because, unlike a subsurface field drainage system, the design of a surface field drainage system cannot easily be derived from such an index. The design criteria for collector drainage systems depend on the type of field drainage system. When a collector drain serves subsurface systems only, its water level must be deep enough to permit the free outflow of water from the field drains. As the storage capacity of the collectors is relatively small, their design discharge is not based on the average monthly or seasonal discharge of the field drains, but on a higher, though less frequent, peak discharge as may occur during a shorter period (e.g. 10 days). Subsequently, the cross-section of the collectors can be calculated with Manning's steady-state formula. When ditches are used as collectors for subsurface drainage systems, they are

preferably narrow and deep to maintain a deep water level. For a collector that serves surface field drainage systems only, its water level can be much shallower and may come close to the soil surface. However, as the design of surface systems is based on the less frequent peak discharge of a shorter critical duration, and as the collector system has even less storage capacity than the field system, its design discharge is taken higher than that of the field drains. Manning's formula can also be used to calculate the cross-sections of collector drains for surface field drainage. In contrast to the narrow cross-sections of collectors for subsurface field drainage, those for surface field drainage are preferably wide and shallow.

When a collector drain serves both surface and subsurface field drainage systems, one often uses a combination of criterion values for the water level in the collector: there is a high water-level criterion (HW criterion) and a normal water-level criterion (NW criterion). Each of these levels is specified with a certain tolerable frequency of exceedance. The corresponding discharge requirement (design discharge) can then be calculated from a water balance. How the capacity and dimensions of the collector system are calculated. An example of the influence of the length of the critical duration on the average design discharge is presented in Table 5.1. It shows that the design discharge for drainage by pumped wells, with a critical duration of 6 to 12 months, can be taken as 1.1 to 1.6 mm/d, whereas drainage by pipes or ditches, with a critical period of 1 month to a growing season, requires a design discharge of 2.6 to 2.8 mm/d.

**Table .**Average drainage rate (mm/d) as a function of length of the critical period in an irrigated area

Crop	Peak month	Growing season	Peak half year	Whole year
Wheat	2.0	1.6	-	-
Maize	3.0	2.3	-	-
Potatoes	4.5	2.6	-	-
Combination*	2.8	-	1.6	1.1

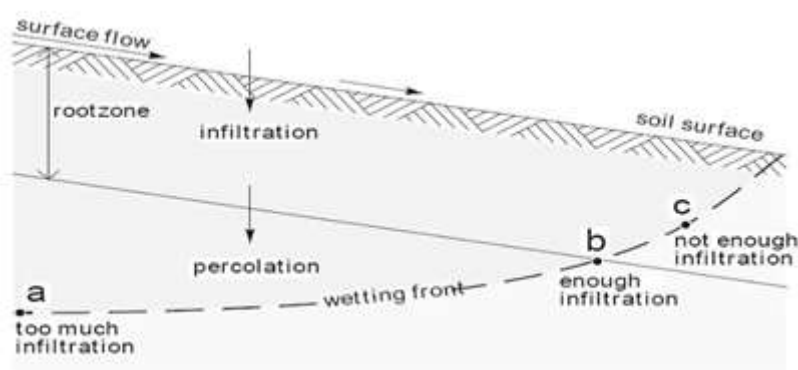
\* A cropping pattern of 2/3 winter wheat, 1/3 spring potatoes and 1/3 summer maize

**Irrigation, Soil Salinity, And Subsurface Drainage**

Subsurface drainage systems are often used in irrigated, waterlogged, agricultural lands in arid and semi-arid regions to reduce or prevent soil salinity. The salt balance of these lands depends largely on the water balance, in which the amount of irrigation water is a dominant term. When sufficient irrigation water is applied, the effect of drainage on the salt balance stems from the discharge of salts along with the drainage water. Hence, drainage for salinity control is primarily based on the discharge effect rather than on a lowering of the water table. Criteria for salinity control should therefore be sought in the amount of irrigation water needed to provide sufficient leaching, rather than in the depth of the water table. With a well-designed and properly-operated irrigation system, the water table need not be kept at extra deep levels to control soil salinity. If, on the other hand, the irrigation system is poorly designed and operated, even maintaining very deep water tables will not alleviate soil salinity. Often, one relates the required depth of the water table for salinity control to the upward capillary flow in the soil resulting from a constant depth of the water table and a very dry topsoil. Such conditions imply that, in the absence of irrigation or rain, there is a steady upward seepage of groundwater from the aquifer. When such lands are irrigated and drained, these capillary-flow conditions no longer exist. In semi-arid regions with pronounced wet and dry seasons, it is possible to restrict the drainage to the wet season only. The evacuation of salts during this period is sufficient to maintain a favourable salt balance in the soil, even though some resalinization may take place during the dry season. In addition, the use of salty drainage water with an electrical conductivity up to 10 dS/m for irrigation in the dry season does not negatively affect yields as long as sufficient leaching occurs in the wet season to prevent any annual salt accumulation

Using drainage water for irrigation in the dry season and evacuating it only in the wet season has two advantages: In the dry season, when the evacuation of salty drainage water into rivers with a low discharge is environmentally undesired, and when irrigation water is scarce, the drainage water can be used for additional irrigation and environmental problems are avoided; In the wet season, when the evacuation of salty drainage water into rivers with a high discharge is environmentally acceptable, and when irrigation is only complementary to rainfall, the drainage water can be evacuated for salinity control.(Figure.5.1)





**Figure.** Illustration of the systematic irregularity in the spatial distribution of the deep percolation in an irrigated field

In places where the soil surface has a relatively high elevation, even if the difference is only a few centimetres, or in places with a low infiltration and/or water-holding capacity, the leaching requirement may not be met. This phenomenon often gives rise to a patchy development of soil salinity.

## VI. Conclusion

The previous discussion of field drainage criteria can be summarized as follows. If one expresses the agricultural drainage criterion as the permissible minimum value of the average depth of the water table during a prolonged period, one has formulated a long-term, steady-state criterion. An example of a long-term, steady-state criterion for a subsurface drainage system in irrigated agricultural land is: "The average depth of the water table during the irrigation season should be at least 0.8 m, but need not be more than 1.0 m". An example for humid areas is: "The average depth of the water table during the critical humid season should be at least 0.6 m, but need not be more than 0.8 m". The critical humid season may be either the winter period, as in the temperate zones of Europe where the excess rainfall occurs mainly in winter (off-season drainage), or the summer/cropping season, as in those tropical or subtropical regions where the excess rainfall occurs during the summer or during an important cropping period (in-season drainage). The corresponding discharge rate of the drainage system must be calculated from a water balance as an average rate during the corresponding period, whereby the storage term may be ignored. When one expresses the agricultural drainage criterion in terms of a critically high level above which the water table may rise only infrequently and for short periods, one has formulated a short-term, unsteady-state criterion. An example of such a short-term criterion for a subsurface drainage system is: "The water table may be higher than 0.3 m below the soil surface only for one day a year". The corresponding discharge rate of the drainage system then has to be calculated from a short-term water balance with an infrequent, extreme, recharge whereby the dynamic storage term must be taken into account. This complicates the calculations considerably.

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