What You Need to Know About Waterlogging in Agricultural Lands

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Its that time of the year again. The rains are pouring and the water seems to be going nowhere. Indeed the land is all soaked up and water is just rising up! People are forced to abandon their homes, while in the farms, crops are sinking under the water and some are dying out. Recognizing the symptoms of a problem is one thing. But understanding the problem and why it occurs is the first step towards knowing how to solve it.

1.1 What is waterlogging?

Waterlogging is a condition of land in which the soil profile is saturated with water either temporarily or permanently (figure 1). In waterlogged lands, the water table rises to an extent that the soil pores in the crop root zone are saturated resulting in restriction of the normal circulation of air. This causes a decline in the level of oxygen and increase in the level of carbon dioxide. Generally, the water table is located at or near the surface resulting in poorly drained soils, adversely affecting crop production. Areas with water table within 2 m below the ground surface are considered as prone to waterlogging and those with water table within 2-3 m are considered to be at risk. Waterlogging can reduce the agricultural and economic value of land causing yield reductions or at times, total crop failures. Waterlogging is a drainage problem.

Figure 1 (a) Temporary waterlogging after a heavy rainstorm *(photos by B. Mati)* **(b) Permanent waterlogging resulting from ground water contribution (wetland)**

1.2 Categories of waterlogging

Waterlogging in agricultural lands can be of various types categorized according to:

a) Causes:

(i) Natural, e.g. natural swamps and valley bottoms

(ii) Human-induced waterlogging, e.g. through agricultural and other activities.

b) Permanence

(i) Temporary – whereby waterlogging lasts a few days to several months
(ii) Permanent waterlogging – which occurs throughout the year.

c) Source of water

(i) Rainfed - mostly source of excess water is direct rainfall
(ii) Irrigated agriculture – waterlogging caused by water supplied for irrigation

d) Located on

(i) Agricultural lands – including cultivated lands
(ii) Other utility lands e.g. built up areas, urban areas.

1.3 Causes of waterlogging

Waterlogging is a drainage problem that results of high water inflow caused by rain, runoff, interflow, rise in groundwater, over irrigation or flooding. Drainage problems can be caused by low water outflow due to low infiltration rate, low hydraulic conductivity, flat terrain, lack of outlet or restricted outlet in the soil. In irrigated agriculture, drainage should be part of the overall design and implementation to avoid problems of waterlogging. Waterlogging can be caused by natural conditions or human induced activities, as follows:

1.3.1 Natural causes

a) Physiography of a watershed

Physiography, i.e. the topography, its slope, shape and drainage pattern has an important bearing on the drainage of a watershed. Areas that lie in valley bottoms, depressions and other flat lowlands tend to become waterlogged naturally as surface flows concentrate in these lowlands, causing natural swamps.

b) Geology

Some areas have an impervious stratum below the top soil which obstructs the infiltration of rainfall. This creates a false water table or perched water table. Also, Areas with shallow soils, high water tables or a hard pan close to the ground surface are likely get waterlogged, particularly if subjected to high rainfall events.

c) The weather

Areas that receive heavy rainfall for prolonged duration can get waterlogged temporarily or permanently (Figure 2-a).

d) Soil type

Heavy clay soils such as black cotton soils are prone to waterlogging, as they hold moisture for long periods. Also, soils prone to surface sealing cause temporary waterlogging (see Section 1.5).

e) Seepage inflows

Seepage and interflow from other water bodies e.g. lakes, rivers and shallow aquifers can cause waterlogging of adjacent lands. Also, subsoil flows from upper regions to lower areas may result in waterlogging (Figure 2-b).

Figure 2 (a) Waterlogging after heavy rains on shallow water table *(photos by B. Mati)* **(b) Waterlogging due to seepage inflows from river valley**

1.3.2 Human-induced causes of waterlogging

Human induced causes of waterlogging in agricultural lands are usually associated with bad water management whether under irrigated or rainfed agriculture. For instance:

a) Irrigation

Irrigation, if not well planned, can cause drainage problems for the irrigated lands and adjacent ones. This is because irrigation adds extra water to the soil profile, over and above the naturally occurring rainfall. There are several ways in which irrigation can increase waterlogging. They include:

(i) ***Over irrigation:*** over irrigation and intensive irrigation result in waterlogging. The excess water from irrigation and without proper drainage contributes to rise in the water table.

(ii) ***Seepage from canals:*** Excessive seepage from unlined canal system and water courses result in the rise of water table leading into waterlogging

(iii) ***Inadequate drainage:*** in irrigated areas, water losses from canal system and water courses continuously contribute to water table (Figure 3-a).

(iv) ***Poor irrigation management*** **:** poor irrigation and cropping management by the cultivator

(v) ***Obstruction of natural drainage:*** interception of natural drainage by the construction of canals, roads, railways, water courses, etc.

(vi) ***Land locked parches having no outlets*****:** Waterlogging develops due to absence of outlet to drain excess irrigation or rain water (Figure 3-b).

Figure 3 (a) Harvesting rice in waterlogged conditions due to poor drainage **(b) Waterlogging due to poor land levelling** *(photos by B. Mati)*

b) Rainfed systems

(i) ***Excessive rainfall:*** Rain, apart from irrigation, is the major cause of water logging when it is in excess and in the absence of adequate drainage (Figure 4-a).

(ii) ***Flat topography:*** Flat terrain with depressions lead to waterlogging as disposal of excess water is delayed resulting in increased percolation into the soil (Figure 4-b).

(iii) ***Occasional spills by floods:*** Occasional flooding of the countryside and storm floods water not quickly drained off gives rise to water table.

(iv) **Closed / contour** water conservation structures – Construction of soil and water conservation structures on the contour can impound too much water causing waterlogging.

Figure 4 (a) Waterlogging from excessive rainfall and diversion of runoff *(photos by B. Mati)* **(b) Waterlogging on wheat field after heavy rainfall due to flat terrain**

1.4 Undesirable effects of waterlogging

Waterlogging can have both beneficial and negative effects. Beneficial effects include being a habitat for certain plants and animals e.g. mudfish. Also, the wetlands regulate the hydrogeology, resulting in more sustainable river flow. However, for agricultural purposes, waterlogging can have negative impacts on the soil, crops and farm operations.

1.4.1 Effects of waterlogging on soils

(i) ***Lack of aeration*****:** Waterlogging expels air from the soil pores resulting in a saturated condition. Without air, plant roots degenerate and crops can die. Certain microorganisms cannot survive resulting in reduced microbiological activity necessary for formation of plant food. Waterlogging also increases acidity build up which is harmful to most food crops.

(ii) ***Reduced soil temperature:*** waterlogged soil is slow to warm up. Lower soil temperature restricts root development, depresses biotic activity in the soil resulting in lowered rate of production of available nitrogen hampering seed germination and seedling growth. Reduction of soil temperatures; results in stunted growth and reduced production of nitrogen.

(iii) ***Salinization:*** *Salinity build up is increased* when water from lower soil layers which may contain salts is brought up to the soil surface by capillary action (Figure 5). Thus, high salinization and deposits of sodium salts in the soil at or near the ground surface are created which may be toxic or lead to the formation of alkaline conditions.

(iv) ***Inhibiting activity of soil bacteria****:* when soil structure is affected and tillage and cultivation of wet soil takes place, bacteria tend to reduce normal biotic activity and this affects root development.

(v) ***Denitrification:*** Denitrification occurs because of the competition for nitrogen by the soil micro-organisms that thrive in saturated soil and reduction in numbers of nitrifying organisms due to lack of aeration. There is reduction of nitrogen in the soil which in affects plant nutrients uptake

(vi) ***Retards cultivation*****:** Difficulty in carrying out normal cultivation in waterlogged soil.

Figure 5 (a) A poorly drained paddy field with salinity build up *(photos by B. Mati)* **(b) Salt crusts visible on the surface after the paddy field dries up.**

1.4.2 Effects on crops

(i) ***Delayed cultivation operations****:* normal cultivation operations of tillage and ploughing are adversely affected due to presence of excess water in the soil (figure 6).

Figure 6 Excessive seepage from canals causes waterlogging in fields *(photos by B. Mati)* **(b) Cultivation and rudimentary tools renders in-field water control difficult**

(ii) ***Aquatic weeds*.** Water-loving wild plants grow profusely and have competition with the crops, thereby affecting the growth of useful crops weed removal also entails extra investments and in extreme waterlogged conditions, only wild grow is there.

(iii) ***Diseased crops:*** Waterlogged conditions cause physiological disease to crops. Decay of roots, external symptoms on the foliage and fruits are common.

(iv) ***Loss of cash crops*:** Cash crops desired to be grown cannot be cultivated and the land is restricted to few crops like paddy rice.

(v) ***Low yields:*** Maturity period of crops is reduced resulting in low yields. The yield of crops is adversely affected if the water table is within 90 cm (sugarcane), 60 cm (rice), 90 cm (gram and barley), 90-125 (wheat), 120 cm (fodder), 125 cm (maize and cotton), and 210-240 cm (lucerne).

(vi) ***Oxygen depletion:*** In saturated soil, plant roots are denied normal circulation of air; the level of oxygen declines and that of carbon dioxide increase resulting in wilting and ultimately death of plants. The rotting of the plant roots under conditions of reduced supply of oxygen, causes yellow color to leaves. The lack of air in the soil causes precipitation of Manganese that is toxic to plants.

1.4.3 Effects on the environment

Waterlogging results in stagnant water which can host disease vectors such as malaria, snails and slugs. It impairs sanitary conditions and can bring on diseases like malaria and bilharzias, resulting in unhealthy environment for human population, animals and plants in an area.

1.5. Soil properties relevant to land drainage

A healthy soil consists of mineral and organic particles, water, air and certain micro-organisms. Plants need all these constituents as a medium for growth. A waterlogged soil is one which is saturated and all the voids (pores) in are filled with water. A soil is unsaturated when part of it is filled with water and part with air. Water in the soil is also called soil moisture. Permeability is the capacity of a soil to transport water; it depends upon the porosity, the pore size distribution, and the soil texture and soil structure. Generally, soils with a drainage problem have low permeability.

1.5.1 Bottom-lands

Most irrigation schemes are located in areas where the terrain is relatively flat, mostly to enable gravity flow of water, and ease of field operations. These areas often have one of more soil types known as bottom-land soils. Bottom-lands are areas of varying shape and size with nearly level and often concave topography and usually have slopes of less than 1%. Included in the category of bottom lands are *"salt flats", "valley bottoms", "depressions"* and volcanic *"sink holes".* They have no outlet and as a result, ground water and surface water accumulate. This leads to subsequent accumulation of fine sediments, or clay particles, making the soils poorly draining. Because of the lack of proper outlets, the external and internal drainage condition is poor, and this can lead to salt accumulation. Bottom-lands are quite often prone to waterlogging.

Soil conditions in bottom lands vary greatly depending on the source and type of parent material, the prevailing drainage condition and the stage of development of the soil. The following soil types are commonly encountered in bottom areas considered for irrigation and drainage: (a) Vertisols (b) Planosols, (c) Saline soils, (d) Sodic/ Alkaline soils, and (e) Alluvial soils.

1.5.2 Vertisols

Vertisols are mainly dark, *montomorillonitic clays* which display characteristic swelling and shrinking or "vertic" properties. They are sometimes called cracking clays or *"black cotton soils"*. Spread over large areas in the semi-arid Tropics, the soils develop large cracks, usually more than 1 cm wide and 50 cm depth during the dry season. When it rains, the soils absorb water and swell, closing the cracks. As the cracks close, water intake by the soils become negligible thus the soil becomes impervious. Due to their low hydraulic conductivity when wet, vertisols are usually poorly drained. They are prone to flooding and seasonal waterlogging during the rainy season. Moreover, vertisols are very hard when dry and very sticky when wet. This affects both land preparation and crop growth conditions. As a result, vertisols require mechanical tillage and can be worked on even during the dry season. Crops sensitive to waterlogging may be planted on ridges, but with water management techniques such as bedding or ridging. The soils are suited for paddy rice production which favours flooding. These soils, however, require a drying out period before flooding in order to maintain their bearing capacity and to absorb air.

1.5.3 Planosols

These soils, also called "*Vlei soils*" are found in plains and plateaus, but have a tendency to develop hard pans. They are, therefore poorly drained. The top soil, which is relatively light in texture and permeable, as shallow as 30 cm, but is abruptly underlain by a slowly impermeable horizon (hard pan). Root development is largely confined to the top soil layer where fertility is low and has problem in maintaining favourable soil moisture for crops. Production may occur on slightly elevated or sloping areas, where drainage to surrounding lower area is possible. These soils are less suitable for surface irrigation, but if top soils are over 60 cm deep, overhead irrigation could provide a favourable moisture regime. Internal drainage of these soils can be improved through sub-soiling, albeit loosening the subsoil has, in many countries, not resulted in notable improvements in productivity.

1.5.4. Saline soils

Saline soils contain high levels of soluble salts, measured as the extractable solution of the soil when it has an electrical conductivity exceeding 4 mmhos/cm, which is beyond the tolerable limits of most crops. Purely saline soils may be non-sodic, meaning the extractable solution could have exchangeable sodium percentage of less than 15, and a pH of less than 8.5. Otherwise, it is common for soils in arid areas to be both saline and sodic. Saline soils are generally light coloured, with low organic matter and poor structure. Crop yields on saline soils is reduced due to the presence of toxic concentration of salts in the root zone.

Visual characteristics of a saline soil

Saline soils are commonly found in poorly draining areas in arid and semi-arid zones. This is because due to high evaporation rates, the salts dissolved in the soil water are pulled to the surface through capillary action. They accumulate and salt efflorescence and crusts form. Visual characteristics of saline soils include:

- White salt crystals (which can be seen precipitated on the sides of the profile pit or along cracks).
- Clay is flocculated and gives a loose granular or blocky structure;
- A white salt crust covering the ground or a very loose surface caused by the growth of long needle-like crystals of sodium Sulphate. If the land is not reclaimed early, it deteriorates to alkalinity.

Problem with salinity build up: From an engineering point of view, excessive contents of soluble salts in the soil cause structural problems. Water dissolves the salts, resulting in collapse of irrigation and drainage ditches. The presence of such soluble salt in the soil moisture creates a high osmotic pressure which subsequently reduces the availability of water to plants. Also, some ions may be present in the soil solution at toxic levels for plant growth.

Remedial measures: Soluble salts can be leached out. This requires good permeability of the soil, good quality irrigation water, and good drainage conditions. Temporary salinity control can be achieved by improving the permeability of the soil, e.g. through deep tillage or incorporation of organic residues.

1.5.6 Sodic/Alkaline soils

Sodic soils contain excessive exchangeable sodium, and are by nature, alkaline. These soils, also called “solonetz” that may contain little soluble salt. A sodic soil has an exchangeable sodium percentage of more than 15, an electrical conductivity of extractable solution measuring less than 4 mmhos/cm and a pH exceeding 8.5. A saline-sodic soil has both salinity and sodicity problems as shown in the Table 1.1:

Table 1.1 Salinity and alkalinity levels in soils

Type of soil	Electrical conductivity (micromhos/cm)	Exchangeable Sodium Percentage (ESP)	pH
Saline	>4000	<15	<8.5
Saline-Alkali	>4000	>15	8.5
Alkali	<4000	>15	8.5-10.0

A high level of exchangeable sodium causes the clay to disperse. The dispersed clay subsequently moves from the top soil into the subsoil and usually a characteristic columnar structure develops. Upon wetting, this horizon becomes virtually impermeable, causing waterlogging. Salts easily accumulate in such a soil.

Visual characteristics of a sodic soil

Asodic soil has a thin, coarse-textured A-horizon from which clay has been illuviated. he A-horizon overlies a compact, heavily textured B-horizon (nitric B-horizon) as a result of clay illuviation from the top. The sol exhibits a columnar structure with rounded tops. It has low permeability due to nitric B-horizon and a dark colours or “black alkali” soils.

Problems: High sodium contents in the soil result in poor soil structure, poor aeration and low permeability. With the sodium present and the salt concentration low, the soil structure collapses on addition of water. Internal drainage becomes almost impossible. Sodic hard pans are also common. High sodium level also preclude uptake of other necessary ions and is toxic to crops.

Remedies: Solonetz soils are generally impossible to reclaim in an economic way. The leaching of sodium is almost impossible as permeability is poor due to the high sodium levels. It is best to avoid irrigating or draining sodic soils.

1.5.7 Acid soils

Acid soils are those with a low pH levels due to accumulation of acidic ions. Examples include the acid Sulphate soils in rich tropical coastal wetlands. They are also found in high rainfall mountain areas having very deep soils. When soil drainage is deep, subsoil layers are exposed to air and become oxidized. This leads to the formation of sulphuric acid from the pyrites, increasing soil acidity, which is harmful to many crops. However, some crops such as coffee and tea, thrive on soils with low pH.

Problems: The pH levels in the water draining from these areas can drop below 3, seriously harming plant and animal life, including mangroves and fish. Iron and aluminum can also be mobilized from soils when then the pH levels drop, causing aluminium toxicity which has implications for human health if the downstream water is used for drinking purposes.

Remedies: Maintaining a high water table to prevent the pyrites from oxidizing, can control soil acidity problem. In some places, lime and organic mulch are applied to neutralize the acidity. Also, minimizing the displacement of acidic ground water to the river by laser leveling, planting in mounds, reducing the length of the drainage ditches to reduce the acid sourced from the drain banks and liming drainage banks. The process of control and leaching is different from salinity, but the effect on water requirements is similar.

1.5.8 Alluvial soils

Alluvial soils are usually found in valley bottoms, and are formed from alluvial deposits originating from upper areas of the watershed. They are young soils that do not have horizon differentiation due to time being too short for soil forming processes, but they show strong stratification due to sedimentary deposition. Coarse soil layers of sand may alternate with fine layers of clay. Alluvial soils have an organic matter content that decreases irregularly with depth and they receive fresh sedimentary materials at regular intervals if flooded. Because they are located in poorly drained valleys, alluvial soils are prone to waterlogging.

Problems: The layers with contrasting texture affect water movement through the soil. Water tends to stagnate in these layers resulting in drainage and aeration problems. The layers may also offer mechanical impedance to root development.

Remedies: Since they are generally fertile, most alluvial soils are well suited to agriculture. Some may require mechanical mixing to homogenize the profiles when stratification is prominent, which is economically feasible. Drainage of alluvial soils may work well if an outlet can be found for the drainage water.