EFFECTS ON CROP AND SOIL AND MITIGATION STRATEGIES IN EXCESS WATER STRESS -A Review

A. Senthilkumar[1]*, B. Bhakiyathu saliha[2], P. Saravana pandian[3], R. Thamizh vendan[4] and A. Gurusamy[5]

[1], [2], [3] Department of Soils and Environment, [4]Department of Agricultural Microbiology, Agricultural College and Research Institute, Madurai-625 104.

[5]Dryland Agricultural Research Station, Tamil Nadu Agricultural University, Chettinad-630 102, Sivagangai district.

***Corresponding author:** senthilhorts052@gmail.com*

Abstract

The excess rainfall (excess moisture stress) hampers crop production often more serious. The proper soil management measures, such as bed planting of crops, contour plowing, bonding, broad bed and furrows, water retention ponds, growing of cover crops, residue mulching and agroforestry can reduce the surface runoff and slow down the rate of runoff from the fields help manage excess and deficit water stress and sustain crop production.

Keywords: *Rainfall, Water Holding Capacity, Mitigation and Adaptation Strategies*

Introduction

Intensification of agriculture during the past two to three decades has several implications, particularly in terms of an increase in global warming, depletion in the groundwater table and rise in the water table at some places, reduction and fluctuation in crop productivity and farmer's income. The amount and distribution of rainfall are majorly responsible for both conditions of drought stress as well as excess water stress (Debaeke *et al.,* 2014). Change in land configuration or excess tillage has reduced the infiltration or penetration capacity of the soil. Rainfall received above the normal leads to runoff and this water is not available to crop plants unless under in-situ moisture conservation. Over the years water productivity of field crops is also diminishing by vagaries in rainfall patterns. However, improving water productivity at the field level can inevitably be achieved by increasing the marketable yield of the crop by reducing various water losses through the effective use of rainfall and stored water (Asseng *et al.*, 2020). Changing land management practices could reduce the infiltration capacity of the soil leading to greater loss of water through runoff. Again shallow soils have less infiltration capacity due to a lack of proper drainage in the soil. Thus, the proper drainage system is required to evacuate excess water from agricultural lands and store it in the conservation tanks/farm ponds.

Classification of Area & Rainfall

Rainfall is the principal source of water for almost all uses. Thus, rainfall is a vibrant module of the Indian economy. Variability in the distribution of rainfall varies in terms of regions and temporal variation in most of India. The average annual rainfall is about 120 cm, above 80% of which is received during the June to September months, however, with great spatial variations.

i. Classification of area based on rainfall variability

a. Heavy rainfall areas: The highest rainfall (more than 2000 mm) occurs in the Western Ghats, Eastern Himalayas as well as the sub-Himalayan areas in the northeast and Meghalaya hills, Assam and West Bengal.

b. Moderately heavy rainfall areas: This rainfall (1000--2000 mm) occurs in Parts of Gujarat, Tamil Nadu, Western Ghats, eastern Maharashtra, Madhya Pradesh, Orissa, the middle Ganga valley.

c. Fewer rainfall areas: The rainfall of 500--1000 mm occurs in the upper Ganga valley, eastern Rajasthan, Punjab, the southern plateau of Karnataka, Andhra Pradesh and Tamil Nadu.

d. Scanty rainfall areas: Rainfall of less than 500 mm occurs in the northern part of Kashmir, western Rajasthan, Punjab and Deccan Plateau.

ii. Classification of rainfall based on intensity or rainfall erosivity

- Light rain-- when the precipitation rate is < 2.5 mm per hour
- Moderate rain -- when the precipitation rate is between 2.5 -- 7.6 mm or 10 mm per hour
- Heavy rain -- when the precipitation rate is > 7.6 mm per hour, or between 10 mm and 50 mm per hour
- Violent rain -- when the precipitation rate is > 50 mm per hour

Typical Water Holding Capacity of Soils

In sandy soil, if heavy irrigation is given the water will rapidly percolate downwards and will be wasted. However, in fine texture soils due to poor permeability and aeration, the water cannot move downward fast enough and accumulates on the surface (Bradford *et al.*, 2012). The water holding capacity of soil under excess moisture conditions could decide the runoff harvesting. The rate at which water infiltrates into the soil is particularly important for harvesting runoff water and subsequent lifesaving irrigation to the crops. The availability of water and infiltration rate varies with different texture soils (Table 1) and it explains a portion of the differences in crop tolerance to waterlogging and the water storage capacity in soil.

Table 1. Water holding capacity and infiltration rate of different texture soils

Soil texture	Field capacity (%)	Permanent wilting point (%)	Plant available water (%)	Infiltration rate range (mm/h)
Coarse sand	6	2	4	30-50
Fine sand	10	4	6	30-50
Loamy sand	14	6	8	-
Sandy loam	20	8	12	20-30
Light sandy clay loam	23	10	13	-
Loam	27	12	15	10-20
Sandy clay loam	28	13	15	-
Clay loam	32	14	18	5-10
Clay	40	25	15	1-5

Source: www.hydrogold.com

Impact of excess rainfall

The severity of the flood effect depends particularly on the plant type, the duration of flooding and the time of year. Flooding leads to deposition of sand and debris on productive lands; erosion of agricultural soils; and loss of beneficial micro-organisms viz. organic matter decompose bacteria and nutrients mobilizing fungi. After floods, farmers face yield losses due to the devastation of arable land, and producers need to plan for the recovery of their arable soils. Flooding also causes delays in farm operations, additional costs of inputs (e.g. fertilizer, pesticides) and increased risk of animal disease, besides delay in sowing of succeeding crops.

Excess rainfall or flooding at any stage of the crop growth could severely hamper the crop growth, and in several circumstances, it leads to severe devastation of crop plants and hence more economic losses (Kramer, 2013). The influence of flooding on agriculture varies considerably according to the tolerance of the particular crop, and the frequency, duration, and seasonality of the rainfall (Hsiao, 2013).

Flooding may cause damage and losses to high-value crops as well as field crops and it depends on the severity and frequency of the flooding. However, evacuation of excess water from plain lands is very difficult than slopping. Among crops, pulses are more susceptible to flooding or water-logged conditions than cereals. Under flooding or anaerobic situations, legumes experience root death due to ethylene production and its slower diffusion into the atmosphere through water than through air. Under, flooded or wet conditions, crop yields will decline intensely if required crop care cannot be provided. In addition, if not properly managed, new waterlogged and saline areas will develop adjacent to the ponds. The problem of salinity is already widespread in canal irrigated areas.

In recent years, parts of eastern India states like Bihar, Madhya Pradesh and Uttar Pradesh have received exceptional amounts of rainfall and caused huge damage to standing crops resulting in potentially devastating economic losses. Under persistently saturated soils and the accompanying flooding by excessive rainfall cause waterlogging (Tezara, *et al.*,2019) If the soil is ill drained, crop production gets negatively affected; plants die and total crop failure occurs or there can be lower plant performance. The most prominent effects of excess water stress are:

• The submerged crop plants in low-lying areas will quickly begin to die (Figure 1 of pigeon pea and maize) because submerged leaves are not able to exchange atmospheric gases (mainly carbon dioxide and oxygen) and cause them to die.

• Abnormally high amounts of rainfall result in the leaching of nutrients, especially granular nitrogen fertilizers which are very soluble and vulnerable to leaching losses.

• Submerged plants are more prone to diseases and pest attacks due to congenital conditions and susceptibility of plants.

• If the saturation/submergence is extended, it negatively impacts the rooting ability to absorb nutrients due to suffocation causing plant death and total crop failure.

• Wet conditions coupled with warm temperatures create a congenial platform for fungal growth and seed germination is affected.

• Weeds compete for space and light, nutrients, grow rapidly and interfere, with crop growth and cultural operations.

• Many toxic salts affect water and nutrient absorption by roots and cause damage to crops associated with nutrient deficiency.

Figure 1. Pigeonpea crop under excess water condition Maize crop loss

Under the conditions of deteriorated soil structures, irrigated crops are more seriously affected by waterlogging compared to rainfed crops which are largely covered by sloping and light-textured soils.

Mitigation and Adaptation Strategies

The risk of flooding to people and communities depends on the occurrence of the flood and the consequences of the floods. The risk may be reduced by a combination of mitigation and adaptation means. The activities to modify to reduce the probability of a flood occurring are referred to as mitigation. Measures taken to reduce the impact of flooding in receptor areas are called adoption (Howell, 2021). Concurrently, soil and water conservation measures pose a crucial place in mitigating excess moisture stress or drought stress to conserve the soil and control erosion. These practices reduce runoff by controlling water movement over the surface of the soil.

Drainage: There is a common practice of preparing grassed waterways during the preparation of a field provided with a channel to take excess water from that field to a safer place, from where it is disposed of (Vartapetian, 2017). These channels or grassed waterways help in the drainage and are positioned in such a way that they do not hinder any agricultural activity such as ploughing, hoeing and harvesting. It is documented that sustainable increases in water productivity through water harvesting, water conservation, supplementary irrigation, better crop selection and improved agronomic practices.

Water harvesting: Storage of excess water in reservoir/farm ponds/dugout structures, collected runoff is applied directly to the cultivated crops. It carries fertile soil and plant nutrients and makes the soil degraded and barren. A relatively high percentage of rainwater goes as run-off and streamflow (Goldhamer and Fereres, 2021). The stored water is used as a lifesaver or for supplementary irrigation during lean periods. However, seepage and percolation losses were high under storage tanks. This could be reclaimed by the application of soil conditioners like bitumen, poly-acrylamide, asphalt and latex emulsions, which improves the infiltration rate and pore space size and stability.

Alley cropping or growing of perennial trees/crops: Growing of annual food crops or arable crops (such as maize) between rows of planted woody shrubs or trees (Gliricidia and Leucaena) have beneficial effects in reducing erosion, surface runoff and soil moisture loss. Perennial vegetation reduces irrigation seepage and recharge of the shallow groundwater. Eucalyptus, being a bio-drainage tree, with the percolation capacity being higher would be a better option for draining out excess water from the crop fields.

Selection of crops for excess water stress: Supplemental nitrogen fertilizer can offset a portion of the yield losses due to excess water because nitrate can act as a secondary source of oxygen for the plant under these situations. In terms of relative crop tolerance, oats are the most tolerant of excess water stress and grasses are more water tolerant than legumes. Whereas, most annual crops, forage legumes and forage grasses can tolerate 3 to 7, 9 to 14 and 10 to 49 days of water stress, respectively (Hsiao and Xu, 2020)

Crops	**Water stress tolerance in ascending order**
Cereals	Oats > wheat > barley
Pulses	Fababeans > soybeans > field beans > peas
Oilseeds	Canola > sunflower > flax
Grass forage	Reed canarygrass > timothy > orchardgrass = perennial ryegrass
Legume forages	Birdsfoot trefoil/red clover > sweet clover > alfalfa

Terracing: The ploughing of slopping lands across the slope (contour cultivation) also helps in soil conservation as it checks the loosened soil from erosion. The angular/curved shape constructed across the contour is useful in preserving infiltration rate which otherwise gets wasted with runoff. The terraces are supported by loose boulders with grasses that help in binding soil particles and also help in the drainage of excess water. The bunds are again used for growing palatable grasses which are used as fodder for livestock and trees are meant for fuel, fodder and fiber.

Micro-irrigation: Harvested water in the storage tanks could be utilized precisely through micro-irrigation techniques, such as sprinkler, drip or trickle irrigation under drought stress conditions to compensate for the shortage of water by irrigation. For example, the adoption of drip irrigation under raised beds results in the highest water use efficiency through higher productivity of finger millet, maize, wheat, cluster bean, soybean, etc. crops.

Bed planting: Growing crops on top of the beds enhances the infiltration rate, protects crops from lodging due to better root growth and provides invisible strength to the crop against excess moisture conditions. Under runoff management situations, bed planting coupled with drip irrigation (Figure 2 of finger millet) using harvested rainwater also serves the need of the farmers.

Figure 2. Vigorous growth of finger millet on beds

Cover crops: Cover crops such as *Mucuna pruriensutilis, Stylosanthes spp., Centrosema pubescens, Pueraria phaseoloides, Setaria spp.* and *Glycine spp*. acts as in-situ mulch. Fallowing with suitable cover crops conserves soil water, improves water use efficiency, weed control and soil organic matter. It is the most acceptable method of building up the organic carbon of soil.

Mulch farming: Maintaining a protective cover of vegetative residues (straw, stalks and stubbles) on the soil surface yields satisfactory results against soil erosion risk. Mulching helps in protecting the soil surface against raindrop impact, decreases flow velocity by imparting roughness, improved infiltration capacity, and enhances the burrowing activity of earthworms (Eudrilus) have been widely reported by improving soil moisture storage in the root zone.

No-tillage farming: No-tillage/zero tillage involves a method of seeding through crop residues by opening a narrow slot in the soil for seed placement without mechanical or secondary tillage operations. The advantages of no-till farming are wide enough and accepted all over the world. Planted cover crops combined with no-till are beneficial in enhancing resource conservation. No-tillage systems have proven less effective on some soils, especially with poor internal drainage, compacted surface and subsoils.

Soil fertility management: The addition of organic manures/compost predominantly increases humus forming material to improve soil structure, water-holding capacity, microbial population and its activity, base exchange capacity and resistance to soil erosion. Proper soil management, ensuring continued maintenance and building up fertility at a high level is crucial for the profitable use of agricultural lands. In addition, the retention or incorporation of residues into the soil is also possible through the application of organic manures. Besides these practices, adoption of good agronomic practices such as deep tillage once every three years through chisel plough, selection of drought or excess moisture stress-tolerant, lodging resistance varieties, application of balanced fertilizers (macro and micronutrients as per the plant needs) along with organic manures, summer ploughing etc. reduces excess soil moisture stress and low moisture stress vis-a-vis.

Conclusion

The success of excess rainfall management depends upon identifying the appropriate strategy or techniques based on acquired knowledge by the farmers for attaining good crop yield under vagaries of climate change conditions. Adoption of good agronomic and soil management practices coupled with biological techniques provides good protection against soil erosion by reducing the velocity of runoff. Physical conservation measures (terraces/contour bunds) have secondary importance in runoff management on steep cultivated lands.

References

Asseng S, Hsiao TC. Canopy CO_2 assimilation, energy balance, and water use efficiency of an alfalfa crop before and after cutting, *Field Crops Research,* (2020), vol. 67 pp. 191-206

Bradford, K.J.; Hsiao, T.C. Physiological Responses to Moderate Water Stress. *Physiol. Plant Ecol*. (2012) II, 12, 263–324.

Debaeke P, Aboudrare A. Adaptation of crop management to water-limited environments, *European Journal of Agronomy*, (2014), vol. 21 (pg. 433-446)

Goldhamer DA, Fereres E. Irrigation scheduling protocols using continuously recorded trunk diameter measurements, I*rrigation Science*, (2021), vol. 20. pp. 115-125.

Howell TA. Enhancing water use efficiency in irrigated agriculture, *Agronomy Journal*. (2021), vol. 93 pp. 281-289.

Hsiao TC, Xu L-K. Sensitivity of growth of roots versus leaves to water stress: biophysical analysis and relation to water transport, *Journal of Experimental Botany*, (2020), vol. 51 pp. 1595-1616.

Hsiao, T.C. Plant Responses to Water Stress. Annu. Rev. *Plant Physiol.*, (2013) vol. 24, 519–570.

Kramer, P.J.Water stress and plant growth. *Agron. Journal.* (2013) 55, 31–35.

Tezara, W., Mitchell, V.J., Driscoll, S.D., Lawlor, D.W. Water stress inhibits plant photosynthesis by decreasing coupling factors and ATP. Nature, (2019) 401, 914–917.

Vartapetian BB, Plant adaptations to anaerobic stress. *Ann Bot*. (2017) 79:3–20