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http://currentagriculturetrends.vitalbiotech.org/

ISSN (E): 2583 – 1933

Curr. Agri.Tren.:e- Newsletter, (2025) *4*(12), 24-27

Current Agriculture Trends:
e-Newsletter

Article ID: 508

Restoring Soil Water-Holding Capacity in Flood-Affected Areas

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Article History
Received: 30. 11.2025
Revised: 5. 12.2025
Accepted: 10. 12.2025

INTRODUCTION

Floods are among the most destructive natural disasters affecting agricultural soils, especially in tropical and subtropical regions. Prolonged waterlogging leads to soil degradation, loss of nutrients, structural breakdown, decline in soil organic matter, and increased erosion upon drying. One of the most critical impacts is the reduction in soil water-holding capacity (WHC)—a key property that determines the ability of soil to retain moisture necessary for crop growth.

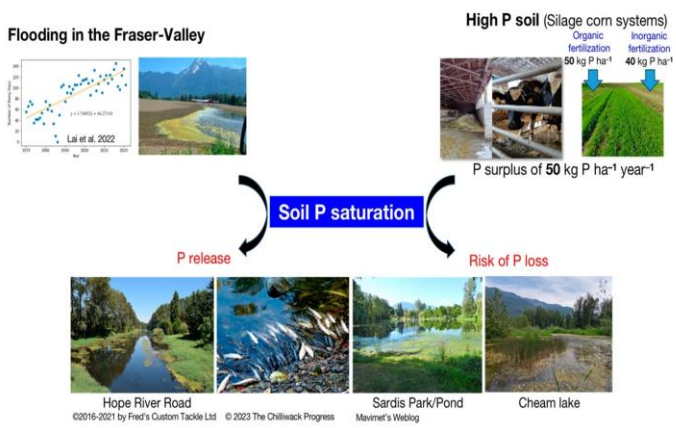
After flooding, soils often exhibit problems such as compaction, reduced infiltration, loss of micro-aggregates, and diminished biological activity, leading to poor soil resilience. Restoring WHC in flood-affected areas is essential for re-establishing soil fertility, improving crop performance, strengthening climate resilience, and ensuring sustainable agricultural production.

2. Flooding Effects on the Properties of Soils

Flooding drastically changes the physical, chemical, and biological nature of the soil. Among others, some of the important impacts of flooding are:

2.1 Soil Structure Damage

- Breakdown of macro-aggregates due to prolonged saturation.
- Dispersion of clay particles and formation of dense layers upon drying.
- Pore space reduced, macropores clogged.



Source: https://www.mdpi.com

ISSN (E): 2583 – 1933

2.2 Soil Compaction

- Heavy standing water increases bulk density.
- Compaction is worsened by machinery use after flooding.
- Root penetration is reduced, thus restricting crop growth.

2.3 Loss of Soil Organic Matter

- Anaerobic decomposition is accelerated by floodwater.
- Drift of plant residues and topsoil erosion reduce the SOM levels.
- Lower SOM decreases the soils capacity to bind and hold water.

2.4 Nutrient Imbalance

- Nitrogen loss through denitrification and leaching.
- Potassium and sulfur washed out.
- Micronutrient immobilization under reduced conditions.

2.5 Reduced Microbial Activity

- Beneficial microbes decline because of low oxygen levels.
- Soil fauna, like earthworms, die or migrate.
- Slower nutrient cycling further reduces WHC.

Source: https://agsolutions.com.au

3. Factors Affecting Soil Water-Holding Capacity

The WHC of a soil is dependent upon several interdependent physical, chemical, and biological factors.

Soil texture is fundamental: sandy soils are dominated by large pores that drain quickly, hence having low WHC, while clay soils retain more water but may have structural collapse after flooding.

Soil organic matter greatly enhances WHC through improved porosity, aggregate stability, and moisture retention. Even a 1% increase in the SOM can result in a 20,000-25,000 gallons per acre increase in WHC.

The soil structure and aggregation determine the balance of macro- and micro-pores, which will affect infiltration and storage.

Bulk density is another important factor; high density reduces pore space thereby limiting retained water.

Biological activity, including earthworms, microbes, and plant roots, creates channels and biopores that enhance porosity and water movement. Restoration strategies must therefore target improvements in texture modification, SOM buildup, structural enhancement, and biological regeneration to effectively rebuild soil WHC in degraded and flood-affected areas.

4. Soil Water-Holding Capacity in Flood-Affected Areas: Possible Restoration Strategies

Different mechanical, organic, biological, and integrated methods need to be undertaken for the restoration of soil WHC in flood-affected areas.

Mechanical and physical interventions: such as deep tillage and subsoiling help break compacted layers formed after prolonged flooding, improving infiltration and root penetration. Land levelling and effective drainage systems, including laser leveling and subsurface drains, prevent future water stagnation. In riverine flood zones, rebalancing sand–silt–clay proportions through clayey soil or FYM addition helps restore soil structure.

Organic amendments: Is the most effective long-term strategy for enhancing WHC. Farmyard manure, compost, and vermicompost enrich soil organic carbon, boost microbial activity, and improve porosity. Biochar significantly increases WHC by 20–40% due to its porous structure and reduces nutrient losses. Green manuring and residue incorporation rebuild aggregates and enhance soil carbon.

Biological approaches: strengthen soil structure naturally. Beneficial microorganisms and mycorrhizae enhance nutrient and water uptake, while earthworms create biopores and improve moisture retention. Deep-rooted and leguminous plants help break compacted layers and add organic matter.

Chemical amendments such as gypsum improve flocculation in sodic soils, while zeolite enhances moisture and nutrient retention.

Integrated practices such as conservation agriculture, cover cropping, and agroforestry further promote long-term soil rehabilitation, improving soil structure and sustaining WHC.

5. Case Studies and Field Experiences

5.1 Indo-Gangetic Plains

- Floods often leave silt to further reduce WHC.
- Solutions: FYM + deep tillage + green manuring increased WHC by 25% over control.

5.2 Assam and Bihar Flood-Affected Areas

Application of biochar at 5 t/ha increased WHC by 30–35%, with associated improvement in crop yield.

5.3 Odisha Coastal Areas

- Saltwater intrusion after cyclones reduced infiltration.
- Application of gypsum + organic matter restored aggregation and water retention.

6. Monitoring and Evaluation of Restoration Success

6.1 Soil Physical Parameters

Soil physical parameters provide a direct measure of improvements in soil structure and water-holding capacity after flooding. Bulk density indicates compaction levels—lower values reflect better aeration and root growth. Porosity measures the volume of pore spaces that store water and air. Aggregate stability shows the soil's resistance to erosion and its ability to retain moisture. Infiltration rate assesses how efficiently water enters the soil, a key indicator of restored soil functionality.

6.2 Soil Chemical Tests

Soil chemical tests help assess the improvement in fertility and water-holding capacity after floods. Soil organic carbon (SOC) is a key indicator of soil health, influencing aggregation, porosity, and moisture retention. Cation exchange capacity (CEC) reflects the soil's ability to hold and exchange essential nutrients, improving plant growth. Nutrient status, including NPK and micronutrients, shows how well the soil supports crop recovery and long-term productivity.

6.3 Biological Indicators

Biological indicators are essential for evaluating soil restoration after flooding because they reflect soil health and ecological functioning. Earthworm population indicates improved soil structure, aeration, and organic matter levels. Microbial biomass carbon measures the abundance of beneficial microorganisms responsible for nutrient cycling and soil aggregation. Enzymatic activities, such as dehydrogenase and phosphatase, show active biochemical processes, signaling enhanced soil fertility and improved water-holding capacity as restoration progresses.

6.4 Remote Sensing and GIS Tools

Remote sensing and GIS play a vital role in assessing soil restoration effectiveness in flood-affected areas. NDVI and moisture index mapping help monitor vegetation vigor, soil moisture distribution, and recovery trends across large landscapes. These tools allow early detection of stress and guide timely interventions. Additionally, monitoring crop growth response through satellite-based imagery provides valuable insights into the impact of restoration practices on overall crop performance and long-term soil health.

CONCLUSION

Floods significantly degrade soil quality by reducing water-holding capacity, destroying soil structure, and depleting organic matter. Restoring WHC is essential for sustainable agriculture, especially in flood-prone regions of India. A combination of mechanical, organic, biological, and chemical approaches, supported by conservation agriculture and integrated management, ensures long-term resilience. Building soil organic matter remains the most effective strategy for enhancing WHC. Innovations like biochar, microbial inoculants, agroforestry, cover crops, and hydrogels offer promising results. Regular monitoring using soil tests and remote sensing helps track progress and ensure sustainable rehabilitation. Restoring WHC improves not only crop productivity but also

ISSN (E): 2583 – 1933

climate resilience and long-term soil health in flood-affected systems.

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