Plant based Bio-drainage Systems for Soil Salinity and Waterlogging Management

Chethan M N[1]*, Arun Kumar M R[1] and Bindu K R[2]

[1]Ph.D. Scholar, Department of Agronomy, College of Agriculture, V. C. Farm, Mandya, Karnataka, India-571405
[2]M. Sc Agriculture, Department of Agronomy, KSNUAHS, College of Agriculture, Shivamogga, Karnataka, India- 577201

Corresponding Author
Chethan M N
Email: chetanmn474@gmail.com

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ABSTRACT

Globally, about 10% of land is affected by waterlogging and over 6% by salinity, reducing soil health and crop productivity. Although conventional drainage systems work effectively, they are expensive and produce effluents that are difficult to handle. Biodrainage offers a sustainable alternative by using deep-rooted, fast-growing and high-transpiring plants to remove excess water and salts through evapotranspiration. This approach not only lowers groundwater levels but also enhances nutrient conservation, promotes carbon sequestration, supports biodiversity and improves crop performance, making it a viable strategy for integrating agroforestry into cropping systems and restoring sustainability in affected agricultural systems.

INTRODUCTION

Waterlogging and soil salinity are major constraints to agricultural productivity in irrigated and rainfed regions, especially where groundwater tables are shallow and fluctuate seasonally. In India, about 4.5 million hectares (M ha) are affected by waterlogging, with 2.2 M ha in canal command areas and 2.3 M ha outside them. Salt-affected soils occupy nearly 6.73 M ha, comprising 2.96 M ha of saline soils and 3.77 M ha of sodic soils. These degraded lands may occur independently or

together, further restricting crop production. In Karnataka, salt-affected land covers approximately 0.15 M ha, posing a significant challenge to sustainable agriculture. In such areas, biodrainage serves as a promising management strategy, using deep rooted and rapidly growing plant species to extract surplus moisture from the capillary zone above the groundwater table. The absorbed water is moves within the plant and predominantly dissipated into the atmosphere through transpiration, thereby lowering excess soil moisture and improving soil physical conditions. This combined process of absorption, translocation and transpiration of excess ground water into the atmosphere through the deep-rooted vegetation defines the concept of bio-drainage.

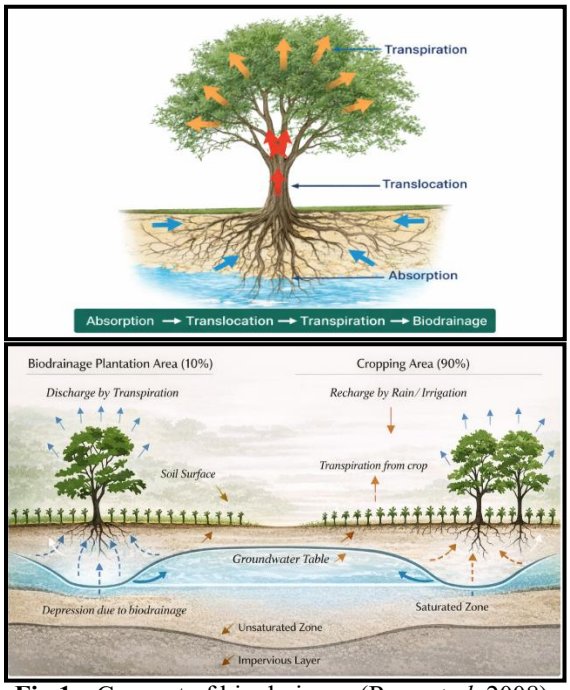

Fig 1:- Concept of bio drainage (Ram *et al*.,2008)

This combined process of absorption, translocation and transpiration of excess ground water into the atmosphere through the deep-rooted vegetation defines the concept of bio-drainage. Through this process, trees help to extract excess moisture and dissolved substances such as salts from the soil and groundwater, thereby acting as natural biological filters that reduce soil salinity and excess water accumulation.

Mechanisms of bio drainage

- Deep-rooted trees can extend into the saturated zone or capillary fringe above the groundwater table and help regulate shallow groundwater levels, whereas shallow-rooted annual crops have little or no contact with groundwater and therefore play a limited role in controlling water table levels.
- For biodrainage to be effective, trees should be fast growing and capable of high transpiration so that they can withdraw large amounts of water from the capillary zone above the groundwater table. Water absorbed by these tree roots is transported to different plant parts and more than 98% of this water is released into the atmosphere through transpiration, mainly via stomata.
- The main aim of a biodrainage system is to lower a high groundwater table to around 2 m below the soil surface to reduce capillary rise of salts and prevent soil salinity, with studies showing that tree plantations can lower the water table by about 1–2 m within 3–5 years (Gafni and Zohar, 2001; Heuperman *et al*., 2002).

Potential Tree Species for Biodrainage Applications

Eucalyptus camaldulensis, Eucalyptus tereticornis, Leucaena leucocephala, Acacia nilotica, Dalbergia sissoo, Sesbania grandiflora, Casuarina equisetifolia, Casuarina obesa, Casuarina cunninghamiana, Hardwickia binate, Casuarina glauca, Acacia stenophylla, Eucalyptus occidentalis, Guazuma ulmifolia and Leucaena shannonii

Fig. 2:- Eucalyptus + Rice intercropping in wetland farm of Kumulur, Tamil Nadu (Source: Masilamani *et al*., 2019)

Advantages of biodrainage

- Bio-drainage is a cost-effective and sustainable approach for managing excess groundwater in waterlogged areas.
- Once established, it requires very little maintenance, making it suitable for long-term use.
- Deep-rooted trees help lower the groundwater table by continuously extracting water from the soil profile.
- Bio-drainage improves soil health by reducing waterlogging and secondary salinization.
- The system contributes to carbon sequestration and supports environmental sustainability.
- Tree-based systems provide additional income through the production of timber, fuelwood, fodder and other tree products.
- Bio-drainage enhances the farm ecosystem by creating green cover and supporting biodiversity.
- It can be easily integrated into agroforestry systems without affecting crop production.

Disadvantages of biodrainage

- Establishment of tree plantations demands additional land, often occupying about 10–15 per cent of a farmer's total landholding.
- Young trees require supplemental irrigation to ensure proper establishment and survival.
- Tree saplings are vulnerable to damage during the initial stages of growth.
- Reduction in groundwater levels is usually limited during the early years of plantation development.
- Trees may compete with adjoining crops for light, soil moisture and nutrients, which can influence crop growth.
- Tree plantations may also encourage increased movement of wild animals, such as blue bulls, leading to disturbances in regular farming operations

CONCLUSION

Waterlogging and soil salinity are major constraints to agricultural productivity in arid and semi-arid regions, particularly in areas with poor natural drainage. Rising groundwater tables promote the upward movement of salts through capillary action, creating unfavorable conditions for crop growth. Biodrainage is a plant-based technique that uses deep-rooted and high-transpiring vegetation to remove excess soil water and regulate shallow groundwater levels. Its effectiveness depends on the selection of salt and waterlogging tolerant species, appropriate planting density and suitable spatial arrangement. Biodrainage can be practiced under both rainfed and irrigated conditions and contributes to improved soil conditions and crop performance. *Eucalyptus* has shown strong potential due to its rapid growth, extensive root system and high transpiration capacity, making it well suited for managing waterlogged and saline soils, while prominent woody species such as *Acacia nilotica,*

Dalbergia sissoo and *Hardwickia binata* can also be grown, offering both effective in water regulation and high economic returns, making them valuable options for integrating into biodrainage systems.

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