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Review Paper

Sustainable Remedies for Water-logging and Salinisation Hazards- A Review

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ABSTRACT

Water-logging and Salinisation are burgeoning menaces in the recent times due to myriad of factors such as increase use of irrigated water in the agricultural fields, unsuitable cropping pattern, climate change, faulty drainage system etc. These hazards ultimately pose serious threat to the sustainability of both economic and environmental sectors. Control and management of these hazards is therefore, the need of the hour for safeguarding our environment. Various conventional engineering measures as well as modern non-engineering techniques are available in the literature to remediate these problems which are especially brutal issues of irrigated arid and semi-arid regions. But individual application of these measures always come up with some limitations or is not preferable for different areas. So, sustainable approaches depending upon the areas affected or integrated approaches where conventional engineering measures are combined with non-engineering measures are the proper solutions for control and management of these menaces. In this review, we have explained some of the important remedies available in literature based on a particular area for managing the twin hazards and to analyze the sustainable solutions based upon the measures discussed.

Introduction

Water-logging and Salinisation are two brutal issues that are spreading at a much faster rate throughout the world causing immense economic and environmental losses. They have the potential to threaten the sustainability of both agriculture and environment sectors (Singh, 2015). Various factors are responsible for waterlogging menace such as heavy rainfall, improper irrigation practices, clayey soil, faulty drainage systems, shallow water table, and seepage from upstream reservoirs etc (Bilal et al., 2014; Pandey et al., 2015). It ultimately leads to the hazard of salinisation due to evaporation of the excess irrigated water in arid or semi-arid regions specially or due to reduction in the ability of roots to screen out salt at the root surface. These menaces are more common in *arid and semi-arid regions* compared to other regions. Both the hazards altogether are much more damaging than either alone. Usually, rainwater or irrigated water that falls on the surface of the soil is infiltrated or percolates down into the ground and stored in the aquifers maintaining the natural water cycle. However, increase in the anthropogenic factors/activities such as land-use changes, climate change, bad irrigation practices, drainage congestion etc, aggravated the menaces of waterlogging and salinisation (Ghosh and Misti, 2020) in recent times. The resultant effects are reduced oxygen condition in the soil, alteration of pH of the soil making it more acidic that affects plant growth and productivity (Hassani et al., 2020), variation of soil temperature leading to reduced activities of micro-organisms, accumulation of harmful salts etc that makes an area unsuitable for humans (Sahu, 2014). But, in some instances, people consider the water-logged condition as an opportunity for fishing activity and rice cultivation. According to estimates, global economic losses due to soil salinization is around US $27.3 billion per year (Qadir et al, 2014) and around 23 million ha of land are affected only due to salinisation and 14 million ha due to water-logging in India (Kumar and Sharma, 2020). Again, there is a record of damage of 2.04 million hectares of land in India by waterlogging alone that represents 4% of all irrigated area in the country. Percentage of salt-affected lands is also increasing with time (Metternicht and Zinck, 2003) and occurs on more than half of the irrigated land in some countries (Table 1). The control of these menaces is therefore, the need of the hour to protect our agriculture and environment sectors. These hazards can be dealt with either by abandoning the affected land or by learning to cope with these disasters. Due to burgeoning global population, we cannot totally abandon the water-

logged and salt-affected lands or allocate some areas for salt-drainage (Konucku et al., 2006), so we should search for some sustainable solutions to control these menaces. In literature, various ways are available to act against the brutality of these issues (Kisekka et al., 2017, Bezborodov et al., 2010). Identification and mapping of the water-logged and salinized areas using Geographic Information System (GIS), Landsat 5 TM, ASTER data etc are some of the ways for dealing with these hazards (Sahu, 2014). The various ways described in the literature for the control and management of water-logging and salinisation are not clearly expressive as one particular way explained is not sufficient to control the twin hazards simultaneously and also some of the measures are area-specific. In the long run, those solutions should be preferred which serves both *economic and environmental sectors* or integrated management approach should be followed. In this mini-review, we have discussed some of the most preferable remedies based on particular areas for control of the twin hazards of water-logging and salinization along with their advantages and disadvantages and finally the conclusion.

Method

This study made use of a review of academic articles, textbooks, internet materials, bulletins and conference papers on waterlogging and salinisation hazards. This led to the compilation of various researchers' work on combined or individual consequences of both these menaces and strategies followed for their prevention and management.

Table 1. Regional Distribution of Salt-affected soils (in million hectares)

Regions	Total Area	Saline soils	Percent
Asia, Australia and the Pacific	3107.2	195.1	6.3
Europe	2010.8	6.7	0.3
Latin America	2038.6	60.5	3.0
Africa	1899.1	38.7	2.0
North America	1923.7	4.6	0.2
India	297.3	6.2	2.1

Source: *FAO data based on the FAO/UNESCO Soil Map of the World (Sengupta, 2002)*

Conventional Engineering Approaches

Conventional engineering approaches are traditional approaches consisting of physical drainage measures such as tube-well, sub-surface drainage, vertical drainage etc for dealing with the twin issues of water-logging and salinisation. These approaches are more useful when the twin issues exist in continuity on the same land and where the sub-soils are sufficiently stable (Sarkar et al, 2019), but at the same time become less useful when cost factor and maintenance comes and huge quantity of drainage effluents are generated that needs to be either recycled or disposed. The disposed effluents again can lead to salt loading of rivers, environmental concerns and complain by the neighboring land owners due to drainage effluents passing across their fields (Singh, 2015). The drainage effluents generated usually consists of nutrients, salts, agro-chemicals and other pollutants that ultimately pollutes our river bodies and agricultural fields, so options for controlling these hazards should be affordable as well as eco-friendly which can be adopted in the long-run in all sectors. These conventional approaches cannot be considered sustainable due to their high cost which farmers are reluctant to pay, unmanageable drainage effluents, environmental concerns etc. However, they can be used in conjunction with the sustainable techniques discussed below or in some instances, the subsurface pipe and vertical well drainage measures can be combined on agricultural soils ecosystem to improve saline-alkali soils (Heng et al., 2022).

Mulching

Mulching is actually a cultural practice that involves covering of the soil surface around the plants with a living or non-living mulch (Kader et al, 2017a). It is another way of dealing with the hazards of water-logging and salinisation by growing plants in water-logged soils and spreading either organic or inorganic materials on top of the soil (Prem et al.,2020). Mulching can be done in various ways such as organic mulching, inorganic mulching, surface mulching, plastic mulching etc that altogether improves productivity and soil structure, increases the availability of nutrients and improves drainage of excess water and also increases water holding capacity of the soil (Kader et al, 2017c) for long time within the soil. It can also be used to prevent the growth of weeds (Sharma and Bhardwaj, 2017), to retain moisture content of the soil and erosion control (Ranjan et al., 2017). Again, mulching and micro-irrigation techniques play a major role in managing excessive irrigation in the fields (Prem et al., 2020).This practice has also some limitations in spite of various benefits such as it may harbor some insects, pests and diseases, more labour requirement, removal and disposal problems, contamination of soil etc. (Steinmetz et al., 2016) which can however be resolved to some extent by using biodegradable and photodegradable mulches.

Bio drainage

Bio drainage is another emerging technology for sustainable management of both water-logging and salinization stress under rainfed as well as irrigated conditions (Dash et al., 2005). In this technique, suitable species of deep rooted fast growing trees are planted that can absorb substantial amount of water from root zone, translocate them to the different plant parts and hence lower down the water-table through evapotranspiration (Ram et al., 2021). Various tree species such as *Eucalyptus, Populus,*

Casuarina, Acacia, Leucaena etc are found to be effective in controlling water-logging and disposing large volume of saline water available in arid areas (Singh and Lal, 2018). Their consumptive water-use varies between 6500 and 28000 m3ha-1 yr-1and can lower the ground water table by 1-2m over a time-period of 3-5 years. *Eucalyptus* trees species are more preferred as they not only lower the water-table and grow fast in diverse soil and climatic conditions, but also increase the crop yield, build up soil nutrients and result in reclamation of water-logged areas in developing countries like India (Ram et al., 2007, Ram et al., 2011; Banik et al., 2018).

It is thus, a combined drainage-cum-disposal system that is economically viable, socially acceptable and eco-friendly drainage measure. In addition, it helps in carbon sequestration and carbon credits, mitigates the problem of climate change and also contributes to increase forest cover, production of food, fodder, fuel wood etc that provides higher income to the farmers (Ram et al., 2011). Despite so many advantages, the biodrainage system has some limitations also such as they result in salt accumulation when the irrigation water is too saline and also not profitable for small farms, thus they can be integrated with conventional engineering approaches to solve these constraints (Patra and Banik, 2018). Some other constraints of this system are requirement of large area for planting the trees, uncontrolled lowering of water table, vulnerability of trees to highly saline conditions (Angrish and Toky, 2014) etc. Also, the planting of the trees used for biodrainage should surround the water-logged area; they should not be planted within (Sarkar et al., 2019). Hence, there should be a *demarcation of recharge and discharge zones* while planning for implementation of bio-drainage system which can be done using GIS so that it can act as both preventive as well as curative system.

Dry-drainage

Dry-drainage is another sustainable approach for controlling the problems of water-logging and salinisation especially in the arid and semi-arid regions. In this system, some fallow areas are kept as salt-discharge areas that operate as *evaporative sinks* extracting or drawing water and salt from neighboring cultivated areas. The fallow areas allocated should be large enough and evaporation from those uncultivated areas should be fast enough for dry-drainage technique to be successful (Konukcu et al., 2006). This type of scheme is more beneficial in the arid and semi-arid regions where evaporative demand is very high and resultant soil salinization is so serious that farmers often abandon those salinized areas which can therefore, be used as "evaporative sinks" to store excessive salts. Successful application of dry-drainage or allocation of salt-drainage areas which is an optimization of dry-drainage system can be found in some recent studies by Konukcu et al., (2006),Wang et al.(2019) etc. They showed that dry-drainage mechanism would be fruitful when the cultivated area and sink area were approximately equal and water-table depth is around 1.5 m. Another constraint of this scheme is that some balance models are required to optimally allocate the parameters of the fallow areas such as numerical models, mass balance models etc (Huang et al, 2021). The optimal allocation of the parameters such as the area ratio of cultivated land to salt discharge areas, the excavation depth, and location layout of salt discharge areas is required for cost-effective and sustainable control of the salinization hazard which can be effectively done by mass-balance or integrated spatial agro-hydro-salinity model namely *SahysMod tool* (Singh et al., 2012; Huang et al., 2021).

Results and Discussion

Water-logging and salinisation are two spatio-temporal phenomena that vary in characteristics at different areas and lead to heavy loss in agriculture and economic sectors. To control these hazards, different approaches discussed above should be used depending upon the areas affected for example, dry-drainage measure should be used in arid and semi-arid areas (Konukcu et al., 2006, mulching can be used for small farms (Prem et al., 2020) etc. and the solutions should be applied considering the sustainability of the approaches. Conventional engineering propositions can be used in areas where the twin hazards of water-logging and salinization exist in continuity but this approach is not sustainable and useful in the long run due to cost and maintenance factors. Mulching helps to cope with the twin menaces in small farms by growing plants or crops within the affected areas and spreading organic or inorganic mulches that improves drainage, availability of nutrients and soil productivity etc on one hand while harbors insects, pests and diseases with contamination of soil on the other hand. Dry-drainage approach or allocation of salt-drainage areas can be considered effective solution for arid and semi-arid regions. However, proper models such as Sahys Mod should be utilized to optimally allocate the parameters of the salt-discharge areas for successful control of the salinisation hazard and sustainable utilization of cultivated land using dry-drainage. The more eco-friendly and sustainable approach, biodrainage could be used in humid to semi-arid areas where some particular tree species such as Eucalyptus, Populus etc are utilized to control the burgeoning menaces of water-logging and salinization. Eucalyptus species having deep root systems are more preferred that can pump excess irrigated or soil water using their bioenergy and radiant energy of the sun (Ram et al, 2021).

This drainage-cum-disposal system is a promising option for overcoming the threats of water-logging and salinisation when proper demarcation of recharge and discharge zones are done using GIS. Again, this approach is not suitable for small farms or for excess salinized areas, but if integrated with other approaches can give better results. Combination of these approaches in integrated form depending upon the areas affected would help to remediate the problems of water-logging and salinisation in this long-run. In this review, it is seen that better irrigation practices and drainage management of the water-logged and

salinized areas alone are not going to solve the twin hazards, rather a combination of various engineering and modern approaches available must be used in integrated way or individually depending upon the areas affected.

Conclusion

A review study has been done on sustainable remedies for managing the twin menaces of water-logging and salinisation. It has been found that various engineering and non-engineering approaches are available in the literature that can play an important role in controlling and managing these hazards. Conventional surface and sub-surface technology is available that can manage those twin hazards when they exist in continuity on the same land but it cannot be considered sustainable approach due to cost and maintenance factor and it also leads to environmental degradation. Looking at the burgeoning population of the world, abandoning of the affected lands is also not a good option so sustainable propositions such as biodrainage, dry-drainage, mulching etc can be adopted to manage the increasing problems of water-logging and salinisation hazards in different areas of the world. These approaches although are cost-effective, eco-friendly and socially acceptable but present some limitations in some instances, which could be rectified by integrating them with some engineering propositions wherever needed or conjugated approaches consisting of one or two measures should be followed.

Recommendations

Some future suggestions after analyzing the various sustainable measures to control water-logging and salinisation hazards can be forwarded as:

Further research should be done on integrated approaches of various measures discussed for a proper solution of these menaces. Salt-tolerant crops such as cotton, alfa-alfa etc should be raised to deal with the issue of salinization or mulch can be spread on water-logged areas to manage excess irrigation. Biodrainage plants such as Eucalyptus should be planted in parallel strips in tropical to temperate areas to reclaim the water-logged and salinized areas by using bio-energy of plants and radiant energy of the sun. Dry-drainage mechanism can be applied in arid and semi-arid areas for controlling water-logging and salinization. Identifying a problem is the first step to solve it, so geospatial techniques can be used to identify the water-logged and salinized areas and develop water and salt balance models which ultimately helps to control and manage those areas. Finally, conjugated approaches or simultaneous application of multiple approaches would probably help us to solve these twin menaces of water-logging and salinization in different areas of the world.

Data Availability Statements

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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