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Phyto-sociological Analysis of Waterlogged Saline Lands of Indian Trans-Gangetic Plains

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Abstract: In the present investigation, a phyto-sociological study in managed and abandoned waterlogged saline sites of Trans Indo-Gangetic plains was undertaken. It was pilot location study done in Sonipat district, Haryana which falls under severely affected category of the waterlogged and salinity problem. The study area was grouped into managed and abandoned sites. In managed sites, the dominant tree was *Eucalyptus* planted in block and boundary arrangement. *Prosopis juliflora* (Mesquite) was dominant tree in abandoned sites without any definite planting pattern and accompanied by low values of shrubs and herbages. *Digitaria sanguinalis* (crab grass) showed highest relative density (53.0) and relative value index (153.0) with lowest value of both the indices (0.56 and 50.6) in *Saccharum ravennae* (elephant grass) in managed sites. *Cyanodon dactylon* showed dominance with highest relative density (63.0) and relative value index (163.0) with lowest (14.0 and 114.0) in *Tamarix dioica* (red tamarix) in abandoned sites. Shannon Weiner (0.46) and Simpson (0.58) Indices were higher in managed sites than abandoned ones. Higher degree of richness in flora in managed waterlogged saline sites is equally supported by the higher species value of diversity index (0.02) than abandoned (0.01) sites. The results of the investigation advocate that the managed sites can render better services than the abandoned sites on phyto-sociological aspects in waterlogged saline landscapes. Higher species richness in managed sites can be linked to better outcomes from ecological and economic perspectives.

Keywords: Biodiversity, *Eucalyptus,* Relative density, Species diversity, Waterlogged saline soils

Geogenic processes and anthropogenic factors resulting in the formation of salt affected soils and the adversities of climate change further fuel to its extent that too in new areas. Globally, one billion hectare area falls under salt lands and out of which 1/3rd is irrigated waterlogged in nature. With each year, 1.50 m ha landmass is adding to the total salt affected areas, globally and if this pace will continue then it would spread to 50 per cent of the cultivable lands by 2050 (Hasanuzzaman et al 2014). In India, 6.73 m ha landmass is affected by salinity (Mandal et al 2010). This problem is more intense as the underlain aquifer is of saline and alkaline in nature. Waterlogged soils cover 4.33 per cent area of the total degraded and wastelands of the country (Maji et al 2010). Waterlogging and salinity is cause of concern to the sustainability of irrigated agriculture in irrigation commands as it is engulfing the culturable lands especially in the Trans Indo-Gangetic plains. This problem occupies more than 3.0 m ha area found in 17 Indian states including Andaman Nicobar islands covering inland and coastal salinity. Trans Indo-Gangetic plains are well known for higher productivity owing to its geographical location and inherent parent material. This region is popularly known as the bread basket of India producing nearly 66 per cent of the total food grains covering the fertile states of Punjab, Haryana, Uttar Pradesh, Bihar, plains of Rajasthan as well as the union territories of Chandigarh and Delhi with total area of 11.7 m ha (Sharma et al 2011, Kaskaoutis et al 2014). Poor drainage system and excessive use of ground water is resulting in waterlogging combined with salinity in the region. Particularly in Haryana state the existing and potential waterlogged saline soils lie mainly in inland depression basin covering Rohtak, Jhajjar, Hisar, Bhiwani, Charkhi Dadri, Sonipat and parts of Jind, Fathebad, Sirsa and Palwal districts.

Drainage, a conventional engineering approach is considered as main remedial option to remove excessive water and salts from the rhizosphere coupled with landshaping technologies for reclamation of waterlogged saline soils. However, such approaches are capital intensive with certain environmental concerns. Contrary to this, biological approaches with the capability of drawing down the water table through combined process of absorption, transpiration and translocation can be trusted upon to address the concern of drainage and other issues. The most common tree in biodrainage is *Eucalyptus tereticornis* (Ram et al 2007, Banyal et al 2019). Analysis of the vegetation structure, composition and organization can be achieved with the help of phyto-sociological study of the area to develop the understanding and functional mechanisms of organisms in any community. It is utmost important to design the suitable plant based systems for efficient management with better outputs through biological approaches especially for salt affected soils. This concept is also applicable to waterlogged saline areas for their biological management by keeping environmental concerns under check. The information about the vegetation structure in natural and man-managed waterlogged saline soils is flimsy and needs comprehensive research. Therefore, the study has been piloted to work on the general vegetation structure to identify the most exacting floral species (trees, shrubs, grasses and others) for ecological rehabilitation besides multifarious economic outputs in waterlogged saline ecologies of the Haryana state.

MATERIAL AND METHODS

Study area: The study was done in three blocks (Mundlana, Kathura and Gohana) of Sonipat district covering managed and abandoned areas suffering with waterlogging and salinity. This district falls under the severely affected waterlogged saline group in the state. The affected blocks of the district were surveyed through transact walk and sites were then randomly selected as per the standard protocols by covering at least 10 per cent of the total affected area for the study (Fig. 1). The selected sites (villages) were Kathura (29°04'47 N, 76°34'53 E) in Kathura block, Jagsi (29°13'48 N, 76°39'48 E) in Mundlana block and Banwasa (29°08'52 N, 76°33'22 E) in Gohana block for detailed phyto-sociological studies. Observations on floral type, abundance, frequency, density and biodiversity were recorded in post monsoon season (September and October, 2022).

Floristic data: Field observations on phyto-sociological aspects was done using the specific quadrat method viz. 10 x 10 m for trees, 5 x 5 m for shrubs and 1 x 1 m for herbs/annuals in each selected sites. Flora naturalized and/or growing in each site was identified on morphological basis using taxonomic references and through the help of locals. The observations on density, frequency and Importance Value Index (IVI) were calculated using the procedure and formula given by Cottam and Curtis (1956) and Misra (1968).

Density and Frequency were calculated using the formula given below:

$$\text{Density} = \frac{\text{Total number of individuals}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Frequency} = \frac{\text{Number of quadrats in which species occur}}{\text{Total number of quadrats}} \times 100$$

The Relative Density, Relative Frequency was calculated using the formula given below:

$$\text{Relative density} = \frac{\text{Number of individuals of the species}}{\text{Total number of individuals of all the species}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Number of occurrence of the species}}{\text{Number of occurrence of all the species}} \times 100$$

The Relative Importance Value Index (RVI) of grass species was calculated by summing the value of relative density and relative frequency.

RVI = Relative frequency + Relative density

Biodiversity Indices: Shannon-Weiner diversity index and Simpsons' index used to determine the species richness in the study area.

Shannon-Weiner diversity index is calculated using the following equation (Shannon-Weiner 1963):

$$H' = -\sum_{i=1}^{s} pi \ln pi$$

Where H' is the species diversity index, s is the number of species, and

pi is the proportion of individuals of each species belonging to the ith species of the total number of individuals.

Simpsons' diversity index: This was calculated using the formulae given below Simpson (1949):

$$D = \sum (n/N)^2$$

Where, n is the total number of individuals of a particular species, N is the total number of individuals of all species

Simpson's diversity index (D) = 1- Simpson's Index

Species diversity index (SDI):

$$\text{SDI} = \frac{\text{Number of species encountered}}{\text{Total number of individuals of all the species}}$$

RESULTS AND DISCUSSION

The higher species diversity was found in managed sites compared to abandoned sites in the study area. Managed sites showed predominance of *Eucalyptus* based block and boundary plantation models whereas few scattered trees of *Prosopis juliflora* (Mesquite) without any specific planting pattern in abandoned sites (Table 1). *Eucalyptus tereticornis* covered 11.1 per cent of the total area under the sampled

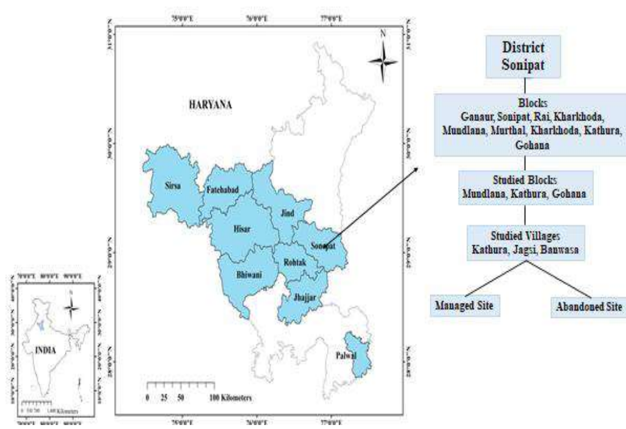

Fig. 1. Scheme of site selection

managed sites. Likewise, *P. juliflora* occupied 8.80 per cent of the area in abandoned waterlogged saline sites. There was no shrub growing on the managed sites owing to the human interventions for higher productive components like trees and agronomical crops. The, salt loving *Tamarix dioica* abundantly grown and occupied about 12.8 per cent of the total sampled area in abandoned sites. Higher species diversity was observed in herbaceous flora in both types of sites. The majority of the herbaceous flora species belongs to grass family. The species wise distribution of annual grass species on both sites are presented in Figure 2 and 3. In total, six grass species (*Cirsium arevense*, *Digitaria sanguinalis*, *Cyanodon dactylon*, *Marsilea quadrifolia*, *Cyantillium cinereum* and *Saccharum ravennae*) were identified from the sampled area under managed sites. All grass species cumulatively covered 88.9 per cent of the total sampled area in the quadrate. *Digitaria sanguinalis* (Crab grass) occupies maximum area (47.0%) among all the six grass species accentuating its wide spread in the study area. The area occupied by other grass species were in the order of 0.50 per cent in *Saccharum ravennae* (Elephant grass) <1.50 per cent in *Cirsium arevense* (creeping thistle) <1.75 per cent in *Cyantillium cinereum* (Little ironweed) <6.25 per cent in *Cynodon dactylon* (bermuda grass) <31.8 per cent in *Marsilea quadrifolia* (Water clover) <47.0 per cent in *Digitaria sanguinalis* (Crab grass) in managed sites. However, only two grass species (Bermuda and nut grass) were found in abandoned sites covering an area of 78.4 per cent of the total sampled area. The area occupied by Bermuda grass was 57.4 per cent and by nut grass was 21.0 per cent from the total covered area by both the grass species, respectively (Table 2). Maximum grass species richness (density) was observed with crab grass followed by water clover and minimum in elephant grass (Table 3). The species wise share was in the order of crab grass (53.0%)> water clover

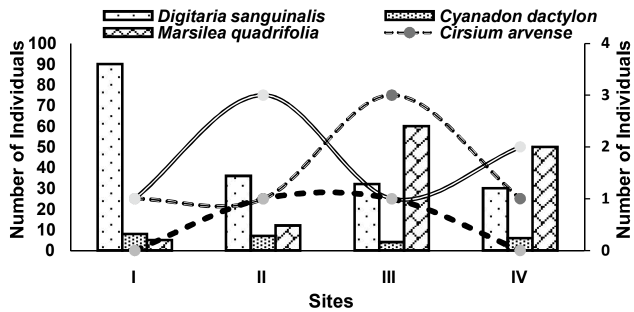

Fig. 2. Species wise distribution of herbaceous flora in managed sites

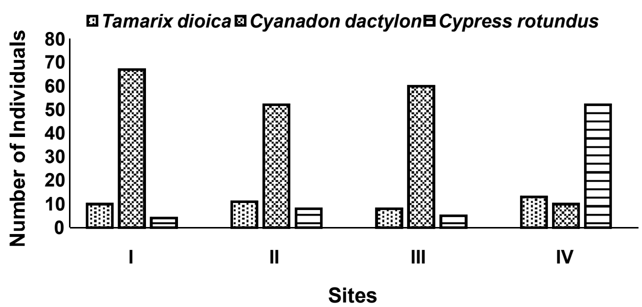

Fig. 3. Species wise distribution of herbaceous flora in abandoned sites

Table 1. Identified flora species in managed and abandoned waterlogged saline sites

Floral diversity		Waterlogged saline sites	
Botanical names	Popular names	Managed sites	Abandoned sites
A. Trees			
Eucalyptus tereticornis	Safeda	+	-
Prosopis juliflora	Mesquite	-	+
B. Shrubs			
Tamarix dioica	Tamarix	-	+
C. Herbaceous flora			
Cirsium arevense	Creeping Thistle	+	-
Digitaria sanguinalis	Crab grass	+	-
Cyanodon dactylon	Bermuda grass	+	+
Marsilea quadrifolia	Water clover	+	-
Cyantillium cinereum	Little ironweed	+	-
Saccharum ravennae	Elephant grass	+	-
Cypress rotundus	Nut grass/Motha	-	+

+ = Present; - = Not present

(35.8%)> bermuda grass (7.04%)> little ironweed (1.97%)> creeping thistle (1.69%) and elephant grass (0.56%), respectively. Further, due to less number of species in abandoned sites, the combined shrub and annual grass species richness (density) was maximum in Bermuda grass followed by nut grass and minimum in tamarix. The share of density was in the order of Bermuda grass (63.0%)> nut grass (23.0%)> tamarix (14.0%), respectively.

The relative frequency of all the grass species in both the managed and abandoned sites was hundred per cent except for Elephant grass which gave 50 per cent value (Table 2). Similar to species richness, the maximum relative density was recorded in Crab grass in managed sites and bermuda grass in abandoned sites. The maximum Relative Value Index (RVI) was observed in crab grass (153.0) followed by water clover (135.8) and the minimum in elephant grass (50.6) in managed sites. However, the highest RVI value was observed in bermuda grass (163.0) and the lowest in tamarix (114.0) in abandoned sites.

Analysis of biodiversity indices provides the information about the social status of the vegetation in community under the studied sites. Overall, comparative site wise indices were derived for both managed and abandoned waterlogged saline sites (Fig. 6). The managed waterlogged saline sites were higher in biodiversity indices value compared to abandoned site with respect to Shannon and Simpson's diversity index. Further, Simpson's diversity index value was lower (0.41) in managed sites than abandoned site (0.47),

Table 2. Area covered (%) with herbaceous floral species in managed and abandoned waterlogged saline sites

Floral diversity		Waterlogged saline sites	
Botanical names	Popular names	Managed sites	Abandoned sites
A. Trees		Area covered (%)	
Eucalyptus tereticornis	Safeda	11.1	-
Prosopis juliflora	Mesquite	-	8.81
	Total	11.1	8.81
B. Shrubs			
Tamarix dioica	Tamarix	-	12.8
C. Herbaceous flora			
Cirsium arevense	Creeping Thistle	1.50	-
Digitaria sanguinalis	Crab grass	47.0	-
Cyanodon dactylon	Bermuda grass	6.25	57.4
Marsilea quadrifolia	Water clover	31.8	-
Cyantillium cinereum	Little ironweed	1.75	-
Saccharum ravennae	Elephant grass	0.50	-
Cypress rotundus	Nut grass/Motha	-	21.0
	Total	88.9	78.4
	Total quadrate sampled area	100	100

Table 3. Phyto-sociological parameters of herbaceous flora growing in waterlogged saline areas

Types of sites	Botanical name	Popular name	Density	Frequency	Relative density	Relative frequency	Relative value Index
Managed sites	*Cirsium arvense*	Creeping thistle	1.50	100	1.69	100	101.7
	Digitaria sanguinalis	Crab grass	47.0	100	53.0	100	153.0
	Cyanadon dactylon	Bermuda grass	6.25	100	7.04	100	107.0
	Marsilea quadrifolia	Water clover	31.8	100	35.8	100	135.8
	Cyantillium cinereum	Little ironweed	1.75	100	1.97	100	102.0
	Saccharum ravennae	Elephant grass	0.50	50.0	0.56	100	50.60
Abandoned sites	*Tamarix dioica*	Tamarix	10.5	100	14.0	100	114.0
	Cyanadon dactylon	Bermuda grass	47.3	100	63.0	100	163.0
	Cypress rotundus	Nut grass/ Motha	17.3	100	23.0	100	123.0

yielding higher diversity in managed site than abandoned sites. Specifically in managed site maximum Shannon-Weiner index was in Water clover (0.16) followed by crab grass (0.15) and elephant grass (0.01). Likewise, Simpson's index value was highest in crab grass (0.28) and lowest in elephant grass (0.00003), illustrating that crab grass emerged as dominant herbaceous species growing managed waterlogged saline sites in Haryana (Fig. 4). In abandoned sites, Shannon-Weiner index was higher (0.15) in nut grass whereas, and Simpson's index in bermuda grass (0.40) (Fig. 5).

Both *E. tereticornis* and *P. juliflora* are phreatophytic tree species which are capable of growing on salt laden soils (Basavaraja et al 2007, Saini et al 2012, Dagar et al 2016, Minhas et al 2020). *Eucalyptus* is the only dominant tree species commonly grown in managed waterlogged saline sites in the study area. Farmers' preferred this species owing to its better phreatophytic nature results in performance in waterlogged saline soils where other tree species can't grow. The other reason for it dominance is the market availability. The other important reason is its higher value in terms of utilization based on time factor as compared to any other tree species in case of waterlogged saline lands (Ram et al 2007, Banyal et al 2019). In abandoned sites, the dominance of *P. juliflora* is beyond any doubt that this is highly tolerant tree species to grow in severely affected waterlogged saline lands. It performs exceptionally well in greening the worlds' dry zones especially saline, alkaline, saline-alkaline (usar) and waterlogged, where no other vegetation exists. Introduction of *P. juliflora* to new areas of the world from its native places North America, South America, Africa and South Asia with a hope to derive analogous benefits from it but it was not as expected. It started spreading and multiplying much faster rate than it was in its natural habitat and turned to be invasive. It has been listed in the world's 100 most dominant invasive plants. This is the reason for its dominance in abandoned waterlogged saline lands. The absence of shrubs in managed sites can be asserted to the intervention by humans as shrubs have no commercial value growing in waterlogged saline sites. However, in abandoned sites shrubs are the dominant component of vegetation structure. It is supported by the findings that Ttmarix is amongst few of the pioneer species tolerant to such harsh situations and can be helpful in initiating the reclamation process for further improvement and utilization of saline landscapes for higher outputs. Vegetation helps in modification of soil properties in terms of physico-chemical attributes in saline landscapes (Duan et al 2022). Joshi et al (2021) also suggested that grasses or herbs exhibit maximum species diversity under and around trees. Crab grass are well known to naturalized in problematic sites and is palatable to livestock adding to its higher utilization value (Jennings et al 2014, Corli and Orsenigo 2022) suggesting that this grass species should have more focus for betterment of waterlogged saline soils in reclamation and output perspectives in managed site. Bermuda grass is well known to salt tolerance thus showed its dominance in abandoned sites with relative value index of 163.0 in the study area. The soil salinity tolerance of bermuda grass goes upto 20.0 dS m^{-1} making it dominant species in abandoned waterlogged saline landscapes (Tran et al 2018).

Presence of such diverse species on both managed and abandoned waterlogged saline sites depict that these sites can be productive upon carrying out certain interventions and efficient management of components. The study clearly depicts that managed sites have an edge over abandoned sites when one compares them on the basis of species diversity. This is supported by the Species Diversity Index of both managed and unmanaged site. The diversity index gave edge to managed site (0.02) over the abandoned (0.01) waterlogged saline.

Waterlogged saline lands are less productive but with proper valuation of the vegetation structure such lands can

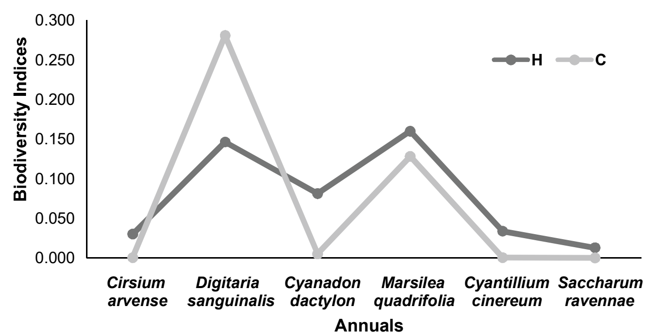

Fig. 4. Biodiversity indices (H-Shanon Weiner and C-Simpson index) of herbaceous flora in managed waterlogged saline sites

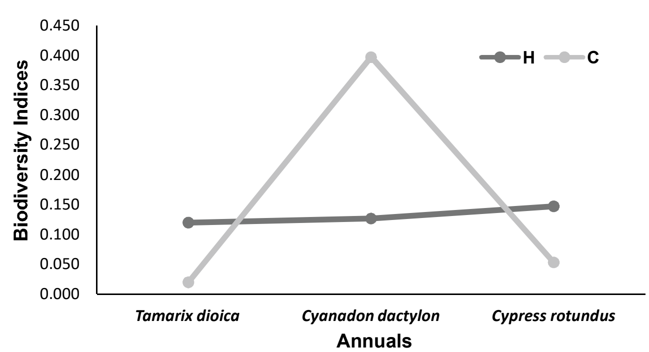

Fig. 5. Biodiversity indices (H-Shanon Weiner and C-Simpson index) of herbaceous flora in abandoned waterlogged saline sites

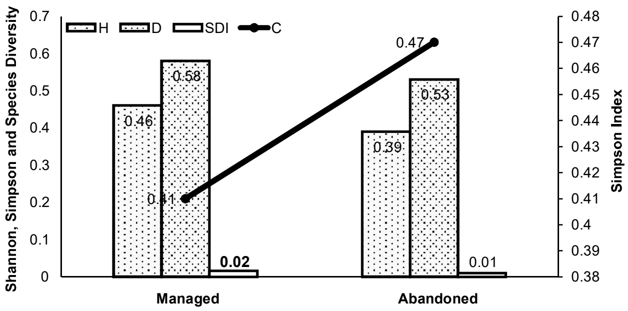

Fig. 6. Biodiversity indices (H-Shanon Weiner, D-Simpson diversity, SDI-Species diversity and C-Simpson index) of waterlogged saline sites

be put to production function by giving focus to the valuable exacting flora in the long run. Managed site has an edge over the abandoned sites in terms of biodiversity that too with valuable species in terms of utilization fronts. The findings are in lines with several theoretical evidences which suggest that greater the biodiversity/species richness on any site the greater would be the related benefits that too with overall ecosystem services (Tilman 2000, Balvanera et al 2006, Cardinale et al 2006, Chaudhari and Pathak 2022). Contrary to this, low diversity gives lesser outcomes in the form of ecosystem services which was observed in abandoned waterlogged saline sites in the study area. The low level of species richness in terms of biodiversity indices in abandoned waterlogged saline sites could be ascribed to the fact that the soil conditions in such sites are not favourable barring few for all type of vegetation. In such situations, only tolerant vegetation can come up that too in sporadic arrangement. In managed waterlogged saline sites, the human interventions for its better management to have higher productivity are the reason for higher floristic biodiversity. The extent of waterlogging and salinity is also less in managed sites than the abandoned sites. Abandoned sites were unattended and remain at the mercy of the nature for its management.

CONCLUSION

The study entrusts in generating a comparable picture of vegetation structure in managed and abandoned waterlogged saline landscapes. The managed site was dominated by *E. tereticornis* in block and boundary plantation models than abandoned site which was dominated by scattered *P. juliflora* trees. Both, managed and abandoned waterlogged saline sites showed variable species diversity index. Crab grass (*Digitaria sanguinalis*) occupied higher share in managed sites. Likewise, bermuda grass (*Cyanadon dactylon*) showed its higher dominance in abandoned waterlogged saline sites. Floristic biodiversity picture would be helpful in laying the protective and remedial management strategies of waterlogged saline lands through bio-reclamation aspects. The promotion of *Eucalyptus tereticornis* especially for abandoned waterlogged saline sites would be more beneficial on time and economic scales.

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