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Sustainable Land Use Planning Through Utilization of Alkaline Wasteland by Biotechnological Intervention

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Abstract: In the present investigation, alkali wasteland (3 hectares) of village Ishwarpur of Mainpuri district in Uttar Pradesh was selected for sustainable land use planning at micro-level. The physical characteristics of soil were 2.0-11.2 % soil moisture; 21.8-50.0 % WHC; 11.0-32.7 % Field capacity; 1.41-1.52 g/cc, bulk density; 30-43.5 % total porosity; 2.0-4.9/non capillary porosity and 18-38.9 °C temperature. The chemical characteristics of the soil were: 9.0 11.0 pH; EC 1.5-7.6 mmhos/cm; 0.010-0.028 % humus; 0.0002-0.2 % TOC; 0.01-0.08 % nitrogen, SAR 29.13-110.94 % and ESP 29.4-60.9 %. The area of other villages under built up, agricultural land, forests, grasslands, riverbed and wasteland was 5, 56, 20, 10, 8, 30 percent respectively. The co-efficient of improvement for soils under crop lands, pastures, forests plantation crops and alkali wastelands ranged from 1.2 to 4.5, 1.5 to 1.8, 1.0 to 1.4, 0.5 to 3.0, respectively. Keeping in view the pre-existing land use, soil properties, farming community's needs and problems based on socio-economic survey, land capability, irrigation modes and literacy was only 2.5, 1.6, 3, 10, 3 and 2 %, respectively but after biotechnological interventions, these parameters changed to 6.0, 5.2, 8, 16,4 and 10 %, respectively. Sixty percent alkali wasteland was reclaimed by conventional methods and demonstration in 3 hectares was set up by *Emblica* cultivation through biofertilizers in such soil. The farmers used this biotechnological intervention for cultivating many plants, tubers, pulses vegetables etc. The biotechnological management practices include use of bioinoculants, Vermicompost, degraded compost of biomass (Molasses, *Eichhornnia*), Organic growth supplements and biopesticides for profitable agriculture. The farmers used their land till optimization for intensive cultivation.

Key words:

INTRODUCTION

The causes of soil alkalinization were mainly analyzed from two aspects, natural and anthropogenic. Natural factors of alkalinization are parent materials, topographic positions, freeze-thaw action, wind conveyance, water properties and semi-arid/sub-humid climate. Some of them were always being neglected, such as freeze-thaw action and wind conveyance. Anthropogenic causes are mainly population pressure, overgrazing and improper agricultural and economic policies. In recent decades, overgrazing played a main role in secondary soil alkalinization, which led to the decline of *Leymus chinensis* grasslands. Now, the alkalinization is very severe and more than 3.2×10^6 ha area has been affected by salt, which becomes one of the three largest sodic-saline areas in the world [1]. In India, 175 million hectares land out of 329 million ha total geographical area are affected by degradation of one or other form[3]. The major causes of degradation are water and wind erosion (150 million ha), salinity and alkalinity (7 million ha), water logging (6 million ha) etc. (Table1). High soil salinity and alkalinity have degraded about 8.5 million ha of once productive land in India. The severity of the problem is increasing and several million ha of the canal irrigated area in the arid and semi-arid regions of the country run the risk of being degraded. Increasing human and livestock pressures on available land necessitates protracted efforts to reclaim lands which are already degraded and to prevent their further degradation.

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Table 1: Distribution of Soil-Erosion and Land-Degradation Areas (m ha = million Hectare, m tones = million tones)

1.	Geographical area	329 m ha
2.	Area subject to water and wind-erosion	150 m ha (2.1 +2.2)
2.1	Area subject to wind-erosion aridity	38.74 m ha
2.2	Area affected by sand-dunes out of 38.74 m ha	7.00 m ha
3.	Area degraded through specific problems	25.06 m ha
3.1	Waterlogged area	6.00 m ha
3.2	Alkaline soils	2.50 m ha
3.3	Saline soil including coastal sandy area	5.50 m ha
3.4	Ravines and gullies	3.97 m ha
3.5	Area subject to shifting-cultivation	4.36 m ha
3.6	Riverine and torrents	2.73 m ha
4.	Total problem-area (2+3)	175.06 m ha
4.1	Annual average loss of nutrients from land	5.37 to 8.4 m tones
5.	Average annual loss of production for not developing ravines estimated at	3.0 m tones
6.	Average annual rate of encroachment of table-lands by ravines	0.008 m ha
7.	Average area annually subject to damages through shifting cultivation	1 m ha
8.	Total flood-prone area	40 m ha
8.1	Annual average area affected by floods	9 m ha
8.2	Annual average cropped area affected by floods	3.8 m ha
9.	Total drought-prone area	260 m ha
10.	Additional land needed by 2000 AD	60 m ha
10.1	For crop-production	10 m ha
10.2	For production of fuelwood	40 m ha
10.3	For production of fodder	10 m ha

Source: *Indian Agriculture in Brief, 1985 [12].*

Providing vegetative cover to such lands with suitable woody and herbaceous species can put the these lands to optimal use and also increase the forest cover of the country [2]. Yield potential of these degraded lands is quite low and these lands are best suited for silvi-pastoral and other tree-based systems. However, to feed increasing population of our country, cultivation of crops on these lands has become mandatory. In Uttar Pradesh alone about 1.3 million ha of land is under salt affected soils. It has been estimated that with the expected increase in the population, an additional 40 million ha for fuel and 10 million ha for fodder and net sown area of 10 million ha for food are needed by the end of this century. These may be possible providing that the usable wastelands are reclaimed, developed and properly utilized. Introducing large-scale farming and afforestation on dry land are one aspects in developing these lands. Immediate reclamation of culturable wastelands (16.3 million ha) fallow lands other than current fallow (9.5 million ha) and utilizable barren or uncultured land (20.1 million ha) including the gullies and ravines (3.97 million ha) waterlogged (6 million ha) alkaline (7 million ha) and soils of shifting cultivating (4.4 million ha) are urgently needed.

Salt-affected soils differ from normal arable soils in respect of two important properties, namely the amounts of soluble salts and the soil reaction. Excess of soluble salts adversely influence the soil its physico-chemical properties which in turn have a strong bearing on the activity of plant roots and growth of plants.

Salt-affected soils are known by different local terms. They are called Kallar or Thur in Punjab, Usar or Reh in Uttar Pradesh, luni in Rajasthan, Khar or Kshar in Gujarat and Maharastra, Chouddu or Uippu in Andhra Pradesh, Choppan in Karnataka. The average of salt degraded lands is nearly 7 million ha in the country. These soils occur extensively in different agro-ecological and soil zones of the country, particularly the arid, semi-arid and the dry sub-humid regions.

Excess of salts may accumulate in the surface horizons of soils mainly due to the following reasons:

- Secondary salinization associated with water logging.
- High salt content of irrigation water.
- Release of immobilized salts already precipitated in soils.
- Atmospheric salt depositions as in coastal areas.
- Weathering of soil minerals.
- Use of fertilizers.

The relative significance of each source in contributing soluble salts to the root zone depends on the natural drainage conditions, soil properties, irrigation water quality, management practices and distance from the coastline. Soluble salt are either neutral in their reaction (e.g. chlorides and sulfates of sodium, calcium and magnesium) or are the soda salts (carbonate and bicarbonates of sodium) capable of producing alkalinity.

Salt-affected soils are grouped according to the nature of plant response to the presence of soluble salts and on the basis of management practices required for their reclamation. Unlike the pedogenic system, it is a simple system of classification requiring information on the nature of soluble salts only. Since salts are either neutral or alkaline in reaction, salty soils are grouped into 2 classes: (i) Saline soils and (ii) Alkali soils. India has a very low per capita land availability of about 0.3 hectare. Reclamation of salt affected soils and other wastelands will reduce the pressure on the productive lands to fulfill the needs of the growing population. Therefore, it has become necessary to develop the marginal and sodic wastelands in to productive land use system. Planting site matched tree species in these areas exerts bioameliorative effects for their reclamation, in addition to providing forest cover, fuel wood, fodder, timber and preventing soil and water loss through runoff besides improving the microclimate of that area [3-5].

It is characterized by an intensive integration of forest trees, field and horticultural crops and shrubs with a basic objective to ensure sustained availability of multiple products as direct benefits such as food, vegetables, fruits, fodder, fuel, foliage, medicine and raw materials for agricultural implements. Other indirect benefits are services such as ornamentals, shading, live fencing and shelterbelt or wind-breaks are also derives. Such intermixing of species of agriculture and forestry, often termed as 'agroforestry' came into international prominence as a potential source of solutions of many inter-related problems of production and conservation, troubling land-use systems in the tropical and subtropical regions. It has also been stated that the tree components along with field crops lead to efficient use of sunlight, moisture and nutrients in agro-ecosystems that in monocropping of either agricultural or forestry crops.

In recent years, people are meeting their diverse biomass needs from the trees in cultivated lands. Such large-scale dependence may act as threat to reduction in tree diversity and density on the farmlands. In view of the depleting timber, Non Timber Forest Product resources in the wild, a diverse agro-ecosystem may help people to meet varied needs.

With variable levels of success, different approaches-salt leaching and drainage interventions, crop-based management, chemical amendments and fertilisers and integrated application of these approaches-have been used to enhance the productivity of salt-affected soils in the Country. From sustainable management perspective, it is revealed from the past research that integrated salinity management and mitigation approaches have the potential to successfully address the complex problems of salt-induced land degradation. As the growing need to produce more food and fibre for the expanding Iranian population necessitates the increased use of salt-affected land resources in the foreseeable future, there is an urgent need to develop and implement a pertinent National Strategic Plan. In addition to establishing networks for monitoring spatial and temporal changes in soil salinity and water quality, this plan should integrate the management of salt-affected environments into the overall management of land and water resources in the country. It should also address different management aspects of salt-affected land resources in a holistic manner by considering the biophysical and environmental conditions of the target areas as well as livelihoods of the affected communities. The involvement of the communities will facilitate in developing a greater understanding about the potential uses and markets of the agricultural products produced from salt-affected areas [6,7].

Recent trends and future demographic projections suggest that the need to produce more food and fibre will necessitate effective utilization of salt-affected land and saline water resources. Currently at least 20 per cent of the world's irrigated land is salt affected and/or irrigated with waters containing elevated levels of salts. Several major irrigation schemes have suffered from the problems of salinity and sodicity, reducing their agricultural productivity and sustainability. Productivity enhancement of salt-affected land and saline water resources through crop-based management has the potential to transform them from environmental burdens into economic opportunities. Research efforts have led to the identification of a number of field crops, forage grasses and shrubs, aromatic and medicinal species, bio-fuel crops and fruit tree and agroforestry systems, which are profitable and suit a variety of salt-affected environments. Several of these species have agricultural significance in terms of their local utilization on the farm. Therefore, crop diversification systems based on salt-tolerant plant species are likely to be the key to future agricultural and economic growth in regions where salt-affected soils exist, saline drainage waters are generated and /or saline aquifers are pumped for irrigation. However, such systems will need to consider three issues: improving the productivity per unit of salt-affected land and saline water resources, protecting the environment and involving farmers in the most suitable and sustainable crop diversifying systems to mitigate any perceived risks. This review covers different aspects of salt-affected land and saline water resources, synthesizes research knowledge on salinity/sodicity tolerances in different plant species and highlights promising examples of crop diversification and management to improve and maximize benefits from these resources [8].

Arbuscular mycorrhizal fungus and bacterial ACC deaminase may ameliorate plant growth under stressful conditions. It was previously shown that, under optimal growth conditions, *P. putida* UW4 AcdS^{+} increases root colonization by *Gi. rosea* resulting in synergistic effects on cucumber growth. These results suggest that while in optimal conditions ACC deaminase is mainly involved in the bacteria/fungus interactions, while under stressful conditions this enzyme plays a role in plant/bacterium interactions [9].

Hence, the objective of this work is to ameliorate the salt affected soil with biofertilizers, Mycorrhizal inoculation and other components for utilization of this wasteland for cultivation of various plants and changing the microclimate.

MATERIALS AND METHODS

The villages with above description were selected and complete date on land use patterns; life style and agricultural practices were noted.

Here, a case study of a village in the Mainpuri district of Uttar Pradesh affected by alkalinity is presented to understand changes in trees species diversity, further perspectives of improvement and land use potential with biotechnological methods. This was done by comparing the changed scenario after 3 years by using biotechnological methods for reclamation of soil and transplantation of alkali resistant grafted trees with multiple cropping.

The villagers were motivated to adopt multicropping concepts between agricultural and forestry crops under a Department of Biotechnology, Ministry of Science and Technology, Government of India, New Delhi sponsored project by using biotechnological methods of reclamation of alkaline soil and transplanting alkali resistant budded trees of economical and ecological importance. The microclimate which was developed by such practices made the soil fertility to be improved and many other plants could survive. It has been stated that the tree components along with field crops lead to efficient use of sunlight, moisture and nutrients in agro-ecosystem than in monocropping of either agricultural or forestry crops. This kind of practice was new to these villagers.

Villages belong to Mauza Nauner of Mainpuri district of Uttar Pradesh, Dannahar situated in between Ghiror and Mainpuri. (Figure1-Map of Mainpuri district). It has 66,752 hectares of alkali land lying uncultured.

The district lies between 26°53’ to 27°31’ north latitude and 78°27’to 79°26’ longitude. According to the Central Statistical Organization, the district covers and area of 4343 sq. km. It is bounded on the North by the Etah district, on the east by the Farrukhabad district, on the south by the district of Itawah and Agra and on the west by Agra and Etah district. The Kalinadi forms the boundary on the North-East and the Jamuna enclosed it on the South-West.

The site is covering the area associated villages of Mainpuri viz. Dannahar, Chaurasi, Ishwarpur and Nauner situated near a small bus stop called as Dannahar on Ghiror-Mainpuri road (G.T. Highway) 110 km approximately North-West to Agra.

The soil is highly alkaline with soil properties shown in Table 2. The entire village ecosystem encompasses an area of 525 ha. Out of which 220 ha is uncultured alkaline wasteland.

The soil of this study was found to be alkaline. The rainwater or applied irrigation water continued to stagnate on soils for a much longer period. The water on the soil surface are dark-coloured, muddy and soapy. During the dry season the soil surface was covered with dark brown or ash-coloured clay crusts because of the dissolution of humus by the alkaline salts. The ground waters associated with alkaline soils are usually sweet but may have high concentration of residual sodium bicarbonate causing alkalinity hazard. Soil profiles of this area were associated with $CaCO_3$ in amorphous form.

The detail land use patterns and sampling are shown in Table 3.

The major farming constraints of these lands are high pH, excess of calcium carbonates, chlorides, sulfates and exchangeable sodium imbalance of electrical conductivity, low infiltration rate, impeded drainage and poor fertility status. In spite of several limitations, salt affected soils have good potential for cultivation of hardy trees under scientific management. Considering these facts, efforts were made to utilize the salt affected soils by fruit based agro-forestry system, so that a permanent vegetation cover may stop further degradation and also rehabilitate these lands in due course of time. Medicinal plants, vegetables, pulses and crops supplemented this agro-forestry system.

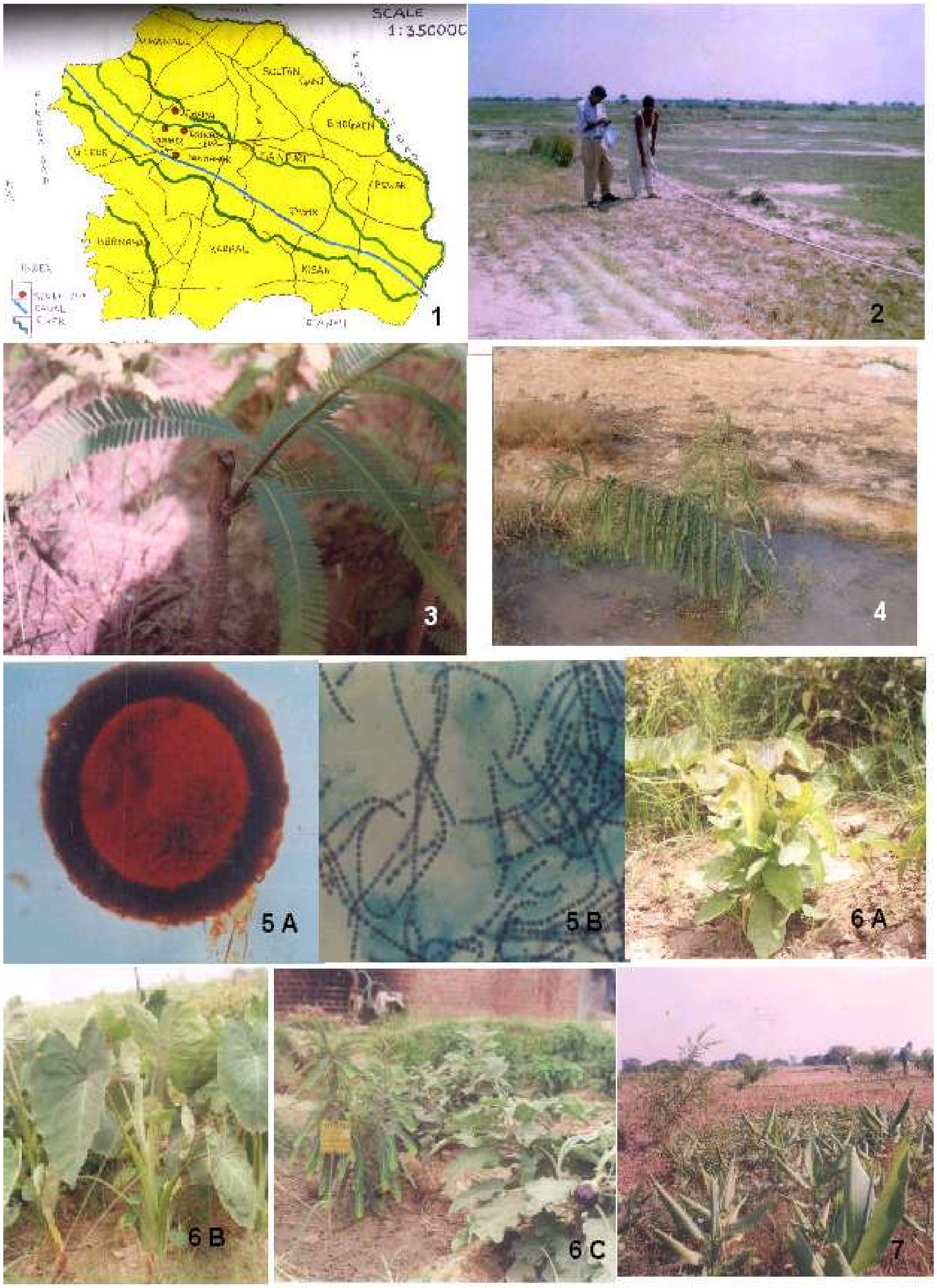


Fig. 1: Map of working site-Mainpuri District (Uttar Pradesh)-villages are shown with red points

Fig. 2: Alkaline experimental soil with scarce vegetation showing *Vitiveria* and *Desmostachya* grasses only.

Fig. 3: Emergence of new shoot of high yielding variety of *Emblica* plant in nursery

Fig. 4: Transplantation of *Emblica* nursery plant in auger hold alkaline soil supplemented with mycorrhizal and biofertilizer inoculation.

Fig. 5A,B: *Gigaspora* sp. Used for inoculating along with *Nostoc* and *Pseudomonas* with composted Eichhornia and Molasses (magnification 10 X 40x)

Fig. 6A-C: Multicropping of Emblica with *Ipomea batata, Solanum melongena* and *Colocasia antiquorum*.

Fig. 7: Change in vegetation and diversity after 3 years-*Emblica* intercropped with *Curcuma longa* (Turmeric).

Table 2: 2a: Physicochemical analyses of the soil

Parameters	Values
Soil Moisture	2.0-11.2 %
WHC (Water holding capacity)	11.0-32.7 %
Field Capacity	1.41-1.52 %
Density	30-43.5 %
Total Porosity	2.0-4.9 / non capillary porosity
Temperature	18-38.9°C
pH	9.0-11.0
EC (Electrical Conductivity)	1.5-7.6 m mhos
Humus	0.010-0.028 %
TOC (Total Organic Carbon)	0.02-0.2%
Total Nitrogen	0.01-0.08 %
SAR (Sodium Adsorption Ratio)	29.13-110.94
ESP (Exchangeable sodium percentage)	29.4-60.9 %

2b: Physico-Chemical Characteristics of the alkaline soil of village, Ishwarpur

Depth (cm)	Organic Carbon	pH value	E.C. (m mhos/cm^2)	C%	N%	P%	P_2O_5	ESP	SAR
0-11	0.4	10	5.2	0.30	0.05	0.0045	0.15	94	570
11-38	0.2	9.8	3.5	0.07	0.014	0.0072	0.12	90	230
38-48	0.2	9.1	2.8	0.09	0.010	0.0025	0.033	84	170

(EC= Electric Conductivity, ESP= Exchangeable Sodium Percentage, SAR= Sodium Adsorption Ratio)

Table: 3 Land-Use categories and area sampled in Ishwarpur village ecosystem of Mainpuri District before and after biotechnological intervention

	Total area (ha)		Sampled area (ha)		
Land use category	Before	After	Before	After	Sampled area and number
Home garden	860	960	0.04	34	Entire area of home-gardens
Paddy	1.975	2.6	1.101	1.7	220 m x 3 m transect
Stream	1.411	1.8	0.321	0.39	1140 m x 1 m transect
Minor forest	25.00	36	0.1	0.15	70 m x 7 m
Alkali wastelands	255.63	106	1.0	1.0	50 m x 5 m

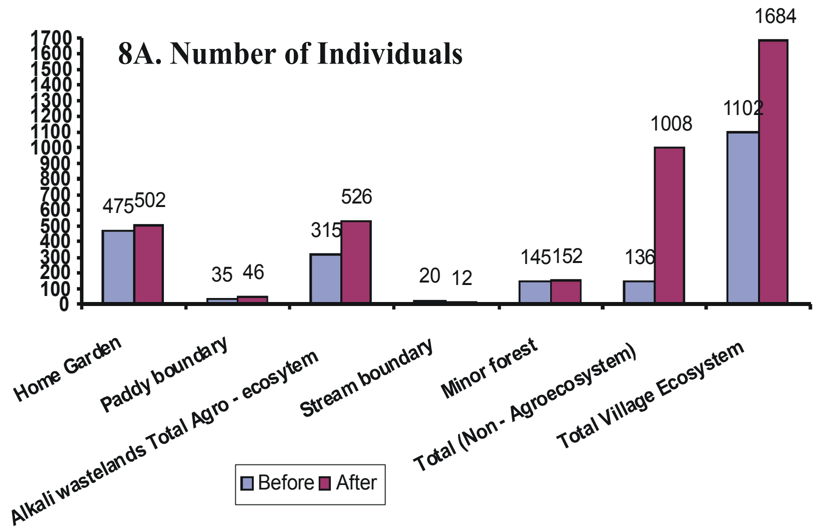
The sample plots were randomly laid in each land-use system such as home-gardens, paddy streams boundary and tank bunds, minor forest and adjacent reserve forest. Details of area sampled are given in Table 3. The total length of paddy and stream boundary was estimated using the village maps. The total length of stream boundary was 1145 million, while paddy boundary was 335 million and wasteland 200m. The maintained width for these boundaries was 2m. Data regarding species name, GBH (Girth, breadth and height), total trees height, etc. were collected for sampled-four locations in 1999, where trees with greater than 10 cm diameter at breast height were recorded. Shannon-Weiner's species diversity index and Sorenson's similarity index were calculated [10]. The index was calculated for all samples pooled over each land-use category. End-use patterns of several species that are grown in their home-gardens were collected through household interviews.

Stem diameter and tree height account for larger proportion of variability in woody biomass of trees. Basal area and height were used for estimating biomass-using equations [11].

The coefficient of improvement was calculated as the ratio between preexisting and potential soil productivity (P/P") and the ratio between actual and potential soil Productivity (P'/P"), to find out the optimum land use recommendations.

RESULTS AND DISCUSSION

Pre-Existing Land Use: The areas under built up, agricultural crops, forests, grasslands, riverbed and alkaline wasteland were 5, 56, 20, 10, 8 and 30% respectively. The cultivated area was under field crops (Paddy-mustard-wheat sequence) and was irrigated with perennial water streams.



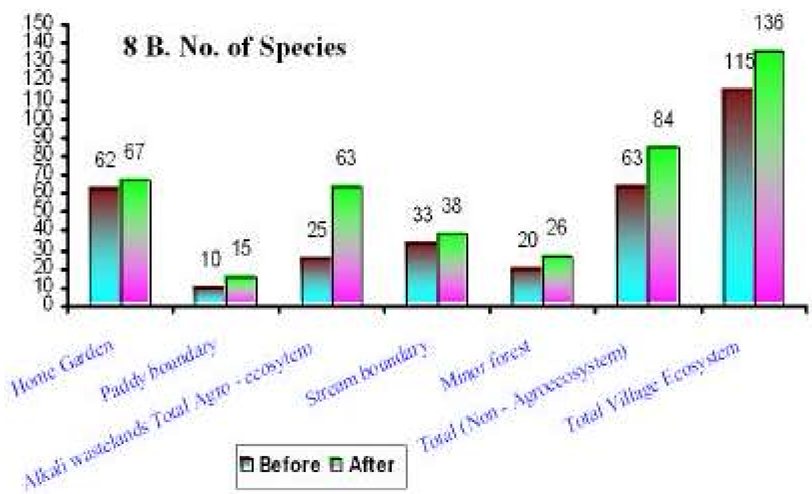
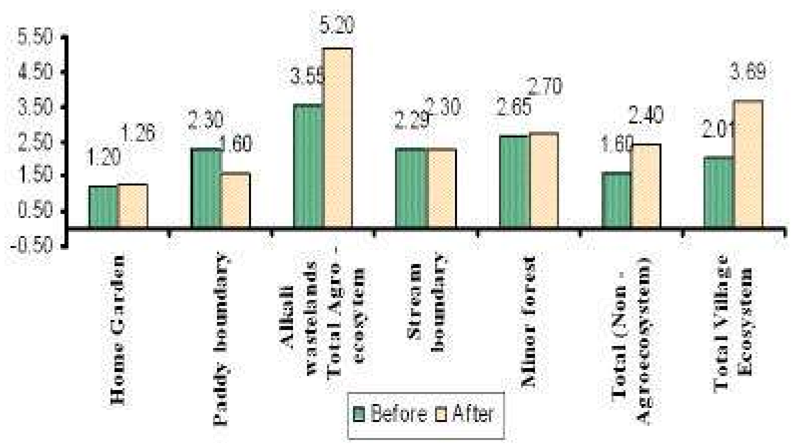


Figure 8 c: SHANNON (H) DIVERSITY



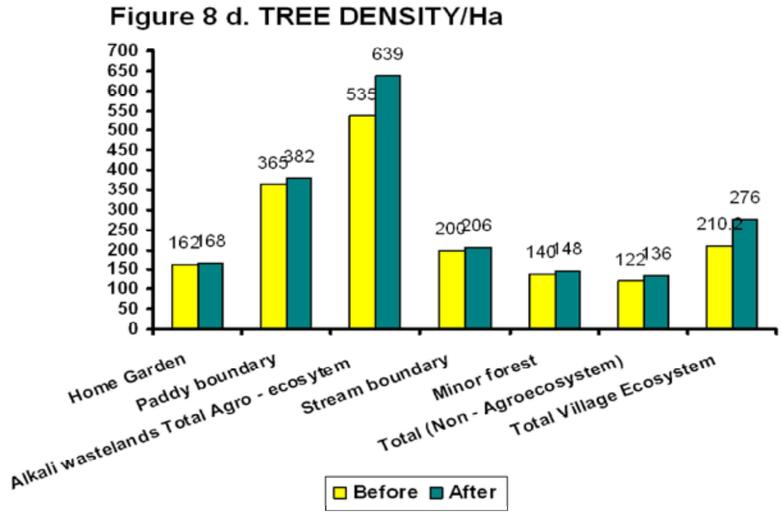


Fig. 8: Characteristics of vegetation in different land uses in alkaline affected villages ecosystem of Mainpuri District before and after biotechnological intervention.

Table 4: Characteristics of vegetation in different land uses in alkaline affected village ecosystem of Mainpuri District before and after biotechnological intervention

	Number of individuals/ species		Shannon (H) (diversity)		Tree density/ha	
Land use category	Before	After	Before	After	Before	After
Home garden	475/62	502/67	1.20	1.26	162	168
Paddy boundary	35/10	46/15	2.30	1.6	365	382
Alkali wastelands						
Total agro-ecosystem	315/25	526/63	3.55	5.2	535	639
Stream boundary	20/33	12/38	2.29	2.3	200	206
Minor forest	145/20	152/26	2.65	2.7	140	148
Total (non agro-ecosystem)	136/63	1008/84	1.6	2.4	122	136
Total village ecosystem	1102/115	1684/136	2.01	3.69	210.2	276

Table 5: Standing biomass and tree population in village agro-ecosystem of alkaline wasteland before biotechnological intervention in Mainpuri District

Species	Total individual	Percentage	Estimated standing biomass	Percentage
Mangifera indica.	30	11.3	13.30	20.12
Artocarpus heterophyllous	14	8.6	4.51	9.21
Casuarina equisetifolia	30	4.1	0.42	1.01
Citrus Sp.	33	3.1	0.15	1.65
Leucaena leucocephala	7	2.1	0.05	0.22
Acacia sp.	20	3.2	0.17	1.43
Dalbergia sp	23	4.1	0.09	1.20
Prosopis sp.	15	1.2	1.12	0.71
Phoenix sp.	17	3.1	1.07	1.50
Kath	10	2.0	1.03	1.10
Total	199	42.8	21.91	38.15

These perennial water streams were found to be mostly inefficient to meet the crop requirements due to large command area, severe water losses during comeyance and frequent damage of Kutcha channels. The alkaline soils were exposed and grasses like *Desmostachya, Cenchrus, Pannicum* etc. could grow in them. Moreover, there were forests of *Acacias, Prosopsis* and shrubs of *Zizyphus*. About 30% of land was in poor condition.

Land Use Potential: In the present study all the land use systems and types were treated as an ecosystem. This village ecosystem consists of 18 ha of minor forest with dominant species such as *Prosopis, Acacias, Saccharum* and *Vetiveria*. The semi dominant species were *Mangifera indica* and *Atrocarpus heterophyllous*. The tree density was 62 per hectare and species diversity was 1.20 (Table 4, Fig 8).

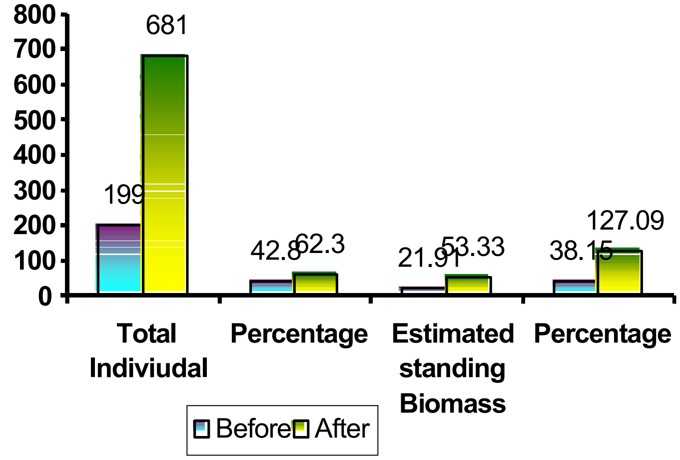


Fig. 9: Standing biomass and tree population in village agro-ecosystem of alkali affected wasteland before and after biotechnological intervention

Furthermore, some species were encountered on non-agricultural lands in the village ecosystem, which include *Saccharum munja*, minor forest. Out of the species present in the agro-ecosystem, the predominant ten species account for 0.4% of the total tree population. Among the ten species, five were local and five were exotic. Among species encountered in the agro-ecosystem, local fruit-yielding species like *M.indica* topped the list (Table 5, Fig 9). Farmers had a good knowledge of growth rates and useful products of many tree species and were able to learn about exotic species also. Some farmers identified species that serve as shade, windbreak, line fence and their importance to maintain soil fertility. Thus people were aware of the interrelated benefits of a balanced mix of species for the home garden.

The current study revealed that due to interventions the scenario of the village ecosystem changed. The soil could be reclaimed to pH-8.5 within 3 years and number of tree species reached to 681 and types of trees were 21. Out of these trees, 10 plants were income generator and estimated biomass was totally 53.53t and maximum percentage was of *Emblica* followed by *Popular*. Thus it was appropriate to consider local community as an integral part of ecosystem function for effectively managing agro-ecosystems in the tropics, with a concern of biodiversity. Although this study analyses were focused on tree diversity and end uses of tree species in different locations and village ecosystem, many questions concerning agro-ecosystem have to be answered to understand the suitability of species in different land uses of the village ecosystem. Some of these aspects to be studied include influence of forest trees on horticultural crops, lopping methods, contribution of these trees for nutrient cycling and determination of tree crop/field crop combination (Table 6, Fig 9).

Actual and Potential Soil Productivity: Working out the capability of a soil to produce food/fuel/fodder under existing (traditional) as well as recommended package of management practices helps to understand the technological gaps.

Preexisting, existing (Actual) and Potential soil productivity for field crops, pastures, forests and plantations and alkaline wasteland ranged from 0.6 to 1.3, 3.95 to 14.4 and 15.5 to 27.9; 2.3 to 6.8, 3.9 to 8.6 and 7.8 to 16.9; 1.6 to 5.3, 3.8 to 8.2 and 6.8 to 12.0; 15 to 40, 9 to 27 and 1.0 to 18.0 respectively. The coefficient of improvement i.e. a ratio of potential to actual soil productivity indicated maximum productivity indicated maximum productivity in the range of 1.93-4.5, 1.63 to 2.15, 1.46 to 2.6 and 0.10 to 0.50 times of actual productivity whereas a ratio of potential to preexisting soil productivity indicated maximum productivity in the range of 17.8 to 103.3, 2.48 to 5.73, 1.92 to 7.5 and 0.05 to 0.40 times of pre-existing soil productivity obtained by adopting scientific or biotechnological soil management practices in agricultural croplands pastures, forests and plantation and alkaline wasteland respectively (Table 7, Figure 10).

Sustainable Land Use Planning: Table 8 shows the existing land uses and advocated land uses along with major land management practices. These lands can be cultivated with remunerative cropping sequences viz-Maize + Vegetables + Wheat, Maize-Pea-Potato,

Table 6: Standing biomass and tree population in agro-ecosystem of alkaline affected soils after biotechnological intervention in Mainpuri District

Species	Total Individuals	Percentage	Estimated biomass (t)	Percentage
Mangifera indica L..	33	12.1	15.20	20.15
Artocarpus heterophyllus Lamk	20	7.5	3.65	9.27
Casuarina equisetifolia Forst.	35	3.2	0.75	1.07
Citrus sp.	41	4.3	0.21	1071
Phoenix	9	2.2	0.09	0.27
Acacia	25	3.2	0.19	1.53
Prosopis	21	4.1	0.13	1.27
Dalbergia	20	1.5	1.17	0.77
Emblica	100	3.7	1.09	61.63
Tectona	70	2.1	1.05	1.13
Psidium	80	3.3	2.25	1.21
Australian Acacia	15	4.7	3.1	2.1
Karonda	10	1.1	4.2	2.02
Musa Paradisica	20	1.1	3.6	1.6
Cassia bandozella	20	1.3	3.1	3.7
Popular	80	1.7	3.5	21.2
Bambusa	40	1.6	4.8	3.2
Eugenia	17	1.1	3.1	1.9
Azardirachta indica	25	1.5	3.1	1.9
Total	681	62.3	53.33	127.09

Table 7: Pre existing (P), Actual (P') and Potential productivity (P") of soils under different land uses

	Field crops				Pastures				Forest and Plantation				Alkaline Wasteland			
Villages	P	P'	P"	Cl	P	P'	P"	Cl	P	P'	P"	Cl	P	P'	P"	Cl
Ishwarpur	1.0	3.95	17.8	4.50	6.8	8.6	16.9	1.90	5.3	8.2	12.0	1.46	25	12	3	0.30
				17.8				2.48				2.26				0.12
Nauner	0.6	12.6	25.6	2.03	2.3	6.5	10.6	1.63	3.8	5.0	7.3	1.46	17	9	1	0.10
				42.6				4.60				1.92				0.05
Chaurasi	1.3	14.4	27.9	1.93	2.6	3.9	7.8	2.00	2.2	3.8	6.8	1.78	15	10	5	0.5
				21.4				3.00				3.09				0.3
Dannahar	0.15	6.2	15.5	2.53	2.3	6.12	13.2	2.15	1.6	4.6	12.0	2.61	40	27	18	0.6
				103.3				5.73				7.5				0.4

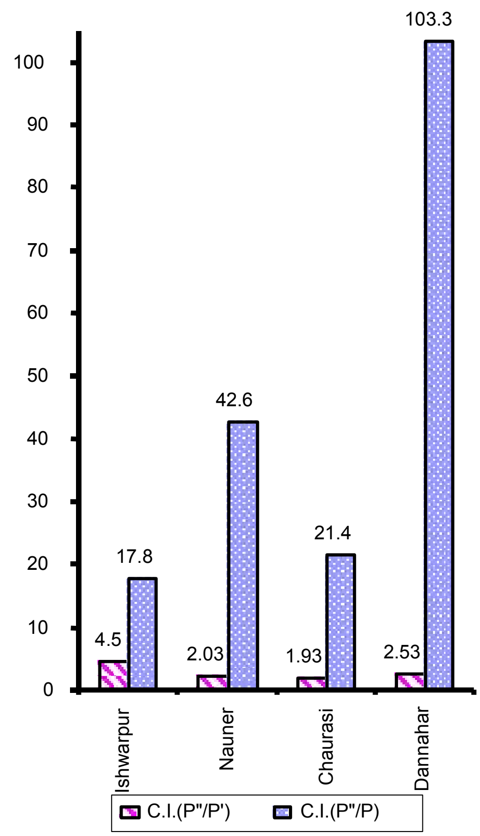
Coefficient of Improvement = Cl (P"/ P'and P"/P)

Table 8: Recommendations for Better Land Use

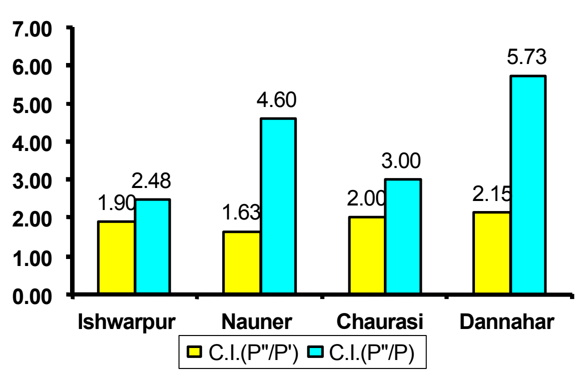
		Existing land use	Proposed land use	Coefficient of improvement		Precaution
1.		Village Ishwarpur		P"/ P'	P"/P	
	A	Crop (Paddy-Wheat)	Intensive cultivation with remunerative crop sequence	4.50	17.8	Alkaline soil reclamation and water conservation
	B	Pastures (Grasses)	Barseem and Fodder crops	1.90	2.48	Alternative uses of land
	C	Forest and Plantations (Prosopis + Mango)	Emblica, Zizuphus, Guava, Citrus, Popular, Teak etc. with multiple cropping	1.46	2.26	Regular use of soil conditioners
	D	Alkali Wasteland (Grasses)	Emblica, Zizuphus, Guava, Citrus, Popular, Teak etc. with multiple cropping	0.30	0.12	Reclamation without break
2.	Village-Chaurasi					
	A	Crop (Paddy-Wheat)	Intensive cultivation with remunerative crop sequence	1.93	21.4	Alkaline soil reclamation and water conservation
	B	Pastures (Grasses)	Barseem and Fodder crops	2.00	3.00	Alternative uses of land
	C	Forest and Plantations (Mango, Jamun, Kaith, Prosopis)	Emblica, Zizuphus, Guava, Citrus, Popular, Teak etc. with multiple cropping	1.78	3.09	Regular use of soil conditioners
	D	Alkali Wasteland (Grasses)	Emblica, Zizuphus, Guava, Citrus, Popular, Teak etc. with multiple cropping	0.5	0.3	Reclamation without break

Table 8: Continued

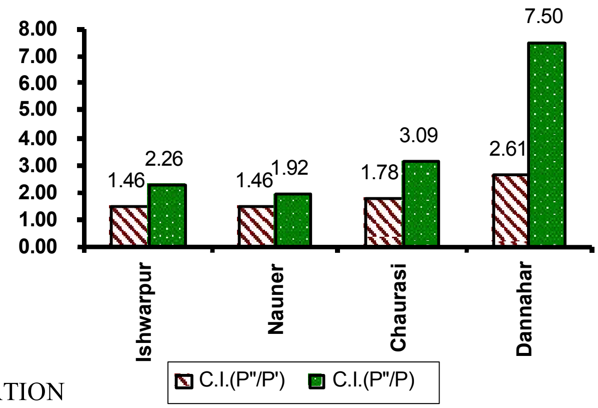
3.	Village-Nauner					
	A	Crop (Paddy-Wheat-)	All above and seasonal vegetables	2.03	42.6	Alkaline soil reclamation and water conservation
	B	Pastures (Grasses + Barseem)	Fodder crops	1.63	4.60	Alternative uses of land
	C	Forest and Plantations (Khajur, Acacia, Jamun)	Emblica, Zizuphus, Guava, Citrus, Popular, Teak etc. with multiple cropping	1.46	1.92	Regular use of soil conditioners
	D	Alkali Wasteland (Grasses)	All above and medicinal plants + biofencing	0.10	0.05	Reclamation without break
4.	Village-Dannahar					
	A	Crop (Mustard)	Emblica, Zizuphus, Guava, Citrus, Popular, Teak etc. with multiple cropping	2.53	103.3	Alkaline soil reclamation and water conservation
	B	Pastures (Grasses)	Fodder crops	2.15	5.73	Alternative uses of land
	C	Forest and Plantations (Prosopis)	Emblica, Zizuphus, Guava, Citrus, Popular, Teak etc. with multiple cropping	2.61	7.5	Regular use of soil conditioners
	D	Alkali Wasteland (Grasses)	All above and medicinal plants + biofencing	0.6	0.4	Reclamation without break



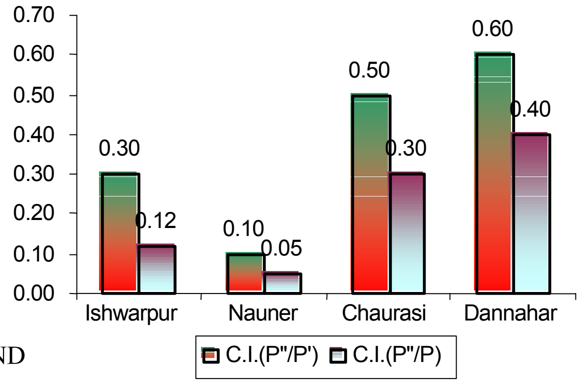
10 a: Field CROPS



10 b: PASTURES



10 c: FOREST AND PLANTATION



10 d: ALKALINE WASTELAND

Fig. 10: Pre Existing (P), Actual P' and Potential Productivity (P'') ratings of soils under different land uses Coefficient of Improvement CI = (P''/P' and P''/P)

Paddy-Vegetables-Potato or sequences with pulses and medicinal plants. Agro horticulture in villages Ishwarpur and Nauner is recommended with intercropping them with Isabgol, Turmeric, Onion, Garlic, Shakarkand etc.

The biofencing with Karonda, Karanj, Mehndi, Agave and Bamboos will be purposeful for conserving soil. Leguminous plants like *Leucaena leucocephala, Cassia sp. Prosopis* etc. will be suitable for green fodder and fuel.

Keeping in view of the above facts this project made agriculture more remunerative and motivated the farmers towards vermicomposting, mushroom cultivation, bee-keeping and nursery raising through organizing frequent farmers training camps with maximum women participation. Such an action plan will assist the development policies makers for farmers in complete harmony with nature.

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