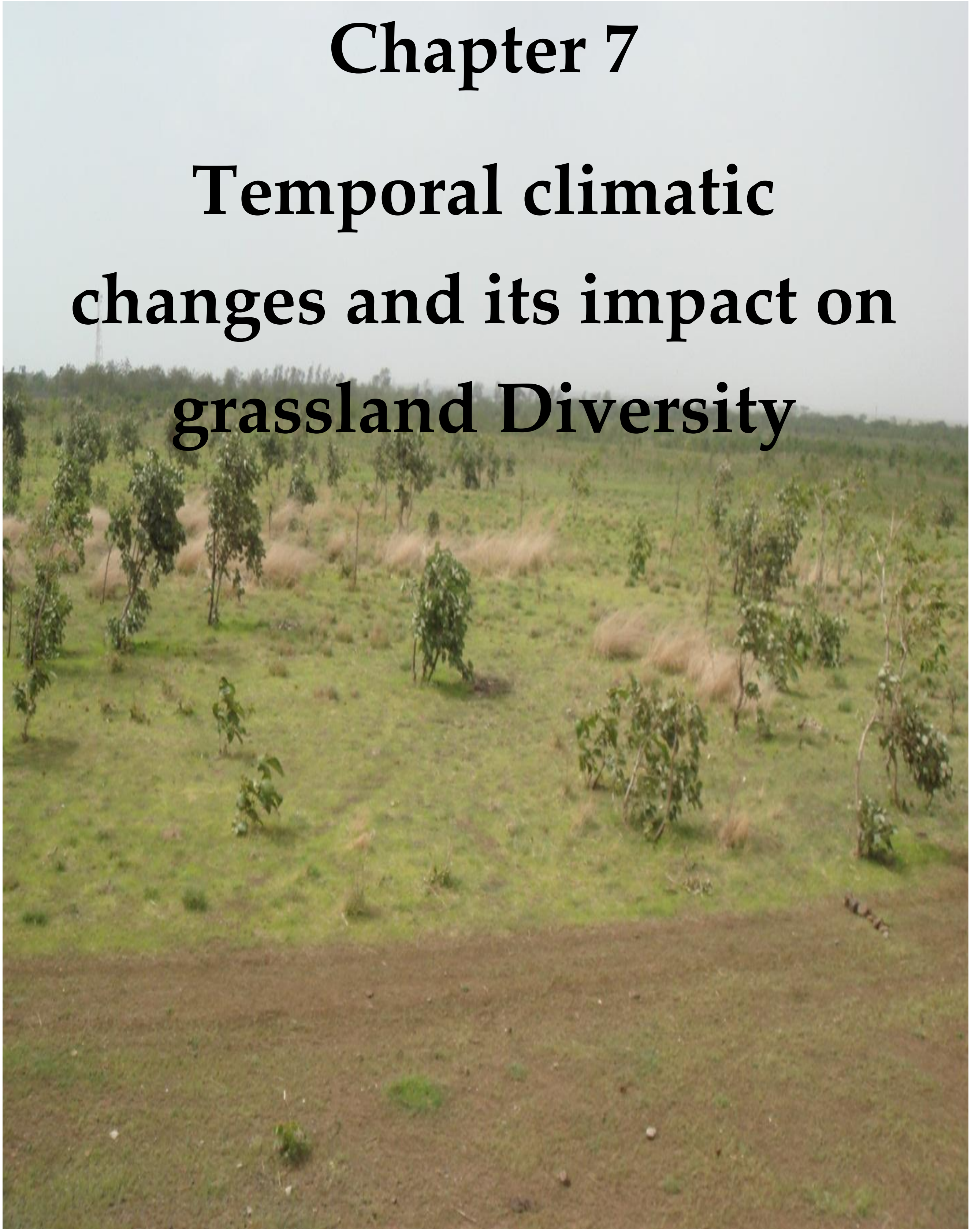
Chapter 7

Temporal climatic changes and its impact on grassland Diversity



Chapter 7

Temporal climatic changes and its impact on grassland Diversity

The world's ecologists believe that all great climatic events may occur due to changes in the global climate change and according to Grime et al. (1994) this in turn is followed by radical or irreversible vegetation changes with local colonizations and extinctions. Stampfli and Zeiter (2004) said that in perennial grasslands severe droughts may open gaps for regeneration by causing the mortality of established plants. Regenerative success depends both on the rate of vegetative growth and the tolerance of shoots, roots and other storage organs to drought, and on the output of seeds and the ability of the resulting offspring to exploit post-drought conditions (Grime, 2001). On the basis of such results we tried to evaluate the vegetation changes which occurred due to unpredictable climate changes in the selected study area.

In the present study, evaluation was done for temporal changes occurred in rainfall pattern and its influence on vegetation, during three successive years. The study was conducted to observe short term successional changes and to record variation if any in the pattern of species emergence. Data were collected simultaneously at different selected sites, and were analyzed. The structure, composition and life-forms changed significantly during succession.

Material and Method

The study was conducted to observe temporal climatic changes and their effect on grassland vegetation during successive years of the study.

a) ***Field Study***

b) ***Vegetation Survey***

Vegetation surveys were conducted during monsoon periods i.e. from June to January for successive years (2007 to 2010). To obtain the relative data in short duration, we tried to visit the selected sites more frequently.

Comparison of Species Composition

To compare species composition within differential habitats, we assembled geographical data for selected three study area of studied grassland (Table 7.1). In total nine study sites differing in their topography and microclimatic conditions were selected. Quadrats of 2m x 2m square (with triplicates) were laid down in the selected sites. In a particular quadrat the occurrence of different grasses and herbaceous legumes along with their abundance were documented. The relative abundance of species was recorded as different categories i.e. abundant, frequent and rare.

Observations for phenology and temporal changes

The developmental stages of different species were also recorded and they are categorized into seedling stage, vegetative stage, flowering stage and fruiting stage, etc. The observations were recorded at each stage of succession, viz: pioneer, seral and climax stages.

c) *Soil Analysis*

Soil analysis has been done for the soil samples collected from the study area.

Soil pH

Electrical Conductivity ($S \cdot m^{-1}$)

Organic Carbon/Total Nitrogen (%)

Soil organic matter

P_2O_5 (Kg/Ac)

K_2O (Kg/Ac)

Sulphur (ppm)

Zn (ppm)

Fe (ppm)

Mn (ppm)

Cu (ppm)

All tests were performed at Gujarat State Fertilizer andChemicals Ltd. (GSFC), Vadodara.

Result and Discussion

The Bandheli grassland may be roughly divided into three types: (a) that occurring on flat, shallow, poor soil, **Site-I**; (b) that occurring on hilly areas with scattered surface stones, **Site-II**; (c) that occurring on fairly deep rich soils with a comparatively high water content, **Site-III**. Likewise, Rampur grassland was divided in to three main sites: a) Rampur b) Rozam and c) Kalitalai and these three sites were further divided into three sub sites. In Rampur grassland, though there was not much difference in soil condition the vegetation was differing depending on water availability. While at Rozam, some kind of undulations in the landscape was present. Kalitalai shows presence of black clay soil. The geographical data for selected study sites in the studied grasslands are given in table 7.1 and general soil condition for both grasslands is given in table 7.2.

The long dry season at once rules out this area as a place for typical grassland. At both these grasslands, the grass vegetation is composed of (1) perennial grasses whose aerial parts wither and die (and are often burnt) annually, (2) annual grasses of varying length of life whose seed lies dormant in the ground till the next rains. In favorable conditions the succession can proceed positively while due to climate change especially due to uneven and erratic rainfall it also can precede negatively. Such changes were studied by us in an area of 754.04 ha of Bandheli grassland and simultaneously in an area of 1987.81 ha of Rampur grassland for three successive years (2007 – 2010).

Table 7.1 Geographical details of the selected study sites

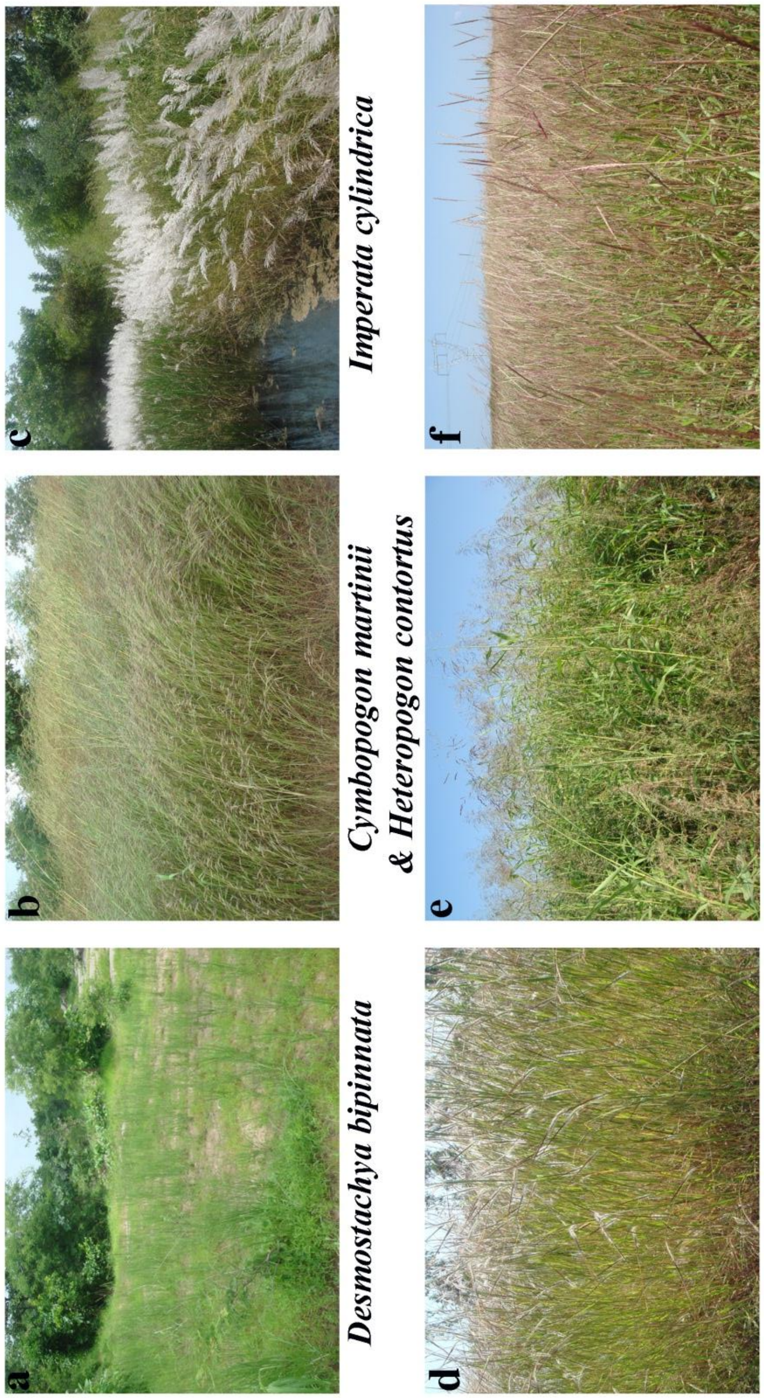
		Bandheli		
	Site: Bandheli I	Site: Bandheli II	Site: Bandheli III	
	N: 22^{0} 51' 10.3"	N: 22^{0} 51' 26"	N: 22^{0} 50' 48.3"	
	E: 073^{0} 42' 52.2"	E: 073^{0} 43' 25.9"	E: 073^{0} 42' 50.9"	
	Elevation: 501 ft	Elevation: 526 ft	Elevation: 472 ft	
		Rampura		
Site: Rampura I	Site: Rampura II	Site: Rampura III	Site: Rampura IV	Site: Rampura V
N: 22°50'21.30"	N: 22°50'18.20"	N: 22°50'19.46"	N: 22°50'4.48"	N: 22°50'7.83"
E: 74°10'56.53"	E: 74°10'56.18"	E: 74°10'52.90"	E: 74°11'3.04"	E: 74°11'2.50"
Elevation: 1254 ft	Elevation: 1249 ft	Elevation: 1254 ft	Elevation: 1264 ft	Elevation: 1264 ft

Rozam				
Site: Rozam I	Site: Rozam II	Site: Rozam II	Site: Rozam IV	Site: Rozam V
N: 22°49'18.31"	N: 22°49'21.72"	N: 22°49'24.69"	N: 22°49'33.56"	N: 22°49'30.79"
E: 74°11'16.07"	E: 74°11'3.34"	E: 74°10'51.27"	E: 74°10'17.54"	E: 74°10'23.33"
Elevation: 1275 ft	Elevation: 1276 ft	Elevation: 1285 ft	Elevation: 1258 ft	Elevation: 1269 ft
Kalitalai				
Site: Kalitalai I	Site: Kalitalai II	Site: Kalitalai III	Site: Kalitalai IV	Site: Kalitalai V
N: 22°50'29.95"	N: 22°50'27.52"	N: 22°50'33.62"	N: 22°50'34.20"	N: 22°50'35.40"
E: 74°12'31.96"	E: 74°12'29.67"	E: 74°12'27.13"	E: 74°12'30.92"	E: 74°12'28.13"
Elevation: 1196 ft	Elevation: 1202 ft	Elevation: 1182 ft	Elevation: 1186 ft	Elevation: 1177 ft

Table 7.2 Soil analysis Data

Soil parameters for Bandheli		**Soil parameters for Rampur**	
Considerably more amount			
pH	6.68	pH	6.59
Electrical Conductivity	0.18 $S \cdot m^{-1}$	Electrical Conductivity	0.16 $S \cdot m^{-1}$
Organic Carbon/Total Nitrogen	1.09 %	Organic Carbon/Total Nitrogen	1.41%
Organic matter	1.88 %	Organic matter	2.43 %
Zn	5.12 ppm	K_2O	180.0 Kg/Ac
Fe	60 ppm	Zn	7.40 ppm
Mn	38.16 ppm	Fe	47.60 ppm
Cu	2.38 ppm	Mn	144.0 ppm
		Cu	7.0 ppm
Considerably low amount			
P_2O_5	6.00 Kg/Ac	P_2O_5	4.00 Kg/Ac
K_2O	93.00 Kg/Ac	Sulphur	9.50 ppm
Sulphur	15.30 ppm		

At Bandheli grassland, at rocky area (B - II) the gradually accumulating soil carried first of all species of the Liliaceae such as *Chlorophytum borivilianum,*



a *Desmostachya bipinnata*

b *Cymbopogon martinii & Heteropogon contortus*

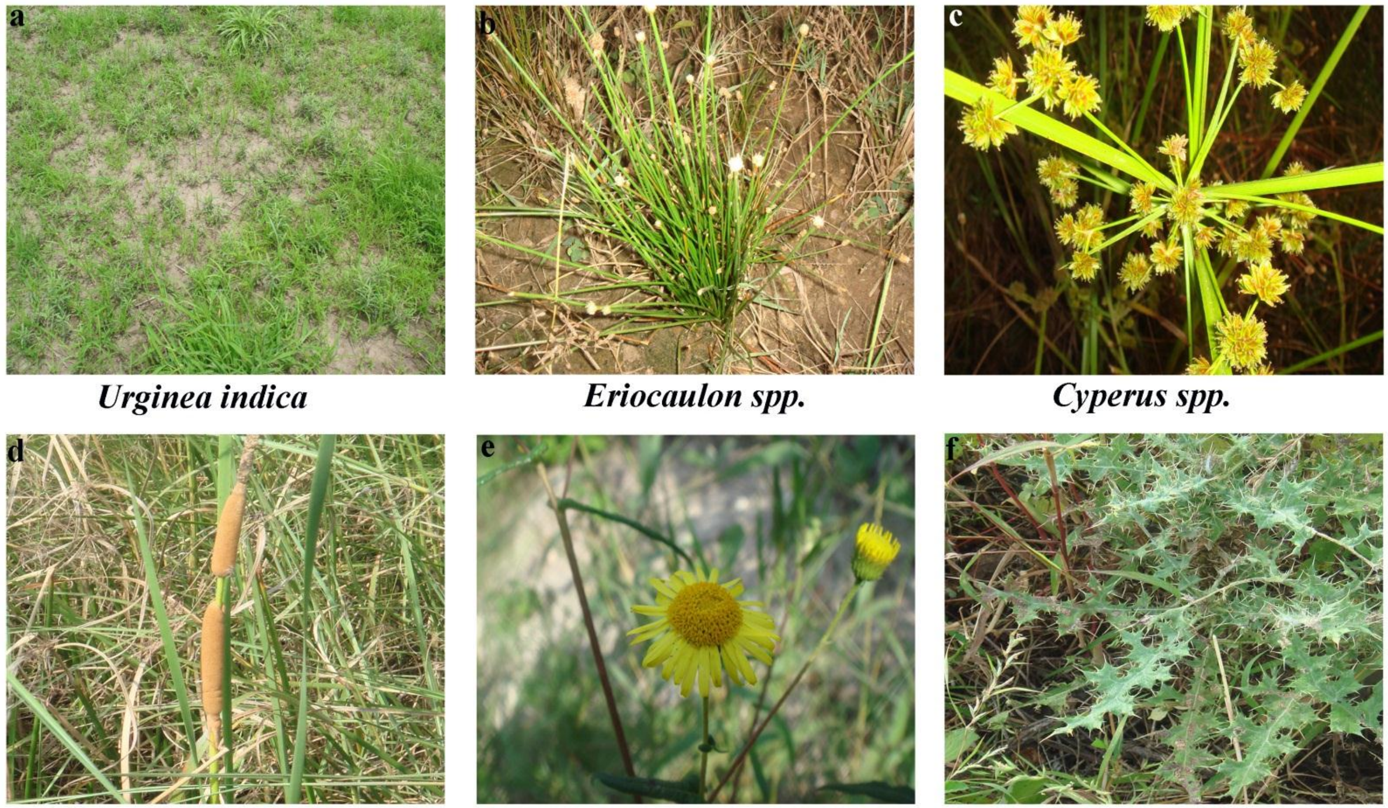
c *Imperata cylindrica*

d *Heteropogon contortus*

e *Shorghum halepanse*

f *Ischaemum rugosum*

Plate 7.1 Grasses at different sites



Urginea indica *Eriocaulon spp.* *Cyperus spp.*

Typha spp. *Vicoa auriculata* *Echinops echinatus*

Plate 7.2 Other associated species

Urginea indica (**Plate 7.2 - a**) along with warm climate grass species *Desmostachya bipinnata* (**Plate 7.1 - a**). Then came the short-lived dwarf grasses such as *Digitaria granularis, Eragrostiella bifaria, Melanocenchris jacquemontii*, *Oropetium thomaeum*, *Paspalidium flavidum* etc. The next stage was the establishment of *Aristida adscensionis* and *A*. *funiculata* along with the perennial form of *Cymbopogon martinii, Heteropogon contortus, Themeda triandra*. The unenclosed land never got beyond this stage. Under enclosure the next stage was the growth of leguminous species. In the flat shallow soil (B - I), tussock grasses developed very slowly. The stage *Cymbopogon-Heteropogon,* (**Plate 7.1 - b**) therefore, appears to be the climax of the flat, shallow area. In the deeper soils (B - III), with more soil moisture, perennial grasses appeared, but they were different from those found on the stony areas. These perennial grasses were *Bothriochloa pertusa, Dichanthium annulatum*, *Dichanthium caricosum* and *Imperata cylindrica* (**Plate 7.1 - c**). This association was distinctly unstable, and excessive moisture caused a development of Cyperaceae members like species of *Eriocaulon spp.* (**Plate 7.2 - b**), *Cyperus spp.* and other swamp weeds, while artificial drainage brought on an invasion of the perennial grasses from the rocky area and even signs of the *Aristida-Heteropogon* stage. The soil moisture determination from the three typical areas namely; hilly, flat, shallow soil and good, deep soil showed characteristic differences.

At Rampur grassland also same as Bandheli somewhat rocky area is present along with undulations in the landscape. Therefore, the soil carried out species of Liliaceae (*Chlorophytum borivilianum*) along with the sprouting of perennial grass species like *Apluda mutica, Chrysopogon fulvus, Cymbopogon martinii, Dichanthium annulatum, Heteropogon contortus* (**Plate 7.1 - d**)*, Ophiorus exaltatus, Sehima nervosum, Themeda triandra,* etc. After that, short-lived dwarf grasses such as

Brachiaria eruciformis, Echinochloa colonum, E. crus-galli, Eragrostis unoloides, E. tenella, Melanocenchris jacquemontii, *Panicum tripheron*, *Paspalidium flavidum,* etc. The next stage was the establishment of *Aristida adscensionis* and *A. funiculata* along with the other perennial form. But at the same time soil of Kalitalai showed the presence of species like *Andropogon pumilus, Dinebra retroflexa, Ischaemum pilosum,* etc. Opposite to the Bandheli grassland, here along with the grasses some leguminous species showed their vegetative growth. The unenclosed land never got beyond this stage and only shows growth of leguminous species. Here also the tussock grasses show their development very slow. Where the soils were somewhat deeper with more moisture content, perennial grasses appeared, but they were different from those found on the other areas. At Rampur species like *Chrydopogon fulvus*, *Heteropogon contortus*, *Themeda triandra,* etc. while at Rozam species like *Arthraxon lanceolatus, Coix lachryma-jobi, Chionachne koenigii, Sorghum halepanse* (**Plate 7.1 - e**), etc. were dominantly present. The soil of Kalitalai, again differing in its moisture content and show presence of species like *Ischaemum rugosum* (**Plate 7.1 - f**). Here the association was distinctly unstable, and excessive moisture caused development of a Cyperaceae member (*Cyperus spp*., *Typha spp*.) (**Plate 7.2 – c and d**) and other swamp weeds. From the observations of successive three years, assumption was made that the soils of Rampur and Rozam exhibits similarity up to some extent in soil condition and vegetation while soils of Kalitalai showed 100% opposite vegetation at generic level. Rozam showed the establishment of species like *Sehima ischaemoides, Themeda laxa,* etc. in somewhat stony area while these species were absent at Rampur. Other major difference between Rampur and Rozam was that both places showed difference in vegetation at species level. Both grasslands show one common pattern of increase in unpalatable species i.e. *Cymbopogon martinii* which occupy maximum land of the grassland and it was expanding year by year.

Concisely, the distribution pattern or in other words the availability of different grasses along with their natural associate legumes is given in table 7.3, 7.4, 7.5 and 7.6.

Table 7.3 Distribution of different species at Bandheli grassland

Sr.		B - I			B - II			B - III		
No.	Species Name	07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10
1	*Aeschynomene indica*	o	o	o	-	-	-	-	-	-
2	*Alloteropsis cimiciana*	f	o	f	-	-	-	a	a	a
3	*Alysicarpus belgaumensis*	-	r	r	-	-	-	-	-	-
4	*Alysicarpus monilifer*	f	o	o	-	-	-	o	o	o
5	*Alysicarpus procumbens*	r	r	r	-	-	-	o	o	o
6	*Alysicarpus vaginalis*	f	f	f	f	f	f	f	f	f
7	*Apluda mutica*	a	f	a	-	-	-	-	-	-
8	*Aristida adscensionis*	f	a	a	f	f	f	-	-	-
9	*Aristida funiculata*	f	f	f	f	f	f	-	-	-
10	*Atylosia platycarpa*	-	-	-	-	r	r	-	-	-
11	*Atylosia platycarpa*	-	-	o	-	-	r	-	-	r
12	*Atylosia scarabaeoides*	f	f	f	f	f	f	f	f	f
13	*Bothriochloa pertusa*	-	-	-	-	-	-	a	a	a
14	*Cassia absus*	f	a	f	f	f	f	-	-	-
15	*Capillipedium huegelii*	-	-	o	-	-	-	-	-	-
16	*Cassia occidentalis*	r	-	-	r	-	-	-	-	-
17	*Cassia tora*	f	f	f	-	-	-	-	-	-
18	*Cenchrus ciliaris*	-	-	-	a	f	a	-	-	-
19	*Chloris barbata*	o	o	-	-	-	-	-	-	-
20	*Clitoria ternatea*	r	-	-	-	-	-	-	-	-
21	*Crotalaria notonii*	-	-	-	r	r	r	-	-	-
22	*Crotalaria spectabilis*	-	-	-	-	-	-	f	f	f
23	*Cymbopogon martinii*	a	a	a	a	a	a	a	a	a
24	*Cynadon dactylon*	f	f	f	f	f	f	f	f	f
25	*Dactyloctenium aegyptium*	o	o	o	o	o	o	-	-	-
26	*Desmostachya bipinnata*	f	f	f	f	f	f	-	-	-
27	*Dichanthium annulatum*	r	r	r	-	-	-	r	r	r
28	*Digitaria adscendens*	f	f	f	-	-	-	-	-	-
29	*Digitaria granularis*	-	-	-	-	r	r	-	-	-
30	*Eleusine indica*	r	r	-	-	-	-	-	-	-

Sr. No.	Species Name	B - I			B - II			B - III		
		07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10
31	*Eragrostiella biferia*	-	-	-	-	r	-	-	-	-
32	*Eragrostis japonica*	-	-	-	-	r	-	-	-	-
33	*Eragrostis nutans*	-	-	-	-	r	-	-	-	-
34	*Eragrostis viscosa*	-	-	-	-	r	-	-	-	-
35	*Eragrostis tenella*	f	f	f	f	f	f	f	f	f
36	*Eragrostis tremula*	-	-	-	-	-	-	-	-	r
37	*Hackelochloa granularis*	f	f	f	f	f	f	-	-	-
38	*Heteropogon contortus*	a	a	a	a	a	a	a	a	a
39	*Imperata cylindrica*	-	-	-	-	-	-	a	a	a
40	*Indigofera cordifolia*	f	f	f	f	f	f	f	f	f
41	*Indigofera echinata*	o	o	o	o	o	o	o	o	o
42	*Indigofera hirsuta*	-	-	-	-	-	-	o	o	-
43	*Indigofera linifolia*	f	f	f	-	-	-	f	f	f
44	*Indigofera tinctoria*	-	-	-	-	-	-	-	r	r
45	*Melanocenchris jacquemontii*	-	-	-	f	f	f	-	-	-
46	*Oropetium thomaeum*	-	-	-	f	f	f	-	-	-
47	*Panicum trypheron*	o	o	o	-	-	-	o	o	o
48	*Paspalidium flavidum*	o	o	o	-	-	-	-	-	-
49	*Pterotis indica*	-	-	-	-	-	-	-	-	r
50	*Schoenefeldia gracilis*	f	f	f	-	-	-	-	-	-
51	*Setaria glauca*	f	f	f	f	f	f	-	-	-
52	*Sporobolus coromandelianus*	-	-	-	-	r	r	-	-	-
53	*Sporobolus fertilis*	-	-	-	-	r	-	-	-	-
54	*Sporobolus halvolus*	-	-	-	-	-	r	-	-	-
55	*Sporobolus diander*	o	o	o	a	a	a	o	o	o
56	*Tephrosia perpurea*	o	o	o	-	-	-	-	-	-
57	*Tephrosia villosa*	-	-	-	o	o	o	-	-	-
58	*Themeda cymbaria*	-	-	-	-	-	-	o	-	f
59	*Themeda quadrivalvis*	-	-	-	o	o	-	-	-	-
60	*Themeda triandra*	f	f	f	f	f	f	f	f	f
61	*Zornia gibbosa*	f	f	f	f	f	f	f	f	f

Table 7.4 Distribution of different species at different sub sites of Rampur

Sr.		R – I			R – II			R – III			R – IV			R – V		
No.	Species Name	07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10
1	*Alysicarpus monilifer*	o	o	o	o	o	o	-	-	-	o	o	o	o	o	o
2	*Alysicarpus vaginalis*	o	o	o	o	o	o	-	-	-	o	o	o	o	o	o
3	*Apluda mutica*	-	r	r	-	-	r	-	-	-	-	-	-	-	-	-
4	*Aristida adscensionis*	o	o	-	-	-	-	-	-	-	-	-	-	-	-	-
5	*Atylosia scarabaeoides*	-	-	-	-	-	-	-	-	-	o	o	o	o	o	o
6	*Cassia occidentalis*	o	-	-	o	o	-	-	-	-	-	-	-	-	-	-
7	*Cassia tora*	f	-	-	o	o	o	-	o	o	-	-	-	-	-	-
8	*Cenchrus setigerus*	f	f	f	-	-	-	-	-	-	-	-	-	-	-	-
9	*Chrysopogon fulvus*	f	f	f	a	a	a	a	a	a	a	a	a	a	a	a
10	*Clitoria ternatea*	r	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	*Crotalaria albida*	-	-	-	-	-	-	-	-	-	r	-	-	-	-	-
12	*Crotolaria burhia*	-	-	-	-	-	-	-	-	-	r	-	-	-	-	-
13	*Crotolaria calycina*	-	-	-	-	-	-	-	-	-	o	o	o	o	o	o
14	*Crotolaria juncea*	o	o	o	-	-	-	-	-	-	-	-	-	-	-	-
15	*Crotalaria leptostachya*	o	o	-	-	-	-	-	-	-	o	o	o	o	o	-
16	*Crotolaria mysorensis*	-	-	-	-	-	-	-	-	-	o	o	o	o	o	o
17	*Crotolaria orixensis*	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
18	*Cymbopogon martinii*	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
19	*Cynodon dactylon*	r	r	r	o	o	o	o	o	o	o	o	o	o	o	o
20	*Dactyaloctanium aegyptium*	f	f	f	o	o	o	o	o	o	-	-	-	-	-	-
21	*Dichanthium annulatum*	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
22	*Digitaria adscendens*	o	o	o	-	-	-	o	o	o	-	-	-	-	-	-
23	*Echinochloa colonum*	o	o	o	o	o	o	o	o	o	-	-	-	o	o	o
24	*Echinochloa crusgalli*	o	o	o	-	-	-	o	o	o	-	-	-	-	-	-
25	*Eleusine indica*	o	o	o	-	-	-	o	o	o	-	-	-	-	-	-
26	*Eragrostis cilianensis*															
27	*Eragrostis ciliaris*	r	r	r	-	-	-	-	-	-	-	-	-	-	-	-
28	*Eragrostis tenella*	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
29	*Eragrostis unioloides*	-	-	-	r	-	-	-	-	-	-	-	-	-	-	-
30	*Goniogyna hirta*	o	o	o	-	-	-	-	-	-	-	-	-	-	-	-
31	*Heteropogon contortus*	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
32	*Indigofera cordifolia*	o	o	o	o	o	o	-	-	-	-	-	-	-	-	-
33	*Indigofera echinata*	o	o	o	o	o	o	-	-	-	-	-	-	-	-	-
34	*Indigofera enneaphylla*	o	o	o	-	-	-	o	o	o	-	-	-	-	-	-
35	*Indigofera linifolia*	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o

Sr. No.	Species Name	R – I			R – II			R – III			R – IV			R – V		
		07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10
36	*Indigofera spicata*	r	r	r	-	-	-	-	-	-	-	-	-	-	-	-
37	*Melanocenchris jacquamontii*	o	o	o	-	-	-	-	-	-	-	-	-	-	-	-
38	*Ophiorus exaltatus*	-	-	-	-	-	-	-	-	-	f	f	f	f	f	f
39	*Panicum trypheron*	o	o	o	o	o	o	-	-	-	-	-	-	-	-	-
40	*Paspalidium flavidum*	o	o	o	o	o	o	o	o	o	-	-	-	-	-	-
41	*Rhynchosia minima*	-	-	-	-	-	-	-	-	-	o	o	o	o	o	o
42	*Sehima nervosum*	-	-	-	o	f	f	-	-	-	-	-	-	-	-	-
43	*Sehima sulcatum*	-	-	-	o	o	o	-	-	-	-	-	-	-	-	-
44	*Setaria glauca*	o	o	o	o	o	o	o	o	o	-	-	-	-	-	-
45	*Setaria tomentosa*	o	o	o	o	o	o	o	o	o	-	-	-	-	-	-
46	*Setaria verticillata*	o	o	o	-	-	-	-	-	-	-	-	-	-	-	-
47	*Sporobolus marginatus*	-	-	-	-	-	-	-	-	-	-	r	-	-	-	-
48	*Themeda triandra*	o	o	o	o	o	o	-	-	-	o	o	o	o	o	o
49	*Zornia gibbosa*	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f

Table 7.5 Distribution of different species at different sub sites of Rozam

Sr. No.	Species Name	Ro - I			Ro – II			Ro - III			Ro - IV			Ro - V		
		07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10
1	*Aeschynomene indica*	-	-	-	o	o	o	-	-	-	o	o	o	-	-	-
2	*Alysicarpus monilifer*	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
3	*Alysicarpus rugosus*	-	-	-	-	r	r	-	-	-	-	-	-	-	-	-
4	*Alysicarpus tetragonolobus*	-	-	-	-	r	r	-	-	-	-	-	-	-	-	-
5	*Alysicarpus vaginalis*	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
6	*Apluda mutica*	-	r	r	-		r	-	-	-						
7	*Aristida adscensionis*	-	-	-	-	-	-	-	-	-	o	o	o	o	o	o
8	*Arthraxon lanceolatus*	-	-	-	-	-	-	-	r	r	-	-	-	-	-	-
9	*Atylosia scarabaeoides*	o	o	o	o	o	o	-	-	-	o	o	o	o	o	o
10	*Cassia mimosoides*	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
11	*Cassia occidentalis*	-	-	-	-	-	-	-	-	-	r	r	r	-	-	-
12	*Cassia tora*	-	-	-	-	-	-	-	-	-	o	o	o	-	-	-
13	*Chionachne koenigii*	-	-	-	-	-	-	-	r	r	-	-	-	-	-	-
14	*Chrysopogon fulvus*	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
15	*Coix lachryma-jobi*	-	-	-	-	-	-	o	o	-	-	-	-	-	-	-
16	*Crotalaria juncea*	-	-	-	-	-	-	-	-	-	o	o	o	-	-	-
17	*Crotalaria leptostachya*	-	-	-	-	-	-	-	-	-	r	r	r	-	-	-

Sr. No.	Species Name	Ro - I			Ro – II			Ro - III			Ro - IV			Ro - V		
		07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10
18	*Crotalaria nana*	-	-	-	-	-	-	-	-	-	-	-	r	-	-	-
19	*Crotalaria orixensis*	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
20	*Cymbopogon martinii*	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
21	*Cynodon dactylon*	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
22	*Dichanthium annulatum*	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
23	*Dichanthium caricosum*	-	-	-	-	-	-	-	r	r	-	-	-	-	-	-
24	*Echinochloa colonum*	-	-	-	-	-	-	o	o	o	o	o	o	o	o	o
25	*Echinochloa crusgalli*	-	-	-	-	-	-	o	o	o	-	-	-	o	o	o
26	*Eragrostis tenella*	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
27	*Heteropogon contortus*	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
28	*Indigofera cordifolia*	-	-	-	o	o	o	o	o	o	f	f	f	f	f	f
29	*Indigofera echinata*	o	o	o	o	o	o	o	o	o	f	f	f	o	o	o
30	*Indigofera linifolia*	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
31	*Melanocenchris jacquamontii*	-	-	-	-	-	-	o	o	o	-	-	-	-	-	-
32	*Ophiorus exaltatus*	f	f	f	f	f	f	-	-	-	-	-	-	-	-	-
33	*Sehima ischaemoides*	-	-	-	-	o	o	-	o	o	-	-	-	-	-	-
34	*Sehima nervosum*	-	-	-	-	-	-	-	-	-	f	f	f	f	f	f
35	*Sehima sulcatum*	-	-	-	-	-	-	-	-	-	o	o	o	o	o	o
36	*Sesbania aculeata*	-	-	-	-	-	-	-	-	-	r	-	-	-	-	-
37	*Sesbania sesban*	-	-	-	-	-	-	-	-	-	-	o	o	-	-	-
38	*Sorghum halepense*	-	-	-	-	-	-	-	-	-	f	f	f	f	f	f
39	*Sporobolus marginatus*	-	-	-	-	-	-	-	r	-	-	-	-	-	-	-
40	*Tephrosia strigosa*	-	-	o	-	-	o	-	-	-	-	-	-	-	-	-
41	*Themeda cymbaria*	-	-	-	-	-	-	-	r	r	-	-	-	-	-	-
42	*Themeda laxa*	-	-	-	-	o	o	-	o	o	-	-	-	-	-	-
43	*Themeda triandra*	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
44	*Vigna radiata var. sublobata*	-	-	-	-	-	-	-	-	-	-	-	r	-	-	-
45	*Zornia gibbosa*	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o

Table 7.6 Distribution of different species at different sub sites of Kalitalai

Sr. No.	Species Name	K - I			K - II			K – III			K - IV			K - V		
		07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10
1	*Alysicarpus monilifer*	-	-	-	-	-	-	o	o	o	o	o	o	o	o	o
2	*Alysicarpus rugosus*	-	-	-	-	-	-	-	-	-	-	r	r	-	-	-
3	*Alysicarpus tetragonolobus*	-	-	-	-	-	-	-	-	-	-	r	r	-	-	-
4	*Alysicarpus vaginalis*	-	-	-	-	-	-	-	-	-	o	o	o	o	o	o

Sr. No.	Species Name	K - I			K - II			K – III			K - IV			K - V		
		07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10	07-08	08-09	09-10
5	*Andropogon pumilus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	*Aristida adscensionis*	-	-	-	-	-	-	o	o	o	o	o	o	-	-	-
7	*Aristida funiculata*	-	-	-	-	-	-	o	o	o	o	o	o	o	o	o
8	*Brachiaria eruciformis*	-	-	-	-	-	-	-	-	-	-	f	f	-	-	-
9	*Brachiaria reptans*	-	-	-	-	o	o	-	-	-	-	o	o	-	o	o
10	*Cassia tora*	-	-	-	-	-	-	-	-	-	-	-	-	o	o	o
11	*Clitoria ternatea*	-	-	-	-	-	-	r	-	-	-	-	-	-	-	-
12	*Chionachne koenigii*	-	-	-	-	-	-	-	-	-	-	r	-	-	-	-
13	*Chloris barbata*	-	-	-	o	o	o	o	o	o	o	o	o	o	o	o
14	*Chloris virgata*	r	r	r	o	o	o	-	-	-	-	-	-	o	o	o
15	*Chrysopogon fulvus*	-	-	-	-	-	-	a	a	a	-	-	-	f	f	f
16	*Crotalaria juncea*	-	-	-	-	-	-	-	-	-	o	o	o	-	-	-
17	*Cymbopogon martinii*	f	f	f	-	-	-	f	f	f	-	-	-	o	o	o
18	*Cynodon dactylon*	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
19	*Dichanthium annulatum*	r	r	r	-	-	-	-	-	-	o	o	o	o	o	o
20	*Digitaria adscendens*	-	-	-	-	-	-	o	o	o	f	f	f	f	f	f
21	*Dinebra retroflexa*	-	-	-	-	-	-	-	-	-	o	o	o	o	o	o
22	*Echinochloa colonum*	-	-	-	o	o	o	o	o	o	o	o	o	o	o	o
23	*Echinochloa crusgalli*	-	-	-	o	o	o	-	-	-	o	o	o	o	o	o
24	*Eragrostis tenella*	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
25	*Heteropogon contortus*	-	-	-	-	-	-	o	o	o	-	-	-	-	-	-
26	*Indigofera glandulosa*	a	a	a	-	-	-	-	-	-	-	-	-	-	-	-
27	*Indigofera linifolia*	-	-	-	-	-	-	-	-	-	o	o	o	o	o	o
28	*Ischaemum molle*	-	-	-	-	r	r	-	-	-	-	-	-	-	-	-
29	*Ischaemum pilosum*	a	a	a	-	-	-	-	-	-	-	-	-	-	-	-
30	*Ischaemum rugosum*	-	-	-	f	f	f	-	-	-	-	-	-	-	-	-
31	*Panicum antidotale*	-	-	-	-	-	-	-	-	-	-	o	o	-	-	-
32	*Panicum trypheron*	-	-	-	o	o	o	-	-	-	o	o	o	-	-	-
33	*Paspalidium flavidum*	-	-	-	-	-	-	-	-	-	o	o	o	-	-	-
34	*Rhynchosia minima*	o	o	o	-	-	-	-	-	-	-	-	-	-	-	-
35	*Rottboellia exaltata*	-	-	-	-	-	r	-	-	-	-	-	-	-	-	-
36	*Sesbania sesban*	-	-	-	o	o	o	-	-	-	-	-	-	-	-	-
37	*Sorghum halepense*	-	-	-	-	-	-	a	a	a	-	-	-	-	-	-
38	*Thelepogon elegans*	-	-	-	o	o	o	-	-	-	-	-	-	-	-	-
39	*Themeda triandra*	-	-	-	-	-	-	-	-	-	-	-	-	o	o	o

a = abundant, f = frequent, o = occasionally and r = rare

Countour - made of stones

Cattle grazing - Biotic pressure

Grass stump left after cutting

Cattle grazing

New sprouting after accidental fire

Plate 7.3 Biotic pressures on grasslands

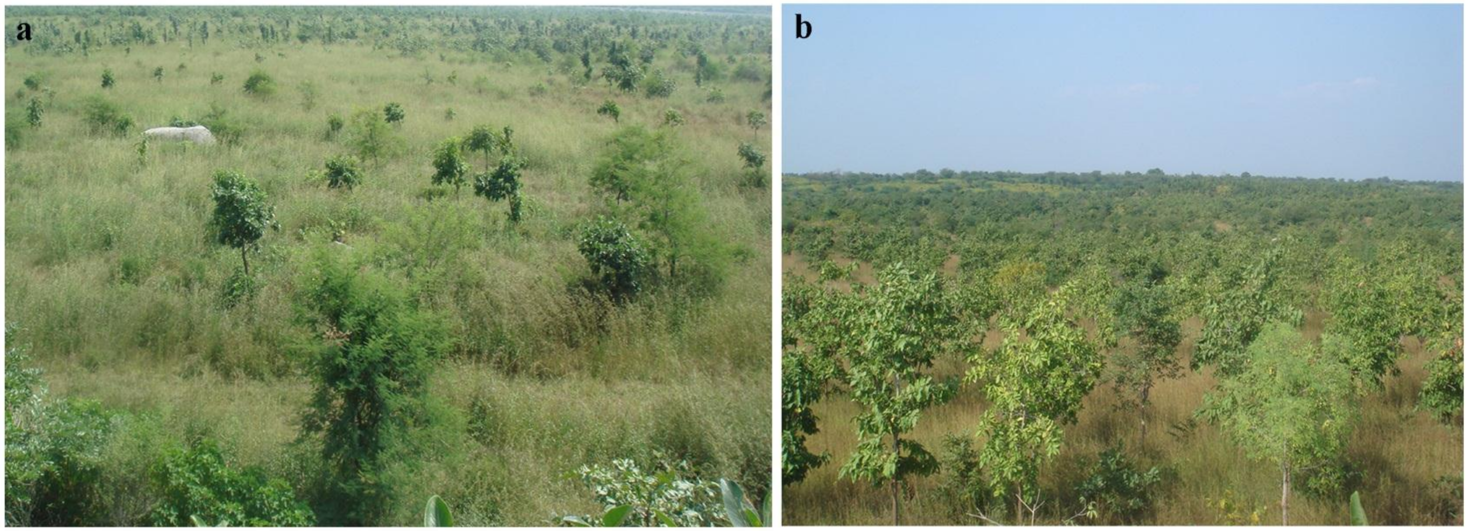
Throughout all of these, at Bandheli grassland species of *Aristida* and *Heteropogon* were found, but in the hilly area xerophytic tussock grasses occur and in the low-lying areas, occasionally tuft of mesophytic perennial grasses were present. While at Rampur grassland, species of *Chrysopogon* and *Heteropogon* were found dominantly everywhere. We could not differentiate the Rampur grassland as flat, hilly and deep soils, thus all over in the grassland tuft of perennial grasses were present. In both grasslands the dominating disturbing factor is cattle. The village cattle are freed every morning to roam over these lands, on which there are no fences of any kind. They begin to graze as soon as there is the faintest appearance of a green leaf and they continue throughout the year as long as there is anything left which is eatable (**Plate 7.3 – b, c and d**). The cattle move freely and so affect a very wide area. Their trampling as well as their grazing has a considerable effect. Another problem during hot weather i.e. March to May, accidental fires (**Plate 7.3 - e**) generally sweep over the area, leaving it with a burnt surface. It will also be understood that Bandheli grassland is peculiarly subject to erosion which may, in the case of a hillside, rapidly remove the surface and get down to bare rock, and in the case of deep soil may excavate an ever-growing ravine. A retrograde succession is thus easily observable anywhere.

In our selected study sites, the environment was very fluctuating during three successive years of the study. The rains were very erratic; due to which the temperature fluctuation level was very high which directly affected the plant growth. Another effect of these fluctuating environments was that, at the time of seed setting, the plants got dried. Thus, almost all dominant perennial palatable grass species of the study area like, *Apluda mutica, Bothriochloa pertusa, Cenchrus ciliaris, Chrysopogon fulvus, Dichanthium annulatum, Heteropogon contortus, Sehima nervosum, Themeda triandra* and many other less dominant species did not show seed formation. This affects the community composition and species diversity in the next season. Due to the erratic rain and fluctuating environmental factors, the exterior configuration of plants got changed. The interior physiological and ecological changes in the aboveground parts and the underground root system resulted from high temperature and dryness which not only suppressed the growth of aboveground parts and underground parts as well which in turn affect the regeneration capacity of that particular species.

Besides all these situations, at all three sites, many dominant perennial grass species and some short lived grass species remains alive with almost completing their lifecycle till the end of the study. They are *Apluda mutica, Heteropogon contortus, Dichanthium annulatum, Cenchrus ciliaris, Cymbopogon martinii, Imperata cylindrica, Dactyloctenium aegyptium, etc*. While amongst legumes species like *Atylosia scarabaeoides, Indigofera linifolia, Tephrosia purpurea, Indigofera echinata, Alysicarpus vaginalis, Alysicarpus procumbens, Cassia tora, Cassia absus, Tephrosia villosa, Crotalaria notonii, Zornia gibbosa, Indigofera cordifolia, Indigofera tinctoria* etc. were alive till the end of the study with completing their life cycle. Likewise at Rampur, species like *Sehima nervosum, Themeda triandra, Ophiorus exaltatus,* etc. and among legumes *Alysicarpus vaginalis, Alysicarpus monilifer, Atylosia scarabaeoides, Crotalaria mysorensis, Crotalaria orixensis, Rhynchosia minima* etc. were alive till the end of the study with completing their life cycle at all three sub sites. While at Rozam, among grasses species like *Chrysopogon fulvus, Coix lachryma-jobi, Dichanthium anulatum, Echinochloa colonum, Heteropogon contortus, Sorghum halepanse, Sehima nervosum, Themeda laxa, Themeda triandra,* etc. and amongst legume species *Alysicarpus tetragonolobus, Indigofera echinata, Crotalaria orixensis, Sesbania sesban,* etc. were alive till the end of the study with completing their life cycle at all three sub sites. The main difference was seen in the quantity of seed yield during successive years.

In initial time of rainy season, the short lived grass species like, *Digitaria granularis, Digitaria adscendens, Echinochloa colonum, Panicum tripheron, Paspalidium flavidum,* etc. reached up to their seed maturation stage. After the short drought condition, when again rainfall occurred, these species flourished again and reached up to their seed maturation stage. In such conditions species recorded in previous year did not show their reoccurrence while emergence of few new species was recorded. This showed the optimistic attitude of these species. It also exhibited that in absence of dominant species these ephemeral grasses can grow well. Heavily grazed perennial grassland habitats dominated by annual plant species returns to perennial species when grazing is reduced or else adequately favorable environmental conditions were available.

The studied area also shows presence of various tree species, *Acacia arabica* is common on good soil while *Acacia leucophloea* and *Acacia catechu* are found on poor soils. These trees, however, are very much nibbled by goats and are also lopped by man for firewood and get little chance to grow to any great size. The presence of considerably good, well-drained soil condition was marked with the presence of *Tectona grandis* kind of dominating species in the consociation of *Lannea coromandelica, Maduhca indica, Anogeissus latifolia, Mitragyna parvifolia, Boswellia serrata,* etc. as these species forming the top canopy of the area. Besides these, other species were *Aegle marmelos, Ougenia oojeinensis, Nyctanthes arbor-tristis* etc. are most common second storey plant species. Species like *Dalbergia latifolia, Acacia catechu, Diospyrus melanoxylon*, etc. also found together with *Tectona grandis.*



Temporal changes in grasslands

Grass drying before seed setting

Plate 7.4 Changes in grasslands

The Bandheli grassland is newly formed one. This place was earlier (approximately before a decade) well established as a dense forest. Due to environmental changes it got converted into open grassland with perennial grass species. Now this grassland is again flourishing with tree species. Thus, in such places the primary advantage of being tall is better access to light. When light levels under the canopy increase, plant growth in the understory often increases dramatically. Water and nutrients can also be limiting for understory plants. Canopy trees use large amounts of water and nutrients, and they have access to the energy to support prolific root growth and build large root systems, allowing them to obtain belowground resources effectively. In contrast, understory species have limited energy to use for acquisition of water and nutrients. Trenching studies have demonstrated that growth of understory plants increases when root competition from trees is removes, even when light is unaffected. And this might be one of the reasons for conversion of grassland into again forest (**Plate 7.4 – a and b**).

Our observations for both grasslands say that some of wild species mentioned in Fig.7.1 - 7.4 were able to grow well either in stress environments, vice-versa or whenever dominant perennial tuft grasses dried and understories come in direct contact with sunlight. In such circumstances such short lived species show their life span exact opposite to the surrounding dominant perennial grasses, e.g. *Themeda cymbaria* shows domination over other species due to fires which may lead to alteration of other disturbances. According to Swamy et al. (2000) such species interaction gives an advantage to certain species over others.

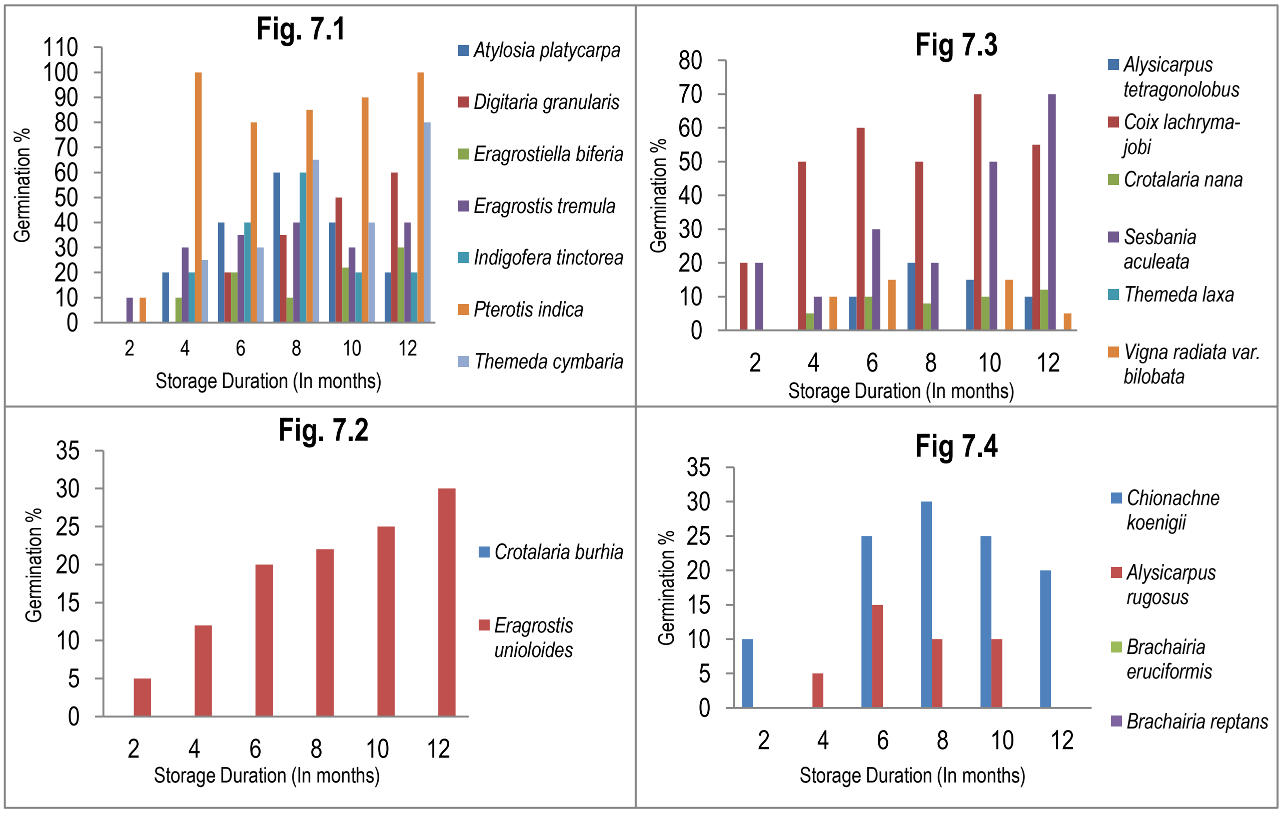


Fig. 7 Adaptations of species against stressed environment

Table 7.7 Instability of species towards fluctuating environment

Species Name	Best rain ('07-'08)	Delayed rain ('08-'09)	Normal rain ('09-'10)
Bandheli grassland			
Atylosia platycarpa (I), (II)	-	√	√
Digitaria granularis (II)	-	-	√
Eragrostiella biferia (II)	-	√	-
Eragrostis tremula (III)	-	-	√
Indigofera tinctorea (III)	-	√	-
Pterotis indica (III)	-	√	-
Themeda cymbaria (I)	√	-	√
Rampur grassland			
Crotalaria burhia	√ (No seed collection)	-	-
Eragrostis unioloides	√	-	-

Rozam grassland			
Alysicarpus tetragonolobus	-	-	√
Coix lachryma-jobi	-	-	√
Crotalaria nana	-	-	√
Sesbania aculeata	√	-	-
Themeda laxa	-	√ (No seed collection)	-
Vigna radiata var. *bilobata*	-	-	√
Kalitalai grassland			
Chionachne koenigii	-	√	-
Alysicarpus rugosus	-	-	√
Brachairia eruciformis	-	-	√ (No seed collection)
Brachairia reptans	-	-	√ (No seed collection)

As a result of such fluctuating environmental conditions, we were not able to record the species which we got in the previous year. And some newer species in the same site which we could not get in previous year, we were able to collect them (Table 7.7). Another major loss of the studied sites of both grasslands that the species which were already established their vegetative growth, were not able to finish their life cycle with reproductive growth as the high temperatures and low rainfall did not allow them for seed setting (**Plate 7.4 – c, d, e and f**).

Successional development of prairies, savannas, and steppes into woodland might take place if not halted by wildfires (Bond et al., 2005) and grazing (Craine and McLauchlan, 2004). The establishment of new members in an ecological community is governed by interactions between the prospective immigrant and resident species, such as competition for resources and facilitation. One of the oldest ecological hypotheses on the establishment success of immigrants was phrased in the context of invasion biology and predicts that more diverse communities are more resistant against invasion (Elton, 1958). For grassland ecosystems, a number of studies have shown that the chance of establishment of newly arriving plants decreases with increasing plant diversity (Fargione and Tilman, 2005; Fargione *et al.,* 2003; Kennedy *et al.,* 2002; Tilman, 1997). However, the presence of particular plant species (Dukes, 2002) or plant functional groups (Mwangi *et al.,* 2007) has in some cases been shown to be more important in influencing invader success than diversity. Invading plant individuals are often more limited by species of the same than of other functional groups, as those may show very similar requirements (Mwangi *et al.,* 2007). Independent of the invading species, the fate of invaders may be affected negatively by the presence of grasses, which with their dense rooting system are highly competitive in the exploitation of soil nutrients and water. Legume presence, on the contrary, often has positive effects on neighboring individuals (Temperton *et al.,* 2007) due to soil enrichment with nitrogen through atmospheric nitrogen fixation.

Over the 20th century there has been a consistent and large scale warming of land and ocean surface. The global mean surface temperature has increased by 0.6^{0}C (0.4-0.8^{0}C) over the last 100 years which can adversely affect the species composition, globally. Approximately 20 to 30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5 to 2.5°C (Anonymous, 2007). Thus in present study the data were collected simultaneously at different successional sites, and were analyzed. The structure, composition and life-forms changed significantly during succession.

Anderson and Thomaz (2008) said in their study that the stability of water level in the disconnected lakes moved community composition from most common and dominant species *Eichhonia azurea, Salvinia spp.*to *Polyganum ferrugineum* and *P. meissmerianum*, which were species characteristic of dry environments. In our study the same situation was observed at Bandheli, Kalitalai and Rampur. Here, natural ravines and lake which was available full of water in the initial years of the study were dried up in the last year. This discontinuity of water availability resulted in the change in the species composition and there was increase or decrease in the number of species (Table 7.7) during the studied period. It was a strong indicative that short term succession had occurred in these areas.

Heat stress severely restricts plant growth and productivity and is classified as one of the major abiotic adversities for many crops (Hassan, 2006) particularly when it occurs during reproductive stages, which may lead to substantial yield loss in wheat (Hays et al., 2007). In addition, it affects the normal physiological functions of the leaves especially photosynthesis (Yan et al., 2011), which can result in increase in leaf injure rate. It was observed in our study that despite initial growth improvement in root system, the root growth was subsequently suppressed as a result of high temperature and dryness, and this resulted in compelled disappearance of few species.

In our selected study sites, the environment was very fluctuating during three years of the study. The rains were very erratic; due to which the temperature fluctuation level was very high which directly affected the plant growth. Another effect of these fluctuating environments was that, at the time of seed setting, the plants got dried. Thus almost all dominant perennial palatable grass species of the area like, *Apluda mutica, Bothriochloa pertusa, Cenchrus ciliaris, Dichanthium annulatum, Heteropogon contortus, Themeda triandra,* and many other less dominant species did not show seed formation. This affected the community composition and species diversity in the next season. Due to the erratic rain and fluctuating environmental factors, the exterior configuration of plants got changed. The interior physiological and ecological changes in the aboveground parts and the underground root system resulted from high temperature and dryness which not only suppressed the growth of aboveground parts and underground parts as well which in turn affect the regeneration capacity of that particular species. Short term changes in rainfall pattern and their impact on grasslands have been studied by many workers and the results emphasize importance of such studies, especially in current scenario of changing environment (Anderson, 2008; Cleland et al., 2013; Frei et al., 2014).

At both the grasslands, one unexpected result observed during our studies was that in certain portions of the land where the grasses were left uncut, with the assumption of allowing them to rot and so add humus to the soil; the grass, however, was so fibrous that it did not decay but laid on the ground acting as a denuding agent, effectively killing vegetation, preventing germination of seeds and preventing percolation of rainwater to the ground. The areas which had been denuded in this manner by the overlying debris were in the following season invaded by ruderals such as *Vicoa auriculata* (Sarpankho) (**Plate 7.2 - e**). It is therefore suggested, that the grass produced must be cut, grazed (but not over-grazed) or burnt if it is not to form an obstacle to next year's growth. Overgrazing also caused an increase of ruderals such as *Echinops echinatus* (**Plate 7.2 - f**). Improvement of such areas is distinctly possible. The first essential is fencing, so that the free movement and indiscriminate grazing of cattle may be checked. Low edge of local stone along the contours (**Plate 7.3 - a**) check run-off, allow accumulation of silt and form starting places for tussock/bunch grasses. Thereafter some simple system of rotational grazing or cutting is all that is needed. Expensive fencing is out of the question, as the present value of these lands is low. There are few villages which have undertaken the organized management of their grasslands (even without fencing) with excellent results, by appointing watchmen to keep away the cattle on particular areas. Until, however, there is some pressing economic factor causing the effective management of these lands to become a matter of urgency, it is not likely that there will be much change in them.

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