A Study of Bushfires in a Ghanaian Coastal Wetland. II. Impact on Floral Diversity and Soil Seed Bank

A. M. Wuver[1], D. K. Attuquayefio[2]* and L. Enu-Kwesi[3]
[1]Achimota School, P.O. Box AH 11, Achimota-Accra
[2]Department of Zoology, University of Ghana, Legon-Accra
[3]Department of Botany, University of Ghana, Legon-Accra
*Corresponding author

Abstract

The study was undertaken at the Muni-Pomadze wetlands near Winneba in the Central Region of Ghana. The main objective was to investigate the impact of bushfires on the vegetation and soil seed bank of the wetland, which ultimately affects its biodiversity. The methodology involved a floristic and seed bank study to determine the effect of bushfires on the flora and seeds in the study area. The results indicated a significant effect of bushfires on the diversity and abundance of floral species, plant life-forms and the soil seed bank. There was a general degradation of the wetland as a result of rampant bushfires. It is recommended that re-afforestation, as well as public education and awareness programmes be initiated in the area. It is also recommended that local participation in biodiversity conservation initiatives should be enhanced.

Introduction

The Muni-Pomadze wetlands in the Central Region of Ghana, an internationally-recognized coastal wetland (Ramsar site), is an important ecotourist area which has suffered from neglect and rampant bushfires over the years, a situation which poses serious threats to its biodiversity. The use of bushfires as a major tool for clearing agricultural land (e.g. shifting cultivation) in most African societies, including Ghana (Hall & Swaine, 1981; Korem, 1985), has resulted in intense burning and grazing of grasslands leading to habitat fragmentation and changes in vegetation height and density. Over the long term, bushfires pose very serious threat to biodiversity conservation in Ghana (Swaine *et al.*, 1997; Gboloo, 1998).

Seed dispersal and subsequent germination are crucial phases in plant regeneration (Harper *et al.*, 1965), as seeds deposited in topsoil by dispersal become the seed bank after transportation through the soil profile by physical processes or soil organisms. The deeper the seed bank, therefore, the longer the seeds had been deposited on the top soil. Seed banks allow seeds to be carried over from year to year, with many plant communities having large natural soil seed banks of herbaceous and weedy species (Thompson, 1978).

Knowledge of the abundance and composition of the soil seed bank, and, therefore, its regeneration potential, is thus crucial in understanding the process of habitat regeneration. For example, the regeneration of natural wildlife habitat after human disturbance (e.g. bushfires) is principally from *in situ* growth of buried seeds (soil seed bank), underground plant parts, or transport of disseminules ("seed rain") into the area after the disturbance (Moore & Wein, 1977). This has implications for biodiversity conservation, since any change in the regeneration potential of a habitat would result in a change in the faunal composition, and ultimately a reduction or loss of biodiversity.

The aim of this study was to investigate the effects of bushfires on the soil seed bank and floral composition of the Muni-Pomadze wetland. Based on the hypothesis that the burning of vegetation impacts negatively on the floristic composition of a habitat, and the richness of the soil seed bank, it could be predicted that there would be significant differences in the floristic composition and soil seed bank between burnt and unburnt habitats.

Materials and methods

Floral survey

Sampling plots were demarcated as described in Attuquayefio & Wuver (2003). Duplicate plots of burnt and unburnt habitats were located at least 500 m from each other to ensure independence of each plot. On each plot, an area of 100 m × 100 m was demarcated using a measuring tape and poles. Each plot was sub-divided into four square strips, each measuring 25 m × 25 m and lying side by side to facilitate the listing of low-lying plant species, and to increase the chance of including most, if not all, available species in the sample (Hawthorne & Abu-Juam, 1995). For each plot, a species list was prepared to include all plant life-forms (trees, shrubs, climbers, herbs, grasses and sedges). Species identification was done on site, but where this was not possible, whole plants or plant parts were pressed for later identification in the Botany Herbarium, University of Ghana.

Soil seed bank study

In order to determine the regeneration potential of the study area, the seed banks of burnt and unburnt plots were examined. Ten soil sample cores were collected at random from each of two burnt and unburnt plots to a depth of about 20 cm at intervals of 5 cm, 10 cm and 20 cm, using a soil corer of diameter 5 cm. Collected samples were stored in polyethylene bags, tagged and transported to the laboratory for determination of their seed bank composition. The soil samples from each plot were thoroughly mixed in the laboratory and transferred to seed-boxes (20 cm × 20 cm × 12 cm) up to about two-thirds full. Two sets of three seed boxes for each sample were prepared for each plot, with one set kept in shade (under a large tree) and the other placed in sunlight (in the open). The seed boxes were covered with a transparent 1-mm wire-mesh sieve to prevent immigration and *in loco* seed deposition, and the contents were watered as necessary to keep them moist. During the dry season, the seeds were watered daily and examined for emergence and identification of the different seedlings at either the seedling or flowering stage, at which they were sent for identification in the Botany Herbarium, University of Ghana. Seedling counts of the various plant life-forms were recorded at the end of each week. Relative numbers of tree species identified from the respective seed-boxes formed the basis for assessing the potential of a particular plot for natural tree regeneration through seed recruitment after degradation or disturbance.

Neotetrazolium test of seed viability

After a 12-week germination study, all soil samples from the seed boxes were examined for ungerminated seeds and unemerged germinated seedlings. The soil samples were sieved with a 1-mm wire-mesh to isolate the dormant (ungerminated) seeds, which were examined for viability using a 1% neotetrazolium chloride solution

(2,3,5-triphenyltetrazolium chloride) (Delouche *et al.*, 1962).

Results

Floral diversity

A total of 66 species of angiosperms (Angiospermae), representing 34 families and 59 genera were recorded during the study. There were 29 families, 51 genera and 56 species of dicotyledons (Dicotyledonae), while four families, 10 genera and 10 species were monocotyledons (Monocotyledonae). The family Graminae (grasses) were the dominant monocotyledons in the area, particularly *Heteropogon contortus, Paspalum vaginatus* and *Sporobolus pyramidalis,* with a general preponderance of grasses, herbs and shrubs over trees (e.g. *Azadirachta indica, Milletia thonningii* and *Zanthoxylum xantholoides*) (Table 1). At the start of the study, 38 and 33 plant species were recorded in the unburnt and burnt plots, respectively. At the end, the numbers had increased to 48 and 55, respectively, on the unburnt and burnt plots. This represented an increase of 26.3% and 66.7% on the unburnt and burnt plots, respectively (Tables 2 and 3).

Effect of burning on seed germination

Tables 2 and 3 indicate the plant species that germinated from the soil seed bank of burnt and unburnt plots. There were 29 species in the burnt plot, as against only 24 species in the unburnt plot. The number of seedlings emerging from the soil of the burnt plot under light conditions was significantly higher than under shade conditions (Tab $t_{0.05}$ = 1.645; Cal $t_{0.05}$ = 4.64; p-value = 0.0000). Similarly, the number of seedlings emerging from the soil of the unburnt plot under light conditions was significantly higher than under shade conditions (Tab $t_{0.05}$ = 1.645; Cal $t_{0.05}$ = 2.59; p-value = 0.0065. Out of the total number of germinating seedlings from the seed bank, 2,500 (71.5%) were recorded under light conditions and 1,000 (28.5%) under shade conditions. There were also significantly more germinated seedlings from the soil samples from the burnt plot than those on the unburnt plot (Tab $F_{0.05}$ = 4.08; Cal $F_{0.05}$ = 12.04; p-value = 0.001).

As indicated in Table 4, no significant difference occurred between the proportions of grasses and sedges emerging from the soils of the two plots (Tab $t_{0.05}$ = 1.960; Cal $t_{0.05}$ = 0.99; p-value = 0.32). The difference between numbers of herbs on the burnt and unburnt plots was, however, significant (Tab $t_{0.05}$ = - 1.645; Cal $t_{0.05}$ = - 2.99; *p*-value = 0.0014). There was also a significant difference in the numbers of shrubs on the burnt and unburnt plots (Tab $t_{0.05}$ = – 1.645; Cal $t_{0.05}$ = – 5.83; p-value = 0.0000). No tree species were represented in the seed bank, even though some small savanna trees (e.g. *Azadirachta indica, Zanthoxylum xantholoides)* were present in the study area. The dominant plant life-forms were herbs and grasses (89.1%), followed by shrubs (10.9%). There were also more monocotyledons (14 families) than dicotyledons (three families).

Table 5 shows the mean number of germinated seeds from different burial depths under light and shade conditions. There was significant difference in the average number of germinated seeds among the different months ((Tab $F_{0.05}$ = 2.84; Cal $F_{0.05}$ = 4.23; p-value = 0.011). Burial depth also had a significant effect on the number of germinated seeds (Tab $F_{0.05}$ = 3.28; Cal $F_{0.05}$ = 46.96; p-value = 0.000). The numbers of

TABLE 1

Floral diversity of Muni-Pomadze Ramsar Site

		Sampling plots			
		Burnt		*Unburnt*	
Species	*Life-form*	*Start*	*End*	*Start*	*End*
ANACARDIACEAE					
1. *Lannea nigritana*	Tree	-	+	-	+
ANNONACEAE					
2. *Uvaria chamae*	Climber	+	+	+	+
AMPELIDACEAE					
3. *Cissus petixculata*	Climber	+	+	+	+
ASCLEPIADACEAE					
4. *Secamone afzelii*	Climber	+	-	+	+
ASERACEAE					
5. *Chromolaena odorata*	Herb	-	+	+	+
6. *Vernonia cinerea*	Shrub	+	+	+	-
7. *Vernonia colorata*	Shrub	-	-	+	+
BORAGINACEAE					
8. *Ehretia cymosa*	Shrub	+	+	+	+
CAESALPINACEAE					
9. *Cassia mimosoides*	Herb	+	+	+	+
CAPPARIDACEAE					
10. *Ritchiea reflexa*	Shrub	-	+	+	+
CHAILLETIACEAE					
11. *Diochapetalum madagascariensis*	Tree	+	-	+	+
COMMELINACEAE					
12. *Commelina africana*	Herb	+	+	+	+
COMPOSITAE					
13. *Melanthera scadens*	Herb	+	+	-	+
CONNARACEAE					
14. *Byrsocarpus coccineus*	Shrub	-	+	+	-
15. *Byrsocarpus cymosa*	Shrub	+	+	-	+
CYPERACEAE					
16. *Cyperus haspan*	Sedge	-	+	+	+
EBENACEAE					
17. *Diospyros abyssinica*	Shrub	+	+	+	+
18. *Diospyros mespiliformis*	Shrub	+	-	+	+
EUPHORBIACEAE					
19. *Bridelia micrantha*	Tree	-	+	-	+
20. *Jatropha gossypifolia*	Shrub	+	+	+	+
21. *Mallotus oppositifolius*	Shrub	-	+	+	-
22. *Phyllanthus pentandrus*	Herb	-	+	+	+
23. *Securinega virosa*	Shrub	-	+	+	+

FLACOURTIACEAE					
24. Flacourtia flavescens	Shrub	-	+	+	+
LABIATAE					
25. Hoslundia opposita	Shrub	+	+	-	+
LAURACEAE					
26. Cassytha filiformis	Climber	-	+	-	+
MALVACEAE					
27. Abutilon grandifolium	Herb	+	+	-	+
28. Sida ovata	Herb	+	+	+	+
MELIACEAE					
29. Azadirachta indica	Tree	+	+	+	+
MENISPERMACEAE					
30. Triclisia subcordata	Climber	+	-	+	+
31. Triclisia warneckes	Climber	+	-	+	-
NYCTAGINACEAE					
32. Boerhavia coccinia	Herb	+	+	-	+
OCHNACEAE					
33. Ochna membranaceae	Shrub	-	+	+	+
PAPILIONACEAE					
34. Abrus precatorius	Climber	-	+	+	+
35. Crotalaria goreensis	Herb	-	+	+	+
36. Glycine hidysaroides	Herb	-	+	+	+
37. Indigofera arrecta	Herb	-	+	+	+
38. Indigofera giganticum	Herb	-	+	+	+
39. Milletia thonningii	Tree	-	+	-	-
40. Milletia zechiana	Tree	-	+	+	+
PASSIFLORACEAE					
41. Passiflora foetida	Climber	+	-	+	+
42. Passiflora glabra	Climber	-	+	+	+
POACEAE (GRAMINAE)					
43. Andropogon gayanus	Grass	+	+	+	+
44. Ctenium newtoni	Grass	-	+	+	+
45. Diheteropogon hagerupii	Grass	+	+	+	+
46. Rottboeillia exaltata	Grass	-	+	+	-
47. Setaria barbata	Grass	+	+	+	+
48. Sporobolus pyramidalis	Grass	-	+	+	+
49. Vetiveria fulvibarbis	Grass	+	+	-	+
RUBIACEAE					
50. Chassalia sp.	Shrub	-	+	+	+
51. Gardenia ternifolia	Shrub	+	+	-	+
52. Pavetta corymbosa	Shrub	+	+	-	+
RUTACEAE					
53. Clausena anisata	Shrub	-	+	+	+
54. Zanthoxylum xanthoxyloides	Tree	-	+	+	+
SAPINDACEAE					
55. Lecaniodiscus cupanoides	Small Tree	+	+	+	+

56. *Paullinia pinnata*	Shrub	+	+	+	+
SAPOTACEAE					
57. *Malacantha alnifolia*	Shrub	+	+	+	+
SOLANACEAE					
58. *Physalis angulata*	Herb	+	+	+	+
TILIACEAE					
59. *Grewia carpinifolia*	Shrub	+	+	-	+
60. *Triumfetta rhomboidea*	Herb	-	+	+	+
VERBENECEAE					
61. *Lantana camara*	Shrub	+	+	-	+
VIOLACEAE					
62. *Hybanthus thesifolius*	Shrub	-	+	+	+

TABLE 2a

Plant species identified from the soil seed bank of the burnt plot under light conditions

Species	*Family*	*Life-form*	*Count*	*%*
1. *Sporobolus pyramidalis*	Graminae	Grass	37	10.9
2. *Andropogon gayanus*	Graminae	Grass	33	9.8
3. *Desmodium triflorum*	Papilionaceae	Herb	23	6.8
4. *Cassia mimosoides*	Caesalpinaceae	Tree	17	5.0
5. *Tragia vogeli*	Euphorbiaceae	Herb	16	4.7
6. *Aeschynomene afraspera*	Papilionaceae	Shrub	15	4.4
7. *Crotalaria goreensis*	Papilionaceae	Herb	14	4.1
8. *Hackleochloa granularia*	Graminae	Grass	14	4.1
9. *Commelina africana*	Commelinaceae	Herb	12	3.5
10. *Hibiscus panduriformis*	Malvaceae	Shrub	11	3.2
11. *Panicum maximum*	Graminae	Grass	11	3.2
12. *Phyllanthus pentandrus*	Euphorbiaceae	Herb	11	3.2
13. *Glycine ternifolia*	Papilionaceae	Herb	10	2.9
14. *Vetiveria fulvibarbis.*	Graminae	Grass	10	2.9
15. *Dactyloctenium aegypticum*	Graminae	Grass	10	2.9
16. *Heteropogon contortus*	Graminae	Herb	10	2.9
17. *Diodia scandens*	Rubiaceae	Herb	9	2.7
18. *Paspalum vaginatum*	Graminae	Grass	9	2.7
19. *Physalis anguiculata*	Solanaceae	Herb	9	2.7
20. *Rottboeillia exaltata*	Graminae	Grass	9	2.7
21. *Sida ovata*	Malvaceae	Herb	9	2.7
22. *Chromolaena odorata*	Compositae	Shrub	8	2.4
23. *Setaria barbata*	Graminae	Grass	7	2.1
24. *Crotalaria retusa*	Papilionaceae	Herb	6	1.8
25. *Hybanthus enneaspermus*	Violaceae	Herb	5	1.5
26. *Phyllanthus amarus*	Euphorbiaceae	Herb	4	1.2
27. *Jacquemontia tamnifolia*	Convolvulaceae	Herb	3	0.9
28. *Cyperus rotundus*	Cyperaceae	Sedge	3	0.9
29. *C. haspan*	Cyperaceae	Sedge	2	0.6
Total		338	100	
Species diversity			3.23	

TABLE 2b

Plant species identified from the soil seed bank of the burnt plot under shade conditions

Species	*Family*	*Life-form*	*Count*	*%*
1. *Sporobolus pyramidalis*	Graminae	Grass	18	7.8
2. *Desmodium triflorum*	Papilionaceae	Herb	12	7.2
3. *Tragia vogeli*	Euphorbiaceae	Herb	12	7.2
4. *Paspalum vaginatum*	Graminae	Grass	10	6.0
5. *Crotalaria goreensis*	Papilionaceae	Herb	9	5.4
6. *Andropogon gayanus.*	Graminae	Grass	7	4.2
7. *Panicum maximum*	Graminae	Grass	7	4.2
8. *Aeschynomene afraspera*	Papilionaceae	Shrub	5	3.0
9. *Hackleochloa granularia*	Graminae	Grass	5	3.0
10. *Chromolaena odorata*	Compositae	Shrub	5	3.0
11. *Dactyloctenium aegypticum*	Graminae	Grass	4	2.4
12. *Heteropogon contortus*	Graminae	Herb	4	2.4
13. *Rottboeillia exaltata*	Graminae	Grass	4	2.4
14. *Setaria barbata*	Graminae	Grass	4	2.4
15. *Crotalaria retusa*	Papilionaceae	Herb	4	2.4
16. *Cassia mimosoides*	Caesalpinaceae	Tree	3	1.8
17. *Sida ovata*	Malvaceae	Herb	3	1.8
18. *Vetiveria fulvibarbis.*	Graminae	Grass	2	1.2
Total			116	100
Species diversity			2.20	

TABLE 3a

Plant species identified from the soil seed bank of unburnt plot under light conditions

Species	*Family*	*Life-form*	*Count*	*%*
1. *Andropogon gayanus*	Graminae	Grass	65	13.4
2. *Panicum maximum*	Graminae	Grass	61	12.5
3. *Sporobolus pyramidalis*	Graminae	Grass	57	10.7
4. *Desmodium triflorum*	Papilionaceae	Herb	47	9.7
5. *Sida ovata*	Malvaceae	Herb	45	9.2
6. *Chromolaena odorata*	Compositae	Shrub	33	6.8
7. *Cassia mimosoides*	Caesalpinaceae	Tree	22	4.5
8. *Jacquemontia tamnifolia*	Convolvulaceae	Herb	21	4.3
9. *Aeschynomene afraspera*	Papilionaceae	Shrub	21	4.3
10. *Setaria barbata*	Graminae	Grass	20	4.1
11. *Paspalum vaginatum*	Graminae	Grass	18	3.7
12. *Diodia scandens*	Rubiaceae	Herb	14	2.9
13 *Phyllanthus pentandrus*	Euphorbiaceae	Herb	12	2.5
14. *Cyperus haspan*	Cyperaceae	Sedge	9	1.8
15. *Hybanthus enneaspermus*	Violaceae	Herb	7	1.4
16. *Cyperus rotundus*	Cyperaceae	Sedge	6	1.2
17. *Hackleochloa granularia*	Graminae	Grass	6	1.2
18. *Rottboeillia exaltata*	Graminae	Grass	6	1.2
19. *Phyllanthus amarus*	Euphorbiaceae	Herb	6	1.2
20. *Physalis anguiculata*	Solanaceae	Herb	6	2.7
21. *Glycine ternifolia*	Papilionaceae	Herb	4	0.8
22. *Tragia vogeli*	Euphorbiaceae	Herb	3	0.6
23. *Commelina africana*	Commelinaceae	Herb	1	0.2
24. *Hibiscus panduriformis*	Malvaceae	Shrub	1	0.2
Total			489	100
Species diversity			2.75	

TABLE 3b

Plant species identified from the soil seed bank of unburnt plot under shade conditions

Species	*Family*	*Life-form*	*Count*	*%*
1. Desmodium triflorum	Papilionaceae	Herb	28	13.3
2. Sida ovata	Malvaceae	Herb	27	12.8
3. Sporobolus pyramidalis	Graminae	Grass	26	12.4
4. Panicum maximum	Graminae	Grass	25	11.9
5. Aeschynomene afraspera	Papilionaceae	Shrub	16	7.6
6. Setaria barbata	Graminae	Grass	15	7.1
7. Hybanthus enneaspermus	Violaceae	Herb	13	6.2
8 Tragia vogeli	Euphobiaceae	Herb	13	6.2
9. Diodia scandens	Rubiaceae	Herb	9	4.3
10. Chromolaena odorata	Compositae	Shrub	7	3.3
11. Andropogon gayanus	Graminae	Grass	6	2.8
12. Phyllanthus pentandrus	Euphorbiaceae	Herb	6	2.8
13. P. amarus	Euphorbiaceae	Herb	5	2.4
14. Rottboeillia exaltata	Graminae	Grass	4	1.9
15. Paspalum vaginatum	Graminae	Grass	3	1.4
16. Hackleochloa granularia	Graminae	Grass	3	1.4
17. Glycine ternifolia	Papilionaceae	Herb	3	1.4
Total			210	100
Species diversity			1.98	

TABLE 4

Seedling counts of different plant life forms on burnt and unburnt plots

	Burnt plot		*Unburnt plot*			
Life-form	*Count*	*%*	*Count*	*%*	*Total count*	*Total %*
Grass/Sedge	645	47.3	957	45.6	1,602	46.3
Herb	603	44.3	876	41.8	1,479	42.8
Shrub	114	8.4	264	12.6	378	10.9
Climber	0	0	0	0	0	0
Tree	0	0	0	0	0	0
Total	1,362	100	2,097	100	3,459	100
Total %	39.4		60.6			100

germinated seeds under light and shade conditions were also significantly different (Tab $F_{0.05} = 4.08$; Cal $F_{0.05} = 50.37$; p-value = 0.0000). In both the burnt and unburnt plots, the 0-5 cm layer had the highest number of germinated seeds under both light and shade conditions. Under light conditions, the percentage germination in the burnt plot was 60.9%, while that in the unburnt plot was 59.7%. Under shade conditions, the percentage germination for burnt and unburnt plots were 57.8% and 57.1%, respectively. Also, there was greater floral diversity under light than shade

TABLE 5

Mean number of germinated seeds from different burial depths in soils under light and shade conditions

	Burnt plot depths (cm)						*Unburnt plot depths (cm)*					
	Light condition			*Shade condition*			*Light condition*			*Shade condition*		
Month	*0-5*	*5-10*	*10-20*	*0-5*	*5-10*	*10-20*	*0-5*	*5-10*	*10-20*	*0-5*	*5-10*	*10-20*
Jan-Feb	29	24	6	15	8	3	54	33	11	27	15	7
Mar-Apr	46	26	9	19	10	4	80	35	14	34	18	8
May-Jun	72	30	12	23	13	6	95	44	21	39	20	10
Jul-Aug	59	19	6	10	3	2	63	30	9	20	7	5
Total	206	99	33	67	34	15	292	142	55	120	60	30

TABLE 6

Number of germinated seeds from soils obtained at different burial depths from burnt and unburnt plots under light and shade conditions

	Burnt plot depths (cm)						*Unburnt plot depths (cm)*					
	Light condition			*Shade condition*			*Light condition*			*Shade condition*		
Week	*0-5*	*5-10*	*10-20*	*0-5*	*5-10*	*10-20*	*0-5*	*5-10*	*10-20*	*0-5*	*5-10*	*10-20*
1	256	0	0	117	0	0	132	0	0	187	0	0
2	145	0	0	44	0	0	240	0	0	88	0	0
3	101	102	0	14	33	0	252	125	0	46	47	0
4	65	74	0	16	20	0	87	128	0	22	50	0
5	43	52	0	10	14	0	60	73	0	13	34	0
6	8	35	33	6	11	0	6	42	0	6	22	22
7	0	23	26	0	12	16	0	36	43	0	13	19
8	0	15	15	0	7	10	0	18	49	0	9	15
9	0	6	12	0	5	7	0	4	40	0	5	19
10	0	0	8	0	0	2	0	0	25	0	0	11
11	0	0	5	0	0	4	0	0	8	0	0	4
12	0	0	0	0	0	0	0	0	0	0	0	0
Total	618	307	99	207	102	39	777	426	165	362	180	90

conditions in both burnt (3.23; 3.20) and unburnt (2.75; 1.98) plots. There was very low germination of seeds at depth 10-20 cm on all plots. The *neotetrazzolium test* showed that all the seeds that did not germinate by the end of the eleventh week were not viable.

Effect of seed burial depth on germination

The length of time taken for the seeds to germinate increased with increasing seed burial depth (Table 6). At depth 0-0.5 cm, the seeds started germinating by the end of the first week, while seeds buried at 5-10 cm depth also started germinating after two weeks. The seeds at depth 10-20 cm started germinating after five weeks, and at the end of the 6th week, all viable seeds at depth 0-5 cm had germinated. At the end of the 9th week, all viable seeds at depth 5-10 cm had germinated (Table 6).

Discussion

Floral diversity

The vegetation of the Muni-Pomadze wetland was known to be originally forest (Dickson, 1969), so the preponderance of grasses, shrubs and herbs over tree species suggests some degree of habitat degradation resulting from unsustainable human activities (e.g. bushfire setting, fuelwood gathering, farming, etc.). Bushfires destroyed viable seeds and prevented flowering and/or seeding of the tree species. Indeed, nearby sacred groves and woodlot plantations contained more tree species, probably because they were under some form of protection. If undesirable human activities in the wetland continue, grass species numbers will increase, and the numbers of tree species will continue to decline. This is because grasses are able to regenerate from underground tussocks or dormant buds which are often well protected from bushfires.

It is not clear why some plant species were absent at the end of the study in both the burnt and unburnt plots, but it could be conjectured that such plant species do not produce seeds continuously, apart from the seeds not being persistent for long periods. Increase in numbers of plant species on both burnt and unburnt plots could be attributed to enhanced flowering and/or seeding, as well as the effects of bushfires, herbivory, dispersal and rainfall. The burning of germination-inhibiting accumulated litter probably explains the increased numbers of plant species after vegetation burning, due to enhanced seed dispersal in the absence or reduction of obstructions to wind dispersal and immigration of seeds from other areas.

Water is crucial for initiating the physiological process of germination. The low rainfall experienced at the beginning of the study, which resulted in little seepage of water into the soil, and, consequently, low soil moisture content, did not, therefore, provide the necessary environmental conditions for seed germination. The resulting seed dormancy was, however, broken after the rains, resulting in increased numbers of plant species on the plots. Large proportions of seeds reaching the ground were also destroyed by insects, small mammals and fungal infection. Since both heat and burning affect seed viability (Mucunguzi & Oryem-Origa, 1996), the higher species diversity of plants on the burnt plot under both light and shade conditions suggests that burning stimulated germination of more plant species on the burnt plot. The burning provided new opportunities for many plants, resulting in increased species richness of the burnt plots (Armesto & Pickett, 1985). Burning also removed the vegetation and exposed the seeds in the soil to more light, stimulating the germination of some species and induced dormancy in others.

Longman (1969) found that seed dormancy in *Tridax procumbens* (tropical weed), was broken by light, while an ecologically-similar plant *Dactyloctenium aegytium* germinated after stimulation by temperature fluctuations. Heat from bushfires also breaks seed dormancy in thick- or hard-coated seed (Sabiiti & Wein, 1988; Portluck *et al.*, 1990). Bushfires also release ash in usable forms, increasing soil nutrient content in the process (Daubenmire, 1968; Korem, 1985), as well as decreasing soil acidity, improving nitrification and favouring decomposing microbes (Afolayan, 1978b; Kunsela, 1992). The fewer seeds recorded on the burnt plot may be due to the intensity and frequency of bushfires during the period, which generated too much heat that killed some of the seeds. In addition, occurrence of bushfires during the flowering and/or fruiting season might have burnt the flowers and/or seeds, resulting in a decline in total number of seeds stored in the natural seed bank of the burnt plot.

Even though trees formed part of the flora of the study area, the absence of tree seeds from the seed bank studies suggested that such seeds probably required some human intervention (e.g. tillage) to stimulate germination. Previous studies have indicated the presence of many tree species (e.g. *Anogeissus* sp., *Antiaris* sp., *Bombax* sp., etc.) in the coastal scrub vegetation of Ghana (Taylor, 1963; Dzomeku & Enu-Kwesi, 1997). Observations on a sacred grove at Senya Beraku, about 15 km east of Winneba, also revealed a number of tree species (e.g. *Anogeissus* sp., *Ceiba* sp. and *Antiaris* sp.) (Dzomeku & Enu-Kwesi, 1997). It was expected that some of such trees would be part of the original vegetation composition of the Muni-Pomadze wetland, which is located in the same ecozone. It could, therefore, be conjectured that anthropogenic influences (e.g. bushfires, fuelwood harvesting and farming, etc.) may have destroyed the potential for flowering and seeding of such tree species. Assuming the seeds of such tree species were produced at all, they could have been consumed by frugivorous and granivorous animals such as birds and rodents.

Seed burial depth

The capacity of some seeds to remain viable in soil for long periods of time has been known for many years (Kellman, 1970). Since viability of a seed is affected by its age, it is reasonable to expect a general decline in germination with increasing soil depth, as was observed in both burnt and unburnt plots. Successful seed germination is also related to the intensity of heat in the soil. Although it appears that the heat generated by burning is strong enough to increase the permeability of the seed coat to water and gases, long exposure may result in the deterioration of seed vigour or embryo death in some tree species (Portlock *et al.*, 1990).

Mucunguzi & Oryem-Origa (1996) observed that both fire and seed burial depth influenced seed viability, and that seed survival increased with burial depth. In this study, however, there was a decrease in the number of germinated seeds with increasing depth. This finding is consistent with the report by Auld (1986) that maximum seed germination occurred at 3-4 cm, below which heating did not stimulate germination. Moore & Wein (1977) also found that the greatest number of seedlings (70-100%), was obtained at a burial depth of 0-2 cm, after which the number decreased with increasing depth. Strickler & Edgerton (1976) also reported a decrease in the number of germinated seeds with increasing depth. As recorded in this study, the higher percentage germination at burial depth 0-5 cm could be attributed to fire providing the appropriate stimulus for germination at that depth. Afolayan (1978b) noted that increased soil *p*H and mineral content were noticeable only in the top 0-10 cm layer after a bushfire. Other germination-reducing factors with depth are predation and fungal pathogen attack (MacKay, 1972). Continued seed metabolism also decreases viability (Moore & Wein, 1977).

The depth of seed burial could also have induced seed dormancy and prevented germination. It is likely that soil temperature, moisture and oxygen content at greater depths were not appropriate for germination, hence the decline of germination with burial depth. The enforced dormancy could, however, be beneficial as it would add to the natural seed bank and maintain the potential to produce seedlings under improved conditions. The difference in the number of seedlings between the two sites may be attributed not only to the difference in quantity of seeds in the seed bank, but also to the effect of bushfires. It appeared that the heat that induced significant germination in the unburnt plot generally proved detrimental to seed germination from the burnt plots. Lower intensity of fire might remove only litter, while fires of greater intensity might remove all the organic matter and even increase heat in the upper layers above the lethal temperature for seed survival. Low-intensity fire would destroy a large proportion of the seeds, but seeds lower in the soil profile could recolonize the area.

Life-form changes

The results obtained in this study on the effect of burning on tree species are consistent with studies by other workers in West African forest and savanna. Vegetation disturbance is usually followed by a succession pattern that includes species that previously occupied the site (Hall & Swaine, 1981). The significant difference in proportions of the different life-forms between burnt and unburnt plots is indicative of changing physiognomic types of savanna vegetation, due largely to anthropogenic influences (e.g. bushfires, fuelwood collection, farming, hunting, etc.). Afolayan (1978a) reported a similar change in tree species composition attributable to bushfires. In this study, the repeated annual burning which is characteristic of savanna, appeared to be the cause of the gradual change in the composition of trees, shrubs and grasses in the study area. This has serious implications for the future of the habitat in the light of the expected increase in bushfire frequency as a result of increased drought, winds and global warming (Overpeck *et al.,* 1990).

Unlike grasses, shrubs and trees tend to be more affected by bushfires, because more of their living tissue occurs above ground level. They also often do not produce seeds until several years after a seed germinated. Once fire destroy the seeds of trees and shrubs from the seed bank, they can only be replaced by "seed rain" from nearby vegetation. This is consistent with the findings by Aubreville (1959) and Lawson (1966) that the major factor limiting the occurrence of woody plants on the Accra Plains is bushfires. The absence of seeds of tree species from the seed bank suggests that there were very few (if any) of these seeds in the soil, indicating a trend towards increasing deforestation. Annual bushfires burn dry grasses, damage tree boles and hinder tree (woody plant) and seedling regeneration (Afolayan, 1978a). This may have caused the decline of tree species in the area, as corroborated by the findings by Brookman-Amissah *et al.* (1980) in a study in north-east Ghana savanna.

Continuous burning over a long period of time dramatically changes the physiognomy of vegetation, and ultimately results in a change in faunal composition. The decline in numbers of one species may, therefore, greatly affect the composition of other floral and faunal species. Elimination of trees by repeated burning has long-term repercussions on the ecosystem, since animals need browse plants for feeding and shelter when grasses dry out and become coarse and unpalatable. Although savanna trees are described as fire-tolerant or fire-resistant, the few trees scattered within the study area did not have thick barks. This probably explains the decreased number of tree species in the study area. For example, *Diospyros mespiliformis*, which occurs on the site, also occurs in both dry and woodland savanna.

Acknowledgement

Partial support for this study was provided through fellowship by the Volta River Authority (VRA). Special thanks go to Messrs James K. Adomako, Daniel K. Abbiw, Patrick Ekpe and Joseph Y. Amponsah of the Department of Botany, University of Ghana, for their help in plant identification. The authors are also grateful to Mr K. Nketiah (Officer-in-Charge) and the staff of Winneba Fire Service Station for assistance in the provision of bushfire data, and during the controlled vegetation burning.

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