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Some Aspects of the Ecology of *Senna occidentalis* (L.) Link around Awka in Anambra State, Nigeria

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Abstract This study investigated the ecological characteristics, abundance and distribution of *Senna occidentalis* (L.) and the associated species in the sampled sites around Awka in Anambra State, Nigeria. The aim of the study was to determine the ecological status of this important plant in order to proffer appropriate conservation measures to forestall its extermination in the study area (if need be). Abundance measures such as relative density, relative frequency, relative abundance, and importance value indexs were estimated for the plant and its associated species in the study sites. The Shannon-Weiner index of diversity was adopted to determine the species diversity of the sampled sites. The relative abundance values for *S. occidentalis* in the study sites (Iffite Awka and Agu-Awka) where it was found were 1.41 and 1.60, respectively, and the importance value indexs for the plant in the same sites where it existed were 15.42 and 17.05, respectively. Those values were lower than those of some of the associated plant species in those sites. The plant was neither sighted nor recorded in Okpuno and Amansea study sites. The results showed that *S. occidentalis* is neither abundant nor dominant in the study area. The Shannon-Weiner index of diversity of the four sampled sites was 3.131, 3.273, 2.392, and 2.857, respectively. The sites where the plant existed had more species richness than the sites where it was not found. The calculated equitability of distribution of the plant and the associated plant species in the sampled sites for sites Iffite, Agu-Awka, Okpuno and Amansea, were 0.86, 0.91, 0.81, and 0.88, respectively. This implies that the plant species were largely evenly distributed in all the sites. Since *S. occidentalis* was not abundant in the study area, there is an urgent need for conservation measures to be implemented for the plant.

Keywords *Senna occidentalis*, Abundance, Distribution, Diversity, Conservation, Ecological Status

1. Introduction

Senna occidentalis (L.), (Family: Fabaceae) formerly known as *Cassia occidentalis* and commonly called coffee senna or septic weed, is a plant often found in roadsides, waste areas, disturbed sites, grasslands, and coastal environments in the tropical regions of the world [1, 2]. It is a semi-woody annual shrub or undershrub or sometimes short-lived perennial shrub that can grow up to 2.0 m in height [3, 4]. The stem of the plant is erect, sparsely branched, glabrous, reddish-purple in colour when young but turns greenish-brown as it matures. Leaves are pinnate, alternately arranged, borne on reddish petioles and have three to six pairs of oppositely arranged glabrous leaflets with entire margins. Leaflets are ovate to ovate-lanceolate in shape, with acuminate apices and rounded at the base. The inflorescences are axillary racemes with yellow-

petaled flowers [5]. The plant reproduces by seeds which are dispersed by water, by sticking to animals, vehicles and machinery or spread as contaminants of farm produce [6].

Different parts of *S. occidentalis* plant have a lot of active phytochemicals that support its numerous uses in traditional medicine. It is used to treat typhoid and malaria [7, 8]. The plant is considered hepato-protective and as such, is an ingredient of many liver tonics [9]. The plant is used to treat hepatitis and liver cirrhosis [10, 11], and gastrointestinal complaints such as dyspepsia, flatulence, stomach ache, and constipation [12, 13, 10]. The plant is also cardioprotective and is used to treat congestive heart failure and hypertension [14, 15]. Aqueous extracts of the leaves have been reported to have antimutagenic, anticancer, and detoxification properties [16, 17]. The plant has also been used to expel intestinal parasites and worms [18]. In some places, the seeds of coffee senna are roasted and used as a coffee substitute or brewed into coffee-like beverages [19]. It is also used for landscape purposes as a flowering shrub [20].

Senna occidentalis has been categorized as a least-concern species by the International Union for Conservation of Nature (IUCN) [21]. However, according to IUCN, its current population trend is still unknown and there is a continuing decline and extreme fluctuations in its subpopulations. In addition to the decline in subpopulations, there is also a decline in area, extent and quality of its habitats [21]. It is pertinent to note that the IUCN global category for a species may be different from the country or local category for that species. Discrepancies and irregularities between the IUCN global categorization and some local records and categorization for many species have been recorded [22]. For *S. occidentalis*, the global assessment was done for IUCN by only two experts, who may have not carried out any field survey in Nigeria to determine the abundance and distribution of the plant in the country. Therefore, their assessment may have been based on personal knowledge and information they could source on the plant. Lack of proper field assessment in a locality or country could create a discrepancy and misinformation which could discourage conservation efforts in such country or locality.

The propensity of some plant species to become invasive and a menace in many ecosystems has encouraged efforts to exterminate such plant species and discouraged their study. This ecological study is necessary due to the fact that *S. occidentalis* is highly useful, from medicinal and economic points of view, and therefore, its conservation status needs to be assessed locally in order to expedite conservation actions on the plant if needed. The objectives of the study include: to carry out ecological studies of the plant and other associated species in order to determine their abundance and distribution in Awka, Anambra State, and to evaluate the extent of the impacts of the associated species on *S. occidentalis*.

2. Materials and Methods

2.1. Study Area

This study was carried out around Awka town in Anambra State, Nigeria. Awka is a town that lies between latitudes 7 °00 and 7 °10 N and longitudes 6 °05 and 6 °15 E in the tropical rain forest zone of Nigeria. The area has a mean monthly minimum temperature of 26 ℃, and a single rainy season with intensive rainfall which occurs from March to November with an annual range of 1200 – 1500 mm. The pedology of the area reveals that the soil is of sedimentary origin with sandstones and shale as the dominant parent materials. The soil is very rich in iron and belongs to the ultisol order [23].

2.2. Sampling for Abundance and Species Diversity

Four different locations namely: Agu-Awka, Iffite, Okpuno and Amansea within Awka South Local Government Area of Anambra State, Nigeria were selected for sampling. The selected sampling locations are grassland ecosystems which are homogenous in nature with similar soil and environmental conditions, and levels of disturbance. A study site (25 m X 25 m) for each location was mapped out. A random sampling technique was adopted in sampling the four locations. The sites were delimited with a measuring tape and pegs. Ten random points were generated by assigning numbers 1 to 10 (each number written twice). Two numbers were picked randomly ten times, one after the other. The numbers were replaced in the bag containing them before the next picking. The two numbers picked were used in generating the x and y coordinates of each site. The points of intersection of the coordinates were chosen as the random sampling points. A quadrat measuring 1 m X 1 m was used in sampling the sites for species abundance at the random sampling points generated. The quadrat was placed ten times in each of the four sampling sites with each sampling point at the middle of each quadrat. All plant species found within each quadrat were counted one after the other, recorded and identified.

2.3. Measures of Abundance

Measures of abundance were estimated using the methods of the U.S. Bureau of Land Management [24]:

$$\text{Density, D.} = \frac{\text{Number of each species}}{\text{Total area sampled } (m^2)}$$

$$\text{Relative Density, R.D.} = \frac{\text{Density of each plant species X } 100\%}{\text{Total densities of all plant species.}}$$

$$\text{Frequency, F.} = \frac{\text{Number of times a species occurred X } 100\%}{\text{Total number of times searched for it.}}$$

Relative frequency, R.F. =

$$\frac{\text{Frequency of each species X 100\%}}{\text{Total frequency of all species}}$$

Abundance, A. =

$$\frac{\text{Total no. of individuals of a sp. in all quadrats}}{\text{Total no. of quadrats where the spp. occurred}}$$

Relative Abundance, R.A. =

$$\frac{\text{Abundance of an individual species X 100\%}}{\text{Total abundance of all species in the area}}$$

Importance Value Index, IVI, was determined by adding all the relative values of the individual plant species.

IVI = R.D. + R.F. + R.A., as modified [25].

2.4. Species Diversity and Equitability of Sampled Sites

The species diversity of each sampled site was determined by using the Shannon-Weiner's Index of diversity [26, 27].

Shannon-Weiner's index of diversity,

$$H^1 = -\sum\{(Pi) \text{ X } (ln Pi)\}.$$

Where: H^1 is the Shannon-Weiner's index of diversity; $\sum$ is summation sign; Pi is the proportion of the ith (individual) species in the community; *ln* Pi is the natural log of the proportion of individual ith species.

Equitability, E, (evenness of the distribution of all the species in the study area):

$$E = H^1/H_{max}$$

where: H^1 is the Shannon Weiner's index of diversity; H_{max} is the maximum equitability; H_{max} = *ln* S. where S is the total number of species; *ln* S is the natural logarithm of the total number of species.

2.5. Jaccard Index of Similarity (JIS) of Sampled Sites

The study sites were compared in pairs based on the presence/absence of common and unique species in those sites using the Jaccard index [26].

$$JIS_{(x, y)} = c / (a + b + c);$$

where: *c* is the number of common species; *a* is the number of species unique to the first community, x; *b* is the number of species unique to the second community, y. Note: For Jaccard index of similarity, the higher the value the more ecologically similar the two sites are.

3. Results

This ecological study revealed that a total of thirty-nine different plant species were recorded for Agu-Awka location (Site 1). A small density value (3.10/m^2) and low relative abundance value (1.41 %) were observed for *S. occidentalis* at Agu-Awka. Meanwhile, *Gomphrena celosioides* had the highest density of 11.5/m^2 at Agu-Awka location which was followed by *Imperata cylindrica* (5.1/m^2) and *Ageratum conyzoides* (4.6/m^2) in that order (Table 1). In a similar trend, *G. celosioides* also had the highest importance value index (IVI) in the Agu-Awka study site (38.84), which was followed by *I. cylindrica* (17.7) and *A. conyzoides* (17.3), respectively. The abundance values for *G. celosioides*, *Euphorbia hirta*, and *I. cylindrica* were 38.33, 18.50 and 12.75, respectively, in that decreasing order.

A total of thirty-six different plant species were recorded at Iffite Awka (Site 2). Similar to observations in Agu-Awka, *S. occidentalis* was also found at Iffite Awka but with a low density of 3.10 (/m^2) and low relative abundance of 1.60 %. Meanwhile, *Sida acuta, E. hirta* and *G. celosioides* had the top three densities (in decreasing order) of 7.7, 7.0 and 5.8, respectively, at Iffite Awka. *Gomphrena celosioides, S. acuta* and *I. cylindrica* had the top three abundance values of 19.3, 15.4, and 14.0, respectively, in decreasing order. Similar to the trend observed in species density, *S. acuta, E. hirta* and *G. celosioides* had the top three IVI values of 26.08, 23.99, and 22.83, respectively, in decreasing order (Table 2).

Observations from Okpuno (Site 3) revealed a complete absence of *S. occidentalis* in that location. A total of nineteen plant species were recorded for Okpuno Awka. *Imperata cylindrica, C. odorata,* and *Centrosema pubescens* were the dominant plant species at Site 3 with densities (/m^2) of 8.20, 3.10, and 3.00, respectively, and IVI of 58.89, 29.34, and 28.29, respectively, in decreasing order (Table 3). Similarly, *S. occidentalis* was not found at Amansea (Site 4). Rather, *S. obtusifolia* that belongs to the same Genus *Senna* was observed in the site. A total of twenty-six species were recorded for the Amansea site. *Imperata cylindrica, Tridax procumbens, and C. odorata,* were the dominant plant species at Amansea with densities (/m^2) of 5.0, 3.10, and 2.70, respectively, and IVI of 42.61, 24.91, and 21.26, respectively, in decreasing order (Table 4).

Estimation of the species diversity of the sampled sites revealed that the Iffite site had the highest Shannon-Weiner index of diversity (3.27) among the four sites, while Okpuno Awka had the least value of the Shannon-Weiner index of diversity (2.39). Equitability in all the four sampled sites is relatively similar with values ranging from 0.81- 0.91 (Table 5).

The result of the Jaccard index of similarity (JIS) of the studied sites showed that there is relatively higher similarity (0.65) between Agu-Awka and Iffite study sites where the plant existed, whereas very low values of JIS between the other sites indicate that they are not similar in terms of species composition (Table 5). Thirty plant species were common between (shared by) Agu-Awka and Iffite sites, whereas Okpuno and Amansea (JIS = 0.36), where *S. occidentalis* was absent, shared twelve plant species. The least value of JIS (0.26) was obtained from the comparison between Agu-Awka and Okpuno (Table 5).

Table 1. Measures of Abundance of plant species in Agu-Awka site

S/N	Plant spp.	Density (/m^2)	R. D.	Freq. (%)	R. F. (%)	A. (/m^2)	R. A. (%)	I.V.I.	Pi	*ln* Pi	*Pi * ln Pi*
1.	*Senna occidentalis*	3.10	5.25	100	10.20	3.10	1.41	15.42	0.050	-3.244	-0.162
2.	*Imperata cylindrica*	5.10	8.32	40	3.60	12.75	5.78	17.70	0.082	-2.489	-0.205
3.	*Commelina benghalensis*	1.20	1.96	20	1.80	6.00	2.72	6.48	0.019	-3.912	-0.076
4.	*Paspalum scrobiculatum*	0.70	1.14	10	0.90	7.00	3.17	5.21	0.011	-4.509	-0.051
5.	*Gomphrena celosioides*	11.5	18.76	30	2.70	38.33	17.37	38.83	0.185	-1.671	-0.310
6.	*Amaranthus spinosus*	0.50	0.82	20	1.80	2.50	1.13	3.75	0.008	-4.828	-0.039
7.	*Larpotea aestuans*	0.60	0.98	30	2.70	2.00	0.91	4.59	0.010	-4.605	-0.045
8.	*Ipomoea involucrata*	0.40	0.65	20	1.80	2.00	0.91	3.36	0.006	-4.962	-0.032
9.	*Cleome viscosa*	0.40	0.65	20	1.80	2.00	0.91	3.36	0.006	-4.962	-0.032
10.	*Ageratum conyzoides*	4.60	7.50	80	7.21	5.75	2.61	17.32	0.074	-2.590	-0.192
11.	*Spigelia anthelmia*	2.70	4.40	50	4.50	5.40	2.45	11.35	0.044	-3.124	-0.136
12.	*Panicum maximum*	1.10	1.79	20	1.80	5.50	2.49	6.08	0.018	-4.017	-0.071
13.	*Phyllanthus amarus*	0.40	0.65	20	1.80	2.00	0.91	3.36	0.006	-4.962	-0.032
14.	*Ipomoea triloba*	0.60	0.98	30	2.70	2.00	0.91	4.59	0.010	-4.605	-0.045
15.	*Hyptis suaveolens*	2.10	3.43	40	3.60	5.25	2.38	9.41	0.034	-3.381	-0.115
16.	*Synedrella nodiflora*	0.70	1.14	10	0.90	7.00	3.17	5.21	0.011	-4.509	-0.051
17.	*Physalis angulata*	0.20	0.33	20	1.80	1.00	0.45	2.58	0.003	-5.809	-0.019
18.	*Mitrocarpus villosus*	1.50	2.45	30	2.70	5.00	2.27	7.42	0.024	-3.730	-0.090
19.	*Boerhavia diffusa*	0.70	1.14	30	2.70	2.33	1.06	4.90	0.011	-4.509	-0.051
20.	*Sida rhombifolia*	0.50	0.82	20	1.80	2.50	1.13	3.75	0.008	-4.828	-0.039
21.	*Malvastrum coromandelium*	0.60	0.98	30	2.70	2.00	0.91	4.59	0.010	-4.605	-0.045
22.	*Desmodium scorpiurus*	0.50.	0.82	20	1.80	2.50	1.13	3.75	0.008	-4.828	-0.039
23.	*Crotolaria retusa*	1.10	1.79	60	5.41	1.83	0.83	8.03	0.018	-4.017	-0.071
24.	*Euphorbia hirta*	3.70	6.04	20	1.80	18.50	8.39	16.23	0.060	-2.813	-0.168
25.	*Mimosa invisa*	3.60	5.87	50	4.50	7.20	3.26	13.63	0.058	-2.830	-0.164
26.	*Aspilia africana*	1.40	2.28	30	2.70	4.67	2.12	7.10	0.023	-3.772	-0.085
27.	*Vernonia ambigua*	0.10	0.16	10	0.90	10.00	4.53	5.59	0.002	-6.215	-0.010

Table 1 continued

28.	*Centrosema pubescens*	0.90	1.47	20	1.80	4.50	2.04	5.31	0.015	-4.200	-0.061
29.	*Chromolaena odorata*	1.40	2.28	30	2.70	4.67	2.12	7.10	0.023	-3.772	-0.085
30.	*Tridax procumbens*	2.00	3.26	40	3.60	5.00	2.27	9.13	0.032	-3.411	-0.110
31.	*Andropogon tectorum*	0.40	0.65	20	1.80	2.00	0.91	3.36	0.006	-4.962	-0.032
32.	*Andropogon gayanus*	0.10	0.16	10	0.90	1.00	0.45	1.51	0.003	-5.809	-0.015
33.	*Sida acuta*	2.80	4.57	30	2.70	9.33	4.23	11.50	0.045	-3.079	-0.139
34.	*Axonopus compressus*	0.70	1.14	10	0.90	7.00	3.17	5.21	0.011	-4.509	-0.051
35.	*Vernonia cinerea*	1.60	2.61	40	3.60	4.00	1.81	8.02	0.026	-3.650	-0.094
36.	*Talinum triangulare*	0.20	0.33	10	0.90	2.00	0.91	2.14	0.003	-5.809	-0.019
37.	*Euphorbia heterophylla*	1.60	2.61	20	1.80	8.00	3.63	8.04	0.026	-3.650	-0.094
38.	*Triumphetta cordifolia*	0.30	0.49	10	0.90	3.00	1.36	2.75	0.005	-5.298	-0.026
39.	*Solenostemon monostachyus*	0.40	0.65	10	0.90	4.00	1.81	3.36	0.006	-4.962	-0.032
	TOTAL	**62.00**	**99.99**	**1110**	**99.93**	**220.61**	**100.00**				**-3.131**

Note: R. D. = Relative density, R. F. = Relative Frequency; A. = Abundance; R. A. = Relative Abundance; I.V.I. = Importance value Index; P_i is the proportion of the ith (individual) species in the community.

Table 2. Measures of Abundance of plant species in Iffite-Awka site

S/N	Plant spp.	Density (m^{-2})	R. D. (%)	Freq. (%)	R. F. (%)	A. ($/m^2$)	R. A. (%)	I.V.I.	Pi	*ln* Pi	*Pi * ln Pi*
1	*Senna occidentalis*	3.10	5.25	100	10.20	3.10	1.60	17.05	0.053	-2.946	-0.155
2	*Gomphrena celosioides*	5.80	9.83	30	3.06	19.30	9.94	22.83	0.098	-2.320	-0.228
3	*Imperata cylindrica*	2.80	4.75	20	2.04	14.00	7.21	13.99	0.047	-3.048	-0.145
4	*Commelina erecta*	1.30	2.20	20	2.04	6.50	3.35	7.59	0.022	-3.815	-0.084
5	*Mariscus alternifolius*	0.60	1.00	10	1.02	6.00	3.09	5.11	0.010	-4.588	-0.047
6	*Amaranthus spinosus*	0.90	1.53	30	3.06	3.00	1.54	6.13	0.015	-4.183	-0.064
7.	*Synedrella nodiflora*	2.40	4.07	40	4.08	6.00	3.09	11.24	0.041	-3.202	-0.130
8	*Ipomoea involucrata*	0.50	0.85	10	1.02	5.00	2.57	4.44	0.008	-4.771	-0.040
9	*Cleome viscosa*	0.80	1.36	30	3.06	2.67	1.37	5.79	0.014	-4.301	-0.058
10	*Ageratum conyzoides*	2.40	4.07	30	3.06	8.00	4.12	11.25	0.041	-3.202	-0.130
11	*Spigelia anthelmia*	1.30	2.20	20	2.04	6.50	3.35	7.59	0.022	-3.815	-0.084

Table 2 continued

12	*Eragrostis tenella*	0.30	0.51	10	1.02	3.00	1.54	3.07	0.005	-5.282	-0.027
13	*Phyllanthus amarus*	0.70	1.19	30	3.06	2.33	1.20	5.45	0.012	-4.434	-0.053
14	*Ipomoea triloba*	0.20	0.34	10	1.02	2.00	1.03	2.39	0.003	-5.687	-0.019
15	*Hyptis suaveolens*	1.50	2.54	30	3.06	5.00	2.57	8.17	0.025	-3.672	-0.093
16	*Emilia praetermissa*	0.40	0.68	20	2.04	2.00	1.03	3.75	0.007	-4.994	-0.034
17	*Pennisetum polystachion*	0.20	0.34	10	1.02	2.00	1.03	2.39	0.003	-5.687	-0.019
18	*Mitrocarpus villosus*	1.10	1.86	20	2.04	5.50	2.83	6.73	0.019	-3.982	-0.074
19	*Boerhavia diffusa*	0.60	1.02	20	2.04	3.00	1.54	4.60	0.010	-4.588	-0.047
20	*Sida rhombifolia*	0.40	0.68	10	1.02	4.00	2.06	3.76	0.007	-4.994	-0.034
21	*Desmodium scorpiurus*	0.60	1.02	20	2.04	3.00	1.54	4.60	0.010	-4.588	-0.047
22	*Crotolaria retusa*	0.20	0.34	10	1.02	2.00	1.03	2.39	0.068	-2.691	-0.182
23	*Euphorbia hirta*	7.00	11.86	60	6.12	11.67	6.01	23.99	0.119	-2.132	-0.253
24	*Mimosa invisa*	3.00	5.08	40	4.08	7.50	3.86	13.02	0.051	-2.979	-0.151
25	*Aspilia africana*	1.10	1.86	20	2.04	5.50	2.83	6.73	0.019	-3.982	-0.074
26	*Vernonia cinerea*	1.30	2.20	40	4.08	3.25	1.67	7.95	0.022	-3.815	-0.084
27	*Chromolaena odorata*	1.70	2.88	30	3.06	5.67	2.92	8.86	0.029	-3.547	-0.102
28	*Tridax procumbens*	4.00	6.78	70	7.14	5.71	2.94	16.86	0.068	-2.691	-0.182
29	*Andropogon tectorum*	0.40	0.68	20	2.04	2.00	1.03	3.75	0.007	-4.994	-0.034
30	*Sida acuta*	7.70	13.05	50	5.10	15.40	7.93	26.08	0.131	-2.036	-0.266
31	*Axonopus compressus*	1.40	2.37	20	2.04	7.00	3.60	8.01	0.024	-3.741	-0.089
32	*Vernonia ambigua*	1.20	2.03	30	3.06	4.00	2.06	7.15	0.020	-3.895	-0.079
33	*Talinum triangulare*	0.30	0.51	10	1.02	3.00	1.54	3.07	0.005	-5.282	-0.027
34	*Triumphetta cordifolia*	1.00	1.69	20	2.04	5.00	2.57	6.30	0.017	-4.078	-0.069
35	*Solenostemon monostachyus*	0.30	0.51	10	1.02	3.00	1.54	3.07	0.005	-5.282	-0.027
36	*Conyza sumatrensis*	0.50	0.85	30	3.06	1.67	0.86	4.77	0.008	-4.771	-0.040
	TOTAL	**59.00**	**99.99**	**980**	**99.96**	**194.26**	**100.00**	**299.95**			**-3.273**

Note: R. D. = Relative density, R. F. = Relative Frequency; A. = Abundance; R. A. = Relative Abundance; I.V.I. = Importance value Index; P_i is the proportion of the ith (individual) species in the community.

Table 3. Measures of Abundance of plant species in Okpuno site

S/N	Plant spp.	Density (/m^2)	R. D. (%)	Freq. (%)	R. F. (%)	A. (/m^2)	R. A. (%)	I.V.I.	Pi	*ln* Pi	*Pi * ln Pi*
1	*Emilia praetermissa*	0.20	0.75	10	2.00	0.20	0.20	2.95	0.008	-4.890	-0.037
2	*Imperata cylindrica*	8.20	30.83	50	10.00	16.40	18.06	58.89	0.308	-1.177	-0.363
3	*Pennisetum polystachion*	1.30	4.89	60	12.00	2.17	2.39	19.28	0.049	-3.016	-0.148
4	*Mimosa pudica*	0.30	1.13	10	2.00	3.00	3.30	6.43	0.011	-4.485	-0.051
5	*Pennisetum pedicellatum*	0.30	1.13	20	4.00	1.50	1.65	6.78	0.011	-4.485	-0.051
6	*Ageratum conyzoides*	1.40	5.26	20	4.00	7.00	7.71	16.97	0.053	-2.944	-0.155
7	*Spigelia anthelmia*	0.30	1.13	10	2.00	3.00	3.30	6.43	0.011	-4.485	-0.051
8	*Panicum maximum*	1.90	7.14	50	10.00	3.80	4.18	21.32	0.071	-2.639	-0.189
9	*Hyparrhenia rufa*	0.30	1.13	10	2.00	3.00	3.30	6.43	0.011	-4.485	-0.051
10	*Euphorbia hirta*	1.40	5.26	10	2.00	14.00	15.42	22.68	0.053	-2.944	-0.155
11	*Mimosa invisa*	0.80	3.01	20	4.00	4.00	4.40	11.41	0.030	-3.504	-0.105
12	*Centrosema pubescens*	3.00	11.28	30	6.00	10.00	11.01	28.29	0.113	-2.182	-0.246
13	*Chromolaena odorata*	3.10	11.65	60	12.00	5.17	5.69	29.34	0.117	-2.150	-0.251
14	*Tridax procumbens*	0.70	2.63	20	4.00	3.50	3.85	10.48	0.026	-3.638	-0.096
15	*Andropogon tectorum*	0.50	1.88	20	4.00	2.50	2.75	8.63	0.019	-3.974	-0.075
16	*Sida rhombifolia*	1.50	5.64	40	8.00	3.75	4.13	17.77	0.056	-2.875	-0.162
17	*Axonopus compressus*	0.40	1.50	10	2.00	4.00	4.40	7.90	0.015	-4.197	-0.063
18	*Hyparrhenia involucrata*	0.70	2.63	30	6.00	2.33	2.57	11.20	0.026	-3.638	-0.096
19	*Loudetia arundinacea*	0.30	1.13	20	4.00	1.50	1.65	6.78	0.011	-4.485	-0.051
	TOTAL	**26.600**	**100.00**	**500**	**100.00**	**90.82**	**99.98**				**-2.392**

Note: R. D. = Relative density, R. F. = Relative Frequency; A. = Abundance; R. A. = Relative Abundance; I.V.I. = Importance value Index; P_i is the proportion of the ith (individual) species in the community.

Table 4. Measures of Abundance of plant species in Amansea site

S/N	Plant spp.	Density (/m^2)	R. D. (%)	Freq. (%)	R. F. (%)	A. (/m^2)	R. A. (%)	I.V.I.	Pi	*ln* Pi	*Pi * ln Pi*
1	*Senna obtusifolia*	0.30	1.02	20	3.08	1.50	1.22	5.32	0.010	-4.585	-0.047
2	*Emilia praetermissa*	0.30	1.02	10	1.54	3.00	2.43	5.00	0.010	-4.585	-0.047
3	*Imperata cylindrica*	5.30	18.03	20	3.08	26.50	21.51	42.61	0.180	-1.713	-0.309
4	*Centrosema pubescens*	1.00	3.40	20	3.08	5.00	4.06	10.54	0.034	-3.381	-0.115
5	*Amaranthus spinosus*	0.30	1.02	10	1.54	3.00	2.43	5.00	0.010	-4.585	-0.047
6	*Hyparrhenia rufa*	0.90	3.06	50	7.69	1.80	1.46	12.21	0.031	-3.486	-0.107
7	*Ipomoea asarifolia*	0.50	1.70	20	3.08	2.50	2.03	6.81	0.017	-4.074	-0.069
8	*Ageratum conyzoides*	2.30	7.82	30	4.62	7.67	6.22	18.67	0.078	-2.548	-0.199
9	*Panicum maximum*	0.60	2.04	20	3.08	3.00	2.43	7.56	0.020	-3.892	-0.079
10	*Eleusine indica*	0.30	1.02	10	1.54	3.00	2.43	5.00	0.010	-4.585	-0.047
11	*Physallis angulata*	0.20	0.68	10	1.54	2.00	1.62	3.84	0.007	-4.990	-0.034
12	*Sporobolus pyramidalis*	2.00	6.80	30	4.62	6.67	5.41	16.83	0.068	-2.688	-0.183
13	*Hyptis suaveolens*	1.70	5.78	40	6.15	4.25	3.45	15.38	0.058	-2.850	-0.165
14	*Pennisetum polystachion*	1.00	3.40	50	7.69	2.00	1.62	12.71	0.034	-3.381	-0.115
15	*Andropogon gayanus*	0.50	1.70	20	3.08	2.50	2.03	6.81	0.017	-4.074	-0.069
16	*Solenostemon monostachyus*	0.30	1.02	10	1.54	3.00	2.43	5.00	0.010	-4.585	-0.047
17	*Crotolaria retusa*	0.50	1.70	20	3.08	2.50	2.03	6.81	0.017	-4.074	-0.069
18	*Euphorbia hirta*	1.40	4.76	10	1.54	14.00	11.36	17.66	0.048	-3.045	-0.145
19	*Aspilia africana*	1.10	3.74	30	4.62	3.67	2.98	11.34	0.037	-3.286	-0.123
20	*Chromolaena odorata*	2.70	9.18	50	7.69	5.40	4.38	21.26	0.092	-2.388	-0.219
21	*Tridax procumbens*	3.10	10.54	70	10.77	4.43	3.59	24.91	0.105	-2.250	-0.237
22	*Andropogon tectorum*	0.40	1.36	30	4.62	1.33	1.08	7.06	0.014	-4.297	-0.058
23	*Sida rhombifolia*	1.50	5.10	30	4.62	5.00	4.06	13.78	0.051	-2.976	-0.152
24	*Axonopus compressus*	0.40	1.36	10	1.54	4.00	3.25	6.15	0.014	-4.297	-0.058
25	*Vernonia cinerea*	0.30	1.03	10	1.54	3.00	2.43	5.00	0.010	-4.585	-0.047
26	*Vernonia ambigua*	0.50	1.70	20	3.08	2.50	2.03	6.81	0.017	-4.074	-0.069
	TOTAL	**29.40**	**100.01**	**650**	**100.05**	**123.21**	**100.00**				**-2.857**

Note: R. D. = Relative density, R. F. = Relative Frequency; A. = Abundance; R. A. = Relative Abundance; I.V.I. = Importance value Index; P_i is the proportion of the ith (individual) species in the community.

Table 5. Shannon Weiner's index of diversity, equitability of distribution of species, and Jaccard Index of Similarity

Site	*S*	H^1	H_{max}	E
1	39	3.13	3.66	0.86
2	36	3.27	3.58	0.91
3	19	2.39	2.94	0.81
4	26	2.86	3.26	0.88

Jaccard index of similarity (JIS) of the sites

Site 1 & 2	Sites 1 & 3	Sites 1 & 4	Sites 2 & 3	Sites 2 & 4	Sites 3 & 4
0.65	0.26	0.35	0.28	0.38	0.36

Note: Site 1 = Agu-Awka; Site 2 = Iffite-Awka; Site 3 = Okpuno; Site 4 = Amansea; *S* is the total number of species; H^1 is the Shannon Weiner's index of diversity; H_{max} is the maximum equitability; $H_{max} = ln\ S$; *ln* S is the natural logarithm of the total number of species; E = Equitability or evenness of distribution of species

4. Discussions

Ecological studies on individual plant species are very important in order to have a good understanding of the behaviour and population dynamics of the individual species. Such studies also provide information on the interactions between the plant and the other plant species within a community and the community's plant species composition and structure [28]. The survey of the abundance of *S. occidentalis* showed that the plant is not abundant in the study area, as its presence was observed in only two of the study sites. The plant does not exert much ecological influence over other associated plant species found thriving in the same sites, as can be seen from the fact that there were other plant species that had higher importance value index than *S. occidentalis*. However, this observation contradicts the report that the plant is invasive and problematic [29, 30].

Importance value index (IVI) provides the true overall picture of the ecological importance and influence of a species with respect to a community. It is the measure of how dominant a plant species is in any ecosystem [31]. The species with the highest IVI in an ecosystem is the most dominant in that ecosystem [32]. Our results showed that *S. occidentalis* is not the dominant plant species in all the study sites. Therefore, it has little influence in the study area. It could be that the plant was newly introduced and is just getting established in the two areas where it was found. The plant is known to be native to South America and Mexico, and introduced to Nigeria [33, 34].

The presence of highly invasive plant species such as *Chromolaena odorata*, *Mimosa invisa*, *Andropogon spp*., *Pennisetum spp*., and *Hyparrhenia spp*., in the study area may have significantly affected the abundance and distribution of *S. occidentalis*. The presence of invasive weeds in any area reduces significantly the number of associated species [35]. In addition, allelopathy exhibited by *C. odorata* [36, 37] may also have inhibited the establishment, growth and spread of *S. occidentalis* in the locality. For instance, *Mimosa invisa*, which was found colonizing three of the study sites (Agu-Awka, Iffite, and Okpuno) successfully, is an aggressive invader that has the ability to dominate and suppress all other plant species around it due to its highly competitive ability in any community it comes into [38]. Invasive alien species are notable for huge negative ecological impacts on plant biodiversity by causing loss or decrease in native or associated species in any ecosystem through competition for habitat and nutrients [39].

The IUCN categorization of the plant as Least Concern (LC) species [21], cannot be said to be a true representation of the ideal status of *S. occidentalis* in the study area. This is due to the fact that the observed number (quadrat count), the relative density and relative abundance values of the plant in the two study sites where it was found were very low. Meanwhile, the plant was not seen physically in the other two study locations – Okpuno and Amansea in Awka. The absence of the plant in Okpuno and Amansea study sites can be attributed to anthropogenic factors such as unsustainable agricultural practices, unregulated construction of buildings, cattle grazing and to a lesser extent, erosion disaster (as observed by the author). This observation agrees with IUCN that there is a continuing decline in the subpopulations, area, extent and quality of habitats of *S. occidentalis* [21]. It could also be that the plant is yet to be introduced in those two locations.

The rapid rate of land use change, aggressive invasion of the area by alien species, devastations caused by gully erosions and landslides, and cattle grazing, coupled with the restricted range of the plant species suggest that *S. occidentalis* is threatened and has fallen under the endangered category in Awka, Anambra State. The study sites having relatively low species richness underline the challenges of plant species conservation in the area. This situation is worsened by the fact that the plant species is not in *ex-situ* cultivation anywhere in Nigeria. Any random or sudden environmental disaster or major alien species invasion could speedily lead to the extinction of the local population of the plant in the study area.

Two plant communities or study areas can be compared on the basis of the species present in those communities or study areas being compared using the Shannon-Weiner index of diversity and the Jaccard Index of similarity [40]. The two study locations where the plant existed (Agu-Awka and Iffite) were richer in terms of the number of plant species and species diversity than the other two areas where it was non-existent. The fact that the two sites where *S. occidentalis* was found were more similar in species composition, but much less similar from the other sites where the plant was not found, could be attributed to lesser anthropogenic disturbances (land use changes) in those similar sites (Iffite and Agu-Awka). Different land use changes such as agricultural expansion, seasonal bush fires, deforestation, urbanization, and sprawl have been confirmed to negatively and significantly affect plant

diversity and ecosystem services [41-43]. Furthermore, the higher value of Jaccard similarity index is well correlated with uniform environmental conditions [44].

5. Conclusions

Senna occidentalis is not abundant in the study sites in the communities where they were found in Awka. Therefore, we categorized *S. occidentalis* as a threatened or endangered species since habitat destruction, unsustainable agricultural practices, urbanization and uncontrolled construction of buildings are going on extensively in the study area. The presence of aggressive invading plant species is also contributing significantly to the decline in the population and distribution of *S. occidentalis* in the area. The danger posed by soil erosion to the existence of the plant in the area cannot be neglected.

Therefore, conservation strategies should be initiated urgently in order to preserve this plant from becoming extinct. Since the conservation needs of this plant species are critically high, practical conservation methods should also address the challenges of land use change and invasive weed species, since they are the culprits in the declining populations of *S. occidentalis* in the area. There is a need that local communities and government should support such conservation efforts for them to be successful. The plant and its habitats need further evaluations in other places within and outside Nigeria to ascertain its population, distribution and conservation status.

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Conflict of Interest

Authors declare no conflict of interests.

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