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Variations of biomass and carbon contents in different traits and components of herbaceous species from tropical grassland

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Abstract

Grasslands play a critical role in the global storage of atmospheric carbon (C). Precise estimation of C contents in different plant components is essential to formulate a strategy for mitigating the atmospheric C. Biomass (B) and C of different herbaceous plant components at species, functional group and site levels from tropical grassland locating on the campus of Banaras Hindu University, Varanasi, India were estimated. For this; 117 herbaceous species just-before flowering were harvested. B and C contents for each species and component were measured and statistically analyzed. The measured C (g plant^{-1}) across the components varied from 0.08 to 31.12. On gm^{-2} basis; it varied between 29 (leaf) and 49 (root). Plant components, species and functional groups in isolation caused significant differences in the measured C. In the present study; the C content of stem was greater than the leaf and root. The perennial, erect, leguminous and native traits had greater C than the others. Therefore, this observation revealed that the perennial, erect, leguminous and native plants could be a better option for reducing the atmospheric CO_2 by capturing it and then converting into B through photosynthesis. Further, the fitted regression equation between the root and shoot for B and C could be used for the extrapolation of B and C of the root component based on the shoot component. The conservative field measurement methods may give precise data on B and C but are destructive to grassland, difficult, time-consuming, and costly to cover at large scale. Hence, the present work could be substantial for the estimation of root C based on shoot component.

Keywords: *Carbon, Biomass, Plant component, Plant functional traits, Tropical grassland*

1. Introduction

In current Anthropocene epoch; increased concentration of atmospheric Carbon dioxide (CO_2) is perceived as a major driver for global climate change events because among the greenhouse gases; CO_2 alone has the

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potential to contribute a total of 60% of the global warming (Broecker, 1975; and IPCC, 2014). As a consequence, we are observing an increase in earth's temperature, spatiotemporal changes in precipitation patterns, extreme weather events and shifting of seasons under the umbrella of global climate change events (IPCC, 2014). The fossil records suggested that ≈ 55.9 m.y.a, the release of natural CO_2 in high amount, rose 5 °C global temperature and caused strong warming (Alley, 2016). The events which took place at that time (dwarfing of large animals, ecosystem disruptions, soil degradation, hydrological variability, larger and more intense storms, loss of vegetation, biodiversity and soil fertility, poleward migration of terrestrial species, species extinction, increased leaf damage by insects and invasion of new species) are continuing and predicted to be repeated more intensively (Alley, 2016).

Looking into above challenges, the world scientific communities are primarily concern for estimating the total worldwide Carbon (C) storage in terrestrial vegetation (Odiwe *et al*., 2016) and to identify the potential sinks of C required to curb the increasing rate of atmospheric CO_2 (IPCC, 2014; Lu *et al*., 2015; and UNFCCC, 2015). Thereafter, total terrestrial C pools have been estimated in the range of 2477 PG C (IPCC, 2003) and 3120 PG C (Lal, 2010). Current estimate revealed 1912.2 PG C for 1-m depth soil and 1415.7 PG C stored in above and below ground plant biomass. Unfortunately, a big debate is persisting about the ecological research on the amount, uncertainty and accuracy of C stored in the terrestrial ecosystems (Le *et al*., 2012) due to differences in sampling periods, intensity and spatial resolution of the soil profile databases, in addition to variations in estimation methods (Mokany *et al*., 2006; Le *et al*., 2012; and Russell *et al*., 2015). Therefore, the estimation of C present in missing or uncertain form from diverse terrestrial vegetations is needed for a better understanding of global atmospheric CO_2 mitigation.

The ecological research on C portioning in different plant components is not only important for the assessment of competitive fitness, reproduction, and growth of the plants against the environmental change (Dickson, 1989) but also precisely contribute in global total C estimation and prediction (Mokany *et al*., 2006; and Russell *et al*., 2015). The studies on the C storage in above-ground plant components from diverse ecosystems are extensively documented (Bunker *et al*., 2005) while root received little attention although it contributes almost 30% of the total terrestrial soil C stock and C present in uncertain form is totally ignored (Mokany *et al*., 2006). As the root-B is difficult (digging or uprooting) and expensive to measure; therefore, it is further challenging to reduce the uncertainty for the total C stock prediction in different plant components of the global terrestrial biosphere (Mokany *et al*., 2006; Le *et al*., 2012; and Russell *et al*., 2015). Similarly; the plant functional trait being a key component of the global C cycle, regulates the storage and fluxes of soil C and facilitates in developing strategies to mitigate the elevated level of atmospheric C (De Deyn *et al*., 2008). Hence, assessment of plant C based on herbaceous plant functional trait (which is an uncertain or missing component) perspective is equally essential as partitioning in different plant components as for C mitigation and storage is concerned.

Given that tropical forests account for two-thirds of all terrestrial B and exhibit more C stock per unit area than any other land cover type (Pan *et al*., 2013). Many large-scale forest experiments from the tropics have improved our understanding of CO_2 emission and storage from different terrestrial C pools of the world (Peng *et al*., 2013). Unfortunately, grasslands being under the uncertain component of the total C budget have been ignored while they cover nearly one-fifth of the world's land surface area (Leith, 1978; Singh *et al*., 2006). They harbor more than 90% plant species of the forest (Gilliam, 2007), represent more than 20% of global total net primary productivity (Hall and Scurlock, 1991; and Grace *et al*., 2006), contribute 50% calories consumed worldwide (Irving, 2015) and store roughly 34% of the global terrestrial C pool (White *et al*., 2000). These species also substantially contribute to the soil C sequestration (Dinakaran *et al*., 2014) because of higher root production and relatively slower rates of C turnover (Fisher *et al*., 1994). They have tremendous potential to influence the global C reserves (San Jose´ *et al*., 1998) and CO_2 reduction from the atmosphere (Minami *et al*., 1993).

The regression equations, C: B and root (R): shoot (S) ratios are commonly used non-destructive methods for B and C computation in different vegetations (Bollinder *et al*., 2002; Frank *et al*., 2004; UNFCCC, 2015; Sainju *et al*., 2017). Moreover, the regression equations for measuring B and C of grasses have not been developed while C: B and R: S ratios for estimating the B or C is very rare (Sainju *et al*., 2017). However, different methods have been employed to estimate C storage in the different components of grasslands, including remote sensing (Piao *et al*., 2004) modeling and field investigation data (Yang *et al*., 2010), but even precise estimation of total C in different plant components of herbaceous vegetation at cheap cost is lacking. The use of the IPCC default

R: S value for estimating the root B or C of grasslands locating in different ecological conditions may cause the discrepancy in the prediction of total B or C (Barbosa *et al*., 2012), while the use of the vegetation-specific R: S ratios improve the accuracy in estimating the root B or C for the purpose of C accounting at global level (Mokany et al. 2006). Thus, it is urgent to find out the suitable and efficient methods for C estimation from the tropical grassland which could be useful in predicting the global C budget.

In the majority of local, regional, and global assessments, the C content has been assumed to vary between 35 and 65 % of the dry weight, while 50 % of the dry weight has been marked for the quantification of tree C (Lewis *et al*., 2009; Blanc *et al*., 2009; and Thomas and Martin, 2012), unfortunately such needful quantification for tropical grassland is disappointing. The massive degradation (20–25% of the world's native grasslands have been degraded), reduction of per capita grasslands and loss of herbage B and organic C due to rigorous anthropogenic events (Sala and Paruelo, 1997; and Sagar *et al*., 2017) further mound the pressure for the C estimation under the global climate change crisis in the Anthropocene era.

Looking into above problems the objectives of the present study were: (1) to estimate C content in different components of tropical grasslands, and (2) to develop regression equations between root and shoot (R:S ratios) C useful for the estimation of root C based on shoot C. Such an approach could be helpful in reliable estimation of global terrestrial C for formulating a suitable strategy required to mitigate the rate of increasing C.

2. Materials and Methods

2.1. Study Area

The study was conducted on the campus of Banaras Hindu University (25.3176° N latitude and 82.9739° E longitude and 80.71 m above sea level), Varanasi, India, during January 2014 - December 2015. The climate is a tropical monsoon. The cold winter (November to February), hot summer (April to June) and warm rainy (July to September) are distinct seasons. The months of October and March are transitional months between rainy and winter, and between winter and summer seasons, respectively (Verma et al. 2015). During the study period, the mean maximum temperature was 30.19 °C (range 8–44.6 °C) while the mean minimum temperature was 20.27 °C (range 6.4–30.8 °C). The soil is alluvial, well-drained, pale brown, silty loam and inceptisol. In general, it is moderately fertile being low in available nitrogen and medium in available phosphorus and potassium with neutral to alkaline soil pH (Sagar et al. 2008).

2.2. Vegetation Sampling and Analyses

During the study period; through the intensive survey, a total of 117 mature herbaceous species (at the onset of the flowering stage) were collected from the entire campus of the University. For each species; 3-10 healthy individuals (depending upon the availability) just before the flowering stage were harvested. Each harvested plants were separated into root, leaf, and stem components (Poorter and Bergkotte, 1992). For our convenience, the term 'stem' is used throughout the ms instead of 'culm' (generally used for the grasses). The plant fractions were oven-dried at 80 °C to constant weighed. The oven dried plant material was used to determine the ash content. Ash content was measured after combustion of the sample in a muffle furnace at 550°C for 6 h (Singh *et al*., 2011). C content was determined by using the loss on ignition method (Mcbrayer and Cromack, 1980) which is approximately 50% of ash-free weight (van Soest, 1963). The plant functional attributes were studied at life form (forbs, grasses, legumes, and sedges), growth form (erect, prostrate, procumbent and decumbent), lifespan (annual, biennial and perennial), and origin or distribution (native, non-native and cosmopolitan) levels (Verma *et al*., 2015). These traits were determined with the help of Flora of Raipur, Durg, and Rajnandangaon (Verma *et al*., 1985) and Flora of the upper Gangetic plain (Duthie, 1903).

The study also estimated B and C contents on three sites differing in anthropogenic perturbations (less / site-1, medium / site-2, and high / site-3) on the campus of Banaras Hindu University. For each site; 15, 1×1m plots were used for the sampling of plants for their B and C measurement. Hence, a total of 45, 1×1 m plots (3 sites × 15 replicate) were used for the validation of C content. For each 1 × 1 m plot, above ground peak, live B of all species was clipped at the soil surface in mid-October of the sampling year. All samples were oven-dried at 80°C to constant mass and weighed. This oven dried B was used for the determination of C content.

3. Statistical Analyses

Analysis of variance (ANOVA) procedure of SYSTAT package ver. 13 (SYSTAT, 2009) was used to see the effects of species, components, and traits on the measured B and C contents. A Tukey's HSD test was used to understand variations of C content among the different plant components and sites. Regression analysis was used to see the relationships of B contents between roots and shoots as well as C contents between roots and shoots components with the help of SYSTAT software ver. 13 (SYSTAT, 2009).

4. Results

4.1. Species Composition

A total of 117 herbaceous species belonging to 95 genera and 31 families were recorded from the campus of Banaras Hindu University. The family Poaceae had the highest species number (19) and fifteen families had single species. Among all the families, the four families (Poaceae, Asteraceae, Fabaceae, and Cyperaceae) were species-rich (Appendix 1). On the basis of dry B (g plant^{-1}); Aurobindo donex, Anisomelos indica and Hyptis suveolens were dominant species in the study area (Appendix 1).

4.2. B and C Across the Species and Components

The statistical analysis implied that the plant B and C differed significantly due to species ($F_{116,1170} = 61$, $P \leq 0.0001$ and $F_{116,1170} = 61$, $P \leq 0.0001$), plant components ($F_{2,1170} = 248$, $P \leq 0.0001$ and $F_{2,1170} = 279$, $P \leq 0.0001$) and their interactions ($F_{232, 1170} = 11$, $P \leq 0.0001$ and $F_{232, 1170} = 12$, $P \leq 0.0001$).

Across the species and components; maximum B (g plant^{-1}) for leaf (46.04), stem (65.49), and shoot (11.53) components as well as for total plant (133.85) were represented by A. donex, while maximum root B was exhibited by *Rauwolfia serpentina* (25.58). Conversely; the minimum B for leaf (0.19), stem (0.08) and shoot (0.16) components were showed by *Polygonum barbatum, Lippia alba, Tanacetum parthenium*, respectively. Further, *Lindernia anagallis* had minimum root (0.01) as well as total plant (0.37) B (Appendix 1). Interestingly, these species also exhibited similar patterns regarding the maximum and minimum values for C content on g plant^{-1} basis. For instance; the observed C for leaf, stem, shoot, root and total plant varied from 0.08 (*P. barbatum*) to 20.20 (*A. donex*), 0.03 (*L. alba*) to 31.12 (*A. donex*), 0.07 (*T. parthenium*) to 51.31 (*A. donex*), 0.004 (*L. anagallis*) to 10.88 (*R. serpentina*) and 0.15 (*L. anagallis*) to 60.69 (*A. donex*), respectively (Appendix 1).

Species-wise, the measured C from dry B for leaf, stem, shoot, root and total plant ranged between 37 (*Rorippa dubia*) and 47 (*Phyllanthus asperalatus*), 38 (*L. anagallis* and *L. alba*) and 48 (*Cassia tora, Cleome viscosa, Croton bonplandianus, Desmodium gangeticum, Desmostachya bipinnata, Hyptis suveolens, Melilotus indica, P. asperalatus, Rauvolfia serpentine, Saccharum munja, S. spontaneum, Scoparia dulcis, Sida rhomboidea and Vetiveria zizanoidies*), 38 (*Trianthema portulacastrum*) and 47 (*C. viscosa, C. bonplandianus*), 36 (*H. suveolens*) and 50 (*Digitaria ciliaris*), and 39 (*R. dubia*) and 47 (*C. bonplandianus*), respectively.

The average B partitioning into the different plant components indicated that the shoots had

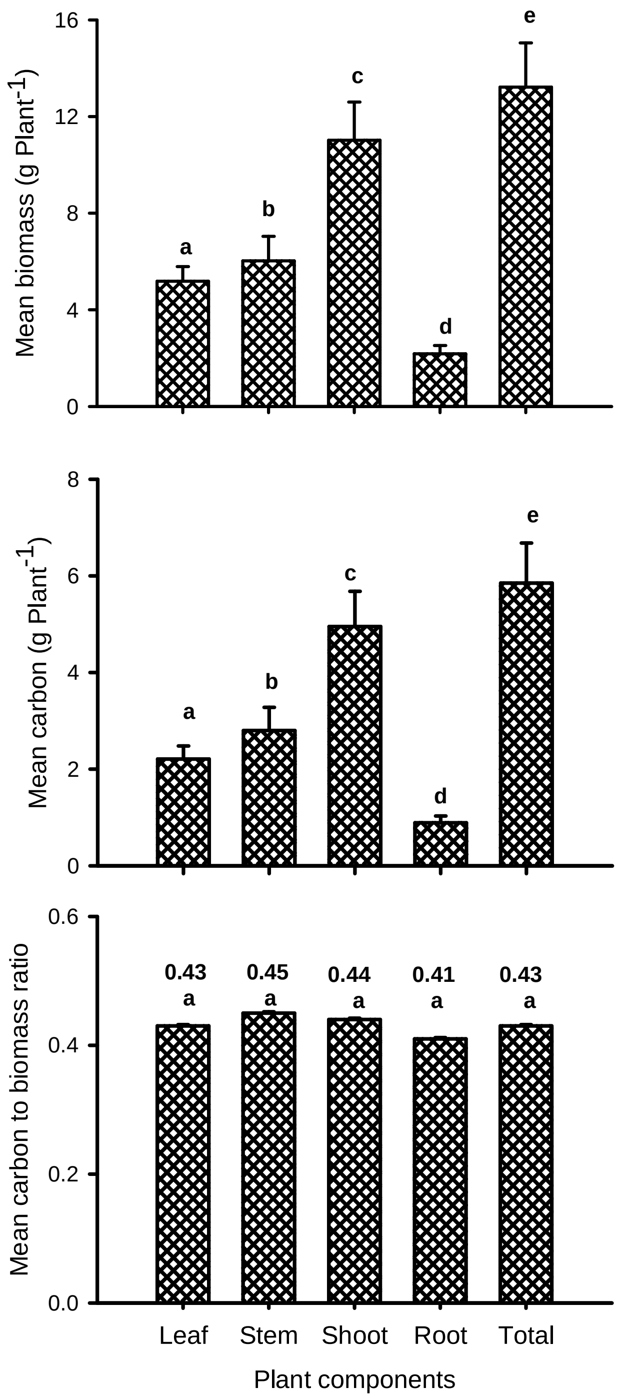

Figure 1: Mean biomass (g plant^{-1}), carbon content (g plant^{-1}) and carbon to biomass ratio based on 117 herbaceous species for different plant components in the tropical grassland at Varanasi, India. Bars affixed with different letters within each component are significantly different from each other.

five times greater B than the roots (Figure 1). More or less similar trend was also exhibited by C portioning into different plant components (Figure 1). The patterns of B, as well as C across the plant components, significantly varied in the order of stem>leaf>root as suggested by the Tukey's HSD analysis (Figure 1).

4.3. Functional Group Effects on B and C

ANOVA showed that B and C contents of different plant components differed substantially due to variations in the functional groups related to nativity and growth forms (Table 1). The plant components of life form functional groups also changed notably due to variations in their B and C contents, except B as well as C of root component and whole plant B. For lifespan functional group; only B and C of root component as well as whole plant varied statistically (Table 1).

Table 1: Summary of ANOVA (*F*-value and degree of freedom) of dry weight (biomass) and carbon contents in different plant components of herbaceous species due to variations in species, family, lifespan, nativity, life and growth forms.

Variables	Species	Family	Lifespan	Nativity	Lifeform	Growth form
	$F_{116,390}$	$F_{30,476}$	$F_{2,504}$	$F_{2,504}$	$F_{3,503}$	$F_{3,503}$
Leaf biomass	30.82***	4.20*	2.49^{ns}	10.14***	3.12*	4.46**
Leaf carbon	31.50***	3.92*	2.55^{ns}	10.24***	3.43*	4.39*
Stem biomass	29.71***	5.94**	1.94^{ns}	7.12**	3.31*	6.13**
Stem carbon	30.07***	5.98**	2.07^{ns}	7.02**	3.36*	6.27**
Shoot biomass	33.80***	5.38**	2.28 ns	8.60***	2.89*	5.67**
Shoot carbon	33.66***	5.29**	2.38 ns	8.50***	3.09*	5.75**
Root biomass	13.79***	4.24*	8.41***	18.64***	0.56^{ns}	2.92*
Root carbon	13.61***	4.12*	8.39***	18.86***	0.62^{ns}	2.91*
Total biomass	33.98***	5.38**	3.49*	10.61***	2.51^{ns}	5.49**
Total carbon	33.70***	5.28**	3.50*	10.40***	2.72*	5.61**
Root:shoot carbon ratio	9.98***	11.40***	10.37***	7.91***	0.81^{ns}	17.28***

Note: The one, two and three asterisks superscripted on different *F*-values indicate the significance levels at $*P \leq 0.01$, $**P \leq 0.001$, $***P \leq 0.0001$ and ^{ns} insignificant. The subscripted values to the *F* indicated the degree of freedom.

Results showed that the perennials, native, grasses and erect functional group categories represented greater B and C in their stems compared to other components of the functional groups (Table 2). Their corresponding S: R ratios for B and C ranged from 4.3 to 4.7, 4.2 to 4.5, 5.3 to 5.8, and 5.4 to 5.9. Annual, non-native, legume and decumbent functional group categories had 6.8 and 7.5, 6.5 and 7.2, 5.5 and 6.3, and 6.4 and 6.9 times higher shoot B and C than their root components. Interestingly; perennial, cosmopolitan, sedge, and prostate functional groups represented the lowest shoot to root (highest root to shoot) ratios for B and C in their respective functional groups (Table 2).

4.4. Effects of site on B and C contents (g m^{-2})

Statistical analysis showed that the sites caused significant difference in the herbaceous species (F2, 42: 33.06, $P \leq 0.001$) which varied from 9 (site-3) - 15 (site-2). Analysis further revealed that sites substantially influenced the B and C contents of leaf (F2, 42: 9.31, $P \leq 0.001$ and F2, 42: 8.92, $P \leq 0.001$), shoot (F2, 42: 10.56, $P \leq 0.001$ and F2, 42: 10.64, $P \leq 0.001$), root components (F2, 42: 13.96, $P \leq 0.001$ and F2, 42: 13.50, $P \leq 0.001$) and whole plant (F2, 42: 25.09, $P \leq 0.001$ and F2, 42: 23.90, $P \leq 0.001$). For example, across the sites; the B and C contents of leaf, stem, shoot, root components, and whole plant ranged from 48 to 102 and 21 to 42, 70 to 94 and 31 to 42, 118 to 195 and 51 to 85, 73 to 184 and 29 to 75, and 192 to 380 and 81 to 160, respectively (Table 3). The trend showed that the values of these variables for different plant components were lowest at highly disturbed location (site-3) and highest at less disturbed (site-1) location (Table 3).

Table 2: Mean herbaceous biomass; B (g plant^{-1}), carbon; C (g plant^{-1}), C to B ratios and for different plant trait categories in tropical grassland. Values in parentheses are ± 1*SE*.

Plant components	Annual		Biennial		Perennial	
Leaf biomass (B)	4.50	(0.66)	4.90	(0.98)	5.63	(1.13)
Leaf Carbon (C)	1.94	(0.29)	2.01	(0.40)	2.43	(0.49)
C:B ratio	0.431		0.411		0.432	
Stem biomass	4.95	(1.22)	6.17	(2.26)	7.06	(1.76)
Stem carbon	2.27	(0.58)	2.77	(1.01)	3.31	(0.83)
C:B ratio	0.459		0.451		0.467	
Shoot biomass	9.45	(1.81)	11.07	(3.15)	12.69	(2.84)
Shoot carbon	4.22	(0.84)	4.78	(1.37)	5.75	(1.31)
C:B ratio	0.447		0.436		0.452	
Root biomass	1.38	(0.56)	1.84	(0.43)	2.96	(0.69)
Root carbon	0.56	(0.10)	0.74	(0.17)	1.22	(0.29)
C:B ratio	0.404		0.403		0.410	
Total biomass	10.83	(2.02)	12.91	(3.33)	15.65	(3.34)
Total C	4.78	(0.93)	5.52	(1.45)	6.97	(1.51)
C:B ratio	0.442		0.426		0.444	
	Native		**Non-native**		**Cosmopolitan**	
Leaf biomass	7.77	(1.99)	4.22	(0.50)	4.06	(2.21)
Leaf carbon	3.36	(0.87)	1.82	(0.22)	1.73	(0.96)
C:B ratio	0.432		0.432		0.427	
Stem biomass	9.80	(3.16)	4.92	(0.91)	2.45	(1.19)
Stem carbon	4.56	(1.49)	2.27	(0.43)	1.11	(0.52)
C:B ratio	0.464		0.462		0.452	
Shoot biomass	17.56	(5.09)	9.14	(1.35)	6.51	(2.28)
Shoot carbon	7.93	(2.33)	4.09	(0.63)	2.84	(0.98)
C:B ratio	0.452		0.458		0.438	
Root biomass	4.21	(1.27)	1.41	(0.18)	4.07	(1.99)
Root carbon	1.75	(0.54)	0.57	(0.07)	1.68	(0.84)
C:B ratio	0.416		0.405		0.411	
Total biomass	21.77	(6.05)	10.54	(1.48)	10.57	
Total carbon	9.68	(2.73)	4.66	(0.68)	4.51	
C:B ratio	0.445		0.443		0.432	

Table 2 (Cont.)

	Forbs		Grasses		Legumes		Sedges	
Leaf biomass	4.56	(0.60)	7.77	(2.55)	4.61	(1.85)	3.91	(0.70)
Leaf carbon	1.94	(0.26)	3.42	(1.13)	2.07	(0.84)	1.64	(0.30)
C:B ratio	0.424		0.439		0.451		0.421	
Stem biomass	5.87	(1.14)	8.69	(3.72)	5.94	(2.77)	1.20	(0.20)
Stem carbon	2.70	(0.54)	4.12	(1.77)	2.81	(1.32)	0.53	(0.09)
C:B ratio	0.457		0.473		0.462		0.446	
Shoot biomass	10.43	(1.69)	16.46	(6.17)	10.55	(4.60)	5.11	(0.83)
Shoot carbon	4.64	(0.77)	7.54	(2.86)	4.88	(2.15)	2.17	(0.36)
C:B ratio	0.445		0.454		0.461		0.426	
Root biomass	1.95	(0.39)	3.10	(1.25)	1.91	(0.91)	1.80	(0.40)
Root carbon	0.80	(0.17)	1.29	(0.53)	0.78	(0.37)	0.72	(0.16)
C:B ratio	0.412		0.414		0.409		0.410	
Total biomass	12.38	(1.93)	19.56	(7.26)	12.46	(5.43)	6.91	(1.21)
Total carbon	5.44	(0.87)	8.82	(3.31)	5.65	(2.49)	2.89	(0.51)
C:B ratio	0.441		0.451		0.454		0.421	
	Erect		**Prostate**		**Procumbent**		**Decumbent**	
Leaf biomass	5.67	(0.78)	3.83	(1.12)	2.10	(1.15)	3.08	(1.07)
Leaf carbon	2.45	(0.34)	1.65	(0.49)	0.87	(0.48)	1.32	(0.47)
C:B ratio	0.431		0.432		0.415		0.429	
Stem biomass	7.34	(1.34)	2.42	(0.55)	2.09	(1.22)	2.39	(1.06)
Stem carbon	3.43	(0.64)	1.08	(0.25)	0.88	(0.49)	1.04	(0.46)
C:B ratio	0.466		0.451		0.424		0.440	
Shoot biomass	13.01	(2.08)	6.24	(1.61)	4.19	(2.36)	5.47	(2.06)
Shoot carbon	5.87	(0.96)	2.73	(0.71)	1.75	(0.96)	2.36	(0.90)
C:B ratio	0.450		0.438		0.423		0.432	
Root biomass	2.39	(0.45)	1.82	(0.46)	0.83	(0.63)	0.86	(0.26)
Root carbon	0.99	(0.19)	0.74	(0.19)	0.33	(0.24)	0.34	(0.10)
C:B ratio	0.413		0.412		0.401		0.400	
Total biomass	15.41	(2.42)	8.07	(1.74)	5.02	(2.99)	6.33	(2.20)
Total carbon	6.86	(1.10)	3.47	(0.76)	2.08	(1.20)	2.70	(0.96)
C:B ratio	0.444		0.432		0.413		0.425	

Table 3: Mean value of herbaceous biomass (g m^{-2}) and carbon content (g m^{-2}) of herbaceous species at three locations of tropical grassland differing in disturbance intensity. Values in parentheses are ± 1*SE*.

Vegetation parameters	Less (Site-1)	Medium (Site-2)	High (Site-3)
Leaf biomass	101.56 (13.18)	59.80 (7.72)	48.80 (4.05)
Leaf carbon	42.45 (5.55)	25.06 (3.30)	20.61 (1.76)
Stem biomass	93.86 (10.20)	85.47 (10.58)	69.51 (5.56)
Stem carbon	42.29 (4.58)	38.09 (4.72)	30.99 (2.51)
Shoot biomass	195.42 (16.06)	145.27 (10.85)	118.31 (7.70)
Shoot carbon	84.77 (6.96)	62.82 (4.68)	51.35 (3.40)
Root biomass	184.49 (23.73)	109.66 (9.71)	73.45 (5.63)
Root carbon	74.87 (10.07)	43.00 (3.93)	29.12 (2.31)
Total biomass	379.91 (28.59)	254.92 (13.11)	191.76 (10.33)
Total carbon	160.46 (12.65)	106.16 (5.35)	80.75 (4.42)

The mean C: B ratios for different plant components varied between 0.41 (root) and 0.45 (stem). Root had comparatively larger variability (0.36 to 0.50) than the other traits, while the whole plant expressed least (0.39-0.47) variability in the C: B ratios (Table 4). Thus, the results suggested that the C prediction based on C: B ratio for the whole plant will be more consistent.

Table 4: Variations in different ratios related to carbon and biomass of different herbaceous plant components across the species in a tropical grassland at Varanasi, India. Values in the parentheses are ±1*SE*.

Ratios	Range	Mean
Root to shoot biomass	0.02-9.88	0.41 (0.106)
Root to shoot carbon	0.02-10.50	0.40 (0.110)
Carbon to biomass ratio for Leaf	0.37-0.47	0.43 (0.002)
Carbon to biomass ratio for Stem	0.38-0.48	0.45 (0.002)
Carbon to biomass ratio for Root	0.36-0.50	0.41 (0.002)
Carbon to biomass ratio for Shoot	0.38-0.47	0.44 (0.002)
Carbon to biomass ratio for total plant	0.39-0.47	0.43 (0.002)

4.5. Relationships Between Root and Shoot Components Related to B and C Contents

Various significant regression equations between shoot (X) and root (Y) based on B and C contents considering species as data points are shown in Figure 2. Among these significant equations; the considerable R^2 (determination coefficient) varied from 0.27 (logarithmic equation for C content) to 0.52 (power equation for B).

Similarly, the Standard Error of Estimate (SEE) ranged between 1.12 (power equation for C) and 3.15 (logarithmic equation for B). In both the cases; next, to the power equation, the maximum R2 (0.46; for B, and 0.45; for C content) and minimum SEE (2.72; for C content and 1.15; for B) was exhibited by the linear equation (Figure 2).

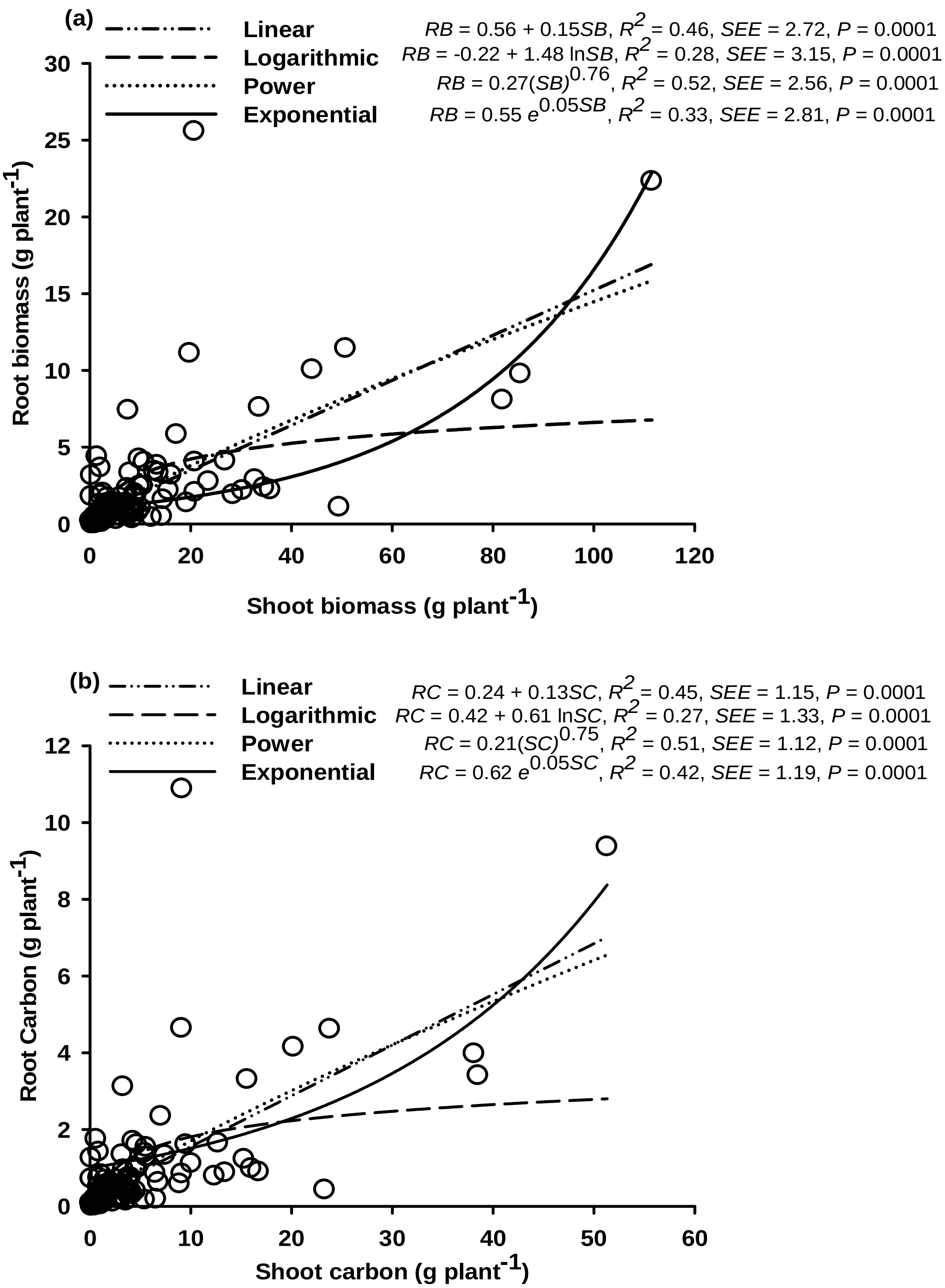

Figure 2: Linear and non-linear relationships (a) between shoot biomass; *SB* (*X*-axis) and root biomass; *RB* (*Y*-axis), and (b) between shoot carbon; *SC* (*X*-axis) and root carbon; *RC* (*Y*-axis) based on 117 herbaceous species in the tropical grassland at Varanasi, India. R^2=Determination coefficient, *SEE* = Standard Error of Estimate, *P* = level of significance.

5. Discussion

5.1. Species-wise B and C contents

A. donax showed maximum above ground B and C contents; hence, this could be used as an energy crop. It is advocated because of the greater photosynthetic capacity of A. donax in full sunlight compared to other C3 plants as suggested by Webster *et al*. (2016). The B production of A. donax in terms of energy and at the same time reduction of atmospheric CO_2 seems to be an interesting observation (Lewandowski *et al.,* 2003). Further, reports indicated that A. donax may reach B yields up to 100 t ha^{-1} in the second or third year of cultivation under the suitable climate and irrigation (Vasconcelos *et al.,* 2007). It forms dense stands on highly disturbed lands (Saltonstall and Bonnett, 2012), highly fire-tolerant species and having a high level of carbohydrates in its cell walls (67.85 % dry weight; Scordia *et al.,* 2010; and Chandel *et al.,* 2011), hence, could be a valuable species for C sequestration and a suitable substrate for ethanol production (Scordia *et al.,* 2010; and Chandel *et al.,* 2011).

The average total C of herbaceous species was 42.72% of their dry biomass. Similar to the present study, Davies *et al*. (2011) also reported 42.02% C of the dry biomass for the herbaceous species. Tumuluru (2015) reported 43.92 and 42.08% C of the dry biomass for the corn stover and switchgrass, respectively. However, in various studies, it was around 45% of the plant dry biomass (Olson *et al.,* 1983; and Wang *et al.,* 1999). Across the species, percent of total above-ground C on the dry-weight basis from steppe grassland of Inner Mongolia, China has been reported in a range of 15 to 41 having 29 as mean value (Sagar *et al.,* 2017). The percent below ground C on the dry weight basis was 40.60. *The NGGI Workbook* 4.2 Revision 2 (1997) assumed 42% C of the root dry matter for crops and grasses.

The study showed 51 – 85 (gm^{-2}) above ground C. Based on 0.43 C: B ratio, other studies also reported 44 to 154 (gm^{-2}) above ground C in an N-input study from the study area (Verma *et al.,* 2013 and 2015). In a steppe grassland of Inner Mongolia, China it was in a range of 7.12 to 10.72 (Sagar *et al.,* 2017) while in other studies of USA, the value was around 140-150 (Golubiewski, 2006; and Davies *et al*., 2011). Thus, the above ground C in the present study fall under these reported ranges; viz: 7.12 (Sagar *et al.,* 2017) and 150 (Golubiewski, 2006; and Davies *et al*., 2011).

5.2. Plant Component-wise C Content

Similar to the present study, significant variations in the root, stem and leaf B and C contents were reported by Poorter and Bergkotte (1992). The percentage above ground C was substantially higher than the below-ground C which signified the dependency of the plant growth on the supply of C from the shoots, and the nutrients and water from the roots. Thus, the assimilation of C by foliage and the acquisition of mineral nutrients and water by fine roots are balanced with the utilization of C and nutrients in the plants (Cannell and Dewar, 1994). Further, the C allocation to above ground and below ground plant parts are facilitated by nitrogen supply via regulating the cytokinins and sucrose productions (Van der Werf and Nagel, 1996). The cytokinins and sucrose productions through N supply could be other reason for allocating greater C in the stem than the other organs (Van der Werf and Nagel, 1996). Notably greater C in stem compared to root and leaf could be due to storage of greater B in stem component than the others because the stem part of the plant has been reported to contain a comparatively higher concentration of lignin than the leaves and roots (Poorter and Bergkotte, 1992).

5.3. Functional traits-wise C content

In the present study, the perennial plants stored more C and B in comparison to annual and biennial plants which could be attributable to the excess accumulation of photosynthates in form of carbohydrates, lipids and other chemical compounds (Dickson, 1989). Since the present study area experienced a marked seasonality, hence, this storage reserve material could be used by the plants for their respiration and maintenance during the dormant season (Dickson, 1989). It has been argued that in the seasonal environments, perennial plants have the ability to fix and store enough C, over the growing season to survive the winter and emerge following the year (Farrar *et al*., 2014) and different species incorporates different C according to their specific metabolism (Liu *et al.,* 2017).

Among all life form categories, the legumes had relatively more C compared to others. It may be further linked to their nitrogen-fixing ability in their root nodules which is utilized by such plants for their B and C production. Probably, it could be a reason for considering the leguminous plant as a key driver for C sequestration in many studies (Fornara and Tilman, 2008; and Wu *et al*., 2016). On the other hand, grasses showed high B (84.2 %) and C allocation above ground compared to the below ground (15.8%). Similar to our results, Irving (2015) also reported 80-85 % B in above ground and only 15 -20% in below-ground components of the grasses.

The study suggested that erect plant trait harbored greater B and C than the other traits which could be due to the availability of sufficient light to capture the atmospheric C. It is well-known fact that light is an important limiting factor for the growth and B build-up in the plants (Neufeld and Young, 2003). As observed in other studies; the tall plants were thought to be more competent in atmospheric C capturing and B build-up and outshade the short-statured species (Diekmann and Falkengren-Grerup, 2002). Thus, the erect plant species had greater B and C than the prostrate and short-statured plants due to their high C capturing ability in presence of sufficient sunlight (Sagar *et al*., 2012; and Verma *et al*., 2015). Greater uptake of atmospheric CO_2 into the B of erect trait through the photosynthesis (Cardinale *et al*., 2012), benefits the storage of CO_2 into the soil as soil organic-C (Fornara and Tilman, 2008; Cong *et al*., 2014; and Sagar *et al*., 2017), hence, such trait could be a strategy in sequestering the C into the soil as organic-C against the problem of global warming.

The notable changes in above ground and below ground C partitioning (R:S ratio) based on C content due to differences in species, lifespan, nativity and growth forms could be related to the deeper and denser rooting systems. The deeper, larger and denser rooting systems accumulate greater B and C in below ground than the above ground and are more beneficial for the accumulation of C into the soil (Rasmussen *et al*., 2010). In present study; *R. serpentine*, *Evolvulus alsinoidis, Convolvulus prostatus, Boerhavia diffusa, Alysicarpus vaginalis, Lauania procumbence, Ruellia tuberosa* and *Vetiveria zizanoidies* have high R:S ratio because of deeper and denser rooting systems that could have facilitated greater resource allocation in the roots (Coleman and McConnaughay, 1995; and Poorter *et al*., 2012).

5.4. Impact of disturbances on B and C

Studies have suggested that grazers increase soil compaction, disturb soil aggregates and decrease the stability of soil aggregate, and change the soil structure. Compact soils show lower porosity, higher bulk density; lower moisture content due to reduced water infiltration and increased run-off / drainage reduced plant available water and reduced soil aeration. Further, biotic disturbances reduce soil organic matter, deplete clay content in the soil and reduce soil structure, increase soil erosion and reduction of topsoil, generating the denser subsoil exposed, promoting higher bulk density at the soil surface (See Sagar and Verma for greater detail) and ultimately, loss of herbaceous B and C. Moreover, reduction in B and C along the disturbance gradient may be argued because of harvesting of above-ground herbage cover which may inhibit the oxygen level in the roots, consequently, there could be a failure of reproduction and death of a certain individual (Matayaya *et al*., 2017). The above ground herbaceous plant component is related to the photosynthetic tissue of the plant. Hence, the removal of the above-ground herbage cover results in the reduction of the plants' photosynthetic tissue which causes loss of carbon and nutrients for growth and development of the plants (Ferraro and Oesterheld, 2002) and reduction in the herbaceous biomass (Leriche *et al*., 2003). Therefore, biotic pressure modulated these conditions and synergistically reduced the B and C contents of the herbaceous species.

5.5. C:B as a C estimator

In prediction analysis for selecting a suitable model, it is necessary to test all reasonable models as rigorously as possible against known standards to avoid summary judgment based on a single data set (Colwell and Coddington, 1994) because the utility of a model generally depends on its ability to predict unknown value for a given known value (Systat, 2009). Further, higher correlation coefficient, lower standard error of estimate (standard error of estimate quantifies the spread of the real data points around the fitted regression curve), least discrepancy in prediction (Sagar *et al*., 2003; and Systat, 2009) and wide adaptability with minimum time and cost epitomize the performance and utility the of model (Colwell and Coddington, 1994; and Xie *et al.* 2009). For estimation of root C using different regression equation (based on root and shoot C), the power equation had higher correlation coefficient and lowest SEE than the others, thus, C: B ratio could be an appropriate estimator of the C content.

6. Conclusion

Comparatively greater C in perennials, erects, legumes and native trait categories than the others suggested that the species having such traits could be used for reducing the atmospheric CO_2 by capturing it and then converting into the B through the photosynthesis. The conservative field measurement methods may give precise data on B and C, but are destructive to grassland, difficult, time-consuming, and costly to cover at large scale, hence, the C:B ratio could be used as an estimator of C at species, components, functional group and site levels in the tropical grassland.

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Conflicts of interest

We declare that we have no conflicts of interest.

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Appendix

Table A1: Species-wise variation in mean dry biomass (g plant^{-1}), carbon content (g plant^{-1}), carbon to biomass ratio (C: B) and percent discrepancy in prediction based on average C: B (Discre[1] = 0.43) herbaceous species occurred in tropical grassland at Varanasi, India. Values in parentheses are ± 1*SE*. The abbreviations used; AGB = above ground dry biomass, RB = root biomass, E = Erect, P = Prostrate, De = Decumbent, Pro = Procumbent, A = Annual, Bi = Biennial, Pe = Perennial, G = Grasses, Se = sedge, NLF = Non leguminous forbs, LF = leguminous forbs, N = Native, NN = Nonnative, COS = cosmopolitan.

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
Acalypha indica L.[E,A,NLF,N]	Euphorbiaceae	Shoot	2.65	(0.19)	1.17	(0.08)	0.44	2.61
		Root	0.39	(0.03)	0.16	(0.01)	0.41	–4.81
		Stem	1.12	(0.15)	0.52	(0.07)	0.46	7.38
		Leaf	1.53	(0.18)	0.65	(0.07)	0.42	–1.22
		Total	3.03	(0.19)	1.33	(0.08)	0.44	2.04
Achyranthes aspera L. [E,Bi,NLF,N]	Amaranthaceae	Shoot	28.41	(1.12)	12.36	(0.48)	0.44	1.16
		Root	1.92	(0.59)	0.79	(0.28)	0.41	–4.51
		Stem	19.08	(1.02)	8.46	(0.45)	0.44	3.02
		Leaf	9.33	(0.55)	3.90	(0.23)	0.42	–2.87
		Total	30.33	(1.41)	13.15	(0.66)	0.43	0.82
Aerva sanguinolenta L. [E,Pe,NLF,N]	Amaranthaceae	Shoot	3.22	(0.73)	1.45	(0.34)	0.45	4.51
		Root	0.81	(0.11)	0.35	(0.06)	0.43	0.49
		Stem	1.71	(0.43)	0.78	(0.20)	0.46	5.73
		Leaf	1.50	(0.30)	0.67	(0.14)	0.45	3.73
		Total	4.03	(0.82)	1.79	(0.39)	0.44	3.19
Ageratum conyzoides L. [E,A,NLF,NN]	Asteraceae	Shoot	1.55	(0.40)	0.71	(0.18)	0.46	6.13
		Root	0.13	(0.04)	0.05	(0.02)	0.38	–11.80
		Stem	0.67	(0.16)	0.31	(0.08)	0.46	7.06
		Leaf	0.89	(0.24)	0.40	(0.11)	0.45	4.33
		Total	1.68	(0.43)	0.76	(0.20)	0.45	4.95
Ageratum houstonianum L. [E,A,NLF,NN]	Asteraceae	Shoot	8.86	(2.79)	3.94	(1.27)	0.44	3.30
		Root	0.95	(0.28)	0.38	(0.11)	0.40	–7.50
		Stem	5.37	(1.81)	2.47	(0.85)	0.46	6.51
		Leaf	3.49	(1.02)	1.47	(0.44)	0.42	–2.09
		Total	9.80	(3.01)	4.32	(1.36)	0.44	2.45
Alternanthera sessilus L. [P,A,NLF,NN]	Amaranthaceae	Shoot	9.62	(2.37)	4.21	(1.04)	0.44	1.74
		Root	0.78	(0.14)	0.31	(0.05)	0.40	–8.19
		Stem	3.98	(1.01)	1.76	(0.45)	0.44	2.76
		Leaf	5.64	(1.40)	2.45	(0.60)	0.43	1.01
		Total	10.41	(2.47)	4.51	(1.07)	0.43	0.75

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
Alysicarpus monilifer L.[P,Pe,LF,N]	Fabaceae	Shoot	5.14	(0.27)	2.27	(0.11)	0.44	2.63
		Root	1.35	(0.18)	0.53	(0.07)	0.39	–9.53
		Stem	2.94	(0.15)	1.33	(0.06)	0.45	4.95
		Leaf	2.21	(0.20)	0.94	(0.08)	0.43	–1.10
		Total	6.50	(0.35)	2.80	(0.14)	0.43	0.18
Alysicarpus vaginalis L. [De,Pe,LF,N]	Fabaceae	Shoot	2.08	(0.13)	0.87	(0.05)	0.42	–2.80
		Root	1.88	(0.16)	0.74	(0.08)	0.39	–9.24
		Stem	1.40	(0.08)	0.60	(0.03)	0.43	–0.33
		Leaf	0.68	(0.06)	0.27	(0.02)	0.40	–8.30
		Total	3.96	(0.17)	1.61	(0.07)	0.41	–5.76
Amaranthus spinosus L. [E,A,NLF,NN]	Amaranthaceae	Shoot	17.22	(1.74)	7.04	(0.75)	0.41	–5.18
		Root	5.83	(0.89)	2.35	(0.41)	0.40	–6.68
		Stem	8.96	(0.97)	3.64	(0.25)	0.41	–5.85
		Leaf	8.25	(2.24)	3.40	(0.91)	0.41	–4.34
		Total	23.05	(2.06)	9.39	(0.97)	0.41	–5.55
Amaranthus viridis L.[E,A,NLF,NN]	Amaranthaceae	Shoot	2.75	(0.99)	1.12	(0.40)	0.41	–5.58
		Root	0.81	(0.50)	0.30	(0.18)	0.37	–16.10
		Stem	1.09	(0.33)	0.44	(0.13)	0.40	–6.52
		Leaf	1.66	(0.69)	0.68	(0.28)	0.41	–4.97
		Total	3.56	(1.45)	1.42	(0.56)	0.40	–7.80
Ammania baccifera L. [E,A,NLF,N]	Lythraceae	Shoot	1.64	(0.57)	0.72	(0.26)	0.44	2.06
		Root	0.12	(0.05)	0.05	(0.02)	0.42	–3.20
		Stem	0.79	(0.28)	0.36	(0.13)	0.46	5.64
		Leaf	0.85	(0.33)	0.37	(0.15)	0.44	1.22
		Total	1.76	(0.58)	0.77	(0.26)	0.44	1.71
Anagallis arvensis L.[E,A,NLF,NN]	Primulaceae	Shoot	1.61	(0.88)	0.69	(0.39)	0.43	–0.33
		Root	0.09	(0.03)	0.04	(0.01)	0.44	3.25
		Stem	0.48	(0.24)	0.21	(0.11)	0.44	1.71
		Leaf	1.13	(0.63)	0.48	(0.28)	0.42	–1.23
		Total	1.70	(0.91)	0.73	(0.40)	0.43	–0.14
Anisomalis indica L. [E,Pe,NLF,N]	Lamiaceae	Shoot	85.47	(6.53)	38.12	(3.34)	0.45	3.59
		Root	9.78	(3.63)	3.98	(1.39)	0.41	–5.66
		Stem	55.97	(6.85)	26.02	(3.16)	0.46	7.51

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
		Leaf	29.50	(1.66)	12.10	(0.82)	0.41	–4.83
		Total	95.25	(9.37)	42.10	(4.43)	0.44	2.71
Argemon mexicana L. [E,A,NLF,NN]	Papaveraceae	Shoot	8.43	(2.70)	3.68	(1.16)	0.44	1.50
		Root	1.13	(0.29)	0.47	(0.13)	0.42	–3.38
		Stem	2.46	(0.62)	1.08	(0.26)	0.44	2.06
		Leaf	5.97	(2.09)	2.60	(0.91)	0.44	1.27
		Total	9.56	(2.97)	4.15	(1.28)	0.43	0.94
Atylosia marmorata Benth.[P,A,LF,NN]	Fabaceae	Shoot	5.76	(0.30)	2.60	(0.12)	0.45	4.74
		Root	1.21	(0.24)	0.48	(0.08)	0.40	–8.40
		Stem	2.14	(0.24)	0.98	(0.11)	0.46	6.10
		Leaf	3.61	(0.19)	1.62	(0.07)	0.45	4.18
		Total	6.97	(0.44)	3.08	(0.17)	0.44	2.69
Aurondo donex L. [E,P,G,NN]	Poaceae	Shoot	111.53	(8.49)	51.31	(4.24)	0.46	6.53
		Root	22.32	(0.87)	9.37	(0.48)	0.42	–2.43
		Stem	65.49	(6.21)	31.12	(2.96)	0.48	9.51
		Leaf	46.04	(2.31)	20.20	(1.29)	0.44	1.99
		Total	133.85	(8.93)	60.69	(4.51)	0.45	5.16
Blumea lacera L.[E,A,NLF,NN]	Asteraceae	Shoot	8.08	(1.51)	3.36	(0.62)	0.42	–3.40
		Root	1.23	(0.26)	0.49	(0.10)	0.40	–7.94
		Stem	2.60	(0.69)	1.16	(0.31)	0.45	3.62
		Leaf	5.48	(0.85)	2.20	(0.32)	0.40	–7.11
		Total	9.31	(1.68)	3.86	(0.69)	0.41	–3.71
Boerhavia diffusa L. [Pro,Pe, NLF,Cos]	Nyctaginaceae	Shoot	7.61	(1.87)	3.28	(0.82)	0.43	0.23
		Root	7.42	(3.72)	3.12	(1.67)	0.42	–2.26
		Stem	4.81	(1.38)	2.15	(0.62)	0.45	3.80
		Leaf	2.79	(0.54)	1.12	(0.22)	0.40	–7.12
		Total	15.03	(4.13)	6.39	(1.82)	0.43	–1.14
Caesulia axillaris Roxb. [De,A,NLF,N]	Asteraceae	Shoot	20.87	(0.93)	9.13	(0.29)	0.44	1.71
		Root	2.07	(0.32)	0.85	(0.14)	0.41	–4.72
		Stem	10.61	(0.65)	4.64	(0.28)	0.44	1.67
		Leaf	10.25	(0.52)	4.48	(0.20)	0.44	1.62
		Total	22.93	(0.98)	9.98	(0.36)	0.44	1.20

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
Cleome viscosa L.[E,A,NLF,NN]	Capparidaceae	Shoot	26.87	(4.91)	12.71	(2.48)	0.47	9.09
		Root	4.10	(1.05)	1.65	(0.34)	0.40	–6.85
		Stem	18.91	(3.79)	9.10	(1.84)	0.48	10.65
		Leaf	7.96	(1.12)	3.61	(0.65)	0.45	5.19
		Total	30.97	(5.70)	14.36	(2.72)	0.46	7.26
Commelina benghalensis L. [Pro,A,NLF,NN]	Commelinaceae	Shoot	13.59	(2.96)	5.58	(1.25)	0.41	–4.73
		Root	3.36	(1.00)	1.29	(0.36)	0.38	–12.00
		Stem	6.96	(1.67)	2.84	(0.73)	0.41	–5.38
		Leaf	6.63	(1.33)	2.75	(0.55)	0.41	–3.67
		Total	16.95	(3.59)	6.88	(1.49)	0.41	–5.94
Convolvulus prostratus Forssk. [P,Pe,NLF,N]	Convolvulaceae	Shoot	2.11	(0.43)	0.87	(0.19)	0.41	–4.29
		Root	3.66	(0.57)	1.42	(0.23)	0.39	–10.83
		Stem	0.84	(0.25)	0.37	(0.11)	0.44	2.38
		Leaf	1.26	(0.23)	0.51	(0.11)	0.40	–6.24
		Total	5.77	(0.21)	2.30	(0.09)	0.40	–7.87
Coronopus didynamus L. [De,A,NLF,NN]	Brassicaceae	Shoot	5.29	(1.36)	2.28	(0.59)	0.43	0.23
		Root	0.29	(0.05)	0.11	(0.02)	0.38	–13.36
		Stem	2.57	(0.69)	1.10	(0.30)	0.43	–0.46
		Leaf	2.73	(0.67)	1.18	(0.30)	0.43	0.52
		Total	5.58	(1.34)	2.39	(0.58)	0.43	–0.39
Croton bonplandianus Baill. [E,Pe,NLF,NN]	Euphorbiaceae	Shoot	8.76	(1.43)	4.13	(0.68)	0.47	8.79
		Root	0.83	(0.17)	0.37	(0.09)	0.45	3.54
		Stem	7.14	(1.12)	3.40	(0.53)	0.48	9.70
		Leaf	1.62	(0.43)	0.73	(0.20)	0.45	4.58
		Total	9.58	(1.58)	4.49	(0.75)	0.47	8.25
Cynodon dactylon L. [P,Pe,G,COS]	Poaceae	Shoot	2.12	(1.26)	0.97	(0.58)	0.46	6.02
		Root	0.53	(0.14)	0.21	(0.06)	0.40	–8.52
		Stem	1.09	(0.70)	0.51	(0.33)	0.47	8.10
		Leaf	1.04	(0.56)	0.46	(0.25)	0.44	2.78
		Total	2.65	(1.34)	1.18	(0.61)	0.45	3.43
Cyperus brevifolius Rottb. [E,Pe,Se,NN]	Cyperaceae	Shoot	5.10	(0.32)	2.05	(0.12)	0.40	–6.98
		Root	1.16	(0.07)	0.46	(0.03)	0.40	–8.43

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
		Stem	0.75	(0.10)	0.33	(0.04)	0.44	2.27
		Leaf	4.35	(0.23)	1.73	(0.09)	0.40	–8.12
		Total	6.26	(0.35)	2.51	(0.13)	0.40	–7.24
Cyperus cyperoides Kuntze. [P,Pe,Se,NN]	Cyperaceae	Shoot	1.93	(0.90)	0.87	(0.41)	0.45	4.61
		Root	0.83	(0.18)	0.34	(0.07)	0.41	–4.97
		Stem	0.50	(0.17)	0.23	(0.08)	0.46	6.52
		Leaf	1.44	(0.73)	0.64	(0.33)	0.44	3.25
		Total	2.76	(1.06)	1.22	(0.46)	0.44	2.72
Cyperus difformis L. [E,A,Se,NN]	Cyperaceae	Shoot	7.93	(1.28)	3.19	(0.52)	0.40	–6.89
		Root	3.34	(0.17)	1.35	(0.09)	0.40	–6.39
		Stem	2.19	(0.40)	0.94	(0.17)	0.43	–0.18
		Leaf	5.74	(0.90)	2.25	(0.36)	0.39	–9.70
		Total	11.28	(1.38)	4.54	(0.59)	0.40	–6.84
Cyperus esculentus L. [E,M,Pe,Se,N]	Cyperaceae	Shoot	5.89	(0.66)	2.63	(0.31)	0.45	3.70
		Root	1.72	(0.49)	0.70	(0.20)	0.41	–5.66
		Stem	1.77	(0.26)	0.81	(0.12)	0.46	6.04
		Leaf	4.12	(0.44)	1.82	(0.21)	0.44	2.66
		Total	7.61	(1.06)	3.33	(0.47)	0.44	1.73
Cyperus iria L. [E,S,A,Se,NN]	Cyperaceae	Shoot	3.56	(0.45)	1.50	(0.18)	0.42	–2.05
		Root	1.71	(0.23)	0.69	(0.10)	0.40	–6.57
		Stem	0.84	(0.11)	0.38	(0.05)	0.45	4.95
		Leaf	2.71	(0.37)	1.12	(0.15)	0.41	–4.04
		Total	5.27	(0.58)	2.19	(0.24)	0.42	–3.47
Cyperus killinga Endl. [E,Pe,Se,NN]	Cyperaceae	Shoot	3.10	(0.24)	1.25	(0.09)	0.40	–6.64
		Root	1.16	(0.17)	0.46	(0.07)	0.40	–8.43
		Stem	0.65	(0.07)	0.27	(0.03)	0.42	–3.52
		Leaf	2.45	(0.24)	0.98	(0.09)	0.40	–7.50
		Total	4.26	(0.32)	1.71	(0.12)	0.40	–7.12
Cyperus rotundus L. [P,Pe,Se,COS]	Cyperaceae	Shoot	9.79	(0.47)	4.27	(0.20)	0.44	1.41
		Root	4.25	(0.43)	1.70	(0.18)	0.40	–7.50
		Stem	1.44	(0.10)	0.66	(0.04)	0.46	6.18
		Leaf	8.35	(0.38)	3.61	(0.16)	0.43	0.54
		Total	14.04	(0.81)	5.97	(0.33)	0.43	–1.13

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
Cyperus strigosus L. [E,Pe,Se,NN]	Cyperaceae	Shoot	3.54	(0.26)	1.49	(0.11)	0.42	–2.16
		Root	0.77	(0.06)	0.31	(0.03)	0.40	–6.81
		Stem	0.94	(0.08)	0.42	(0.04)	0.45	3.76
		Leaf	2.59	(0.20)	1.07	(0.08)	0.41	–4.08
		Total	4.31	(0.30)	1.80	(0.12)	0.42	–2.96
Dactyloctenium aegyptium L.[De,A,G,NN]	Poaceae	Shoot	8.46	(0.31)	3.58	(0.17)	0.42	–1.61
		Root	0.35	(0.02)	0.14	(0.01)	0.40	–7.50
		Stem	2.26	(0.10)	0.99	(0.04)	0.44	1.84
		Leaf	6.21	(0.21)	2.59	(0.14)	0.42	–3.10
		Total	8.81	(0.32)	3.72	(0.18)	0.42	–1.84
Desmodium gangeticum (L.) DC. [E,LF,Pe,N]	Fabaceae	Shoot	50.77	(0.19)	23.81	(0.08)	0.47	8.31
		Root	11.44	(0.13)	4.62	(0.04)	0.40	–6.48
		Stem	31.40	(0.42)	14.92	(0.20)	0.48	9.50
		Leaf	19.37	(0.43)	8.89	(0.20)	0.46	6.31
		Total	62.21	(0.22)	28.43	(0.12)	0.46	5.91
Desmodium trifolium L. [E,Pe,LF,NN]	Fabaceae	Shoot	1.00	(0.27)	0.47	(0.13)	0.47	8.51
		Root	0.51	(0.21)	0.20	(0.08)	0.39	–9.65
		Stem	0.57	(0.25)	0.27	(0.12)	0.47	9.22
		Leaf	0.44	(0.04)	0.20	(0.02)	0.45	5.40
		Total	1.51	(0.41)	0.67	(0.17)	0.44	3.09
Desmostachya bipinnata (L.) Stapf [E,Pe,G,NN]	Poaceae	Shoot	35.80	(7.54)	16.75	(3.67)	0.47	8.10
		Root	2.23	(0.04)	0.90	(0.02)	0.40	–6.54
		Stem	27.94	(6.03)	13.40	(2.82)	0.48	10.34
		Leaf	7.85	(1.52)	3.36	(0.87)	0.43	–0.46
		Total	38.03	(7.57)	17.66	(3.68)	0.46	7.40
Digitaria ciliaris Retz.[De,A,G,NN]	Poaceae	Shoot	1.05	(0.10)	0.47	(0.04)	0.45	3.94
		Root	0.02	(0.01)	0.01	(0.00)	0.50	14.00
		Stem	0.52	(0.08)	0.24	(0.04)	0.46	6.83
		Leaf	0.52	(0.10)	0.23	(0.04)	0.44	2.78
		Total	1.06	(0.10)	0.48	(0.05)	0.46	5.04
Echinochloa colona (L.) Link[De,A,G,NN]	Poaceae	Shoot	4.03	(1.23)	1.85	(0.54)	0.46	6.33
		Root	1.32	(0.00)	0.51	(0.02)	0.39	–11.29

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
		Stem	0.82	(0.15)	0.38	(0.06)	0.46	7.21
		Leaf	3.21	(1.08)	1.47	(0.47)	0.46	6.10
		Total	5.35	(1.23)	2.36	(0.52)	0.44	2.52
Echinochloa crusgalli L. [De,A,G,NN]	Poaceae	Shoot	1.91	(0.40)	0.84	(0.18)	0.44	2.23
		Root	1.31	(0.26)	0.51	(0.09)	0.39	–10.45
		Stem	0.55	(0.14)	0.25	(0.06)	0.45	5.40
		Leaf	1.36	(0.26)	0.60	(0.12)	0.44	2.53
		Total	3.22	(0.64)	1.36	(0.26)	0.42	–1.81
Eclipta alba L. [P,A,NLF,NN]	Asteraceae	Shoot	1.54	(0.52)	0.65	(0.23)	0.42	–1.88
		Root	0.21	(0.05)	0.09	(0.02)	0.43	–0.33
		Stem	0.67	(0.28)	0.30	(0.13)	0.45	3.97
		Leaf	0.88	(0.25)	0.35	(0.10)	0.40	–8.11
		Total	1.75	(0.55)	0.74	(0.24)	0.42	–1.69
Eleusine indica Gaertn. [E,A,G,NN]	Poaceae	Shoot	10.78	(0.80)	4.65	(0.26)	0.43	0.31
		Root	4.04	(0.66)	1.61	(0.25)	0.40	–7.90
		Stem	4.78	(0.97)	1.98	(0.34)	0.41	–3.81
		Leaf	6.00	(0.58)	2.67	(0.27)	0.45	3.37
		Total	14.82	(0.44)	6.26	(0.15)	0.42	–1.80
Eragrostis tenella L. [E,Pe,G,NN]	Poaceae	Shoot	1.20	(0.17)	0.52	(0.07)	0.43	0.77
		Root	0.28	(0.15)	0.11	(0.06)	0.39	–9.45
		Stem	0.51	(0.06)	0.24	(0.03)	0.47	8.63
		Leaf	0.70	(0.13)	0.29	(0.05)	0.41	–3.79
		Total	1.49	(0.32)	0.64	(0.13)	0.43	–0.11
Erigeron bonariensis L.[E,A,NLF,NN]	Asteraceae	Shoot	3.61	(1.36)	1.64	(0.61)	0.45	5.35
		Root	0.46	(0.22)	0.18	(0.08)	0.39	–9.89
		Stem	1.54	(0.57)	0.73	(0.27)	0.47	9.29
		Leaf	2.07	(0.84)	0.91	(0.36)	0.44	2.19
		Total	4.07	(1.58)	1.82	(0.69)	0.45	3.84
Euphorbia hirta L. [Pro,A,NLF,NN]	Euphorbiaceae	Shoot	1.91	(0.28)	0.86	(0.12)	0.45	4.50
		Root	0.18	(0.03)	0.08	(0.01)	0.44	3.25
		Stem	1.16	(0.17)	0.53	(0.08)	0.46	5.89
		Leaf	0.75	(0.14)	0.32	(0.06)	0.43	–0.78
		Total	2.09	(0.31)	0.94	(0.14)	0.45	4.39

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
Euphorbia pulcherrima Willd ex Klotzsch [E,Pe,NLF,NN]	Euphorbiaceae	Shoot	14.55	(2.02)	6.80	(0.94)	0.47	7.99
		Root	1.59	(0.51)	0.63	(0.19)	0.40	–8.52
		Stem	8.83	(1.26)	4.19	(0.61)	0.47	9.38
		Leaf	5.72	(0.83)	2.61	(0.37)	0.46	5.76
		Total	16.15	(2.48)	7.44	(1.11)	0.46	6.66
Euphorbia thymifolia L. [P,A,NLF,NN]	Euphorbiaceae	Shoot	10.15	(3.15)	4.54	(1.46)	0.45	3.87
		Root	1.03	(0.70)	0.40	(0.27)	0.39	–10.73
		Stem	2.87	(1.12)	1.31	(0.52)	0.46	5.79
		Leaf	7.29	(2.10)	3.23	(0.96)	0.44	2.95
		Total	11.18	(3.07)	4.94	(1.42)	0.44	2.68
Evolvulus nummularius L. [P,Pe,NLF,NN]	Convolvulaceae	Shoot	2.97	(0.15)	1.32	(0.06)	0.44	3.25
		Root	0.23	(0.02)	0.09	(0.02)	0.39	–9.89
		Stem	1.06	(0.12)	0.49	(0.05)	0.46	6.98
		Leaf	1.92	(0.04)	0.84	(0.02)	0.44	1.71
		Total	3.20	(0.16)	1.42	(0.06)	0.44	3.10
Evolvulus alsinoides L. [Pro,A,NLF,NN]	Convolvulaceae	Shoot	1.43	(0.36)	0.60	(0.15)	0.42	–2.48
		Root	4.39	(0.71)	1.75	(0.28)	0.40	–7.87
		Stem	0.81	(0.27)	0.34	(0.11)	0.42	–2.44
		Leaf	0.62	(0.10)	0.26	(0.04)	0.42	–2.54
		Total	5.82	(1.03)	2.35	(0.42)	0.40	–6.49
Fimbristylis schoenoides Vahl. [E,A,Se,N]	Cyperaceae	Shoot	5.16	(2.39)	2.28	(1.07)	0.44	2.68
		Root	1.23	(0.54)	0.48	(0.21)	0.39	–10.19
		Stem	1.71	(0.92)	0.76	(0.41)	0.44	3.25
		Leaf	3.45	(1.49)	1.52	(0.67)	0.44	2.40
		Total	6.39	(2.93)	2.76	(1.28)	0.43	0.45
Gnaphalium luteoalbum L. [De,A,NLF,NN]	Asteraceae	Shoot	2.45	(0.26)	0.96	(0.11)	0.39	–9.74
		Root	0.29	(0.05)	0.11	(0.02)	0.38	–13.36
		Stem	0.98	(0.10)	0.40	(0.05)	0.41	–5.35
		Leaf	1.47	(0.19)	0.56	(0.08)	0.38	–12.88
		Total	2.74	(0.30)	1.07	(0.12)	0.39	–10.11
Gomphrena celosioides Mart [E,A,NLF,NN]	Amaranthaceae	Shoot	3.72	(0.59)	1.65	(0.26)	0.44	3.05
		Root	1.01	(0.15)	0.41	(0.06)	0.41	–5.93

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
		Stem	1.59	(0.26)	0.71	(0.12)	0.45	3.70
		Leaf	2.14	(0.34)	0.94	(0.14)	0.44	2.11
		Total	4.74	(0.66)	2.07	(0.28)	0.44	1.54
Heliotropium indicum L. [E,A,NLF,NN]	Boraginaceae	Shoot	23.56	(5.76)	10.05	(2.56)	0.43	–0.80
		Root	2.77	(0.31)	1.12	(0.13)	0.40	–6.35
		Stem	13.06	(3.88)	5.80	(1.79)	0.44	3.18
		Leaf	10.50	(2.18)	4.25	(0.88)	0.40	–6.24
		Total	26.33	(5.83)	11.17	(2.58)	0.42	–1.36
Herpestis monniera Benth. [E,Pe,NLF,N]	Scrophulariaceae	Shoot	0.39	(0.08)	0.18	(0.03)	0.46	6.83
		Root	0.11	(0.08)	0.04	(0.03)	0.36	–18.25
		Stem	0.12	(0.02)	0.05	(0.01)	0.42	–3.20
		Leaf	0.28	(0.06)	0.13	(0.03)	0.46	7.38
		Total	0.50	(0.13)	0.22	(0.06)	0.44	2.27
Hyptis suaveolens L. [P,A,NLF,NN]	Lamiaceae	Shoot	81.90	(8.95)	38.51	(4.21)	0.47	8.55
		Root	8.08	(0.64)	3.41	(0.49)	0.42	–1.89
		Stem	56.67	(6.74)	27.08	(3.20)	0.48	10.01
		Leaf	25.24	(2.47)	11.44	(1.13)	0.45	5.13
		Total	89.99	(9.20)	41.92	(4.31)	0.47	7.69
Imperata cylindrica P. Beauv [E,Pe,G,NN]	Poaceae	Shoot	8.07	(6.29)	3.39	(2.62)	0.42	–2.36
		Root	1.08	(0.61)	0.44	(0.25)	0.41	–5.55
		Stem	3.78	(3.04)	1.74	(1.40)	0.46	6.59
		Leaf	4.29	(3.26)	1.65	(1.22)	0.38	–11.80
		Total	9.15	(6.56)	3.83	(2.73)	0.42	–2.73
Lathyrus aphaca L. [E,A,LF,NN]	Fabaceae	Shoot	2.37	(0.76)	1.07	(0.34)	0.45	4.76
		Root	0.10	(0.03)	0.04	(0.01)	0.40	–7.50
		Stem	0.82	(0.27)	0.36	(0.12)	0.44	2.06
		Leaf	1.54	(0.50)	0.71	(0.23)	0.46	6.73
		Total	2.47	(0.79)	1.11	(0.35)	0.45	4.32
Launaea procumbens Roxb. [P,Pe,NLF,N]	Asteraceae	Shoot	2.62	(0.37)	1.13	(0.14)	0.43	0.30
		Root	2.02	(0.07)	0.83	(0.02)	0.41	–4.65
		Stem	1.48	(0.02)	0.67	(0.01)	0.45	5.01
		Leaf	1.14	(0.35)	0.45	(0.13)	0.39	–8.93
		Total	4.64	(0.44)	1.96	(0.16)	0.42	–1.80

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
Leucas aspera L. [E,A,NLF,NN]	Lamiaceae	Shoot	3.80	(1.61)	1.58	(0.67)	0.42	–3.42
		Root	1.02	(0.48)	0.40	(0.19)	0.39	–9.65
		Stem	2.01	(0.85)	0.87	(0.37)	0.43	0.66
		Leaf	1.79	(0.76)	0.71	(0.30)	0.40	–8.41
		Total	4.82	(2.08)	1.98	(0.85)	0.41	–4.68
Lindernia anagallis Burm.f. [De,A,NLF,N]	Linderniaceae	Shoot	0.36	(0.08)	0.14	(0.03)	0.39	–10.57
		Root	0.01	(0.00)	0.004	(0.00)	0.40	–7.50
		Stem	0.13	(0.03)	0.05	(0.01)	0.38	–11.80
		Leaf	0.23	(0.05)	0.09	(0.02)	0.39	–9.89
		Total	0.37	(0.08)	0.15	(0.03)	0.41	–6.07
Lippia alba Mill. [E,Pe,NLF,NN]	Verbenaceae	Shoot	0.39	(0.08)	0.16	(0.03)	0.41	–4.81
		Root	0.09	(0.05)	0.04	(0.02)	0.44	3.25
		Stem	0.08	(0.02)	0.03	(0.01)	0.38	–14.67
		Leaf	0.31	(0.06)	0.12	(0.03)	0.39	–11.08
		Total	0.47	(0.09)	0.19	(0.04)	0.40	–6.37
Malvastrum tricuspidatum L. [E,Pe,NLF,NN]	Malvaceae	Shoot	6.83	(0.40)	2.93	(0.15)	0.43	–0.24
		Root	0.68	(0.07)	0.26	(0.03)	0.38	–12.46
		Stem	2.21	(0.17)	0.97	(0.08)	0.44	2.03
		Leaf	4.62	(0.31)	1.97	(0.15)	0.43	–0.84
		Total	7.51	(0.45)	3.20	(0.17)	0.43	–0.92
Medicago polymorpha L. [P,A,LF,NN]	Fabaceae	Shoot	12.27	(3.09)	5.44	(1.34)	0.44	3.01
		Root	0.43	(0.11)	0.17	(0.04)	0.40	–8.76
		Stem	6.77	(2.02)	3.13	(0.92)	0.46	6.99
		Leaf	5.50	(1.13)	2.32	(0.45)	0.42	–1.94
		Total	12.70	(3.17)	5.61	(1.37)	0.44	2.66
Melilotus alba Desr. [E,Bi,LF,NN]	Fabaceae	Shoot	20.84	(2.07)	9.53	(1.15)	0.46	5.97
		Root	4.04	(0.93)	1.61	(0.40)	0.40	–7.90
		Stem	11.41	(0.53)	5.17	(0.46)	0.45	5.10
		Leaf	9.44	(1.54)	4.36	(0.71)	0.46	6.90
		Total	24.88	(3.00)	11.13	(1.53)	0.45	3.88
Melilotus indica L. [E,A,LF,NN]	Fabaceae	Shoot	3.54	(0.56)	1.65	(0.26)	0.47	7.75
		Root	0.41	(0.08)	0.17	(0.04)	0.41	–3.71

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
		Stem	1.57	(0.24)	0.75	(0.11)	0.48	9.99
		Leaf	1.97	(0.33)	0.90	(0.15)	0.46	5.88
		Total	3.94	(0.63)	1.82	(0.29)	0.46	6.91
Melochia corchorifolia L. [E,PE,NLF,NN]	Malvaceae	Shoot	2.24	(0.24)	1.01	(0.11)	0.45	4.63
		Root	0.26	(0.05)	0.10	(0.02)	0.38	–11.80
		Stem	1.39	(0.24)	0.63	(0.11)	0.45	5.13
		Leaf	0.86	(0.04)	0.38	(0.02)	0.44	2.68
		Total	2.50	(0.27)	1.11	(0.12)	0.44	3.15
Nicotiana alata Link and Otto. [E,Pe,NLF,NN]	Solanaceae	Shoot	1.86	(0.39)	0.86	(0.18)	0.46	7.00
		Root	0.19	(0.06)	0.08	(0.02)	0.42	–2.12
		Stem	0.78	(0.18)	0.37	(0.08)	0.47	9.35
		Leaf	1.08	(0.22)	0.49	(0.10)	0.45	5.22
		Total	2.05	(0.41)	0.93	(0.19)	0.45	5.22
Occimum basilicum L. [E,Pe,NLF,N]	Lamiaceae	Shoot	7.70	(2.16)	3.33	(0.94)	0.43	0.57
		Root	0.58	(0.16)	0.25	(0.07)	0.43	0.24
		Stem	3.54	(0.99)	1.61	(0.45)	0.45	5.45
		Leaf	4.16	(1.18)	1.72	(0.48)	0.41	–4.00
		Total	8.28	(2.32)	3.58	(1.00)	0.43	0.55
Oldenlandia corymbosa L. [P,A,NLF,NN]	Rubiaceae	Shoot	12.82	(2.74)	5.44	(1.32)	0.42	–1.33
		Root	3.45	(2.90)	1.39	(1.16)	0.40	–6.73
		Stem	6.86	(1.72)	3.02	(0.80)	0.44	2.32
		Leaf	5.96	(1.01)	2.43	(0.52)	0.41	–5.47
		Total	16.27	(5.63)	6.83	(2.48)	0.42	–2.43
Oldenlandia gracilis (Wall) Hook. f. [E,A,NLF,NN]	Rubiaceae	Shoot	2.28	(0.05)	0.99	(0.02)	0.43	0.97
		Root	0.47	(0.04)	0.19	(0.02)	0.40	–6.37
		Stem	0.99	(0.04)	0.45	(0.02)	0.45	5.40
		Leaf	1.29	(0.07)	0.54	(0.02)	0.42	–2.72
		Total	2.75	(0.08)	1.18	(0.02)	0.43	–0.21
Oplismanus composites Retz. [P,Pe,G,NN]	Poaceae	Shoot	0.87	(0.40)	0.39	(0.18)	0.45	4.08
		Root	0.20	(0.11)	0.08	(0.04)	0.40	–7.50
		Stem	0.34	(0.16)	0.15	(0.07)	0.44	2.53
		Leaf	0.53	(0.23)	0.23	(0.11)	0.43	0.91
		Total	1.06	(0.51)	0.46	(0.22)	0.43	0.91

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
Oxalis corniculata L. [Pro,Pe,NLF,NN]	Oxalidaceae	Shoot	1.23	(0.72)	0.53	(0.31)	0.43	0.21
		Root	0.17	(0.10)	0.07	(0.04)	0.41	–4.43
		Stem	0.78	(0.55)	0.34	(0.23)	0.44	1.35
		Leaf	0.45	(0.18)	0.19	(0.08)	0.42	–1.84
		Total	1.40	(0.70)	0.60	(0.30)	0.43	–0.33
Parthenium hysterophorus L. [E,Pe,NLF,NN]	Asteraceae	Shoot	8.42	(1.02)	3.61	(0.45)	0.43	–0.29
		Root	0.96	(0.14)	0.39	(0.05)	0.41	–5.85
		Stem	4.54	(0.63)	2.00	(0.29)	0.44	2.39
		Leaf	3.88	(0.40)	1.61	(0.16)	0.41	–3.63
		Total	9.37	(1.15)	4.00	(0.50)	0.43	–0.73
Paspalidium flavidum A. Camus [P,Pe,G,NN]	Poaceae	Shoot	9.24	(0.96)	4.05	(0.43)	0.44	1.90
		Root	1.83	(0.43)	0.75	(0.18)	0.41	–4.92
		Stem	3.94	(0.50)	1.78	(0.23)	0.45	4.82
		Leaf	5.30	(0.47)	2.27	(0.21)	0.43	–0.40
		Total	11.06	(1.19)	4.80	(0.52)	0.43	0.92
Peristrophe bicalyculata Nees. [E,Pe,NLF,NN]	Acanthaceae	Shoot	19.22	(4.67)	8.90	(2.20)	0.46	7.14
		Root	1.38	(0.35)	0.59	(0.17)	0.43	–0.58
		Stem	14.81	(3.99)	7.00	(1.91)	0.47	9.02
		Leaf	4.41	(0.75)	1.91	(0.33)	0.43	0.72
		Total	20.60	(5.01)	9.49	(2.37)	0.46	6.66
Phalaris minor Retz. [E,A,G,N]	Poaceae	Shoot	0.46	(0.06)	0.20	(0.02)	0.43	1.10
		Root	0.16	(0.04)	0.06	(0.02)	0.38	–14.67
		Stem	0.17	(0.01)	0.08	(0.01)	0.47	8.63
		Leaf	0.29	(0.04)	0.12	(0.02)	0.41	–3.92
		Total	0.62	(0.06)	0.26	(0.02)	0.42	–2.54
Phyllanthus asperalatus L. [E,A,NLF,NN]	Euphorbiaceae	Shoot	3.49	(1.91)	1.64	(0.91)	0.47	8.49
	Root	0.35	(0.17)	0.15	(0.08)	0.43	–0.33	
		Stem	1.60	(0.89)	0.76	(0.43)	0.48	9.47
		Leaf	1.89	(1.02)	0.88	(0.48)	0.47	7.65
		Total	3.84	(2.08)	1.79	(0.99)	0.47	7.75
Physalis minima L. [E,A,NLF,NN]	Solanaceae	Shoot	7.49	(3.50)	3.16	(1.47)	0.42	–1.92
		Root	0.48	(0.16)	0.19	(0.06)	0.40	–8.63

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
		Stem	4.16	(2.11)	1.76	(0.89)	0.42	–1.64
		Leaf	3.33	(1.45)	1.40	(0.60)	0.42	–2.28
		Total	7.97	(3.54)	3.35	(1.48)	0.42	–2.30
Polygonum barbatum L. [E,Pe,NLF,NN]	Polygoniaceae	Shoot	0.50	(0.16)	0.22	(0.07)	0.44	2.27
		Root	0.07	(0.02)	0.03	(0.01)	0.43	–0.33
		Stem	0.30	(0.08)	0.14	(0.03)	0.47	7.86
		Leaf	0.19	(0.09)	0.08	(0.04)	0.42	–2.12
		Total	0.57	(0.17)	0.25	(0.07)	0.44	1.96
Polygonum glabrum Willd. [E,A,NLF,NN]	Polygoniaceae	Shoot	32.78	(13.47)	15.29	(6.37)	0.47	7.81
		Root	2.90	(0.92)	1.23	(0.42)	0.42	–1.38
		Stem	24.63	(9.79)	11.59	(4.66)	0.47	8.62
		Leaf	8.15	(3.73)	3.70	(1.73)	0.45	5.28
		Total	35.68	(14.32)	16.52	(6.76)	0.46	7.13
Polypogon monspeliensis L. [E,A,G,NN]	Poaceae	Shoot	2.17	(0.46)	1.00	(0.21)	0.46	6.69
		Root	0.38	(0.07)	0.15	(0.03)	0.39	–8.93
		Stem	0.67	(0.14)	0.31	(0.07)	0.46	7.06
		Leaf	1.50	(0.32)	0.69	(0.15)	0.46	6.52
		Total	2.55	(0.53)	1.16	(0.24)	0.45	5.47
Ranunculus sceleratus L. [E,A,NLF,NN]	Ranunculaceae	Shoot	7.44	(1.46)	3.32	(0.64)	0.45	3.64
		Root	2.33	(0.89)	0.96	(0.37)	0.41	–4.36
		Stem	3.65	(0.75)	1.63	(0.32)	0.45	3.71
		Leaf	3.79	(0.74)	1.69	(0.33)	0.45	3.57
		Total	9.77	(1.78)	4.27	(0.78)	0.44	1.61
Rauvolfia serpentina (L.) Benth. [E,Pe,NLF,N]	Solanaceae	Shoot	20.75	(5.26)	9.14	(2.19)	0.44	2.38
		Root	25.58	(5.79)	10.88	(2.59)	0.43	–1.10
		Stem	9.38	(2.32)	4.48	(1.11)	0.48	9.97
		Leaf	11.37	(3.21)	4.66	(1.17)	0.41	–4.92
		Total	46.33	(10.34)	20.01	(4.69)	0.43	0.44
Rorippa dubia Hara. [E,A,NLF,N]	Brassicaceae	Shoot	0.91	(0.01)	0.35	(0.01)	0.38	–11.80
		Root	0.34	(0.04)	0.14	(0.02)	0.41	–4.43
		Stem	0.13	(0.01)	0.06	(0.01)	0.46	6.83
		Leaf	0.78	(0.00)	0.29	(0.00)	0.37	–15.66
		Total	1.25	(0.05)	0.49	(0.02)	0.39	–9.69

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
Ruellia tuberose L. [E,Bi,NLF,NN]	Acanthaceae	Shoot	3.15	(0.73)	1.31	(0.31)	0.42	–3.40
		Root	1.32	(0.20)	0.54	(0.08)	0.41	–5.11
		Stem	1.36	(0.39)	0.60	(0.17)	0.44	2.53
		Leaf	1.80	(0.36)	0.72	(0.14)	0.40	–7.50
		Total	4.47	(0.91)	1.85	(0.38)	0.41	–3.90
Rumex dentatus L. [E,Bi,NLF,N]	Polygonaceae	Shoot	7.81	(2.16)	3.44	(0.90)	0.44	2.38
		Root	1.06	(0.36)	0.45	(0.16)	0.42	–1.29
		Stem	3.61	(0.81)	1.67	(0.37)	0.46	7.05
		Leaf	4.20	(1.37)	1.77	(0.54)	0.42	–2.03
		Total	8.87	(2.48)	3.89	(1.05)	0.44	1.95
Rungia pectinata Nees. [Pr,A,NLF,N]	Acanthaceae	Shoot	2.49	(0.54)	1.06	(0.23)	0.43	–1.01
		Root	0.23	(0.06)	0.10	(0.02)	0.43	1.10
		Stem	0.99	(0.22)	0.45	(0.10)	0.45	5.40
		Leaf	1.50	(0.35)	0.61	(0.14)	0.41	–5.74
		Total	2.72	(0.59)	1.16	(0.25)	0.43	–0.83
Saccharum munja roxb [E,Pe,G,NN]	Poaceae	Shoot	33.64	(4.67)	15.61	(2.03)	0.46	7.33
		Root	7.60	(1.00)	3.31	(0.49)	0.44	1.27
		Stem	17.89	(3.48)	8.55	(1.67)	0.48	10.03
		Leaf	15.76	(1.43)	7.06	(0.59)	0.45	4.01
		Total	41.24	(4.64)	18.92	(2.05)	0.46	6.27
Saccharum spontaneum L. [E,Pe,G,N]	Poaceae	Shoot	49.50	(3.98)	23.30	(2.06)	0.47	8.65
		Root	1.10	(0.25)	0.43	(0.08)	0.39	–10.00
		Stem	25.99	(3.14)	12.54	(1.55)	0.48	10.88
		Leaf	23.51	(1.70)	10.75	(0.81)	0.46	5.96
		Total	50.60	(3.96)	23.73	(2.05)	0.47	8.31
Salvia plebeia R.Br. [E,A,NLF,NN]	Lamiaceae	Shoot	13.36	(1.56)	5.57	(0.59)	0.42	–3.14
		Root	3.83	(0.22)	1.54	(0.13)	0.40	–6.94
		Stem	6.28	(0.67)	2.88	(0.30)	0.46	6.24
		Leaf	7.08	(0.91)	2.70	(0.29)	0.38	–12.76
		Total	17.19	(1.75)	7.11	(0.72)	0.41	–3.96
Scoparia dulcis L. [E,Pe,NLF,NN]	Scrophulariaceae	Shoot	1.96	(0.44)	0.87	(0.20)	0.44	3.13
		Root	0.64	(0.14)	0.28	(0.06)	0.44	1.71

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
		Stem	0.91	(0.25)	0.44	(0.12)	0.48	11.07
		Leaf	1.05	(0.23)	0.44	(0.10)	0.42	–2.61
		Total	2.60	(0.52)	1.15	(0.25)	0.44	2.78
Sida acuta Burm. F. E,Bi,NLF,NN	Malvaceae	Shoot	10.52	(1.91)	4.74	(0.90)	0.45	4.57
		Root	2.47	(0.76)	0.99	(0.30)	0.40	–7.28
		Stem	6.53	(1.24)	3.05	(0.58)	0.47	7.94
		Leaf	3.99	(0.75)	1.69	(0.34)	0.42	–1.52
		Total	12.99	(2.52)	5.74	(1.13)	0.44	2.69
Sida rhomboidea. Roxb E,Pe,NLF,NN	Malvaceae	Shoot	9.90	(0.90)	4.56	(0.40)	0.46	6.64
		Root	2.48	(0.26)	0.99	(0.09)	0.40	–7.72
		Stem	5.49	(0.51)	2.64	(0.25)	0.48	10.58
		Leaf	4.42	(0.41)	1.92	(0.19)	0.43	1.01
		Total	12.39	(0.91)	5.55	(0.39)	0.45	4.01
Solanum nigrum L. E,A,NLF,NN	Solanaceae	Shoot	6.45	(0.52)	2.71	(0.20)	0.42	–2.34
		Root	1.29	(0.58)	0.52	(0.23)	0.40	–6.67
		Stem	2.33	(0.40)	0.99	(0.19)	0.42	–1.20
		Leaf	4.12	(0.32)	1.72	(0.12)	0.42	–3.00
		Total	7.74	(1.04)	3.22	(0.41)	0.42	–3.36
Solanum xanthocarpum Schard. E,Pe,NLF,N	Solanaceae	Shoot	15.64	(4.58)	6.49	(2.12)	0.41	–3.62
		Root	2.18	(0.66)	0.86	(0.26)	0.39	–9.00
		Stem	7.99	(4.38)	3.52	(1.97)	0.44	2.39
		Leaf	7.65	(0.56)	2.97	(0.26)	0.39	–10.76
		Total	17.82	(4.92)	7.36	(2.24)	0.41	–4.11
Sonchus oleraceus L. E,A,NLF,NN	Asteraceae	Shoot	8.71	(2.42)	3.77	(1.05)	0.43	0.66
		Root	0.74	(0.28)	0.30	(0.12)	0.41	–6.07
		Stem	3.36	(0.72)	1.45	(0.33)	0.43	0.36
		Leaf	5.35	(1.70)	2.32	(0.73)	0.43	0.84
		Total	9.45	(2.44)	4.08	(1.06)	0.43	0.40
Sonchus asper (L.) Hill E,Bi,NLF,NN	Asteraceae	Shoot	8.94	(2.42)	3.77	(1.01)	0.42	–1.97
		Root	1.99	(1.05)	0.75	(0.40)	0.38	–14.09
		Stem	3.77	(1.31)	1.62	(0.57)	0.43	–0.07
		Leaf	5.17	(1.21)	2.15	(0.49)	0.42	–3.40
		Total	10.93	(3.29)	4.52	(1.33)	0.41	–3.98

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
Sorghum halepense (L.) Pers. [E,Pe,G,NN]	Poaceae	Shoot	3.88	(0.46)	1.64	(0.18)	0.42	–1.73
		Root	1.40	(0.14)	0.57	(0.05)	0.41	–5.61
		Stem	0.64	(0.14)	0.30	(0.06)	0.47	8.27
		Leaf	3.24	(0.33)	1.34	(0.12)	0.41	–3.97
		Total	5.28	(0.48)	2.21	(0.19)	0.42	–2.73
Spergula arvensis L. [E,A,NLF,NN]	Caryophyllaceae	Shoot	3.38	(0.00)	1.53	(0.00)	0.45	5.01
		Root	0.42	(0.00)	0.17	(0.00)	0.40	–6.24
		Stem	1.75	(0.00)	0.82	(0.00)	0.47	8.23
		Leaf	1.63	(0.00)	0.72	(0.00)	0.44	2.65
		Total	3.80	(0.00)	1.70	(0.00)	0.45	3.88
Spilanthus acmella Murr. [E,Pe,NLF,NN]	Asteraceae	Shoot	2.08	(0.26)	0.91	(0.11)	0.44	1.71
		Root	0.20	(0.03)	0.08	(0.01)	0.40	–7.50
		Stem	1.04	(0.15)	0.47	(0.07)	0.45	4.85
		Leaf	1.04	(0.13)	0.44	(0.06)	0.42	–1.64
		Total	3.09	(0.98)	1.24	(0.38)	0.40	–7.15
Stellaria media (L.) Vill. [E,A,NLF,NN]	Caryophyllaceae	Shoot	0.25	(0.04)	0.10	(0.02)	0.40	–7.50
		Root	1.80	(0.65)	0.72	(0.25)	0.40	–7.50
		Stem	1.29	(0.37)	0.52	(0.15)	0.40	–6.67
		Leaf	2.28	(0.27)	0.99	(0.12)	0.43	0.97
		Total	0.77	(0.34)	0.31	(0.13)	0.40	–6.81
Tanacetum parthenium (L.) Sch. Bip. [E,Pe,NLF,NN]	Asteraceae	Shoot	0.16	(0.11)	0.07	(0.05)	0.44	1.71
		Root	0.22	(0.08)	0.09	(0.03)	0.41	–5.11
		Stem	0.55	(0.27)	0.22	(0.10)	0.40	–7.50
		Leaf	3.34	(0.96)	1.34	(0.38)	0.40	–7.18
		Total	6.70	(0.45)	2.66	(0.18)	0.40	–8.31
Trianthema portulacastrum L. [P,A,NLF,NN]	Aizoaceae	Shoot	0.32	(0.05)	0.12	(0.00)	0.38	–14.67
		Root	3.16	(0.17)	1.26	(0.08)	0.40	–7.84
		Stem	3.54	(0.25)	1.41	(0.10)	0.40	–7.96
		Leaf	7.02	(0.45)	2.79	(0.18)	0.40	–8.19
		Total	0.94	(0.35)	0.38	(0.13)	0.40	–6.37
Tridax procumbens L. [Pro,Pe,NLF,NN]	Asteraceae	Shoot	1.72	(0.42)	0.72	(0.17)	0.42	–2.72
		Root	0.23	(0.03)	0.10	(0.02)	0.43	1.10

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	Family	Components	Biomass (B)		Carbon (C)		C:B	Discre[1]
		Stem	0.58	(0.08)	0.26	(0.04)	0.45	4.08
		Leaf	1.14	(0.18)	0.46	(0.08)	0.40	–6.57
		Total	1.95	(0.45)	0.81	(0.18)	0.42	–3.52
Trifolium resupinatum L. [E,A,NF,NN]	Fabaceae	Shoot	1.06	(0.26)	0.48	(0.12)	0.45	5.04
		Root	0.07	(0.29)	0.03	(0.01)	0.43	–0.33
		Stem	0.36	(0.59)	0.16	(0.27)	0.44	3.25
		Leaf	0.70	(0.27)	0.32	(0.13)	0.46	5.94
		Total	1.13	(0.29)	0.51	(0.13)	0.45	4.73
Triumfetta rhomboidea Jacq. [E,Pe,NLF,NN]	Malvaceae	Shoot	7.26	(0.32)	3.36	(0.14)	0.46	7.09
		Root	1.38	(0.47)	0.57	(0.10)	0.41	–4.11
		Stem	4.39	(3.30)	2.07	(1.59)	0.47	8.81
		Leaf	2.87	(1.39)	1.30	(0.61)	0.45	5.07
		Total	8.64	(0.61)	3.93	(0.25)	0.45	5.47
Uraria picta (Jacq.) DC. [E,Pe,LF,N]	Fabaceae	Shoot	16.17	(4.67)	7.45	(2.20)	0.46	6.67
		Root	3.19	(0.15)	1.33	(0.28)	0.42	–3.14
		Stem	9.49	(0.82)	4.43	(0.40)	0.47	7.88
		Leaf	6.68	(1.35)	3.02	(0.60)	0.45	4.89
		Total	19.36	(4.95)	8.79	(2.30)	0.45	5.29
Verbescum chinensis (L.) Santapau. [E,A,NLF,NN]	Scrophulariaceae	Shoot	5.64	(2.16)	2.49	(0.99)	0.44	2.60
		Root	0.52	(0.70)	0.21	(0.06)	0.40	–6.48
		Stem	2.36	(1.19)	1.11	(0.55)	0.47	8.58
		Leaf	3.28	(0.62)	1.38	(0.24)	0.42	–2.20
		Total	6.16	(2.31)	2.70	(1.05)	0.44	1.90
Vernonia cinerea L.[E,A,NLF,NN]	Asteraceae	Shoot	4.32	(1.81)	1.87	(0.79)	0.43	0.66
		Root	1.39	(3.93)	0.60	(0.32)	0.43	0.38
		Stem	2.52	(2.45)	1.15	(1.17)	0.46	5.77
		Leaf	1.79	(1.71)	0.72	(0.79)	0.40	–6.90
		Total	5.71	(2.50)	2.46	(1.11)	0.43	0.19
Vetiveria zizanoidies L. [E,Pe,G,N]	Poaceae	Shoot	19.82	(3.80)	9.10	(1.78)	0.46	6.35
		Root	11.12	(0.05)	4.64	(1.74)	0.42	–3.05
		Stem	6.29	(0.06)	3.01	(0.03)	0.48	10.14
		Leaf	13.53	(0.03)	6.09	(0.01)	0.45	4.47
		Total	30.94	(3.20)	13.75	(1.51)	0.44	3.24

Appendix (Cont.)

Table A1 (Cont.)

Herbaceous Species	**Family**	**Components**	**Biomass (B)**		**Carbon (C)**		**C:B**	**Discre[1]**
Zephyranthes citrina Baker. [E,Pe,NLF,NN]	Amaryllidaceae	Shoot	0.76	(0.04)	0.34	(0.02)	0.45	3.88
		Root	0.22	(0.16)	0.09	(0.02)	0.41	–5.11
		Stem	0.42	(0.47)	0.19	(0.22)	0.45	4.95
		Leaf	0.34	(0.28)	0.15	(0.12)	0.44	2.53
		Total	0.98	(0.05)	0.43	(0.02)	0.44	2.00

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