Ceylon Journal of Science 45(1) 2016: 43-55
DOI: http://dx.doi.org/10.4038/cjs.v45i1.7363

RESEARCH ARTICLE

Diversity, composition and richness of soil seed banks in different forest communities at Dotalugala Man and Biosphere Reserve, Sri Lanka

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Received: 11 March 2016; Accepted: 05 May 2016

Abstract: The soil seed bank provides an indication of the regenerative potential of forest ecosystems following disturbances. The present study was conducted to examine the spatial and temporal distribution of soil seed bank in three different forest communities identified in an upper montane forest ecosystem (Dotalugala Forest Reserve) in the Knuckles Range, Sri Lanka. The three forest communities were upper-montane forest (UMF), mid-elevational wet face forest (MWF) and mid-elevational dry face forest (MDF), hereafter referred to as UMF, MWF and MDF, respectively. Ten surface soil samples were collected from five, 10 m × 15 m permanent plots (2 composite samples from each plot) established in each of the three forest communities. The soil samples were spread on seed beds in a glasshouse and emerging seedlings were counted and identified into different morphospecies. Two soil samplings were conducted during dry and wet seasons. Seed beds were maintained for nearly 3-4 months until no seedlings emerged. The results revealed higher number of germinable seeds in the wet season (1,157, 1,381 and 1,231 seeds) than in the dry season (507, 641 and 597 seeds) in UMF, MWF and MDF forest communities, respectively. The richness had similar trend between seasons (31, 35 and 34 morphotypes in the wet season and 24, 27 and 27 in the dry season in UMF, MWF and MDF, respectively). However, the density and richness showed no significant differences between forest communities during both seasons. Species composition differed between seasons and forest communities. Woody species dominated the soil seed bank during the dry season, while non-woody species dominated in the soil seed bank during the wet season. These temporal fluctuations in seed banks may possibly be due to site-specific (predation, senescence and germination of seeds) and plant-specific (phenology, dormancy of seeds) factors prevailing in these forest communities. Seeds of invasive species were represented comparatively less in all three communities, indicating no significant threat from invasive species to these forest communities. A number of pioneer species including *Maesa indica, Acronychia pedunculata* and *Macaranga spp*. were recorded in all three sites signifying their resilience and regenerative potential following a disturbance.

Keywords: Knuckles Range, Forest community, soil seed bank, pioneer species.

INTRODUCTION

The tropical montane forests are highly diverse ecosystems (Myers *et al*., 2000), providing important ecosystem functions and services (Costanza *et al*., 1997). According to the International Union for Conservation Nature (IUCN) (2007), the Tropical Montane Cloud Forests (TMCFs) cover is less than 1% of the total land area in Sri Lanka. In spite of their restricted distribution in the island, more than 50% of residing species in TMCFs are endemic to Sri Lanka (Ranasinghe *et al*., 2006). The montane forests in the Knuckles Range are under threat due to cardamom cultivation, which started more than a century ago and continued until 1985, leading to loss of biodiversity and soil erosion (Gurusinghe, 1988; Gunawardhana, 2003; Dhakal *et al*., 2012). The cardamom plantations were abandoned soon after the Knuckles Forest Reserve (KFR) received its protected status prohibiting such activities (IUCN, 1994). In addition, these forests are also under threat due to land conversion, fuel wood extraction, illegal logging and ever increasing human population. Therefore, the conservation of these valuable and highly vulnerable ecosystems

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could be of high priority that needs due attention from the relevant authorities.

The tropical montane forests differ from most of the other ecosystems due to their occurrence in high elevation landscapes with steep slopes and undulating terrain (Beck *et al*., 2008). Therefore, the habitat heterogeneity together with anthropogenic and natural disturbances (forest die-back, hurricanes etc.) can make these forests very complex systems. The landscape matrix plays a decisive role in recovery processes following disturbances (Chazdon, 2007). The soil seed bank of an ecosystem can provide crucial information on the status of the standing vegetation and its regenerative potential (Butler and Chazdon, 1998). Many studies have been carried out in different parts of the world to assess soil seed banks with objectives leading to restoration and reforestation (Carter and Ungar, 2002; Leck, 2003), succession (Bossuyt and Hermy, 2004), disturbances (Amiaud and Touzard, 2004), invasive species (Drake, 1998) and management interventions (Lopez-Marino *et al*., 2000; Kinloch and Friedel, 2005).

The Dotalugala Man and Biosphere (MAB) reserve is consist of three major forest physiognomies, which is identified as upper montane (UMF), mid-elevational dry (MDF) and mid-elevational wet forest (MWF) communities (Ekanayake *et al*., 2013). The study also revealed that the three forest communities are equally diverse in vegetation with high endemicity (Ekanayake, 2014). However, cardamom cultivation in these forests has markedly changed the forest structure and edaphic properties (Dhakal *et al*., 2012; Ekanayake, 2014). This study aimed to evaluate the soil seed bank of three different forest communities identified in the Dotalugala MAB Reserve, which is located south-easterly in the Knuckles Range, Sri Lanka. The study also determined the temporal variations of the soil seed bank, and potential threats to these communities by the spread of invasive species. Such information is imperative in future forest management interventions to safeguard these diverse and vulnerable ecosystems for future generations.

MATERIALS AND METHODS

Description of the study site

The Dotalugala MAB reserve (DMR) is located in the south and south-eastern parts of the Knuckles Forest Reserve (KFR) in Sri Lanka (7° 17' – 7° 21' N and 80° 49' – 80° 57' E) (Figure 1). DMR encompasses an area of 1,620 ha with tropical upper montane evergreen cloud forests as the main vegetation type (Bharathie, 1989). The mean annual temperature of the KFR is 26°C, which can vary between 18.5°C to 21°C depending on the altitudinal variations (Cooray, 1998). The average annual rainfall in the area varies from 2,540 mm on the eastern side of the KFR to 3,810 - 5,080 mm on the rest of the KFR (Cooray, 1998) and receives an ample amount of rainfall from both monsoons due to its strategic location in the island (Werner, 1982). However, the eastern parts of the KFR, where the Dotalugala MAB Reserve locates, receive its majority of the precipitation during the north-east monsoon which is active from November to February.

Description of the forest communities

The study was carried out in three forest communities, viz., upper montane forest (UMF), mid-elevational wet face forest (MWF) and mid-elevational dry face forest (MDF) identified previously in the Dotalugala MAB Reserve based on the differences observed in the forest structure and the composition (Table 1; Ekanayake, 2014).

Table 1: The main characteristic features of the three forest communities identified at Dotalugala MAB reserve.

Forest Community	Elevation (m)	Aspect	Soil pH	Name of the community
UMF	>1400 m	Mainly South-west	Acidic	Upper Montane forest (UMF)
MWF	<1360 m	South-west	Acidic	Mid-elevational wet-face forest (MWF)
MDF	<1325 m	North-east	Comparatively less acidic	Mid-elevational dry-face forest (MDF)

Source: Ekanayake, 2014.

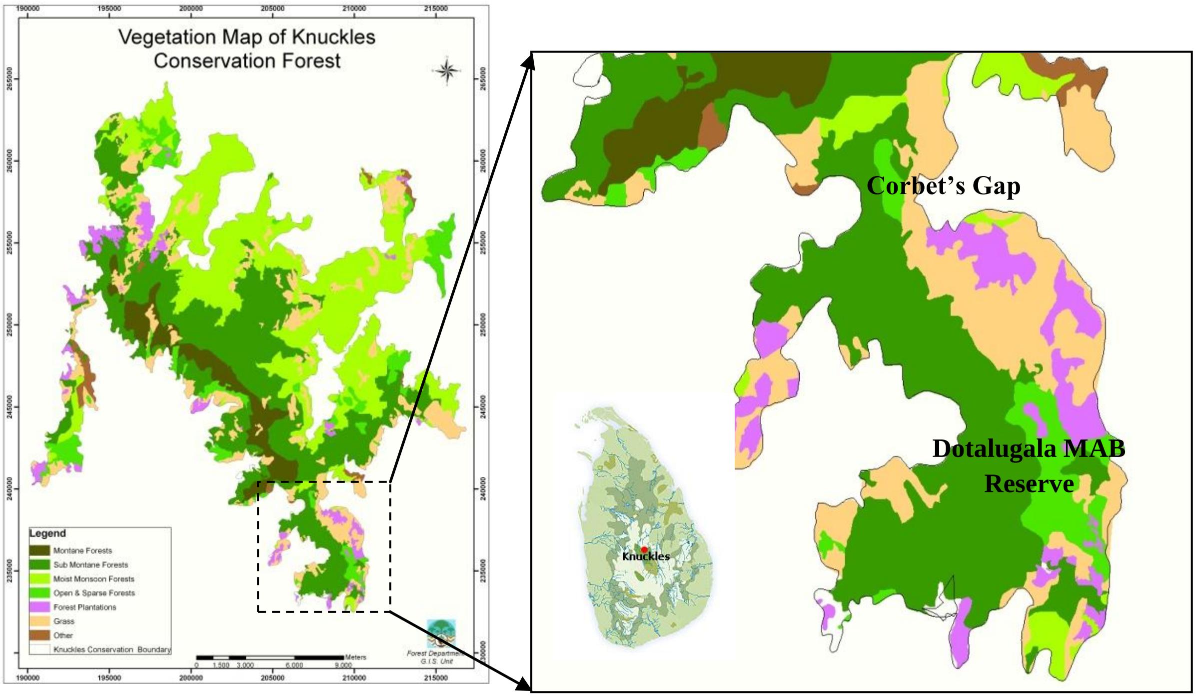

Figure 1: The location of the Dotalugala MAB reserve in the south-eastern part of the Knuckles Forest Reserve, Sri Lanka (Source: Forest Department, Sri Lanka).

According to Ekanayake (2014), *Calophyllum trapezifolium* (Calophyllaceae), *Eurya ceylanica* (Theaceae) and *Acronichia pedunculata* (Rutaceae) are the most commonly found canopy species at UMF in DMR. Furthermore, *Eugenia thwaitesii*, *Calophyllum trapezifolim*, *Eurya ceylanica*, *Syzygium fergusoni*, *Agrostistachys coriacea*, *Psychotria nigra* and *Gaertnera walkeri* were recorded as the most common species at MWF, whereas *Psychotria nigra*, *Gaertnera walkeri* and *Lasianthus strigosus* were listed as the most common species in MDF.

Soil sampling

A previous study has established five, 10 m x 15 m permanent experimental plots in each of the three forest communities (totaling 15 plots) (Ekanayake, 2014). From each of these plots, 10 soil samples (using a wooden quadrat of 15 cm × 15 cm and to a depth of 4 cm) were taken along two transects parallel to the contour and pooled them into two sub-samples, totaling 10 soil samples from each forest community (30 samples from all 3 forest communities). Two soil sampling occasions were carried out to represent wet (December, 2012) and dry seasons (June, 2013). Soil samples were brought to the Department of Botany, University of Peradeniya in labeled and sealed polythene bags. Each soil sample was spread (approximately 2 cm thick layer) on 50 cm × 50 cm seed beds (prepared using wooden beams and lined with thick gauge black polythene) containing a layer of sterilized river sand, in the glasshouse. Five control seed beds (containing sterilized river sand only) were also maintained to detect any contaminations during the course of the experiment. The seedling emergence was monitored (initially every day and later in every 2-3 day intervals) over a period of 12 – 14 weeks until no more new seedlings were emerged. The seed beds were watered as required. The emerging seedlings were initially identified into different morphological species (hereafter will be referred to as morphospecies). Representative seedlings of each morphospsecies were carefully uprooted and planted in plastic pots to facilitate identification into species levels. The voucher specimens prepared from each morphospecies are kept at the Department of Botany, University of Peradeniya. However, the taxonomic classification of the seedlings was not emphasized much in the study due to lack of resources for seedling identification.

No herbivory and competition between seedlings (seedlings were uprooted frequently to avoid any shading effect) were observed during the study period. However, in dry season soil samples, a significant number of seedlings died even before they were identified into morphospecies. Therefore, the dead seedlings were only taken into account in calculating the total germinable seeds in the dry season. In control seed beds, few seedlings were recorded from one morphospecies. Since only few seedlings of this morphospecies appeared in experimental seed beds, they were not considered for any calculations.

Data analysis

The seed abundance and richness are defined as the observed number of germinants and morphospecies in each forest community, respectively. Shannon-Weiner indices were calculated for different forest communities. All data were analyzed using Generalized Linear Model (GLM) after testing for normality of distribution using Anderson-Darling test (Minitab 16.0 version). The forest community (UMF/MWF/MDF), season (wet/dry) and woody/non-woody nature were used as random factors in the GLM analysis. Their interactions were also noted. Mean separations were done using Tukey's test at 5% probability level

RESULTS

In total, 1,157, 1,381 and 1,231 germinable seedlings in the wet season, and 507, 641 and 597 seedlings in the dry season were recorded in the forest communities, UMF, MWF and MDF respectively. The emerging seedlings were identified into 31, 35 and 34 morphospecies in the wet season and 24, 27 and 27 in the dry season in UMF, MWF and MDF forest communities, respectively (Table 2; Figure 2). Out of the total number of 37 morphospecies recorded in the wet season, 29 species (78%) were present in all three forest communities while eight species (22%) were present in either one or two forest communities. During the dry season, out of the 40 morphospecies recorded, only 18 (45%) were present in all 3 forest communities whereas 22 morphospecies (55%) present in at least one or two forest communities (Figure 3).

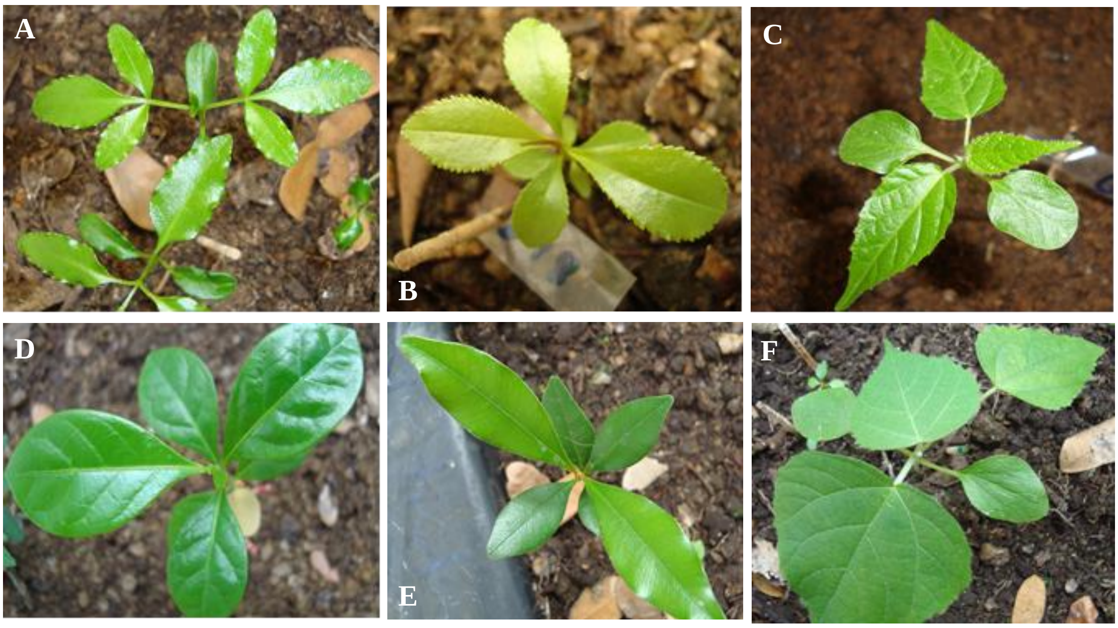

Figure 2: Some tree seedlings (A: *Acronychia pedunculata*; B: *Symplocos cochinchinensis*; C: un-identified; D: un-identified; E: *Calophyllum* sp. and F: *Macaranga* sp.) recorded in wet and dry season soil seed banks in forest communities at Dotalugala MAB Reserve, Sri Lanka.

The Shannon-Weiner (S-W) Diversity index showed higher values in the wet season than in the dry season in all three forest communities (Table 2). In the wet season, UMF and MWF forest communities had higher S-W diversity indices compared to MDF, while UMF had higher species diversity than that of MWF and MDF, in the dry season.

During the wet season, a significantly higher mean abundance of emergents was recorded in all three forest communities compared to that of the dry season (Figure 4). The mean species richness had significantly higher values during the wet season compared to that of the dry season. In spite of seasonal variations, the mean seed abundance and richness showed no significant differences between the three forest communities (Figure 4).

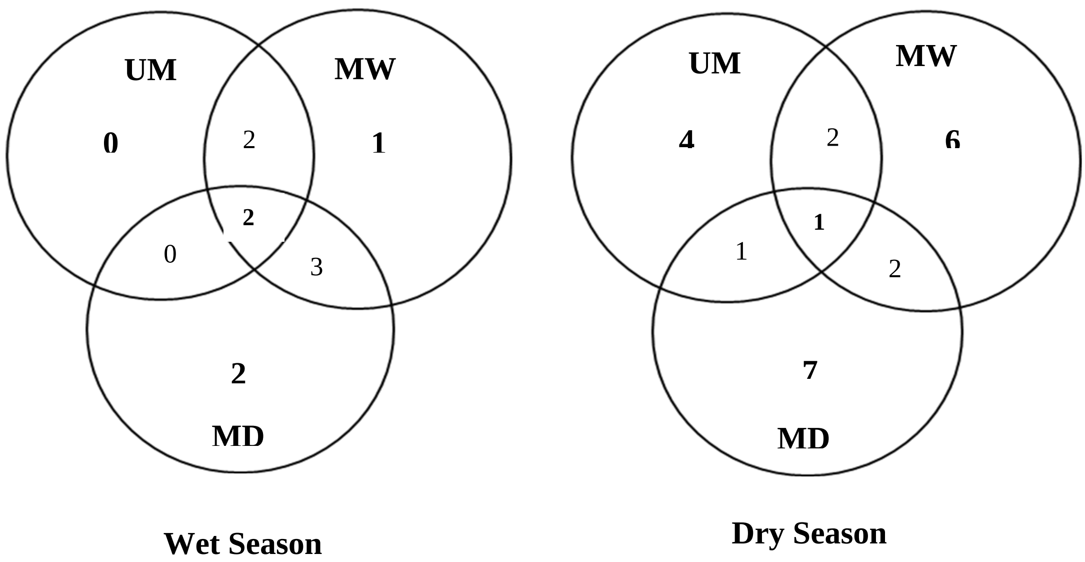

Figure 3: Venn diagrams showing the distribution of 31, 35 and 34 morphospecies in the wet season and 24, 27 and 27 morphospecies in the dry season among the three forest communities, UMF, MWF and MDF, at Dotalugala MAB Reserve, Sri Lanka.

Table 2: The abundance (total number of germinable seeds), richness (total number of morphospecies) and Shannon-Weiner Diversity Index recorded in wet and dry season soil seed banks in three forest communities (UMF, MWF and MDF) at Dotalugala MAB reserve in the Knuckles Forest Reserve of Sri Lanka.

	Forest Communities		
	UMF	MWF	MDF
Wet Season			
Abundance	1,157	1,381	1,231
Richness	31	35	34
S-W Diversity Index	2.29	2.36	2.11
Dry Season			
#Abundance	507	641	597
Richness	24	27	27
S-W Diversity Index	2.07	1.93	1.72

From dry season soil samples, a significant number of seedlings died before they were identified into different morphospecies. Accordingly, 84, 136 and 109 seedlings from UMF, MWF and MDF forest communities have been excluded from the rest of the data analysis.

Out of all germinated seeds during the wet season, 46% of seedlings were belonged to woody species, whereas in the dry season, representation of the woody species has increased up to 68%. However, no significant differences were observed between the richness of woody and non-woody species among the three forest communities during the wet season. In contrast, woody species significantly dominated the soil seed bank over non-woody species in the dry season and this was evident in all three forest communities (Figure 5 and Table 3). There was a significant interaction between season (wet/dry) and habit (woody/non-woody) ($F = 14.09$, $p = 0.000$).

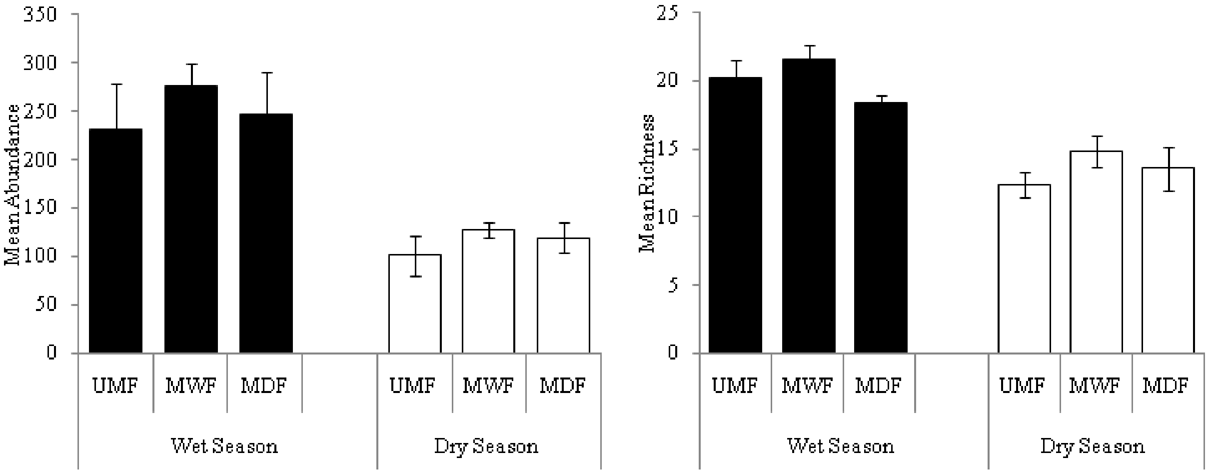

Figure 4: Mean seed abundance and richness during wet and dry seasons in three forest communities (UMF, MWF and MDF) at Dotalugala MAB reserve in the Knuckles Range of Sri Lanka. The mean abundance and richness had significantly higher values in the wet season than in the dry season (GLM: $F = 31.55$, $p \leq 0.001$).

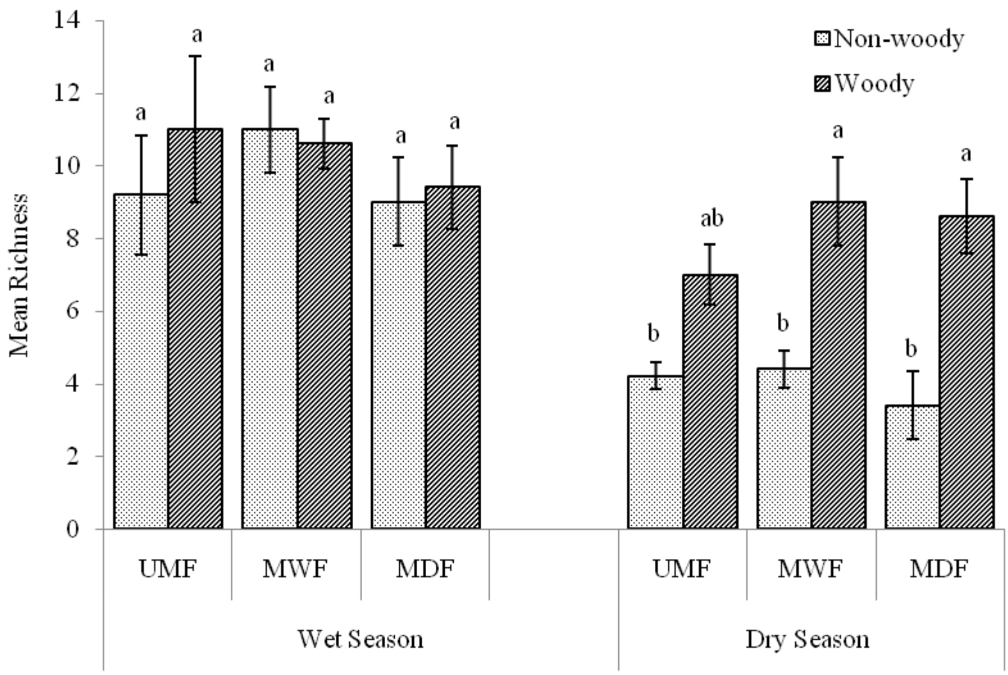

Figure 5: Mean richness of woody and non-woody species recorded in wet and dry seasons at three forest communities (UMF, MWF and MDF) at Dotalugala MAB reserve, Sri Lanka. Bars with different letters indicate significant differences between means at $p \leq 0.05$ level after GLM.

The density of germinable seeds was higher in the wet season than that in the dry season in all three forest communities (Figure 6). In consistent with richness data, seeds of non-woody species dominated the soil seed bank during the wet season and woody seeds during the dry season (Figure 6). Further, non-woody seeds were relatively more abundant in UMF and MWF forest communities than the woody seeds, with no such difference was recorded in MDF.

The pioneer tree species including *Maesa indica* (Roxb.) DC, *Acronichya pedunculata* (L.) Miq. and *Macaranga* spp. were recorded in soil seed banks of all three forest communities during both wet and dry seasons. Some differ in numbers between forest communities, and also germination patterns between seasons (wet and dry) (Figure 7). *Maesa indica* seeds germinated relatively quickly in dry season soils compared to that in the wet season, and this was evident in all three forest communities. In contrast, seeds of *Acronychia pedunculata* started to germinate after approximately 16 days in both wet and dry season soils. In contrary to the relatively slow seed germination rates in *M. indica* and *A. pedunculata*, seeds of *Macaranga* germinated rather quickly reaching the climax after 11 days in all three communities and in both seasons. However, UMF showed lower abundance of *Macaranga* seeds compared to other two forest communities (MWF and MDF) during both seasons.

Table 3: The summary statistics of GLM analyses showing the significant effects between seasons (wet/ dry), forest communities (UMF, MWF and MDF) and woody/non-woody nature and their respective interactions for species richness (number of morphospecies) and density of germinable seeds (individuals/m^2) at Dotalugala MAB Reserve in Sri Lanka.

		Species richness (per sq. m)		Density (per sq.m)	
Source of variation	df	F	p	F	p
Seasons (S)	1	67.27	0.000^{***}	59.94	0.000^{***}
Forest communities (C)	2	2.12	0.131^{ns}	0.75	0.476^{ns}
Woody/non-woody (W)	1	25.04	0.000^{***}	0.09	0.766^{ns}
S*C	2	0.64	0.530^{ns}	0.20	0.816^{ns}
S*W	1	14.09	0.000^{***}	20.36	0.000^{***}
C*W	2	0.19	0.829^{ns}	3.55	0.036^{*}
S*C*W	2	1.84	0.170^{ns}	0.21	0.808^{ns}

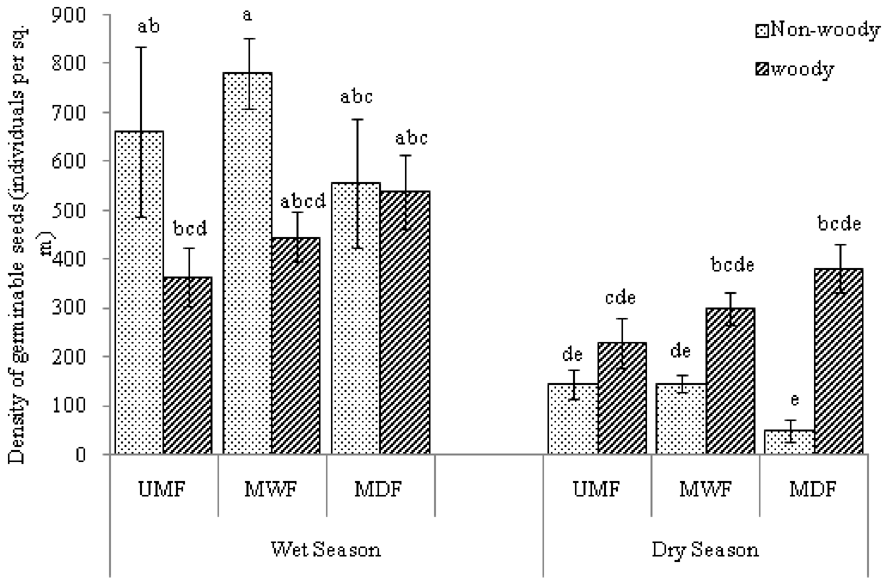

Figure 6: Mean density of woody and non-woody seeds (individuals/m2) recorded in wet and dry seasons in three forest communities (UMF, MWF and MDF) at Dotalugala MAB reserve, Sri Lanka. Bars with different letters indicate significant differences between means at p ≤ 0.05 level after GLM.

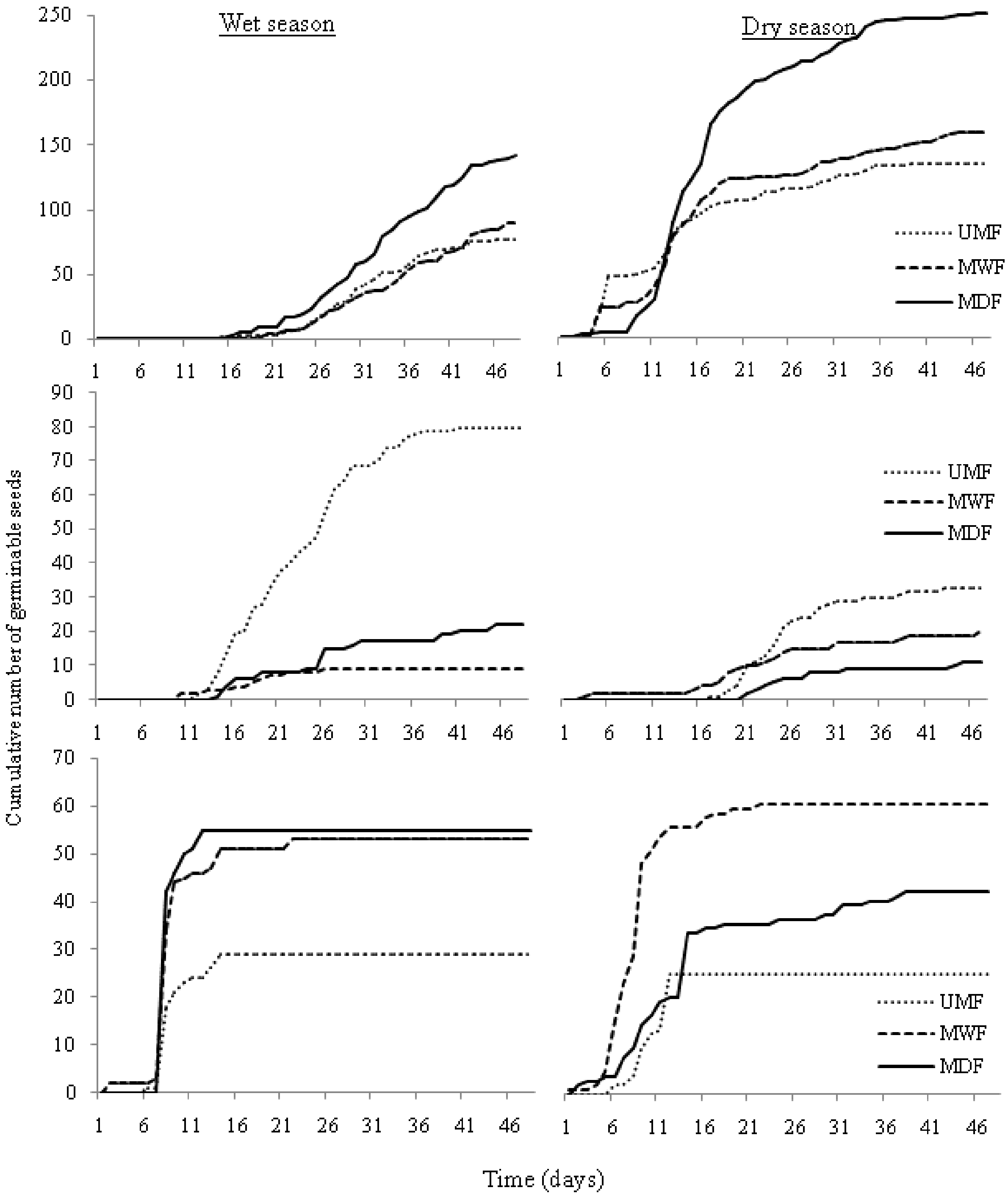

Figure 7: Cumulative number of germinable seeds over time (since soils were laid on seed beds allowing germination) of three pioneer species, *Maesa indica*, *Acronychia pedunculata* and *Macaranga* sp. recorded in UMF, MWF and MDF forest communities during wet and dry seasons at Dotalugala MAB reserve, Sri Lanka.

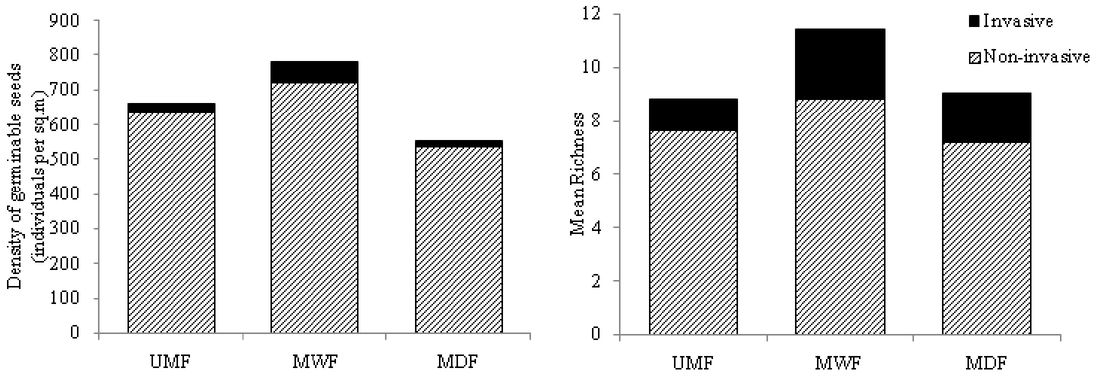

Figure 8: The contribution of seeds of invasive species to the density and richness of non-woody seeds in UMF, MWF and MDF forest communities at Dotalugala during the wet season.

During the study, few invasive species were identified including *Clidemia hirta*, *Agertina riparia, Mikania micrantha* and *Austroeupaotrium inulifolium.* Interestingly, *Clidemia hirta* and *Agertinia riparia* were not recorded in the soil seed bank of UMF. From the total density of non-woody species, invasive species represented significantly less in all three forest communities (6 %, 8 % and 5 % in UMF, MWF and MDF, respectively). However, compared to UMF and MDF forest communities, the density and richness of invasive species was slightly higher in MWF (Figure 8).

DISCUSSION

The density of seeds in forest communities at Dotalugala varied from 1,000 – 1,300 seeds per m^2 during the wet season and 450 – 550 seeds per m^2 in the dry season. Saulei and Swaine (1988) noted that in tropical forests the seed density in soil seed bank is generally lower than 500 seeds per m^2. However, the present findings did not totally agree with this generalization as the seed densities during the wet season showed much higher values (more than double) in all three forest communities studied at Dotalugala. The study also observed higher seed densities and species richness in the wet season than in the dry season and this trend was evident in all three forest communities. Non-woody species have contributed to these higher values in the wet season. However, previous studies conducted in different ecosystems too observed seasonal differences in soil seed banks though it is hard to generalize the findings (Grombone-Guaratini *et al.*, 2004; Flores and Dezzeo, 2005; Tang *et al.*, 2006). In contrary to the present findings, Martins and Engel (2007) observed a higher density of seeds at the end of a dry period than at the end of a rainy period, in a study carried out in seasonal semi-deciduous forest fragments in Brazil. Higher rates of seed dispersal and favourable micro-climatic conditions for seed germination during the dry season (Daws *et al.*, 2005), together with higher mortality rates of seeds during rainy seasons (J´anzen and V´azquez-Yanes, 1990; Dalling *et al.*, 1998) are identified as possible reasons to higher density and richness of seeds during the dry season. Similar results were also obtained by other researchers studying tropical ecosystems (Dalling *et al.*, 1997; Pérez and Santiago, 2001). However, in the present study, higher densities were recorded in the wet season in all three forest communities compared to the dry season. Favourable microclimatic conditions and phenological events can be considered as possible reasons for higher density and richness of seeds during the wet season at Dotalugala. According to Shen *et al.* (2007), if seed maturation and germination incidences are not synchronized plants tend to delay their germination until conditions are suitable for seedling survival. They also confirmed that the seed density can be influenced not only by the rate of seed input, but also due to loss of seeds due to predation, senescence and germination (Shen *et al.*, 2007). Therefore, both site-specific (predation, senescence and germination) and/or plant-specific (phenology, dormancy etc.) factors may have contributed to seasonal fluctuations of the soil seed banks at Dotalugala reserve.

In spite of clear seasonal fluctuations of seed abundance at Dotalugala, no significant differences were observed in density and richness of seeds between the three forest communities studied. A previous study confirmed that in spite of physiognomic differences, there were no differences in floristic compositions among the three forest communities identified at Dotalugala (Ekanayake, 2014). Therefore, the soil seed bank results are in comparable with the findings of the above-ground vegetation of these three forest communities at Dotalugala. However, the richness of the soil seed bank was much lower than that of the above-ground vegetation, and this was evident in both seasons in all three forest communities (Table 4). Hopfensperger (2007) revealed that the least similarity (31%) between the standing vegetation and its associated seed bank in forest ecosystems, after reviewing 108 studies carried out between 1945 and 2006. Kalesnik *et al.* (2013) also observed similar results in a study carried out in a secondary forest in Argentina. Mature forests generally consist of a small seed bank composed of species not present in the standing vegetation due to the fact that most shade-tolerant species do not develop persistent seed banks (Nakagoshi 1985; Thompson 1998). Other studies also suggest that the species composition of soil seed banks greatly differ from the species composition of the tropical forest canopy as the seeds of primary species rarely occur in the soil due to large seed size, high water content and rapid germination strategies (Vazquez-Yanes and Orozco-Segovia 1993).

At Dotalugala, the non-woody species dominate the soil seed bank in the wet season, while woody species dominate in the dry season. A lower density of woody species than that of herbaceous (non-woody) species in the soil seed bank has been reported by many workers previously irrespective of seasonality (Young *et al.,* 1987; Grombone-Guaratini and Rodrigues, 2002). Fragmentation has been suggested by other researchers as a possible reason for dominance of non-woody seeds in seed banks of forest ecosystems as forest patches are usually surrounded by non-natural vegetation (Poiani and Dixon, 1995; Dalling and Denslow, 1998). In support of the present findings, Grombone-Guaratini *et al.* (2004) also observed higher density of woody seeds in the dry season, in a study carried out in a tropical forest in Brazil. The lack of tree and shrub species in the seed bank during the wet season perhaps due to vulnerability of seeds to high predation and pathogen attacks during the rainy season compared to that in the dry season (Dalling *et al.,* 1998; Lemenih and Teketay, 2006). It is also can explained by some inherent characteristics shown by non-woody species which include efficient modes of seed dispersal, rapid maturation and germination, and also their ability to produce higher number of seeds (Hopkins *et al.,* 1990).

The study recorded number of pioneer tree species including *Maesa indica*, *Acronychia pedunculata* and *Macaranga* spp. in the study sites. The significant role of pioneer tree seeds in the soil seed bank in facilitating the regeneration process following disturbances has been highlighted in previous studies in the tropics (Garwood, 1989; Roizman, 1993; Araujo *et al.,* 2001). . Therefore, the availability of viable seeds of pioneer species in the soil seed bank is critical for forest recovery after a disturbance event. However, the rate of germination and abundance of pioneer tree seeds showed differences between seasons and forest communities at Dotalugala. *Maesa indica* showed rapid germination during the dry season than that in the wet season suggesting that *Measa* seeds need an environmental cue/s to initiate germination. In contrast to *Maesa indica* and *Acronychia pedunculata*, *Macaranga* seeds germinated rather quickly in both wet and dry seasons. *Acronychia* has taken approximately 26 days to reach its germination climax during the course of the study period while *Maesa* has reached its climax after 41 and 21 days in wet and dry seasons, respectively. The general view of tropical seeds is that they have short spans of viability (Mabberley, 1983; Ng, 1983). In contrary to this general view, others observed that some tropical seeds demonstrate different forms of dormancy (Whitmore, 1984), in particular with pioneer species having long longevity with turnover rates of more than a year (Lugo and Zimmerman, 2002). Martins and Engel (2007) having observed higher density of pioneer tree seeds in the dry season, suggested that seeds of pioneers undergo some form of dormancy.

Table 4: A comparison of the floristic data of the above-ground vegetation and the below-ground soil seed banks of the three forest communities (UMF, MWF and MDF) studied at Dotalugala MAB reserve, Sri Lanka.

	Forest Communities		
	UMF	**MWF**	**MDF**
[1]**Vegetation**			
Floristic richness[#]	198	213	232
Species richness	90	94	104
[*]Most common species	*Calophyllum trapezifolium* (T) *Eurya ceylanica* (T) *Acronychia pedunculata* (T)	*Eugenia thwaitesii* (T) *Calophyllum trapezifolium* (T) *Eurya ceylanica* (T) *Agrostistachys coriacea* (T)	*Psychotria nigra* (S) *Gaertnera walkeri* (S) *Lasianthus strigosus* (S)
[2]**Soil seed bank**			
Species richness (Wet season)	31	35	34
Species richness (Dry season)	24	27	27

According to Ekanayake (2014), out of the three forest communities, MDF is the most vulnerable community for disturbances due to its close proximity to human settlements and cardamom cultivation areas. Other two forest communities, UMF and MWF, are located in areas with no direct access to humans and as a result less vulnerable to any form of anthropogenic disturbances. In spite of these differences, the results showed that invasive seeds represent only 4-8% of the total soil seed bank in all three forest communities studied at Dotalugala, indicating less threat form invasive species. However, early studies reported that in spite of substantial changes that occur in the standing vegetation due to invasions, the impact on the soil seed bank is not significant (Vilà and Gimeno, 2007; Gaertner *et al.*, 2011; Abella *et al.*, 2012, 2013). Gioria *et al.* (2014) suggested that seed rain and seed persistence of some native species can maintain the soil seed bank reasonably un-changed at least until major changes occur in the vegetation.

CONCLUSION

The results suggest no significant differences among the three forest communities in terms of density and richness of the soil seed banks. However, the species compositions of seed banks have shown some variations between communities, and this was more conspicuous during the dry season. Seasonal variations of the soil seed banks among the three forest communities were striking with higher densities and richness during the wet season. Presence of pioneer tree species in all sites and their germination patterns indicate the ability of these forest communities to regenerate after a disturbance. Invasive species contribute less to the soil seed bank indicating less threat to the existing vegetation from invasive species.

ACKNOWLEDGEMENTS

We would like to acknowledge the University of Peradeniya for providing financial assistance (Grant Number: RG/2012/43/S) to carry out this research project successfully.

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