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Similarity between Soil Seed Bank and Above-Ground Vegetation in Different Ecosystems of Tropic and Temperate Regions

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Abstract: Similarity between seed bank and standing vegetation depends upon seed dispersal mechanism, presence of seeds of target/non target plant species in soil, dormancy period, and seed size. These parameters affect similarity directly whereas light intensity, temperature, rainfall, soil moisture and vertical distribution of seed in soil affect similarity indirectly. This relationship provide information about how ecosystem changes in respect to disturbances, succession and restoration efforts and which ecosystems have potential to drive the ecosystem either seed bank or above-ground vegetation. Understanding the mechanisms controlling community composition dynamics in various ecosystems allows ecosystem managers to derive conservation and management techniques from several sources like preservation of typical forest species as gene bank. In general tropical ecosystems were more dynamic and show substantial similarity as to that of temperate.
Keywords: Soil seed bank, Above-ground vegetation, Tropics, Temperate region, Similarity index.

I. INTRODUCTION

Soil seed bank is an important clue in conservation biology due to its regenerative power and vegetation recovery. It is a potentialseed source for regeneration of plant communities and provide information about past of existing above-ground vegetation and coming future deviation. Higher similarity between soil seed bank and above-ground vegetation showed better regeneration power of seed bank that established above-ground vegetation. It is presence of both viable and non-viable seeds incorporated into the soil. The objective of this study was to know the effect and role of seed bank in restoration, disturbances management and secondary succession. Although, several studies were available on similarities between soil seed bank and above-ground vegetation (Leck & Graveline 1979; Henderson et al. 1988; Levassor et al. 1991), but substantial studies showed poor similarities between species composition of soil seed bank and above-ground vegetation (Bakker & Berendse 1999; Lemenih & Teketay 2006). This review highlights about similarity of species composition between seed bank and vegetation in two extreme regions - tropic and temperate ecosystems of the world.

The similarity is an issue now-a-days to understand whether seed bank is driving the above-ground vegetation or above-ground vegetation is driving the seed bank dynamics and trends existing over various spatial and temporal scales (Hopfensperger 2007). The similarity provides information about resilience of ecosystems against disturbances, ecosystems drivers of succession and probability of restoration of ecosystem diversity (Hopfensperger 2007). If similarity exists between the seed bank from year 1 and the vegetation in year 2, then it is possible that the seed bank contributed to the composition of the vegetation in year 2 (Hopfensperger 2007). Various ecosystems of both temperate and tropic regions are important for conservation and management of plants to maintain ecosystem sustainability for our future generations. This analysis may highlight whether soil seed bank drive standing vegetation or above-ground vegetation drive seed bank. This review flavored that ecosystems of tropic region have higher similarity index than temperate region. Further, lesser similarity was noticed in plantation followed by agro-ecosystem, natural forest and grassland of both regions. Although, maximum works on seed bank and standing vegetation have been done in different types of grassland of both regions and least in an agro-ecosystem but in comparison of regions, tropics has higher similarity than temperate in all ecosystems, however moist has higher similarity than dry tropics.

A. Similarity between soil seed bank and above-ground vegetation

In this analysis 100 selected papers were downloaded from Google search engine based on similarity between soil seed bank and above-ground vegetation in different ecosystems. Those papers which have discussed similarity between seed bank and above-ground vegetation on basis of Sorenson's and Jaccard's similarity index in four important ecosystems (agro-ecosystem, plantation,

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grassland and natural forest) of two main regions (tropics and temperate) of the world were shortlisted. Soil seed bank of dry and moist tropical ecosystems of India with ecosystems of temperate region were compared. The data source of Sorenson's similarity index (1948) and Jaccard's similarity index (1912) was taken from shortlisted text, data, calculations and tables and compared with each other to hypothesize which ecosystems were driven by seed bank. These two similarity indices were used to calculate relationship between soil seed bank and above-ground vegetation for each article's data. Managed, disturbed, semi-natural and natural ecosystems were considered under priorities.

Sorenson's similarity index (1948) = 2C/ (A+B), where A = the number of species of above-ground vegetation, B = the number of species of soil seed bank, and C = the number of common species found in both soil seed bank and above-ground vegetation and Jaccard's similarity index (1912) = C/ (A+B+C) where C = total number of species present in both soil seed bank and standing vegetation, A = number of species present in soil seed bank but not in standing vegetation, B = number of species present in standing vegetation but not in soil seed bank. The species total number obtained from either direct from document in the article, or adding the number of species listed in tables and appendices found in the manuscripts. An analysis of variance (ANOVA) followed by a Tukey's comparison test comparing the similarity index among four ecosystems of both regions proved statistically significant ($F = 2.128$, $p < 0.001$). General Linear Model (GLM) procedure (ANOVA) on SPSS version 16 (2008) was used to get impact of regions and ecosystems on similarity index. Natural forest and grassland have higher similarity, whereas plantation and agro-ecosystem have moderate or intermediate similarity. Further, all four ecosystems differ significantly ($p < 0.05$) in similarity. Significant impact of regions ($F = 0.771$, $P < 0.05$), and ecosystems ($F = 2.119$, $p < 0.000$) on similarity index were recorded. While comparison of each ecosystems on the basis of similarity index between temperate and tropics regions no significant difference ($F = 0.377$, $p = 0.77$) was noticed.

Greater similarity value is found in tropical grassland and natural forest whereas lower similarity was observed in temperate plantation or managed forest (Fig. 1). This exercise envisaged that tropical has higher similarity than temperate environment between seed bank and above-ground vegetation, as detailed of each discussed below (Table 1). Tropical environment is more favorable for seed germination due to appropriate rainfall, light, soil moisture and low predation which enhances germination of seeds. High similarity is also due to presence of desirable species seeds in soil seed bank which exist in above-ground vegetation. The soil factors of tropics also enhance seed germination due to favorable condition such as availability of water, compactness of soil, texture and nutrient availability. Tropical soil seed bank form both transient and persistent seed bank; this persistency of seeds provide longer dormant period to live for longer time so they can germinate after disturbances and secondary succession play substantial role in re-establishment of vegetation. The seeds in tropical soil seed bank were generally near the surface. The greatest similarity was in the ecotonal community, the community that forms at the interface between prairie and woodland (Rosburg 2001). The floristic dissimilarity has been observed between soil seed banks and above-ground vegetation generally in various ecosystems of the world (Kellman 1970; Thompson & Grime 1979). The environmental factors which are around the buried viable seeds in soil depth influence their germination and survival (Sakai et al. 2005). In some moist tropical grassland, high similarity is found due to high seed density, species richness, diversity, evenness this may be due to moderate grazing which create better soil texture and soil depth rotation; this high similarity may be due to presence of both transient and persistent seed bank. Further low similarity is found in moist tropical forest due high germination of weed seed, grasses and forbs; less shrubs and woody plants (Mall & Singh unpublished data). High similarity between seed bank and above-ground vegetation of any ecosystems of the world give better recruitment for the seed germination.

B. Grassland soil seed bank and above-ground vegetation relationship

This is one of the most studied ecosystems on soil seed bank and above-ground vegetation relationship in most regions of the world. As grassland get aged or stable similarity also increased. Disturbances in grassland ecosystems lead to low species richness and similarity index. The similarity is expected to decrease with increasing community stability and stress, due to lack of disturbance creating sites for germination from the seed bank and higher investment in clonal instead of sexual reproduction in stressful conditions (Bekker et al. 1997). Higher similarity is due to presence of seeds which exist in standing vegetation and persistent seed banks as result of higher seed germination from soil seed bank and short distance seed dispersal (Dessaint et al. 1997; Bossuyt & Hermy 2004). Regions also affect the similarity as high similarity index was observed in tropical region than temperate. Generally, spatial pattern of seeds clustered around parent plants (Shaukat & Siddiqui 2004). Composition and species richness of vegetation were related to composition and species richness of seed bank (Lopez-Marino et al. 2000). Frequent grazing and disturbances also lead to high similarity (Thompson & Grime 1979). The differences in species composition, number of species and germination

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success of the soil seed bank down the soil profile might be attributed due to differences in soil texture and other soil quality parameters (Hopkins & Graham 1983) and under influence of grazing (Tessema 2011a). Heavy grazing reduce soil buffer provided by soil seed bank (Tessema 2011b).

Some study (Kalamees & Zobel 1998) also highlighted low similarity in grassland due to succession. The seeds in tropical soil seed bank were generally near the surface. The similarity was greater at the site with the more recent history of grazing, and was more dissimilar at the site that had been in public ownership longer. Forest and grasslands can be considered as long term stable ecosystems with low disturbance destroying the vegetation but in tropical grasslands high similarity was found due to high seed density, species richness, diversity and evenness (Srivastava 2002; Mall & Singh Unpublished data). This may be due to moderate grazing which create better soil texture and soil depth rotation but low similarity was found in moist tropical forest due to high germination of weed seeds, grasses and forbs; less shrubs and woody plants (Mall & Singh unpublished data). Continuous grazing can cause loss of important plant species.

C. Agro-ecosystem seed bank and above-ground vegetation relationship

Hill et al. (1989) observed that high similarity exist in an agro-ecosystem due to spatial pattern of seeds clustered around parent plants. The similarity was expected to be greater and increase with time (Garcia 1995). The time during cultivation may also play role in moderate similarity. Depth of plowing, habitat alterations and complex interactions like allelopathy (Rice 1979), predation (Janzen 1974), safe site availability (Harper 1977) and influx of seeds into cropped areas affect the relationship between soil weed seed bank and above-ground vegetation in different ways (Garcia 1995). In comparison of tropical agro-ecosystem to temperate agro-ecosystem, tropical agro-ecosystem has low similarity in comparison of temperate but in some study it is exceptional (Srivastava 2002; Mall & Singh unpublished data). The relationship between seed bank flora and above-ground is species dependent (Wilson & Aebischer 1995). Some study found dissimilarity between seed bank and vegetation in agro-ecosystem (Berge & Hestmark 1997; Gonzalez-Rivas et al. 2009) but other study recorded high similarity (Boutin 2005; Dessaint et al. 1997; Srivastava 2002; Mall & Singh Unpublished data). Cultivation and grazing might have caused high degree of similarities (Henderson et al. 1988).Native species compete with desired species in cropland this means certain number of seeds of desired species in seed bank may help desired vegetation to establish itself (Wang et al. 2010). These species carry out local adaptation (Wang 2006; Jiao et al. 2007) which promotes competitive advantage under the specific local ecological conditions. The native species can withstand extreme selective events over the long term representing a sustainable restoration strategy (Montalvo et al. 1997). In various agricultural fields short-lived species (annual and biennials) dominate the soil weed seed bank and perennial exclusively dominate the standing vegetation, and some perennials dominate both seed bank and standing vegetation (Berge & Hestmark 1997). This finding indicates that 80% of the perennials unique to soil seed bank depend on seeds for reproduction and nearly 30% of the species found in the vegetation depend on seeds for reproduction so there is moderate similarity between seed bank and above-ground vegetation. Low or no similarity is also found in agricultural fields of Nicaragua (Gonzalez-Rivas et al. 2009). A number of the species common to both the soil seed bank and above-ground vegetation are annual and ruderals (pioneer) with a persistent seed bank so seed bank plays important role in establishment of standing vegetation and population dynamics (Berge & Hestmark 1997). The similarity is high in old fields than uncultivated grassland because of presence of large number of native species that are absent or rare in seed bank that are important in vegetation of uncultivated grassland. Similarity decrease with time where ruderal annuals dominate both soil seed bank and standing vegetation in the early stage of succession then disappear from the vegetation while persisting in the seed bank (Chippindale & Milton 1934; Moore 1980), if late successional species become more common in both seed bank and standing vegetation, similarity increase with time (Bossuyt & Hermy 2004; Hopfensperger 2007). This is minor effect of succession with time on similarity results from low recruitment of pioneers from the persistent seed bank in late succession stages; this also shows that the relationship between transient seed bank and vegetation does not change during the course of succession (Scott & Morgan 2012). The dissimilarity is also due to presence of those species in seed bank which are not present in standing vegetation owing to persistence or dispersal (Thompson & Grime 1979; Scott & Morgan 2012). Persistent seed banks are not the key mechanism of resilience to agricultural disturbance in the vegetation and successful reinvasion of common species appears to result more from seed dispersal from outside of the disturbed site and cannot depend on the seed bank once species have been eliminated from the standing vegetation (Thompson & Grime 1979; Bekker et al. 2000).

D. Plantation seed bank and above-ground vegetation relationship

Soil seed bank provides very less contribution in both temperate and tropical plantation due to presence of woody species. Generally seed bank of plantation contain agricultural weeds, grasses, sedges and forbs due to local seed rain or seed dispersal. Seeds of woody plants hardly germinate due to large size which destroyed because of predation and have less dormancy time which bound them to involve in soil seed bank formation. Some tree species which has low and high dormant period their seeds are found in seed bank both in temperate and tropics regions. The general dissimilarity is manifested by dissimilarities in species composition, plant/seedling densities and frequencies. Fenner (1985) suggested that similarity is greatest in frequently disturbed ecosystems and the difference increase as succession progresses. Species represented in the seed bank may have been derived from vegetation present at the site in previous years (Warr et al. 1993). The soil seed bank in plantation mainly constitutes annual plant species perennials are scanty and infrequent. The plantation mainly constitutes economically important woody plants in both temperate and tropics which lead low species richness in both seed bank and vegetation and generally their seeds are large size which gets caught by predators and these are late successional plant species. In comparison of natural forest plantation has greater seed density of few species in tropical plantation (Wang et al. 2009). Similarity is higher in tropical plantation in comparison of temperate plantation because in tropical generally monoculture of one species is adapted and similarity of seed bank with vegetation is higher due to presence of agricultural weeds grasses, sedges and forbs and others while in temperate, mixed plantation get preference, so similarity is low in this forest (Decocq et al. 2004). Some authors reported good potential regeneration power of late successional species in seed bank with significance role in regeneration of vegetation community regeneration (Leckie et al. 2000), but some (Onaindia & Amezaga 2000) suggested that due to scarcity of typical forest species in the seed bank, its significance as the source of seeds is negligible for understory regeneration. The low similarity in forest is due to minor contribution of dominant species to the formation of the persistent seed bank (Baskin & Baskin 1998) and also due to less viability of large sized seeds of these dominant species (Asadi et al. 2012). The presence of a species in the seed bank but not in the vegetation could be a consequence of seed dispersal from adjacent agricultural-pastoral zone or the persistence in the soil layer after the death of an adult plant (Esmailzadeh et al. 2011).

E. Natural forest seed bank and above-ground vegetation relationship

Low similarity exist in natural forest of both temperate and tropics. In natural forest there is higher seed germination of agricultural weed seeds than seed germination of shrubs and trees. This may be due to different dormancy time of seeds. The abiotic factors like rainfall, soil moisture, humidity and light also play important role in germination of seeds of different plant species. The main factor for seed bank and standing vegetation relationship is seed rain or seed dispersal. Most typical species of stable habitats in contrast do not produce long lived seeds (Lee 2004). This dissimilarity is due to frequent occurrence of perennial grasses and woody species in the above-ground vegetation (Tessema 2011a) and more annual forbs in the soil seed bank (Solomon et al. 2006; Hopfensperger 2007). Such dissimilarities are caused by species differences in seed dormancy and germination rates caused due to embryonic dormancy or impermeable seed coat or both (Baskin & Baskin 2004). In a study of seed banks in European forests varying in age from young (55 to 116 years old and established on formerly arable land) to old-growth forest (greater than 250 years), similarity between seed bank and vegetation decreased in the older forests. Species in the seed banks were mainly those typically found along forest edges, in earlier successional stages, or in small disturbances within the forest. This makes it clear that minimization of disturbance is imperative for successful management of old-growth forests.

In tropical forests, there is often little correspondence between the composition of the vegetation and the seed bank (Guevara & Gomez-Pompa 1972; Hall & Swaine 1980; Saulei & Swaine 1988; Hopkins et al. 1990; Teketay & Granstrom 1995), or between the annual seed rain and the seed bank (Uhl & Clark 1983; Saulei & Swaine 1988). Similarity in tropical deciduous forest after distinguished those disturbances driving the community composition with higher similarity between seed bank and vegetation and similarity decreasing with succession after the disturbance (Rico-Gray & Garcia Franco 1992). Some (Livingston & Allessio 1968; Matlack & Good 1990) also found that pioneer species form persistent seed bank and late successional species form transient seed bank also leads to low similarity in natural forest. The same patterns are common in temperate forests (Livingston & Allessio 1968; Enright & Cameron 1988; Matlack & Good 1990; Schiffman & Johnson 1992; Sem & Enright 1996). Woody species in temperate forest generally do not produce long-live seeds and persistent soil seed bank (Esmailzadeh et al. 2011). Bossuyt & Honnay (2008) affirmed that few forest species produce long-live seeds because stable but stressful forest environment will select for traits associated with a higher seedling establishment success rate rather than for dispersal in time or space. Bossuyt & Hermy (2004) reported that regeneration of forests in temperate region that some forest species reproduce vegetative or by transient seeds. Some species which have persistent seed bank failed to germinate in late successional stage due to lack of light intensity and thick litter layer which require light for seed germination and so seed persist in soil for longer time. So many pioneer and native do not

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germinate and play no role in regeneration characterizing low similarity in temperate forest due to large seed size and seed predation of late succession species (Gashaw et al. 2002; Decocq et al. 2004) in comparison of small seed size because large sized seed get affected and easily available for predation. Large seeded late successional species were absent in the formation of persistent seed bank. The large seeded species prefer to form seedling bank rather than seed bank due to the lack of dormancy mechanisms. The species which produce small seed and may remain viable for a long time in the soil seed bank of European temperate forests (Godefriod et al. 2006). This explain that seed bank have potential to regenerate earlier succcesional stage plant species in forest.

II. CONCLUSION

The ecosystems of tropics have higher similarity between soil seed bank and above-ground vegetation than temperate region because pioneer species form persistent seed banks. Moist tropics have high similarity than dry tropics. One main important hypothesis is that low similarity is found between seed bank and above-ground vegetation of any stable ecosystem. Thus ecosystems composition drivers and mechanisms may improve the conservation and management of ecosystems around the world.

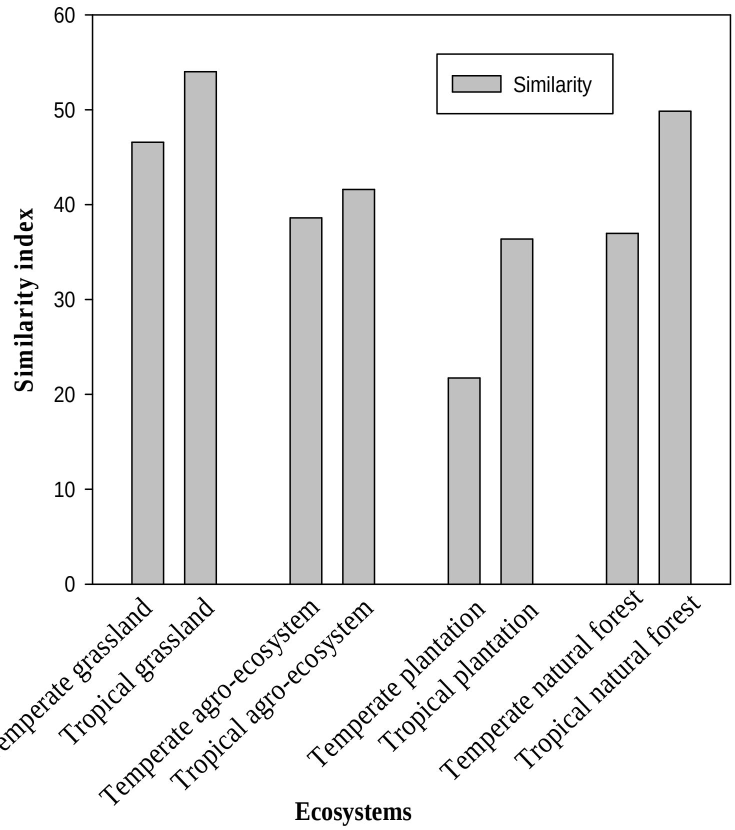

Figure 1: Various ecosystems of two regions showing similarity index between soil seed bank and above-ground vegetation.

Table 1. The study location, ecosystems (grassland and agro-ecosystem) and Sorenson's similarity index were taken and calculated from text, table and other various sources of published and unpublished papers.

References	Study location	Ecosystem	Sorenson's similarity index* and Jaccard' similarity index**
Temperate Region			
Bekker et al. 2000	Netherlands	Grassland	47.0*
Bossuyt & Hermy 2004	Belgium	Grassland	55.3*
Kamees & Zobel 1998	Estonia	Grassland	64.6-88.0*
Tracy & Sanderson 2000	USA	Grassland	60.0*
Kim & Lee 2005	South Korea	Grassland	16.0-20.0*

Berge & Hestmark 1997	Norway	Agro-ecosystem	21.0-51.0**
Boutin 2006	Canada	Agro-ecosystem	64.0*
Dessaint et al. 1997	France	Agro-ecosystem	55.0-86.0**
Gonzalez-Rivas et al. 2009	Sweden	Agro-ecosystem	8.0-14.0**
Pellissier et al. 2004	France	Agro-ecosystem	56.6*
Amezaga & Onaindia 1997	Spain	Plantation	53.3*
Amrein et al. 2005	Switzerland	Plantation	4.0*
Decocq et al. 2004	France	Plantation	27.1*
Esmailzadeh et al. 2011	Iran	Plantation	24.3**
Godefroid et al. 2006	Belgium	Plantation	0.0*
Bossuyt et al. 2002	Belgium	Natural forest	31.2*
Diaz-Villa, M.D. et al. 2003.	Spain	Natural forest	37.5*
Drake 1998	USA	Natural forest	47.1*
Leckie et al. 2000	Canada	Natural forest	13.0-58.0*
McNicoll & Augspurger 2010	USA	Natural forest	36.0**
Tropic Region			
Scott & Morgan 2012	Australia	Grassland	29.0-46.0*
Yan et al. 2012	China	Grassland	74.0-85.7*
Zhao et al. 2011	China	Grassland	26.0-28.0*
Srivastava 2002	India	Grassland (Dry tropics)	69.0*
Mall & Singh (Unpublished data)	India	Grassland (Moist tropics)	72.0*
Armengot et al. 2011	Spain	Agro-ecosystem	26.0*
Garcia 1995	Brazil	Agro-ecosystem	36.0-39.0*
Hill et al. 1989	Canada	Agro-ecosystem	61.0-70.0*
Zhan et al. 2007	China	Agro-ecosystem	50.0-67.0*
Srivastava 2002	India	Agro-ecosystem (Dry tropics)	35.0-38.0*
Mall & Singh (Unpublished data)	India	Agro-ecosystem (Moist tropics)	36.8-39.1*
Sakai et al. 2005	Japan	Plantation	65.9*
Senebeta & Teketay 2002	Ethiopia	Plantation	22.0-55.0**
Wang 1997	Australia	Plantation	57.9*
Wang et al. 2009	China	Plantation	26.1-48.0*
Lemenih & Teketay 2005	Ethiopia	Plantation	11.0*
Mall & Singh (Unpublished data)	India	Plantation (Moist tropics)	38.1*
Mwauv & Witkowski 2009	Uganda	Natural forest	75.0-98.0*
Rico-Gray & Garcia-Franco 1992	Mexico	Natural forest	15.8*
Senebeta & Teketay 2002	Ethiopia	Natural forest	28.0-57.0**
Lu & Tang 2010	China	Natural forest	40.6-86.0*
Kellerman 2004	South Africa	Natural forest (Moist tropics)	44.4*
Mall & Singh (Unpublished data)	India	Natural forest (Moist tropics)	27.4*

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