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The Role of Soil Seed Banks and Seed Dispersal Mechanisms for an Ecosystem Restoration and Biodiversity Conservation: Review Article

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Abstract
Land degradation, species extinction, desertification, and climatic risks are natural marvels of the earth recently. In response, the 2012 United Nations Rio+20 conference on sustainable development set the goal of restoring 150 million ha of disturbed and degraded land by 2020. Therefore, restoration ecology is intended to restore a degraded ecosystem and disappeared plant species. In this regard, plant reappearance to a degraded ecosystem largely depends on the presence of viable seed banks in the soil. Consequently, seed banks preserve functionally and genetically varied below-ground plant species pool available for germination. Furthermore, seed banks represent local 'biodiversity reservoirs' that can pay to local population persistence and maintenance. However, the presence of soil seed banks varied along with ecosystem types and climatic gradients. Hence, if plant seeds have been lost from the soil, it has to be transported to the site by dispersal agents. Accordingly, seed dispersal lets plants to colonize new areas, avoid sibling competition, natural enemies, and met genetic structure and population dynamics. Though dispersal plays a major role in ecosystem restoration and biodiversity conservation, its effectiveness varies with dispersal agents, species, and ecosystem types. Furthermore, changes in climatic factors can have a direct impact on phase of seed dispersal, either by increasing or decreasing the dispersal distance. However, seeds did not behave in a similar ways with respect to germination after arrival to a site due to dormancy, and environmental factors. Thus dormancy guarantees species capacity to survive, decrease competition between individuals, and prevent unseasonable germination. Therefore, scientific information on the contribution of soil seed banks and seed dispersal mechanisms for biodiversity conservation and ecosystem restoration is vital for designing conservation strategies, restoration plans, and climate change mitigation strategies.
Keywords: climate change, colonization, dormancy, extinction, germination, habitat, plant species
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1. Introduction

'Species extinction rates in recent eras are estimated to be 100 to 1000 times greater than pre- human times' (Adams and Hutton 2007). These elevated rates are primarily due to the degradation of native ecosystems by human activities. Consequently, land degradation, habitat destruction, species extinction, and desertification are natural phenomena of the earth recently (Cowie et al. 2011). In response, the '2012 United Nations Rio+20 conference on sustainable development set the goal of restoring 150 million hectares (ha) of disturbed and degraded land by 2020' (Menz et al. 2013). Consequently, there is a growing universal attention on restoration of degraded ecosystems (Choi et al. 2008). The expected benefits are the preservation and recovery of biodiversity and enhancement of its values (Scherr and Mcneely 2008). In this regard, soil seed banks (SSBs) offer the potential to make a significant contribution to the natural regeneration of plants (Grime 2001). Furthermore, the reappearance of plants in a degraded ecosystem depends on the presence of viable seed (Bakker et al. 1996). However, the potential of SSBs for restoration depends on the richness and density of native and invasive species (Lang and Halpern 2007).

Ecosystem restoration, population persistence, and future vegetation dynamics retained via seed banks (Mcdonald et al. 2016). Stabilization of a site after disturbance is also accomplished through seed banks. Thus ecological and genetic diversity is conserved and maintained through seed banks. Besides, 'SSBs symbolizes native biodiversity reservoirs' that give to indigenous population persistence and maintenance (Plue and Cousins 2013). However, site stabilization and ecosystem enhancement process are influenced by the nature and severity of disturbance. Hence, the restoration plan will be more effective if the information on soil seed bank status is incorporated into the program. Conversely, seeds has to be transported to the site by dispersal agents if it had been lost in an ecosystem (Bakker et al. 2000). Therefore, the ecological restoration process are achieved through the introduction of species as seeds or Diasporas (Mcdonald et al. 2016).

Seed dispersal (SD) is the 'movement of organisms, their propagules, and genes away from the parent plants' (Nathan 2001; Petit et al. 2004). Seeds are dispersed through various means such as wind, water, animals, and man (Wenny and Levey 1998). Consequently, it is via seed dispersal that plants inhabit fresh sites, avoid sibling competition, and natural enemies (Khurana and Singh 2001). Hence, regeneration and restoration process in an ecosystem will take place through seed dispersal mechanisms (SDMs).

'Ecosystem restoration is an extended duty targeting at repairing disappeared plant species, ecosystem structure and functions' (Khurana and Singh 2001). Though restoration science and practices are not upfront (Donald et al. 2006) due to absence of consent among ecologists on restoration theory and practice, the scale and range of interventions are reliant on ecosystem conditions (Mcdonald et al. 2016). Therefore, it is timely to review the role of seed banks (SBs) and SDMs for ecosystem restoration. This review article targets to supply response for the following scientific questions: (1) what are the nature of SSBs and factors determine its success under different ecosystems and climatic conditions? (2) How SSBs contribute to ecosystem restoration and biodiversity conservation? (3) What is the seed dispersal mechanism, how it works and what factors affect its success? (4) How seed dispersal mechanisms contribute to ecosystem restoration and biodiversity conservation?

2. Main text

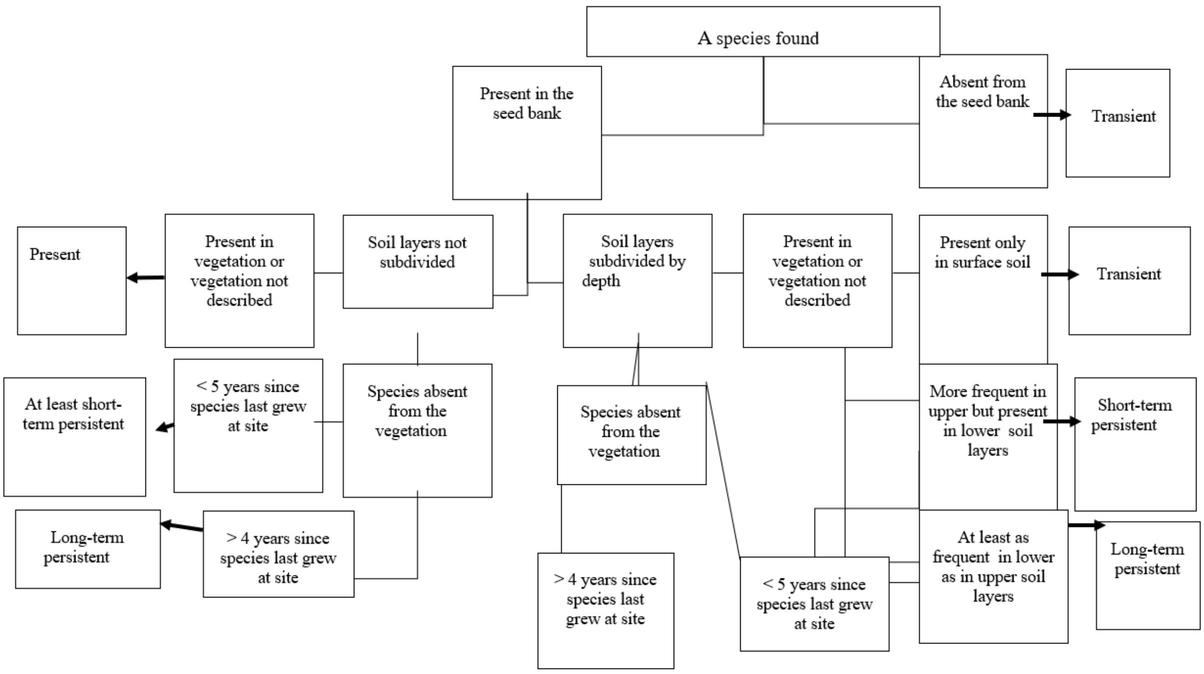
2.1. Concepts, nature, and types of seed banks

In angiosperms, SSBs are viable seeds stowed in a mineral soil that can germinate once germination requirements are encountered (Saatkamp et al. 2014). On the other hand, the soil seed bank (SSB) is the life cycle origin for the annuals. In perennials, there are banks of vegetative propagules like tubers, rhizomes, and stolons (Hotes et al. 2004). Likewise, spores are served as seed banks in mosses and ferns. Therefore, SSBs vary according to species, life forms, seed proximity, seed persistence, and physiological state (Laura and Brenda 2000).

'Living seeds found in the soil at different quantities' (Thompson and Grime 1979), seasons, depths, and duration (Poschlod et al. 1998) and 'states of dormancy' (Baskin and Baskin 2014). For example, a species called '*Ranunculus arvensis'* has a thick seed coat and spike that decompose after burial in the soil for a few years (Saatkamp et al. 2009). Though seeds of many plant species scarcely move into the soil, they persevere at the soil surface and in the litter for many years (Coomes et al. 2003). For instance, the larger and harder fruits of '*Medicago* and *Neurada* that contain dozens of seeds' can give rise to several plants over several years. Consequently, the time seeds spend in the soil varies from species to species (Saatkamp et al. 2014).

SSBs are categorized based on their 'longevity, species types, seed characteristics, burial depth, and seed dormancy' (Khurana and Singh 2001). Thus scientific information on seed longevity leads to classification of SSBs as described in (Figure 1). Consequently, 'transient seeds had distinguished for species that have viable seeds present for less than one year' (Thompson and Grime 1979). While 'persistent seeds remain for more than one year'. Similarly, persistent SSBs can be 'short and long term persistent'. The short term persistent seeds are detectable for more than one year and less than 5 years. On the other hand, long-term persistent seed banks could present for more than 5 years (Figure 1).

Figure 1: 'Classification rules for soil seed banks' (Thompson and Grime 1979)



Temporary SSBs are composed of seeds with short life species and have no existent dormancy (Christoffoleti and Caetano 1998). Accordingly, species such as '*Avenua fatua, Galium aparine, Lapsana communis,* and *Centaurea cyanus'* have temporary seed banks. While, *Sinapis arvensis, Aethusa cynapium, Papaver rhoeas, Viola arvensis,* and *Kickia spuria* have persistent SSBs. Based on 'persistence seed longevity-index' (LI), seeds are classified into transient (t), short-term persistent (sp) and long-term persistent (lp) (Bekker et al. 1998). The index ranged from 0 (strictly transient) to 1 (strictly persistent). Therefore, the smaller the seed is the higher is its proportion in deeper soil layers. However, in restoration ecology, the transient and persistent seed banks express little about longevity (Mineke and Bakker 2002). A modified version of the seed bank classification is (a) Transient: seeds which persist in the soil for less than 1 year. (b) Short-term persistent; seeds that persist in the soil for at least a year, however, less than 5 years. (c) Long-term persistent; seeds that persist in the soil for at least 5 years. The last category is the only one likely to contribute to the regeneration of destroyed communities in the context of restoration ecology (Bakker et al. 1991; Poschlod and Jackel 1993)

2.1.1. Seed viability and germination

The seed is 'minuscule plant responsible for regeneration and reproductive success in plants'. Following fertilization, growth arrays in various parts of the ovule. The zygote develops into the embryo. Therefore, the primary endosperm nucleus gives rise to endosperm and the integuments form the protective seed coat (Bentsink and Koornneef 2008) in the process. Conversely, the quiescent seeds germinate under favorable conditions, while others may not due to internal and external factors (Khurana and Singh 2004).

The incidence of a seed coat, biochemical inhibitors, and immature embryo are internal factors affecting seed germination. Those events incorporate the uptake of water by the quiescent and terminates with the elongation of the embryonic axis. At a time of germination (Manz et al. 2005), water uptake by seed is tri-phasic stage. In Phase I there is a rapid initial uptake of water. While phase II is the plateau phase and in phase III there is a further increase in water uptake. At the first signs of germination, transcription, translation, and DNA repair followed by cell-elongation, radicle protrusion, and resumption of cell division takes place (Masubelele et al. 2005). Therefore, germination process is complete following the rupture of micropylar endosperm by the emerging radicle (Khurana and Singh 2004; Manz et al. 2005 ; Bentsink and Koornneef 2008).

'Seed viability' is the ability of seeds to remain under germination capacity. Seeds are classified into orthodox and recalcitrant categories on the basis of their viability (Debeaujon et al. 2000). Orthodox seeds are usually dormant and can retain their viability for longer periods under fully hydrated oxygenic conditions. While recalcitrant seeds show little or no dormancy and cannot be dried below a critical moisture content (Fleck and Woolfenden 1997; VanderWall and Moore 2016). Therefore, the maintenance of seed viability will largely depend on the seed characteristics and location (Benvenuti 2007).

2.2. Factors affecting seed bank viability, longevity, and germination

2.2.1. Fungi, soil fertility, temperature, moisture, and location

'Seeds that are not dormant have the capacity to germinate under usual physical environmental factors suitable for the genotype' (Baskin and Baskin 2003). Proper substratum, moisture, a promising temperature, and adequate oxygen are the requirements for germination of most seed varieties (FAO 2010). Seed germination may also be sensitive to light and nitrates as well. Besides, moisture, oil contents, seed-covering structures, and temperature are parameters that determine post ripening process (Manz et al. 2005). Ripening is also prevented when seeds are stored at very high air humidity.

Fungi diminish the seed viability and alter seed germination too. However, fungal attack on buried seed depends on soil moisture content and level of temperature (Wagner and Mitschunas 2008). Furthermore, soil organic matter (OM) and Nitrogen content have a significant influence on fungal activity. Accordingly, Nitrates promote germination process and contribute to the depletion of persistent SSBs (Bekker et al.(1998). Likewise, soil fertility could significantly affect SSB persistence. Though soil water content and temperature are external factors that inhibit seed germination, their action for buried seeds are less intense. Furthermore, seed viability and germination are influenced by seed features and locality (Benvenuti 2007). For instance, it has been indicated that for a given set of plant species, seed mortality is higher in wet areas, unless fungicide is applied (Schafer and Kotanen 2003). It is also well documented that dispersal agents, soil, and climatic conditions, predators, and competitors are different among various sites. Those all have an influence on seed viability, germination, and longevity (Du et al. 2007).

2.2.1.1. Vegetation cover and disturbance

Most seeds can notice 'vegetation cover via far-red or red light ratios at the soil surface'. While others sense gaps from below ground via diurnal fluctuating temperature (Thompson and Price 1977). Therefore, density and height of vegetation covering the SSBs influence seed germination too. However, gap specialist can maintain SSBs under dense vegetation cover (Saatkamp et al. 2014). Whereas those species could possible depleted more rapidly in open areas.

Seeds move up and down in the soil profile due to rain (Benvenuti 2007). Likewise, soil tabulation and earthworm activities may also play a similar role as well. Therefore, the success of seed banks depend on the seed density ready to germinate when the environmental conditions are favorable to do so (Bakker et al. 1996). Thus the longevity of seeds represent a major mechanism for plant survival (Roberts and Neilson 1981). In this regard, the interactions among herbicides, land preparation, and cultural practice will also alter the size and nature of seed banks (Bennington et al. 1991; Milberg 1992). Approaches to investigate the seasonal dynamics of the seed bank (in relation to seed input, germination, and decay) are the depth distribution of seeds, seed size, and shape (Hotes et al. 2004).

2.3. Seed dormancy

'Dormancy' is a situation where alive and viable seeds did not germinate. However, they are able to germinate in the future when proper conditions for germination are met (Bradford and Nonogaki 2008). Besides, it is the failure of an intact feasible seed to complete germination process under promising situations (Bewley 1997). Nevertheless, dormancy is influenced by light, temperature, and the duration of seed storage (Clerkx et al. 2003). Likewise, seed dormancy can vary among wild and cultivated plants (Koornneef 2002). Therefore, seed dormancy is one of the least understood phenomena in seed biology and remains confusing despite much recent progress. This could be due to different developmental phases, interaction with environmental factors, and difficulties to detect genetic and physiological difference. Furthermore, testing dormancy based on germination, the degree, and the capacity of the embryo to overcome dormancy is an other strain (Bentsinka and Koornneef 2008). However, a distinction can be made among timing, and imbibition of the seed in the embryo, the endosperm, and in the testa. Therefore, interface among these features, the large effect of the environmental factors make dormancy a very complex process (Bentsinka and Koornneef 2008).

In germination process the plant embryo leaves the quiescent state, mobilize stored nutrients, overcome the barrier of surrounding tissues, and resume cell elongation, cell division, and development (Finkelstein et al. 2008). Thus dormant seeds that exhibit seed coat require scarification and fire for dormancy release (Hilhorst 2007). Dormancy can be also controlled and released by plant hormones such as Abscisic Acid, Gibberellins, and Ethylene (Finkelstein et al. 2008). Innate dormancy (primary) and induced dormancy (secondary) characterize the development of the dormancy in the mother plant after dissemination (Bentsinka and Koornneef 2008). Primary dormancy is acquired either during seed maturation, or exposure to unfavorable temperatures. In contrast, lack of adequate light and nitrate may lead seeds to a state of secondary dormancy as well.

Seed dormancy can be physiological, morphological, and physical (Finkelstein et al. 2008). All types may impose a delay between seed shedding and germination (Baskin and Baskin 2003). Physiological dormancy is the most abundant form and is found in seeds of gymnosperms and all major angiosperm clades. For example plant species such as; Helianthus annuus, Lactuca sativa, Lycopersicon esculentum, Nicotiana spp., Avena fatua, and several portion of cereals suffered with such types of dormancy. Furthermore, morphological dormancy is evident in seeds with embryos that are underdeveloped but differentiated into cotyledons and hypocotyl-radical. These embryos merely need time to grow and germinate. It is common in celery (Apium graveolens and the family Apiaceae) (Baskin and Baskin 2003). Mechanical and chemical scarification can break such dormancy. Plant species in the family 'Fabaceae' faced with this type of dormancy (Baskin and Baskin 2003; Finkelstein et al. 2008). Although physiologically fully dormant seeds cannot germinate regardless of environmental conditions, seeds with intermediate dormancy can germinate slowly under a narrower range of light and temperature conditions (Hilhorst 2007). Enforced dormancy (inability of seeds to germinate) can guarantee the survival of seeds under adverse conditions and when plants had eliminated in the area (Jurado and Flores 2005; Carol and Baskin 2014).

2.4. Seed bank dynamics

Seed banks are influenced by seed production, dispersal, persistence, and turnover (Leek and Simpson 1994). They act to stabilize and ensure species survival in the forest ecosystems. The seed input to an ecosystems is determined by the seed "rain". In such ways, seeds are mechanically ejected by fire, wind, water, and animals to the ground (Bekker et al. 2000). However, in unsuitable habitats (with variable rainfall, drought, flooding, vegetation gaps, disturbances, and frost) formation of the persistent seed bank is considered as plant's strategy to survive. Consequently, traits that increase seed survival depends on ecosystem types and species (saatkamp et al. 2014). Although seed invention is a significant trait for seed persistence (Butler et al. 2007), it does not ensure germination and growth in any kind of vegetation type. However, a large seed production enhances the chance to find a safer place (Jakobsson and Eriksson 2000). Therefore, seedlings which are from larger seeds take improved probabilities to endure due to their nutrient contents (Leishman 2001).

2.5. Contributions of seed banks for an ecosystem restoration

On evolutionary timescales seed banks increase the mean generation times of population, thereby affecting the potential rate and direction of evolutionary change (Evans and Dennehy 2005). Besides, it allows risk avoidance strategies for seeds to sprout (Gremer and Venable 2014). Furthermore, seed banks in an ecosystem provide an information as to what species exists or not in the standing vegetation and represent a pool of regenerative potential (Funk et al. 2008). Thus it helps to accumulate plant species, even if they have disappeared from the established vegetation. For example, species such as *Anthyllis vulneraria* and *Parnassia palustris* have a long-term persistent seeds (Katharina et al. 2009). Therefore, seed banks (SBs) provide a potential source of resilience when an ecosystem faces environmental change and disturbance. Therefore, separating the role of SBs in the community and population dynamics is essential for understanding the basic ecological patterns and processes (Alexander et al. 2012).

Viable seeds in the soil are vital for the restoration of the forest ecosystems (Bossuyt et al. 2001). Furthermore, SSBs are a basic tool to restore plant communities after desertion by human use, fire, and diverse direct destruction (Bakker et al. 1996). According to Scott and Morgan (2012), SSBs are often taken as an indicators for the restoration of potential biodiversity of an area. Accordingly, if the seed density in the soil is sufficient and the environmental conditions are suitable, the restoration potential can be activated with the help of management measures in an ecosystem being restored (Laughlin 2014). However, without proper ongoing management activities, the persistent SSBs and germinating seeds that are not established as plants can be depleted from the ecosystem. Furthermore, to obtain the positive or negative role of the seed banks, it is essential to gain the information on SBs composition before starting a restoration project (Bakker et al. 1996).

For plants with persistent seeds, SSBs could not only be derived from stored seeds in the soil over many years, but it could be recently imported from the current species pool (Bekker et al. 2000). Therefore, the seed bank is available to provide propagules for the species turnover (Pakeman and Small 2005; Luo and Wang 2006; Scott and Morgan 2012). Bekker et al. (2000) stated that the SSB in an ecosystem is the major source for re-colonization of plants after disturbance. However, lack of viable seeds for the target species could be a constraint to this view. The success of ecosystem restoration depends on distance, patch size, and habitat types (Orrock et al. 2006). Basically, it is via dispersal of SSBs that several species reach the restoration sites. Consequently, to restore endangered habitats that contain rare species, the prevailing SBs must be realized (Bossuyt et al. 2005; Plassmann et al. 2010). Therefore, soil seed banks preserve seeds that have similar characteristics to the original vegetation. So that they represent a source of re colonization (Blanckenhagen and Poschlod 2005). However, species that have long-term persistent seeds are the first to reappear to the restoring ecosystem. For instance, species such as '*Euphorbia cyparissias'* and '*Carex ornithopoda*' have superior probabilities to be established from seeds (Blanckenhagen and Poschlod 2005). In contrast, plant species without persistent seed banks rely on dispersal. Therefore, in bare ground areas, anemochorous plants are successful colonizers of an ecosystem. Likewise, SSBs act as a reserve to which new recruitment may occur if environmental conditions are favorable (Senbeta and Teketay 2002; Kolodziejek and Patykowski 2015).

2.6. Effect of climate change and ecosystem types on seed bank

SB populations are heterogeneous and distributed based on ecosystem types and climate change impacts (Zhang et al. 2012). Accordingly, climate change will directly affect the distribution of species. It is due to the climate change that the species distribution will shift from the area that they have adapted (Meynecke 2004). Therefore, SSBs varied along ecosystem types and climatic gradients (Ooi et al. 2012). The global circulation model predicts mean annual temperature increase from 2.1 to 4.6 ^{0}C in year 2080 in the northern temperate zone ((Intergovernmental Panel on Climate Change); IPCC 2001). Thus global warming will cause extinction and range shift of species (Thomas and Lennon 1999). Therefore, increasing temperature will allow plant species to colonize new habitats beyond their original ranges in the north (Hughes 2000). Similarly, the climate-induced modification of species physiology, phenology, and ecology cause net extinction via the invasion of competitive species in the south. However, most forest species are habitat specialists that are able to adapt stable environmental conditions (Hermy et al. 1999). Consequently, tracking the changing environment and colonizing new areas beyond their original ranges are among coping strategies of plants for climate change (Ooi et al. 2012).

Wet areas are becoming dry in the recent era due to climate change. Dry areas are also experiencing more rainfall and CO_2 at an alarming rate (Cochrane et al. 2015). These changes are not only visible in plant growth and distribution, but also affect SSBs and SDMs too. Furthermore, climate change aggravates colonization of an invasive alien species and invasive alien species can in turn induce climate change as well (Hellmann et al. 2008). Therefore, an invasive species can facilitate climatic stress through increasing ecosystem susceptibility to climatic agitation. It also reduces the number of native species and ecosystem functioning (Masters and Norgrove 2010).

Climate change is affecting species dispersal and its future impacts are projected to be extensive (Sala et al. 2000). An extra threat that has emerged recently due to climate change is the 'outflow of genetically modified organisms' (GMOs) or parts of their genotype (Dale et al. 2002). Therefore, climate change induced reductions in habitat size and patch connectivity alter the geographical location of suitable niches. This in turn causes modifications in species distribution (Mccarty 2001). In extreme cases, the entire future climatically suitable niche lies outside the present species range, necessitating migration for the species to survive (Sutherst 2000; Winkler and Fischer 2002). Furthermore, changes in the availability and suitability of habitats (Visser and Both 2006), contradictory habitat uses (e.g. nest, shelter, site selection, and survival rates) are in direct effects of climate change (Telemeco et al. 2009). Therefore, climatic variations reduce the number of species and seed density at a certain micro-habitats and time (Silva-Costa and Bugoni 2013; Baskin and Baskin 2014).

Seed bank distribution is not the same among ecosystem types such as tropical, temperate, deciduous, desert, and coniferous forests. For example, temperate rain forests contain abundant seeds of pioneer species (Dalling et al. 1997). Though soils of tropical rain-forests have high water content though out the year, their seed banks are dominated by pioneer species (Thompson and Pellmyr 1992). Furthermore, rainforest seeds exhibit reduced viability and rapid germination. Conversely, in most Noe-tropical savannas which are rain-less for about 4 to 5 months the number of seeds and species are relatively small (Skoglund 1992). Furthermore, dry Afro montane regions are characterized by possessing large numbers of buried seeds of forbs, grasses, and sedges. Though most of plant species in dry Afro montane forests store large quantities of seeds, most of seed banks represented in the standing vegetation are herbs. While in Afro montane region SSBs have the capacity to survive for a longer period of time (Demel and Anders 1995; Santos et al. 2018). According to (Teketay (1997), when SSBs in Afro montane vegetation are compared with forests and arable lands, arable lands have the highest seed density of herbaceous. Vandvik et al. (2016) noted that Heartlands have a higher proportion of the total seed bank diversity (Table 1).

At a desert ecosystem, SSBs are usually composed of very small seeds. However, those seeds lack dispersal structures and are characterized by temporal and spatial fluctuations in quantity (Thompson and Grime 1979). Therefore, favorable conditions for germination and seedling establishment are unpredictable both in space and time in desert ecosystems (Anderson et al. 2012). While, in grassland ecosystems, there are consistent patterns of decreasing SBs towards a warmer climate (Mccarty 2001). In contrast, there is lower total seed production and density in alpine climates (Cummins and Miller 2002 ; Molau and and Larsson 2014). Therefore, micro-habitats (gaps, beneath shrubs and trees), and forest-stands affect seed bank density, and distribution too (Neeman and Izhaki 1999).

Table 1: 'The extent of SBs along with different habitats types; Number of observations (n), parameter estimates for the intercept (c), and slope (z) along with adjusted R^2 values are given'.

habitat	Stratum	n	intercept	Slope	Adjusted R^2
Field of Study †					
Alpine	seed bank	24	-0.05	0.48	0.87
Sub-alpine	seed bank	65	0.67	0.41	0.89
Boreal	seed bank	54	1.30	0.28	0.92
Alpine	vegetation	72	0.97	0.27	0.79
Sub-alpine	vegetation	71	0.97	0.25	0.76
Boreal	vegetation	72	1.16	0.22	0.79
Literature Study ‡					
Forest	seed bank	93	3.93	0.42	0.64
Grassland	seed bank	111	3.95	0.32	0.51
Heathland	seed bank	45	3.64	0.19	0.20
Grassland*	seed bank	30	4.34	0.44	0.84
Heathland*	seed bank	19	3.52	0.13	0.21
Grassland*	vegetation	30	3.42	0.36	0.84
Heathland*	vegetation	19	3.05	0.19	0.47

* 'Based on the subset of regained studies that include both seed bank and vegetation data'
† 'area in cm^2 calculations from the field study' and
‡ 'area in m^2 calculations from the literature study' (Vandvik et al. 2016).
"Note that because of variation in scales, different area values (cm^2 vs m^2) are used in the calculations for the two types of data and the intercepts are therefore not directly comparable".

2.7. The role of seed banks for biodiversity conservation

On ecological timescales, SBs represent local 'biodiversity reservoirs' that can contribute to population persistence and biodiversity preservation (Plue and Cousins 2013b). It contributes to the maintenance of genetic and trait diversity within populations (Mandak et al. 2012) and preserves plant species through temporal storage effects (Funk et al. 2008; Haddad et al. 2003). On evolutionary timescales, SBs increase the mean generation times of populations, thereby affecting the potential rate and direction of evolutionary changes (Evans and Dennehy 2005). Therefore, SSBs provide a memory of past vegetation and represent the structure of the future population too. So that characteristics of the SSBs are essential in determining the regeneration potential and resilience of the target community (Bekker et al. 2000). Thus SSBs constitute the survival of plant species (Baskin and Baskin 2003), a source of propagules after disturbances, and seed production failing periods (Williams et al. 2005). Therefore, a 'healthy' SSB is vitally important for the conservation of biodiversity and long term species survival (Adams et al. 2005). It offers the opportunity for plants to disperse through time (Plue et al. 2008) and conserve remnant plants. Likewise, SSB retains a functionally and genetically diverse below-ground plant species pool available for germination and re existence (Anderson et al. 2012; Gremer and Venable 2014).

Disentangling the role of SBs for biodiversity conservation and population dynamics is essential for understanding the basic ecological patterns and processes (Alexander et al. 2012). Seed banks have also been recognized by their potential contributions for the restoration of threatened and declining plant populations (Adams et al. 2005) and communities (Fourie 2008). However, the success of seed banks for biodiversity conservation depends on the nature of a site. For example, SSBs that arrive on sites that have a weedy nature are less diverse (Bossuyt and Honnay 2008). Tekle and Bekele (2000) documented a very low similarity between seed banks and the standing vegetation (Table 2). Therefore, SBs are different from the existing vegetation of relatively little value for the conservation and restoration (Scott and Morgan 2012).

Table 2: 'Species numbers and life-forms occurring in the seed bank and standing vegetation' (Tekle and Bekele 2000).

Life form	NSB[a]	NSEB[b]	NSC[c]	NSEV[d]	NSV[e]
Trees	2	0	2	30	32
Climbers	6	1	5	4	9
Shrubs	3	1	2	50	52
Grasses	7	3	4	34	38
Herbs	53	24	29	98	127
Total	71	29	42	216	258

[a]NSB: 'Number of species in seed bank';
[b]NSEB: 'Number of species exclusive the seed bank';
[c]NSC: 'Number of species common to the seed bank and the standing vegetation';
[d]NSEV: 'Number of species exclusive to the standing vegetation';
[e]NSV: 'Number of species in the standing vegetation';

Therefore, herbs were dominant in the seed bank and standing vegetation (Table 2). Herbs that exclusively occur in the seed bank and standing vegetation accounted for 83 and 45 % respectively (Tekle and Bekele 2000). Furthermore, the composition, and abundance of seed-bearing species and species life forms are influenced by composition, phenology of local vegetation, and disturbances at forest edge (Fourie 2008; Esmailzadeh et al. 2011).

3. Mechanisms and types of seed dispersal

Dispersal is the movement of organisms, their propagules, diaspores, and genes (e.g. pollen in plants) away from the parent plant (Nathan 2001; Petit et al. 2004). Seeds can be dispersed individually or collectively both in space and time. Hence, the arrangements of seed dispersal are determined by the dispersal mechanisms. It has substantial inferences for the demographic and genetic structure, migration outlines, and species interactions (Duncan and Chapman 1999). Therefore, seed dispersal and movement of propagules subsequently depend on abiotic and biotic agents. Though there is a variation in structures, dispersal types, and diaspores among plants (Poschlod 1995), to what extent are this related to SD in the field is hardly known (Poschlod et al. 1996). However, the prevailing little information on mechanisms of seed dispersal (MSD) is used to classify types of diaspores, structure, and possible dispersal means for water, man, and machine dispersal agents (Willson and Traveset 2000).

3.1. Types of seed dispersal mechanisms

3.1.1. Seed dispersal by wind

Seeds that are dispersed by wind can float on the air and flutter to the ground. Besides, the types of seeds dispersed by wind are usually smaller, lighter, have wings and feather-like structures that enabled them to flow in the air. Though some wind dispersed seed pods face downwards, many have their opening at the top (Nathan et al. 2002). Those types of seeds need the wind to bend their stalks enough to let them fall out. Furthermore, wind-dispersed neo- tropical plants have adaption to release their seeds at dry season, when trade winds are stronger and trees lose leaves (Green and Figuerola 2005; Traveset et al. 2014).

Wind dispersal takes place in almost all species. Although most seeds can travel notable distances (Nathan et al. 2002; Valido et al. 2019), seeds with a mass less than 0. 05 mg (species in Orchidaceae and Pyrolaceae family) have the potential to be dispersed over a long distances (Green and Figuerola 2005). Those are pioneer species that appear on restoration sites very quickly if conditions are suitable (Nathan 2001). However, potential wind dispersal distances can be derived from fly characteristics and fall velocity. Furthermore, plant species such as '*Betula*, *Acer*, *Lathyrus*, and *Viola*' could cover over 500 m via wind (Verkaar 1990). On the other hand, most herbs including '*Tragopogon'* would need more than one century to cover 500 m distance by the wind. However, different meteorological conditions and thermal connections were not comprised. Therefore, flying distances are investigated in wind tunnels. Accordingly, seed wings carried out by wind are twisted and balanced (Duncan et al. 2009). However, some seeds such as 'Lime and Ash' have only a single wing (Nathan et al. 2002). Therefore, a plentiful of seeds are need to maximize the possibility of germination at a suitable site. For example, species in the 'Asteraceae' family have reduced dispersal capabilities due to few seeds produced per species (Cody and Overton 1996). Moreover, the manner of seed flight differs from dust and aerosols (Trakhtenbrot et al. 2005). It is not also surprising that wind dispersal will take place along the soil surface. Therefore, seeds that move along the ground (secondary dispersal) can cover distances from several centimeters to several meters (Parolin 2006). For example, seeds of '*Spergularia salina'* were transported to bare soil than dense vegetation. Conversely, it traveled no further than 1 m via wind and dispersed extra centimeters via water (Higgins et al. 2003). Therefore, wind dispersal can also be combined with other dispersal possibilities.

3.1.2. Seed dispersal by animals

Animal disperses (birds, mammals, ants, and vertebrates) are expected to play a key role in formation of plant communities, expanding existing population, founding new ones, and creating SSBs (Schupp and Fuentes 1995). In this regard, if the area surrounding the disturbed site has enough animals, habitat, and seeds to disperse, animals will accelerate plant succession on disturbed patches (Neilan et al. 2006; Howe et al. 2014). Moreover, animal directed dispersal may have large-scale effects on the geographic expansion and plant resilience (Lankau et al. 2011). For example, old fields were quickly colonized by 'black walnuts (*Juglans regia*)' because of 'Rooks (*Corvus frugilegus*) and *Carrion Crows'* preferentially cached nuts in disturbance zones of Poland. Consequently, the range of *J. regia* has undergone rapid expansion over the past 50 years (Lenda et al. 2012). Although animal dispersal is a passive form of transportation via attachment to fur or wool, it is believed to cover long dispersal distances depending on the duration of attachment, movement, and speed of the animal.

A vast proportion of plant species are dispersed via vertebrates, but not by other means in the tropical forests (Charles-Dominique 1993). Thus the relative importance of different dispersal mechanisms are different among forests of neo-tropical and paleo-tropical (Richards et al. 2012), evergreen and deciduous (Brown and Lugo 1990). For example, in species-rich neo-tropical forests, 87 to 90% of species produce diaspores that are dispersed by the vertebrate gut (Peres and van Roosmalen 2002; Tabarelli and Peres 2002). However, large-seeded forest trees are recently unable to colonize new patches as their vertebrate disperses are now under extinction. Similarly, large-seeded (>20 mm) fleshy-fruit species show very low colonization rates and are missing due to extinction of large-vertebrate in the previous three centuries (Cox et al. 1991; Thetbaud et al. 1991). Similarly, in the Atlantic forests, and neo-tropics fruits of the families 'Melastomataceae, Rubiaceae, Flacourtiaceae, and Myrsinaceae' are usually consumed by small passerines such as manakins and tangaras (Develey and Peres 2000). For example, seven 'tanager' species are known to eat fruits of '*Leandra barbinervis*, *Leandra levigata,* and *Miconia rigidiuscula* (Melastomataceae species), in southern Atlantic montane forest (Rodrigues et al. 2009). Therefore, seed passage over long retention times through their digestive tract effectively increased germination rates of four species under the 'Myrtaceae' family (Traveset et al. 2007 ; De moraes et al. 2000). Besides, seeds of families (Eugenia, Camponesia) and Myrtaceae genera, are primarily dispersed by tamarins, capuchins, howlers and spider monkeys. Likewise, Myrtaceae seeds are frequently ingested by primates ranging in size from tamarins to woolly monkeys (Terborgh and Joseph 1994). Likewise, quetzals, toucanets, and bellbirds are the dispersers of 40 tree species of the family Lauraceae (Wenny and Levey 1998).

Mammals are considered as potential seed dispersers for fleshy-fruited plants. They have high retention time in the gut, which enable frugivorous mammals to be key vectors for long-distance dispersal (Jordano 2017). Therefore, those long-distance mammalian driven dispersal events determine the colonization capacity of vacant sites and plant population expansion to different habitats (Cain et al. 2000 ; Nathan 2006). Besides, seeds attached to the hair of fallow deer and cattle might be dispersed 1 km (Kiviniemi 1996 ; Pesendorfer et al. 2016). However, body size, digestive strategies, ranging behavior, and defecation influence the success of mammalian dispersal too. In this regard, larger animals prefer to swig bigger seeds. Furthermore, more than 8% of artificially attached seeds both with hooks (*Bromus erectus*) and smooth surface (*Helianthemum nummularium*) are transported over more than 40 days via sheep (Fischer et al. 1996). Consequently, at least more than three million seeds are dispersed by the wool of a flock of sheep of 350 individuals during one vegetation period. During this time sheep could cover distances over more than 100 km. Likewise, 21 grassland species were dispersed by the dung of sheep. Conversely, most grazing animals disperse seeds via dung. For example, seeds of *Matricaria chamomilla* (198000 seeds with a germination capacity of 27%) and Plantago species (85000 seeds with a germination capacity of 58%) were dispersed by cow dung (Wehncke et al. 2010; Power and Koutsos 2019 ; Rehm et al. 2019).

Animal dispersed seeds and fruits which are covered by hooks or spines will be attached via animals' fur or feathers (Powe and Koutsos 2019). Therefore, those seeds will be carried out a sufficient distance from the parent plant to give them a space to grow (Traveset et al. 2007). Ultimately, some plants produce their seeds inside fleshy fruits to give a chance to be eaten by animals. Therefore, the fruit is digested, but the seeds pass through the digestive tract and are dropped in other locations. However, seed predation and animal dispersal varies over time and space in relation to their abundance and activity (Traveset et al. 2014).

Feeding patterns preference among animals affect the success of animal dispersal too. For example, birds, rodents, and fish preferentially feed on large seeds (Rehm et al. 2019). Whereas invertebrates often show a preference for smaller seeds. On the other hand, seeds that have hooks or sticky surfaces are able to hitch on the fur of mammals. Despite seeds with a nutritive reward that attract foraging animals, are transported by their gut (Traveset et al. 2014; Power and Koutsos 2019). In the process dispersal seeds can be cached among a suitable habitat already colonized by the species, at unsuitable habitat, and in suitable habitat that can be colonized in the process (Pesendorfer et al. 2016). Accordingly, it is help full to recognize the structure of landscape and vegetation which attracts hoarders (Bossuyt et al. 2020). So that seed dispersal via animals is a particular function that greatly illustrates the importance of studying ecological interactions at a community level (Green and Figuerola 2005; Kollmann 2000; Chapman et al. 2018).

3.1.3. Seed dispersal via man and machines

Humans are encouraging ecosystem restoration process though seed dispersal though their roles are a controversial (Lippe et al. 2013). For example, humans are a key agent for the disappearance of a plenty of plant species and biodiversity resources (Auffret and Cousins 2013). Besides, in Mediterranean ecosystems alone, intense human presence has resulted in several phases of habitat degradation (Valladares et al. 2014). It is also via human activities that the Brazilian Atlantic forest which is the highest global priorities for conservation (Myers et al. 2000) had disturbed through shifting agriculture, logging, wildfires and fores fragmentation (Oliveira-Filho et al. 1994; Gascon et al. 2000). Roadsides are particularly relevant as many invasive species expand their ranges rapidly along with road networks (Tabarelli et al. 1999; Liu et al. 2008). On the other hand, much of biodiversity resources and plant species have also come to existence as a result of humans at various ecosystems. In this regard, humans are the one who carries seeds from one locality to another and from country to country as a secondary dispersal (Wichmann et al. 2009 ; Lippe et al. 2013). Therefore, human-mediated dispersal is a driver of the long-range spread of plants and is increasingly gaining attention in dispersal ecology (Wichmann et al. 2009).

Due to agricultural practices in historical times, attachment to vehicles was among possibilities for plants to migrate long distances. Seeds reach over more than 256 km through vehicles and motors via attachment with mud on cars (Duncan and Chapman 1999 ; Lippe et al. 2013). Besides, harvesting machinery (Auffret and Cousins 2011) and Hay-making machinery are expected to disperse seeds which might contribute to grassland restoration in nature reserves (Bakker and Olff 1995). In this regard, a single tractor can transport up to thousands of seeds of many species. However, Vehicles transport fast-growing weeds that can contribute little to restoration of plants important for conservation (Strykstra et al. 1998). Therefor, machines can play a positive or negative role depending on a species and ecosystems.

3.1.4. Seed dispersal through water

This mode of dispersal is particularly applied to fruits which are waterproof, float like a water lily, and seeds of palm trees and alder (*Alnus glutinosa*) (Thetbaud et al. 1991). Thus this kind is an important mechanism that determines the spatial distribution of seed banks in wetlands (Welling et al. 1988 ; Huiskes et al. 1995). Furthermore, the tidal water can disperse many more seeds (Change et al. 2005). On the other hand, scirpus seeds can float on the water surface for several days, which facilitates its long-distance dispersal (Chen et al. 1992). Thus the distribution of Scirpus seeds may heavily be influenced by the tidal regime besides the location of mother plants (Cheng-huan et al. 2009).

'Wings of seeds dispersed by water contain pockets of air' that enable them to float on the water. Therefore, the presence of floating devices enables seeds to travel by oceanic current or rivers (Cappers 1993) (Parolin 2006). Likewise, lines of seedlings from seeds deposited along the water's edge during a flood can originate. On the other hand, there are plant seeds such as 'marsh thistle (*Cirsium palustre*) and alder' that can germinate on the water itself. However, there are many seeds that did not spend much energy in complex mechanisms for dispersal. For example, 'Bluebells or wild hyacinths (*Hyacinthoides non-scripta*)' is an example of a plant that simply drops its seeds directly into the ground. Similarly, 'wood cranesbill (*Geranium sylvaticum*)' disperses its seeds thru own adaptive mechanisms. However, such plants will tend to spread and colonize new areas very slowly (Tudge 2006). Futhermore, common 'dog violet (*Viola riviniana*)' uses the similar strategy after seeds are spread further tranquil by ants.

3.2. Factors affecting the effectiveness of dispersal

3.2.1. Ecological factors, the nature of the seed, and disperses

Seeds are specialized structures that rise plant success thru conferring their offspring at a suitable site. However, a variety of factors will determine the success of seed dispersal and dispersal phenology (Traveset et al. 2014). Therefore, seed predation may vary among seeds deposited in different forms (Dale et al. 2002). Moreover, fruit enlargement and seed maturation should be matched with accessibility of dispersal agents and suitable environmental conditions (Traveset et al. 2012). Dispersal mode and success is also influenced by seed size as well (Butler et al. 2007). Although morphological adaptations increase the probability of dispersal, seeds are able to disperse via other vectors that they are not adapted (Higgins et al. 2003). Likewise, numerous plant species have seeds that have not any specific adaptation mechanism for dispersal. The manner of land preparation and soil management favors the uniform distribution of the seeds in the soil too (Bossuyt et al. 2020). On the other hand, landscape composition, configuration, and land-use changes influence the success of dispersal (Mcdonald et al. 2016).

Seed dispersal effectiveness comprise of visitation rate, the number of seeds acquired per visit, treatment in the mouth, gut and aspects of seed deposition (Schupp et al. 2010). Therefore, characterizing seed dispersal effectiveness allows us to compare contributions of different disperses to plant demography and fitness (Figuerola et al. 2003). For example, gut passage in all bird species enhanced seed germination rate and dispersal quality. Therefore, quantifying seed dispersal effectiveness and the processes that affect its components allow ecologists to learn about the contribution of dispersal to the fitness of a plant species (Schupp et al. 2010). As a result, the structure of the soil surface, vegetation, movement to the ground and structures that catch seeds affect the success of dispersal after arrival (Bossuyt et al. 2001).

3.2.2. Dispersal distance

The contribution of dispersal distance to plant fitness in terms of seed dispersal effectiveness is unclear (Schupp et al. 2010) although distance is important for colonization. Therefore, even though long-distance dispersal events is difficult to quantify, its consequence is helpful to the population dynamics (Nathan and Muller-Landau 2000). Besides, long distance dispersal allows colonization of new areas, the expansion, and movement of species across ranges (Cain et al. 2000). Therefore, distance will provide the success of seed dispersal-effectiveness. (Lesser and Jackson 2013). However, at a diverse landscapes, increasing dispersal distances can reduce density-dependent mortality caused by intraspecific competition, specialized pathogens and predators (Schupp et al. 2010).

Long-distance dispersal facilitates gene flow, novel population establishment, spatial synchrony, population rescue, and range shifts in response to environmental variation (Engler and Guisan 2009). used parentage analysis of trees in newly established stands of ponderosa pine (*Pinus ponderosa*). Therefore, long-distance dispersal events are necessary for population establishment and initial population growth (Lesser and Jackson 2013). Furthermore, long-distance dispersal increase dispersal effectiveness by enhancing dispersal quality. Besides, long dispersal distances can facilitate the arrival of seeds to locations suitable for seed germination and seedling growth (Wenny 2001). For example, 'White-spectacled Bulbuls (*Pycnonotus xanthopygos*) and Tristram's Starlings (*Onychognathus tristramii*)' disperse desert seeds in such way (Spiegel and Nathan 2007). However, some species disperse seeds to distant patches, whereas others to within habitat patches (Wenny 2001; Gomeza et al. 2003). On the other hand, seed viability may reduced as dispersal distance increases (Valido et al. 2019). For instance, according to Trakhtenbrot et al. (2005) and Higgins (2013) from seeds traveled more than 3 m, only 5% turned out to be viable, compared with 60% of the seeds at 1 m distance. Therefore, survival of plants that are dispersed far away from the parents are higher due to activities of density-dependent seed and seedling predators and pathogens, which often target the higher concentrations of seeds underneath adults (Harms et al. 2000). Moreover, competition will be lower when seeds are transported away from their parents (Valido et al. 2019). In contrast, long-distance dispersing seeds may have low viability as they may arrive to un suitable and eroded sites. Moreover, those sites could have harsh environment and extra enemies (Mcdonald et al. 2016).

3.2.3. Seed selectivity

When the seed size is large and seed numbers are not limited, birds forage on and disperse seeds that they preferred. For example, arthropods and fungi often damage pine cones and acorns during maturation (Espelta et al. 2009). Besides, many birds examine seeds and avoid those with damage caused by insects (Tomback and Linhart 1990). Therefore, it is via visual inspection that the birds assess seeds (Espelta et al. 2009). Similarly, 'Clark's Nutcrackers (*Nucifraga columbiana*)' discarded 4.5% of pinyon pine seeds. Furthermore, birds did not only ignore damaged seeds within a tree; they also avoid trees and entire stands with low-quality cones. Thus the avoidance of damaged seeds via birds enhances the quality of seed dispersal. Beside seed size, the chemical composition affect the preferences of birds. For example, many broad-leafed trees and shrub species rely on scatter-hoarders for seed dispersal. Those species include; 'walnuts (Juglans spp.), hickories (Carya spp.), hazelnuts (Corylus spp.), beeches (Fagus spp.), and oaks (Quercus spp.) (Tomback and Linhart 1990 ; Tomback et al. 2016).

' The role of dispersal mutualism with plants is illustrated by the geographic distribution of the interaction and the adaptations of both disperses and plants'. Furthermore, plants have developed adaptations in seed morphology, chemical defenses, and annual seed-production patterns that maximize the mutualistic benefit from their animal partners (Vander Wall and Beck 2012) . Accordingly, most plants have large seeds that contain high levels of carbohydrates, moderate levels of lipids, and proteins which quickly satiate animals. Therefore, the more time the animal spends eating at the source, the longer it is exposed to predators and the more competitors can transport away (Vander Wall and Moore 2016). Furthermore, seeds such as 'acorns contain tannins and phenolic compounds' that are difficult to digest but that allow the seeds to be stored for an extended time without rotting. However, acorns are recalcitrant and do not remain viable in the seed bank for more than a year.

3.2.4. Effect of climate change and ecosystem types on seed dispersal

The initiation of dispersal, its subsequent movements, and settlement decisions are influenced by climatic conditions (IPCC 2007). Accordingly, climate change is predicted to have direct and indirect effects on the mode of seed dispersal both at the aquatic and terrestrial environments (Cain et al. 2000 ; Meynecke 2004). Furthermore, climatic factors can have a direct impacts on organisms during the transfer phase of dispersal, either by increasing (Cormont et al. 2011) or decreasing the dispersal distance (Bullock et al. 2012). Therefore, ongoing rapid climate change is resulted in shifting species' suitable environmental conditions (IPCC 2007). Though plants might survive to rapidly changing climate by shifting their distribution, mode of dispersal, and evolutionary adaptations (Bellard et al. 2012) , small and threaten population might extinct. Because those populations often occur in small and geographically restricted populations with low change of dispersal (Corlett 2011). Therefore, climate-induced factors could deteriorate habitat quality and growth of plant species (Bellard et al. 2012).

Climate change adjusts the geographical location of climatic niches and modifications of species allocations (Sala et al. 2000). In thrilling belongings, the whole future climatically suitable niche lies outside the present species range, necessitating migration and dispersal of the species to survive. For example, plant species that rely on another biota for dispersal, such as seeds carried by ants, will suffer if the phenology of the dispersal agent becomes asynchronous under climate change (Warren et al. 2016). Similarly, pole pine seeds had spread to post-glacial zone recently. In both terrestrial and marine ecosystems, most dispersing units move short distances away from the source although this is more prevalent in marine areas due to climate change (Kinlan et al. 2005). However, climate change induced factors may increase or decrease dispersal abilities depending on the ecosystem system types and species. Accordingly, changes in climatic factors at a certain ecosystems affects modes of seed dispersal but not in others. For example, in Amazonian forests (Vieira and Scariot 2006) and the Brazilian Atlantic forest (Tabarelli et al. 1999) plant species which were dispersed previously by abiotic means are gradually replaced by vertebrates. Besides, non-optimal temperature may induce flotation and dispersal in aquatic molluscs (Rosa et al. 2012). On the other hand, wind-dispersed thistles decreased reductions in wind speed (Bullock et al. 2012), while it increased as plants grow taller in warmer conditions.

4. The role of seed dispersal for an ecosystem restoration

Seed arrival is just the first step in ecosystem restoration process and ongoing vegetation dynamics. Moreover, sub-population genetic diversification, re-colonization, and re-establishment of populations will take place via dispersal as well. Therefore, early successional plants and communities which regrow from seeds will not able to colonize unless dispersal (Bruno 2014). However, effective colonization distance and invasions will vary with the type of plant species. For instance, short dispersed trees such as 'Scots pine' are less likely to colonize more remote, denuded areas, even when they would be able to grow well there. On the other hand, 'Rowan berries' carried long distances in the gut of birds can grow well in a rocky treeless landscape. Thus the preservation of the seed dispersal process should be considered as a tool for passive and low-cost ecological restoration (Henry and Maria 2014). However, out of all potential colonizers, species that have better dispersal abilities are expected to arrive faster and being adapt better.Therefore, dispersal and establishment ability of colonizing species is vital for ecosystem restoration (Tudge 2006).

In ecological restoration scenario, seed dispersal can be useful in both the planning stage and the monitoring of restoration effectiveness (Klaus et al. 2018). Consequently, it provides a valuable tool to look species composition and ecosystem functioning (Hansen et al. 2010). Thus the success of restoration depends on conditions for germination in the micro-habitat where seeds were dispersed (Poschlod et al. 1996; Poschlod et al. 2005). Likewise, it is though seed dispersal mechanism that seeds reach habitats that are favorable for survival. Accordingly, seeds which reach nutrient-rich sites have a higher chance of survival than that arrive nutrient poor sites (Lengyel et al. 2010). Therefore, dispersal strategies enable seeds to avoid adverse environmental effects such as fire and drought. Similarly, seed dispersal mechanism permit plants to colonize vacant habitats and new geographic regions that are not yet occupied by other plants (Manzano and Juan 2006). Though dispersal is the most important factor in a second phase of restoration, the permeability of landscapes to dispersal affects the rate of population spread and the genetic information exchange (Lavorel et al. 1995). Therefore, intensive land use can favor germination and establishment of species under extinction (Corlett 2011).

5. Contribution of seed dispersal for biodiversity conservation

Seed dispersal plays a key role in biodiversity conservation (Haddad et al. 2003) and is vital for plant survival (Von Blanckenhagen and Poschlod 2005). Accordingly, seeds arrive to the soil through dispersal and leave through germination and death. Hence, understanding the relative importance of seed dispersal via time and space is essential for understanding population dynamics and community assembly (Vigdis and Deborah 2006). More specifically, seed dispersal helps to minimize loss and threats of biodiversity (land-use change, invasive species, climate change and over-exploitation) (Sala et al. 2000) and genetically modified organisms or parts of their gene-type (Dale and Marie-Josée 2002).

It is through dispersal that seeds are able to escape from harsh climatic situations, (unsuitable sites, pests, pathogens, ruminants, and invasive species) (Trakhtenbrot et al 2005; Wehncke et al. 2010). Therefore, seed dispersal rashes plant threats resulted from excessive movement of elements not native to an ecosystem. Moreover, seed dispersal via various dispersal agents can be plentiful for population dynamics, genetic composition, and population processes (Bolker and Pacala 1999 ; Nathan 2001). Therefor, the rate of population spread in an ecosystem will be regulated through seed dispersal (Green and Figuerola 2005). Furthermore, seed dispersal lets re-occupation of patchy and fragmented surroundings that harbor populations (Trakhtenbrot et al. 2005). Correspondingly, It is helpful to exchange genetic information, facilitate genetic connectivity between fragmented patches, and promote long term species survival. Therefore, precise information on the role of dispersal for biodiversity conservation is helpful to design conservation strategy and restoration programs in degraded ecosystems.

6. Conclusions

Restoration ecology is aimed to restore a degraded ecosystem and re-establish disappeared plant species. In this regard, the re-appearance of plants in a degraded ecosystem largely depends on the presence of viable seed banks in the soil. Therefore, soil seed banks function as a reservoir for recruitment and are presumed to be a key component in ongoing vegetation dynamics and ecosystem restoration. However, the survival of seed banks depend on ecosystem types, climatic factors, and species. For example, seedlings from larger seeds take improved probabilities to endure due to their nutrient content. Besides, soil seed banks in an Afro montane ecosystem have the capacity to survive for a longer period of time than tropical rain forests and savannas. Furthermore, plants in this ecosystem store large quantities of seeds in the soil. In addition to ecosystem types and climate change, micro-habitats and forest-stands affect density and distributions of seed banks too. Therefore, it is crucial to gain the species composition of the seed bank before starting a restoration project in an ecosystem.

If the species had been lost from the soil seed bank, it has to be transported to the site of re-appearance by dispersal agents. Therefor, the presence of dispersal agents have a significant role in the success of ecosystem restoration process. In this regard, colonization rates, population spread, persistence, genetic structure, and population dynamics are influenced by seed dispersal. Hence, seed dispersal is helpful to illustrate the importance of studying ecological interactions at a community level. Consequently, seed dispersal can be useful both in the planning stage and the monitoring of restoration effectiveness. However, effective colonization distance varies with plant species as plants with better dispersal abilities arrive faster and adapt within habitats. Furthermore, the survival of seeds that is dispersed away from the parent plant are often higher.

Seed dispersal and soil seed banks conserve biodiversity via maintenance of genetic diversity, exchange of genetic information, facilitate genetic connectivity and long term survival. However, soil seed bank populations are heterogeneous and abnormally distributed based on ecosystem types and climate change effects. For example, soil seed banks have low survival rates in drier years. Climate change also affects dispersal either by rising or declining dispersal abilities and distance. Furthermore, seed dispersal enable seeds to escape unsuitable situations and threats. Generally, updated scientific information on soil seed bank dynamics, seed dispersal mechanisms, and restoration success are vital. Therefore, these help to make valid recommendations to develop the land-use plan, biodiversity conservation strategies, restoration programs, and climate change mitigation actions.

Declaration of interests

☒ The author declares that **he has no** known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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