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The Role of Soil Seed Bank in Forest Regeneration

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Authors' contributions

This work was carried out in collaboration among all authors. Author DMT designed the study. Author OJO managed the literature searches, author TCO wrote the first draft of the manuscript and author AIW revised the second manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Forest degradation and deforestation disrupts the structure and functions of the ecosystem with negative impacts on biodiversity and natural regeneration of the forests. In Nigeria, forests are lost through burning, shifting cultivation and logging of trees, thus reducing the potential of the forest to naturally regenerate and perform ecosystem functions as expected in a forest reserve. There have been insufficient knowledge about the role soil seed bank plays in forest restoration, and this will play an essential role in the natural regeneration of forest reserves. Seed bank performs tremendous roles in the restoration of degraded forest reserves, which includes donation of propagules, conservation of genetic diversity, the composition of the understorey plant community and recovery of biodiversity. These ecosystem functions are dependent on the dynamics of the soil seed bank as well as favourable environmental conditions.

Keywords: Resilience; biodiversity; dormancy; dispersal.

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1. INTRODUCTION

The seed bank can be described as the storage of plant seeds in the superficial soil. It can also be defined as the sum of all the litter and soil [1]. Soil seed bank can also be defined as the survival of viable seeds in the soil replacing the adult plant [2]. Soil seed bank describes and depicts seeds present in the soil [3]. This reservoir corresponds to the seeds which are yet to germinate, having inherent potential of replacing adult plants, which had disappeared by natural death or not, and potential plants that are susceptible to plant diseases, disturbance and animal consumption [4]. The soil at various depths is greatly increased momentarily by diverse medium of seed dispersal (animals, wind, water etc.), which is responsible for the addition of seed to the soil. Seeds are responsible for non-vegetative production of seedlings which could give rise to a naturally regenerated forest, assisted natural regeneration and artificial forest regeneration. Regeneration of forest can be described as the process of rejuvenating or reviving degraded forest ecosystems, degradation resulting from wild fire, human impact (burning activities, logging, farming) and natural disasters (flood, volcano, hurricane etc). One of the key roles played by soil seed bank is that, it is an essential component of plant communities [2] and can be used to predict secondary succession [5,6]. The seed bank houses seeds which are the basic parts of all plants which carries genetic materials from one generation to another generation, hence, their role in forest regeneration cannot be over-emphasized [7,8]. The availability or absence of seeds determines the representation or its complete loss in a natural forest ecosystem [9]. However, when the seed bank is replaced deliberately or consciously for restoration purposes by human efforts, it can be referred to as artificial forest regeneration (plantation forests). Aside from housing seeds, the seed bank serves as a living history of non-existing plant species, whose dead traces or remnants could not be found. After subjecting results obtained from the seed bank to data analysis, the future of a forest ecosystem can be pre-determined. Understanding the role of seed bank and it's uses will not only add to existing knowledge, but will also assist in regeneration of degraded forests in Nigeria. The composition of seed banks is variable, and is classified as temporary or persistent, when modifying the regeneration of the vegetation during different time of the year. Temporary banks are composed of seeds of short life, which do not present dormancy and are dispersed in time for short periods during the year [10]. Species like *Avena fatua*, *Alopecurus myosuroides*, *Galium aparine*, *Lapsana communis*, *Matricia perforate*, *Centaurea cyanus*, are classified as temporary, having more than one year of age and reserves of seeds remain in the soil year after year, generally buried into the soil. *Chenopodium album*, *Sinapis arvensis*, *Aethusa cynapium*, *Papaver rheoeas*, *Viola arvensis*, *Kickia spuria*, *Capsella bursa-pastoris* and *Amaranthus retroflexus* are examples of persistent soil seed banks [11]. There is an urgent need to naturally restore degraded forest reserves in Nigeria, hence it is expedient to understudy the more on the role seed bank plays in the process of natural forest regeneration.

2. DISCUSSION

2.1 Characteristics of the Soil Seed Bank

2.1.1 Soil seed bank density and seed dormancy

The success of a seed bank depends on the seed density ready to germinate, when replacement of a plant is necessary and when the environmental conditions for establishment are favourable [11]. The longevity of seeds represents a major mechanism of survival of certain weed species, and this leads to a continuous source of emergency. The seed longevity represents a major mechanism of survival of certain weed species, and this leads to a continuous source of emergency [8]. The seed longevity in the soil varies among species characteristics of the seeds, burial depth, and climatic conditions [12]. A study with weed species buried and placed to germinate in different times of the year After 40 years, the species, *Amaranthus retroflexus*, *Ambrosia elator*, *Lepidium virginucum*, *Plantago major*, *Portulaca oleracea* and *Rumex crispus* were the originated seedlings [13].

The seed dormancy is another characteristic that affects the seed bank reservoir. The seed populations of several vegetable species behave in different ways with respect to germination; the weeds produce polymorphic seeds, with a certain proportion that is dormant while the others are not [14]. Several internal and external factors prevent seeds from germinating. Among the internal factors are: the presence of a seed coat, which is a barrier to the penetration of water and oxygen; presence of a biochemical inhibitor in the seed; and immature embryo. Among the external factors, the most common are soil water content and temperature [15]. The term innate dormancy (primary) and induced dormancy (secondary) characterise the development of the dormancy in the mother plant and after the dissemination in space, respectively [14]. The term enforced dormancy, has been used for the inability of the seeds to germinate due to an enviromental restriction, like water deficit, low temperature and poor aeration [16]. However, some seed physiologists do not consider the induced dormancy as an actual dormancy but responds only to favourable conditions for germination [17]. This situation is more conveniently referred to as a case of quiescent seeds. The dormancy represents a mechanism of species preservation in the seed bank, distributing the germination through the year [9]. It can guarantee the species survival in the form of seeds, under adverse conditions, even when the population of plants is completely eliminated [14].

2.1.2 Dispersal of seedbank

Most species are capable of long-distance seed dispersal, despite morphological dispersal syndromes that would indicate morphological adaptations primarily for short-distance dispersal [18,19]. Assessments of mean migration rates found no significant differences between wind and animal dispersed plants [20]. Long-distance migration can also be strongly influenced by habitat suitability [21] suggesting that rapid migration may become more frequent and visible with rapid changes in habitat suitability under scenarios of rapid climate change. The discrepancy between estimated and observed migration rates during re-colonization of northern temperate forests following the retreat of glaciers can be accounted for by the underestimation of long-distance dispersal rates and events [10]. Nevertheless, concerns persist that potential migration and adaptation rates of many tree species may not be able to keep pace with projected global warming [22]. However, these models refer to fundamental niches and generally ignore the ecological interactions that also govern species distributions.

2.2 The Need for Forest Restoration

2.2.1 Deforestation: A major cause for the need of forest restoration

Deforestation can be defined as the conversion of forest ecosystem (natural and secondary re-growths) to a preferred permanent non-forested land use such as agriculture and urban development [23]. Deforestation is of major concern for the developing countries of the tropics [24] because it causes rapid reduction of the tro pical forests [25] causing loss of biodiversity and enhancing greenhouse effect [26]. A plantation of trees established primarily for timber production can also be referred to as a forest according to Food and Agricultural Organisation [27] and therefore does not classify natural forest conversion to the plantation as deforestation (but still records it as a loss of natural forests). Deforestation has served a major threat to the forest ecosystems from time immemorial, causing a major loss of biodiversity as well as global climate change [28]. These loss can be attributed to illegal logging of trees for fuelwood and charcoal, wildfire, unregulated burning for harvesting logs, urbanization and natural disasters.

Forest degradation occurs when the ecosystem functions of the forest are degraded but where the area remains forested rather than being cleared [29]. Logging opens mature forest area for colonization [30]. Also, new roads are constructed in the forest during logging [31]. This has the potential of increasing spontaneous colonization of logged forest by agricultural colonist. The ability of such tropical forest ecosystems to recover is limited as high and excessive logging has negative effects on the availability of quality seed germplasm for natural regeneration [32,33]. Professor Norman Myers, one of the foremost authorities on rates of deforestation in tropical forests described rate of world's deforestation thus: "the annual destruction rates seems set to accelerate further and could as well double in another decade" [34]. Hence, an urgent need for forest restoration.

Forest restoration or rehabilitation aims to manage ecosystems for conservation and preservation rather than extraction [35]. Four possible methods for restoring forest vegetation exist: (i) natural regeneration, (ii) direct seeding, (iii) planting seedlings, and (iv) incorporating restoration goals in plantation programs [36]. Natural regeneration is the cheapest approach for rehabilitating degraded forest ecosystems, provided that the previous disturbance has left some residuals (e.g. soil seed banks, mother trees or root shoots) that can serve as "succession primers" [37]. In frequently disturbed habitats, such as arable fields, vegetation composition is expected to be mainly determined by the seed bank composition [38]. In order to achieve restoration of forests, the soil seed bank performs the following roles [39].

2.2.2 Propagules donor

One of the significant role the seed bank plays is donating propagules to the soil eco system. These propagules are derived from viable seeds present in or on the soil. Species have two main means by which they adapt to change: they can either disperse by seed or vegetative propagules in the direction of a more favourable environment, or they can change their gene frequencies to favour genotypes (genetic constitutions) that are better adapted to the changed environment [40]. In restoring degraded forests, the first step is to quantify the natural regeneration potential of the forest and this is carried out by determining the population dynamics of the accrued seeds in the soil as well as that of the seedling emergence [37], this will help us to know if the regeneration process should be allowed to take place naturally or further assisted. Assessment of the seedlings emergence from the naturally regenerated soil seed bank will bring about an understanding of the species whose seeds are viable in the seed bank and are able to subject to natural selection and contribute to the adaptive capacity or resilience of tree species and forest ecosystems [41,38]. Diversity at each of these levels has fostered natural (and artificial) regeneration of forest ecosystems and facilitated their adaptation to dramatic climate changes that occurred during the quaternary period [42], this diversity must be maintained in the face of anticipated changes from anthropogenic climate warming [43].

2.3 Composition of the Understory Plant Communities

The seed bank plays a crucial role in determining the composition and spatial structure of understory plant communities in degraded forests following soil disturbances such as wildfire, harvesting and/or logging [44,45]. This could be derived from the species composition and species richness of the seedlings which emerges from the soil seed bank. While some seeds are visible enough to identify because of their physical attributes, other seeds are tiny and will require some advanced techniques for identifying the seed [46]. The knowledge of the understorey plant communities with the canopy/tree community helps in the understanding of the diverse kind of plants that existed prior to perturbation. Invasive species among the understorey plant communities could be prevented once identified through early observation from the seedling emergence in a naturally regenerating forest or seed specific identification. Preventing the wide-spread of invasive species can be done early enough if observed from the soil seed bank before displacing the indigenous species [42].

2.4 Recovery of Biodiversity in Tropical Forests

As defined by the Convention on Biological Diversity, “biological diversity” means the variability among living organisms from all sources including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, among species, and of ecosystems [47,48]. Biodiversity may include the variety of life at multiple scales of ecological organization, including genes, species, ecosystems, landscapes, and biomes [49,50]. Biodiversity can be referred to as the variety that exists among all levels of life forms. One of the major roles of regeneration from soil seed bank is recovery of biodiversity in tropical forests as observed in Porto Trombetas, Para state, Brazil after a major disturbance as a result of anthropogenic impact. The role of biodiversity in the resilience of forest-carbon dynamics is evidenced by the specialized species that have evolved and characterize the distinctive forest ecosystems found in the major climatic and forest domains tropical, temperate, and boreal [23]. Over time, evolution results in new plant traits, through the filter of natural selection [51], and aided by ecological processes such as dispersal, result in forests comprising species that function optimally under the climatic conditions and disturbance regimes prevalent in each domain. The recovery-ability of vegetation after disturbance is believed to lie mainly in the buried seed population [52]. Resilience in ecosystems is related to the biological diversity in the system and the capacity that it confers to maintain ecosystem processes [53].

Table 1. Relative importance values of seedling emergence in sample plots of Olokemeji Forest Reserve, Ogun state Nigeria

S/N	Species	Family	HP1 (0-15cm) RIV	HP(15-30cm) RIV	UP(0-15cm) RIV	UP(15-30cm) RIV	FT1(0-15cm) RIV	FT1(15-30cm) RIV	FT2(0-15cm) RIV	FT2(15-30cm) RIV	AP1(0-15cm) RIV	AP1(15-30cm) RIV	AP2(0-15cm) RIV	AP2(15-30cm) RIV
1	*Leptochloa caerulescens*	Poaceae	0.54	0	1.08	0.54	8.66	0	7.57	1.62	0.54	0	0	0
2	*Talinum fruticosome*	Potulaceae	2.21	2.95	0	0	2.21	0.74	0	0	6.64	2.21	2.21	0.74
3	*Phyllantus amarus*	Euphobiaceae	4.73	0	1.58	0.78	2.37	2.37	0	1.57	0	0	0.78	0
4	*Oldelandia corymbosa*	Rubiaceae	0	0	12.29	0.77	0.38	0	0	0	0	0	0	0
5	*Mariscus alternifolius*	Cyperaceae	1.98	0	1.32	6.61	0	0	0	1.98	0.66	0	0	0
6	*Desmodium scopiurus*	Fabaceae	1.74	0	0.87	0	0	1.74	0	0	0	0	0	0
7	*Euphorbia heterophylla*	Euphobiaceae	0	0	1.41	0.7	0	0	0	0	2.11	0	0	0
8	*Chromolaena odorata*	Asteraceae	0	0	1.09	0	0	0	0	1.09	1.09	0	0	0
9	*Cynodon dactylon*	Poaceae	0	0	0	0	1.09	1.09	0	0	0	1.09	0	0
10	*Brachiara deflexa*	Poaceae	0	0	1.09	0	0	0	0	0	2.19	0	0	0
11	*Ageratum conysoides*	Asteraceae	0	0	0	0	0	0	0	0	2.17	0	0	0
12	*Tridax procumbens*	Asteraceae	0	0	0	0	0	0	0	0	1.09	0	0	0
13	*Vernonia galnensis*	Asteraceae	0	0	0	0	0	0	0	0	0	0	1.09	0

Source: (Taiwo et al., 2017)

Table 2. Relative importance value of woody species in study plots of Olokemeji Forest Reserve, Ogun state, Nigeria

Species	FT1 RIV	FT2 RIV	HP RIV	UP RIV	AP1 RIV	AP2 RIV
Tectona grandis	15.31	17.22	5.73	16.45	0	0
Albizia zygia	0	0	11	0	3.41	2.56
Azadiracta indica	0	0	5.68	2.84	0	0
Agnossius leocarpus	0	0	6.05	0	0	0
Albizia lebeck	0	0	0	4.95	0	0
Delonix regia	0	0	0	4.39	0	0
Gliricidia sepium	0	0	4.39	0	0	0

Citation: Taiwo et al., 2017

3. CONCLUSION

In order to restore the forest, studying the role of soil seed bank will bring to awareness the species composition of the seedlings, the historical knowledge of the lost forest as well as the biodiversity of the species of seedlings observed from the soil seed bank, all of these important information will help to proffer the type of forest restoration that can be successfully practised in degraded forests ecosystem.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Appendix 1. Natural regeneration of lowland Amazonian rainforest 18 years after clearcutting. Regrowth primarily from soil seed bank and re-sprouting of harvested trees. Porto Trombetas, Brazil

Appendix 2A and 2B. Forest resilience as illustrated by the recovery of mixed-wood forest in eastern Canada as a result of red pine plantation on a logged site, with natural infilling by deciduous species over a period of about 50-80 years

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