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ABSTRACT

Windbreaks are important to agricultural landscapes as well as biodiversity. They may preserve crops and livestock, harbor a diverse seed bank, as well as serve as corridors for forest animals. I examined species richness and density of seedlings within the understory of windbreaks connected to a forest. It was expected that closer proximity to forest would have higher species richness and seedling densities. A total of 220 seedlings were observed spanning across 35 different species and 23 families. The plant families of Lauraceae, Myrtaceae, and Solanaceae were found to have the greatest number of species diversity. *Viburnum costaricanum,* family Caprifoliaceae, and *Conostegia xalapensis*, family Melastomataceae, were found to have the two highest abundances of individual species. It was also observed that bird dispersed species, and medium growth tree species were the most abundant. Linear regressions confirmed that species richness increases with closer proximity to the forest, as well as abundance with closer proximity to the forest. This study suggests that attaching windbreaks to forest increases seedling diversity and abundance on the agricultural landscape. The study also proposes that there may be a limit to the distance that animals travel into the windbreaks, which forms a gradient of seedling growth. Therefore, the location of windbreaks is of vital importance.

RESUMEN

Los corta-vientos son importantes tanto para la agricultura como para la biodiversidad. Estos pueden preservar cultivos y ganado, albergar un banco diverso de semillas, así como servir de corredor para animales. Examiné la riqueza de especies y densidad de plántulas en el sotobosque de corta-vientos conectados al bosque. Un total de 220 plántulas se observaron, estás pertenecientes a 35 especies diferentes en 23 familias. Las familias Lauraceae, Myrtaceae y Solanaceae presentaron una mayor diversidad. *Viburnum costaricanum* (Caprifoliaceae) y *Conostegia xalapensis* (Melastomastaceae) presentarón la mayor abundancia. Se observó además que las especies dispersadas por aves, y especies de árboles de tamaño mediano son las más abundantes. Regresiones lineales confiran que la riqueza de especies aumenta con la proximidad al bosque, así como la abundancia es mayor cerca del bosque. Este estudio sugiere que corta-vientos conectados al bosque aumentan la diversidad y abundancia de plántulas en paisajes agrícolas. El estudio además propone que puede haber una distancia límite en la cual los animales viajan en el corta-vientos, lo que forma un gradiente de crecimiento de plántulas. Por lo tanto, la ubicación de los corta-vientos es de suma importancia.

INTRODUCTION

Human modifications to the environment are undeniable. A net loss of approximately 7-11 million km^2 has occurred in the last 300 years, mainly for timber extraction and agricultural expansion (Foley *et al.* 2005). Currently one of the largest terrestrial biomes is croplands and pastures, making up nearly 40% of land surface; even more, human activities comprise one-third to one-half of global ecosystem production (Foley *et al.* 2005). This means that one-third to one-half of the land transformations and usage is due to activities humans deem necessary, such as farming, logging, etc. In other words, human "needs" are dominating the planet. The structure and functioning of ecosystems are changed by human land use, as well as the interactions of the ecosystem with other systems such as water, atmosphere, and adjacent land (Vitousek *et al.* 1997).

The Monteverde region, which includes Cañitas, has experienced a variety of land transformations (Burlingame 2000). Land has switched between forests, pastures, and croplands several times throughout the last 60 years (Burlingame 2000). Currently, Monteverde is perceived as a farming and conservation community (Griffith *et al.* 2000). Strong winds during the dry season can have damaging effects on farm productivity, such as soil erosion, pasture and crop stress, which can indirectly decreases milk and crop yields on a farm (Burlingame 2000). To combat this, projects centering on the creation of windbreaks were started about 25 years ago (Harvey 2000b). One main purpose windbreaks serve to benefit agriculture is by protecting cattle and crops from the strong winds that could otherwise be damaging or cause injury (Nielson & DeRosier 2000). Over the course of these projects, more than a million trees have been planted in windbreaks, and over 70% of farms participated in the projects (Griffith *et al.* 2000).

Windbreaks also have other benefits, such as doubling as natural fencing and providing refuge by acting as corridors to birds, insects, and small mammals, which are often known to be popular pollinators and seed dispersers of species in these regions (Harvey 2000a,b; Brandle *et al.* 2004). These corridors may also connect diversity-rich forest fragment "islands", and preserve biodiversity by lowering rates of species extinction (Hobbs 1992). Windbreaks also help to increase the diversity of the farms by serving as protection, habitats, and stepping-stones for plant and animal species (Schroth *et al.* 2004). Diversity is an important factor in agricultural systems for more than just food production. It helps recycle nutrients, regulate microclimates, water processes; diversity also may suppress unwanted species, and remove harmful chemicals (Altieri 1999).

In 1995 Harvey surveyed windbreaks for species richness and abundance of seeds and seedlings in the understory of windbreaks in the Monteverde region. She found that windbreaks can enhance the seed bank by attracting seed-dispersing birds from the forest, in comparison to pastures. However she also found that seed disposition in proximity to the forest did not have a clear pattern (Harvey 2000b). Her study was one of the first to explore the effectiveness of windbreaks in preserving biodiversity; my study was created as a likeness to Harvey's efforts. I examined species richness and density of seedlings located within the understory of windbreaks connected to forest. Since Harvey surveyed the seedlings/windbreaks at a young age (6 years), I thought it would be interesting to examine the now older windbreaks for richness and density.

METHODS

Seedlings were examined in three different windbreaks connected to a forest fragment on the Bella Cruz farm in Cañitas, Costa Rica. Square plots were made of PVC piping with sides of 0.85 meters. Beginning where the windbreak met the forest, plots were placed down the windbreak at 10-meter intervals (Figure 1).

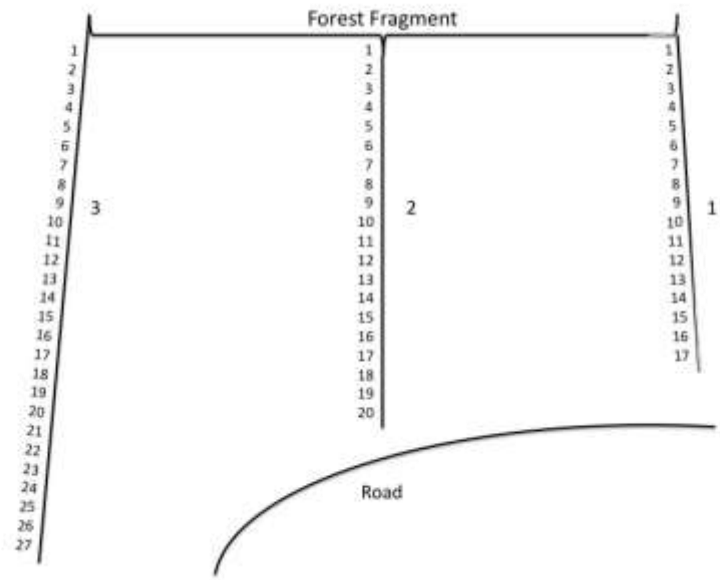

FIGURE 1. Diagram of my study site at the Bella Cruz farm in Cañitas, Costa Rica. The vertical lines represent the windbreak. The numbers 1, 2, and 3 to the right of the lines correspond to the number of the windbreak. The numbers trailing down the "windbreak" correspond to plot number, lower numbers are closer to the forest.

Within each plot, woody seedling observations were made. I excluded grasses, vines, lianas, and other non-woody seedlings; my goal was to survey the tree species within the windbreaks because the trees have a greater importance for biodiversity and regeneration properties of windbreaks. Woody plant samples were collected and numbered, with the abundance of each recorded. Samples were later taken to a Monteverde, Costa Rica plant expert for identification. The number of samples taller than 0.85 meters was also noted. A total of 64 plots were examined, 17 in the first windbreak, 20 in the second, and 27 in the third. Number of plots per windbreak varied with the length of the windbreak, as plots were placed down the entire length.

RESULTS

Species Richness

Combining the three windbreaks there was a net of 220 seedlings observed spanning 35 different species. Lauraceae was the family that had the largest number of different species, six total. The next families found to have a large number of different species were Myrtaceae and Solanaceae with four and three respectively (Table 1). The two most common individual species were *Viburnum costaricanum* of the family Caprifoliaceae with 35 % and *Conostegia xalapensis* of the family Melastomataceae with 14 % of the samples. No other individual species made up more than 9 %, with the majority composing less than 5 % each.

TABLE 1. Species of seedlings collected in three windbreaks connected to a small forest fragment, Cañitas, Costa Rica. Growth Form abbreviations are as follows: Tl= Large tree/Canopy, Tm=Medium tree/subcanopy, Ts=Small tree/understory, E=Epiphyte, S=Shrub. Disperser abbreviations are as follows: B=Bird, CH=Bat, EX=Explosive, G=Gravity, M=Mammal, W=Wind.

Family	Species	Growth Form	Dispersal mode
Apoycenaceae	*Apoycenaceae Spp. 1*		? B/W
Araliaceae	*Dendropanax arboreus*	Tl	B
Araliaceae	*Oreopanax vestitus*	E	B
Caprifoliaceae	*Viburnum costaricanum*	Tm	B
Erythroxylaceae	*Erythroxylum macrophyllum*	Ts	B
Euphorbiaceae	*Croton monteverdensis*	T	EX
Euphorbiaceae	*Croton niveus*	Ts	EX
Fabaceae	*Diphysa americana*	Tm	W
Flacourtiaceae	*Xylosma spp.*	T	B
Lauraceae	*Cinnamomum costaricensus*	Tl	B
Lauraceae	*Cinnamomum paratriplinerve**	Tl	B
Lauraceae	*Cinnamomum tonduzii*	Tl	B
Lauraceae	*Nectandra membranacea*	Tl	B
Lauraceae	*Nectandra salicina*	Tl	B
Lauraceae	*Persea spp.*	Tl	B/M
Malvaceae	*Pavonia rosea*	S	M
Melastomataceae	*Conostegia xalapensis*	Tm	B
Meliaceae	*Trichilia havanensis*	Tl	B
Moraceae	*Sorocea trophoides*	Tm	B
Myrtaceae	*Eugenia monteverdensis*	Tl	B/CH
Myrtaceae	*Myrcia splendens*	Tm	B
Myrtaceae	*Myrcianthus spp. A*	Tm	B
Myrtaceae	*Psidium guaiava*	Ts	M
Oleaceae	*Chionanthus panamensis*	Tl	B
Rubiaceae	*Rubiaceae Spp. 1*		? B/G
Rubiaceae	*Psychotria quinqueradiata*	S	B
Rutaceae	*Zanthoxylum fagara*	Tm	B
Sapindaceae	*Cupania spp.*	Tm	B
Sapotaceae	*Pouteria exfoliata*	Tl	M
Solanaceae	*Cestrum tomentosum*	T	B
Solanaceae	*Solanum cordovense*	Ts	B
Solanaceae	*Solanum tuerckheimii*	S	CH
Thymeliaceae	*Daphnopsis americana*	Tm	B
Tiliaceae	*Triumfetta semitriloba*	S	M
Verbenaceae	*Citharexylum costaricensis*	Tm	B

Other Observations

Of the 35 presumed different species of seedlings observed, 33 were identified to species. From species data, it was determined that 65% of the species are dispersed by only birds, but 71% can be dispersed by birds, while the remaining 29% dispersed by other methods such as exploding, wind, mammals, or bats (Table 1, Fig. 4). Birds disperse *Viburnum costaricanum* and *Conostegia xalapensis*, the two most commonly observed species.

Species also varied in their growth forms. Tree seedlings made up the greatest abundance growth form with 94%. Of the various types of trees, medium/sub canopy trees were the most common seedlings followed by large/canopy tree seedlings (Table 1, Fig. 5).

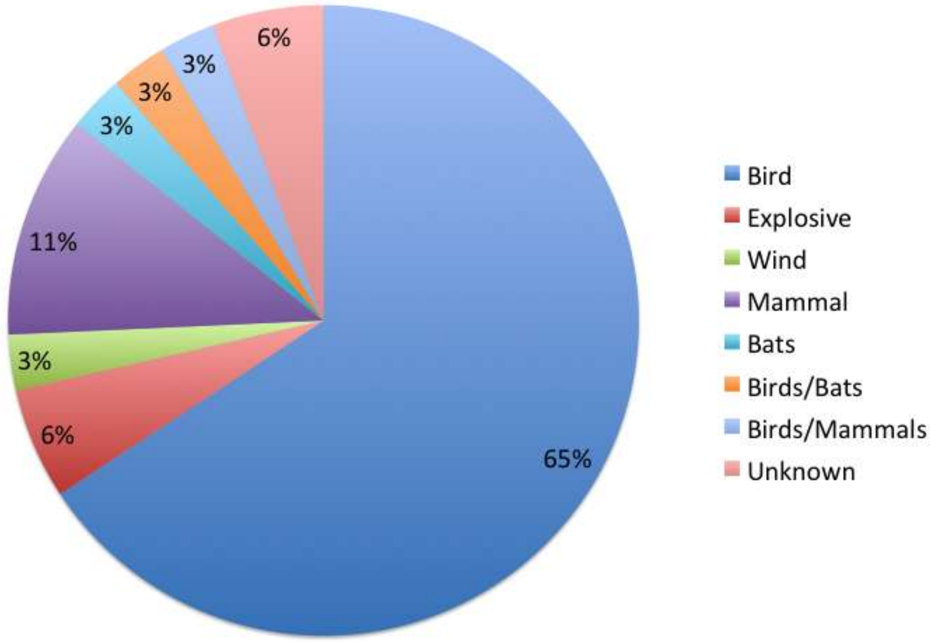

FIGURE 4. Percentages of Dispersal Modes for observed seedling species.

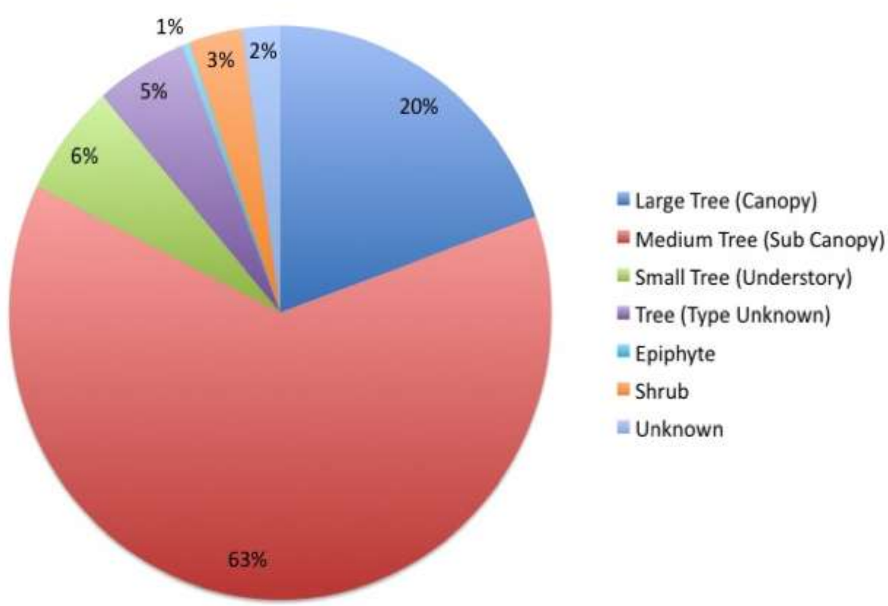

FIGURE 5. Percentage distribution of seedling species growth forms.

Highest species richness was found within 50 meters from the forest with 22 different species. Moving away from the forest, 17 different species were found in the plots 51-100 meters from the forest, 11 different species were found 101-150 meters from the forest, and 15 species were found in the plots 151-270 meters from the forest. Richness decreased significantly (F=11.7506, df=1,62, p = 0.001) as distance from the forest increased (Fig. 2).

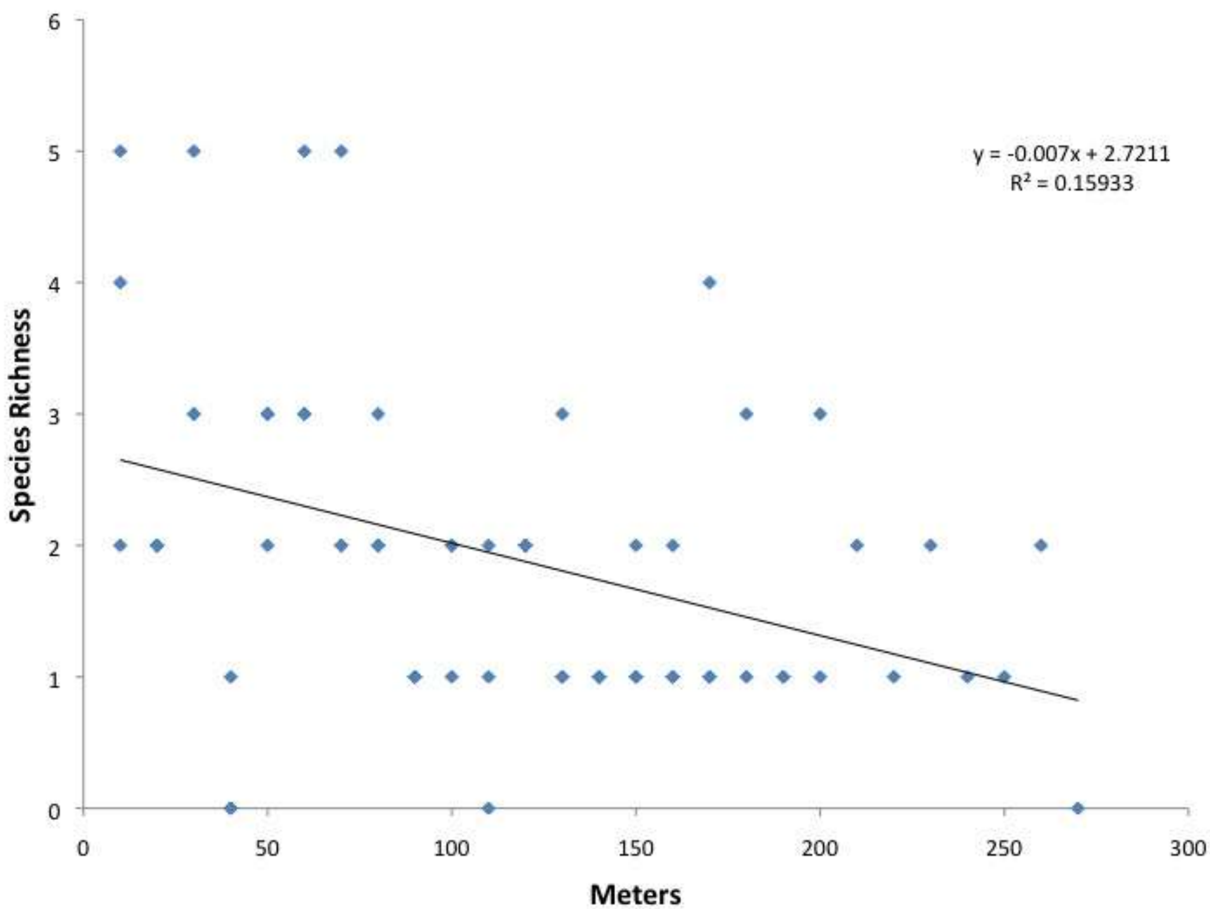

FIGURE 2. Distribution of species richness per plot as distance from the windbreaks connection to the forest increases. Sixteen percent of the change in species richness can be accounted for by the distance from the forest. Canitas, Monteverde, Costa Rica.

Abundance

Of the 220 seedlings observed, 60% of them were found within 100 meters of where the windbreak connected to the forest. The remaining 40% were found between 101 meters and 270 meters. Abundance of seedlings decreased significantly (F=15.8, df=1,62, p = 0.0002) as the distance from the forest increased (Fig. 3).

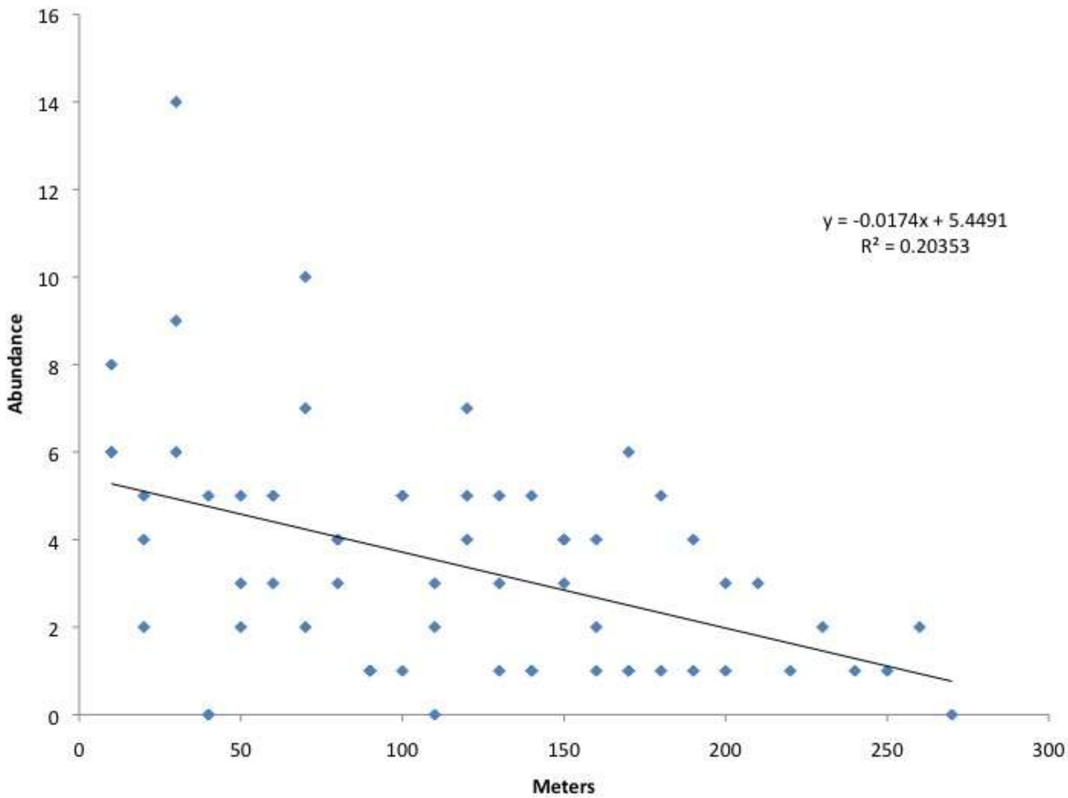

FIGURE 3. Distribution of seedling abundance as distance from the windbreaks connection to the forest increases. Twenty percent of the change in species richness can be accounted for by the distance from the forest. Cañitas, Monteverde, Costa Rica.

DISCUSSION

The Lauraceae family possibly had the largest number of individual species because it is a large family whose highest abundance and diversity (69 species in Monteverde) occurs commonly in the cloud forests of Costa Rica (Haber *et al.* 2000). Therefore, since it has a large occurrence in the area already, it is more likely to have high seedling diversity and/or abundance in addition. Another reason the Lauraceae family may have high diversity in windbreaks is because nearly all the species are dispersed by birds (Haber *et al.* 2000). This is important because birds often use windbreaks for perches and refuge (Nielson & DeRosier 2000). Myrtaceae and Solanaceae are close seconds because they are commonly dispersed by bird species as well (Haber *et al.* 2000). Myrtaceace also has relatively high diversity (31 species in Monteverde) in tropical forests, especially those at mid-elevations (Haber *et al.* 2000), such as tropical lower montane wet forests in Cañitas, Costa Rica.

However, *Viburnum costaricanum* of the family Caprifoliaceae and *Conostegia xalapensis* of the family Melastomataceae made up the largest percent of seedlings. This may be because they are both distributed by a large variety of birds. *Conostegia xalapensis* has a small fruit that contains a large amount of small seeds this high amount of seeds increases dispersal capabilities, and may account for its increased frequency of occurrence within windbreaks (Haber *et al.* 2000, Zuchowski 2007). *Viburnum costaricanum* also has a small fruit, however there is only one seed per fruit, therefore dispersal is still dictated by its small fruit size; also, it is possible that the seed has greater germination capabilities, which again increases overall seedling abundance (Haber *et al.* 2000). Another reason these two species were the most abundant could be due to their capability to be used as natural fencing (Haber *et al.* 2000). This multiple functionality increases the benefits to farmers, and it may be possible that these species were planted at some point for lower growth windbreak and natural fencing, and have since thrived. Natural fencing was observed in the windbreaks, however the trees were not typed to see if they were *Viburnum costaricanum* or *Conostegia xalapensis*.

Greater species richness and seedling abundance increasing with increased proximity to the forest may be explained by windbreak usage. It has been observed that birds use windbreaks as corridors. They may be optimal foraging habitats for insectivorous birds because of their large edges, or as was investigated in this study, a refuge where fruit and seedeaters may consume their meal (Nielson & DeRosier 2000). However, while birds are undeniably using windbreaks as corridors, if they are coming from the forest, it is reasonable to presume that there may be a limit as to how far the birds travel. This theory may also be applicable to other seed distributors, such as rodents. Animals may only leave the forest to a certain extent, therefore creating a gradient, which results in higher species richness closer to the forest, and since there is higher traffic at the connection between windbreak and forest, there is a greater likelihood that seeds will be distributed there, whether as a result of being dropped, defecated, or deposited in other ways; therefore, resulting in higher seedling abundance with closer proximity to the forest.

Medium/sub canopy tree seedlings are most common in windbreaks possibly because they are better adapted to a variety of conditions. Windbreaks have a multitude of different climatic conditions. The seedlings must be tolerant to whatever conditions arise. Possible extreme conditions may include sun, shade, strong winds, extreme rain, and dry weather. In the forest, sub canopy trees are adaptive to their conditions, in that they grow in the shade, and do what they need to there, however if a light gap appears, they benefit more. They are also tailored to function under the new conditions the light gap brings such as wind, rain, and increased drying.

In conclusion, this study found highest abundance and species richness with closer proximity to forest, which suggests that attaching windbreaks to forest increases species richness and abundance of seedlings. The study also proposes that there may be a limit to the distance that animals travel into the windbreaks, which allows for the creation of a gradient of seedling growth. Therefore, the location of windbreaks is of vital importance to conservation and farmers.

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