

## SHORT COMMUNICATION

# Effect of distance from edge on exotic grass abundance in tropical dry forests bordering pastures in Ecuador

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**Abstract:** We compared exotic pasture grass cover near the edges of 20–25-y-old secondary forests (N = 8) with those of mature forests (N = 8), bordering actively grazed pastures on the Pacific Coast of Ecuador. We estimated grass cover in 224 1 × 3-m plots along transects that ran from the pasture edge into forest interiors (11–44 m). Using a spline regression, we divided the transects into three segments: exterior (in the pasture), edge and interior (in the forest). With a stepwise regression, we tested the effect of transect section, forest type and distance from edge on grass cover. Forest type, distance from edge, interior transect section and the combined effect of distance from edge in both the interior and exterior sections explained variation in grass cover. Grass abundance was higher and penetrated further into secondary than mature forests. Edge proximity and differences in forest canopy openness likely favours recruitment and persistence of pasture grasses.

**Key Words:** edge effect, fragmented landscapes, land use legacy, pasture abandonment, regeneration, secondary forest, spline regression

Forest regeneration occurring on abandoned agricultural land in the tropics tends to occur without intentional human assistance (Aide *et al.* 2000) therefore it is important to document possible impediments to this type of secondary succession. Factors influencing regeneration include the severity of previous degradation, the surrounding matrix and edge type (Aide *et al.* 2000, Ewers & Didham 2005, Griscom & Ashton 2011, Griscom *et al.* 2009, Harper *et al.* 2005, Mesquita *et al.* 2015). These in turn influence the ability of pasture grasses to persist at the time of abandonment (Aide & Cavelier 1994, Griscom & Ashton 2011, Guariguata & Ostertag 2001). However, it remains less understood how natural regeneration processes vary across different tropical vegetation types.

In wet tropical forests, canopy closure is critical to kill sun-loving species, including pasture grasses (Aide *et al.* 2000, Holl 2002, Nepstad *et al.* 1990, Uhl *et al.* 1988). Where many canopy trees are deciduous, such as in tropical dry forests, seasonal leaf fall may favour longer

persistence of pasture grasses (Aide *et al.* 2000, Nepstad *et al.* 1990, Uhl *et al.* 1988), or allow their colonization (Janzen 2002, Veldman & Putz 2011). Dry forests are also prone to fire, which promotes the persistence and colonization of exotic pasture grasses (D'Antonio & Vitousek 1992, Griscom & Ashton 2011, Janzen 2002, Scholes & Archer 1997, Veldman & Putz 2011). Remnant and colonizing exotic grasses also compete with tree seedlings delaying or arresting forest succession (Scholes & Archer 1997, Sun & Dickson 1996, Zimmerman *et al.* 2000).

To improve our understanding of regeneration in dry tropical environments, we surveyed exotic grass abundance in secondary forests adjacent to active pastures, and compared these patterns with those on the edges of mature forests. Despite 20–25 y of abandonment, we hypothesized that significantly higher amounts of pasture grasses would still be found in secondary forest and that these penetrate further into secondary forest interiors compared with mature forest fragments.

We conducted our study in a fragmented landscape of dry forests in coastal Ecuador in the surroundings of

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Tabuga (UTM 17M 590180m E 9983303m S). This area is part of the Chocó/Darién/Western Ecuador biodiversity hotspot (Myers *et al.* 2000). A mosaic of land-cover types characterizes the landscape, dominated by a matrix of pasture grasses (i.e. *Megathyrsus maximus* and *Cynodon* spp.) introduced from Africa (Jørgensen & León-Yáñez 1999, Williams & Baruch 2000). Forest cover includes secondary, mature and selectively logged forests.

We surveyed grass abundance in eight secondary forests and in eight mature forests adjacent to unfenced, active, pastures. The secondary forests we sampled developed in areas cleared for cattle in the 1950s and 1960s but abandoned in the 1980s and 1990s (Rweyemamu *et al.* 2008). The eight mature forests surveyed showed no signs of intensive logging or other recent anthropogenic disturbances, and most were protected by the Ecuadorian government's Socio Bosque programme at the time this study was conducted (de Koning *et al.* 2011).

We measured exotic pasture grass abundance in evenly spaced 1 × 3-m plots on randomly selected sides of transects that ran perpendicular to the forest edge. Each transect started in an open pasture and ended in the forest interior where grass was no longer found (11–44 m); inter-plot distances varied with transect length from 0 m in transects shorter than 20 m and up to 3 m in transects of 44 m. Per cent grass cover was estimated as the proportion of 20 × 20-cm subplots in which grass occurred.

To understand the effect of distance from the edge on grass cover, we used spline regression. Sampled transects were divided into three sections: exterior (open pastureland), edge (the transition between pasture and forest) and interior. In its simplest form, a spline regression partitions the explanatory variable of grass cover into disjoint hyper-regions, where the slope of the regression changes at specific points called knots. Within each hyper-region a linear relationship is used to explain the influence of one or more explanatory variables on the response variable (Balshi *et al.* 2009, Marsh & Cormier 2001). We constrained the model to identify two knots in grass cover, which divided the sampled transects into exterior, edge and interior. To remove random variation in management across sites, we used the running mean between adjacent plots. Spline regressions were conducted independently for each secondary forest and mature forest transect.

To compare mature and secondary forests on the basis of distance from the edge on grass abundance, we used a general stepwise regression model with the running mean of grass cover as the response variable. Categorical predictors included forest type (mature or secondary) and transect sections (exterior, edge and interior). The relative distance of each plot from the edge-interior knot was used as continuous predictor and we

tested for interactions between each of our predictors. Multiple regression models were conducted using SPSS (version 21). The Breusch-Pagan & Koener and Hayes & Cai (2007) macros in SPSS were used to statistically identify and account for heteroscedasticity in model residuals. To ensure normality of residuals, grass cover was square-root transformed (Standardized Residual Kolmogorov–Smirnov  $P = 0.067$ ). Spline regression models were conducted in R (Version 0.98.1062) using the 'segmented' package (Muggeo 2003, 2008).

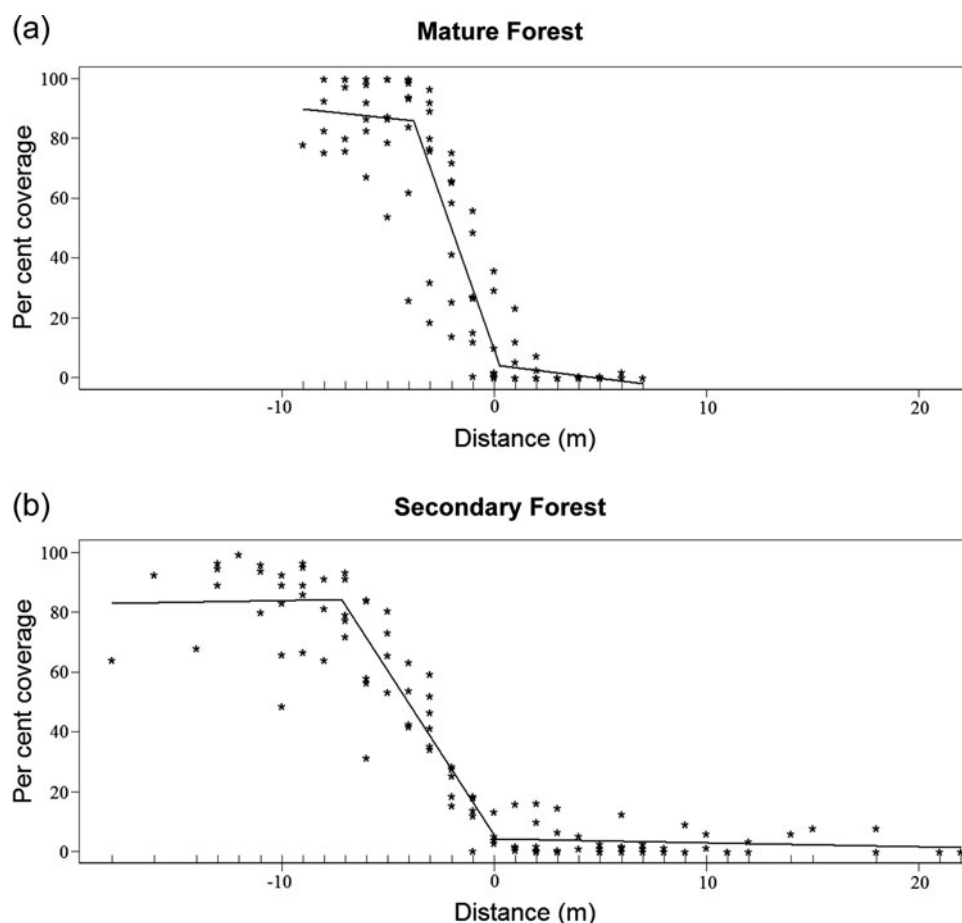
Grass cover decreased from open pastureland into both mature and secondary forest interiors, but grasses were more abundant in the interiors of the latter (Figure 1, Table 1). Higher variation in grass cover was found in pastures bordering secondary forests compared to those bordering mature forests. The calculated width of secondary forest edges for the response variable grass cover (~7 m, Figure 1b) was also more than double that of mature forest (~3 m, Figure 1a). In the forest interiors, grass disappeared at 10 m from the edge in mature forest (Figure 1a) but was still present > 20 m from the secondary-forest edge (Figure 1b).

The stepwise regression model of grass cover along transects revealed a decrease in the categorical predictor interior habitat (Pearson Correlation [PC] with grass cover = -0.838). The interaction between the predictors distance from edge and interior habitat (PC with grass cover = -0.023), and the interaction between habitat type and interior habitat (PC with grass cover = -0.545) were significant. In other words, grass cover decreased with distance into forest interiors, but this relationship differed between mature and secondary forest (Table 1).

The presence of grasses in secondary forests at a distance > 20 m from the pasture edge and a wider 'edge' section in secondary forests indicates a more permeable edge in secondary forest compared to mature forest. Higher variation in grass cover found in pastures bordering secondary forests (Figure 1b) compared with mature forests (Figure 1a) likely reflects differences in management. These findings should be interpreted in light of the fact that the 20–25-y-old secondary forests we sampled were the oldest in the region. We suspect that the presence of grasses on the edges of mature and especially secondary forest is related to the seasonal loss of leaves and low-density canopy of these forests compared with those in more humid tropical areas. Also, given that these pastures were not fenced, continued perturbations by cattle are likely, especially on the edges of secondary forests developing on abandoned pastures. Whether the grasses in the secondary forests are remnants or colonists, their presence is worrisome insofar as they compete with tree regeneration and increase forest flammability. The persistence of exotic grasses in seasonal tropical secondary forests despite two decades of abandonment could inform regeneration initiatives,

**Table 1.** Parameter estimates plus interactions in a stepwise spline regression of grass abundance across eight pasture–mature forest and eight pasture–secondary forest transects in tropical dry forests in Ecuador. P values indicate significance (only significant variables are shown).  $R^2$  indicates model goodness. Interior = transect section in mature or secondary forest. Exterior = transect section in pastureland. Distance = squared root of relative distance between edge–interior–knot and exterior/interior transect sections. Forest type = mature or secondary forest.

	Grass coverage (%)	t/F statistic	P value	$R^2$
Constant	0.50	0.82	0.41	
Interior	– 5.90	– 20.81	<0.001	
Distance (m)	3.37	10.2	<0.001	
Forest type	1.51	6.52	<0.001	
Distance × exterior	– 2.12	– 4.28	<0.001	
Distance × interior	– 3.78	– 10.5	<0.001	
Type × interior	– 2.72	– 8.14	<0.001	
Model goodness of fit		369	<0.001	0.89



**Figure 1.** Spline regression models of grass abundance across eight pasture–mature forest transects (a) and eight pasture–secondary forest transects (b) in tropical dry forests in Ecuador. Distance denotes the relative distance of a sampled plot from the edge–interior transition point (or knot).

specifically in fragmented landscapes, where secondary forests have an important role in conservation.

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