Initial survivorship of 51 woody species in a reforestation experiment established after gold mining in the Peruvian Amazon

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INTRODUCTION

Within the wide range of tropical forest degradation drivers, gold mining is one of the most aggressive and difficult to restore due to the magnitude and severity of its environmental impacts, making restoration particularly difficult (Bradshaw, 1997). Surprisingly, the science and practice of how to restore tropical forests after gold mining operations is still very limited (e.g. Roman et al. 2015). Here, we present initial results of one of the largest reforestation experiments in areas mined for gold across the tropics. We show an initial survivorship analysis in a trial of 51 woody species in areas where suction pumps were used to mine gold from alluvial deposits in Madre de Dios. This region is one of the highest biodiversity places on earth (Gentry, 1988; Asner et al. 2012) and has become an epicenter for gold mining in the Amazon watershed (Asner et al. 2013; Elmes et al. 2014).

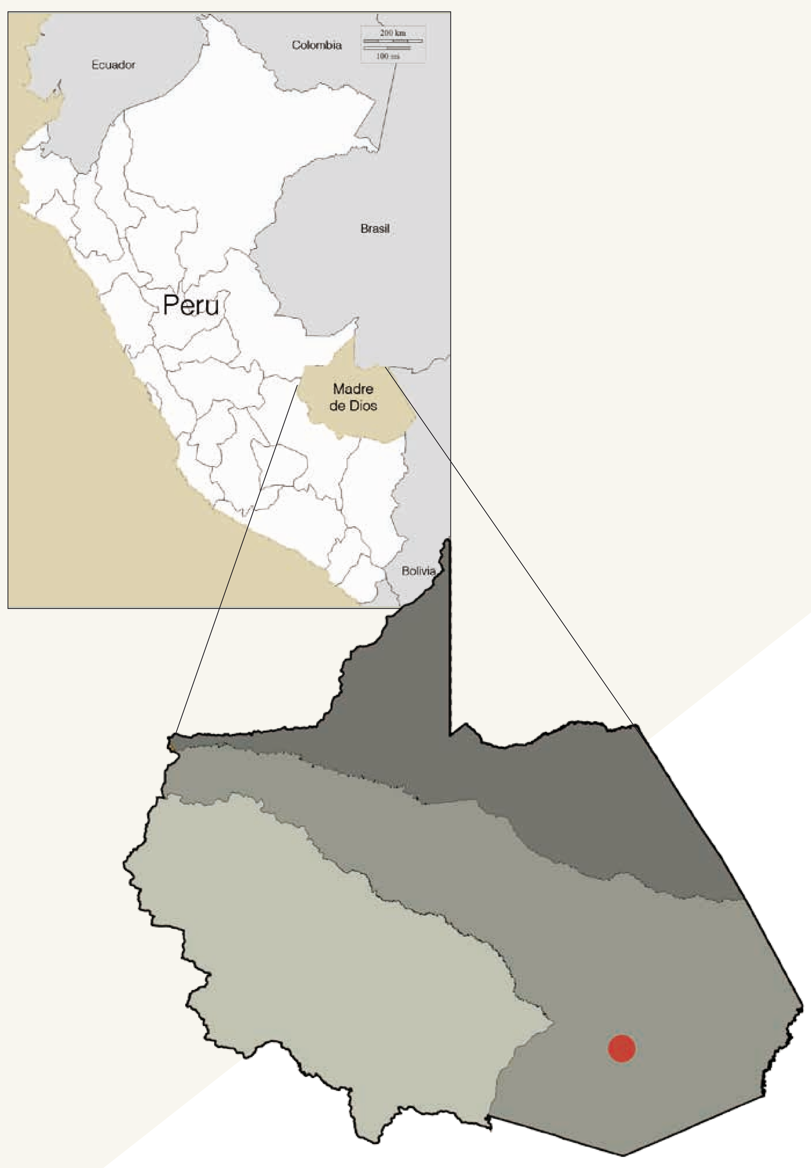

Fig. 1: Study area in Madre de Dios (Peru).

METHODS

A series of experimental reforestation plots were established in mining concessions in the Peruvian Amazonian district of Laberinto, where gold mining has been performed for more than 60 years (Fig. 1). A total of 6,150 seedlings from 51 species were planted in 4 sites comprised of 15 subplots ranging from 0.3 to 0.5 ha each, covering a total area of 6.3 ha (Fig. 2). Percent survival was calculated 3 months after planting on a subplot basis and before applying any amendments to the soil. Survivorship was analyzed to detect possible correlations with the initial seedling size; meanwhile ANOVA was performed to detect survivorship differences between species and degradation categories in the study sites (bare soil, gravel mounds, and natural regeneration). Drones were used to create orthomosaics in order to assess the spatial distribution of seedling's mortality across the plots.

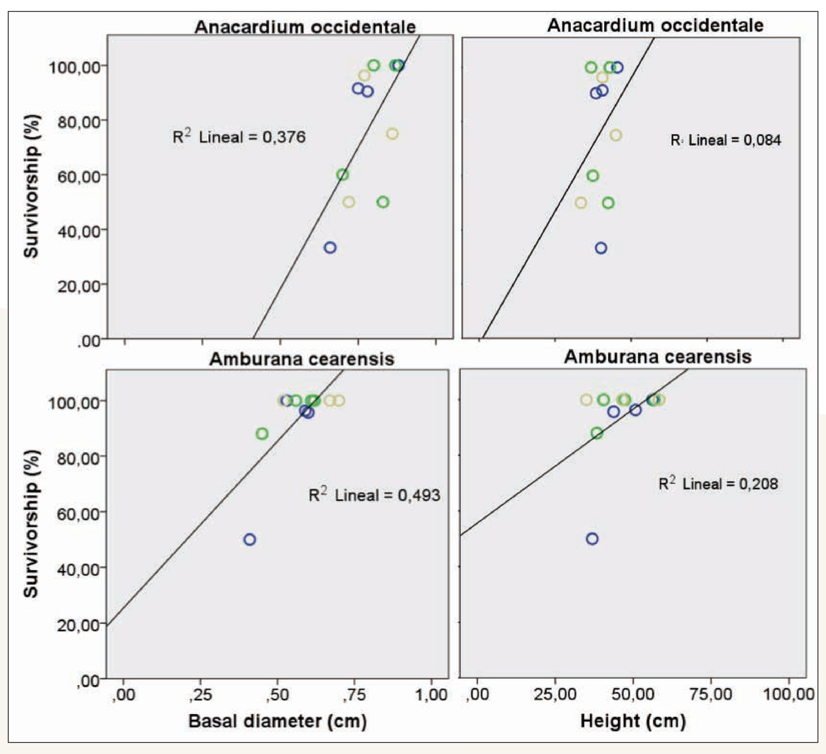

Fig. 4: Influence of plant basal diameter and height on seedling survivorship.

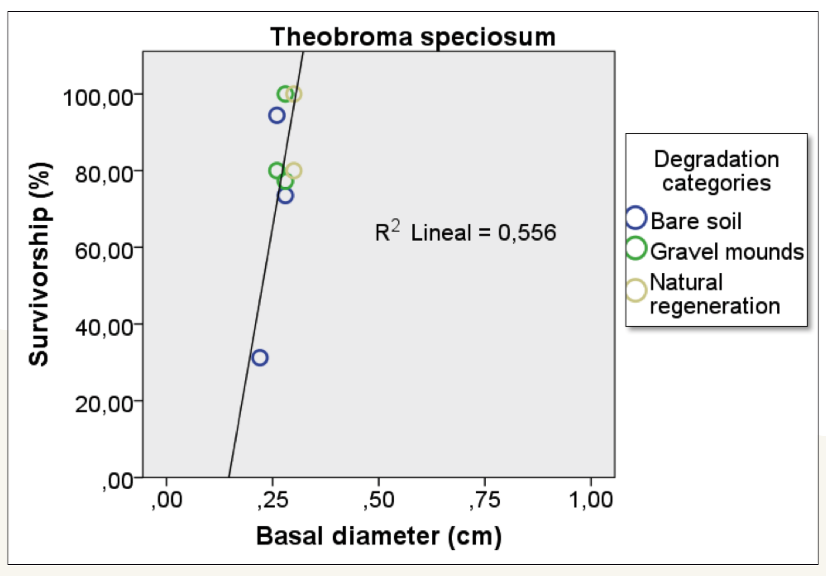

Fig. 5: Influence of degradation categories on the survivorship of a shade-tolerant species

RESULTS & DISCUSSION

Initial results are promising given that a total of 37 species showed excellent survival rates (>75%); 12 species presented good survival rates (50-75%); and only 2 species showed moderate survivorship (26-50%), according to the performance standards proposed by Elliot et. al (2003) (Fig. 3).

Correlation analysis across species showed that survivorship of 18 species was increased in plants with greater basal diameters at the time of planting. Also, survivorship of 4 species was favored in the presence of taller plants (Fig. 4).

Moreover, we found initial evidence that survivorship was influenced by species (ANOVA, F=2,87; $p<0.05$) and degradation categories (ANOVA, F=6.01; $p<0.05$), especially when certain species were planted in bare soils where extreme environmental conditions could limit seedling survivorship (Fig. 5). Imagery from the drones also revealed high mortality zones related to the occurrence of temporal floods during the wet season (Fig. 6).

Fig. 2: Establishment of reforestation plots in a mining concession in Laberinto.
Photo : CINCIA- Jesus Alferez

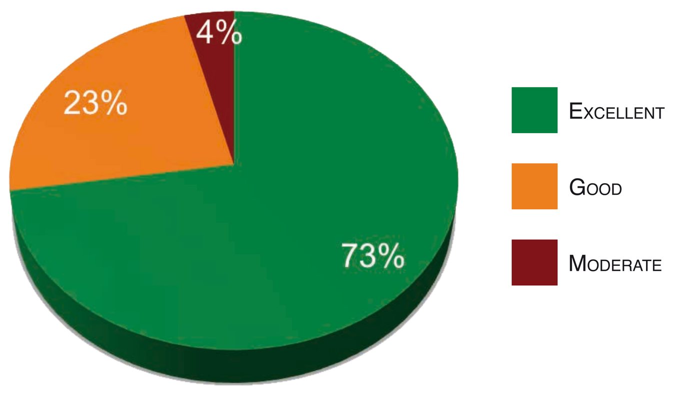

Fig. 3: Percentage of species showing survivorship performance standards (Elliot et al. 2003).

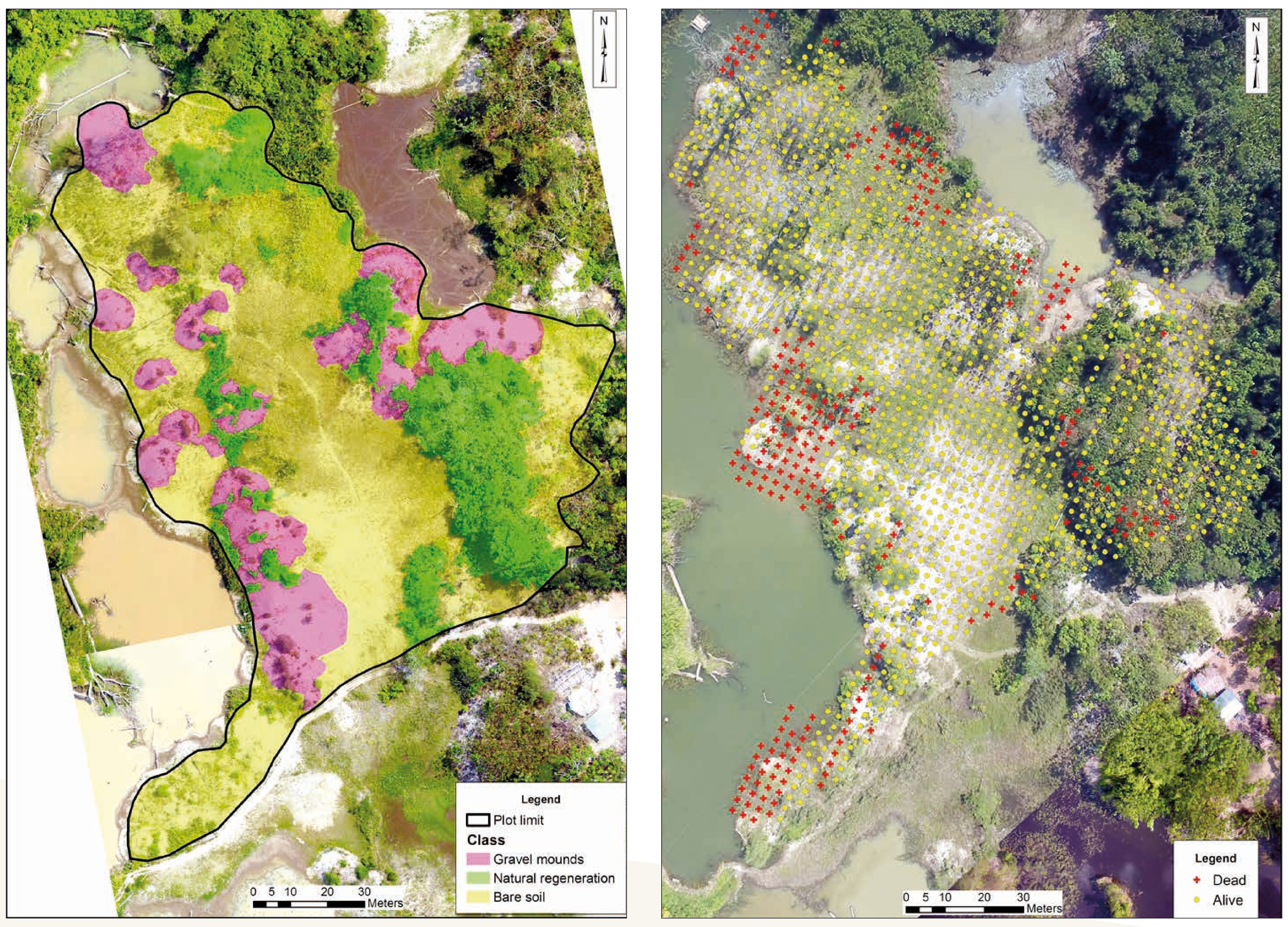

Fig. 6: Degradation categories of one of the reforestation sites (a);)Mortality zones in areas temporally flooded (b).
Illustration : CINCIA - Martin Pillaca

CONCLUSION

This study demonstrates that restoration plantings are feasible in highly disturbed areas. We present initial evidence on the potential of a wide range of species to survive across degradation categories, as well as the influence of seedling size at the time of planting on survivorship.

Further trials, that will be established across different sites mined with heavy machinery and suction pumps, will significantly increase knowledge on restoration.

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LITERATURE CITED

1. Asner, G.P., Mascaro, J., Muller-Landau, H.C., Vieilledent, G., Vaudry, R., Rasamoelina, M., et al., 2012. A universal airborne LiDAR approach for tropical forest carbon mapping. Oecologia 168, 1147–1160.
2. Asner, G.P., Llactayo, W., Tupayachi, R., Luna, E.R., 2013. Elevated rates of gold min- ing in the Amazon revealed through high-resolution monitoring. PNAS 110, 18454–18459.
3. Bradshaw, A. 1997. Restoration of mined lands – using natural processes. Ecological Engineering 8: 255-269.
4. Elliott, S., P. Navakitbumrung, C. Kuarak, S. Zangkum, V. Anusarnsunthorn, and D. Blakesley. 2003. Selecting framework tree species for restoring seasonally dry tropical forests in northern Thailand based on field performance. Forest Ecology and Management 184:177–191.
5. Elmes, A., Ipanaqué, J.G.Y., Rogan, J., Cuba, N., Bebbington, A., 2014. Mapping licit and illicit mining activity in the Madre de Dios region of Peru. Remote Sens. Lett. 5, 882–891.
6. Roman-Dañobeytia, F., Huayllani M., Michi A., Ibarra F., Loayza-Muro R., Vázquez T., Rodríguez T., García T. 2015. Reforestation with four native tree species after abandoned gold mining in the Peruvian Amazon. Ecological Engineering 85, 39-46.
7. Gentry, A.H., 1988. Tree species richness of upper Amazonian forests. PNAS 85, 156–159.

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