RESTORATION OF RUPESTRIAN FIELDS, ECOSYSTEMS OF THE CERRADO BIOME THREATENED BY LAND-USE CHANGES (protocol and preliminary results).

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Abstract: Rupestrian fields or *campos rupestres*, located in eastern Brazil, are a more or less continuous herbaceous stratum with sclerophyllous evergreen small shrubs between rocky outcrops which occurs between 800m and 2000m. It is the largest vegetation formation of the Espinhaço Range and the harsher physiognomy of the biome Cerrado. While their soils are shallow, sandy, highly acidic and poor in nutrients, they are very diversified with one of the highest level of endemism in Brazil. Interactions between the substrate, local topography and microclimate create a huge variety of micro-habitats generating a mosaic of communities. Currently, the Cerrado is one of the most endangered biome of South America and rupestrian fields remain poorly documented. Because of intense anthropic pressures, ecological restoration studies are urgently needed to rehabilitate this ecosystem and services they provide. This study tests the transfer of herbaceous native species from rupestrian fields to restore three kinds of degraded areas (with stony substrate, sandy substrate or ferruginous substrate) using hay collected on two types of rupestrian fields (sandy and stony). We manipulated 2 or 3 levels of 3 treatments in a multifactorial experiment: weeding/plant interactions, nutrient addition/no fertilization, hay from stony site/from sandy sites/no hay. Experimentations were carried out in three replicate sites for each kind of degraded areas (n=9) and each treatment was replicated 4 times at each site in blocks. Controls were also set up in the field and in greenhouse. Preliminary results are discussed.

Keywords: Extraction of soils and minerals, Hay transfer, Natural grassland, Savannas.

Introduction

Global environmental changes, such as land use and climate changes have profound effects on ecosystem functioning, generating among others pollution, biodiversity reduction and loss or alteration of the ecosystem services e.g. soil conservation. Land-use changes are responsible for the transformation of 43% of terrestrial ecosystems (Daily 1995), leading to an increase in degraded ecosystem. The loss of such ecosystems highlights the need for conserving remnant areas and for creating programs to manage and conserve them (Anderson 1995; Hobbs & Norton 1996).

The biome Cerrado covers 2 million of km², representing about 22% of Brazil's land surface. In 2000, the Cerrado was appointed as a biodiversity hotspot, due to its high biodiversity and the high degree of threat (Myers et al. 2000). According to Dias (1992), the number of plants, animals and fungi are estimated to about 160,000 species (Oliveira & Marquis 2002) in this biome. Rupestrian fields or *campos rupestres* (in Portuguese), located in eastern Brazil, are a more or less continuous herbaceous stratum with sclerophyllous evergreen small shrubs between rocky outcrops which occurs between 800m and 2000m (Giulietti *et al.* 1997). It is the largest vegetation formation of the Espinhaço Range and the harsher physiognomy of the biome Cerrado. While their soils are shallow, sandy, highly acidic and poor in nutrients (Giulietti *et al.* 1997), they are very diversified with more than 4,000 plant species along Espinhaço Range with one of the highest level of endemism in Brazil. Interactions between nature of the substrate, local topography, microclimate and fire perturbations create a huge variety of micro-habitats generating a mosaic of communities (Goodland & Ferri 1979; Giulietti *et al.* 1987). They are subject to major stresses due to environmental conditions but these last few years they are also confronted with a high level of disturbances: road construction, mining and fires, increasing soil erosion in these regions.

In Brazil, in order to control soil erosion, many mitigation projects use exotic species for revegetalisation, such as *Melinis minutiflora*, an African grass (Griffith & Toy 2001) although exotic species are one of the major threats to local diversity. The use of native species is more appropriate for restoration projects both to maintain local diversity (Dobson *et al.* 1997) and because colonization by local species is the first step in the process of ecosystem succession (Bradshaw 2000)

Because of the intense anthropogenic pressures, ecological restoration studies are urgently needed to rehabilitate these ecosystems and the services they provide. The aim of this work was to test the transfer of herbaceous native species from rupestrian fields to restore three kinds of degraded areas (with stony substrate, sandy substrate or ferruginous substrate) using hay collected on two types of rupestrian fields (sandy and stony) in order to accelerate colonization of vegetation on the ground and provide fast soil protection from runoffs.

Materials and methods

The *campos rupestres* are predominantly found in the states of Minas Gerais, Bahia and Goiás (Oliveira & Marquis 2002), mainly in the Espinhaço range mountain. The work was developed in the Private Reserve Vellozia (19°16'45.7"S, 43°35'27.8"W altitude 1200 m) located in the Serra do Cipó, southern of the Espinhaço Range, Minas Gerais, Brazil at the boundary of the Serra do Cipó National Park. The climate is classified as Cwb (C: hot temperature, w: dry winter, b: hot summer), according to the Köppen system. There are four distinguishable seasons: a rainy season from November to January, a post-rainy season from February to April, a dry season from May to September, a post-drought season in October. The average annual rainfall is 1622 mm and average annual temperature of 21.2°C (Madeira & Fernandes 1999).
For this experiment, three kinds of degraded areas were selected: one with a stony substrate, one with a sandy substrate and one with a ferruginous substrate (Fig.1). Areas were degraded by the construction of a highway (MG-010). The hay was collected at the end of October 2010 and the beginning of November 2010 on two types of rupestrian fields (sandy and stony) using a leaf vacuum. Experiments were carried out in January 2010 in three replicate sites for each kind of degraded areas (n=9) and each treatment was replicated four times at each site in blocks.

a) b) c)

Figure 1. Degraded areas selected for the experiment with a) ferruginous substrate, b) rocky substrate and c) sandy substrate.

We manipulated 2 or 3 levels of 3 treatments in a multifactorial experiment: weeding/plant interactions, nutrient addition (NPK 10.10.10)/no fertilization, hay from stony sites (18.4gr) / from sandy sites (73.1gr) / no hay (control).
Kruskall-Wallis tests, followed by non-parametric multiple comparisons with Bonferoni correction were performed with the software R (R Development Core Team 2008).

Results and discussion

A few months after sowing, the number of quadrats with new seedlings is greater on the degraded area with rocky substrate (Fig.2). This could be due to the formation of favourable micro-habitats for plant germination created by small stones. They may retain seeds and/or provide shade and moisture to seedlings. However, neither the presence of hay nor the kind of hay influences the germination of new seedlings (Fig.2, Table 1) or the number of seedlings per quadrat (Table 1).

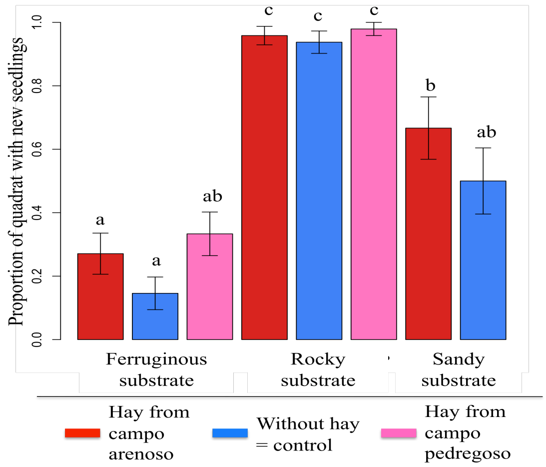


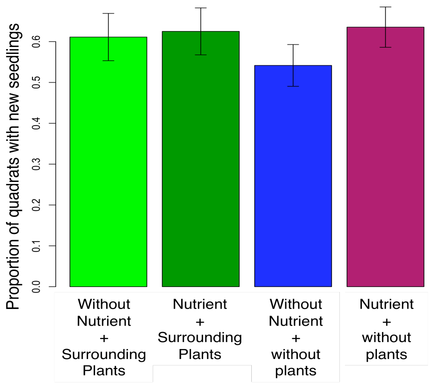
Figure 2. Proportion of quadrats with new seedlings according the kind of degraded areas and the types of hay (Kruskal-Wallis chi-squared = 155.5, p-value < 0.001, non-parametric multiple comparisons with Bonferoni correction: different letters indicate significant differences).

Table 1. Proportion of quadrats with new seedlings and seedlings number in each quadrat according the types of hay.

Hay from →	*campo arenoso*		*control without hay*		*campo pedregoso*		Kruskal-Wallis test
	mean	sd	mean	sd	mean	sd	
Proportions of quadrat with new seedlings (%)	62.5	4.4	53.3	4.6	65.6	4.9	p > 0.05
Seedlings number per quadrat	3.5	0.4	3.6	0.5	4.6	0.6	p > 0.05

The absence of significant differences between results with and without hay may be explained by the fact that the date for hay harvest may have been inappropriate thus transferring few seeds. 2009 was an exceptional year where the rainy season started earlier, in September. Hay was harvested at the end of October, while part of the seeds may have already dropped on the ground or germinated. The best time for hay harvest is at the peak of seed production during the dry season, before the rain but hay should also be harvested several times during the year. The presence of a lot of perennial species on the intact rupestrian fields where the hay was collected may also have led to low amounts of seeds in the hay as some of these species may not produce much viable seeds. Finally, the best time for hay transfer may be during the first rains of the rainy season while in this experiment, hay was transferred later.

Even if the proportion of quadrats with new seedlings and the number of seedlings in each quadrat are not statistically different in the different treatments (Fig.3), trends can be observed. Neighbour plants seem to increase the number of new seedlings. They may retain seeds and create a microenvironment favourable for germination or they produce the seeds from which these new seedlings come from. This last explanation seems the more plausible because new seedling species are the same than the species observed on the degraded areas. Soil fertilisation has no effect on germination rate. Monitoring for a longer time is necessary to see if seeds from the hay will germinate.

a) 

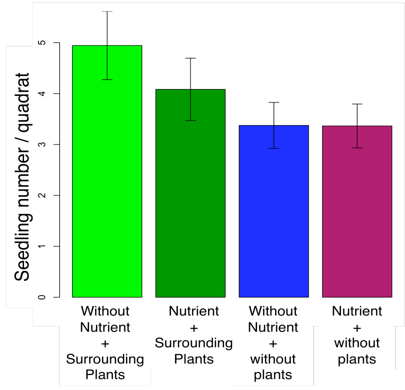
b) 

Figure 3. a) Proportion of quadrats with new seedlings in the different treatments (Kruskal-Wallis chi-squared = 2.08, p-value = 0.55), b) seedling number per quadrat in the different treatments (Kruskal-Wallis chi-squared = 2.58, p-value = 0.46)

Conclusions

It is important to continue to monitor this experimentation; four months are not sufficient to clearly identify the effects of treatments. An improved experiment is already being planned for which hay has been harvested all along this year (2010) in order to improve seed pool; the set-up is planned at the beginning of the rainy season using new treatments.
These preliminary results highlight the difficulties to restore fragile ecosystems resulting from particular environmental conditions and subjected to high stresses. The difficulties to restore herbaceous layer of rupestrian fields emphasize the importance to conserve this endangered ecosystem.

Acknowledgements

Financial support for this research was provided by the Collège Doctoral Franco-Brésilien (EGIDE-Ministère des affaires étrangères et européennes, France), the Univerity of Avignon (Bourse Perdiguier) & IMEP. We appreciate the assistance of Daniel Teixeira da Costa Araujo, Fernando Augusto de Oliveira Silveira and Luiza Fonseca Amorim de Paula for field work.

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