DEGRADATION PROCESS, PHYTOSOCIOLOGY AND RESTORATION OF GRASSES USED FOR GRAZING RUMINANTS IN BRAZIL

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ABSTRACT

The aim of this study is to present the main pasture grasses used in Brazil, the process of pasture degradation, pasture phytosociology, some undesirable pasture plants, and pasture restoration techniques. A wide plant availability and the high forage yield of its pastures make Brazil an important producer of plants for animal feed. The great majority of pastures in Brazil contain grasses of the genus Brachiaria, known for its strength and high forage potential. However, the pastures are undergoing constant degradation caused by improper handling, which leads to unsustainability. This is possibly due to extensive and extractive exploitation using a low level of technology and unsuitable management practices. Based on the principle that pastures can be restored, alternative techniques are required to promote improvements in forage quality. For this, it is important to recognize the undesirable pasture plants, which directly interfere with livestock production by competing with forage species for water, nutrients, space and light, as well as producing phytotoxins that prevent or suppress the growth of forage species. In the process of pasture restoration, the main objective is to maintain the vital functions of the ecosystem and to mitigate damage from undesirable plants through the immediate coverage of the soil.

Key words: management practices, pasture degradation, recovery, undesirable plants.

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INTRODUCTION

Brazil has the potential to be a major producer of fodder plants for animal feed, as it is a country of excellent standing on the world stage, and has shown significant development in recent years (Souza et al., 2017). Grasses have always been regarded as low demand crops needing constant replanting, and these factors have resulted in low productivity rates and consequent economic failure. The wide availability in the country of plants with high forage yield is one of the factors that help increase the capacity of pastures, as shown in Table 1 (Emerenciano Neto et al., 2013; Fontes et al., 2014).

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Genotype</th>
<th>Production (kg ha⁻¹)</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brachiaria brizantha</td>
<td>Marandu</td>
<td>7780</td>
<td>Morais et al. (2014)</td>
</tr>
<tr>
<td>Brachiaria brizantha</td>
<td>MG4</td>
<td>8050</td>
<td>Seidel et al. (2014)</td>
</tr>
<tr>
<td>Brachiaria brizantha</td>
<td>Xaraés</td>
<td>8432</td>
<td>Alonso and Costa (2017)</td>
</tr>
<tr>
<td>Panicum maximum</td>
<td>Mombaça</td>
<td>16063</td>
<td>Lopes et al. (2016)</td>
</tr>
<tr>
<td>Brachiaria ruziensis</td>
<td>Ruziensis</td>
<td>12050</td>
<td>Rodrigues et al. (2014)</td>
</tr>
<tr>
<td>Andropogon gayanus</td>
<td>Andropogon</td>
<td>4782</td>
<td>Costa et al. (2016)</td>
</tr>
</tbody>
</table>

Table 1. Production of green biomass (kg ha⁻¹ per cut) of tropical grasses.

The great majority of the pastures found in Brazil are composed of grasses of the genus Brachiaria, due to its climatic tolerance and high forage potential. However, the tolerance of this species to tropical environments does not prevent the pastures being degraded by improper handling methods (Lisbôa et al., 2016; Costa et al., 2017). The extent of Brachiaria pasture has been increasing in Brazil in comparison to other forages. It has become popular mainly because it is rustic and can adapt to the most varied edaphoclimatic conditions. Currently, Brazil exports seeds with a rate of approximately 80% germination for up to 40 countries,
Brachiaria being the largest producer and exporter of tropical forage seeds in the world (Cardoso et al., 2014).

With the increase in the use of grasses from the Brachiaria and Panicum genera in Brazil but little technical knowledge about the optimum management methods for these pastures, there is a great need for research in this field. These species are the most used in animal production because they adapt well to tropical and subtropical climates and have high biomass production (Gomes et al., 2011; Portela et al., 2011).

In the 1990s the forages Brachiaria brizantha cv. Marandu and Andropogon gayanus cv. Planaltina were introduced to Brazil by Embrapa. Both were readily accepted by the farmers, especially the Marandu grass, due to its resistance to grasshoppers. After these forages, several cultivars of Panicum were introduced. In 2000, the Xaraës grass was brought in (Costa et al., 2008).

The genus Brachiaria belongs to the Poaceae family. It is native to Africa and widely used in tropical America. Although this type of forage establishes well, the development of a large number of undesirable plants can occur when it is not properly handled (Castro Junior et al., 2008). Marandu grass (Brachiaria brizantha) is an alternative for ruminants due to its agronomic characteristics, and has enabled large areas in Central Brazil to be used for pasture (Fontes et al., 2014).

MG4 grass (Brachiaria brizantha) is originally from Colombia and was introduced to Brazil by Matsuda Genética nº 4, in 1995, through the International Center for Tropical Agriculture (ICTA). It is a tolerant variety that can grow in regions with poor soils and low rainfall (due to its deep root system), revives well after burning and has good regrowth capacity (Fontes et al., 2014). The cultivar MG4 grows in clumps, with a height between 0.8 and 1.5 m. It has small horizontal roots, hard and bends and covered with scales (Almeida et al., 2014).

Xaraës grass (Brachiaria brizantha) is a tropical grass native to Burundi, East Africa. This variety was introduced into Brazil in 1994 after various tests and in vitro culture. In the course of a decade it showed a good adaptation to regions with a very humid tropical climate and long periods of drought (4 to 5 months) and still remained green. This variety has high forage potential, rapid regrowth and very vigorous plants that reach 1.60 m (Almeida et al., 2014).

The Mombasa grass (Panicum maximum), is considered one of the most productive tropical forages available for animal feed (Simonetti et al., 2016). It is a grass with high yield and nutritional quality presenting many advantages for livestock production. Panicum maximum covers more than 20 million hectares in Brazil and, with the development of genetically improved cultivars, its high propagation capacity and ability to adapt to different types of soil and climate shows its importance as a tropical forage (Braz et al., 2017).

Andropogon grass a grass native to the African continent is perennial and 1.5 to 2.5 m height. It is well adapted to dry regions and sandy, acid soils with low fertility. When young it has good acceptability and nutritious qualities. However, it produces an inflorescence with hard stems and is poorly accepted by ruminants when in an advanced vegetative stage (Silva et al., 2014). According to Cavalcanti and colleagues (Cavalcanti et al., 2016), the Andropogon stands out for its high biomass production and tolerance to prolonged drought periods. With such characteristics, this grass is considered one of the species most adapted to certain Brazilian regions. It is currently widely used as cultivated pasture, mainly in the areas of the Cerrado biome.

Pasture degradation in Brazil

According to the Brazilian Association of Meat Export Industries (ABIEC, 2018), in 2015, the pasture area in Brazil corresponded to 167,487,880 hectares. The Midwest represents 32%, the North 25%, the Northeast 21%, the Southeast 14% and the South 9% (Figure 1). These areas of cultivated pastures reflect, directly, the significant extent of herd grazing in Brazil. The extent is such that, of the 39.1 million animals slaughtered in the year 2015, only 13% come from animals finished in feedlot. The data presented here could be considered to be even more significant because the livestock is grazing on degraded pastures. The unsustainable nature of this production system is evident, arguably enhanced by extensive and extractive exploitation at a low technological level with minimal use of proper management practices (Rocha Junior et al., 2013). For example, the Cerrado biome corresponds to approximately 24% of Brazilian territory, and more than half, approximately 32 million hectares, is in some stage of degradation. The development of the herd kept on pasture can be maximized, not only with formation of new pasture areas, but also with restoration of degraded pastures, by using ecological principles and adopting appropriate management practices for each forage species.

Macedo (2005) defines pasture degradation as a gradual process of loss of vigor, productivity, natural restoration ability, the capacity to sustain production levels and the quality demanded by the animals, as well as to overcome the harmful effects of pests, diseases and undesirable plants, culminating in the advanced degradation of natural resources due to inadequate management (Figure 2).
The failure to manage pastures, combined with intense grazing, activates the degradation process. Consequently, attacks by pests and disease initiates soil degradation through the compaction and erosion (Figure 2).

Brazilian pastures are being cultivated for long periods without management practices, i.e., the natural resources of the soil are extracted for the cultivation of forage plants, so that, over the years, soil fertility decreases, triggering a number of problems in agricultural areas. Due to the fall in soil and plant productivity and reduction of animal support capacity by the area, the farmers abandon these sites for new agricultural fields (Pereira et al., 2013).

In the mid-1970s, the conventional African grasses that existed in Brazil began to be replaced by varieties with better adaptability and productivity. The Brachiaria, which also came from Africa, appeared as an option at that time. However, a short time later it was observed that it was very demanding with respect to soil fertility and consequently the pastures, under inappropriate management, began to degrade (Xavier et al., 2011).

According to Qi et al. (2012) and Gang et al. (2014), disordered overgrazing and deforestation are the major causes of desertification and pasture degradation, and thereby compromise ecosystem functions. In addition, pasture degradation is directly linked to climatic variations as well as human interference.

According to Balbino et al. (2011), the degradation of pasture has become one of the main signs of the low sustainability of livestock farming in several regions of Brazil. Factors such as high stocking rates, lack of replenishment of soil nutrients, and low technological investment have had negative consequences for the development and sustainability of livestock, resulting in low fodder supply, low zootechnical indexes and a low productivity of meat and milk per hectare.
In this scenario (high levels of degraded pastures), farmers must seek alternatives to improve the forage conditions based on principles of pasture restoration. These methods aim to re-establish the forage production by keeping the same species or cultivar. The restoration process can be direct or indirect, depending on the degree of pasture degradation. In most cases it is necessary to prepare the soil and perform fertilization (Nogueira et al., 2015).

**Phytosociology of pastures:** The number of undesirable plants in the pasture depends on plant species, density, distribution, forage crop, spacing, soil, climate, management, and time of plantation. A form of floristic identification in agricultural areas is known as phytosociological survey. This provides temporal and spatial information on the plant community through frequency, density, abundance and relative importance indices of the plants in the ecosystem. Information on the number of individuals and the distribution of existing species in the pasture through a phytosociological study is of great relevance in the search for pasture management and restoration strategies (Firn, 2007; Santos et al., 2015). It is essential to know about the undesirable plant species in pastures, because each plant has particular properties and the effects of its infestation in cultivated areas may vary with the type of soil management. The objective of identification of undesirables is to know the individual effects and the interactions of plants that infest the diverse crops, in order to develop general and specific management regimes for undesirable species (Cruz et al., 2009).

Undesirable plants directly intervene in livestock production by competing with the forage species for water, nutrients, space and light, as well as producing phytoxins that prevent or suppress the growth of forage species (Reigosa et al., 2013). The relevant characteristics of undesirable plants are those that influence the degree of interference with cultivated plants such as support capacity, arrangement and height of plants, climatic and environmental conditions, preferred soil type, and the period that these undesirable plants remain together with crops. However, the growth of plantations directly interferes with the determination of distance and plant installation the interposition rate of undesirable plants in crops, since the spacing between the plants determines the degree of competitiveness. The groups of weeds vary according to the size of the plant, and type of growth. For example, erect plant species produce little shade when compared to plants with prostrate habit (Batista et al., 2017).

**Undesirable plants in pasture:** In the pastures, a certain number of undesirable species spontaneously form a plant community, coexisting to a degree with the established forage plants. Some of these species can be considered innocuous, because they are accepted by ruminants and do not interfere with the established fodder plants. On the other hand, some species are undesirable because they compete with fodder plants or because they have toxic properties. It should be noted that not all plants demonstrated experimentally as undesirable should be considered to be toxic for animals because they do not produce clinic pathological conditions under natural conditions (Barbosa et al., 2005).

Undesirable plants are any species that germinate spontaneously and adversely affect the development of the crop, or opportunistic species occurring in degraded environments (Diniz et al., 2017). By competing for resources, undesirable plants promote low pasture support characteristics, increase pasture formation and restoration time, and poison or cause injury to the animals, compromising herd quality.

The identification of undesirable plants in pastures is important and the characteristics of these species should be understood before implementation of any program to restore degraded pastures. However, this can relatively easily be achieved through floristic surveys of undesirable plants and studies on phytosociology that can contribute information on the structure of the community in question. It is also important to carry out studies on floristic diversity to fine-tune recommendations for field management methods (Costa and Mesquita, 2016). A survey provides information on the composition (%) of the undesirable plants present in the pastures (Table 2). Surveys by Silva et al. (2004) provided valuable information on the different plant species.

### Table 2. Concentration of undesirable plants in pasture.

<table>
<thead>
<tr>
<th>Family</th>
<th>Scientific name</th>
<th>Concentration (%)</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubiaceae</td>
<td>Borreria latifolia (Aubl.) Schum</td>
<td>3.12</td>
<td></td>
</tr>
<tr>
<td>Oxilidaceae</td>
<td>Oxalis sp.</td>
<td>1.62</td>
<td></td>
</tr>
<tr>
<td>Euphorbiaceae</td>
<td>Croton campestris St. Hil.</td>
<td>21.31</td>
<td></td>
</tr>
<tr>
<td>Cyperaceae</td>
<td>Cyperus compressus L.</td>
<td>0.60</td>
<td>Galvão et al. (2008)</td>
</tr>
<tr>
<td>Cyperaceae</td>
<td>Fimbristylis miliacea (L.) Vahl</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>Cyperaceae</td>
<td>Fimbristylis dichotoma (L). Vahl</td>
<td>0.86</td>
<td></td>
</tr>
</tbody>
</table>
Goulart et al. (2009) reported that undesirable plants remove the vital nutrients (e.g., nitrogen, phosphorus, and potassium) from the soil that otherwise could supply the nutritional requirements of pasture in the region. Thus, when these plants are allowed to develop along with the pasture there will be a loss of forage development. Little is known about the undesirable plants in Northeastern pastures, and there is, therefore, a need to obtain information to help develop effective ways of controlling these species. In addition, studies on the ecology of undesirable plants are crucial to inform control strategies. Pitelli (2014), points out that any program for the control of undesirable plants must consider the mode of reproduction and dispersion of the species. Without adequate knowledge of these undesirable plant traits, control attempts are usually uncoordinated and unsuccessful.

**Pasture restoration:** In the process of pasture restoration, use of right the type of grasses as well as the application of an appropriate management regime is critical if positive results are to be maintained. However, in the early stages of pasture restoration, the main objective is to make the vital functions of the ecosystem viable. However, it is often impossible to recreate the original structure of a system in one step. First, it is necessary to mitigate the effects of the undesirable elements through immediate coverage of the soil (Cann, 2000; Santos et al., 2015).

There are two types of degradation: agricultural and biological degradation. In agricultural degradation there is an increase in the proportion of undesirable plants in the pasture, gradually decreasing the support capacity of the pastures. In biological degradation, the soil loses the ability to sustain plant production adequately, leading to the replacement of pasture plants with plants adapted to low soil fertility or the appearance of bare areas where the vegetation has failed (Pitelli, 2014).

Degraded areas need to be restored because they are of fundamental importance in environmental, technical and economic terms. For the restoration of pastures, it is essential to institute the correct management of the forage plants as well increase the soil fertility. Given that the management of areas with some degree of degradation differs from that of areas that have been recently planted or managed intensively for a long time, it is extremely important to obtain accurate information on the use of nutrients by grasses. This information can help to reduce nutrient losses from the environment, thereby increasing production and profitability (Ieiri et al., 2010; Castagnara et al., 2011; Santini et al., 2015).

Effective pasture management aims to balance the quantity and quality of fodder to guarantee the nutritional requirements of the animals while ensuring the persistence and production of the grasses. Pasture productivity stems from the continuous emission of leaves and tillers, a process that ensures the restoration of the foliar area after animal grazing and creates perennial pasture (Costa et al., 2017). According to Pereira et al. (2013) management must be in balance with the environment in which it is being developed, maintaining soil fertility, microbiology, physical and chemical characteristics, and harmony with other wild species and local flora.

According to Ydoyaga et al. (2006) direct mechanical and chemical methods can also be used in the restoration of degraded pasture. The methods chosen must be appropriate to each specific production system and aim to maximize the relationship between environmental, social and economic elements. The mechanical methods refer to the sorting of soil that may be compacted due to the trampling of animals; the chemical methods involve fertilizing and correcting the soil by supplying it with nutrients necessary for plant vigor and development.

Other authors discuss direct and indirect techniques. In this paper, we present the results of a study of the genetic variability of the pasture and of the degradation of the pasture, with no permanent or temporary introduction of a new component to the system (Townsend et al., 2010). Indirect, when performed through mechanical, chemical and cultural practices, however, with crop - livestock integration, bieng annual pasture or an annual crop of grains for a certain period (Macedo, 2005). Both are used in Brazil (Table 3).

**Table 3. Survey of degraded pasture recovery methods in Brazil.**

<table>
<thead>
<tr>
<th>Method</th>
<th>Experimental Time</th>
<th>Region</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>6 months</td>
<td>Southeast</td>
<td>Santini et al. (2015)</td>
</tr>
<tr>
<td></td>
<td>4.5 months</td>
<td>Southeast</td>
<td>Ieiri et al. (2010)</td>
</tr>
<tr>
<td></td>
<td>2 months</td>
<td>Midwest</td>
<td>Castro Junior et al. (2008)</td>
</tr>
<tr>
<td>Indirect</td>
<td>4.6 months</td>
<td>Northeast</td>
<td>Ydoyaga et al. (2006)</td>
</tr>
<tr>
<td></td>
<td>3.8 months</td>
<td>Northeast</td>
<td>Silva et al. (2004)</td>
</tr>
<tr>
<td></td>
<td>43 months</td>
<td>North</td>
<td>Costa et al. (2004)</td>
</tr>
</tbody>
</table>
Santini et al. (2015) working with direct methods, observed that the use of liming and fertilization, in a single application, is not sufficient for the complete recovery and increase of the productivity and quality of B. decumbens Stapf. cv. Basilisk. However, in order to evaluate the different doses and mode of application of phosphorus during the recovery process of a degraded pasture of the same grass, Leiri et al. (2010) verified that the application of 0, 50, 100, and 150 kg of P$_2$O$_5$ ha$^{-1}$ promoted responses in dry matter productivity of 1607.6, 2146.7, 2599.4, and 2594.0 kg ha$^{-1}$, respectively, whereas the methods of phosphorus application did not influence productivity.

Ydoyaga et al. (2006) working with B. decumbens Stapf using direct and indirect methods verified that the deferment of pasture for 138 days in the rainy period assists its recovery, especially when associated with nitrogen and phosphate fertilization. Silva et al. (2004) observed that a system without soil preparation, associated with phosphate fertilization, was the most efficient for the recovery of B. humidicola pasture, and that the pasture presented satisfactory recovery results with 113 days postponement. Costa et al. (2004) obtained satisfactory results by using various techniques – harrowing, plowing + harrowing, with or without legumes, associated with phosphate fertilization – for the recovery of degraded pastures of B. brizantha cv. Marandu.

Recovery by direct methods (plowing and harvesting) is not efficient, and causes a possible reduction in the grass population (Carvalho et al., 2017). Townsend et al. (2010) observed in direct recovery / renovation, costs went from R$ 800.00 for low intervention to 1.950,00 ha$^{-1}$ for high, values that can prevent the adoption of medium and high-level intervention technologies.

Barducci et al. (2009), using indirect methods, found that the simultaneous cultivation of corn with P. maximum cv. Mombasa compromises grain yield, and corn intercropping with B. brizantha cv. Marandu presents higher dry mass yield. Araújo et al. (2018) found that in formation or renewal of pasture through crop-livestock integration (B. brizantha cv. Marandu + maize), the exclusive operational cost (COE) of the pasture was R$ 1.123,80 ha$^{-1}$, which is independent of (R$ 561,40 ha$^{-1}$). With this approach, the average gross revenue (R$ 1.329,00 ha$^{-1}$), less the corn COE (R$ 561.40 ha$^{-1}$), gave a positive gross margin (R$ 767.60 ha$^{-1}$).

Direct or indirect recovery methods require rigorous cost analysis as they demand high investment. Both methods can be used, the degree of degradation determines the investment required. In advanced cases of degradation, indirect methods prove more efficient.

**Final considerations:** The degradation process is caused by exploitative and extractive practices. To obtain positive results in the process of grass restoration, it is essential to know the phytosociological aspects of the pasture and to identify undesirable plants and understand their mode of establishment in the area. These plants directly interfere with livestock production by competing with forage species. In the process of pasture restoration, the implementation of appropriate management practices is essential. These practices should consider the level of degradation, and seek to achieve soil-plant balance in order to guarantee the nutritional requirements for the animals, and at the same time ensure the persistence and production of grasses.

**Author Contributions:** LRB, MJA, RLE and TPDS conceived and designed the study. TPDS, RVRS and ALS contributed to the writing of the manuscript.

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