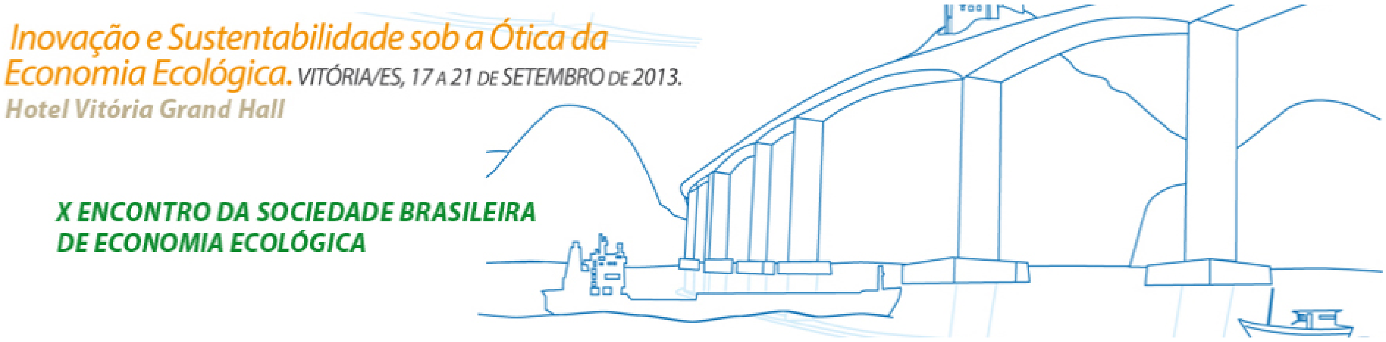

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THE EFFECT OF FOREST PROXIMITY ON BIOLOGICAL CONTROL OF PASTURE IN NORTHWEST MATO GROSSO, BRAZIL: A COST-BENEFIT ANALYSIS FOR LAND USE POLICY

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The effect of forest proximity on biological control of pasture in Northwest Mato Grosso, Brazil: a cost-benefit analysis for land use policy

Eixo temático. Sustentabilidade dos Biomas Brasileiros e as Políticas Públicas / Biodiversidade e suas ligações com resiliência ecossistêmica e o bem-estar humano

Abstract. This research aims to generate information for landowners and policymakers, to motivate them to take into account the value of the forest in agroecosystems management in Northwest Mato Grosso. Biological control of pasture pests is analyzed as an important ecosystem service (ES) provided by the forest for a key economic activity in the municipality of Cotriguaçú. The value of biological control, and the criteria for maximizing it, will be assessed by the correlation between forest proximity and spittlebug (*Homoptera: Cercopidae*) infestation level on cattle ranching pastures, and its estimated economic loss. Different scenarios in terms of conservation strategies and better cost-efficiency will be generated from the estimated value of this ES with the opportunity cost of conserving the remaining forest.

Resumo. Este estudo visa gerar informações que possam auxiliar a proprietários de terra e "policymakers" do Noroeste do Mato Grosso a levar em consideração o valor da floresta no manejo do agroecossistema. Para este fim, avalia-se o serviço ecossistêmico controle biológico fornecido pela floresta à pecuária, uma atividade econômica chave no município de Cotriguaçú. O valor do controle biológico, e os critérios para maximizá-lo, são avaliados pela correlação entre a proximidade da floresta e o nível de infestação de cigarrinha-das-pastagens (*Homoptera: Cercopidae*); assim como pelas perdas econômicas estimadas na atividade pecuária. A partir do valor deste serviço ecossistêmico, e do custo de oportunidade de conservar a floresta remanente, serão desenvolvidos diferentes cenários, em termos de estratégias de conservação e melhor relação custo-eficiência

Keywords: Amazon, cattle ranching, pasture pests, biological control valuation, land use policy.

1 Introduction

1.1 General context

The municipality of Cotriguaçú is located in the "Arc of Deforestation", which lies at interface between the Amazon rainforest in the State of Mato Grosso, and large-scale agribusiness enterprises that have been expanding northward from the Cerrado. The regional deforestation process, historically favored by policies aimed at encouraging agribusiness (Greenpeace, 2009), sets a high opportunity cost for conservation of standing forests (Reydon, 2011), which is difficult to offset through mechanisms such as Payment for Environmental Services – PES.

Considering the relevance of the Amazon rainforest in terms of biodiversity conservation and its role in climate regulation, as well as in the political sphere with policies involving Brazilian commitments to cut down on deforestation, the priority now is to identify other factors that can encourage producers to preserve the forests remaining on their properties. Parallel to this, in order to be viable, forest conservation should condition but not be an obstacle to local socio-economic development, since there is a low-income population that needs improved access to basic services. Besides, there is also a local elite that will certainly firmly oppose any initiatives contrary to their economic interests, presently linked to the wealth-concentrating development model that has been The municipality of Cotriguaçú is located in the "Arc of Deforestation", which lies at the adopted in Brazil as a whole (Mendoça, 2010).

Finally, the central government is unable to guarantee compliance with environmental legislation, given, among other issues, the nation's enormous extent and complexity, and the interest of a major block of the nation's politicians in agribusiness and expansion of arable land area (Greenpeace, 2009).The recent controversial change in the Brazilian Forest Code can be considered a paradigmatic example of that, since has weakened environmental protection on private lands, contrary to the recommendations of the leading scientific societies of the country (Silva et al., 2011).

1.2 The relevance and vulnerability of family cattle ranching in Northern Mato Grosso, and its relationship with deforestation

Cattle-raising is one of the main economic activities in the Northwest region of the State of Mato Grosso (NW MT), and is expanding throughout all the municipalities in the region. The municipalities with the highest growth rates are Colniza and Cotriguaçú, with the later posting herd growth of no less than 191% in the past seven years, an average of 31.8 % per year. Growth of the cattle herd in the region reflects the shift of cattle-raising activities to the northern portion of the state (Dias Filho and Andrade, 2006, Agrosuisse, 2010), with the subsequent threat that this represents for the native forest still existing in the region (Reydon, 2011; Dias Filho e Andrade, 2006).

According to the Brazilian Statistics Bureau (IBGE) most of the area of the municipalities of Cotriguaçú, Juína and Juruena is made up of large ranching properties (76% of the area), which measure 1,441 hectares on average, while family properties (24% of the area) occupy an average of just 60 hectares (IBGE, 2006).We can thus confirm that the number of establishments dedicated to family production is almost nine times higher, based on which a considerable portion of the rural population of these municipalities is linked to such activities.

The region's herds are mainly fed on extensive pasture. As pastures are considered low-value crops per unit of area, after they dominate the landscape it is only rarely that measures are taken to maintain or improve the production of forage. Accordingly, even when high levels of pest insect infestations are detected, and the damage is clearly evident, it is common for no control measures to be taken at all (Valerio et al, 1996).

In the context of lack of clear definition regarding property rights, which is common in the Amazon region, such a strategy is favored, since the stimulus is to open up new forest areas to create pasture. In the traditional model for expansion of the Brazilian agricultural frontier, when a producer opens up new areas he earns income from the sale of wood, and does not need to invest in pasture restoration, since the recently cleared soil is naturally already quite fertile, while the degraded soil becomes used for agricultural production (Alves, 2009; Greenpeace, 2009; Vivan et al., 2010; Reydon, 2011).

Real estate speculation is also credited with being an important factor that encourages this process of deforestation and opening up of new pasture lands, since there are expectations – on the part of those clearing forests – that there will be demand for land without forest cover in the future. Valuation of the land, influenced also by the proximity of regions that permit productive exploration, occurs to the extent the collective expectations are raised. There are factors that stimulate this projection, such as the rise in the price of agricultural commodities (beef or soya, for example), or announcements by major agribusiness players pointing to improved prospects for this sector in Brazil. Recently, these factors converged, leading to a situation where the demand for land increased even more and prices too kept pace, further pressuring deforestation (Reydon, 2011).

Nonetheless, in areas with well-defined property rights, producers have a limited amount of land and cannot resort to the strategy of opening up new pastures indefinitely, even if they ignore the limitations in force on deforestation under the Brazilian Forestry Code. With this "solution" discarded, over the medium- or even the long-term, producers are obliged to assume the consequences of the management of their properties, be it good or poor, and this aspect has not yet been fully assimilated by the region's producers, accustomed as they are to the permanent expansion of the farming and livestock raising frontier.

In this sense, it should be highlighted that insofar as non-family producers are sufficiently capitalized to be able to occasionally assume serious damage to their pasture – due to pests, for example –, family producers are more vulnerable to such damage, habitually needing to resort to the sale of their cattle when that harms befall them. For this reason, family producers would be especially benefited by the implementation of techniques that allow them to maintain more stable pasture production through agro-ecosystem stabilization.

The family segment of Brazilian agriculture and livestock-raising and the production chains interlinked to it accounted in 2005 for 9.0% of Brazil's GDP, while the nation's agribusiness corporations accounted in that same year for 27.9% of the country's GDP (Guilhoto et al., 2007). The weighty role played by family farms and ranches in generating wealth and the economic and social relevance – besides the ecological importance – of undertaking lines of research in this field is thus clearly supported.

1.3 Research approach and objectives

Aiming to reduce deforestation, in the scenario previously outlined, the solution is not to make legislation more restrictive, since this would be a controversial measure. The approach should rather be to change the incentives to deforest which rural landowners receive. In this sense, it is fundamental to identify factors that can be added to the already-existing command and control policies, as well as potential economic instruments to compensate actors to preserve standing forests.

With the advance of deforestation, pastures in this region have been increasingly attacked by a pest known as *spittlebug* (Hemipter: *Cercopidae*), an insect which sucks the sap from pasture grasses, causing severe damages on it (IMEA, 2011). According to the bibliographic literature on the subject, both processes are interrelated, since the replacement of forest with pasture brings with it greater availability of food for this insect, coupled with the disappearance of its potential predators (Sujii *et al.*, 2001; Aguiar Menezes, 2003; Embrapa, 2007). In addition, conventional control efforts (pesticides, fire, plant resistance, cultural practices) have not been effective in controlling spittlebug populations (Silva, 1984; Valerio & Koller, 1993; Valerio, 2009; Dias-filho, 2011).

Therefore, we identified the local demand to seek alternative solutions to control spittlebug populations in pastures. In this sense, this study proposes an evaluation and assessment of the biological control provided by forests to the emblematic production system in the region: extensive grazing. Thereby, it is hoped to enhance recognition, on the part of producers and technicians, of the value of the standing forest for their own activities. This will complement the policies for deforestation reduction, in line with the commitments assumed by Brazil in this respect.

This research aims to generate two kinds of effects: a more integrated, efficient, and ecologically balanced landscape planning, by producing the technical basis for training both technicians and policymakers, and promoting a change in the incentives for owners to deforest. Instruments that could be brought to bear include extension and agroenvironmental measures. Additional incentives could be derived through PES or REDD+ measures. The final result of this work is hoped to promote greater compatibility of ranching with biodiversity conservation within the productive landscape in one of the most threatened regions of the Amazon basin.

2 Literature review

2.1 The spittlebug pest

2.1.1 Relevance of the pest

Pasture spittlebugs (*Homoptera, Cercopidae*) are the principal pests of forage grasses in the American Tropics. This is in large measure due to the extensive monocultures resulting from introduction of the grass known scientifically as *Brachiaria decumbens* cv. Basilisk. Adaptation of this grass to the highly acid and low fertile soils of the savannah increased the capacity to withstand heavy grazing on the region's pastures, encouraging the development of livestock ranching. Over time, the susceptibility of such pastures to spittlebugs was verified (Valerio, 1997).

Occurrence of these insect pests begins with the commencement of the rainy season of the year, when both the pastures and the animals are weakened after the dry season. The damages caused are due to the suction of froth and the injection of salivary secretions in the vegetable fibre. Although nymphs do cause damages, this is principally due to the action of adult insects (Valerio, 2009).

Spittlebugs can drastically reduce pasture production and quality of the pasture, which loses its support capacity. Nonetheless, by and large most of the damages they cause affect already weakened pastures, especially because of the low fertility of the soil, although there have also been reports of a correlation between the intensity of the damages and a shortage of water (Ibíd.). This points once again to the importance of ecosystem services, in this case regulation of the microclimate, the water cycle and the cycling of nutrients, as well as protection against erosion, services that are strongly dependent on forest cover.

It is estimated that the losses caused by these insects in the Brazilian savannah reach figures between US$ 99 and 819 million per year, varying based on the area infested and the level of infestation (Macedo, 2005). The magnitude of the damages caused by these insects and their growth trends, coupled with the unsatisfactory results obtained in prior attempts at pest control, have generated a demand among the region's producers for alternative control measures, including biological pest management.

The principal species in the mid-north region of the State of Mato Grosso is *Deois flavopicta*, with its population representing up to 87% of the total spittlebug population in the region (Mascarello, 2002).

2.1.2 Biological cycle

The females lay the eggs at the level of the soil or on vegetative remains near the host plant. The number of eggs per female varies according to the species. The incubation period can last up to 200 days, in the case of quiescent eggs (Souza, 2008).

The nymphs feed on the surface roots or at the base of the plant at the level of the soil. Based on suction of the plant they produce a white froth that begins to wrap around the insect to protect it from the losses of humidity and, up to a certain point, from its natural enemies (Valerio, 2009; Souza, 2008). Contrary to the feeding habits of nymphs, adults feed on the part of the plant sticking up into the air, remaining on the apical third until roughly 9 am, and after 3 pm in the afternoon, avoiding exposure to the high temperatures in the hottest hours of the day. Parallel to this, in regions with marked dry season, the spittlebug spend this period in egg form, with the other phases only occurring during the wet season (Valerio, 2009).

The egg only develops with the beginning of the rainy season (September and October, generally), hatching after approximately 17 days. With variations depending on the species, the nymph phase lasts roughly 30 days and the adult phase approximately 10 days, with the pre egg-laying phase lasting three days. If there are no thermal limitations, the limit of generations is determined by the rainy season (Ibid.). In the region this period occurs between October and February, during which three generations occur (Mascarello, 2002).

2.1.3 Methods for controlling pasture spittlebugs

The habitual manner for attempting to control the pests involve the use of pesticides or fire. According to Townsend et al (2001), pesticides are not justified in extensive pastures. Risks for the environment, the human health, and their low effectiveness on controlling spittlebug infestation levels(Whittemore et al., 1987; Guivant, 2000; Amaral, 2001; Pessoa et al., 2003; Pessoa et al., 2006; Lima et al., 2007; Pignati & Machado, 2007; Zeilohofer et al., 2007; Waichman et al., 2008; Pignati, 2011; Townsend et al., 2001), induce a search for other methods.

Pesticides only affect the adult individuals present at the time of application. Moreover, their application is time-consuming and costly, for which reason it is not a very viable proposition for small producers. Besides, chemical control causes major imbalances in local ecosystems, prejudicing the soil biota responsible for its structure and evolution of same (Whittemore et al., 1987; Zeilhofer et al., 2007; Correia, 2002), with the resulting loss of pasture production. Also affected are members of the community of predators in the ecosystem, which regulates the community of phytophagous insects, which over the medium term favors the pest phenomenon. On the other hand, as spittlebug infestation is particularly serious in degraded pastures, and pesticides affect too on plant health, the use of these substances may cause an increase on spittlebug population, being harmful to the pasture, as well as to the agro-ecosystem (Carballo and Guaharay, 2004).

In the case of fire, this is a cheap technique that proves to be effective on a short-term basis, due to the partial elimination of spittlebug adults, nymphs and eggs, for which reason it has been repeatedly used. Even so, this solution remains controversial. According to a study on *Z. Entreriana* and *D. flavopicta,* with *Brachiaria decumbens* as host (Koller et al., 1987), the populations ofnymphs and adults return to similar levels and at times even higher levels than those previously prevailing 75 days after the fire. On the other hand, burning pastures eliminates the spittlebug's natural predators and, on a medium- and long-term basis, favors pasture degradation through the loss of soil nutrients with the transportation thereof by water and wind (Costa et al., 2005). Despite this, even some authors recommend the use of fire as a spittlebug control strategy in pasture areas to be recovered or in areas with extremely high population levels of these insects (Valerio and& Koller, 1993).

Experiments have been conducted with spittlebug control involving use of the entomopathogenic fungus *Metarhizium anisopliae,* with variable results. The need to be extremely careful insofar as regards product quality in buying, transport, handling and applying the fungus, as well as in managing the grass after application, are indicated as the main causes of the low effectiveness of applying the fungus among the region's producers (Alves, 2007; Alves, 2010; Castillo, 2006; Loureiro, 2005; Rabinovitch, 1998; Teixeira, 2010).

As a solution for effective spittlebug combat, various authors have pointed to the need to implement Integrated Pest Management – MIP – (Almeida & Filho, 2001; Alves, 2007; Maia & Carvalho, s.d.; Valerio & Koller, 1992; Zimmer & Barbosa, 2005), which consists of the intelligent use of several control measures, with a view to achieving economic efficiency along with heightened ecological and social consciousness (Silva, 2007). This combination of measures generally considers the use of resistant species, diversification of pasture, biological control and adaptation of cultural practices.

2.2 Theoretical basis for maximizing biological control of the spittlebug provided by forest

2.2.1 Spittlebug regulatory factors

The reproductive capacity of a species is limited by the resistance that the environment exercises on its biotic potential (Silva et al, 1998).

Population spurts among phytophagous insects are caused by changes in biotic or physical factors of the environment. The management of an insect population to prevent population spurts requires determining what factors have changed into the environment to convert the insect's population into a problem (Sanders and Knight, 1968). Field population dynamics is a function of the climatic conditions of each region, the availability and characteristics of the host pasture and abundance of natural enemies (Silveira Melo, 1984; Sujii, 1998; Pires et al, 2000).

Pasture spittlebugs are found naturally in several Brazilian ecosystems (Valerio and Koller, 1993), albeit inserted within trophic chains that regulate them, for which reason they appear in small population densities. In a study conducted in the *Cerrado* biome (Pires et al., 2000), the density with which spittlebugs appear naturally in the Cerrado is very low, if compared with the densities noted in *Brachiaria ruzenzis* pastures (between 105 and 2,273 times lower, depending on the characteristics of the sample area), and the proximity of infested cultivated pastures.

In a study conducted by Oliveira (1998), it was verified that females are not particularly disposed to lay their eggs in *Brachiaria decumbens* pastures, when compared with other autoctone pastures (e.g., *Axonopus marginatus*), or better quality plants (in terms of composition of nitrogen, fiber or water). Even so, the performance of the nymphs, in terms of total survival and duration of the nymph stage, is better in plants with low fiber and silica content, and high nitrogen and water content (Oliveira Neto, 1998a; Sujii et al., 2001).

Additionally, according to a study by Silva et al (1998), female *Deois flavopicta* Stal spittlebugs raised on *Brachiaria decumbens* Stapf posted fertility rates of 38 eggs/female, much higher than the rate of 12 eggs/female for those raised on *Axonopus marginatus* Chase, a native host. On the other hand, the density of adults had a regulatory effect on the insect population.

According to Sujii *et al*. (2001), the host plant on which the nymphs feed has consequences for their size and, as a result, on the size of the adults that emerge from them, but does not influence the fertility of these adults. On the contrary, feeding in the adult stage has a bearing on the fertility of the female, being greater in spittlebugs that feed during the adult stage in *B. ruzensis* pastures. This strategy favors the successful colonization of other species of grasses with greater nutritional quality. Lower fertility was also noted in cases of food scarcity, implying a certain capacity for self-regulation.

A study on the variables affecting spittlebug population dynamics conducted by Oliveira Neto et al (1998b) showed that the reproductive capacity of females, together with the mortality of nymphs due to prolonged hydric stress and high predator rates, are the main variables – among those studied – that determine the abundance of insects in the field. The variables studied were: diapausic eggs, heat shock, date of commencement of the rainy season, initial period with damp soil, hydric stress, nymph stage mortality and fertility.

The death of spittlebug eggs owing to hydric stress can be favored through the elimination of the remains of straw present in the pasture, and keeping a low pasture height through heavy stocking rates (Valerio and Koller, 1988). Even so, this overload worsens the vegetative vigor of the plant, which is also submitted to greater hydric stress, which leaves it more vulnerable to potential spittlebug attacks. This absence of humidity also reduces the incidence of fungi and other natural enemies that occur naturally in the pasture and which contribute to biological control of spittlebugs. Likewise, the possibility of carrying out biological control through application of *Metarhizium anisopliae* will wind up being discarded.

According to these studies, it can be concluded that spittlebug population level depends on the resistance that the environment exercises on its biotic potential. In other words, it depends on: quantity and quality of available pastures, microclimatic variables, and predation rates. All of these variables are closely related to the vegetation surrounding pastures, and consequently are susceptible of being changed by means of landscape management.

2.2.2 Natural enemies of the pasture spittlebug

According to the literature reviewed, natural enemies play a relevant role in controlling the spittlebug, and measures should be adopted aimed at maintaining and/or increasing their populations, in the search for biological equilibrium (Valerio, 2009: Townsend et al, 2001; Silva, 1998; Leite, 2005; Almeida & Filho, 2001).

Nevertheless, there are divergent views about the role of the different spittlebug natural enemies quoted in the literature. Marucci (2006) highlighted birds, funguses and flies as the main predators of the spittlebug. However, according to Valerio (2009), the most important natural enemies are *Metarrhizium anisopliae*, *Anagrus urichi, Salpingogaster nigra, Porasilus barbiellini*, and ant species. Other compilations of the natural enemies of pasture spittlebugs can be found on Alves (1986), and Silva (1998).

There are some studies trying to determine the relevance of each group of spittlebugs' natural enemies. The literature indicates encouraging results, albeit inconsistent ones, involving the use of *Metarrhizium anisopliae.* According to Loureiro (2005), treatment with this fungus, six days after application, resulted in a mortality rate of over 70%, in some crops reaching a full 100%. In another experiment with this fungus, Teixeira (2010) obtained nymph control efficiency in *Brachiaria brizantha* of between 85.3% and 93.72% after 75 days.

In view of the literature reviewed, it can be concluded that, there are relevant natural enemies that can cut down on the populations of pasture spittlebug, though *a priori* they aren't specific. The most outstanding are the fungus *Metarrhizium anisopliae,* birds (during this study *Crotophaga ani* and *Sturnella militaris* were constantly spotted in pastures, perched on fences or bushes, or foraging in the pasture), ants, spiders, asilids, syrphids, microhimenopters and nematodes.

2.2.3 Spittlebug dispersion

According to Nilakhe and Buainain (1988), adults have good long-distance flight capacity, being able to fly as high as 5 or 6 meters and distances of up to almost a kilometer (910) in a single flight, or even three kilometers under favorable meteorological conditions. In spite of this, according to the in-depth study on *Deois flavopicta* Stal conducted by Sujii, et al. (2000), the vast majority of spittlebugs move around through short and low leaps and flights of up to 6 meters in length and 1 meter in height, on a helter-skelter basis. The population would thus seem to present a movement of dispersal, increasing the distance between individuals within an area of occurrence, with such physical factors as wind direction and sun position appearing not to influence the standard of the insect's movement.

The occurrence of low vegetation, similar to pastures, around the pasture area proper, favors the dispersal of spittlebugs. On the other hand, the occurrence of savannah or jungle vegetation nearby inhibits their movement toward the pasture, and encourages the return to the pasture (Ibid). Accordingly, the presence of jungle thickets at the edge of the pasture has a barrier-like effect, given spittlebug dispersal.

Further according to this study, *D. flavopicta* females maintain an area of life in a radius of between 50 and 100 meters from the emergency point, tending to remain on the vegetation spot if it is surrounded by vegetation the size of bushes or trees.

2.3 Biodiversity on agro-ecosystems and biological pest control

2.3.1 Biodiversity and equilibrium in agroecosystems, a means of biological pest control

As can be seen, after reviewing the headings of regulatory factors and control measures, to avoid the damages associated with insect pests, the focus should be on deciphering the mechanisms that condition the biotic stability of agro-ecosystems, in order to propose pest management strategies that preserve their inherent balance and include resources that are both locally accessible and low in cost (Altieri, 1985).

Systems which evolved simulating the structural and biotic diversity of natural ecosystems nearby are less susceptible to pest attacks (Altieri and Latourneau, 1982). In fact, structurally complex landscapes enhance local diversity in agroecosystems which may compensate for local high intensity management (Tscharntke, 2005).

According to Carballo *et al.* (2004), the most effective and long-lasting pest control method is biological pest control, since it is exercised by natural enemies of the pests in question, is cheap, effective and permanent and, moreover, does not negatively interfere in any other process of the ecosystem. Furthermore, combating agricultural pests through biological control contributes to cutting down on the pesticides present in water, and is furthermore a technology dominated for centuries.

Pastures are semi-perennial crops that last a long time and have low value per unit of area, which favours the adoption of pest management tactics (Valerio and Koller, 1993). On the other hand, beef cattle ranching is an extensive activity in Brazil, for which reason we have to think of measures that are low in cost and can be easily adopted.

For many species of insects alterations in the host plant can have consequences in terms of their survival, development, fecundity and dispersal (Kain et al., 1975). Consequently, the control of pasture insect populations can be enhanced through alterations in the host plants (Valerio and Koller, 1993). Given that the benevolent insects are more abundant and efficient in diversified agroecosystems, it is possible to encourage the natural enemies to reach optimum population levels through alterations in the vegetation diversity of the agroecosystems (Altieri & Whitcomb, 1979)

2.3.2 Managing natural enemies through landscape planning in the agro-ecosystem

Biological control can be carried out through management of the composition and density of the vegetation in and around the cultivated field, thus inducing decisive increments in providing alternative foods (prey, hosts, pollen and nectar), and in creation of habitats that are favorable for benevolent insects, thus guaranteeing their survival and reproduction.

The proximity and diversity of this vegetation will determine the type and quantity of benevolent insects that colonize the crop, with predators and parasites being more effective in complex habitats. According to Aguiar Menezes (2003), species composition is more important than the number of species.

For a particular pest in a given location, we can find out which are their natural enemies there and seek to benefit them, through landscape planning to satisfy their specific demands. Nevertheless, ranchers need to avoid the risk of competition between this non-productive-vegetation patches and the crop (Altieri, 1986), or as in this case, pasture. On the other hand, forest canopies have innumerable species that can be consumed by beef cattle, many of them with higher nutritional value than forage grass (Camarão et al, 1990; Camarão et al, 2000). For these reasons, the economic aspects of this landscape planning at each location should be defined.

2.3.3 Relationship between the forest and the spittlebug's natural enemies

The distance to the nearest rainforest edge appears to be of major importance for the diversity of important functional groups such as bees and ants, so local and landscape management matter (Tscharntke, 2005; Klein et al. 2003; Ricketts et al. 2004).

Maintenance of native vegetation in and hillsides protects areas and guarantees places for birds, efficient predators of spittlebugs, to make their nests (Alves, 1999). The total elimination of shade trees can have a huge impact on ant diversity, as many species cannot abide places with little shade (Altieri and Nicholls, 2010).

Forest influence on biological control service could extend up to 100 meters, according to Wratten (1988), while the effects of the biological control provided by a corridor could be especially noticed in the first 30 meters (Nichols et al., 2001, Altieri, 2005). Acording to Altieri and Nicholls (2010) The presence of certain bushes can foster communities of natural enemies, at a distance of approx 3-10 times its height downwind and 1-2 times their height to windward.

Vegetation strips for natural enemies every 50 to 100 m are considered effective in providing biological control in the agroecosystem (Altireri et al., 2005). Accordingly, the presence of forest patches or strips of native vegetation to shelter and multiply the natural enemies of spittlebugs is of major importance. Priority should also be placed on reforestation of areas that are inappropriate for pastures, in order to shelter and multiply the natural enemies (Souza, 2008).

3 Methodology

The value of biological control is assessed by the level of spittlebug infestation achieved and estimated economic losses caused annually in different types of mosaic. Economic losses caused by spittlebug were estimated by survey interviews with farmers from the municipality, and infestation levels were estimated by sampling.

In sampling we measured the infestation levels of spittlebug nymphs and adults on a set of 5 sample plots of one hectare – 100 m x 100 m – in cattle ranching properties with different arrangements of forest or forest fragments and *Brachiaria brizantha* pastures. Each sample plot has 25 sample points[i], regularly established in a 25 x 25 meter grid (see Figure 2). Samples were taken once a week for three weeks, during the wet season.

The infestation level of the nymphs was measured using a 25 cm x 25 cm wire square. It was fixed randomly on the floor, near each sample point, and the number of spittles was counted. The infestation level of adults was measured using a sweeping net, doing 10 sweeping movements near each sample point (Valério, 2002).

The value of this ES is determined by relating the pasture infestation level data recorded in each plot – three having forest fragments inside or around the plot, and two without – to subsequent economic loss derived from the questionnaires. The economic analysis consists of partial budgets of pasture management using conventional pesticides and biological control (forest proximity) to compare the relative net returns, incorporating opportunity costs and productivity benefits.

The possible correlation between forest proximity and pest infestation level will determine the criteria for maximizing biological pest control, which could generate a valuable tool for decision-making on landscape planning using tools such as MARXAN. Mosaic effect on infestation reduction could be multiplied across the landscape at a municipal or regional level to motivate broader land use management strategies, including forest fragment connectivity. In this sense, different scenarios, in terms of conservation strategies and better cost-efficiency, will be generated from the estimated value of ES using the opportunity cost of conserving the remaining forest.

4 Results

4.1 Relationship between spittlebug infestation level on pastures and the forest

Aiming to better know the relationship between infestation level and forest proximity, we are studying: The relationship between spittlebug infestation level and studied variables[ii] through Principal Component Analysis; Correlation between spittlebug infestation level and forest proximity, for each sample point[iii]; Correlation between spittlebug infestation level and type of mosaic, for each plot[iv].

Through this analysis we expect to establish which factors, between those studied, may have more impact on spittlebug infestation level, how large is the influence radius of the biological control service provided by the forest, and which control level of the pest each type of mosaic can provide.

4.2 Value of biological control provided by forest

The value of biological control has been calculated through the estimated economic losses caused by spittlebugs in each of the studied types of mosaic. Average economic losses for the region have been estimated through questionnaires applied to producers of the municipality. These losses have been associated with the type of mosaic by means of spittlebug infestation levels detected in the sampling.

4.2.1 Economic losses caused by spittlebug in the previous period

Economic losses caused by spittlebug to pastures in the municipality were estimated from interviews with farmers selected to reflect the sample universe of the region. As a result we obtained average losses estimated at R$ 240 / ha / year, as can be seen in the summary of results in Table 5.

Table 5. Summary of losses caused by spittlebug

Landowner	Activity	Economic losses caused by spittlebug (R$/year)	Economic losses caused by spittlebug (R$/ha/year)
Adavir Maribudel	Beef and dairy	20,115	92.40
Evaldir Schmitz	Beef	47,827.50	208.90
Jaime Leidentz	Beef	181,020	289.20
Luciano Emanuel Morães (São Marcelo Ranch)	Beef	50,000	5.20
José Carlos Souza	Dairy	31,800	1,223.10
Darci Brambila	Beef and dairy	22,450	44.90
Frederico Telck	Beef	44,700	298.00
Valdir Antonio Bernardi	Beef	157,000	196.30
Gilberto Alves (São Nicolau farm)	Renting pasture	50,625	42.20
Ismael Amaral Newman	Beef	175	0.60

Average: R$ 240 ha.ano^{-1}

Estimation of economic losses caused by spittlebugs on pastures for each analyzed type of mosaic

For each of the main types of forest-pasture mosaic in the region we estimated the level of biological control provided to pasture by forests, as well as the economic losses associated with each type of mosaic. Both estimates have been carried out through variations in spittlebug infestation level in the plots with different arrangements of forest and pasture, compared with the control plots without the presence of forest.

To determine economic losses associated to spittlebugs in each type of mosaic we took as a reference losses determined through survey interviews. These losses have been considered associated with pasture without the presence of forest patches or significant vegetation – trees or bushes – within or near the plot. This is the prevalent mosaic model including pastures in the region, and having it as reference allows us to obtain a more conservative estimate of the biological control value.

There are different studies that attempt to determine the relationship between spittlebug infestation levels and productivity or economic losses, including Silva (1982), Ferrufino (1987), Valerio and Nakano (1988), Holmann and Peck (2002), Macedo (2005), and Pabón (2006).

Considering the low suitability of models we identified, we have established a minimum and a maximum value of infestation for which economic losses are known. Subsequently, a linear relationship has been assumed between the variables. It has been considered enough, given the exploratory character of this study. The results are detailed in Table 6.

As a minimum we considered the absence of spittlebug, which, therefore, do not cause economic losses (R$ 0/ha/year). The level of infestation detected in pastures without forest inside the plot or in the surroundings and, therefore, without biological control, was taken as maximum reference. In this case, being conservative, we assume that losses associated with these pastures correspond to average losses estimated for the region through applied questionnaires (R$ 240/ha/year).

Table 6: level of infestation level and economic losses by type of mosaic.

Plot reference	CHARACTERIZATION		AVERAGE INFESTATION LEVEL				Economic losses caused by spittlebug[1] (R$/ha/year)
	Plot	Surroundings	Absolute		Relative		
			Nymphs (nº/m²)	Adults (nº/10 redadas)	Nymphs (%)	Adults (%)	
Roque / Claudir[2]	Pasture	Pasture	23.45	1.17	100	100	240.00
Valdir	Pasture with with a few scattered trees	Forest on 3 sides and farming in the fourth. Outside the property only pasture[3]	28.40	0.53	121.1	45.3	108.72
Sergio	Pasture with riparian protected area[4]	Pasture with some forest patches	8.30	0.24	35.4	20.5	49.20
São Marcelo Farm	Pasture with multiple patches of natural vegetation	Similar pasture in the surroundings and large forest reserve at 100 m (several km2)	3.40	0.03	14.5	2.6	6.24

[1] Based on adult population, which are primarily responsible for the damage caused by spittlebugs. Calculated as: (relative adult infestation level /100) * 240.

[2] Average values in plots of renovated pasture (Roque) and without reform (Claudir).

[3] Forest on three sides: 200 m, 400 m and 600 m, respectively. The pasture outside the property has a history of high levels of spittlebug infestation, according to the owner.

[4] Called *Área de Preservação Permanente* (APP).

4.2.2 Level and value of biological control service for each type of studied mosaic

Biological control level has been calculated as the percentage that separates adult infestation level detected in each plot, from reference infestation level for conventional farms in the region (corresponding to control-plots without forest).

Comparing economic losses associated with spittlebug in each type of mosaic, with the losses in the control-plots, we have an estimation of the value of biological control service provided by forest in each studied mosaic (see Table 7).

Table 7. Level of control and value of biological control service enjoyed by each plot.

Plot reference	CHARACTERIZATION		AVERAGE INFESTATION LEVEL		AVERAGE BIOCONTROL LEVEL		Economic losses caused by spittlebug [1] (R$/ha/year)	Value of biological control service enjoyed [2] (R$/ha/year)
	Plot	Surroundings	Nymphs (%)	Adults (%)	Nymphs (%)	Adults (%)		
Roque / Claudir[3]	Pasture	Pasture	100	100	0	0	240.00	0
Valdir	Pasture with a few scattered trees	Forest on 3 sides and farming in the fourth. Outside the property only pasture[3]	121.1	45.3	-21.1[4]	54.7	108.72	131.28
Sergio	Pasture with riparian protected area[5]	Pasture with some forest patches	35.4	20.5	64.6	79.5	49.20	190.80
São Marcelo Farm	Pasture with multiple patches of natural vegetation	Similar pasture in the surroundings and large forest reserve at 100 m (several km2)	14.5	2.6	85.5	97.4	6.24	233.76

[1] Based on adults population, which are primarily responsible for the damage caused by spittlebugs. Calculated as: (adults relative infestation level /100) * 240.

[2] Calculated as avoided losses, compared with the conventional reference property which has only pasture (Roque / Claudir).

[3] Average values in plots of renovated pasture (Roque) and without reform (Claudir).

[4] The higher moisture associated to the higher presence of vegetation could be encouraging oviposition of spittlebugs coming from surrounding pastures, and favoring their survival. Then, the also increased presence of predators nearby forest could be responsible for the much lower population level detected in the adult stage. Further studies are required in this regard.

[5] Called *Área de Preservação Permanente* (APP).

4.3. The opportunity cost of maintaining the forest

4.2.3 Rents associated with deforestation in the municipality

The opportunity cost of keeping a forest area standing is determined by the potential gains of exploiting that area in another activity viable in the municipality. According Reydon (2011), the deforestation of a hectare of forest in Cotriguaçu brings a net return of R$ 2,400/ha from sale of timber, and R$ 120/ha/year from the ensuing cattle ranching activity. In the municipality, the average price of an hectare of land covered with forest is R$ 546.13 and the average price for a pasture reaches R$ 2,083.69; Therefore, deforestation provides also a real estate gain associated with the increase of value of deforested land of 1,537.56 R$/ha.

Regardless of the quoted data, which certainly affect decision making, this study aims to compare the opportunity cost of keeping the forest, with the value that the presence of forest adds to cattle ranching on conventional properties of the municipality. The opportunity cost has been estimated through the return offered by cattle ranching in Cotriguaçu.

4.2.4 Opportunity cost of keeping the forest in Cotriguaçu

According to surveys by CIFOR, the income associated with cattle ranching in the municipality, reached R$ 165.83/ha/year in the case of small farms and R$ 68.79/ha/year in the case of large farms. Weighting this value with the relative surface area they occupy in Cotriguaçu, according to IBGE (2006), we obtained a weighted average of R$ 103.65/ha/year.

Table 8. Area occupied by family farms and agribusiness properties, in the municipality of Cotriguaçu.

Type of farm	Occupied area in the municipality (ha)	Occupied area in the municipality (%)
Family	110,165	35.92
Agribusiness	196,496	64.08
TOTAL	306,661	100

Adapted from IBGE (2006).

According Vivan et al. (in prep.), the income associated with meat production in the county – activity associated with large farms – would come to US$ 114 / ha / year, as in the joint production of meat and milk - activity associated with small family farms – would generate an income of US$ 212/ha/year. Weighting this value produced an average of US$ 149.20/ha/year. Converted to R$[v], this value would be R$ 289.94/ ha/year.

However, according Agrosuisse (2010), who was based on data from ANUALPEC (2010), the return associated with cattle ranching in the municipality is R$ 98.30/ha/year.

Table 9. Cattle ranching productivity in the municipality of Cotriguaçu according to different sources.

	Cattle ranching productivity (R$/há/ano)			
	CIFOR (Guerra, 2012)	Reydon (2011)	Agrosuisse (2010)	*Vivan* (2010)[vi]
Householders	165.83	-	-	411.98
Large landholders	68.79	-	-	221.54
Weighted average	103.65	120	98.3	289.94

AVERAGE: R$ 107,32 /ha/year

Considerating the literature on cattle ranching productivity in the municipality of Cotriguaçu, we consider as a benchmark for the study area the average value of the results, i.e., R$ 107.32/ha/year.

4.2.5 Biological control value provided by forest vs. opportunity cost

The value of the biological control produced by each type of pasture-forest mosaic (Table 7), is in all cases greater than the average cattle ranching productivity in the municipality (R$ 107.32/ha/year). We conclude therefore that the strategic maintenance of forest patches in and around the pasture could generate greater economic returns, through the biological control of spittlebugs, than the deforestation of these areas for conversion to cattle ranching.

According to IFT (2010), based on data from PRODES-INPE (2008), in Cotriguaçu there are 7.594 km^2 of forest, the 81% of the forest that originally existed in the municipality. 2.985 km^2 of that total are within Indigenous Lands or Conservation Units, in which only respectively 0.02% and 0.08% of the original forest had been cleared. The rest of the forest is divided between settlements and rural properties, which retain respectively 617 km^2 and 3,992 km^2 of forest remnants.

According to the data obtained in this study, forests surrounding pastures in the municipality are providing a biological control service estimated between R$ 131.28/ha/year and R$ 233.76/ha/year.

The next steps of this study will include the development of different scenarios of landscape planning for the municipality. In addition, guidelines for a biological- control-friendly landscape planning will be developed for the region

5. Conclusions[vii]

The preliminary analysis of collected data shows a correlation between low spittlebug infestation level (adults, which cause the greatest part of the damages), and the presence of forest in the agroecosystem.

Economic losses related to spittlebug on pastures within the municipality, are so high, that cattle ranching becomes unfeasible in some cases. These losses include the death of cattle, costs of pasture reform, decreasing profits due to the weight loss of cattle and the sale of breeding cattle, which would otherwise produce one calf per year.

Depending on the type of mosaic of forest and pasture, the biological control afforded by forest proximity can maintain the spittlebug population at a level well below that at which economic damage would be sustained, potentially reducing economic losses by up to 97.4%

Based on this survey, biocontrol provided by the forest reduced economic losses by between 54.7 and 97.4%.

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Notes

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[i] Except the plot on Sergio's farm, where four sampling points were excluded from the analysis because they were inside the forest patch, and therefore there were no pasture on them.

[ii] Forest fragmentation and connectivity, distance to the forest, forest fragment area in the plot, pasture reform (yes or no), stocking rate, and nymphs and adults infestation levels

[iii] To determine the relationship between spittlebug infestation level on each sample point and forest proximity, a correlation analysis between micro-scale studied variables (adults and nymphs infestation level, forest fragment size and degradation and pasture height) and forest distance on the direction of the cardinal points is being made. The direction of prevailing winds was not considered, as wind is not considered an important factor in spittlebug dispersion (Sujii, 1999).

[iv] To determine the relationship between the infestation level and the mosaic in which the pasture is inserted, we studied the correlation between the level of infestation and the fragmentation and connectivity of forest around each plot. We also considered the distance between the center of the pasture and the forest on the direction of the cardinal points.

[v] Considering an average exchange rate in 2012 of R$ 1.9433/US$ 1.00. http://www.acsp.com.br/indicadores/IEGV/IEGV_DOLAR.HTM

[vi] Provisionally, that value was not included in the average because it is far superior to others.

[vii] The next steps of this study will include the development of different scenarios of landscape planning for the municipality. In addition, guidelines for biological-control-friendly landscape planning will be developed for the region.

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