Transition from Semi-Confinement to Pasture-Based Dairy in Brazil: Farmers' View of Economic and Environmental Performances

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The production of ecosystem goods and services has increased significantly in the last hundred years, while the capacity of ecosystems to generate supporting and regulating services has decreased. In this context, agriculture and livestock production have become major concerns. At the same time, livestock, particularly dairy cows, play a key role and can serve to improve ecosystems, production, and rural livelihoods. We randomly selected and conducted semi-structural interviews with sixty-one dairy family farmers from four cooperatives in the Encosta da Serra Geral Region of the Atlantic Rainforest in Santa Catarina, Brazil. The goal was to analyze their production and viewpoints about environmental variables after adopting management-intensive grazing (MIG). The overall results showed that when farmers changed from semi-confinement and continuous grazing to MIG, they perceived improvements in

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production, livelihoods, and ecosystem services. Moreover, according to farmers' insights, MIG could be a tool to increase water and soil quality, animal health, alleviate poverty, and complement Brazilian conservation efforts.

Keywords pasture management, dairy, family farmer, ecosystem services, conservation, livelihoods

INTRODUCTION

An increase in global incomes and population is predicted to substantially increase the demand for dairy products in coming years (FAO 2011). At the same time, agriculture in general and cattle in particular pose serious threats to global ecosystems. Meeting the growing demand for dairy products without risking environmental degradation requires greater milk production on less land, or else production techniques that are less harmful to the environment (Tilman et al. 2011).

The clash between this growing dynamic is evident in the State of Santa Catarina, Brazil. Brazil's dairy production ranks 3th worldwide and, while most current production is consumed domestically, it has recently started to target international markets (Arruda 2012). Santa Catarina has been the leading State in pasture-based family dairying, ranking 5th nationwide with 13% growth in 2012 (GRural 2012). Together with four other States, they are responsible for 69% of Brazil's dairy production. With a vast potential to be explored, dairy ranks fourth in terms of GDP and plays an important role in the State's economy and rural livelihoods (Dartora 2002; ICEPA 2010).

Constituting 90% of the rural population, family farmers are responsible for 83% of dairy production in Santa Catarina (IBGE 2012), and 70% of all agricultural output on less than 41% of the total agricultural area. With more than 60 thousand dairy farmers, milk production is the main activity of smallholders in Santa Catarina. Approximately 62% of the dairy farms are smaller than 20 hectares, and dairy is their main source of income (Risson, Gabriel Jr., and Pauli 2010). The economic feasibility of family farms is a major State concern because it directly relates to rural and urban migration and social wellbeing. Dairy production on naturalized pastures has grown substantially in the last decade, with a high demand for extension support and appropriate technologies (Dartora 2002; Bauer et al. 2009).

Confinement or semi-confinement dairying still are the most frequent activities among small and mid-size farmers in Santa Catarina. However, such production methods may threaten both long-term viability of smallholders' livestock systems and important ecosystem services they often affect (Stofferahn 2006; Farley et al. 2011). Santa Catarina is part of the critically endangered Atlantic Rainforest Biome, which generates a wide array of ecosystem goods and services such as water supply, climate regulation, food provision, pollination, and cultural and spiritual amenities (Silvano et al. 2005; Ditt et al. 2010), that are essential to human wellbeing (Daily et al. 1997; MEA 2005). The extension of the ecosystem along the Brazilian coast, with substantial variation in elevation and climate, allowed an extraordinary biodiversity with high levels of endemism (Cincotta, Wisnewski, and Engelman 2000; Myers, Mittermeier, Mittermeier, Fonseca, et al. 2000; Costa et al. 2005; Tabarelli et al. 2005; Brooks et al. 2006). As a result, the Atlantic Rainforest was recognized as a major biodiversity hotspot (Myers, Mittermeier, Mittermeier, da Fonseca, et al. 2000). It was declared a Biosphere Reserve by UNESCO, in

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1991, and one of the most threatened biomes worldwide, with only around 7% of the original Atlantic Rainforest remaining in Brazil (Grelle 2003; Tabarelli et al. 2005).

Currently, most of Santa Catarina's subsistence agriculture and dairy farms are located within this biome. The farm size, in this study, averaged between 5 to 10 hectares coinciding with the State's average family farm area (Risson, Gabriel Jr., and Pauli 2010). In this context, the State net forest loss of 78% (FSOSMA 2010) is mostly due to agricultural land conversion, which represents a loss of ecosystem structure and associated ecosystem functions and services (Foley et al. 2007). Semi-confinement with continuous grazing, corn silage fields on steep slope terrains and riparian areas, high loads of fertilizers to cope with nutrient loss due to soil erosion, and animals concentrated indoors with poor manure management have degraded important ecosystem functions, causing cascading disservices (Zhang et al. 2007). These disservices often affect the provision of ecosystem goods and services ultimately affecting the small farms' economic feasibility and capacity to maintain the livelihoods (MEA 2005). The small farmers inability to cope with high scale industrialized dairy is evident (Lyons et al. 2000; Hinrichs and Welsh 2003; Stofferahn 2006), but is particularly notable in the Atlantic Rainforest Biome due to landscape characteristics and social structures.

During the late nineties, the Federal University of Santa Catarina (UFSC), sponsored a pasture outreach program Grupo Pastoreio Voisin (GPV) requested by a farmers' association called AGRECO in order to find a solution for high debt load, low profitability and high environmental damage by family dairy farms. The program designed a participatory action research, and started with five family farms (Saade 2002). By 2003, 34 farmers were working with pasture-based

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dairy year round. A partnership involving the State Agriculture Research and Extension Agency-EPAGRI, UFSC, GPV and four dairy Coops was formalized, in 2004, to fulfill Santa Catarina's increasing demand for grazing technical support. By 2008, this initiative had become a Southern State Grazing Program with 622 farmers and four dairy Coops, and a prize-winning program, due to its affect on both the environment and smallholders livelihood, (Epagri 2010), driven by an unusual demand from farmers (Schmitt F, Murphy, and Farley 2010). Research by Epping (2003) and Rizzoli (2004) also suggested that farmers who switched to management-intensive grazing (MIG) in Southern Brazil observed improvements across a wide spectrum of production and environmental variables.

MIG, is a pasture-based alternative farming practice under active study with increasing implementation worldwide, (Hopkins and Del Prado 2007; Mannetje 2007; Schmitt F, Murphy, and Farley 2010), with potential for increasing dairy production per hectare while restoring ecosystem services. However, livestock production can present different trade-offs.

The ongoing debate about the effects of MIG adoption include (its) disadvantages over confinement on productivity per animal, potential inferiority related to continuous management, especially on rangelands, the disconnection between management and scientific knowledge, or even claims that it has too narrow a focus (Hubbard 1951; Heady 1961; Gammon 1978; Hart et al. 1993; Maraschin 1994; Briske et al. 2008). Several studies also stress that pasture-based dairy management can have negative environmental effects (Stout et al. 2000; McDowell et al. 2008).

However, other studies found evidence of low environmental effects (Basset-Mens, Ledgard, and Boyes 2009; Rotz et al. 2009), related to soil health (Dorsey, Dansingburg, and Ness 1998),

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erosion and soil structure (Dorsey, Dansingburg, and Ness 1998; Sovell et al. 2000; DeVore 2001; Teague et al. 2011), riparian areas (Lyons et al. 2000), wildlife (Holechek et al. 1982; Paine et al. 1995; Temple et al. 1999; Ignatiuk and Duncan 2001), energy conservation (Paine 1999; Horrigan and Walker 2002), GHG emissions (O'Brien et al. 2010), carbon sequestration (Conant, Paustian, and Elliott 2001) and biodiversity (Sanderson et al. 2004; Potts et al. 2009). Some studies also emphasize the socio-economic performance of MIG when compared with confinement feeding (Murphy, Rice, and Dugdale 1986; Rust et al. 1995; Hanson et al. 1998; Winsten, Parsons, and Hanson 2000; Hanson et al. 2013), or the increased carrying capacity and competitiveness when compared with continuous grazing, mainly on forage land, (Murphy, Rice, and Dugdale 1986; Hanson et al. 1998).

Ultimately, individual farmers decide what technology to adopt, based on their perceptions. The objective of this research is to understand the different aspects of the transition, from semi-confinement to pasture-based dairy, learning from farmers that adopted and maintained MIG for at least 3 years, thereby acquiring intimate knowledge of the managerial system. The factors studied included pasture and animal productivity, animal health, characteristics of the investment, and ecosystem services such as, soil quality, erosion control, enhanced vegetation cover, biodiversity, and water quality. We also considered farmers' views about environmental awareness and appropriate conditions to comply with the BFA. We wanted to understand and better explain the uncommon demand for grazing among farmers and dairy Coops in Southern Brazil and suggest some direction to the policy design.

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Distinct hypotheses guided this research. First, farmers who transitioned from traditional semi-confinement dairy to MIG in Santa Catarina, would experience increased productivity and improvement in their livelihoods. Second, farmers would perceive improved ecosystem services after transitioning to MIG. Moreover, testing these hypotheses will provide an exploratory approach to determine if any important correlations suggest ways to improve future adoption.

METHODOLOGY

Location and Biophysical Characteristics

The studied farms are located within 14 municipalities in the "Encosta da Serra Geral" in Santa Catarina, Brazil, within the Atlantic Rainforest Biome (Figure 1). Santa Catarina has 6.6 million inhabitants and 95.7 thousand km^2 (1.3% of Brazil) (IBGE 2013).

Santa Catarina has a subtropical, mesothermic, humid climate without dry seasons. Weather in the region varies widely depending on altitude, from sea level in coastal areas to 1200 meters in mid-western mountains that reach 1,800 meters high. Average temperature is 18° C and precipitation is 1700 mm/yr (Nimer 1990). Soils are mostly poor, acidic, with steep slopes. Soil phosphorus is the main limiting element, varying from 0.4 to 6.0 ppm; potassium varies from low to medium (54-99 ppm); organic matter can reach 2.5%, and pH 4.6. Vegetation is predominantly broadleaf and semi-deciduous broadleaf, mixed with Araucaria (*Araucaria angustifolia)* conifer in high-altitude areas, resulting in highly complex ecosystem heterogeneity (Brannstrom 2002; Webb et al. 2005). Between 17% and 22.4% of the State is covered with

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secondary forests; primary forest remnants are rare (Tabarelli et al. 2005; Zurita 2006; FSOSMA 2010).

Family Farm Agriculture and the Brazilian Forest Act

Generations of farmers have made their living through the goods produced in this biome, either by harvesting timber for industry, or by farming thereafter. From the arrival of Portuguese colonizers, the Atlantic Rainforest has been severely affected by repeated "slash and burn" logging practices for timber and charcoal extraction (Myers 1988).

The Brazilian Forest Act (BFA) enacted in 1934, integrated conservation and development goals to prevent irreversible damage to forest cover, and degradation of ecosystem functions critical to agriculture. The BFA, updated in 1965 and 2000, recognized Brazil's biomes as a national patrimony, and sought to regulate these with a protection gradient categorized by four forest types: (1) productive (by permit); (2) protective (specifically, forests protecting watersheds, soils, water bodies, biodiversity and cultural benefits); (3) replanted; and (4) remnants (in national, state and municipal areas). The category "protective" was set aside for permanent protection areas (PPA), which requires landowners to maintain native vegetation on hilltops, steep areas, and around water sources and riparian areas (Baptista 2008). It also mandates farmers to maintain "legal reserve" (LRs) areas on their farms for biodiversity conservation (Ditt et al. 2008).

Many smallholders in Santa Catarina do not comply with the law, mainly because many of them had already removed much of the forest from their farms before the BFA came into effect. Thus, some of the protected areas are in the core of their agriculture parcels. Enforcing the BFA by completely restoring the forest would entail immediate socio-economic problems and would force many family farms into extreme poverty (Souto 2009). Compliance with the law without causing poverty will require farming practices that sustain farming communities, and minimize affects on the ecosystem structure, functions and services (Farley et al. 2011; Alvez et al. 2012; Schmitt et al. 2013).

Current farming practices are primarily subsistence agriculture and small family-owned and operated dairy farms. Semi-confinement using corn silage and concentrates as the main feed sources is the traditional dairy production method. With a record high grain prices, this method resulted in low economic viability, depressed communities, high environmental damage, and overwork.

MIG, controls grazing frequency and intensity by moving livestock through as many paddocks as necessary, to regrow the forage on previously used paddocks (Murphy 2008). It was developed in France (Voisin 1988) and later refined by farmers and researchers in New Zealand and Ireland (Murphy 1996; Murphy 2008). Scholars such as Voisin (1988), Sorio Jr. (2000) Pinheiro Machado (2004), and Muprhy (2008), indicate that the success of MIG depends on careful implementation of four principles that address forage and animal needs. First, forage management must allow recovery periods between grazings that are long enough to restore forage to an optimum height. In this stage, carbohydrates are replenished in the roots, crowns or stolons, depending on the species (Voisin 1988). Second, occupation periods must be short enough so that forage regrowth is not re-grazed. Third, animals with higher nutritional requirements need to graze the greatest amount of high quality forage. Fourth, producing animals must not stay in the same paddock more than a day for dairy and up to three days for beef cattle (Murphy 2008).

Data Analysis

To further investigate how farmers perceive the transition from semi-confinement to MIG, 61 farmers were randomly selected from the main dairy cooperatives - Darolt (n=15), Della Vitta (n=15), Doerner (n=15) and Geração (n=16), for in depth surveys. This sample represents 15% of the total population adopting MIG, in Southern Santa Catarina. Semi-structured interviews (Rizzoli 2004; Lindlof and Taylor 2010) were conducted *in situ,* in 2009 and analyzed, in 2011. Four broad topics were addressed: farm demographics, production, ecosystem services, and environmental law and policy. Farmers were asked to rate these dimensions before and after MIG adoption. They also provided production and demographic factual data, which was initially organized, coded, and formatted in a MS Excel spreadsheet. Ordinal variables were re-coded in a Likert-type scale, and statistically analyzed using IBM Statistical Package for Social Sciences 20.0 (PASW 2010). Data was then grouped and studied by dairy cooperatives.

After organizing and summarizing descriptive statistics (including count, means and measures of spread), statistical analyses were performed to assess significant differences and explore relationships between key variables. A one-sample t-test compared demographic variable means. The paired t-test, at $p<0.05$, compared differences in reported production means before and after MIG adoption. A one-way ANOVA at $p<0.05$ was performed to analyze demographic and production differences. A *post hoc* analysis using Tukey (HSD) at $p \leq 0.05$ assessed multi-comparison effects by dairy coops.

To determine if adoption of MIG was perceived to influence environmental variables, non-parametric tests were applied to categorical data. The Wilcoxon signed-rank test analyzed if adopting MIG changed ordinal variables, such as, presence of macro/mesofauna (beetles, worms, etc.), and riparian and water sources protection. McNemar's cross-tabulation tested associations between before and after MIG variables, such as, animal access to PPA. Kruskall-Wallis at $p<0.05$, tested differences in ranked ordinal variables grouped by cooperative. Therefore, the measurement observations were converted to their ranks in the overall data set: the smallest value was assigned a rank of 1; the next smallest a rank of 2, and so on (Ott and Longnecker 2008).

RESULTS

Table 1 shows differences in some demographic and production variables. For example, MIG enabled farmers to greatly increase paddock number, while reducing manure in milking parlors. Since cows were on pasture most of the time, coming into parlors only for milking and concentrate feeding, most manure was left on pastures.

Variables depicted in Table 2 show production improvements after changing from semi-confinement to MIG. Average daily production, number of heifers, and income more than doubled after adopting MIG.

Table 3 shows demographic and production descriptive figures according to dairy coops.

Analysis of Environmental Variables

We asked interviewees to classify the status of many environmental variables during the transition from semi-confinement to pasture-based dairying. Some of the analyzed variables were soil physical, chemical, and biological characteristics, water flow and quality, biodiversity, pasture cover and quality, and forest remnant characteristics. Production and environmental performance were analyzed using data provided by each farmer. Farmers' viewpoints about the condition of environmental variables were analyzed. Table 4 summarizes differences in environmental variables before and after change to MIG.

About 32% of farmers perceived improvement in forest remnants and water source preservation, after the transition. Protective buffer increased to 55% after MIG, compared to 12% before. Sixty one percent of farmers observed increases in dung beetles and worms on pastures, compared to previous continuous grazing.

A Kruskal-Wallis test further evaluated differences on perceived changes, in different environmental variables, between dairy cooperatives assessing mean ranks of variable scores for each cooperative group.

To determine the association between MIG adoption and environmental variables we used the McNemar correlation test, which showed that before adopting MIG, 83% of farms surveyed had access to PPA while none used these areas after changing to MIG (p=0.000). There was also an association between forest remnants and preservation of water sources after MIG (p=0.000).

Almost 64% of farmers over seeded grasses and legumes for winter pasturing, versus 6.4%, before MIG adoption (p=0.000). About 34% of farmers noticed meso or macrofauna in their pastures before MIG, and 59% of them observed it after MIG adoption.

DISCUSSION

One of the most significant results of this study was the effectiveness of MIG on increasing production. Farmers also perceived better environmental performance, including soil health and water quality after implementing MIG, coinciding with results of numerous other studies (Walton, Martinez, and Bailey 1981; Murphy, Rice, and Dugdale 1986; Voisin 1988; Murphy 1996; Winsten 1999; Pinheiro Machado 2004; Rotz et al. 2009; Farley et al. 2011; Alvez et al. 2012).

Farmers who adopted MIG increased number of animals, daily production, productivity per cow, and income while barely increasing the total land area used for grazing (Table 2). Maraschin (1994) has argued that traditional grazing can produce more on a per cow basis than MIG, during the highest producing season, but in this study cows averaged 28% more production after changing to MIG. Similarly, numerous other studies found production increases per area, after switching from continuous grazing to MIG (Walton, Martinez, and Bailey 1981; Murphy, Rice, and Dugdale 1986; Romero 1994; Pinheiro Machado 2004). One possible explanation for this production improvement is the change in grazing management (Walton, Martinez, and Bailey 1981). According to Pinheiro Machado (2004), well managed pastures under MIG can at least

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double production, compared to continuous grazing. Production costs can also be reduced due to less needed feed supplementation (Bauer et al. 2009).

Improved production was due to careful implementation of the four MIG principles (Voisin 1988). In this study, pastures were subdivided into an average of 41 paddocks. This applied high concentrations of organic matter (via manure and urine) on pastures, which increased soil biodiversity and fertility, thereby increasing forage production. Each day a milking cow can deposit up to 100 kg of nitrogen and over 40 kg of phosphorus, potassium, and calcium, respectively, via manure and urine (USDA-NRCS 2008). Higher biodiversity (meso/macrofauna) was also reflected by rapid dung decomposition in the pastures. At the same time, manure in milking parlors was reduced because cows spent less time indoors than on pasture. This may have reduced incidence of flies and mastitis. A previous assessment by Rizzoli (2004) detected that most farms reduced pesticide applications, while pest incidence (ticks, worms, flies, and other sanitary problems) decreased on all farms after transitioning to MIG. This possibly was due to a break in the pest cycle, caused by short occupations and long rest periods of paddocks. Under MIG, each paddock is only occupied for half a day, and rested afterwards for a few to several weeks before being regrazed. Depending on number of rotations, paddocks are only occupied a total of several days per year. This gives to each paddock sufficient recovery time. Consequently, some pests may be unable to complete their life cycle without a host (cow), especially during long winter rest periods.

As MIG is increasingly adopted among farmers, largely motivated by lower cost potential, production per area improvement, and increasing net income (Winsten, Parsons, and Hanson

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2000), environmental benefits beyond the farm level can be achieved. Environmental variables such as soil moisture, forage cover and management of forest remnants demonstrated improvement, after MIG. However, farmers did not perceive similar improvements in water quality variables and status of PPA areas, especially among smaller farms located in sensitive ecological areas. Since water typically flows across numerous farms, changes in quality may depend on how upstream farmers manage their farms and cattle. Table 4 highlights changes in winter grass and legume over seeding, and the presence of meso/macrofauna, after MIG adoption. In addition, most interviewees observed more soil humidity in their farms, due to changes in management practices, which increased soil cover and organic matter. Consequently, after changing to MIG, erosion gullies stabilized and in some cases were reduced. The presence of meso/macro fauna indicated the existence of habitat for biodiversity, an important ecosystem function. They enhance soil health and protect water quality. These organisms are directly dependent on high-stock densities which play a key role in feeding them, by recycling nutrients through manure and urine, boosting soil fertility (Sjodin, Bengtsson, and Ekbom 2008; Giraldo et al. 2011).

Farmers also had a positive attitude about the presence of trees on pasture. However, while forest remnants, water source preservation and buffer protection improved after changing to MIG, we found that some farmers, especially the smallest, did not or could not protect water sources and buffers because these farms are located on ecologically sensitive areas, coinciding with findings of Bilotta et al. (2007). Occupying areas targeted for permanent preservation, such as hilltops, riparian buffers, and other areas with water sources, may impair ecosystems affecting the flow of services for agriculture (Zhang et al. 2007).

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Beyond changing grazing practices, which had side environmental benefits, the environmental awareness variables also showed improvements after MIG. Most respondents said that they would not be willing to recover damaged PPA; however, most farmers asserted that they would fence off and protect PPAs if a compensation is given. When asked, “would you be willing to receive compensation to conserve the forest and adopt better management practices?” most of them would accept compensation for maintaining PPAs. This finding suggests possible mechanisms to achieve landscape-level environmental goals beyond win-win improvements due to MIG. The original 1.5 million km^2 of the Atlantic Rainforest, which has been almost entirely deforested to satisfy both urban and agricultural expansions (Schäffer and Prochnow 2002), is presented with challenges and opportunities for conserving this biome Balmford et al. (2002), while protecting and enhancing rural livelihoods.

Despite progress toward a more integrated conservation plan, a fragmented system of protected areas alone is insufficient to improve biodiversity conservation of this hotspot (Mesquita 1999; Morsello 2001; Câmara 2002; Mesquita 2002; Milano 2002). Also, protection laws fail to recognize potential complementarities to forest protection that might come from farming practices that increase beneficial ecosystem services and reduce further deforestation, by improving farm productivity and sustainable livelihoods. Therefore, creating linked and buffered protected areas seems to be essential for restoring national and regional biodiversity conservation strategies (Alvez et al. 2012). In addition, future dairy policies must include agroecological practices that simultaneously target current environmental degradation, rural livelihoods, and population growth trends. Payment for ecosystem services (Farley et al. (2011), to finance adoption of agroecological practices that improve farmers’ livelihoods, and decrease need for continuous payments, seems to be a reasonable solution. Given the cooperative dairy structure and role of university extension in the region, institutional arrangements can address many problematic design flaws of past PES programs that paid landowners directly. Our findings suggest that smaller farmers would still need further technical and financial support to cope with the BFA because of the location of their farms, and to continue reducing rural poverty. In this respect, programs such as "Bolsa Floresta" (forest stipend program), which address poor family farms like those in the Amazon State, may be viable alternatives to reduce both deforestation and poverty.

CONCLUSION

Our results revealed that production increased after adopting MIG. Milk production and number of animals doubled and pest incidence decreased without increasing farm area. Moreover, farmers perceived significant improvements in some ecosystem functions such as soil cover, moisture and biodiversity (macro/mesofauna), improved water quality and environmental awareness after MIG adoption. This supports the case that MIG is a viable production system to improve sustainability of farmers' livelihoods and complement environmental conservation efforts.

We also found that smaller farms in PPA, clearly infringe BFA regulations, posing a particular challenge for policymakers, given the Brazilian goals of poverty alleviation and forest restoration. Regardless of potential environmental improvements from MIG, there remains the question about appropriate scale of agriculture in the Atlantic Rainforest. MIG alone cannot fully

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restore ecosystem structure and forest loss. In addition, most farmers (particularly the smallest) did not fully agree with the idea of protecting and conserving forest remnants and PPA, unless they were compensated for this effort.

Since most farmers perceived that trees on pasture are advantageous, the complement between MIG and trees, associated with productive forests in Legal Reserves and in some cases with PPA in agroforestry arrangements, seems to be an obvious and immediate solution to curb deforestation. Furthermore, the reincorporation of native trees on pasture and restoration of riparian areas with native species can contribute to increasing biodiversity, without affecting (and perhaps increasing) dairy production, while complying with the BFA. Additionally, specific PES schemes associated with internal support mechanisms and programs could support farmers' adoption of these agroecological practices.

REFERENCES

Alvez, Juan P., Abdon L. Schmitt Filho, Joshua Farley, Gisele Alarcon, and Alfredo C. Fantini. 2012. The Potential for Agroecosystems to Restore Ecological Corridors and Sustain Farmer Livelihoods: Evidence from Brazil. *Ecological Restoration* 30 (4):288-290.

Arruda, R. 2012. Preço do leite foi o que colocou Brasil na 3ª posição do ranking mundial. Editora Pecuária.

Balmford, Andrew, Aaron Bruner, Philip Cooper, Robert Costanza, Stephen Farber, Rhys E. Green, Martin Jenkins, Paul Jefferiss, Valma Jessamy, Joah Madden, Kat Munro, Norman Myers, Shahid Naeem, Jouni Paavola, Matthew Rayment, Sergio Rosendo, Joan Roughgarden, Kate Trumper, and R. Kerry Turner. 2002. Economic Reasons for Conserving Wild Nature. *Science* 297 (5583):950-953.

Baptista, Sandra Regina. 2008. Forest Recovery and Just Sustainability in the Florianopolis City-Region. Dissertation, Geography, Rutgers, The State Unuversity of New Jersey, New Brunswick, NJ.

Basset-Mens, C., S. Ledgard, and M. Boyes. 2009. Eco-efficiency of intensification scenariosfor milk productionin New Zealand. *Ecological Economics* 68 (6):1615-1625.

Bauer, Eliane, Abdon L. Schmitt F, Jailson Epping, and J. Farley. 2009. Dairy Production in Florianópolis: Farmers' Perceptions about the Transition from Conventional Dairy to Voisin Management Intensive Grazing. Paper read at Resumos do VI CBA e II CLAA, at Curitiba, Brazil.

Bilotta, G. S., R. E. Brazier, and P. M. Haygarth. 2007. The Impacts of Grazing Animals on the Quality of Soils, Vegetation, and Surface Waters in Intensively Managed Grasslands. In *Advances in Agronomy*, edited by L. S. Donald: Academic Press.

Brannstrom, C. . 2002. Rethinking the 'Atlantic Forest' of Brazil: new evidence for land cover and land value in western São Paulo, 1900–1930. *Journal of Historical Geography* 28 (3):420-439.

Briske, D. D., J. D. Derner, J. R. Brown, S. D. Fuhlendorf, W. R. Teague, K. M. Havstad, R. L. Gillien, A. J. Ash, and W. D. Williamns. 2008. Rotational Grazing on Rangelands: Reconciliation of Perception and Experimental Evidence. *Rangeland Ecol Management* 61:3-17.

Brooks, T. M., R. A. Mittermeier, G. A. B. da Fonseca, J. Gerlach, M. Hoffmann, J. F. Lamoreux, C. G. Mittermeier, J. D. Pilgrim, and A. S. L. Rodrigues. 2006. Global biodiversity conservation priorities. *Science* 313 (5783):58-61.

Câmara, I. de G. . 2002. A política de unidades de conservação: uma visão pessoal. Paper read at Unidades de conservação: atualidades e tendências, at Curitiba, PR Brazil.

Cincotta, R. P., J. Wisnewski, and R. Engelman. 2000. Human population in the biodiversity hotspots. *Nature* 404 (6781):990-992.

Conant, Richard T., Keith Paustian, and Edward T. Elliott. 2001. Grassland Management and Conversion into Grassland: Effects on Soil Carbon. *Ecological Applications* 11 (2):343-355.

Costa, L. P., Y. L. R. Leite, S. L. Mendes, and A. D. Ditchfield. 2005. *Mammal Conservation in Brazil* (19):672-679.

Daily, Gretchen C. , Susan Alexander, Paul R. Ehrlich, Larry Goulder, Jane Lubchenco, Pamela A. Matson, Harold A. Mooney, Sandra Postel, Stephen H. Schneider, David Tilman, and George M. Woodwell. 1997. Ecosystem Services: Benefits Supplied to Human Societies by Natural Ecosystems. *Ecological Society of America* 2:18 p.

Dartora, V. 2002. Produção Intensiva de Leite à Base de Pasto: Processamento,Transformação e Comercialização como Alternativa para Agricultura Familiar de Pequeno Porte. MS Thesis, Centro de Ciencias Agrarias, Universidade Federal de Santa Catarina.

DeVore, B. 2001. Same storm, different outcomes. *The Land Stewardship Letter* 19 (2).

ACCEPTED MANUSCRIPT

Ditt, E. H., S. Mourato, J. Ghazoul, and J. Knight. 2010. Forest conversion and provision of ecosystem services in the Brazilian Atlantic Forest. *Land Degradation & Development* 21 (6):591-603.

Ditt, Eduardo H., Jonathan D. Knight, Susana Mourato, Claudio V. Padua, Rafael R. Martins, and Jaboury Ghazoul. 2008. Defying legal protection of Atlantic Forest in the transforming landscape around the Atibainha reservoir, south-eastern Brazil. *Landscape and Urban Planning* 86 (3-4):276-283.

Dorsey, J., J. Dansingburg, and R. Ness. 1998. Managed Grazing as an Alternative Manure Management Strategy. USDA-ARS Land Stewardship Project.

Epagri. 2010. Produção de Leite com Sustentabilidade na Agricultura Familiar da Região Sul de Santa Catarina. In *18º Prêmio Expressão de Ecologia*. Florianopolis, SC: Editora Expressao.

Epping, J. 2003. Grupo de Pastoreio Voisin: Análise da Metodologia Empregada na Implantação de Projetos. Book, Centro de Ciencias Agrarias, Universidade Federal de Santa Catarina, Florianopolis, SC.

FAO. 2011. How to Feed the World in 2050. on line:http://www.scp-knowledge.eu/sites/default/files/knowledge/attachments/How%20to%20Feed%20the%20World%20in%202050.pdf.

Farley, Joshua, Abdon Schmitt Filho, Juan Alvez, and Norton Ribeiro de Freitas, Jr. 2011. How Valuing Nature Can Transform Agriculture. *Solutions* 2 (6):64-73.

Foley, Jonathan A., Gregory P. Asner, Marcos Heil Costa, Michael T. Coe, Ruth DeFries, Holly K. Gibbs, Erica A. Howard, Sarah Olson, Jonathan Patz, Navin Ramankutty, and Peter Snyder.

ACCEPTED MANUSCRIPT

2007. Amazonia revealed: forest degradation and loss of ecosystem goods and services in the Amazon Basin. *Frontiers in Ecology and the Environment* 5 (1):25-32.

FSOSMA. 2010. Atlas dos Remanecentes Florestais da Mata Atlantica periodo: 2008-2010. Dados Parciais dos Estados Avaliados ate Maio 2010. Sao Paulo: Fundacao, SOS Mata Atlantica. (INPE) Instituto nacional de Pesquisas Espaciais.

Gammon, D. M. 1978. A review of experiments comparing systems of grazing management on natural pastures. *Proceedings of the Annual Congresses of the Grassland Society of Southern Africa* 13 (1):75-82.

Giraldo, Carolina, Federico Escobar, JuliÁN D. CharÁ, and Zoraida Calle. 2011. The adoption of silvopastoral systems promotes the recovery of ecological processes regulated by dung beetles in the Colombian Andes. *Insect Conservation and Diversity* 4 (2):115-122.

Grelle, Carlos Eduardo Viveiros. 2003. Forest Structure and Vertical Stratification of Small Mammals in a Secondary Atlantic Forest, Southeastern Brazil. *Studies on Neotropical Fauna & Environment* 38 (2):81.

GRural. 2012. Santa Catarina é líder nacional de crescimento na industrialização do leite. edited by Globo. Rio de Janeiro: Globo Rural.

Hanson, G. D., L. C. Cunningham, S. A. Ford, L. D. Muller, and R. L. Parsons. 1998. Increasing intensity of pasture use with dairy cattle: An economic analysis. *Journal of Production Agriculture* 11 (2):175-179.

ACCEPTED MANUSCRIPT

Hanson, J.C., D. M. Johnson, E. Lichtemberg, and K. Minegishi. 2013. Competitiveness of management-intensive grazing dairies in the mid-Atlantic region from 1995 to 2009 *J. Dairy Sci.* 96:1-11.

Hart, R. H., J. Bissio, M. J. Samuel, and J. W. Waggoner, Jr. 1993. Grazing Systems, Pasture Size, and Cattle Grazing Behavior, Distribution and Gains. *Journal of Range Management* 46 (1):81-87.

Heady, Harold F. 1961. Continuous vs. Specialized Grazing Systems: A Review and Application to the California Annual Type. *Journal of Range Management* 14 (4):182-193.

Hinrichs, C. Clare, and Rick Welsh. 2003. The effects of the industrialization of US livestock agriculture on promoting sustainable production practices. *Agriculture and Human Values* 20 (2):125-141.

Holechek, J.L., R. Valdez, S.D. Schemnitz, R.D. Pieper, and C.A. Davis. 1982. "Manipulation of Grazing to Improve or Maintain Wildlife Habitat. *Wildlife Society Bulletin* 10 (3):204-210.

Hopkins, A. , and A. Del Prado. 2007. Implication of climate change for grassland in Europe: impacts, adaptations and mitigation options: a review. *Grass Forage Sci.* (62):118-126.

Horrigan, L.R. S., and P. Walker. 2002. How Sustainable Agriculture Can Address the Environmental and Human Health Harms of Industrial Agriculture. *Environmental Health Perspectives* 110 (5):445-456.

Hubbard, William A. 1951. Rotational Grazing Studies in Western Canada. *Journal of Range Management* 4 (1):25-29.

IBGE. 2012. Indicadores IBGE: Estatistica da Producao Pecuarias em Junho de 2012. Brasil: Instituto Brasileiro de Geografia e Estadistica.

IBGE. 2013. Perfil de Santa Catarina. Brasil: Instituto Brasileiro de Geografia e Estadistica.

ICEPA. 2010. Síntese Anual da Agricultura de Santa Catarina 2009-2010. Instituto CEPA.

Ignatiuk, J.B., and D.C. Duncan. 2001. Nest Success of Ducks on Rotational and Season-Long Grazing Systems in Saskatchewan. *Wildlife Society Bulletin* 29 (1):211-217.

Lindlof, T.R., and B.C. Taylor. 2010. *Qualitative Communication Research Methods*: SAGE Publications.

Lyons, J., B. M. Weigel, L. K. Paine, and D. J. Undersander. 2000. Influence of intensive rotational grazing on bank erosion, fish habitat quality, and fish communities in southwestern Wisconsin trout streams. *Journal of Soil and Water Conservation* 55 (3):271-276.

Mannetje, L. 2007. Cimate changes and grassland through the age: an overview. *Grass and Forage Science* (62):113-117.

Maraschin, G. E. 1994. Sistemas de Pastejo. In *Pastagens: Fundamentos da Exploracao Racional*, edited by A. M. Peixoto, Moura, J.C. de, e Faria, V.P. Piracicaba: FEALQ.

McDowell, R.W., Z. Dou, J.D. Toth, B.J. Cade-Menun, P.J. Kleinman, K. Soder, and L. Saporito. 2008. A comparison of phosphorus speciation and potential bioavailability in feed and feces of different dairy herds using 31p nuclear magnetic resonance spectroscopy. *J Environ Qual.* 37 (3):741-52.

ACCEPTED MANUSCRIPT

MEA. 2005. *Millennium Ecosystem Assessment, Ecosystems and Human Well-Being: A Framework for Assessment*. Washington, DC: Island Press.

Mesquita, C.A.B. 2002. Capacitação como meio para conservar terras privadas. Paper read at Anais do III Congresso Brasileiro de Unidades de Conservação, at Brazil.

Mesquita, C.A.B. . 1999. Conservación privada en América Latina: el caso de las Reservas Particulares del Patrimonio Natural, Brasil. Paper read at II Congreso Interamericano de Conservación Privada, at Sarapiquí, Costa Rica.

Milano, M.S. 2002. Por que existem as unidades de conservação? Paper read at Unidades de conservação: atualidades e tendências, at Curitiba, PR Brazil.

Morsello, C. . 2001. Áreas protegidas públicas e privadas: seleção e manejo. São Paulo, Brasil: Annablume e Fapesp.

Murphy, B., J. Silman, L. McCrory, S. Flack, J. Winster, D. Hoke, A. Schmitt and B. Pillsbury. 1996. *Environmental, economic, and social benefits of feeding livestock on well managed pasture*, *Environmental Enhancement Through Agriculture*. Boston: Tufts University Press.

Murphy, W. M. 2008. *Greener pastures on your side of the fence: better farming with Voisin management intensive grazing*. 4th ed. Colchester, VT: Arriba Pub.

Murphy, William M., John R. Rice, and David T. Dugdale. 1986. Dairy farm feeding and income effects of using Voisin grazing management of permanent pastures. *American Journal of Alternative Agriculture* 1 (04):147-152.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca, and J. Kent. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403 (6772):853-858.

Myers, Norman. 1988. Threatened biotas: "Hot spots" in tropical forests. *The Environmentalist* 8 (3):187-208.

Myers, Norman, Russell A. Mittermeier, Cristina G. Mittermeier, Gustavo A. B. da Fonseca, and Jennifer Kent. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403 (6772):853-858.

Nimer, E. 1990. Clima. In *Fundação Instituto Brasileiro de Geografia e Estatística. Geografia do Brasil: Região Sul*. Rio de Janeiro: IBGE.

O'Brien, D., L. Shalloo, C. Grainger, F. Buckley, B. Horan, and M. Wallace. 2010. The influence of strain of Holstein-Friesian cow and feeding system on greenhouse gas emissions from pastoral dairy farms. *Journal of Dairy Science* 93 (7):3390-3402.

Ott, L., and M. Longnecker. 2008. *An introduction to statistical methods and data analysis*: Brooks/Cole Cengage Learning.

Paine, L. 1999. Managed Intensive Grazing: Promises and Realities. University of Winsconsin: UW-Extension Columbia County.

Paine, L.K., G.A. Bartlet, D. J. Undersander, and S.A. Temple. 1995. Agricultural Practices for the Birds. *The Passenger Pigeon* 57 (2):77-87.

PASW. 2010. PASW Statistical Package. Chicago, IL: SPSS, Inc.

Pinheiro Machado, L. C. 2004. *Pastoreo Racional Voisin: Tecnologia agropecuaria para el tercer milenio*. Buenos Aires: Hemisferio Sur.

Potts, S. G., B. A. Woodcock, S. P. M. Roberts, T. Tscheulin, E. S. Pilgrim, V. K. Brown, and J. R. Tallowin. 2009. Enhancing pollinator biodiversity in intensive grasslands. *Journal of Applied Ecology* 46 (2):369-379.

Risson, C., E. Gabriel Jr., and J. Pauli. 2010. Desenvolvimento, Democracia e Gestao do Credito: A Agricultura Familiar em Debate. Passo Fundo, RS Brasil: Fundacao IMED.

Rizzoli, Allan. 2004. Grupo de Pastoreio Voisin: Resultados de Parcerias entre EPAGRI, Acadêmicos e Professores da UFSC e Unisul, Prefeituras Municipais, Sindicatos e ONGs, Departamento de Zootecnia, Universidade Federal de Santa Catarina, Florianopolis, SC Brasil.

Romero, N. F. 1994. *Alimente seus pastos com seus animais*. Guaíba - RS: Livraria e Editora Agropecuária Ltda.

Rotz, C. Alan, Kathy J. Soder, R. Howard Skinner, Curtis J. Dell, Peter J. Kleinman, John P. Schmidt, Ray B. Bryant, and ARS USDA. 2009. Grazing Can Reduce the Environmental Impact of Dairy Production Systems. *Forage and grazinglands*.

Rust, J.W., C.C. Sheaffer, V.R. Eidman, R.D. Moon, and R.D. Mathison. 1995. Intensive rotational grazing for dairy cattle feeding. *American Journal of Alternative Agriculture* 10 (04):147-151.

Saade, J.P. 2002. Grupo de Pastoreio Voisin: Metodologia de Implantacao, Zootecnia, Universidade Federal de Santa Catarina, Florianopolis.

ACCEPTED MANUSCRIPT

Sanderson, M. A., R. H. Skinner, D. J. Barker, G. R. Edwards, B. F. Tracy, and D. A. Wedin. 2004. Plant species diversity and management of temperate forage and grazing land ecosystems. *Crop Science* 44 (4):1132-1144.

Schäffer, W. B., and M. Prochnow. 2002. A Mata Atlântica e você: como preservar, recuperar e se beneficiar da mais ameaçada floresta brasileira. edited by Apremavi. Brasília, Brasil.

Schmitt, Abdon, Joshua Farley, Juan Alvez, Gisele Alarcon, and PaolaMay Rebollar. 2013. Integrating Agroecology with Payments for Ecosystem Services in Santa Catarina's Atlantic Forest. In *Governing the Provision of Ecosystem Services*, edited by R. Muradian and L. Rival: Springer Netherlands.

Schmitt F, Abdon L, W. M. Murphy, and J. Farley. 2010. Grass based agroecologic dairying to revitalize small family farms throughout student technical support: The development of a participative methodology responsible for 622 family farm projects. *Advances in Animal Biosciences*.

Silvano, Renato A. M., Shana Udvardy, Marta Ceroni, and Joshua Farley. 2005. An ecological integrity assessment of a Brazilian Atlantic Forest watershed based on surveys of stream health and local farmers' perceptions: implications for management. *Ecological Economics* 53 (3):369-385.

Sjodin, N. E., J. Bengtsson, and B. Ekbom. 2008. The influence of grazing intensity and landscape composition on the diversity and abundance of flower-visiting insects. *Journal of Applied Ecology* 45 (3):763-772.

ACCEPTED MANUSCRIPT

Sorio Jr., Humberto. 2000. *A Ciência do Atraso: Índices de lotação da Pecuária do Rio Grande do Sul*. Passo Fundo, RS Brasil: Editora da UFPS.

Souto, Luis Eduardo. 2009. Código (anti) ambiental de Santa Catarina. *O Eco* on-line: http://www.oeco.com.br/convidados/64-colunistas-convidados/21295-codigo-anti-ambiental-de-santa-catarina.

Sovell, L.A., B. Vondracek, J. A. Frost, and K.G. Mumford. 2000. Impacts of Rotational Grazing and Riparian Buffers on Physiochemical and Biological Characteristics of Southeastern Minnesota, USA, Streams. *Environmental Management* 26 (6):629-641.

Stofferahn, C.W. 2006. Industrialized Farming and Its Relationship to Community Well-Being: An Update of a 2000 Report by Linda Lobao. Grand Forks, ND: Department of Sociology The University of North Dakota.

Stout, W. L., S. L. Fales, L. D. Muller, R. R. Schnabel, G. F. Elwinger, and S. R. Weaver. 2000. Assessing the effect of management intensive grazing on water quality in the northeast U.S. *Journal of Soil and Water Conservation* 55 (2):238-243.

Tabarelli, M., L. P. Pinto, J. M. C. Silva, M.M. Hirota, and L. Bede. 2005. Challenges and Opportunities for Biodiversity Conservation in the Brazilian Atlantic Forest. *Conservation Biology* 19 (3):695-700.

Teague, W. R., S. L. Dowhower, S. A. Baker, N. Haile, P. B. DeLaune, and D. M. Conover. 2011. Grazing management impacts on vegetation, soil biota and soil chemical, physical and hydrological properties in tall grass prairie. *Agriculture, Ecosystems & Environment* 141 (3–4):310-322.

ACCEPTED MANUSCRIPT

Temple, S. A., B.M. Fevold, L. K. Paine, D. J. Undersander, and D.W. Sample. 1999. Nesting birds and grazing cattle: accommodating both on Midwestern pastures. *Studies in Avian Biology* 19:196-202.

Tilman, David, Christian Balzer, Jason Hill, and Belinda L. Befort. 2011. Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences*.

USDA-NRCS. 2008. Agricultural Waste Characteristics. In *Part 651 Agricultural Waste Management Field Handbook*. Washington, DC: USDA, Natural Resource Conservation Services.

Voisin, A. 1988. *Grass Productivity*: Island Press.

Walton, P. D. , R. Martinez, and A. W. Bailey. 1981. A Comparison of Continuous and Rotational Grazing. *Journal of Range Management* 34 (1):3.

Walton, P. D., R. Martinez, and A. W. Bailey. 1981. A Comparison of Continuous and Rotational Grazing. *Journal of Range Management* 34 (1):19-21.

Webb, T. J., F. I. Woodward, L. Hannah, and K. J. Gaston. 2005. Forest cover–rainfall relationships in a biodiversity hotspot: the Atlantic forest of Brazil. *Ecological Applications* 15 (6):1968-1983.

Winsten, J. 1999. The profitability of management-intensive grazing for northeastern dairy farms. *American Journal of Agricultural Economics* 81 (5):1296-1296.

Winsten, J.R., R.L. Parsons, and G.D. Hanson. 2000. A Profitability analysis of dairy feding systems in the Northeast. *Agricultural and Resource Economics Review* 29 (2).

Zhang, W., T. Ricketts, C. Kremen, K. Carney, and S. Swinton. 2007. Ecosystem services and dis-services to agriculture. *Ecological Economics* 64 (2):253-260.

Zurita, G. A., N. Rey, D. M. Varela, M. Villagra, and M. I. Bellocq. 2006. Conservation of the Atlantic Forest into native and exotic tree plantations: effects on bird communities from the local and regional perspectives. *Forest Ecology and Management* 235 (1-3):164-173.

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TABLE 1. Demographic and production management variables

Variables	n	Mean (SD)	*t*-test $p<0.05$
Farmer's age	54	45.6(12)	0.004
Family members working in the farm	61	2.5(1.4)	0.785
When did you start using MIG (yrs.)	58	3.5(2)	0.042
Payment of investments (months)	49	16.6(14.8)	0.224
Number of paddocks	58	41.3(18.6)	0.000
For how long using homeopathy on animals? (yrs.)	42	13.8(16.3)	0.275
Manure reduction in milk parlor (%)	31	61(19.6)	0.000

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TABLE 2. Comparisons and differences in production indicators

Variables[a]		N	Mean (SD)	% change	Paired *t*-test $p<0.05$
Area used for activities (ha)	Before MIG	56	10.4(8.9)	8.9	0.000
	After MIG	56	11.3(8.8)		
Milking cows (heads)	Before MIG	56	15.7(9.6)	67.2	0.000
	After MIG	56	26.3(11.6)		
Young stock (heads)	Before MIG	41	8(5.7)	104.5	0.000
	After MIG	54	16.4(8.8)		
Production per cow (l/day)	Before MIG	47	6.5(2.9)	28.6	0.000
	After MIG	55	8.3(3.5)		
Ave daily production (l)	Before MIG	50	105.8(74.7)	102.6	0.000

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	After MIG	57	223.9(123.3)		
	Before MIG	49	9,981(7,044)		
Income generated (USD) (yr)				128.6	0.000
	After MIG	49	21,122(11,632)		

[a] The same data, analyzed by dairy cooperatives, yielded differences in all variables, but the *Area used for activities* in Darolt (p=0.177), Doerner (p=0.683), Geração (p=0.435), *Production per cow* in Della Vitta (p=0.105) and Doerner (p=0.832).

TABLE 3. Demographic and productive farm analysis by Dairy Coop. in Santa Catarina

Variables	Dairy Cooperative Means (SD)				ANOVA
	Darolt (n=15)	Della Vita (n=15)	Doerner (n=15)	Geracao (n=15)	p<0.05
Age (yrs.)	45(12.6)	45 (10.5)	50(14.6)	40(8.7)	.283
Household size (people)	4.5(1.2)	4.5 (1.5)	3.9(2.1)	4.4(1.5)	.603
Number of paddocks (units)	37(13)	41(10)	48(29)	40(17)	.440
Time using MIG (Yrs)	3.2(.8)	3(1.2)	3.3(1.7)	4.7(3.1)	.069
Payment of investment (months)	8.5(6)b	16.4(12)ab	13.8(17.5)b	29.5(16.8)a	.003
Manure reduction in milk parlor (%)	62(17.2)	59(27.6)	60(19.5)	n/a	.943
Use of homeopathy (Yrs)	32(10.3)a	9.8(19)b	2.4(1.4)b	4.7(2.7)b	.000

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Cow pie degradation (days)	26(11)b	22.6(7)b	46.7(14.4)a	45a	.034
Production before MIG (l)	158(59)a	78(75)b	101(80)ab	70(57)b	.04
Production after MIG (l)	300(139)a	206(141)ab	162(89)b	167(96)bc	.01
Production per cow before MIG (l/day) (l/cow/day)	7.7(2.7)a	5.5(2.8)ab	8.2(2.9)a	4.5(2)b	.06
Production per cow after MIG (l/day)	9.9(3.2)	7.7(4.3)	7.9(4)	7(2.6)	.211
Milking cows before MIG (heads)	21(7.5)a	15(11)a	10(5.4)b	14(9.8)a	.013
Milking cows after MIG (heads)	30(11)	26(12)	21(10)	25(12)	.183
Heifers before MIG (heads)	10(5)	9(6)	6(6)	5(3)	.106
Heifers after MIG (heads)	21(6)a	16(8)ab	11(8)b	12(7)b	.006

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Area before MIG (ha)	9.6(4.5)	13.7(15.2)	9.3(7.6)	9.6(7)	.613
Area after MIG (ha)	10.5(4.6)	13.8(12.8)	9.2(8.1)	10.5(6.3)	.516
Income before MIG (US$ x1,000)	13,5(1,9)	9,7(2)	9,1(2,3)	6,6(1,5)	.080
Income after MIG (US$ x1,000)	25,3(3,2)	21,9(4)	15,9(2,1)	15,8(2,5)	.095

[a] In the letter designations "a" represents the highest means, "b" indicates the next highest mean, and so forth, to denote multi-comparison analyses. Means followed by the same letter, in the same row, did not significantly differ between dairy coops by Fisher Tukey ($p \leq 0.05$).

[b] Sample size denotes the maximum number of farms sampled within each cooperative. Not every farm answered every question.

TABLE 4. Wilcoxon sum-rank test comparison of environmental variables before and after MIG adoption

Variables	n	Mean ranks	Z	p<0.05
Was there any kind of forest remnant and water preservation?		10.5		
	60		-4.025	0.000
Is there any kind of forest remnant and water preservation?		10.5		
Were water sources protected?		5.5		
	33		-1.696	0.090
Are water sources protected?		5.5		
Were riparian buffers protected?		20.0		
	58		-4.003	0.000
Are riparian buffers protected?		20.0		
Animals had access to PPA[a]		1.0		
	42		-1.000	0.317
Animals have access to PPA		.0		

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Which was the frequency of pasture renovation?		13.06		
	59		-.258	0.797
Which is the frequency of pasture renovation?		20.08		
Did you over seed grasses and legumes for winter pasturing?		21.43		
	47		-4.527	0.000
Do you over seed grasses and legumes for winter pasturing?		18.5		
Did you observe meso/macrofauna on your pastures?		0.0		
	46		-5.209	0.000
Do you observe meso/macrofauna on your pastures?		14.5		
Which was the frequency of pasture burn?		1.0	-1,000	
	61			0.317
Which is the frequency of pasture burn?		0.0		

[a] Permanent Preservation Areas.

FIGURE 1. Location of the State of Santa Catarina and area of study.

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