CAPÍTULO 5

AGROECOLOGY AND FARMER LIVELIHOODS: A COMPARATIVE ANALYSIS BETWEEN MANAGEMENT INTENSIVE GRAZING AND CONVENTIONAL DAIRY IN SANTA CATARINA, BRAZIL

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ABSTRACT

The conflict between food production and environmental conservation demands alternative agricultural practices that can maintain or increase food production, protect and restore critical ecosystem processes, and reduce dependence on non-renewable agricultural inputs. Deforestation in Brazil's Atlantic Forest, for which agriculture has been a primary driver, already threatens the biome's impressive biodiversity and the ecosystem services it helps sustain. Many small family farms in Santa Catarina—located in the South Region of Brazil—have adopted the Voisin Rational Grazing (VRG) system as an alternative to conventional and environmentally detrimental dairy activities. Whether or not VRG is a viable approach to sustainable intensification on small farms depends on its economic and ecological impacts. This article, which is a chapter of a PhD dissertation defended at Graduate Program on Environmental Science (PROCAM), presents the results of a research project designed to test economic impacts. Using detailed monthly accounting of revenues and expenditures on VRG and conventional farms, we compare farm profitability of both systems. We found that the VRG system is more profitable than the conventional dairy system in Santa Rosa de Lima, a municipality in Santa Catarina. However, most farmers combine VRG with some conventional practices, which affect both profitability and potential ecological benefits. Voisin Rational Grazing in Santa Rosa de Lima is also correlated with reduced use of degrading inputs, suggesting a gradual transition to a more agroecological system.

Key words: profitability, management intensive grazing, agroecology, dairy production.

1. INTRODUCTION

The industrialized agrifood system poses a major threat to environmental conservation efforts (Tilman, 1999) due to its negative impacts on the environment, such as land conversion and habitat loss, wasteful water consumption, soil erosion and degradation, pollution, genetic erosion, and climate change (WWF, 2015). According to Tomczak (2006), our current food production system has increased crop yields by using large amounts of fossil fuel energy in the form of synthetic nitrogen fertilizers, petroleum-based agrochemicals, diesel powered machinery, refrigeration, irrigation and an oil dependent distribution system. The dependence on non-renewable fossil fuel resources has become increasingly scarce and expensive. Additionally, it destroys biodiversity, contributes to global climate change, degrades soil and water quality, and also is a threat to food security and future food supply.

According to the Food and Agriculture Organization of the United Nations (FAO), agriculture activities occupy 38.47% of the Earth's surface (FAOSTAT, 2012). The emissions from this activity, jointly with the land use change, is responsible for one quarter of the global anthropogenic greenhouse gas emissions (GHG) in the world (IPCC, 2014). With 32% of its land in agriculture production, Brazil is the third highest emitter of CO2 equivalent (CO2e) emissions from agriculture in the world (FAOSTAT, 2012).

The picture is still worse for cattle activity, which is responsible for the majority of agricultural GHG emissions. Globally, cattle activity is responsible for 47.1% of all agricultural CO2e emissions due to enteric fermentation and manure left on pasture, and permanent pasture area covers about 21.66% of the land surface (IBGE, 2012). In Brazil, cattle production is responsible for 90.5% of all emissions from Brazilian agricultural activities, and permanent pasture occupies 23.45% of Brazilian territory (FAOSTAT, 2018).

Estimations of an increase of 50% on animal protein demand by the year 2050 (FAO, 2017; Tilman, 1999) alerts to the need of an agricultural systems that can "increase food production from existing farmland in ways that place far less pressure on the environment and that do not undermine our capacity to continue producing food in the future" (GARNETT et. al., 2013, p. 33), premise of agroecological systems.

In that context, during the late 1990s, alternatives to conventional dairy system have emerged in Santa Catarina, southern Brazil: the Voisin Rational Grazing (VRG), which gained popularity on family dairy farms through a project developed by the Federal University of Santa Catarina (UFSC) and The State Agricultural Research and Extension Agency (EPAGRI) (ALVEZ, 2012).

The southern state of Santa Catarina is located in the Brazilian Atlantic Forest Biome, which, among the most biologically rich and most threatened ecosystems on the planet, makes it an international hotspot for conservation priorities (ALVEZ, 2012; FARLEY et al., 2012; JOLY et. al., 2014; MYERS et. al., 2000). Santa Catarina also happens to be the fourth largest state for milk production in the country, accounting for 9.6% of all Brazilian milk production (EPAGRI/CEPA, 2018). Therefore, milk production is very important for the state economy, representing 80% of the total monetary value of livestock activity and being present on 45% of all Santa Catarina's farms (IBGE, 2018, 2013).

1.1 The Voisin Rational Grazing (VRG)

The VRG system, also known as management intensive grazing (MIG), is a pasture-based agroecological approach to dairy and meat production that obeys four laws: rest, occupation, maximum yield, and regular yield (MACHADO, 2010; MELADO, 2003). These laws advocate managing the pasture and herd in a way that respects the recovery time of the grass, avoids overgrazing, and respects the different nutritional requirements of the animals (VOISIN, 1988). Animals graze in paddocks for a short period of time and are then rotated to a new paddock (WINSTEN et al., 2000).

According to Farley et al. (2012), VRG offers a sustainable alternative to conventional cattle production by improving family farmer livelihoods while reducing or even reversing ecological degradation.

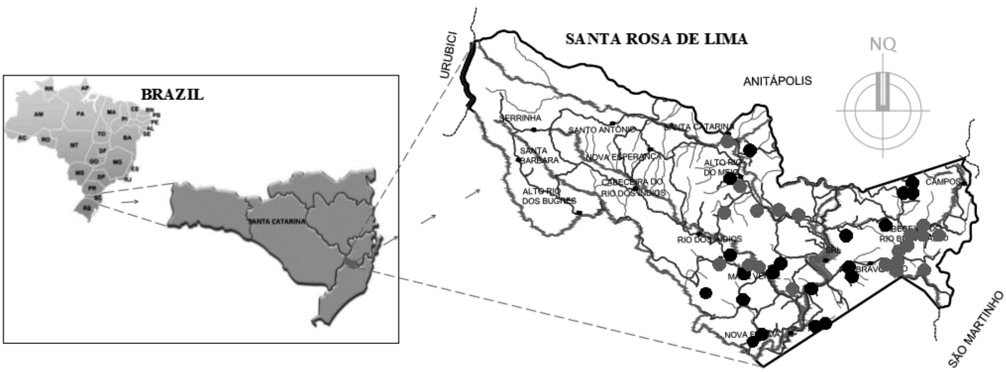
Researches on ecological advantages of VRG conducted in Santa Catarina suggest that VRG can recover natural pasture, increase water retention, decreased erosion, reduce pressure on native forest, improve animal healthy, increase biodiversity, improved soil fertility and porosity, control natural pest, increase carbon sequestration, water regulation, and nutrient cycling (ALVEZ, 2012; BAUER, 2009; FARLEY et al., 2012; MELADO, 2007; MEURER, 2008; BRASILEIRO-ASSING, 2018). However, on the economic advantages of VRG implementation in Santa Catarina, the literature is scarce. While we found research that calculates the potential costs of introducing implementation of the VRG system, we found no detailed studies quantifying the annual production costs or benefits to farms already applying VRG in the region (BRUGNARA, 2015; DIAS, 2014; MACHADO, 2004). Therefore, a question remains: are the farms applying VRG more profitable than farms adopting conventional systems for milk production? In order to answer this question and to contribute to filling this literature gap, the present researcher aims to provide a detailed economic assessment and comparison of farms in Santa Rosa de Lima that have adopted VRG to those that have not analyze the economic advantages of VRG in Santa Catarina.

2. MATERIALS AND METHODS

2.1 Study Location and Data Collection

This research study was conducted in Santa Rosa de Lima, a small municipality in the southern part of the Brazilian state of Santa Catarina. We selected 40 farms in Santa Rosa de Lima for this study, 20 of which used traditional pasture management (pasture and semi-pasture-based without VRG techniques) and 20 that used VRG. Participation was voluntary, but otherwise the sample was random. Farm distribution of this selection of 40 farms is shown in Fig. .1

Figure 1 – Distribution of original farm samples in Santa Rosa de Lima. Black dots represent VRG farms and gray dots represent conventional farms.



This sample represents roughly 34% of all 119 dairy farms in the municipality, of which 53 are known to use VRG and 66 are known to use solely conventional grazing methods (Luiz Miguel Rech, personal communication, 2014).

Data for this study consisted of detailed annual accounting data. Farmers were asked to monthly account for dairy-related expenditures and revenues during one year, between August 2013 and July 2014. From 40 farmers (our initial sample), 35 agreed to participate. However, during the project, three farmers withdrew, four more were excluded from the sample due to incomplete information, and one more was excluded because the income from animal sales exceeded income from the sale of milk. The resulting final sample size was 27 farms – 15 that used VRG and 12 that used conventional methods.

2.2 Accounting Method

The spreadsheets were developed based on the International Accounting Standards Board (IASB) rules (Comitê de Pronunciamentos Contábeis, 2018). For the income analysis, information on costs and revenues were recorded. We applied the absorption costing method, which considers the average total cost (variable plus fixed costs) as the unit production cost (Garrison et. al., 2011). Farmers completed a spreadsheet with information on their variable, fixed, and opportunity costs. Variable costs are those expenses that vary with production, and fixed costs are expenses not affected by the amount produced in the short run (MARTINS, 2015). Fixed costs must be paid even if production drops to zero. Production cost, cost of sales, and other expenses include: animal feed (crop and supplements), veterinary costs, insemination, electricity, fertilizer, herbicide, grass seedlings and seeds, crop seedlings and seeds for silage, maintenance of machines and buildings, taxes (annual tax on rural property and annual car registration), insurance (car insurance), machine rental, fuel, and labor.

Opportunity costs represent forgone income rather than actual expenditures (idem).[11] In our research, we applied as opportunity costs wages that could be earned by working off-farm; on-farm use of raw materials harvested (for example using wood for fences in lieu of timber purchases); and interest farmers could have made by depositing their financial capital in a savings account rather investing it in the production process (6.16% registered for the accounting year) (BANCO CENTRAL DO BRASIL, 2014). We valued all dairy-related farm labor at R$

[11] Opportunity costs are not typically recorded in income statements, but as they are costs we felt should be considered in making decisions, they were included in our analysis (Averkamp, 2016b).

8.75/h, the expected payment per rural labor hour in the Santa Rosa de Lima municipality (Valnério Assing, personal communication, 2014).

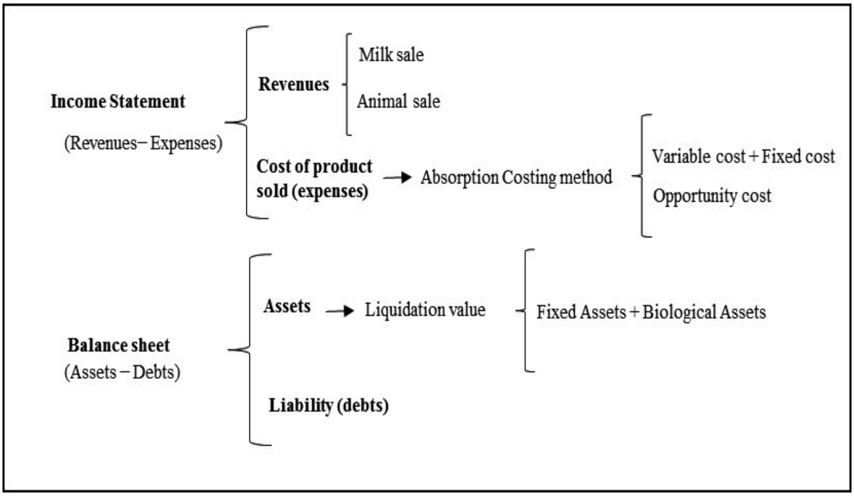
For the income statement analysis, the sales from dairy activity were recorded. Milk sales were considered the main product and animal sales were considered a sub-product of the dairy activity.

For the balance sheet analysis, assets and liabilities were recorded and compared in order to understand the financial solvency of the activity. Money that farmers had in a checking or savings account were not recorded, in part because we assumed that farmers would not feel comfortable sharing this information. Assets included land (for pasture and crops of animal feed), machines (milking machines, milk coolers, forage crushers, weed whackers, and chainsaws), tools (shovels and wheelbarrows), buildings (barns, manure compost dumps, and warehouses), transports (cars or motorcycles), and herd (cows, heifer, calves, and bulls).

We used the liquidation values reported by the farmers for asset values. We did not include depreciation in this analysis for three reasons: the liquidation price already assumes depreciation from past years, 80% of asset values were from assets with negligible depreciation (or even rising values due to market dynamics, e.g. land and biological assets), and information about purchase price and dates were not available.

The payments of principal on debts are not included in the income statement but are presented in the balance sheet, including any interest paid on the principals. Separation of interest and principal on debts was not possible since some farmers did not know what interest rate they were paying. Fig. 2 summarizes the framework used for the accounting analysis of dairy activity.

Figure 2 – Accounting analysis framework for dairy activity.



2.3 Economic Analysis

In order to conduct the economic analysis, some conventional indicators were calculated, such as gross profit, net profit, return on assets (ROA) and the benefit–cost ratio (BCR). See **equations 1, 2, 3 and 4**.

Gross profit = revenue – direct costs of production (e.g.: expenditures) **equation 1**

Net profit = Gross profit – indirect expenses (e.g. opportunity costs of labor) **equation 2**

ROA(net) = profit(net) /asset values **equation 3**

BCR(net)[12] = income(net) /costs **equation 4**

Gross profit here tells the income farmers actually receive, while net profit tells us how much profit farmers make from farming as compared to alternative uses of farmland, labor and other opportunity costs. We calculated two different values for both ROA and BCR, one ignoring opportunity costs (gross ROA and BCR) and the other including them (net ROA and BCR). Both indicators measure how efficient management is at using its assets and investment to generate earnings.

[12] The BCR is conventionally calculated as the ratio between the net present value (NPV) of income and the NPV of costs, which is appropriate when analyzing investments with immediate costs and future benefits, such as if conventional farmers were considering whether or not to invest in VRG. Since our study was focused on a single year of data with negligible new investments, our BCR used the current period income and costs.

2.4 Statistical Analysis

We divided the total values of all variables related to cost, profit and revenue by liters, in order to evaluate these variables through economic efficiency lenses.

To analyze the differences between farm characteristics of the two groups (VRG and conventional farmers), we used t-tests for data, which showed normal distribution. To test the normality of distributions, we applied the Kolmogorov-Smirnov test. Analyses were conducted using IBM Statistical Package for Social Sciences (SPSS) Version 24. Results with a p-value less than 0.10 ($p<0.10$) were considered statistically significant. We decided to use this less common significance indicator, as it was more applicable to our sample size.

To evaluate the significance of the t-test results, effect size tests were conducted for any variables that showed significance. According to Fritz, et al. (2012), the larger the effect size, the greater the potential for an experimental variable to have a practical or theoretical impact or importance. For the analysis of our parametric data, we used the University of Colorado's online effect size calculator (https://www.uccs.edu/lbecker/) to measure Cohen's d, where $d = 0.2$ is considered a small effect, $d = 0.5$ is considered a medium effect, and $d = 0.8$ is considered to be a large effect. (Fritz et al., 2012; Lindenau and Guimarães, 2012).

To better understand the effect size results, we used the probability of superiority (PS) correspondent to the effect size results, according to the Fritz, et al. (2012) table on associated d and PS values. According to the authors, "PS gives the percentage of occasions when a randomly sampled member of the distribution with the higher mean will have a higher score than a randomly sampled member of the other distribution."

3. RESULTS

3.1 General farm system characteristics

The animal diets in the dairy systems found in Santa Rosa de Lima are comprised mainly of pasture, corn silage, forage and rations[13], which classifies Voisinistas and conventional farmers alike as using semi pasture-based systems. All farmers leave the animals in the pasture all day and then feed them in the barn twice a day while they are being milked.

[13] Wheat bran, Corn bran, Soybean bran, and mix of assorted cereals.

Table 1 – Average of rations and silage use for cow and heifer per day

Variable	Voisin (n=15)		Conventional (n =12)		*p*-value	Effect Size	
	Average	SD[3]	Average	SD		d[1]	PS[2]
Rations (Kg/cow and heifer/day)	1.65	1.24	1.05	0.96	0.181		
Silage (Kg/cow and heifer/day)	6.49	3.72	8.84	2.27	0.067†	0.76	70

[1]Cohen's effect size for parametric data. $d \leq 0.2$ = small, $0.2 < d < 0.8$ = medium, and $d \geq 0.8$ = large effect size.

[2]Probability of Superiority.

[3]Standard deviation

†denotes significance at $\alpha = 0.10$

Although Voisinistas feed cows and heifers 1.65 kg of rations (purchased feed) per day, which is 57% more than the conventional farmers (1.05 kg/day), the statistical significance of this difference was low (**table 1**). In contrast, the conventional farmers feed cows and heifers significantly more silage than do Voisinistas.

The average Voisin farm was larger than the average conventional farm size, though the difference was not statistically significant for pasture area or cropped land taken individually (**table 2**). The herd size, total animal units (AU) and the number of cows were all greater on the Voisin farms, with a large effect size and PS, but measures of stocking rates were not statistically different between the samples (**table 2**).

Table 2 – Farm Characteristics

Variable	**Voisin (n=15)**		**Conventional (n =12)**		***p*-value**	**Effect Size**	
	Average	SD[1]	Average	SD		d[2]	PS[3]
Dairy farm area (Ha)	15.85	5.88	12.29	3.92	0.084†	0.71	69
Pasture area (Ha)	11.45	5.82	8.75	2.67	0.126		
Cropped land (Ha)	4.4	3.2	3.54	1.74	0.411		
Number of animals (cows, heifer, steer, calf and bull)	48.47	14.89	32.75	14.35	0.010†	1.07	78
Total Animal Unit (AU)[14]	35.9	12.11	25.22	13.44	0.040†	0.83	72
Number of cows	23.33	9.58	12.92	5.99	0.003†	1.30	82

[14] To calculate UA, we used equivalences from Embrapa's (2014) suggestion: we assumed that one adult bull or ox = 1.25 UA; one cow = 1 UA; one heifer =0.75 UA; and one calf or younger heifer = 0.25 UA.

Stocking rate of pasture area (AU/ha)	3.63	1.77	3.14	2.02	0.508		
Stocking rate of dairy farm area (AU/ha)	2.49	1.32	2.27	1.49	0.692		

[1]Standard deviation

[2]Cohen's effect size for parametric data. $d \leq 0.2$ = small, $0.2 < d < 0.8$ = medium, and $d \geq 0.8$ = large effect size.

[3]Probability of Superiority.

†denotes significance at $\alpha = 0.10$

3.2 Income statement and balance sheet results.

The expenditures were not statistically different between Voisin and conventional systems. However, the total costs were different. This differences was confirmed by the medium effect size and PS (*d* =0.67 and PS =68), see **table 3**.

Table 3 – Monthly farm inputs divided per hectare, animal unit (AU) and hectare

Variable	**Voisin (n=15)**		**Conventional (n=12)**		***p*-value**	**Effect size**	
	Average	SD[1]	Average	SD		d[2]	PS[3]
Expenditures (U$/ liter month)	0.21	0.04	0.25	0.08	0.181		
Total costs (U$/liter month)	0.51	0.24	0.70	0.31	0.089†	0.67	68
Unpaid labor (U$/liter month)	0.24	0.19	0.38	0.17	0.053†	0.79	70
Paid labor (U$/liter month)	0.003	0.004	0.002	0.005	0.952		
Rations (U$/liter month)	0.10	0.04	0.09	0.05	0.590		
Fertilizer (U$/liter month)	0.02	0.01	0.04	0.02	0.039†	0.92	74
Herbicides(U$/liter month)	0.008	0.004	0.008	0.007	0.934		
Total feed (U$/liter month)	0.18	0.04	0.22	0.09	0.190		
Medication costs (U$/liter month)	0.01	0.01	0.01	0.009	0.893		
Opportunity costs (U$/liter month)	0.25	0.19	0.41	0.17	0.046†	0.81	71

[1]Standard deviation

[2]Cohen's effect size for parametric data. $d \leq 0.2$ = small, $0.2 < d < 0.8$ = medium, and $d \geq 0.8$ = large effect size.

[3]probability of superiority.

†denotes significance at $\alpha = 0.10$

The value of family (unpaid) labor was significantly smaller for Voisinistas, and the significance of this difference was confirmed by its effect size and PS, 0.79 and 70, respectively. This is expected, since milk production is higher for Voisinistas due to the combination of greater dairy farm area, stocking rates (**table 2**) and liters per cow (**table 4**), even though some of the differences are not statistically significant when viewed alone. This is also reflected in the opportunity cost (60% higher for conventional farmers), since the unpaid labor was the main component of the opportunity cost for both systems (42% and 57% of the Voisin and conventional Total Costs), and again the Voisinistas have more milk production. For the opportunity cost, the significance of the difference was also confirmed by the large *d* and PS (0.81 and 71, respectively).

The largest component of Expenditures was purchased feed (rations), representing 47% and 34% of the Voisin and conventional farmers' Expenditures totals, respectively. Voisinistas spent more money on rations than the conventional farmers. However, this difference was not significant.

On agrochemical use, Voisinistas were using 50% less fertilizer than conventional farmers. This difference was statistically significant (p-value = 0.03), confirmed by the large *d* and PS (0.92 and 74, respectively). Both types of systems are using an insignificant amount of herbicides (close to zero when normalized by the total of milk produced).

Data from accounting project found no significant difference in spending on medications between the two systems (**table 3)**.

On farm outputs (**table 4**), the average productivity per cow was higher for Voisinistas, though the difference was not statistically significant. However, the more relevant measure of milk (milk production per hectare) was 80% higher for Voisinistas, and the difference was significant. Similarly, revenue per hectare and per AU was higher for Voisinistas, though only the former was statistically significant. However, this significance was not considered very high, it showed a p-value of 0.096, a medium effect size (d=0.68), and consequently, a probability of superiority not too high (PS = 68), see **table 4**.

Table 4 – Cow and land productivity, revenue per hectare and animal unit (AU), percentage of revenue from milk and animal sales on total sales, and coefficient of milk production variation

Variables	Voisin (n=15)		Conventional (n=12)		*p*-value	Effect Size	
	Average	SD[1]	Average	SD		d[2]	PS[3]
Cow productivity (liter/cow/day)	12.38	4.43	10.06	2.80	0.128		
Milk/Hectare (liter)	426.78	303.20	237.24	172.31	0.066†	0.76	70

Revenue (U$/month/Hectare)	198.55	132.30	123.84	77.93	0.096†	0.68	68
Revenue (U$/AU month)	78.05	31.09	60.52	26.13	0.131		
Milk sales (% of total sales)	0.94	0.08	0.86	0.18	0.149		
Animal sales (% of total sales)	0.06	0.08	0.14	0.18	0.149		
Coefficient of milk production variation	0.196	0.079	0.243	0.084	0.146		

[1]Standard deviation

[2]Cohen's effect size for parametric data. d ≤ 0.2 = small, 0.2 < d < 0.8 = medium, and d ≥ 0.8 = large effect size.

[3]probability of superiority.

†denotes significance at α = 0.10

The coefficient of milk production variation[15] was 24% higher for conventional farmers than for Voisinistas. However, this difference was not statistically significant (see **table 4**).

The assets are shown to be 26% higher for the Voisinistas than for conventional farmers, but Voisinistas have debts 466% higher than the conventional farmers, confirmed by a medium and large effect size, respectively. The balance between the assets and debts shows that both systems have good solvency, or in other words, similar capacity to comply with their liabilities using their assets (see **table 5**).

Table 5 – Farm's assets and debts

Variable	Voisin (n=15)		Conventional (n=12)		*p*-value	Effect Size	
	Average	SD[1]	Average	SD		d[2]	PS[3]
Assets (U$)	194676.70	57435.24	154310.27	55685.42	0.078†	0.71	69
Debts (RS)	24887.38	20655.61	4398.25	6911.96	0.002†	1.33	82
Balance (assets – debts) (U$)	169789.32	60169.21	149912.02	56320.33	0.389		

[1]Standard deviation

[2]Cohen's effect size for parametric data. d ≤ 0.2 = small, 0.2 < d < 0.8 = medium, and d ≥ 0.8 = large effect size.

[3]probability of superiority.

†denotes significance at α = 0.10

[15] The coefficient of milk production variation is the standard deviation of milk production divided by its average. It shows the relative average variation of the milk production.

Table 6 presents the profitability measures described in **section 2.4**. Although there were differences found in the average profitability between the two systems, these differences were not significant.

Table 6 – Profitability measures

Variable	Voison (n=15)		Conventional (n=12)		*p*-value	Effect Size	
	Average	SD[1]	Average	SD		d[2]	PS[3]
Gross Profit (U$/liter month)	0.27	0.06	0.29	0.16	0.537		
Net Profit (U$/liter month)	-0.04	0.23	-0.16	0.34	0.292		
Gross ROA	0.10	0.07	0.06	0.04	0.081†	0.72	69
Net ROA	0.01	0.05	-0.02	0.06	0.068†	0.73	69
Gross BCR	2.38	0.67	2.40	0.90	0.946		
Net BCR	1.06	0.35	0.91	0.43	0.356		

[1]Standard deviation

[2]Cohen's effect size for parametric data. $d \leq 0.2$ = small, $0.2 < d < 0.8$ = medium, and $d \geq 0.8$ = large effect size.

[3]probability of superiority.

†denotes significance at $\alpha = 0.10$

The Return on Assets were higher for Voisinistas, with medium effect size. However, in both systems, returns were not competitive with the interest rates on savings accounts in Brazil for the period (0.0616/year, that is, 6.16%/year), except for the Gross ROA for Voisinistas, which was 0.10.

The Gross Benefit Cost Ratio (based on expenditures) exceeded interest rates on savings accounts for both systems. However Net BCR (based on total costs) exceeded interest rates on savings only for Voisinistas[16]. Comparing the two systems, the BCR was not significantly different for any method of calculation (see **table 6**).

4. DISCUSSION

The Voisin system, in the case study of Santa Rosa de Lima, showed better performance when compared with other pasture-based systems in the municipality for most economic variables. Perhaps most important from the farmers' perspective, Voisinistas had higher gross profits, net profits and returns on investment. Some

[16] To be more attractive than the compensation interest rate on savings, gross BCR has to be more than 1.0616, and net BCR has to be more than 1, since it already includes a 6% return as an opportunity cost.

of this can be attributed to more cows, but Voisinistas produced 80% more milk/hectare than conventional farmers. Voisinistas also had more assets, though this was counterbalanced by more debt than their conventional counterparts. However, the fact that revenue per hectare and milk production per hectare were both higher on Voisin farms strongly suggests better performance from a purely economic perspective, aside from any ecological or social benefits.

Many proponents of the rotational grazing claim that (UNDERSANDER et al., 2002), if farmers correctly apply the four laws of Voisin Rational Grazing System fertilizer requirements are reduced. André Voisin does not reject the advantages of fertilizer use, and acknowledges its positive impacts on growth rates and productivity (VOISIN, 1988).[17] The VRG System should be expected to reduce the use of chemical fertilizer, but not necessarily eliminate it entirely. In fact, Voisinistas were found to have lower fertilizer expenditures per hectare, though the difference was not significant.

Greater spending on feed concentrates was particularly unexpected, since the whole premise of VRG is that it ensures sufficient pasture availability, therefore eliminating the need for supplements. Poor pasture management would justify greater use of supplements (PARKER, 1992), and field observations revealed not all Voisinistas applied all the Voisin laws - for example, just two Voisinistas applied the Maximum Yield law, in which the animals with more nutritional demand (e.g. lactating cows) should graze a paddock first to get the highest quality forage before admitting those with lower nutritional requirement (e.g. calves). However, field observations also showed that some Voisin pastures appeared under-grazed, with abundant forage on farms purchasing supplements. Perhaps the best explanation, suggested by evidence that most farmers did not carefully track expenditures and revenues prior to this study, is that farmers were more interested in maximizing output than in maximizing profits, and purchased additional feed to achieve this; productivist ideology is common in agriculture (CAPELLESSO et al., 2015).

The finding that Voisinistas used less silage per heifer and cow than conventional farmers was not surprising, especially in light of their greater use of feed supplements. Though silage is produced on the farm, it requires more external inputs - such as corn seed, chemical fertilizers and herbicides - than pasture. However, silage production still reduces external inputs relative to feed concentrates. From an agroecology perspective, if it is necessary to complement the animal diet, it is preferable to do so with silage, and, if at all possible, without using agrochemicals.

[17] Although Voisin considers the use of fertilizer, he brings attention to the fears about the penetration of the fertilizer into the pasture.

Finally, it's important to note that although the ROA was higher for Voisinistas, but it was still less than the interest rate on savings, a conservative measure of opportunity cost. The average farmer in this study would earn more by liquidating assets, investing the money in a savings account, and finding another job. One explanation is that farmers simply enjoy their work and can sustain themselves on it, so maximizing monetary returns is not their main goal. Farmers are well known for self-exploitation (GALT, 2013). However, if land values are increasing rapidly, then maintaining land ownership is economically rational: there is considerable evidence that, worldwide, demand for land is based more on the expectation of price increases than on the annual flow of income it provides (HUDSON, 2012). Prices increased by 1888% in the municipality between 1997 and 2015, much greater than returns on a saving account for the same period (407,46%)[18]. Accounting for rising land prices, farming is economically rational.

The results show that, in general terms, farmers applying VRG have been more profitable and have generated more income per hectare of pasture area than farms applying conventional systems for milk production in Santa Rosa de Lima-SC, which are economic conditional requirements to the migration to VRG system, on a farmer perspective. These results are encouraging to think about an application of a more sustainable dairy agrifood system for all Santa Catarina state, perhaps for all Brazilian country. However, as shown, the data collected through the accounting project reveals that VRG farmers are still using petroleum-based agrochemicals that, as mentioned before, are not sustainable resources since, besides are exhaustible, have increased soil and water contamination. Another mentioned unexpected result was the fact of VRG farmers are still feeding animals with rations. Rations that are produced also with petroleum-based agrochemicals and, very probably, through monoculture systems, which demand considerable areas for soil conversion, which, as mentioned before, are one of the main reasons for CO2 emissions.

The reasons why VRG farms are still using agrochemicals and feeding animals were not clear. However, we have some hypotheses that should be tested in future researches: a) lack of knowledge of agroecological practices for weed management, in the case of herbicides use; b) no recognition of the negative effects of the use of these chemical inputs on the environment and animal and human health, in the case of agrochemicals in general; c) farmers are anxious for quick results, in the

[18] Information obtained from the "citizen calculator" available on the Central Brazilian Bank website (www3.bcb.gov.br). The prices evolution does not include inflation rate for the period. Inflation rate for the period (1997-2015) was about 356% (idem), which still makes the alternative of maintaining land ownership preferable.

case of fertilizer use; and d) most VRG farmers are not applying the Maximum Yield law, so they are not exploiting the full potential of VRG system to meet animals nutritional demands, in the case of farmers feeding animals.

5. CONCLUSION

While the study found that VRG is more economically viable than conventional dairy, there appears to be considerable room for both ecological and economic improvement by reducing reliance on off-farm inputs, a core principle of agroecology. As the system has been applied in Santa Rosa de Lima, one cannot state that it is an agroecological system, but there is evidence that it is in process of transformation to one.

According to Gliessman (2016), there are five levels in the conversion process from conventional agricultural practices to agroecological practices. These three levels are: 1) Increasing the efficiency of conventional practices in order to reduce the use and consumption of costly, scarce, or environmentally damaging inputs; 2) Substituting conventional inputs and practices with alternative practices; 3) Redesigning the agricultural system so that it functions on the basis of a new set of ecological processes; 4) Re-establish a more direct connection between those who grow our food and those who consume it; and 5) Build a new global food system, based on equity, participation, democracy, and justice, that is not only sustainable but helps restore and protects earth's life support systems upon which we all depend.

The VRG system can provide the conditions for the transition, so that these five levels can be achieved. It is important to mention that the first step for this transition for farmers in Santa Rosa de Lima was to become aware and to apply the VRG system, which demanded time and knowledge. To implement the system, they had to divide all pasture area in paddocks using electric fences, develop a hydraulic system to provide water for the animals, and other labor and resource intensive changes for their farms. When fencing in the paddocks, they also saw the chance to improve pasture through the insertion of new gasses and leguminous plants. All these factors considered, the implementation of the VRG system requires a large amount of time to be set up. The VRG farmers have still not fully reached the first level mentioned by Gliessman (2016), but they seem to be heading in this direction. With the exception of herbicide use and purchased feed, the VRG systems present lower costs in the use of inputs. For some variables, this difference was not statistically significant because the variation of these values among VRG farmers (standard deviation) was high. It is expected that this variation will decrease with improvement of the system over time, and this difference will be statistically significant for our sample. In addition, for the majority of the indicators of profitability, VRG system showed better performance than the conventional system.

Once VRG farmers reach the first level in Gliessman's agroecological conversion process, the environmental advantages of this system will appear in following levels. However, to guarantee the continuation of this gradual process, other factors would be helpful, such as financial incentives and the improved transferring of knowledge. In this aspect, the government, scientists and technicians will play an important role. VRG is just a first step in the transformation towards economically and ecologically robust agricultural system.

Although our study complements other studies on VRG implementation in Santa Catarina by presenting and analyzing the economic performance of the system, a study with a bigger sample size is suggested.

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