

Research Article

Renato Linhares de Assis, Adriana Maria de Aquino*

The Participatory Construction of Agro-Ecological Knowledge As A Soil Conservation Strategy In The Mountain Region of Rio de Janeiro State (Brazil)

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Abstract: Agriculture in the mountain region of Rio de Janeiro State is characterized by intensive soil use and input. Such mountainous environments are vulnerable to climate events; thus, the current article presents a report on methods applied to exchange academic and traditional knowledge. The aim is to expand farmers' perception about the need of implementing agro-ecological practices, mainly soil management practices, which are important for agricultural sustainability in mountainous environments. The study was conducted in a Nova Friburgo family production unit, in the mountain region of Rio de Janeiro State (Brazil). It consisted of implementing three observation and soil organic-matter management units. The idea was to reduce the incidence of clubroot of crucifers disease caused by *Plasmidiophora brassicae*. The soil fauna was discussed with local farmers, with emphasis on the association between ecological processes and soil management. The present study improved the discussion with farmers and the need of introducing other innovative conservation practices such as no-tillage system and participatory research based on agro-ecological propositions.

Keywords: *Plasmidiophora brassicae*, green manure, no-tillage systems, soil fauna, cauliflower

1 Introduction

The agricultural activity in mountain landscapes have specificities intrinsic to the fragility of their environments

*Corresponding author: **Adriana Maria de Aquino**, Embrapa Agrobiologia, Carlos da Silveira Carneiro, 44. Cascatinha. Nova Friburgo, RJ. Brazil. CEP 28621450, E-mail: adriana.aquino@embrapa.br

Renato Linhares de Assis, Embrapa Agrobiologia, Carlos da Silveira Carneiro, 44. Cascatinha. Nova Friburgo, RJ. Brazil. CEP 28621450

(FAO 2002); difficult access to topography, susceptibility to climatic changes, and shallow soil depth causing landslides and erosion processes, are some of them. The temperature variations between diurnal and nocturnal periods are also limitations to such environments; overall, commercialization and local development are also affected by these limitations. On the other hand, the agriculture in this region allows distinctive food production when it is properly managed.

Suitable agroecosystem managements imply agro-ecological practices such as the right technology basis combined with the need to promote rural development propositions based on participatory methods. This model enables farmers to better understand the land, as well as the agro-ecological knowledge and processes. The aim is to increase farmers' autonomy by finding ways to improve the permanence of agriculture in the mountains due to the adoption of adapted management practices.

Despite the specificities of mountainous ecosystems, most countries develop policies and laws designed for flat areas (UN 2007). However, these laws and policies do not consider the fragility and specific needs of mountainous landscapes, nor the interests and priorities of their inhabitants. In Brazil, there are no detailed public policies that focus on the sustainable development of mountainous regions (Netto 2013). Moreover, the restrictions to activities within the Permanent Preservation Areas (PPAs), as determined by the Brazilian Forest Code, are mostly found within mountainous environments (Netto et al. 2011).

The same national policies apply to Rio de Janeiro State, mainly to its mountain region. The strong agricultural activity walks side by side with the existing Environmental Conservation Units in the area. Public policies are implemented in the region without prior consideration to its environmental and agricultural aspects and mountainous landscape specificities. The characteristics of the region's inhabitants and producers are also overlooked.

Nova Friburgo County stands out as a regional

economic center and as an important vegetable producer, with emphasis on cauliflower, which is concentrated in Campo do Coelho district. Vegetables in the region are commonly grown in small properties as family production type. These production units present typical industrial technology levels focused on the concentrated use of synthetic fertilizers and pesticides (Guerra et al. 2007).

Given the favorable climate in the area, brassicas, cauliflower and broccoli are among the main vegetables grown in production systems of mountainous landscapes. However, according to Carvalho (2016), these climatic conditions also help the development of clubroot of crucifers, a widely spread disease in the region. The dissemination of clubroot of crucifers disease, caused by the fungus *Plasmodiophora brassicae*, is noteworthy in the area mainly in summer crops mostly due to inadequate soil preparation and handling.

Clubroots occurrence is lowest in autumn/winter, thus creating the most suitable climate for crops to grow. Higher temperatures and humidity in spring and summer favor pathogen activity, which leads to significant crop loss. Notwithstanding, spring and summer crops allow greater economic gains to farmers since crop production is lower, which leads to shortage in supply; consequently, higher market prices.

This phytosanitary problem evidences the environmental imbalance in the region, which affects productivity and production costs. There has never been a study to accurately assess the impact of the disease on the vegetable-production economy in the region. However, farmers report that production losses in summer crops range from 40 to 60%. These values were empirically attested in a visit to the region at the time of the research.

According to Carvalho (2016), knowledge of current soil conditions is key to effective soil management strategies, sustainable balance practices and to lower the incidence of the clubroots of crucifers disease. It is also important to present instruments that can allow farmers to follow sustainability pathways, such as strategies that enhance soil organic matter levels and, consequently, affect soil biotic factors (Beemster et al. 1991; Murakami et al. 2000). Ways of increasing soil organic matter can be achieved by using organic materials from the agricultural production unit: crop rotations using soil cover plants, either through conventional tillage or no-tillage system, or by using organic matter sources available in the region.

In 2007, the “Núcleo de Pesquisa e Treinamento de Agricultores” - NPTA (Center for Research and Training for Farmers) was created in Nova Friburgo, Rio de

Janeiro State. NPTA was established after necessities were raised by local demands and farmers’ political articulation, as well as by the Empresa Brasileira de Pesquisa Agropecuária - Embrapa (Brazilian Agricultural Research Corporation) in the mountain region of Rio de Janeiro State, for a more effective local insertion of the corporation (Assis and Aquino 2014). Since then, Embrapa’s operations in this region have strengthened to promote the agroecological transition of family farming systems through participatory research involving several public institutions and farmers associations, as well as wide spread of the agroecological technologies to change the region’s agricultural scene.

Hence, this research aimed at analyzing the soil quality evaluation strategy as an instrument to facilitate the dialogue between technicians and farmers, in a participative process to build agroecological knowledge within the family production systems, to promote agroecological transition processes that contribute to soil conservation and the sustainability of the production systems in local mountain environments in Nova Friburgo municipality, Rio de Janeiro State. We discussed the endemic and widespread phytosanitary problem of clubroot of crucifers in the region caused by *Plasmodiophora brassicae*, which is obligate biotrophic protist widely disseminated mainly due to inadequate soil preparation and management. The research methods and farmers’ participation, including their own knowledge about soil management practices mountainous landscapes, were used to derive solutions to be locally applied. Farmers also discussed previously known and used alternatives more appropriate to mountainous landscapes.

2 Methods

The process of participatory knowledge construction was developed with a group of family farmers of the community of Santa Cruz, in Nova Friburgo municipality, whose main productive characteristic is the intensive vegetable cultivation. Three observation units were conducted to assess the influence of organic waste and soil management on the incidence of Clubroot of Crucifers in the family farm area, located in a secondary valley at 1,100 m at sea level uneven relief. The property covers 19 ha of permanent grassland (9 ha), crops (6.6 ha) and forest (3.4 ha). Small animals are bred and raised for the family’s subsistence and as part of the vegetable cultivation system (Grisel and Assis 2012).

2.1 First observation unit

The first observation unit had large quantities of brewery waste (grains, yeasts, infusorial earth and dirt) produced by four large brewers in the region. Three brewers are in the Mountainous Fluminense Region (Teresópolis and Petrópolis) whereas one is located in the Nova Friburgo's surrounding country area (Macacu waterfalls).

The properly composted poultry remains from a slaughterhouse in São Jose do Vale do Rio Preto, Mountainous Fluminense Region, also were tested.

Seven treatments were tested in the observation unit: Chemical fertilization or the application of 2 L of one of the organic waste materials that have traditionally been used as fertilizer by the local growers:

- Yeasts;
- Grains;
- Infusorial earth;
- Malt residue;
- Composted poultry remains; or
- Chicken litter.

The organic waste material was applied to the soil 15 days before transplanting the cauliflower seedlings.

2.2 Second observation unit

The second observation unit was set in the same family production unit for three crop years. The aim was to attest the effect of green manure to reduce the incidence clubroot of crucifers. Three vegetable crop rotations were used: fertilization¹ without green manure in cruciferous crops during the spring / summer period (cauliflower in the 1st and 3rd years; broccoli in the 2nd year)², fallow (1st year) or carrot cultivation (2nd and 3rd years) in the autumn / winter period; cruciferous crops in spring / summer (cauliflower on the 1st and 3rd years, broccoli in the 2nd year), and black oat vetch intercropping, followed by green corn, in the autumn / winter period; cruciferous cultivation during the spring / summer period (cauliflower in the 1st and 3rd years, broccoli in the 2nd year); and lupine, followed by green corn, in the autumn / winter period.

According to Assis et al. (2007) soil fauna is an important asset to farmers when soil ecological processes

are discussed. Thus, monitoring soil fauna in this observation unit was part of a strategy to trigger the dialogue with the farmers. Sampling was carried out following the MOLDENKE (1994) method, by extracting the active edaphic fauna and meso-organisms present in the soil-litter interface using pitfall traps. Five (5) 500-ml-pots containing 4% formaldehyde were buried in four different locations within the observation unit. Three treated areas, as well as a natural-vegetation section, were monitored. The traps were kept in the locations for seven days.

2.3 Third observation unit

A third observation unit was implemented without soil mobilization for three years before the first crop rotation: cauliflower (spring), lupine (summer), common vetch (fall) and black oats (winter).

Ethical approval: The conducted research is not related to either human or animals use.

3 Results

3.1 First observation unit

The farmer confirmed the absence of clubroot of crucifers in crops grown under the different organic waste treatments applied in the first observation unit. Cauliflower fresh-matter production was also positive when brewer yeast composting was used (Table 1). However, farmers did not support the use of these types of waste for composting due to their lingering smell and difficult handling.

Table 1. Fresh Matter of the cauliflower shoot section treated with different organic waste sources.

Organic waste	Fresh Matter (g) *
Brewer grain	1.31
Brewer yeast	1.89
Infusorial earth	1.39
Malt Residue	1.20
Composted Poultry	1.51
Fertilization	1.53
Fertilization	1.47

* Based on the means of plants daily harvested by the farmer.

¹ The cropping succession strategy in this treatment was decided by the farmer without interference from the technical staff.

² The choice for the cruciferous crop was made between the farmer and the technicians based on their market strategy.

Table 2. The attributes of cauliflower shoots grown in soil subjected to different plant successions and the incidence of clubroot of crucifers in the third agricultural year¹

Treatments	Appearance ²	Fresh Matter	Diameter (cm)	Plants with clubroots of crucifers	
	Scores from 0 to 10	(g)		N	%
Black oat + common vetch/green corn/cruciferous	7.3±3.3	654±166	17.0±3.0	0	0
Lupine + green corn/cruciferous	7.1±2.9	564±144	16.1±1.1	0	0
Fallow/carrot/cruciferous	5.9±1.9	532±92	16.1±2.4	8	80

¹Values representing the means of 10 plants.

²Means of the three evaluators.

3.2 Second observation unit

There was also evident increased organic matter levels *in situ* in the second observation unit due to the green manure practice, which progressively reduced the incidence of clubroot of crucifers over three-crop rotation years. Such reduction reached its peak in the third successional year when the cauliflower-cultivated areas did not present any clubroots incidence (Table 2).

Discussions with the farmer about the ecological soil process in this observation unit helped the farmer identify, through soil fauna monitoring, several soil animals in the cultivation areas, mainly earthworms, millipedes and ants. Although the farmer considered the presence of soil fauna an important soil quality indicator, he did not understand their ecological role.

Removal of traps and soil fauna identification showed numerous and a variety of soil animals, many of which were unknown to the farmer. The farmer's participation was important at this point since it allowed the elaboration of concepts about the abundance and richness of soil fauna groups.

According to the farmer, although the rotation system between green manure and the no-tillage system favored ant populations, ants should not be considered a plague since they did not attack the main crop. This result came up during a discussion about the colorful graphics (Figure 1) and from the observation of soil animals under magnifying glass. The ecological role of some soil invertebrates as predators (spiders, some beetles, ants), saprophagous (ants, springtails, millipedes, woodlice, cockroaches) and herbivores (ants, locusts, bedbugs) was discussed in the aforementioned meetings.

The semi-structured questionnaire answered by the farmer showed they had a better understanding about the ecological role of these organisms in the soil. The results of the questionnaire also demonstrated that soil fauna was larger and more diverse in the natural vegetation

area than in the agricultural land. Additionally, there is an indication of that the number and diversity of predator species in the soil is important for pest control. The results have shown the need of preserving the forest area in the property as a refuge for soil fauna, which can enable fauna migration to farming areas; hence, beneficial to soil conservation.

The farmer stated that treatments using cover crops (tillage or no-tillage) increased the number of soil animals and led to better soil quality and larger crop production. To the farmer, the local soil is darker and softer than the soil without fauna, and to him greater soil mobilization reduces the amount of soil animals. Consequently, soil fauna is an utmost instrument of discussion with farmers. Their comprehension about the ecological processes occurring in the soil allows a new perception about different soil management practices and how these practices associate with natural resources.

3.3 Third observation unit

The third observation unit resulted from the two previous ones and led to discussions with the farmer about the appropriate agro-ecological practices for local mountainous environments. The discussions led to the conclusion that black oats and lupine can be used as cover crop both in winter and summer through no-tillage system. This scenario was observed in family production systems that used vegetable crop rotation in mountainous environments in Rio de Janeiro State.

No soil mobilization practice as well as other soil conservation benefits, such as lower erosion rates, have favored water resource efficiency and higher long-term soil moisture.

The successful green manure integration as cover crop happened after some adjustments were made in the black oat cultivation periods to the crop rotation dynamics

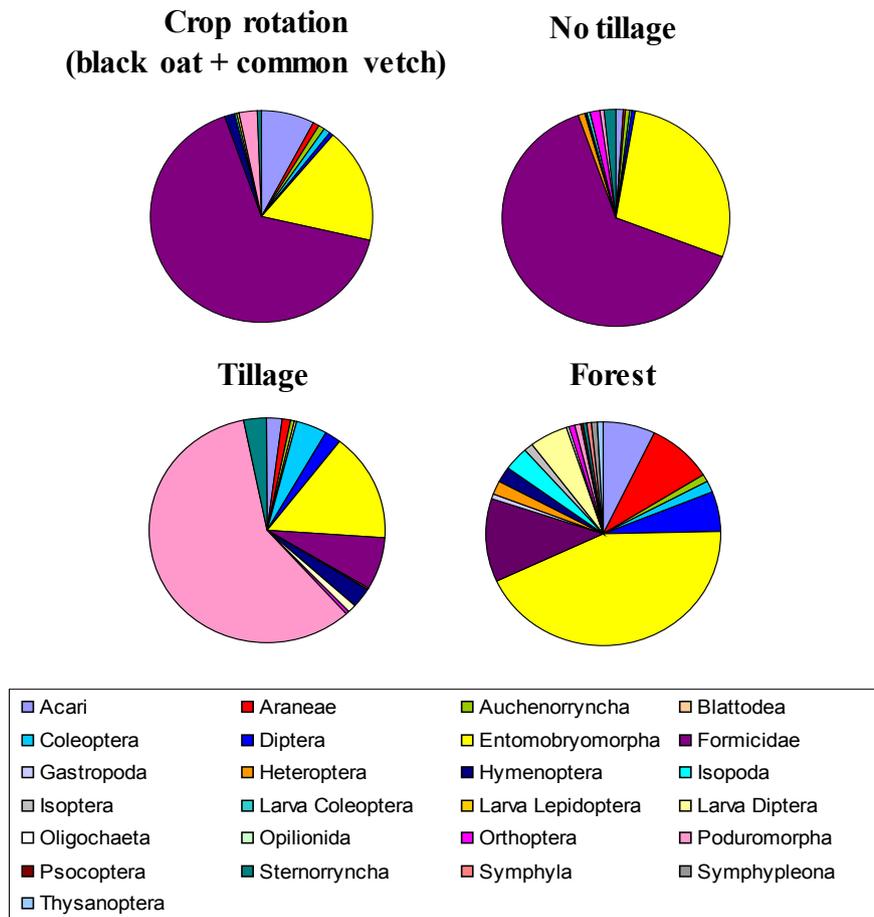


Figure 1. Color graphics discussed with the farmer about soil organism types found in different cultivation successions and in natural vegetation area.

following suggestions made by farmers and technicians. Accordingly, it was necessary to locally adapt the last sowing by using common vetch under no-tillage on lupine and cauliflower on black-oat straw in order to follow the initial strategy established for this observation unit. Thus, sowing of black-oats was always done between crop rows, at the beginning of the common vetch harvesting period. Despite the constant trampling on the sown area due to long common vetch crop periods, there was always adequate black oat development which allowed enough soil cover for cauliflower to be cultivated in succession.

4 Discussion

The goals of the participatory process method used in the two observation units were to develop soil management strategies and to reduce the incidence of clubroot of crucifers disease. The method also improved the discussions with farmers about the introduction of other

innovative conservation strategies such as no-tillage planting system. Additionally, the participatory process used highlighted the importance of a larger participation of local growers in the decision-making process involving agro-ecological plans/proposals in local mountainous environments.

Agroecological production systems depend on adjustments in the environmental conditions and on the respect to the principles and natural cycles in order to have minimal impact on nature. Generalizing results leads to problems, particularly in production systems such as those herein assessed. Each productive unit, at its limit, presents specific environmental, social and cultural aspects and requires individual adaptations.

The agroecological transition is often focused on biological diversity, material and energy recycling, and on natural biological control. The ways and time to achieve these results depend on the farmer's capacity to relate to innovative methods, to choose transition strategies and to apply the necessary adjustments to local socioeconomic

and ecological conditions (Casado and Mielgo 2000).

Grisel and Assis (2012; 2015) from the analysis applied to general agrarian dynamics in southwestern Nova Friburgo City (RJ), mountain region of Rio de Janeiro State, determined the conditions to change the agro-economic components for a production system that may increase of sustainability.

Agroecological management requires practices that ensure a constant supply of essential organic matter to develop and increase soil fertility. The aim is to stimulate biological activity and to grow well-nourished plants that provide balanced and healthy food. Prioritizing locally available renewable natural resources is essential, since it is important to reduce the dependence of producers on external inputs and to save non-renewable natural resources. Accordingly, the biological process of N_2 fixation is the primary N source and it stimulates crop productivity and careful soil management practices.

Several studies have already shown that soil quality evaluation is a vital environmental quality indicator, as well as the best way to assess the impact of management practices on sustainable productions (Kennedy and Papendick 1995). Soil quality is defined as “the ability of a specific soil type to function within the limits of the managed or natural ecosystem, since it is the basis for the productivity of plants and animals; and to maintain or increase the quality of water and air to promote human health” (Doran and Parkin 1994). Identifying and assessing the quality of chemical, physical and biological key indicators and their sensitivity to changes and disturbances caused by soil management are important for best soil management practices.

Thus, the quality of the soil is considered an instrument of evaluation that may facilitate adaptations of management that promote sustainable agricultural practices. The farmer’s perception in relation to the quality of the soil is crucial when the goal is to develop mechanisms that further decision making about the adoption of management procedures (Andrews et al. 2002; Andrews et al. 2003). Accordingly, the appropriate parameters used to assess the quality of the soil that can help farmers to plan a management system are also some of the biggest obstacles to their own adoption. The implementation of studies to adequate the soil attributes to the farmers’ reality emerges as a fundamental condition to make the wide dissemination of agroecological management practices viable among the rural communities in the region.

The emphasis on ecological practices allows family farms to produce basic-food of quality, to promote generation of income in rural areas, as well as the

conservation of natural resources if local and regional attributes and participatory processes are taken into account.

New ecological practices must go through a gradual dissemination and assimilation process. The first steps towards it in the mountain region of Rio de Janeiro State are to rationalize and eventually replace the use of chemical raw materials. There upon, the gradual agroecological transition from conventional base production systems will be possible. The replacement of old practices by newer ones should be timely and based on farmer’s adaptation process and learning curve. Essentially, it is possible to develop agricultural policies that focus on sustainable growth of regional production systems following farmers’ adaptation and experience.

One of the agroecological basic principles is organic matter management, which represents a source of food and energy. Organic matter is a shelter for organisms as it comprises millions of invertebrates that live, either permanently or for most of their lifespan, in the ground (Aquino, 2001). These organisms are crucial for soil conservation because they are responsible for organic matter decomposition, nutrient cycling, mineral matter aggregation and for maintaining biological balance in the soil (Scheu and Walters 1991; Sanginga et al. 1992; Assad 1997; Lavelle 1996; Cesarz et al. 2015).

Organic matter contribution such as habitat modifications, food availability, microclimate formation and intra-interspecies competition, associated to green manure and to no-tillage production systems, promotes changes in the abundance, diversity and functional organization of the edaphic biota (House and Parmelee 1985, Assad 1997; Aquino et al. 2008; Zhu and Zhu 2015).

Land planning for food production in mountainous environments demands a singular approach in regards to the fragility of such landscapes. However, there is a lack of specific public policies in Brazil unless cultivation takes place in flat areas. Intensive land use in mountainous environment results in extreme soil degradation and increased incidence of crop diseases.

The clubroot of crucifers disease, which has contaminated brassica plants in the mountain region of Rio de Janeiro State, typically occurs in mismanaged environments; mainly soil organic matter. The idea was to use the clubroot of crucifers disease as an example to show farmers that the adoption of agroecological practices is timely. It was also necessary to broaden the discussion about the need of widely spreading distinctive agricultural practices in mountainous environments.

Participatory methods furthered the discussion on better soil management practices. Choices of solutions were

discussed with the farmers that involved the application of green manure in cultures, particularly in black oats, common vetch and lupine. All the aforementioned solutions showed the capacity of reducing the incidence of clubroot of crucifers disease in the experimental areas. These results improved the discussions with the farmers and increased the need to introduce other innovative conservation strategies (e.g. no-tillage system) to improve the participatory research on agroecological proposals.

Green manure use and no-tillage systems favor the biological balance in the soil. The present methodology - from soil fauna sampling to results - was used as a strategy to create a discussion with farmers and with their families. This study also allowed a reasoning regarding ecological soil-management processes and worked as premise for accomplishing the desired changes.

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