Chapter 4
The Structural and Functional Biodiversity of Soil: An Interdisciplinary Vision for Conservation Agriculture in Brazil

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4.1 Introduction

Brazil is a country of continental dimensions with more than 8.5 million km^2, and for this reason it has a great climatic and soil diversity, which culminates in the formation of major biomes of national and international interest. Although some states have a sub-temperate climate, Brazil is essentially a tropical country, with highly weathered soils of low natural fertility. All biomes harbor a great plant and animal biodiversity, part of it still unknown.

Although the conservation and preservation of the Brazilian biomes is a permanent concern, several of them are being threatened by deforestation or expansion of agricultural frontiers. In the Amazon biome, the area deforested over the period ranging from August 2001 to August 2007 reached 118,542 km^2. From August 2006 to August 2007, an estimated 11,532 km^2 was deforested (INPE 2008), which is an indication of a decreasing annual deforestation rate, but nonetheless suggests that understanding and preserving indigenous biodiversity remains a big challenge.

An even more critical situation is observed in the Atlantic Coastal Rainforest (SOS Mata Atlântica 2008) and the Brazilian Cerrado (Machado et al. 2004), where more than 90% and 60% respectively of the native vegetation has been destroyed. These biomes present not only most of the agricultural activities in the country, but also the highest population density.

In parallel, it is estimated that the planted area increased from 1.2% to 2.7% for the 2008/2009 grain harvest in relation to the previous harvest year. This means that

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14 grain crops cover an area of about 48 million ha, of which soybean [*Glycine max* (L.) Merrill] accounts for slightly less that half of the total (MAPA 2008). Agribusiness has a strategic participation in the Brazilian trade balance, accounting for about 25% of the GDP over the years 2000–2007.

Thus, Brazil is experiencing the dichotomy of expanding the agricultural sector, which is important for the economy, while preserving its biomes. In addition, the combined promotion of agricultural production and environmental conservation has often led to a clash between the agricultural and the environmental sectors.

Research in agricultural production systems has been focused on conservation, in the search for new paradigms both for agricultural production and for environmental conservation. This strategy is based on the notion that it is feasible for agricultural management to incorporate ecological principles related both to restoration and maintenance of environmental services such as those provided by soil and water, and to the promotion of biodiversity conservation. In addition, conservation agriculture systems should introduce designs that allow recovery and preservation of threatened natural systems, such as those which subsist in highly fragmented areas.

This chapter intends to illustrate the involvement of agrobiological processes in conservation agriculture, and will place an emphasis on the soil biota community and its importance for soil function. It will also examine how biodiversity and biological activity relate to the productive capacity of soils. Because the soil biological component must be considered in the design of resource management strategies (Lavelle et al. 1997), it is necessary to know the soil community, to assess its functions, and finally to optimize its activities through proper practices.

Serious environmental problems have arisen with effects that go beyond the agricultural ecosystem, impacting natural and even urban environments. For example, the erosion of land and contamination due to chemical inputs such as fertilizers and pesticides are observed throughout the Brazilian territories. The loss of biodiversity, which is currently occurring all over terrestrial landscapes, disrupts food chains, exposes pathogens to new hosts, and diminishes nutrient availability at landscape scale.

4.2 The Unknown Soil Biodiversity

Soil microbial biodiversity is essential for maintenance of ecological processes such as organic matter decomposition, nutrient cycling, soil aggregation and control of pathogens (Kennedy 1999). Acting intensively in food chains and in several ecological processes, soil micro-organisms reflect the past history of the environment. It is therefore essential to understand the relationship between organisms and their environment through an investigation of structural and functional diversity of microbial communities and of their response to various natural and anthropogenic disturbances (Ranjard et al. 2000).

The most obvious benefit of biodiversity is to ensure that a multiplicity of functions can be performed by soil organisms. These biodiversity issues have also led to extensive discussions on functional redundancy (Giller et al. 1997). Thus, agricultural management should be concerned with the various groups of organisms that perform a given function, rather than with the abundance or distribution of a particular species.

The soil harbors more biodiversity than any other ecosystem on Earth. One reason for this great diversity of micro-organisms and invertebrates is the soil horizontal and vertical heterogeneity. In addition, the combined action of biotic and abiotic factors results in the formation of functional domains such as the rhizosphere. These domains are formed by the action of regulators such as plants, soil fauna, and edaphoclimatic conditions, among others.

4.3 Agrobiological Processes for Conservation Systems

4.3.1 Processes Mediated by Nitrogen-Fixing Bacteria

The energy efficiency and economic benefits of agricultural conservation systems are key determinants of the sustainability of these systems and of their potential for further development. In Brazil, little attention has been given to the distribution of energy flows in agricultural systems. Commonly, systems have been developed based on the intensive use of fertilizers obtained as oil by-products, and especially of nitrogen fertilizers (Urquiaga and Zapata 2000).

Agrobiological processes based on the soil biota may contribute to the generation of biological inputs for agriculture (see Chap. 11), and hence to the development of soil conservation practices. For example, the sustainability of food crops, forages, and green manure legumes is mainly associated with their ability to establish symbiotic associations with stem- and root-nodulating N_2-fixing rhizobia.

In the Brazilian agribusiness context, the impact of biological nitrogen fixation (BNF) in soybean, which is grown without the use of nitrogen fertilizers, brings to the economy an estimated US$ 6 billion per harvest (US$ 147/barrel), contributing to the competitiveness and success of the soybean agribusiness and boosting the Brazilian trade balance.

In addition to soybeans, other legumes in Brazil stand out for their economic and social importance. Cowpea (*Vigna unguiculata*) is quite suited to semi-arid regions, due to its high nutritional value, rusticity, adaptability to low soil fertility, and tolerance to drought, high temperatures and salinity. Cowpea was traditionally grown in northeast Brazil, a region with recognized edaphoclimatic limitations that affect the productivity of most crops. The sustainable activity of farmers in this environment requires technological innovation aiming at grain yield increase (Rumjanek et al. 2005).

For years, it was considered that the promiscuous nodulation ability of cowpea with native rhizobia from the group "cowpea miscellaneous" hindered the selection and exploitation of rhizobia for this culture (Rumjanek et al. 2005). However, based on efficiency studies (Martins et al. 1997), rhizobial ecology and characteristics such as tolerance to antibiotics (Xavier et al. 1998), salinity, and temperature (Xavier et al. 2007), it was possible to select a strain capable of increasing productivity by up to 30% (Martins et al. 2003) (Fig. 4.1). These data indicate that it is possible to select for competitive strains useful for cowpea inoculation in Brazil, so as to increase the productivity of this culture and reduce poverty among farmers.

Nowadays, the cowpea cultivation area is expanding to the North and Middle West regions and gradually the practice of rhizobial inoculation is following the same trend.

Menna et al. (2006) analyzed the molecular phylogeny based on the 16S rRNA gene of 68 elite rhizobial strains used in Brazil as commercial legume inoculants, and found that some differed from the type strains, which suggests that they may represent new species of the *Methylobacterium* and *Burkholderia* genera. The great diversity observed emphasizes that the tropics are an important reservoir of unknown N_2-fixation species and genes. The optimization of BNF in these conditions requires a greater knowledge of the dynamics of populations established in

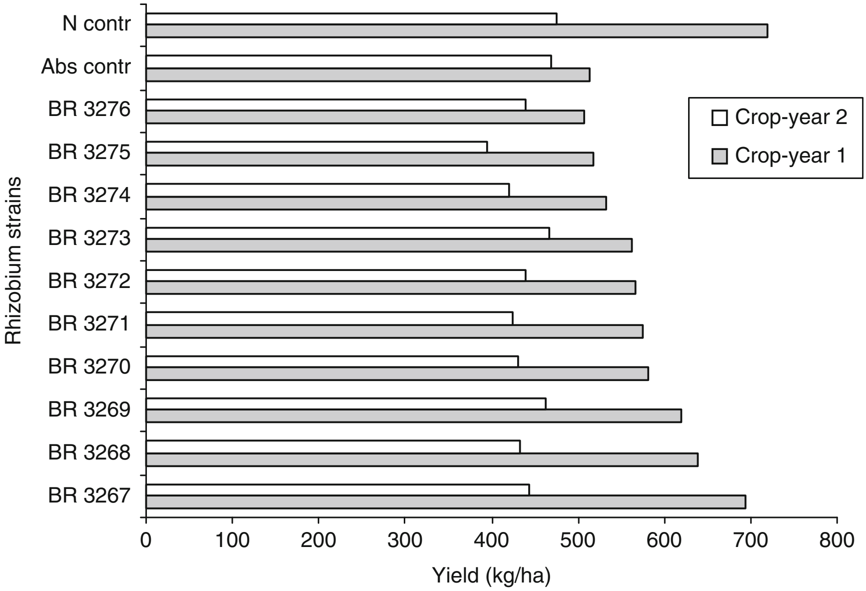

Fig. 4.1 Cowpea grain productivity during two consecutive crops. Data are means of the results obtained with three inoculation schedules differing according to the time of inoculant application, compared by LSD at the 5% level for each crop. Data include grain yields obtained following inoculation with various rhizobial strains and for uninoculated controls with (N contr) or without (Abs contr) nitrogen fertilization

tropical regions as well as of the specificity level and N-fixing efficiency of the symbiotic associations (Santos et al. 2008).

In spite of their potential for increasing nitrogen fixation, the new elite strains are of controversial use, because they belong to genera also containing human and plant pathogenic species. Additional research will be required to resolve this issue.

Other N-fixing bacteria such as those associated with grasses (*Poaceae*) present a potential for improving biological inputs in tropical agriculture. Brazil is the world's largest sugarcane producer with more than 6.7 million ha of planted area. This culture is currently strategic for the Brazilian bioenergy supply. The capacity of diazotrophic plant growth-promoting bacteria to improve sugarcane performance has been demonstrated under both greenhouse and field conditions. A BNF contribution of around 30% of the total nitrogen accumulated was observed in micropropagated plants inoculated with a bacterial consortium, suggesting that the use of a mixed inoculum is a promising strategy for improving biological nitrogen fixation in sugarcane crops (Oliveira et al. 2004, 2006).

Despite the positive results reported in the international literature on the use of inoculants in corn, wheat, and other cereals, such inoculants remain poorly used in Brazil, particularly because of the difficulties associated with evaluation, registration, and quality control of commercial products. Since 2007, a bacterial consortium (*Gluconacetobacter diazotrophicus* BR 11281, *Herbaspirillum seropedicae* BR 11335, *Herbaspirillum rubrisubalbicans* BR 11504, *Azospirillum amazonense* BR 11145 and *Burkholderia tropica* BR 11366) is recommended as an inoculant for sugarcane by Embrapa Agrobiologia. A partnership with the commercial inoculum-producing sector is currently envisioned to promote the widescale use of this mixed inoculant.

In an attempt to improve the inoculant quality in Brazil, different carrier blends together with cowpea rhizobium cells were evaluated at room temperature, and their performance as inoculant was compared to a peat-based inoculant carrier. Rhizobial cells were maintained best in blends containing 50–60 wt% carboxymethyl cellulose (CMC), and the cowpea nodulation of polymer blends was similar statistically to that of peat-based inoculants. CMC/starch polymer blends result in an efficient carrier for rhizobial inoculants, show competitive advantages such as being biodegradable, non-toxic and water soluble, and enable pre-inoculation of seed and maintenance of rhizobium numbers at room temperature comparable to those of traditional peat inoculants (Oliveira et al. 2007; Fernandes Júnior et al. 2009).

4.3.2 Processes Mediated by Plant Growth-Promoting Rhizobacteria

Various bacteria belonging to the *Pseudomonas* genus deserve attention since they are plant growth-promoting rhizobacteria (PGPR). Strains of *Pseudomonas fluorescens* and *Pseudomonas putida* have the ability to colonize the rhizosphere and rhizoplane of cultivated plants. These bacteria promote the growth of plants through a series of mechanisms such as: (1) production of siderophores, which chelate iron and inhibit the growth of certain microbiota components, (2) antibiosis through the excretion of antibiotics (Thomashow 1996), (3) solubilization of phosphates (see Sect. 10.4.2.5), and (4) production of compounds similar to auxins and cytokinins (Antoun and Prévost 2005).

Thomashow and Weller (1996) identified the production of antibiotics by *Pseudomonas* spp. as an efficient mechanism of disease suppression and/or plant growth stimulation. In suppressive soils, there is a direct relationship between the prevalence of soil micro-organisms and levels of their metabolites involved in the biological control process or induction of plant resistance. Moreover, continuous culture of the plant host may lead to the selection of bacterial antagonists to plant pathogens, as was reported for wheat and the fungal agent of take-all, *Gaeumannomyces graminis* var. *tritici* (Mazzola 2002).

Pseudomonas spp. isolates were obtained from soil, rhizosphere, rhizoplane, and inner part of root tissue of lettuce (*Lactuca sativa*) and carrot (*Daucus carota*) grown under organic management, and these bacteria were examined for cultural and molecular characters. The bacterial communities associated with lettuce and carrot differed in composition (Zago et al. 2000). In addition, the populations of bacteria isolated from the rhizoplane and from root tissues differed in composition from those isolated from soil samples. These data suggest the existence of specificity in the plant–bacteria association.

Xavier et al. (2004) also compared the bacteria diversity associated with lettuce and carrot roots, this time examining single strand conformation polymorphisms. The plants were cultivated as single culture (monocrop) or as intercrop in two soil types: Yellow Red Argissol (pH 7.0, Al 0.0 cmol dm^{-3}, Ca 3.3 cmol dm^{-3}, Mg 1.7 cmol dm^{-3}, P 104.5 cmol dm^{-3}, K 240 cmol dm^{-3}, organic carbon 0.755%) and Planosol (pH 7.0, Al 0.0 cmol dm^{-3}, Ca 1.25 cmol dm^{-3}, Mg 1 cmol dm^{-3}, P 16 cmol dm^{-3}, K 71 cmol dm^{-3}, organic carbon 0.355%). It was possible to detect specificities in bacterial communities depending on crop, soil type, and plant growth stages. On the other hand, differences related to intercropping and monoculture management were only detected when group-specific primers were used, especially primers for *Alphaproteobacteria*.

The production gains observed when intercropped cultural systems are used may be related to changes in the taxonomic and functional diversity of micro-organisms associated with the cultures; however, knowledge about these interactions is still very limited. It is possible that intercropping leads to an enrichment of microbial groups with plant growth-promoting activity.

Dias et al. (2008) tested in vitro the antagonism of PGPR strains against *Rhizoctonia solani* and *Sclerotium rolfsii*. A total of 94 bacterial strains isolated from the rhizosphere of four vegetable species under organic cultivation were evaluated. Twenty-two isolates, identified as *P. fluorescens*, were predominant in lettuce and rudbeckia rhizospheres, while in kale and parsley rhizospheres *P. putida* strains prevailed. Sixty percent of the evaluated strains showed antagonistic potential and, among those, 24 isolates expressed antagonism to both target fungi, with *P. fluorescens* being the most representative bacterial species. These data suggest that antibiosis promoted by soil micro-organisms may represent a promising field for the development of new agrobiological inputs.

4.3.3 Processes Mediated by Soil Fauna

Although soil fauna participates actively in several ecosystem processes, little emphasis has been given to a possible management of its functionality, as has historically been done for micro-organisms. Most studies on soil fauna in Brazil are aimed at the effect of different agricultural practices on diversity and structure of these communities. However, some of the benefits of the diversity of invertebrates that colonize the soil and their relationship with conservation farming practices have already been reported for different Brazilian biomes.

One of the effects of soil fauna activity is the production of biogenic structures, i.e., soil aggregates and organic matter formed by the action of soil biota. These products of soil fauna determine in large part the soil structure and, as a consequence, porosity and moisture retention, which are essential to plant growth (Jouquet et al. 2006). Contrary to what is commonly believed, the fauna action on soil structure can be of great magnitude even in the short term. In an experiment involving the transposition of soil monoliths between an area of degraded pasture and a forest area in Central Amazonia region, Barros et al. (2001) found that the forest soil fauna activity was able to restore the structure of compacted soil from the pasture. The time required for this recovery of the soil physical quality was only 1 year.

Another effect of soil fauna is the action of saprophagous species on the litter in the case of natural systems or on the straws or mulches in agricultural systems, particularly those based on conservation. Various invertebrates belong to the guild of the “litter transformers” (Lavelle et al. 1997), and, although they do not promote a profound biochemical transformation in these plant residues, their action on physical transformation and microbial stimulation triggers further steps in the decomposition process (Swift et al. 1979).

There are few estimates of litter consumption potential by saprophagous invertebrates in Brazilian ecosystems. However, it is known that in a native semideciduous forest in southern Brazil, two particular woodlice species, *Alantoscia floridana* and *Balloniscus glaber*, together were able to process 860 kg of leaves per hectare per year, which can represent 16% of the annual intake of leaves (Quadros and Araujo 2008). In another estimate for arboreal leguminous plantations in southeastern Brazil, Correia (2003) showed that a single exotic species of millipede, *Leptogoniulus sorornus*, was able to consume in only 1 month 185 kg ha^{-1} of leaf material deposited on the soil.

Among the factors that affect the litter consumption rate by saprophagous fauna, the C/N ratio and the concentration of polyphenols are probably the most important. Bianchi and Correia (2007) evaluated the feeding activity of the millipede *Trigoniulus corallinus* on the litter of two arboreous species with potential for use in agroforestry systems in southeastern Brazil, namely the leguminous species *Mimosa caesalpinifolia* and the *Myrtaceae* species, *Syzygium cumini*. While the daily consumption rate of the leguminous species was 74.2 mg per individual, in the case of *S. cumini* it was only 2.57 mg per individual. This difference in consumption rate correlated with a difference in the C/N ratio of the leaf material from both arboreous species, which was 15 for *M. caesalpinifolia* and 33 for *S. cumini*. Thus, in conservation systems, to manage the C/N ratio of consortia and soil coverage is an indirect way of managing the saprophagous fauna of soil and of maximizing the benefits of this group of organisms in the decomposition and cycling of nutrients.

4.4 Conservation Systems

4.4.1 No-tillage

The Brazilian no-tillage initiative, which has become an example for tropical countries around the world, has triggered a change in behavior of farmers and technicians in the pursuit of sustainable agriculture. The no-tillage system expanded from about 1 million ha planted with annual crops at the beginning of the 1990s, to over 25 million in 2005/2006. It is now used in all perennial crops, in sugarcane, in the recovery of pastures through rotation between crops and pastures, in reforestation, and in horticulture. Its attractiveness lies in the fact that it decreases the need for manual operations and for animal, tractor, or aerial traction (Plataforma de Plantio Direto 2009; FEBRAPD 2009).

Moreover, this system relies on an integrated vision involving the combination of practices such as: green manuring for the formation of soil coverage; the maintenance of crop residues on the soil surface; the adoption of integrated weed control methods through the use of soil coverage and herbicides; and the avoidance of soil disturbance, except in the sowing furrow. In this system, the soil fauna in a Latosol proved to be more diverse than that of a conventional system, under the climatic conditions of both the Brazilian Cerrado (Silva et al. 2006) and the Atlantic Forest (Rodrigues 2006).

In a study carried out to genetically characterize 30 fast-growing rhizobial strains isolated from the nodules of field-grown Asian and modern soybean genotypes which had previously been inoculated, Hungria et al (2006) observed a putatively new rhizobial species that was present only in undisturbed soils, showing high relatedness to *Rhizobium* OR 191, and another strain resembling *Agrobacterium*. Three species, *Rhizobium tropici, Bradyrhizobium japonicum* and *Bradyrhizobium elkanii*, were found under the no-tillage sustainable management system, while the only species isolated from soils under conventional tillage was *R. tropici*. These results suggested that rhizobial diversity becomes drastically reduced when a conventional soil management system is adopted, as compared to that associated with a no-tillage system.

More recently, soybean nodules were collected from 12 sites from the State of Mato Grosso, in the Brazilian Cerrado, where both soybean and bradyrhizobial strains have been introduced over the past 18 years. Diversity was higher under a no-tillage system than under conventional tillage management, highlighting the importance of maintaining crop residues at the surface of tropical soils. Understanding the ecology of exotic rhizobia after their introduction to new cropping areas represents the first step towards the design of better inoculation strategies, which in turn may result in sustainability and higher plant yields (Loureiro et al. 2007).

In a no-tillage system, the soil biota structure varies according to the crop rotation system and the quality of plant residues used as mulch. Earthworms and other fauna groups become more abundant when mulches with a high nitrogen content, such as soybean and turnip, are used. Upon complete degradation of crop residues, as occurs in the Cerrado, the bare and exposed soil becomes an unsuitable habitat for soil organisms (Aquino et al. 2008). On the other hand, termites are dominant in soils amended with lower quality straw mulching such as that of oats and corn. The distribution of fauna individuals in the soil profile is variable depending on management, time of assessment, and plant cover species used (Silva et al. 2007). Generally, as the amount of residues on the soil surface diminishes due to the decomposition process, there is a tendency for fauna components to concentrate in the lower layers of the soil (Silva et al. 2007).

Aquino et al (2006) observed that several taxonomic groups, such as Isopoda, Diplopoda, Diplura, Gastropoda, Blattodea and Dermaptera, disappeared in the Parana region (Brazil), because of injuries caused by agricultural implements. Members of the first three groups are living in decomposing organic matter and are vital to its fragmentation (Swift et al. 1979; Hashimoto et al. 2004; Tuck and Hassall 2005). Following the reduction in resources and shelters occurring in soils having undergone agricultural transformation, some fauna groups may occupy the remaining available niches, establish effectively and dominate the community. Among these, social insects, especially ants (Formicidae) and termites (Isoptera) stand out in pastures of the Brazilian Cerrado (Benito et al. 2004; Silva et al. 2006). Whereas social insects naturally occur in forest areas, deforestation results in the maintenance of a more specialized population of these insects (Constantino and Acioli 2005). In several regions of Brazil and particularly in the Cerrado, termites modify the landscape in degraded pastures, leaving them covered by *murundus* (earthmounds) (Aquino et al. 2008b).

4.4.2 Agroforestry Systems

In almost all Brazilian biomes, the tree component is dominant and it is no accident that many such biomes receive the designation of forest, such as the Amazon Rainforest and the Atlantic Forest. The forest element has been historically seen in Brazil either as an obstacle to the establishment of intensive agricultural systems such as pastures and grain monocultures, or as a source of wood for different purposes. In both situations, the land use eventually led to the eradication of the forest ecosystem. This type of predatory use of forests has brought 93% of the Atlantic Forest, in the past covering 15% of Brazil's territory, to devastation (Ceccon and Miramontes 2008). Currently, due to greater awareness of environmental problems, there is a tendency to valorize the environmental products and services that the forests can sustainably provide.

In this context, it is not the forest that should make room for agriculture but rather the agricultural activity that should be incorporated into the forest environment. The principle of agroforestry systems is to carry out agricultural production in an environment with a forest structure, allowing the restoration of important ecological functions such as the cycling of nutrients and soil protection (Macdicken and Vergara 1990; see Chap. 9). In the past 20 years, the search for different models and designs of agroforestry systems tailored to specific purposes and environmental conditions has increased significantly. The agroforestry activity in Brazil provides an economic stimulus to forest recovery, leading to the incorporation of the tree component in rural settings, and especially in those that are family-based (Rodrigues et al. 2007).

At least in the case of soil macrofauna, biodiversity loss is minimized upon replacement of the natural ecosystem with another which has a similar structure (Decaëns et al. 2004). For example, when a savanna is transformed into a pasture and a forest into an agroforestry system, a large fraction of the soil fauna community is retained, together with the processes involved.

One of the oldest agroforestry production models in Brazil is cacao production (*Theobroma cacao*), which is established in the state of Bahia, in the Atlantic Forest domain of northeastern Brazil. In this region, cacao is grown in large part either under the canopy of the forest, or in a consortium with the leguminous tree *Erythrina* sp. In these shaded cacao systems, especially those of greater diversity, many ant species are preserved, including some considered rare. Even in the system of cacao with *Erythrina* sp, which harbors less tree diversity, 192 ant species were found, composing a community similar to that of native environments (Delabie et al. 2007).

Soil macrofauna has been investigated in some agroforestry systems with low plant diversity of the Amazon region, in the states of Acre and Rondonia. Compared with that associated with other land uses such as fallow land, annual crops, and pastures of *Brachiaria humidicola*, the soil macrofaunal community in agroforestry systems was more abundant and diverse, with a clear dominance of ants and termites (Barros et al. 2002).

Some agroforestry models in Brazil are based on the functional diversity of plant species, defined according to the successional stage at which these species occur. These systems involve the high density cultivation of a variety of plants with particular architectures, such as herbs, bushes and trees. Some plants are used to promote the recovery of soil fertility, such as N-fixing legumes, whereas others are important to create a shaded habitat or to attract pollinators (Götsch 1995; Vaz 2001). An evaluation of the benefits of this agroforestry model for soil quality was done in an Atlantic Forest area in southeastern Brazil. The agroforestry system examined comprised a total of 20 annual crop and tree species. The stocks of nutrients, organic matter, microbial activity, and composition of the soil fauna were similar in the soils from the agroforestry system and the forest, while in a cassava monoculture (*Manihot esculenta*) in the same area, all these indicators were lower (Silva 2006).

The use of agroforestry systems can also represent an alternative to slash-and-burn systems used by small farmers throughout Brazil (see Chap. 5 for a description of slash-and-burn agriculture). Soil quality was assessed in a transition environment between the Cerrado and Caatinga biomes. The environments compared were agroforestry systems with 6 and 10 years of implantation, traditional slash-and-burn agriculture systems, and the secondary forest in the state of Piaui, in mid-northern Brazil. The largest stocks of nutrients, organic C and N, as well as the greatest diversity of soil macrofauna, were found in the agroforestry system with 10 years of implantation (Lima 2008).

Whereas agroforestry systems promote biodiversity conservation and the provision of environmental services, a forest cover may be incompatible with some farming systems. One example was the simulation of the sugarcane cultivation with rubber (*Hevea brasiliensis*) or eucalyptus (*Eucalyptus grandis*) in alley cropping (Pinto et al. 2005). In the case of grasslands, however, several designs of forestry–agricultural systems with a sparse tree cover have been proposed, with environmental and economic gains (Dias 2008). The introduction of trees, particularly legumes that fix atmospheric N, improves the quality of the environment under the tree canopy, which is reflected in an increase in abundance and diversity of the soil macrofauna. In particular, the abundance of saprophagous and hygrophilous soil fauna groups such as earthworms and woodlice was increased. These benefits of the tree component were related to both the input of organic matter with a lower C/N ratio, and to the change in the microclimatic conditions under the tree canopy (Dias et al. 2006, 2007; see also Chap. 6 for a description of similar tree effects in desert settings).

4.4.3 Agroecological Systems

A new approach to conservation agriculture is based on agroecological systems. The components of these systems are economic (potential for income and employment, market access), environmental (maintenance or improvement of the quality of natural resources and of ecological relationships), social (alleviation of poverty and improvement of food security), cultural (as relates to use of traditional crops), political (organizations involved in changes, participatory decision processes), and ethical (transcendent moral values) (Embrapa 2006). These systems are supported mainly by biological processes aiming to ensure a constant organic matter supply for fertility buildup.

An experimental station dealing with research, extension, and training of human resources in conservation agriculture has been established since 1993 in Seropédica, State of Rio de Janeiro (Brazil). This is known as the "Agroecological Production Integrated System", or as "Fazendinha Agroecológica Km 47." The management adopted in the "Fazendinha" seeks to optimize the recycling of nutrients, and aims at the integration of animal and plant production activities. Additional goals are: a nitrogen self-sufficiency through the systematic use of crop rotation and diversification; the minimization of nutrient loss occurring by percolation and erosion; the maintenance of the plant nutritional balance; the avoidance of stress situations, to insure that plant defense mechanisms be expressed to their full potential; the maintenance of phytoparasites and weed populations to tolerable levels, while avoiding the use of techniques with negative eco-toxicological impacts; the deployment and tracking of agroforestry booths; the development of alternative practices for the management of dairy cattle and laying hens; and finally, the scientific treatment of the system components through a multidisciplinary approach. It is expected that this type of agricultural management involving biota preservation in soil-plant systems will increase the microbial diversity-based antagonism among the rhizobacteria and lead to a natural soilborne plant pathogen suppression (Dias 2006).

Organic management organized along those principles favors populations of different species of Collembola and Acarina when compared with forest and pasture (Badejo et al. 1998). In turn, collembolans change the community of fungi and contribute to the elimination of pathogens such as *R. solani*, *Fusarium oxysporum* and others (Bettiol et al. 2002).

In another study conducted in the same experimental station, Zilli et al. (1999) compared the diversity of rhizobia in cowpea cultivated in soils of a secondary forest, a pasture, and an area under organic production crop. More diversity was observed in the forest, followed by the organic cultivation area and then the pasture.

4.5 Conclusions

The principal functions in soil agroecosystems are those involved with biogeochemical cycles and maintenance of the soil structure: these functions strictly depend on the effective participation of soil biota components. Each of these processes involves the participation, not of a single species, but rather of several species that may be very different and interrelated. The soil biota can be harnessed so as to improve the sustainability of farming systems. More efficient agrobiological processes pave the way for biotechnological applications compatible with the novel soil conservation systems.

Despite the growing interest aroused by the soil conservation systems, there is still little information about the soil microbial community structure and soil biota composition. The study of soil biota and research on soil biodiversity are crucial to the understanding, optimization and control of the mechanisms involved in the maintenance of soil functions in agricultural production systems.

The suggestion is made here that such studies on soil biological processes should be coupled with efforts aimed at the genetic improvement of plants, and that the integration of soil biology and plant genetics has the potential to transform tropical regions into major zones of sustainable food production.

Yet another crucial element in this transformation is the cooperative action of all the different actors in the food production chain. This will be achieved through participatory research and the collective evaluation of the economic, social, and environmental impact of new technologies.

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