Stonemeal Technology: Changing the Poverty Scenario in Brazil

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Abstract: Stonemeal technique within an agro-geo-ecological, technological context was introduced to a specific group of family farmers in the state of Bahia, northeast of Brazil as part of a partnership between the University of Brasilia and the Bahia State government. The group was composed of 'afrodescent' farmers who live in isolated communities. The '*Cio da Terra* Project' aims at improving soils and agricultural production, and serves about 1200 families in ten communities. In general, communities do not have access to official financing, suitable technical assistance and local market access mechanisms. The experiments and tests were implemented in all ten areas with the purpose of demonstrating the feasibility of using stonemeal to improve soil fertility and, consequently, agricultural production. The material used was locally available crushed amphibolites and phosphate rocks, associated with cow manure. After two years of activities, it is possible to say that the results were highly positive, both with regards to increased production and communities' mobilization. On test plots, the levels of available phosphorus, potassium, calcium and magnesium increased in the soil after application of ground rock and cow manure. The soil pH changed and, in many cases, increased from highly acidic to mildly acidic or mildly alkaline. Plant development (corn/maize, beans and cassava) also showed a positive increase in yield when compared with the production on control plots. These initial results point out the feasibility of the agro-geo-ecological projects directed to traditional communities, as they offer new opportunities for social, productive and economic inclusion to family farmers. They also enhance the supply and diversity of food, thus improving the food security among poor farmers.

Keywords: *Stonemeal, Afrodescendents, Social Inclusion, Sustainable Development.*

Introduction

Brazil is an extremely diverse country from a cultural, socio-economic and natural resource perspective. Although Brazil has a strategic wealth, the country's benefits from its development have been unevenly distributed, which generates a great social gradient, from urban to rural areas.

The geo-diversity present in the Brazilian territory is also linked to its continental dimension. Brazil is one of the biggest mineral producers on earth, along with Canada, Australia, and South Africa, exporting iron, aluminum, gold, and precious stones and other mineral commodities. Due to the fact that major parts of the Brazil are located in a tropical climate, the soils derived from this geodiverse rock materials are strongly weathered and naturally impoverished from a plant nutrient availability point of view. This soil related restriction, however, was not a drawback for the Brazilian agricultural development, which, in the last 30 years became one of the largest food producers of the world, with agricultural practices mainly following the techniques and inputs of the Green Revolution. However, this rapid agricultural development has come at an expense. The weathered soils are used only as a substrate where a variety of agro-chemicals, pesticides, and herbicides are added, regardless of the sustainability of the complex web of the soil-forest life system. This input intensive system needs large areas for its production and induces irreversible changes in the ecosystems. The widespread adoption of this productive model has also been causing a series of socio-economic and environmental transformations in Brazil. Among them are: (i) large environmental chances as consequence of the deforestation; (ii) contamination of the hydrological network through excess of nutrients and undesirable agro-chemicals; (iii) loss of agriculture soil by erosion; (iv) urban population increase due to rural exodus (v) biodiversity and genetic resource losses; and (vi) social exclusion of small holder, rural producers (Leonardos and Theodoro, 2000; Ehlers, 1996).

The ‘social collapse’ generated by conventional agriculture is enhanced by negative externalities imposed onto the environment and on family farmers. The inevitable consequence of replacing the old productive systems, rich in wisdom and labor, by capital intensive systems, resulted in an increase in the dependence of the agricultural production system in relation to capital. In addition, the exhaustion of biodiversity has increased the risks of crop losses; agricultural production has become more vulnerable to disasters, diseases and climate variations. Rocha and Theodoro (2006) showed that traditional processes of agricultural practices are more efficient and productive than those generated by modern agriculture. The search for alternatives to the agro-chemical, agro-export model requires, in many cases, creativity and local solutions. New models or anti-models could arise from traditional knowledge and agricultural practices where the sustainability of life is a strategy. This is the case were agro-ecological principles are taken into account in the form of appropriate technologies for the small rural producers. According to Altieri (2001) this new approach combines agrarian science and socio-economic knowledge with ecological principles and tends to reduce risks and promote long term stable production, food diversity and low use of external inputs. The cultivation of complex and diverse systems is vital for the survival of family farmers who are largely excluded from the conventional agricultural model. Soil fertility, plant health control and agro-ecosystem productivity is guaranteed by the beneficial interactions between cultivated plants, trees and animals (Altieri, 2001).

In order to address issues of impoverished soils, social exclusion and ecological/environmental disruption by the present agricultural model, the present work discusses the results of research carried out in one of the poorest regions of Brazil. The main aim of the *Cio da Terra* project was to transfer knowledge and low impact technologies to a group of farmers, who were largely left out from development since the 19th century. 'Stonemeal' technology was chosen for the research, as this technology fulfills the agro-ecological assumptions and benefits from great availability and abundance of the great diversity of rock types present in the region. The social group selected for the research are the 'quilombola' farmers, also called 'afrodecendents', decedents of slaves from Africa, who have been largely ignored in Brazil's history. The search for solutions followed agro-ecology principles that could lead into a fairer and environmentally more balanced world.

Physical Aspect: Rocks and Soils in the Project Area

The geology where the research has been conducted represents high lithologic diversity. The rocks that were used to re-mineralize the soils in the *Cio da Terra* project area occur within the geological environment dominated by the Complexo Ipirá of Archean age. The Complexo Ipirá is composed of a group of supracrustal rocks such as banded gneisses, calcsilicate rocks, impure marbles, quartzite, iron formations and basic and ultramafic greenstones associated with graphitic schist. These are derived from deep-sea sediments and volcanics in an ophiolitic environment (Melo *et al.*, 1991). The complex is divided into five units representing different depositional and geological developments: Pintadas, Serra do Camisão, Juazeirinho, Angico and Umbuzeiro (Folha Pintadas, 1:100.000 PLGB/CPRM). Calc-silicate rocks are widespread in the Serra do Camisão unit followed by quartzites (meta-cherts?). Apatite and vermiculite deposits are associated with calcsilicate rocks with mafic minerals such as diopside and biotite (phlogopite), possibly metasomatized by syenites. Calcite and vermiculite may occur associated with apatite veins. The crushed rocks used in the agricultural experiments of the quilombola farmers are mafic (amphibolite or meta-pyroxenites) and ultramafic greenstones associated with apatite veins in different degrees of alteration. The mafic greenstones are composed mainly of hornblende and plagioclase, and small proportions of quartz, albite, epidote and sphene. The ultramafic rocks are largely composed of olivine and pyroxene relicts and hydrated magnesium silicates. The abundant hydrothermal veins rich in apatite and K-feldspar are dominant in these rocks. In chemical terms, the mineralogy of the crushed rocks used in the experiments indicates a strong enrichment of calcium, phosphorus, potassium, manganese, copper, zinc, sulfur, selenium, cobalt, boron, chlorine and other micronutrients in respect to the crust and the other regional rocks (Table 1).

Table 1 – Chemical analysis by X-ray fluorescence (XRF)

sample	SiO_2(%)	Al_2O_3(%)	Fe_2O_3(%)	MgO(%)	CaO(%)	K_2O(%)	P_2O_5(%)	Co(ppm)	V(ppm)	Zn(ppm)
Am 01	61,8	13,2	4,8	3,7	6,2	4,5	0,98	17	61	66
Am 02	61,4	13,4	4,6	3,9	6,4	4,5	0,93	15	56	65

After crushing the rocks, the material was classified into three granulometric fractions (clay, silt and coarse sand). The fact that these rocks show some sand concentration, favors restructuring and drainage conditions for clay textured soils. Feldspars present some degree of alteration, which may favor the release of potassium, sodium and calcium. Microscopic and macroscopic evaluations[1] of such samples indicate significant hydrothermal alteration. Fracturing in apatite crystals indicates possible enhancement of phosphorus release as it increases the apatite's surface that is exposed to soil microorganisms and solutions.

The evaluation of the chemical and mineral composition of these rocks shows that they have possibilities to be applied as natural fertilizers or re-conditioners for low fertile soils. The usage of these geological nutrient sources are recommended in situations of permanent nutrient need and acid soil pH.

The three regions where experimental units were implemented in the ten quilombolas communities lie in a radius up to 300 km of the deposit of *Terra Produtiva Mining Co*. The dry tropical environments show a relative homogeneity in the climate with similar rainfall and hydrological regime (Figure 1). The soils data show only slight variations in terms of nutrient availability and pH levels (Table 2).

The region 1, Lençóis, is located in the central region of the State within the Chapada Diamantina Group that covers the Tombador, Caboclo and Morro do Chapéu Formations, of Mesoproterozoic age. Conglomerates and sandstones with very well preserved structures are dominant. The soils of the region are extremely sandy and acidic (Table 2).

[1] Petrographic analyses were made at the Geosciences Institute (University of Brasília) by Professor Elói Guimarães.

In region 2, the micro region of Irecê, the soils are derived from Neoproterozoic sedimentary rocks. The dominant rocks belong to the Salitre Formation, formed by calcarenites and siltites with abundant calciferous portions which consist of carbonate and minor phosphate algae laminites. They lie within regular layers of siliciclastic sediments, alternating between fine-grained sediments and thin organic layers. Primary phosphate accumulations are associated with pillar stromatolites (stratiform ore), which is capped by secondary ore of supergenic concentration. The soils generated from these rocks are normally weakly acidic (Table 2), going into lightly alkaline in the more calcareous portions (Folha SD.24-V-A).

Region 3 lies in the Recôncavo Sul region, in a Cretaceous Rift, made up of sandstones, shales and minor limestone lenses. The Rift basement is formed by deeply weathered Archean granulites of the Atlantic Belt yielding low fertility Latosols (Oxisols) and Podsols (Table 2).

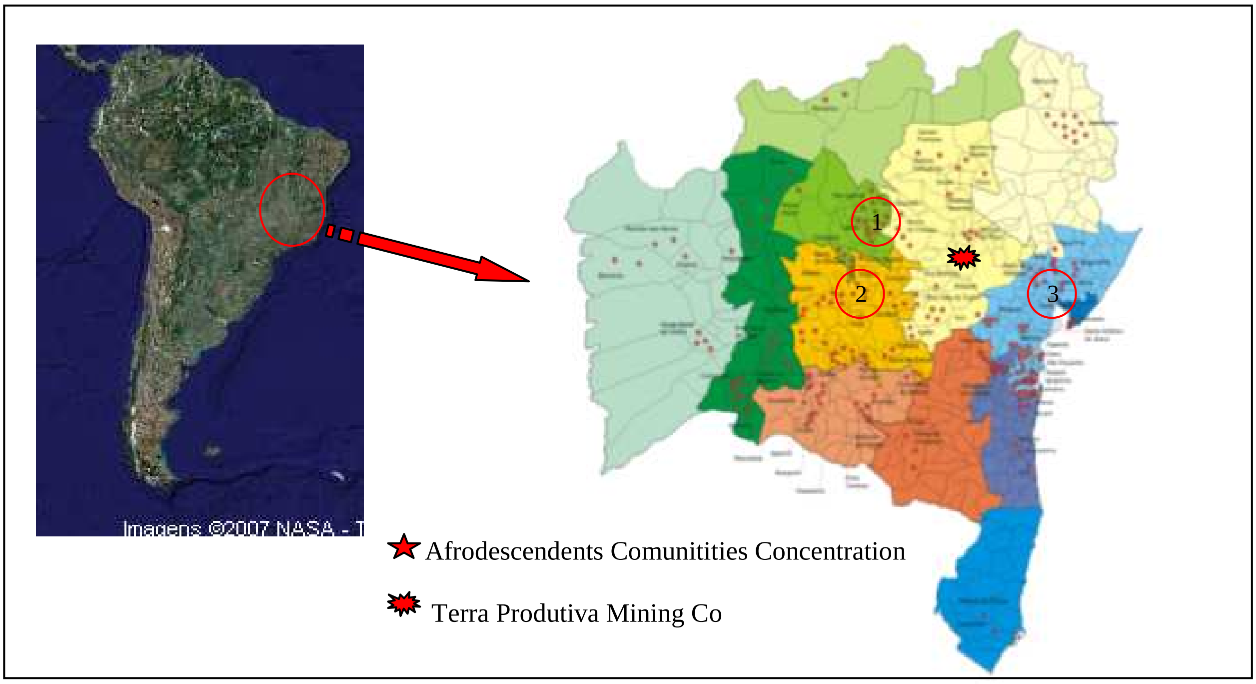

Figure 1 – Location map of the Communities (Regions 1, 2, and 3) where Stonemeal experiments were carried out

Table 2- Chemical soil fertility analyses from the three regions (Analyses by Atomic Emission by Inductive Coupled Plasma - ICP)

Sample	Am 01	Am 02	Am 3	Am 4	Am 5	Am 6	Am 07	Am 08	Am 09	Am 10
pH water	4,6	5,5	7,6	7,2	7,3	7,0	7,3	5,3	4,7	5,3
pH CaCl	4,0	5,1	7,2	6,4	6,4	6,2	6,4	4,4	4,0	4,6
M.O %	1,2	1,9	3,0	2,6	2,6	2,1	3,8	2,7	2,1	3,0
P (ppm)	1,1	24,3	46,6	5,9	6,0	5,7	3,4	5,5	4,8	3,3
S (ppm)	1,2	43,9	33,0	2,9	2,8	2,5	3,8	3,2	5,5	5,7
K (ppm)	58	80	435	284	260	250	160	79	26	59
Ca^{2+} $cmol_c/dm^3$	0,2	7,1	16,9	11,8	12	11,2	20,7	1,4	0,2	1,1
Mg^{2+} $cmol_c/dm^3$	0,3	2,1	4,7	1,9	2,0	1,5	3,2	0,7	0,1	0,8
Al^{3+} $cmol_c/dm^3$	0,9	0,0	0,0	0,0	0,0	0,0	0,0	0,2	1,0	0,1
B ppm	1,0	0,5	1,6	1,3	1,5	1,2	1,3	0,5	0,2	0,3
Zn ppm	0,4	5,6	8,6	1,9	2,0	1,5	0,8	2,5	0,8	1,3
Fe ppm	217	229	24	14	16	12	44	235	267	324
Mn ppm	12,2	2,8	82,7	186,5	168	150	47,9	45,5	4,5	5,9
Cu ppm	1,3	0,8	0,6	1,6	1,8	1,2	0,4	4,0	0,9	1,7

Am 1 and 2 from Region 1
Am 03, 04, 04, 06 and 07 from Region 2
Am 08, 09 and 10 from Region 3

Socio-Economic Context

The conditions described for the areas that cover the *Cio da Terra* project help us to understand part of the widespread poverty in the region. Nutrient-poor soil geochemistry due to severe leaching processes, sometimes enhanced by nutrient poor bedrock, favors the formation of very acid sandy soils and well drained Latosols (Oxisols). In addition, the irregular rainfall concentrated in very short periods limits rural land use in a typical *quilombola* community.

Quilombos are communities originally formed by black slaves brought from Africa in colonial Brazil, who rebelled against the slavery destiny and ran away into isolated areas in the country’s interior. Generally, they chose protected areas beyond steep mountain ranges. From the beginning and up to recent times, they carried out subsistence farming practices. They also practice art craft to keep up their cultural heritage.

The decision to select remaining *quilombos* as the target for this research took into account the four following factors:

- ✓ The communities are historically excluded and urgently need affirmative actions to liberate them from their social exclusion conditions and provide feasible development mechanisms to answer their needs;
- ✓ They have an elementary social organization, where local leadership is unable of giving incentives towards disseminating of knowledge of modern practices;
- ✓ As a result of having different socio-cultural characteristics that connect them with the landscape they live in, they represent a life-forming sustainability differential in all its dimensions. This can facilitate the reproduction of positive results to other rural groups that live in similar situations;
- ✓ Finally, the afrodescendant community public policies for the last years have taken partnership strategies among the different agencies aiming towards their citizenship rights as to repair the historic social inequality.

Among the many activities in the scope of the project are socio-economic and cultural diagnostic surveys of the 10 communities involved in the research. For that, a questionnaire was developed where questions related to the social, economic, productive, cultural and religious aspects were asked; about 900 household heads (men and women) were interviewed. The data were tabulated and submitted to a statistic treatment, where it was possible to provide cross information, such as: income, education, self-declared color, participation in Federal Government inclusion programs, main agricultural crops and practices and access to official financing. The analyses were done for each community individually and systematized for the whole group. The resulting data provide an updated diagnosis of the social group researched, showing the macro-regional scenario that should be taken into account in any interdisciplinary endeavor.

With regards to the question of self-declaration of color of skin, it is noted that, as in the rest of the country, many people do not assume their color and origin due to historic prejudice which exists in the Brazilian society. Many interviewees firmly report the absence of slave ancestors. However, from information acquired by oral historic narratives of elder members of the community, such links exist and is related to the foundation history of all communities. Such narratives point towards black families relationships regardless whether they were freed from slavery or not. Another interesting fact is related to the age group that declare themselves black. In general, the younger people declare themselves black, once they catch a glimpse of the possibilities of the quality of life improvement from communities recognized as afrodescents. Around 92.7% declare themselves as black or mulatto (47% declare themselves mulattos and 45.7% declare themselves black). The rest, 7.3%, declare themselves as white, native-Indian or other.

With regards to family income data, results show a dramatic poverty standard, when traditional factors are taken into account in building the income indicator. Around 51% mentioned that the incomes of an entire family is less than one minimum salary[2], and from this percentage, more than half receive less than half of the minimum salary per month. The number of interviewees that receive more than two times the minimum salaries represents 10% of the respondents who generally belong to a family group formed by elder people, already benefited from the retirement program of the Federal Government. In regard to access to education it was possible to verify the existence of schools in all communities studied by the project. Normally, these schools receive children up to the fourth grade of primary school. To continue their studies, the young people need to travel to the seat of the municipality. It was found that the educational level of the interviewees was very low. Around 50% of the interviewees mentioned that they do not know how to read and write (some sign their names).

[2] The minimum wage in Brazil is today around US$ 195.00

Those with incomplete primary school represent 39.2% and only 4.1% declared that they had completed or are on the way to complete high school level. This group is formed by young people up to 20 years old.

The cross information about income range and education shows the following results. The people who have access to higher salaries (about two minimum wages) generally belong to the illiterate group where most of them are included in social security federal programs. On the other hand, the group that receives the lowest income lies in the group of intermediate education: generally they are young people starting new families. Included in this group are couples who have children in school age and eligible to receiving the benefits of the Federal Government Program Bolsa-Família[3] which in some cases is the only source of income. The group that has completed high school or university, and the vast minority do not have salaries suitable to their education. Results from all income and education groups of the *quilombolas* within the *Cio da Terra* project show they have a dramatic deep exclusion profile, when compared with national indices.

It is noteworthy that besides poverty and lack of opportunity, the majority of the interviewees mentioned they would not like to migrate to other regions to look for better opportunities. They said in their communities there is safety, solidarity and no starvation. The agriculture products have guaranteed their survival. Although there is no material abundance, no one starves. Another factor that is worth mentioning refers to the preservation of the natural environment observed in most *quilombolas* areas. The quilombolas practice sustainable livelihood, which is linked to their full understanding of the natural cycles and resource availability during the different periods.

[3] Bolsa Família Program (PBF) is an income direct transfer mechanism with conditions that benefits poor families (with monthly income per person of R$ 60.01 to R$ 120.00) and extremely poor (with monthly income per person up to R$60.00). The Program is based on the articulation of three essential dimensions to get over hunger and poverty: (i) promotion of the immediate relief of poverty, by means of the direct income transfer to the family; (ii) reinforcement for the basic social rights exercise in the Health and Education areas, by means of conformity with the conditions and (iii) coordination of complementary programs in a way that the beneficiaries can surpass the vulnerability and poverty (http://www.mds.gov.br/programas).

This study also mapped the number of families that receive benefits from federal and state government programs. We verified that 69% of the families had already participated in some type of official program, apart from Social Security pension or retirement cases. Even though in programs of this nature there is a large rate of insert, around 31% mentioned that they had no access to any government inclusion program. In other words, about 300 families of the ten communities are not included in any of the social inclusion programs.

Stonemeal Technology to Change the Poverty Scenario

The establishment of alternative agricultural practices for quilombola farmers' agricultural production is based on the 'stonemeal technique' (Leonardos *et al*., 1972, Theodoro, 2000a). This integrated project attempts to transfer technologies to family farmers, with the aim of achieving long term environmental balance and strengthening the bonds of human beings with nature while guaranteeing quality food production (Leonardos *et al*., 2000, Theodoro *et al*., 2002). Application of ground rock material, instead of chemical fertilizers is considered a low impact and easy to understand technology, with short-term production responses and positive medium and long term effects.

The availability of the nutrients for soils after the application of ground rocks show fundamental differences in relation to chemical fertilizers, with regards to slower dissolution, lower concentration of macronutrients, reduction of contamination risks of water bodies, and lower price for these materials. This fertilization alternative shows rapid results and reduces the input recharging costs (Leonardo *et al*. 1972, 2000; Costa Junior 2002; Theodoro 2000a, 200b, 2005; Theodoro and Leonardos 2006; Fyfe *et al*., 2006). Furthermore, the application of ground rocks tends to make the integration of the mineral sector (which produces large quantities of waste) with the agricultural sector (which needs inputs to guarantee adequate levels of production) feasible. It should be noted that the stonemeal technology transforms a problem of the mineral sector into a solution for the agricultural sector. The utilized rocks for this practice need to contain macronutrients (phosphorus, potassium, calcium and magnesium) as well as micronutrients (molybdenum, cobalt, zinc and others) in considerable amounts.

The use of selected rocks (rich in apatites, vermiculites and calcites, in combination with cow manure) for re-mineralize/rejuvenate the soils in the 10 Experimental Units implemented in the communities served by the *Cio da Terra* Project, have shown positive results. Besides the drought problem, faced by all regions of the project, the farmers showed enthusiasm with the perspective of using a new technology, which they revealed is adequate for their production condition. As important as the production results, are the potentially lower costs for the acquisition of the rock dust. The comparative cost study done by the project's team concluded that the rock dust used in the research (*Natural Plus*, from Ipirá Mining) cost the farmer around seven times less than the same amount of NPK. It is worth mentioning that a 50kg bag of NPK – with a ratio of 4:14:8 –costs R$ 50.00, while the 50kg bag of rock dust, including transportation, costs R$ 7.20. Such characteristic gives the stonemeal technique a significant economic appeal, considering the notable cost reduction in input acquisition.

Research carried out by Leonardos *et al*. (1972, 2000) and Theodoro (2000, 2005, 2006) in Brazil show that, depending on the type of rock (or waste) used and the number of annual crops, application of rock dust must be re-applied only every four or five years, because the rock-forming minerals have slower dissolution rates than conventional fertilizers (NPK). The slow release of rock nutrients is interesting from the plant nutrition point of view, as plants only use nutrients as needed and nutrients are not lost to the drainage system, as in the case of the chemical salts used in conventional fertilizers. Such economic and ecological means of crop fertilization fit well into agro-ecological principles and these are readily accepted by the family farmers. For them, costs and long lasting nutrient availability are the two main reasons why they have accepted the technique. They cannot afford the high costs of chemical fertilizers, and do not want to become dependent on government funding. Farmers involved in the research mentioned that the productivity gains were beyond expectation. But what mostly caught their attention was the fact that the rock dust and manure mix was able to keep soil moisture for longer periods, even in times of droughts.

Considering that the rock dust can be easily found in various regions of Bahia State and large quantities of organic residues (e.g. manure) are available in rural areas, economic and productivity gains could be assured. This would make the 'rocks for crops' strategy a feasible and desirable alternative for quilombolas communities.

Methodology

Throughout the research, many procedures were modified and new tools incorporated in the experiments in order to produce more consistent data and improve data processing. It should be stressed that the intrinsic proposal of our research is to target farmers, perception and learning processes of the principles and practices of agro-ecology. The methodological procedures adopted in the experiments included:

- Chemical characterization of rock materials (Plasma Atomic Emission Spectrophotometry and Atomic Emission by Inductive Coupled Plasma (ICP) Spectrophotometry),
- Geochemical characterization of the rock types (phosphate rocks, amphibolites and limestone),
- Physical and chemical characteristics of the soils that received the rock powder,
- Selection of the crops to be tested (corn, beans, cassava, fruits, etc.),
- Elaboration of a standard experimental design in terms of treatments, repetitions and mixture proportions of the materials to be incorporated into the tested plots,

- Plant development follow-up, checking height, stem diameter and productivity,
- Development of indexes that account economic and environmental gains in the different treatments,
- Survey of local socio-economic and cultural conditions as to understand the potential demands and specifications of the partner farmers as to offer them adequate answers,
- Joint assessment with the local leadership of the market potentials in the region along a survey of alternative products and fluxes that could simultaneously sustain and improve the health of the local economy and the environment,
- Rapid and Participative Diagnostic (DRP) survey among the farmers who were benefited by the research,
- Identification of the local capabilities and leadership in each community to assist them develop and strengthen their social organization;
- Qualification courses and seminars on the basic aspects of agro-ecology technologies, trading, marketing and sustainable development.

The main crops used by the quilombolas farmers are corn/maize, beans and cassava. Depending on the region, some farmers also produce sorghum, peanuts, castor oil plants, lettuce, tomato and various types of fruits.

Results and Discussion

Results of the interviews show that some farmers had already tried to apply some type of chemical fertilizer, especially NPK, but it made them vulnerable and liable to large debts and therefore they stopped purchasing chemical fertilizer. Lack of funds is also responsible for the rudimentary way of cultivating their agricultural land. About 60% of farmers mentioned they do not use any type of agricultural machinery in the farming process. It was also found that due to low levels of income, education and agricultural equipment, 80% of the interviewees never had a loan to finance agricultural activity. The 20% who responded stated that they have had some type of financing, and reported that they had benefited from the National Program of Family Farming Strengthening (PRONAF). They expect to use the Community Association financial modalities that are becoming feasible. Considering this, the configuration of the experimental units followed a simple standard design which was previously discussed with the farmers. This procedure has allowed an easy comparison among the productivity of different rock mixtures, together with cow manure, on a variety of test plots, in a way that the farmers could choose among the treatments that presented the best returns. Figure 2 shows the configuration of the experimental plots (the total area was 5 978 m^2) and photos with some initial results of maize response.

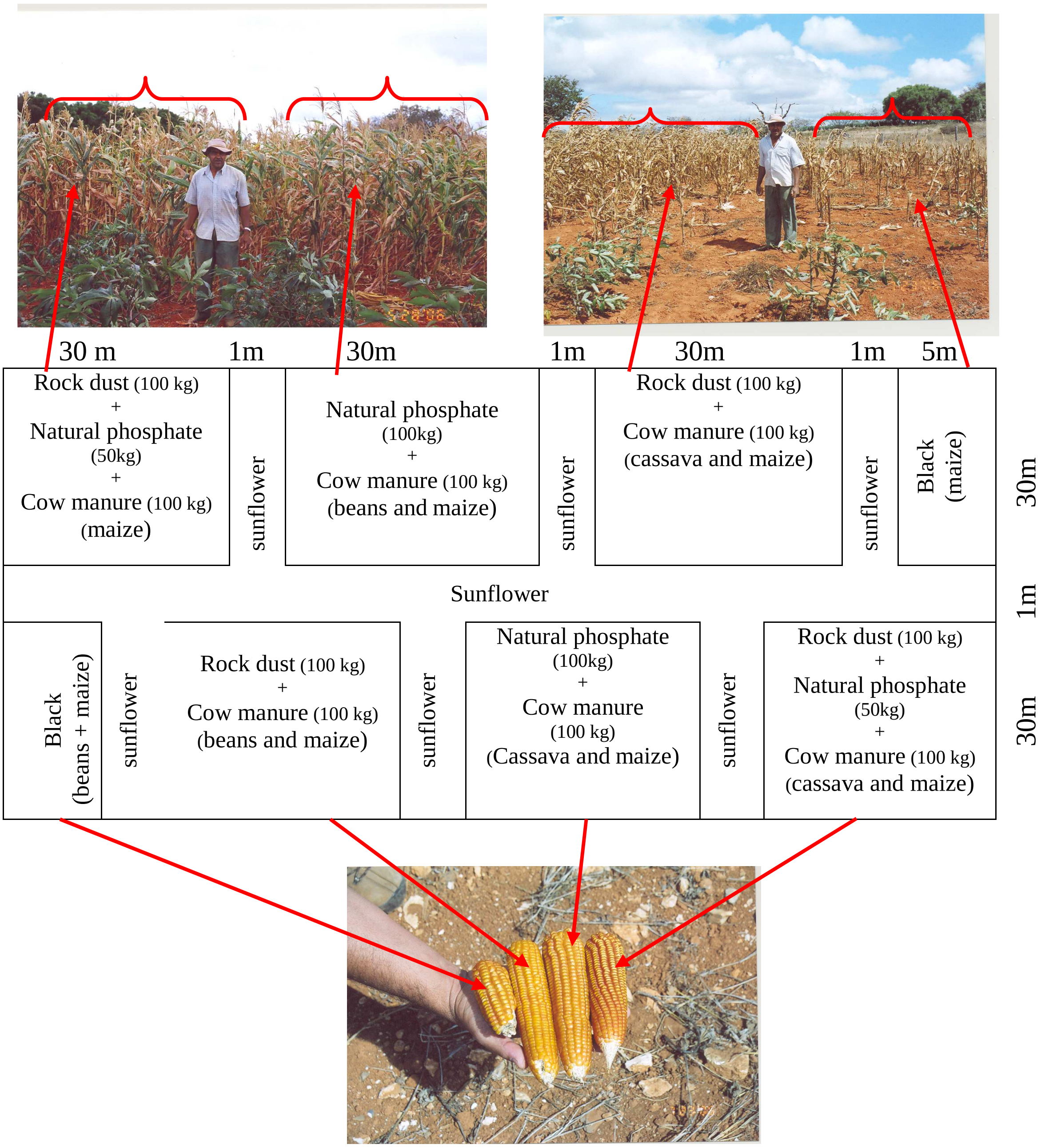

Figure 2 – Experimental site plan and some visual results of the initial experiments.

One of the most relevant results of the project was the positive gains of the soil fertility characteristics. After one year, significant changes were recorded with regards to nutrient element concentrations in soils. Fertility analyses were carried out at room temperature by mild digestion from weak acid (citric acid), giving indications of the nutrient quantities that could be readily available to crops.

By comparing the soils data before and one year after the establishment of the field trials, it was possible to verify that, in general, the soil pH had increased, except in two communities (Alto do Morro – Region 3 and Remanso – Region 1 Communities), where the pH values were slightly lower after the second crop (Figure 3).

Available potassium and phosphorus changes were also observed. In the case of P (Figure 4), there was a positive increase in almost all analyzed soils, except, again, in the Alto do Morro Community. Potassium, being an extremely soluble element, presented an anomalous behavior: sometimes it increased after the second crop but, in general, the addition of rock powder and cow manure to the soil seems has reduced its availability (Figure 5).

Calcium and Magnesium (Figure 6) showed positive variations, especially in areas where their soil content was initially very low, such in the Region 3 communities. In Region 2 - Lagoinha, Lagoa Grande, Sarandi and Boa Esperança Communities – the Ca and Mg values were already sufficient, as the soils of these regions largely originated from dolomitic and calcitic limestone. Thus, the increase in these nutrients from the crushed rocks had little significance. The most striking change recorded was the increase of phosphorus in soils. The micronutrient concentrations all increased and the aluminum values were considerably reduced (data not shown).

Crop productivity at each test site is given here only as qualitative visual indication, documented by photographs, as the local farmers were unable to provide quantitative measurements as previously agreed upon or were unable to follow recommendations, for a variety of reasons including lack of proper instruments.

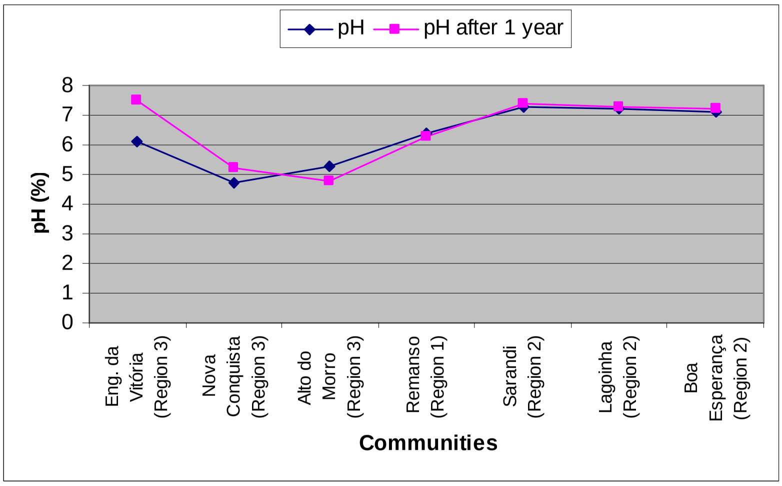

Figure 3 – pH variation before planting and after one year

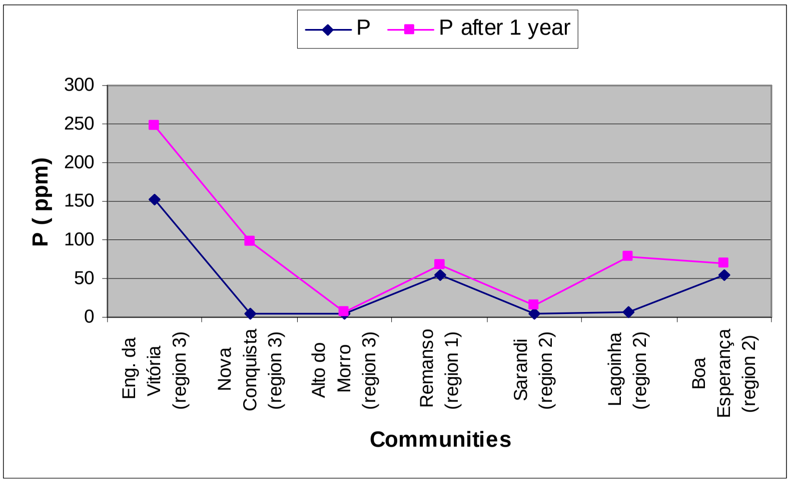

Figure 4 - Phosphorous before planting and after one year

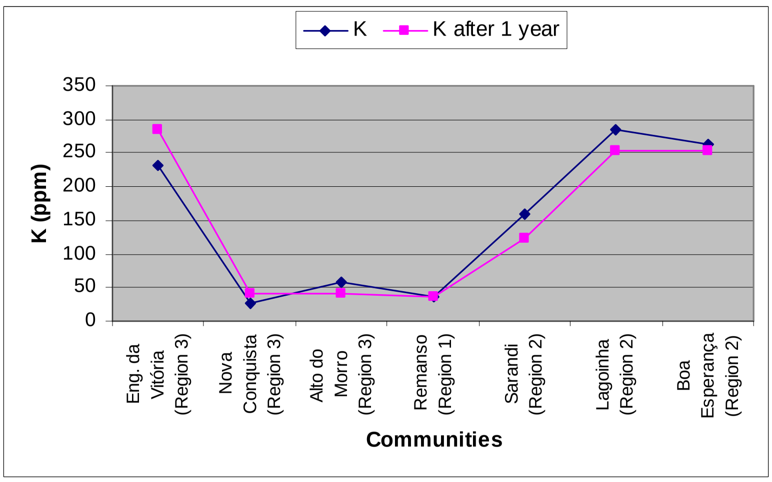

Figure 5 – Potassium variation before planting and after one year

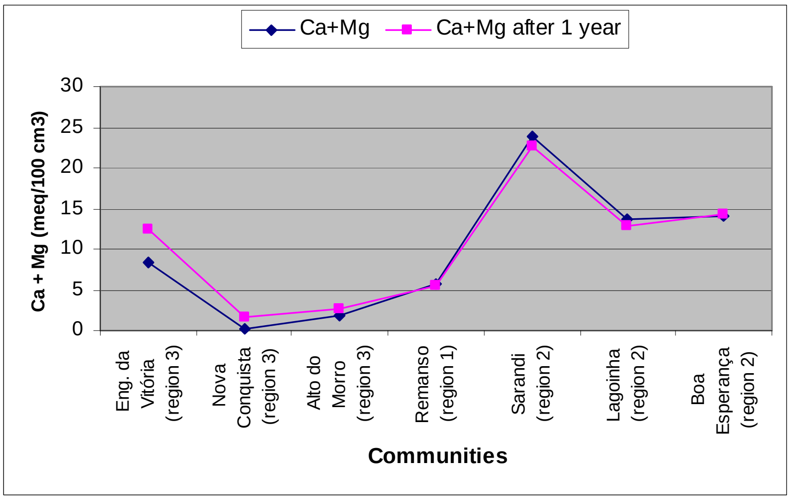

Figure 6 – Calcium and Magnesium variation before planting and after one year

Despite the lack of concrete, productive data, our team was able to semi-quantitatively evaluate productivity based on information by the farmers themselves. On average, crop productivity in the plots where rock powder and manure were added increased between 10 and 30% when compared to control plots and previous crops. As expected, because of significant P addition, the crop which had the best performance in all areas was that of maize. In general, plants became more vigorous, better rooted, with more biomass and better developed maize cobs. Peanuts also had an excellent development (Area 3 communities). The experiments with cassava could not be evaluated as the farmers report and our visual assessment were contradictory.

Although these indicators are inconclusive from a rigorous agronomical and statistical point of view, farmer’s oral reports and photographic results are suggestive of an increase of production when powdered rock fertilization in combination with cow manure was employed. According to the farmers who were unconcerned for the existence of quantitative measurements but who eye-witnessed the productivity gains, this study unfolded new ways of crop fertilization, awakening them for new farming opportunities.

Members of the project team heard farmers repeatedly questioning the recommendations they received from official agricultural extension workers or they observed that the stonemeal technique produced healthier plants and products of a better quality. The fact that farmers have started to produce plants without the use of agro-chemicals assures them food independence and food quality if not long-term food security.

Conclusions

The quilombola farmers in the State of Bahia are destitute of programs or projects that consider their historical and cultural uniqueness. These farmers do not have access to loans, adequate technical assistance addressing their needs and a lack of inclusion and access to local markets. Furthermore, there is hardly any crop surplus for them to sell produce to guarantee their primary needs. Trading with urban centers is very limited.

After two years of activities and despite the fact the quilombola farmers were unable to record crop productivity, the aim of the *Cio da Terra* project was achieved in terms of farmers' mobilization and of the transfer of a desired low cost, environmental friendly technology which the quilombolas used and accepted. The quilombola farmers were thrilled with the perspective of getting involved in new opportunities in terms of mechanisms and practices that would lead to a sustainable livelihood. This would follow their own cultural values, where economic survival is attached to food quality and food security as premises. Despite their expressively insignificant income index, the farmers achieve basic nourishment satisfaction leaving no room for extreme hunger. The vast majority have access to the typical foods of each region. Family and cultural ties, where solidarity thrives have been a decisive factor for the permanence of people in their communities and the maintenance of the family unit. Being classified as very poor, in accordance with the DRP data, the quilombolas communities are far from being poor. On the contrary, they live with *axé* (popular word which means a wish of positive energy) and sacred food from the land, a richness that the white urban society can rarely feel.

In reference to the acceptance of the stonemeal technology, it can be concluded that the most utilized ground rock blend in the experiments was a mix of amphibolites and apatite veins which proved to be a very positive answer as supplier of phosphorus, calcium and magnesium. The wide grain size distribution with a substantial clay fraction profiles guaranteed soil re-structuring, often favoring moisture conservation, and aeration and, consequently, greater productivity in the different cultures it was used. Thus, the use of ground rock, traded as *Natural Plus*, showed itself a perfectly adequate material for the use as a soil rejuvenator/re-conditioner.

The phosphate rock used only in Units of Region 2, also showed very interesting results, especially when mixed with amphibolite powder and organic matter. The availability of phosphorus was enhanced and as result, and better quality plants were obtained.

Such results reinforce the data presented by various authors (e.g. van Straaten, 2002 and 2007) who point out that on poor or depleted soils the addition of phosphate rock powders will increase crop production to a level of the most fertile soils. The ‘Rocks for Crops’ strategy used here reinforces the need to build a new development model for the agricultural sector, where environmental sustainability and the economic sustainability mean the same.

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