The Journal of Animal & Plant Sciences, 23(2): 2013, Page: 633-646
ISSN: 1018-7081

TRADITIONAL AGROECOSYSTEMS VS. ALTERNATIVE AGROECOSYSTEMS IN MAIZE IN CHIAPAS MEXICO

C. E. Aguilar-Jiménez, A. Tolón-Becerra* and X. B. Lastra-Bravo*

Universidad Autónoma de Chiapas. Facultad de Ciencias Agronómicas. Campus V. Km. 7. Carretera Villaflores-Tuxtla Gutiérrez. 30470. Villaflores, México.
*Universidad de Almería. Área de Proyectos de Ingeniería. Ctra Sacramento s/n. La Cañada de San Urbano. 04120. Almería, España.
Corresponding author E-mail: ceaj2001@yahoo.com.mx

ABSTRACT

The purpose of this study was to evaluate environmental variables in a traditional agroecosystem (TA - slash, fell and burn) and alternatives (AA - modifying the sowing density and rotating with *Mucuna deeringiana* Bort.), in Chiapas, Mexico. The variables were analyzed in two seasonal farming cycles, spring-summer (SS–burn) and autumn-winter (AW-no burn). Analysis of the environmental variables indicated better properties in TA, but there was no correlation with the years left fallow. The results were positive for AA, although it was found that TA had beneficial effects on certain variables as a result of being left fallow and adapting to the environment. A relative decrease was observed in the number of species, of individuals and of families as the fallow period was extended (R=67.7%). Modification of the sowing density affected maize yield positively (3.1 t/ha vs. 1.8 t/ha in TA). Models predicting yield well were found for both farming cycles (R=97.6% for SS and 97.3% for AW). It was observed that TA are attacked less by *Diatraea liniolata* Walker, because of the effect of fire on its reproduction. Both before burning and after harvest, soils were observed to be fertile with high content in nutrients, slightly acidic pH and good physical properties. Strong erosion was recorded from the beginning of the culture cycle, especially in TA (33.9 t/ha). The environmental sustainability of TA in the Selva Region was not affected over time by the reduction in fallow periods, but new agroecosystems must be found and implemented in the future.

Key words: Slash, fell and burn agriculture, Traditional land use, *Mucuna deeringiana* Bort., Maya Indians (indigenous people).

INTRODUCTION

Central America is the center of the origin of maize (*Zea mays* L.) and has a wide diversity of varieties of this crop (Keleman *et al*., 2009). Maize is the main crop in the region (Perales *et al*., 2005), and in the complex and diversified Mexican society, it contributes to the subsistence of millions of farmers (Keleman *et al*., 2009). From the first ethnic groups, to modern days, they have depended strongly on its cultivation by different production systems. Keleman *et al*. (2009) have identified five fundamental social processes to explain the wide diversity of maize in the region, the historical and cultural value of maize as the main crop, patterns of land use in response to differing agroecological conditions, how farmers store seeds and how they select them (with home use characteristics), and seed exchange in social networks. At present, *mestizo* producers, contrary to indigenous producers, have been observed to prefer more commercial improved varieties (Brush and Perales, 2007).

In Mexico, about 70% of Mexican peasants use traditional agricultural techniques, working the farms with ancestral methods, and usually under smallholding conditions. Farm work is dependent on environmental conditions and family labour. This system produces 70% of the country’s maize, 60% of the beans, and 50% of its fruits and vegetables. In the Selva Socioeconomic Region of the State of Chiapas, the agriculture sector and mainly traditional farming, is the main economic activity. Maize is mostly a subsistence crop grown on small plots in mixed culture systems (*milpa*), with yields under 1500 kg/ha, and often from purchased grain. (Perales *et al*., 2005; Brush and Perales, 2007). The main production structure is the Ejido, a social landholding system in which each member, *ejidatario*, owns an average of 15 ha. As a result of hereditary distribution, in recent years there has been a trend toward small landholdings, leading to high pressure on land use (INEGI, 2000).

The *milpa* agroecosystem, or traditional rotating or itinerant cultivation, is a seasonal system which includes different maize cultivars in association with others important to the family economy (bean, yucca, squash, chili and other vegetables), and it is the most important in agricultural production to this day (Ochoa-Gaona and González-Espinosa, 2000). This system, which is also known in Mexico as *Roza-Tumba-Quema* or slash, fell and burn (S-F-B) consists of cutting down existing vegetation with a machete or axe (occasionally) and burning the residual dry vegetation. Felling is only done in systems involving high vegetation (>10 m). Allowing land to lie fallow is conducive to high vegetation. In recent years, this system has met with severe limitations due to the high density of the population, intensification of land use, reduced fertility and asymmetry in economic relations between Indian and *Mestizo* societies (Ochoa-Gaona and González-Espinosa, 2000). Its sustainability has also been affected by the number cycles and their duration, and reduction in the fallow period necessary to recover the productive capacity and fertility of the soil.

Specifically, in the State of Chiapas the fallow period has been reduced considerably due to the population explosion (annual mean 3.8%) which is higher than the national rate (2.6%) and which in the indigenous population is as high as 8% (INEGI, 2000). As a result, the productive potential of the soil has diminished considerably, leaving system sustainability, fundamental for it to be maintained over time, at risk (Hernández *et al*., 1995). Daniels *et al*. (2008) demonstrated that the land use "footprint" left by *milpa* covers a wider geographic area than the agricultural plot itself, with an associated restriction in agricultural productivity potentially transferable to the forests that surround the plot cultivated by *milpa*.

In spite of the enormous importance of S-F-B agriculture in Chiapas, both by area and the number of producers who practice it, this system has not been evaluated under current growing conditions. Specifically, in the Selva Region where 80% of its inhabitants are natives who use *milpa* even more, there is no updated basic systematization of information, and experimentation in alternative maize production practices in this territory is unknown. The *Choles*, the second most important ethnic group in the Selva Region, with 40% of the total population, grow seasonal maize under two systems, S-F-B (*milpa*) and slashing but not burning (*tornamil*). The first method is itinerant, while the second tends to be sedentary. Because of the above, it is considered indispensable to begin integral analysis of the dynamics of the current state of itinerant agriculture, evaluate its agro-environmental sustainability based on strategic indicators with different fallow periods and determine the impact of alternative practices (no burn, rotating with *Mucuna deeringiana* Bort. green manure, and modifying the distribution of sowing).

MATERIALS AND METHODS

Study Site: This study was done between 2005 and 2006 in the Ignacio Allende, Venustiano Carranza and Cuctiepa *Ejidos* (communal lands) in the Municipality of Tumbalá, Selva 6th Socioeconomic Region, State of Chiapas, Mexico (400 m a.s.l., 17°16'N, 92°09'W).

According to the Köppen classification adapted to Mexico, the climate is Af(m) with a mean annual temperature of 27.5ºC, mean annual precipitation of 3500 mm, and predominantly light winds of 30 km/h (INEGI, 2000). According to the FAO/UNESCO classification, the soils are mostly lithosols with associated rendzinas and chromic luvisols (INEGI, 2000), fertile and moderately developed, with a depth of less than 0.6 m, well drained, acid, alluvial, and are made up of unconsolidated terrigenous deposits having a granulometry varying from thick sand to gravel at the foot of the mountains, and to mud and clay where lands slope less. Their profile is wet practically all year long, and because of the topography of the land and the presence of lime rocks, its mechanization is limited. Temperature and rainfall records of study site are showed in table 1.

The traditional annual maize production system consists of two seasonal farming cycles, the spring-summer cycle (April to September) known as *milpa de año* (yearly slash, fell and burn) or *cholel* in ch'ol and, the autumn-winter cycle (November to April) known as *tornamil* (slash and fell) or *mol* in ch'ol. The main economic activity is growing maize, beans and coffee. Since environmental variation, especially altitude, is associated with use and evolution of the genetically diverse Creole varieties of maize, exclusively Creole varieties of the tuxpeño race are used (Chambers *et al*., 2007).

Experimental Design: The research was done during the two agricultural cycles (*milpa* and *tornamil*), respecting the traditional sowing system, in a completely random design. Treatments with mixed maize and *nescafé* (*Mucuna deeringiana* Bort.) crops were included in both cycles.

In the spring-summer cycle, eight treatments (T) were set up in the Ignacio Allende Ejido, and 32 0.5-ha experimental units were defined. The four repetitions of each treatment were distributed between two properties belonging to different producers (two per property). Treatment T0 (control) comprised an unperturbed ecosystem that was like an *ejido* reserve, the high evergreen forest. Treatments T1, T2, T3 and T4 were 20, 14 10 and 5-year fallow periods with burn, respectively, to evaluate the S-F-B system used to prepare the fields. Treatments T5 and T6 were 5 and 2-year continuous maize crops, respectively, with no burn. Treatment T7 was maize and *nescafé* with no burn. The four fallow periods were set up to have a margin for comparison among periods of different lengths. They were stratified in five-year periods because in shorter periods no considerable effect was observed. The shortest fallow period was five years, the minimum time the producers in this region leave S-F-B soil unused. The sowing dates were set by the producers themselves according to traditional sowing patterns from April 15 to May15.

In the autumn-winter cycle, six treatments (T') were set up at the Venustiano Carranza and Cuctiepa *ejidos*, with four repetitions of each, in 0.5-ha experimental units. Two experimental units, one applying the traditional and the other the alternative sowing technologies, were located on the same property. The alternative system consisted of modifying the density, because of the positive effects on the production characteristics of maize of reducing the sowing distance between rows and plants.

Sowing by the alternative system was done along with the farmers using a distance between rows and plants of 1.0 x 0.5 m. Two seeds per point were planted with an approximate population density of 40 000 plants/ha. In the traditional system, the distance between rows and plants varied from 1.2 to 1.4 m, and 5 to 6 seeds per point were planted with an approximate density of 30 000 plants/ha. Three systems of land use with no burn were defined for the treatments, because this cycle takes place in the rainy season, and the moisture in the biomass makes burning impossible. Treatments T1' and T3' were the alternative system with 5 and 2 years of continuous cultivation, respectively. Treatments T2' and T4' were the traditional sowing system with 5 and 2 years of continuous cultivation respectively. Treatments T5' and T6' included continuous cultivation with *nescafé* under alternative and traditional systems, respectively.

Sampling and Analysis: The floristic inventory analysis was carried out in three ecosystems, *acahuales* (before slashing), maize fields (weeds) and seed banks. A 2 x 2 m square was used for the inventory, and three replicates were done for each sampling unit. Floristic diversity was determined using the Shannon-Weaver Index (*H'*):

$$H' = -\sum_{i=1}^{S} \frac{n_i}{n} \times \ln \frac{n_i}{n}$$

where *S* is the number of species in a sample or a population, n is the total number of individuals in a sample, n_i is the number of individuals of species *i* in a sample, n_i/n is the fraction of individuals belonging to species *i* in a sample or a population. Similarity among the communities was found using the Sörensen Index (*S*):

$$S_s = \frac{2c}{s_1 + s_2}$$

where s_1 is the number of species in Population 1, s_2 is the number of species in Population 2, and *c* is equal to the number of species common to both populations. The biomass of stem per tree was estimated according to Young (1991). The height of the stem, perimeter at breast height, and number of trees in one hectare with mean perimeter over 0.3 m were determined. In the itinerant agricultural systems, trees cut down at the end of slash and fell (before burn) were measured with a metric measuring tape. In the undisturbed system, the volume was estimated on foot using a hypsometer. The tray method was used for the seed bank analysis. Composite soil samples were collected at a depth of 0 to 0.2 m, and placed in $0.3^*0.5^*0.3$ m wooden boxes. The three samples per sampling unit were left outside right in the plots.

The phenological variables of *Nescafé*, days to emergence and days to flowering, were analyzed in four plots belonging to different producers. For the analysis of agronomic characteristics, the quadrant (1 m^2) was used for three legume development stages. A fresh sample was taken of the whole biomass and of its parts (leaves, stems, flowers, fruits). The samples were dried at ambient temperature to determine the whole biomass weight and its individual parts, both green and dry, and extrapolated to t/ha. To find out the extractions, nitrogen (MicroKjeldhal method), phosphorous (colorimetry method) and potassium (Atomic absorption) were determined.

Agronomic and phenological characteristics of maize were analyzed in 10 consecutive plants at 10 points located in a zigzag per experimental unit. The phenological variables, days to emergence, days to male and female flowering and physiological maturity were determined. The agronomic variables: sowing distances between rows and plants, number of seeds per point (unit), plant height, ear height, leaf area, number of ears, number of grains per ear, ears per plant and plants harvested. And the variables stalk lodging and damage by stem borers (*Diatraea liniolata* Walker). The methodology proposed by Lafitte (1994) was used to estimate grain yield. Five linear meters were measured in the maize field and the plants were counted. Then all the ears were harvested and putting them in order from largest to smallest, the ear in the middle was selected, and the rows per ear and grains per row were counted to get the total grains per ear. The yield of grains per hectare was estimated using the model: (plants per hectare)*(ears per plant)*(grains per ear)*(0.0002857).

Physical and physicochemical characterization of the soil was done in the spring-summer cycle. The morphogenetic methodology was used to describe the soil profiles. Sampling was done before burning and after harvesting at a depth of 0 to 0.2 m.

The main physical and physical-chemical soil properties were determined by the following methods: Bouyoucos hydrometer method (texture), excavation (bulk density - ρ), potentiometer, water-soil ratio 1:5 (pH), conductivity meter, water-soil ratio 1:5 (electric conductivity – EC), Macro Kjeldahl method (N), Olsen method (P), cations extractable with Morgan solution (K), Walkley and Black Oxidation (organic matter and C:N), Versenate method (Ca and Mg) and nail method (erosion). Sampling was done at the cultivation stage when soil was the most erodible, and finished when the land was invaded by vegetation.

Statistical Analysis: Data were analyzed using the PASW Statistics 18 package ver. 18.0.0 for analysis of variance, t-tests at a probability 0.05 ($P<0.05$) and the analysis of correlations between parameters.

Due to the characteristics of the research and uniformity of the sampling units, analyses were done using a simple classification model. The criteria of García-Villalpando *et al*. (2001) were used in the t-tests. Normality was also tested by statistical analysis of asymmetry and standardized kurtosis, and homogeneity of variance by the Levene test. Data given as percentages and counts were not transformed, complying with criteria of De Calzadilla *et al*. (2002).

To find out the relationships between study variables, Multiple Linear Regression models were fit, using the forward selection method suggested for biological studies. The models where the variables showed a significant contribution to the response were selected, considering the standard error of the estimators and parameters, the significance of parameters and model, coefficient of determination and Durbin Watson statistic. For evaluating the absence of correlation of errors, it was assumed that there was no serious self-correlation when it was over 1.4, also taking the graphical residual analysis into account. Finally, considering the technical criteria for the selection of indicators (variables), Principal Component Analysis of multivariate data were run.

RESULTS

Floristic Inventory: No significant differences in floristic similarity (β) were observed between burn and no-burn systems. In general, β of the interactions between communities in treatments were low (Table 2). The closest similarity was observed between treatments T3 and T4, while the widest disparity was found between T0 and T6, and between T2 and T6. The lowest number of species in the *acahuales* (bush stage) was observed in T2 and the highest in T7 (Fig. 1). As the fallow period was lengthened, a relative decrease was observed in the number of species, individuals and families. The most floristic diversity was observed in T4. The estimated volume of stem biomass was highest in the control, followed by T1. The regression analysis of flora in the *acahuales* for the floristic diversity index showed:

$$H' = 0.225 + 0.06\,(\text{number of families}) - 0.0006\,(\text{number of individual s}),\quad R^2 = 67.7\%$$

H’ for components of flora emerging in the seed bank (Fig. 1) was very similar in all the culture systems. T4 stands out for its higher floristic diversity in contrast to T2, where a species of the *Rubiaceae* family are predominant, gradually modifying the index, sensitive to disproportionality. For the sample from the undisturbed jungle (T0), the index was 0.

Physicochemical Characteristics of Nescafé (Mucuna deeringiana Bort): The total biomass weight results were disparate, as observed in Fig. 2, as in the third and last sampling, volumes were 18.4 and 4.8 t/ha for green and dry biomass, respectively. The mean weight of total green biomass was 7.4±9.1 t/ha, and of total dry biomass 2.0±2.4 t/ha. For flowers and fruits, values were practically 0. Regression analysis for *nescafé* biomass volume components found the following model for all dry biomass (t/ha) (y):

$$y = 0.074 + 0.440(\text{green stalk}),\quad R^2 = 99.1\%,$$

predictions of which were shown to be adequate under the conditions of the study, showing that most of the dry *Mucuna deeringiana* Bort biomass is made up of the stalk of the plant.

Concerning the mean major element extractions (Fig. 2), leaf (36.2±43.6 kg/ha) extracted approximately twice as much N as the stalk (16.8±18.7 kg/ha). However, leaf values were not statistically affected by sampling site, but by sampling stage. P was highest in the leaf (1.8±2.1 kg/ha) as well, while K was found to be highest in the stalk (26.4±35.8 kg/ha). Total extractions in the plant parts, stalk, leaf, flower and fruit, were 54.5 kg N/ha, 3.0 kg P/ha and 42.3 kg K/ha.

Phenological and Agronomic Variables of the Maize: During the spring-summer cycle, neither phenological (Table 3) nor agronomic (Fig. 3) characteristics of the maize tended to define traditional S-F-B systems with different fallow periods or alternative systems (no burning and use of green manure). Significant differences were observed in emergence phenological variables ($P<0.03$) and masculine flowering ($P<0.17$). Disparity was greater in the emergence variable in T3 (5.5±10.5 days), T5 (6.0±19.2 days) and T7 (5.5±10.5 days), and in the masculine flowering variable in T4 (69.5±5.8 days), T5 (74.5±5.4 days) and T6 (76.0±7.6 days). In the second evaluation cycle, no significant differences were observed in the phenological variables (Table 3).

Fig. 3 showed no statistical differences in the components of grain yield in the spring-summer cycle. In the autumn-winter cycle, significant statistical differences between treatments were observed in the agronomic variables: ear height (T1, $P<0.03$), number of ears ($P<0.02$, plants per hectare ($P<0.02$) and grain yield ($P<0.004$). In most of the variables, results were better in the plots with the alternative technology, T1’, T3’ and T5’. The benefits of all the treatments were observed in the grain yield with a mean and SED of 3.1 and 1.2 t/ha (T1'), 2.1 and 1.2 (T2'), 3.4 and 1.3 (T3'), 1.6 and 0.3 (T4'), 2.7 and 0.9 (T5') and, 1.7 and 0.8 (T6'). Therefore, the yield from T1' was statistically higher than the other treatments, because of alternative practices. The alternative systems showed an average grain yield of 3.1 t/ha, and traditional systems only 1.8 t/ha.

In the spring-summer cycle, regression analysis generated a very useful model for technical application as indicators under the study conditions, employing the maize grain yield as the dependent variable (*y*):

$$y = -3604.1 + 11.44\,(N^{o}\,ears) + 6.11\,(N^{o}\,\text{kernels}/ear) + 0.06\,(N^{o}\,plant/ha) + 2247.7\,(N^{o}\,ears/plant),\ R^{2} = 97.6\%$$

where *Nº Mz* is the number of ears, *Nº gno/Mz* the number of kernels per ear, *Nº pta/ha* the number of plants per hectare, and *Nº Mz/pta* the number of ears per plant.

A highly predictive model was also found for the autumn-winter cycle that responds positively to increase in its components. This pattern demonstrates the importance of population densities and yield components in determining the final harvest volume.

$$y = -4740.5 + 0.095\,(plant/ha) + 5.9\,(\text{ker}nel/ear) + 2888.79\,(ear/plant),\quad R^{2} = 97.3\%$$

Principal components analysis generated two functions that together extracted 90.58% of the total variation in the information (Fig. 4).

Pests, Diseases and Stalk Lodging: The analysis of the number of plants damaged by stem borers out of 10 plants observed in the S-F-B system, was highest for T6 (7.3), which was statistically different from the rest of the treatments in the spring-summer cycle (Table 4). In the maize stalk lodging variable, T1 was significantly different from the rest of the treatments. In the autumn-winter cycle, no significant differences between treatments were observed, either in the stem borer or stalk lodging damage variables. The results showed a higher presence of the pest in technologies with no burning and an increase in incidence was observed in absence of rainfall and also higher up on the slope where soil got little wetted due to runoff.

Physicochemical Properties of Soil: The texture varied only slightly among the systems studied both before burning and after harvesting (Table 5). The fractions of this physical characteristic were not affected spatially or temporally by the systems. The bulk density (ρ) before sowing and after harvesting was similar (0.85±0.06 g/cm^3), with no great variation among the systems. Estimates of *Da* (0.68±0.06 g/cm^3) were lowest in the control treatment both before and after harvesting.

Soil pH was neutral, both before sowing and after harvesting (6.6±0.2 and 6.9±0.3, respectively), and in general, higher at the end of the cultivation cycle. After harvesting, it was higher for the burn systems (T1=7.4±0.5, T2=7.7±0.7, T3=7.4±0.9 and T4=7.1±0.4), than for continuous cultivation systems with no burn (T5=6.6±0.1 and T6=6.5±0.1).

These soils were very rich in organic matter, and before burning, a positive correlation was observed between the lengthening of fallow periods and organic matter content (T1=135.0±9.4, T2=160.6±28.4, T3=133.1±23.7 y T4=131.1±18.1 g/kg), arriving at statistical similarity between the fallow systems and T0 (124.7±109.7 g/kg). In no-burn treatments, the amounts decreased progressively down to the lowest percentage in the treatments using green manure (T5=94.3±6.4, T6=60.3±11.9 and T7=46.5±7.0 g/kg). At the end of the cultivation cycle, organic fraction determinations were more uniform and statistically similar, with important increases in the no-burn system, especially in the treatments with *nescafé* green manure.

Concerning N, no effects from the treatments were observed on nutrient content in the soils studied due to their nature and management ($P<0.05$). Before and after harvesting in all of the treatments, soils were very rich in N, and in all cases were similar to T0 (0.7±0.2 mg N/kg). Before burning and after harvesting the lowest percentages were found for T5 (0.47±0.03 and 0.45±0.05 mg N/kg), similar to organic matter.

P was high before burning and after harvesting. It was slightly higher after harvesting in treatments with burning due to the effect of ash (T1=67.0±13.63, T2=71.8±25.0, T3=86.5±40.4 and T4=85.2±16.4 mg P/kg). The soil was very rich in K both before burning and after harvesting. The highest values before burning were observed in T6 and T7 (373.3±15.9 mg K/kg and 357.3±7.28 mg K/kg), and in T1 after harvesting (441.3±282.7 mg K/kg). Differences in Ca and Mg were observed before burning and after harvesting, with the highest Ca in T2 (6039.0±1223.8 and 7216±1718.4 mg Ca/kg, respectively). Mg was also highest in T2 before burning (3862.5±1920.1 mg Mg/kg), but after harvesting, the concentration was highest in T0 (2463.5±963.9 mg Mg/kg). There were no significant differences in the C:N ratio after harvesting, and before burning, it was lower in the no-burn treatments.

Principal components analysis of soils before burning resulted in two components, which together accumulated 84.96% of the total variation. The first component was positively represented by N and the C:N ratio and the second by N and P. K was negatively represented in the first component. The S-F-B systems were positively clustered around the chemical properties of the soil in the cluster of systems before burning. For soils after harvesting, three components were generated which all together came to 83.33% of total variation in the information, where macro elements had the most important matrices.

Erosion: Erosion was heavy from the beginning of the cultivation cycle. The highest soil losses were observed in treatments with burning, with means and SED of 33.4±6.9 (T1), 39.3±41.3 (T2), 22.2±11.9 (T3) and 40.7±13.2 t/ha (T4). These results were statistically higher than the alternative practices (T5, T6 and T7). In a correlation analysis of the slope of land and volume of soil eroded, the effects of the first on the second were not significant with a Pearson's coefficient of 0.244.

DISCUSSION

Floristic Inventory: The Shannon-Weaver diversity index showed a similar trend, nearing one in tall jungle (T0). The results showed wide floristic diversity in the *acahuales* and suggested that for studies of absolute flora, sampling quadrants should contain the minimum area which contains 80% of the species, although the sampling spaces conform to the goals and purposes of the study. The β found showed close similarity of the treatments studied, more so in interactions with T0. No group of communities with similar floristic structures was clear. The estimated volume of stalk biomass showed the potential for forest in the region and stimulates management of improved fallow lands, a technology which should be developed.

The equation found in the regression analysis of flora in the *acahuales* shows that diversity of the biospaces was represented by species in different taxa with few individuals, demonstrating the high plant diversity. The index was disproportional, as the number of individuals of a species rises, the index is gradually lower. As consequence, the loss of this secondary vegetation would more homogeneous the landscape and native forest plants, with productive characteristics, could be eliminated.

In the floristic inventory of the seed bank, the results for the treatments with modified systems (T5, T6 and T7) exhibited that the stages of plant rotation were not strongly modified by different periods of fallow. Thus, therefore was a strong adaptation of the species to conditions in the area, where innate, induced and exogenous dormancy seem to dominate the ecosystem. H'=0 in T0 was due to lack of light in the underbrush. Granados and López (2001) believed that light is a primary condition for germination and concluded that induced and forced dormancy are interrupted under favorable conditions.

Physicochemical Characteristics of Nescafé (Mucuna deeringiana Bort): Development was irregular at different places in establishing *nescafé abonera* systems in very stony land and high interspecific competition with endogenous weeds. Biomass volumes were lower than those reported by Quiroga (2000) under controlled experimental conditions (27 and 4 t/ha for green and dry biomass respectively), although he reported similar dry biomass concentrations when evaluating biomass of the aerial parts of tropical legumes. Under such ecological restrictions, a prognosis of organic fertilizer production can be made which would increase the aptitude of the soil and its economic and ecological value. The *abonera* system consists of a closed cycle that resprouts naturally during the biological cycle of maize and develops freely when collected. The biomass from the *abonera* is of great agricultural interest for conservation and soil improvement in mountain tropics. Kaizzi *et al*. (2006) found that rotating with *nescafé* was profitable and productive, regardless of the type of soil, but the *nescafé* must be kept from choking the maize.

N and P contributions to the soil from cultivating legumes showed high natural potential for increasing the productive capacity of soil. Furthermore, *nescafé* can improve the soil fertility in less productive areas, thus ensuring food security (Kaizzi *et al*., 2006). The statistical differences between sampling stages demonstrated that the synthesis and accumulation of major elements was influenced by their seasonal dynamics. It should also be considered that *nescafé* was vulnerable to drought and excessive rainfall (Eastmond and Faust, 2006).

Phenological and Agronomic Variables of the Maize: No worth mentioning effect of *nescafé* on maize yield was observed, even though legumes help fix N and improve soil N economy (Cheruiyot *et al*., 2003). Adiku *et al*. (2009) did not report significant increase in maize yield either in rotation with *Mucuna*. Differences of unitary yields in the production plots might indicate an effect of specific soil conditions on final harvest volume. However, considering the natural and technological homogeneity, when the production plots were analysed occasionally (since each farm has two sampling units), the differences in grain yields within production units were attributed to specific producer management practices as determinant in the maize yield. Furthermore, it is directly related to the content of P Olsen and inversely to the content of Ca and interaction of Fe and P Olsen.

Competition between weeds and maize had a significant effect, due to the large amount of manual labour needed for their control (15 man-days/ha). This activity influenced development of the maize, especially when it was done intermittently, and at the end, determined production. Hernández *et al*. (1995) stressed the complexity of the factors those can become determining for the final volume of the yield in traditional agriculture in tropical regions, and underlines management, especially weed control. Yield components included in the regression model in the first cycle determined the grain production volume to a great extent. They are also the most important to be considered in genetic improvement tests (Lafitte, 1994).

The average grain yields depicted that sowing with a shorter distance between rows and plants and depositing only two seeds per point, has repercussions in the final cycle of cultivation on the number and quality of the ears harvested, thereby affected production. These differences from modifying the seeding density would provide a significant volume in the Selva Region (domain of recommendation), where maize production is based on the S-F-B system. However, sowing densities on slopes (under different systems) continued to be an open subject of research in agriculture.

In principal components analysis, the positive effect of modifying sowing distances, which impacted positively on alternative practices compared to the traditional technology, was apparent in the first group. This underlines the importance of managing the population densities to maize yield (Lafitte, 1994).

Pests, Diseases and Stalk Lodging: Stem borers were identified as the main pest in maize, with highly severe incidence. They are not normally found in the area, and the diagnosis of the crop damaged was new to the indigenous population. The higher frequency of the pest in no-burn treatments proved that fire exerted a control by eliminating entomophagous inocula. The pest usually attacks the early stages when the stalks are soft, which can cause underdevelopment and finally affects population density. The presence of this pest in the Selva Region was recent, since in addition to the fact that it is unknown by the growers, there are no official reports indicating its distribution.

Physicochemical Properties of Soil: Both before burn and after harvesting, soil was observed to be fertile with high nutrient content, a slightly acid pH and good physical properties. The high level of organic matter impacts heavily on the findings, more so because productivity in itinerant agriculture is strongly linked to the release of nutrients by vegetation cut down and the accumulated cuttings burnt. In this sense, more agrobiodiversity of the soil would strengthen characteristics such as resistance to stress and control of ecological processes (pest control, nutrient cycles) (Rossi *et al*., 2010).

The soil texture is considered suitable for growing maize, as in Mexico this crop has a wide distribution over this characteristic, especially in seasonal agriculture (Contreras-Benítez *et al*., 2002). *Da* in the soils studied is also adequate for growing maize. Sánchez (1981) reported similar results in Central American soils used for itinerant agriculture. The lower ρ in T0 was attributable to the large amount of organic matter accumulated over time. Main changes from migratory agricultural practices in physical soil properties in the tropics are in its structure and infiltration capacity.

A neutral pH in soil is suitable for growing maize (Lafitte, 1994). The increase in pH at the end of the growing cycle coincides with the results found by Sánchez (1981) and De las Salas (1987), who attributed it to the effect of accumulated ash due to its high calcium content. The pH tends to acidity due to the geographic location and environmental conditions.

Organic matter reamortization occurs when the clay-humic complexes are not stabilized with the finer fractions of soil. On the contrary, the increased concentration of organic matter in the soil was attributed to decomposition of vegetation incorporated by soil preparation, due to the dynamics exerted by microorganisms because of the high moisture and temperature. An immediate decrease in organic matter from the effect of burning was found. On the other hand, Sánchez (1981) suggested that, as traditionally thought, organic matter in the tropics is not affected by burning, attributing this to its not burning long enough to cause an important decrease. Kotto-Same *et al*. (1997) concluded that fields left to natural fallow again accumulate 9.4 t C/ha/year and that the carbon in the soil remains relatively stable during the slash and burn cycle. However, Gliessman (2002) pointed out that a temperature of 200-300ºC for 20 to 30 minutes can reduce organic matter by up to 85%.

The characteristics typical of the soils under study impact on high concentrations of N, since the soils on the slopes, due to their environmental conditions and nature (highly dynamic), tend to be high in this nutrient. Sánchez (1981) showed that burning volatises most of the C, S and N present in the vegetation, although he stated that some studies in tropical agroecosystems proved that burning and ash did not affect total N content in soil in short term.

No definite behavior of P was observed among the treatments in either cycle, because of the effect of the fallow periods, the presence or absence of burning, or the use of green manure. Higher P after harvesting from the effect of the ash was also found by Sánchez (1981) and De las Salas (1987). In general, the high P content was due to the nature of the soil, agronomic management, its pH and high electrical conductivity. Soils with a higher content in this element in Mexico were located naturally in the tropics, especially in zones with annual precipitation over 1 500 mm (Contreras-Benítez *et al*., 2002). There was no evidence of P deficiency in the itinerant agricultural systems in humid tropical regions, which shows that the small amounts that circulate in the closed nutrient cycle are apparently sufficient to prevent deficiencies under natural conditions (Sánchez 1981). Juo and Manu (1996) concluded that a significant amount of available soluble P was contributed by the ash and by mineralization of fresh wet organic matter, which can be fixed by the oxides in the soil during the growing stage.

The absence of significant differences in the concentration of K was due to the characteristics of the soil itself, which was rich in this element. This favored maize cultivation, since K was the element most extracted from the soil in each harvest. It was found in all of the cells of the plant in relatively large amounts, as an enzymatic activator, favoring the chlorophyll function by transporting glucides and regulating the osmotic pressure of plant cells. K impacted on the phenological variables of the maize although not on the grain yield.

As farm size increased, production intensified and the fallow period was shortened, and the balance of the nutrient cycle was lost in the S-F-B systems (Juo and Manu, 1996). García-Barrios and González-Espinosa (2004) were of the view that reduced fertility of the soil was due both to shorter fallow periods and changes in floristic composition, structure and to the regeneration of forested areas.

The results of principal component analysis for the soil before burning showed that fallowing impacted positively on soil fertility. The three components generated by PCA after harvesting were considered strategic indicators for determining sustainability in the agroecosystems evaluated. In the cluster of systems after harvesting (Fig. 5), similar behavior was observed for soil sampling done before burning, which showed the high fertility of the territory was not affected by burning or by the maize agricultural cycle.

Erosion: According to the results, erosivity and erodibility in the territory was high, mainly because of steep slopes and heavy precipitation. In southern Mexico, losses of 345 t/ha/yr have been recorded in soils with a 15% slope and precipitation of 2 691 mm (Uribe-Gómez *et al*. 2002), in dry tropics, 130 t/ha/yr, with annual precipitation of 1200 mm and 15% slope (Quiroga, 2000), in traditional hillside systems, and 200 t/ha/yr on a 30% slope (Sheng, 1990). The erosion rate depends on soil properties and management after clearing and burning (Sánchez, 1981), and this process along with runoff and leaching affect the availability of nutrients released during burning (mainly K, Mg, Ca, nitrates and sulfates) (Juo and Manu, 1996).

Table 1. Temperature and rainfall data.

	Rainfall mm	**Maximum temperatura** ºC	**Minimum temperature** ºC	**Mean temperature** ºC
		Spring-summer cycle (April to September)		
April	299.00	39.30	18.13	28.72
May	550.00	37.70	20.17	28.93
June	105.00	36.98	19.37	28.18
July	346.00	37.17	20.12	28.64
August	349.50	38.52	19.47	28.99
September	390.00	39.00	20.82	29.91
Total	2039.50	38.11±0.97	19.68±0.92	28.89±0.57
		Autumn-winter cycle (November to April)		
November	172.20	37.30	19.85	28.58
December	106.00	37.02	18.75	27.88
January	471.00	30.77	18.47	24.62
February	246.00	38.05	18.33	28.19
March	157.00	37.88	18.50	28.19
April	75.00	40.57	18.38	29.48
Total	1227.20	36.93±3.27	18.71±0.57	27.82±1.66

Table 2. Sorensen similarity index (S_s) in the *acahuales*. Spring-summer cycle.

	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T0**
T1	-	8	14	16	11	6	11	8
T2	10.95	-	7	12	8	4	8	5
T3	13.72	7.86	-	26	10	16	21	10
T4	16.49	14.28	23.00	-	12	12	19	11
T5	12.50	10.66	9.61	12.12	-	14	18	6
T6	6.06	4.65	13.91	10.90	17.82	-	18	4
T7	10.28	8.51	17.07	16.10	16.51	15.00	-	7
T0	9.30	6.84	9.80	11.34	6.81	4.04	6.54	-

At the top the number of species in common and at the bottom the value of S

Table 3. Analysis of phenological variables of maize.

									Spring-Summer cycle											
																	S.E.D.			
	E	**MF**	**FF**	**PM**	**E**	**MF**	**FF**	**PM**	**E**	**MF**	**FF**	**PM**	**E**	**MF**	**FF**	**PM**	**E**	**MF**	**FF**	**PM**
T1	7	72	75	130	7	72	75	130	8	70	74	127	8	70	74	127	0.9	1.7	0.9	2.6
T2	6	69	73	125	6	69	73	125	6	67	70	121	6	67	70	121	-	1.7	2.6	1.9
T3	5	66	70	126	5	66	70	126	6	70	76	125	6	70	76	125	0.9	1.1	5.2	0.9
T4	6	66	69	125	6	66	69	125	6	73	77	127	6	73	77	127	-	1.5	1.7	1.7
T5	5	71	75	125	5	71	75	125	7	78	81	131	7	78	81	131	1.7	0.3	0.0	5.2
T6	6	71	74	125	6	71	74	125	7	81	84	139	7	81	84	139	0.9	0.3	0.9	1.9
T7	5	74	78	128	5	74	78	128	6	70	74	126	6	70	74	126	0.9	3.5	3.5	1.7
S.E.D.	0.9	1.7	2.8	2.2	0.9	1.7	2.8	2.2	0.9	2.1	2.5	2.1	0.9	2.1	2.5	2.1				
									Autumn-Winter cycle											
																	S.E.D.			
	E	**MF**	**FF**	**PM**	**E**	**MF**	**FF**	**PM**	**E**	**MF**	**FF**	**PM**	**E**	**MF**	**FF**	**PM**	**E**	**MF**	**FF**	**PM**
T1'	6	81	88	133	6	85	90	135	7	81	88	134	7	75	82	137	0.9	6.2	5.2	2.6
T2'	6	81	88	133	6	85	90	135	7	81	88	134	7	75	82	137	0.9	6.2	5.2	2.6
T3'	6	73	79	140	6	78	84	141	6	73	78	131	6	82	87	139	-	6.5	6.4	6.9
T4'	6	73	79	140	6	78	84	141	6	73	78	131	6	82	87	139	-	6.5	6.4	6.9
T5'	6	82	86	138	6	82	86	132	6	76	85	138	6	76	82	137	-	5.2	2.8	4.3
T6'	6	82	86	138	6	82	86	132	6	76	85	138	6	76	82	137	-	5.2	2.8	4.3
S.E.D		5.4	5.2	3.9	-	3.8	3.3	5.0	0.6	4.4	5.6	3.8	0.6	4.1	3.2	1.3				

E. emergence; MF. male flowering; FF. Female flowering; PM. Physiological maturity

Table 4. *P*-values for variables damage by stem borer and stalk lodging.

	Spring-Summer cycle			Autumn-Winter cycle	
	Stem borer damage	**Stalk lodging**		**Stem borer damage**	**Stalk lodging**
T1	0.455	0.310	T1’	0.661	0.660
T2	0.148		T2’	0.542	0.112
T3	0.916	0.183	T3’	0.746	0.448
T4	0.954		T4’	0.765	0.768
T5	0.992	0.909	T5’	0.309	0.706
T6	0.050		T6’	0.441	0.162
T7	0.278				

Table 5. *P*-values for physicochemical properties of soils ($P<0.05$). Spring-summer cycle.

	Before burning												
	Sand	**Clay**	**Silt**	ρ	**pH**	**EC**	**OM**	**N**	**P**	**K**	**Ca**	**Mg**	**C:N**
T1	0.106	0.240	0.041	0.056	0.354	0.201	0.728	0.257	0.550	0.642	0.180	0.283	0.818
T2	0.119	0.347	0.694	0.334	0.018	0.000	0.005	0.861	0.011	0.052	0.451	0.683	0.052
T3	0.472	0.067	0.011	0.015	0.078	0.269	0.013	0.248	0.067	0.271	0.052	0.224	0.049
T4	0.673	0.314	0.785	0.002	0.342	0.070	0.066	0.577	0.963	0.488	0.599	0.143	0.003
T5	0.038	0.083	0.515	0.589	0.266	0.001	0.043	0.001	0.566	0.398	0.451	0.401	0.019
T6	0.293	0.117	0.045	0.038	0.009	0.025	0.005	0.000	0.033	0.413	0.008	0.041	0.012
T7	0.585	0.010	0.014	0.013	0.016	0.323	0.001	0.249	0.874	0.001	0.503	0.080	0.002
T0	0.885	0.854	0.854	0.905	0.138	0.008	0.000	0.309	0.203	0.000	0.197	0.545	0.000
	After harvesting												
	Sand	**Clay**	**Silt**	ρ	**pH**	**EC**	**OM**	**N**	**P**	**K**	**Ca**	**Mg**	**C:N**
T1	0.148	0.229	0.115	0.056	0.075	0.643	0.935	0.176	0.186	0.515	0.102	0.028	0.288
T2	0.796	0.470	0.727	0.334	0.069	0.366	0.885	0.922	0.777	0.241	0.046	0.100	0.058
T3	0.599	0.361	0.390	0.015	0.072	0.089	0.253	0.212	0.514	0.583	0.074	0.040	0.846
T4	0.475	0.943	0.225	0.002	0.330	0.039	0.618	0.919	0.218	0.045	0.119	0.606	0.057
T5	0.215	0.580	0.340	0.589	0.507	0.941	0.569	0.722	0.037	0.706	0.145	0.599	0.968
T6	0.024	0.397	0.158	0.038	0.001	0.001	0.022	0.001	0.003	0.320	0.003	0.011	0.350
T7	0.392	0.921	0.341	0.013	0.000	0.485	0.088	0.081	0.791	0.022	0.297	0.037	0.366
T0	0.600	0.651	0.369	0.905	0.665	0.092	0.701	0.393	0.939	0.036	0.175	0.082	0.500

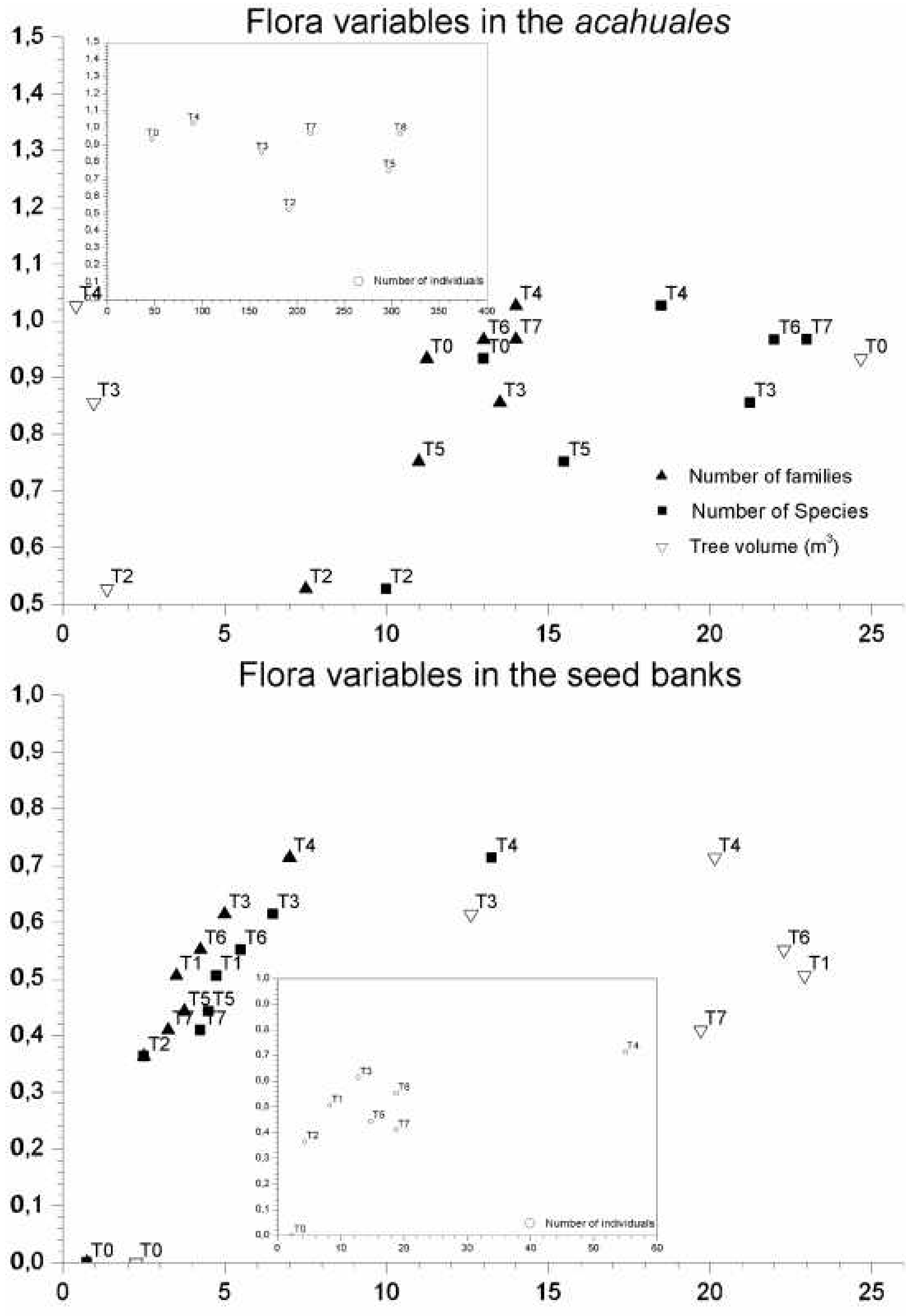

Fig. 1 Variables of flora in *acahuales* and seed bank. Spring-summer cycle.

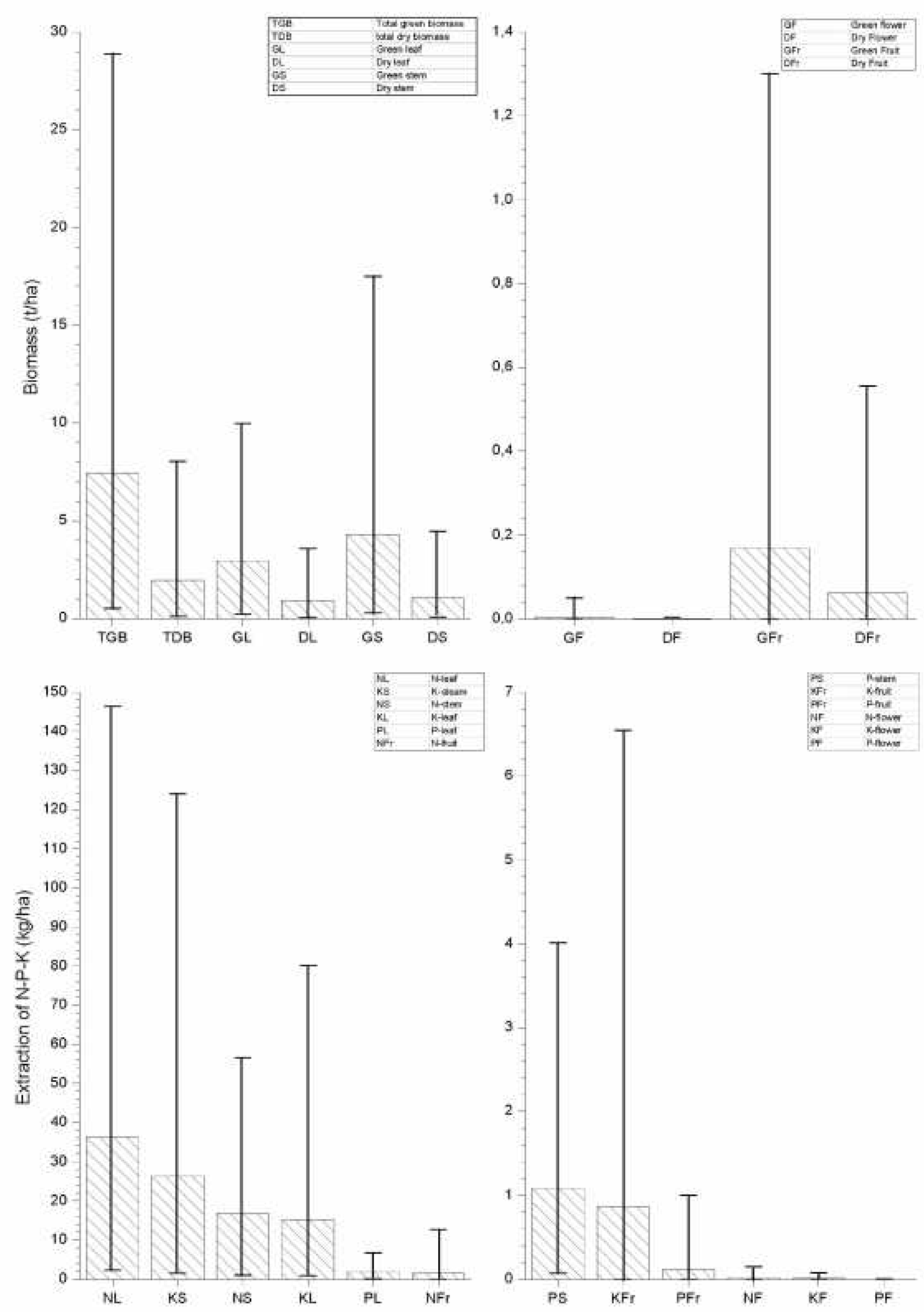

Fig. 2 Biomass and extraction of major elements (N, P, K) by vegetative parts of the *nescafé* plant. Autumn-winter cycle.

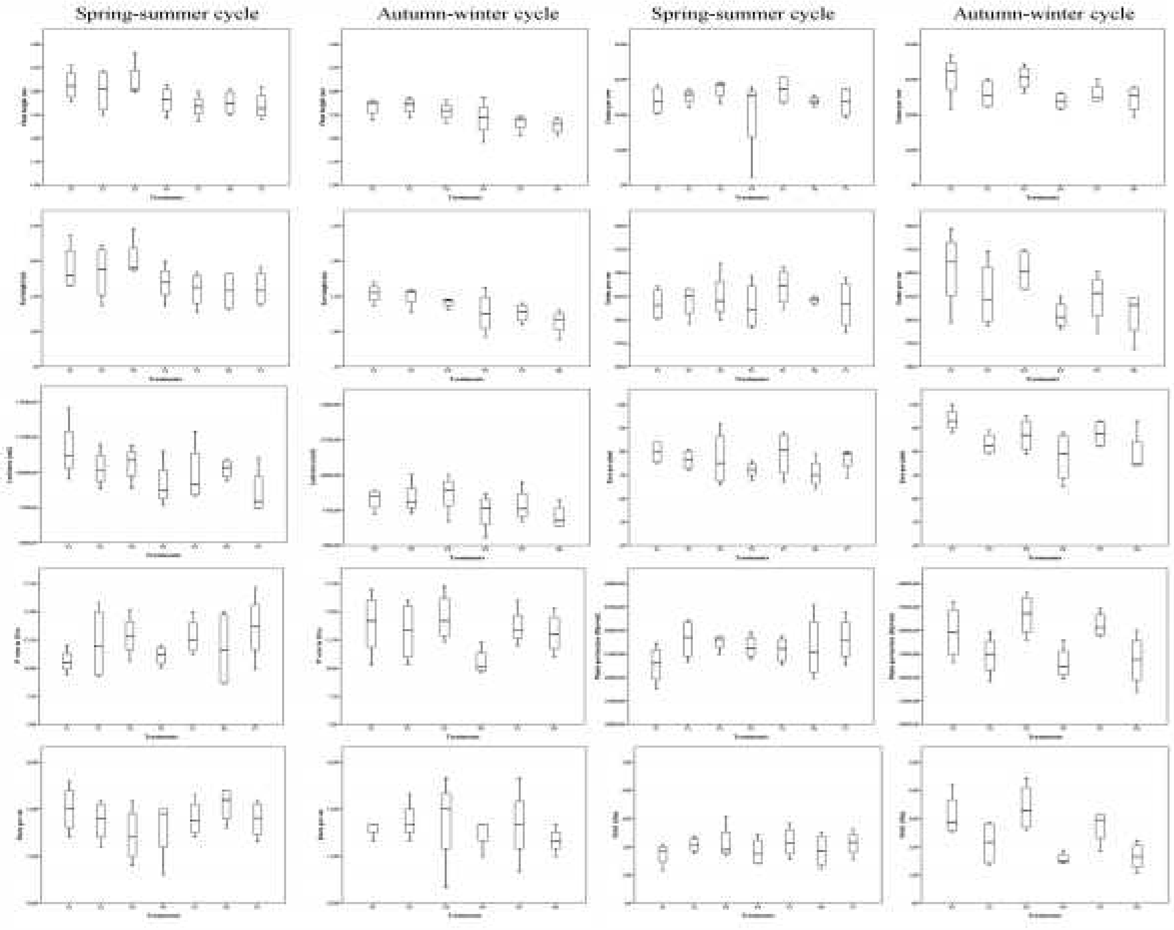

Fig. 3 Box diagrams of agronomic variables of maize.

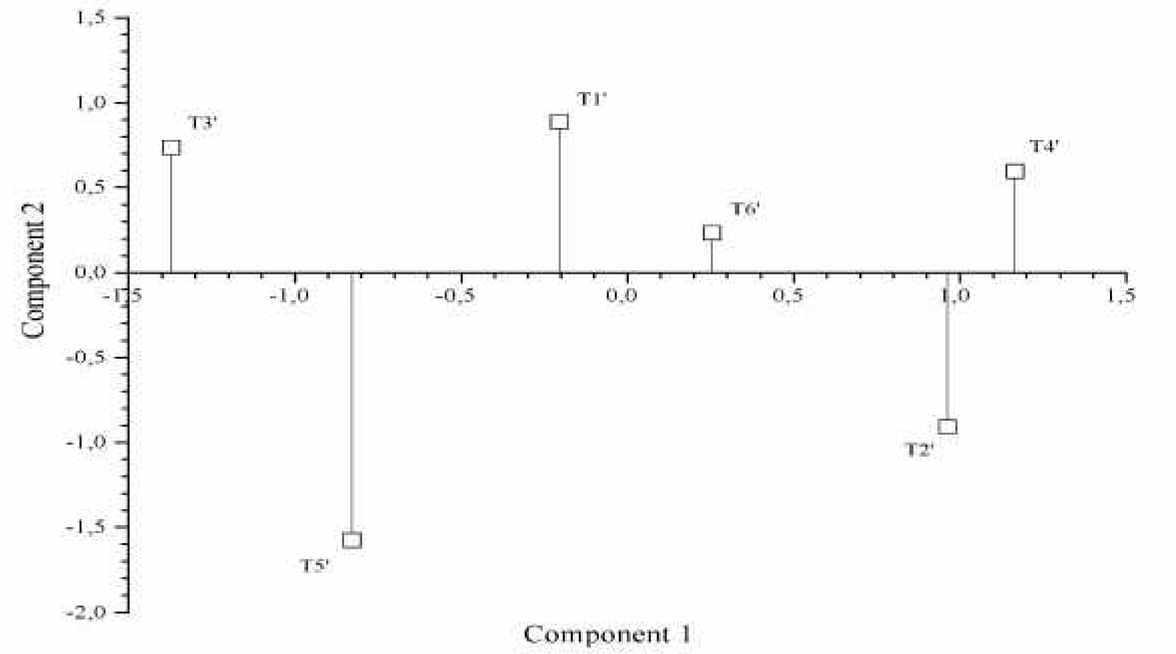

Fig. 4 Principal components for agronomic variables of maize in traditional and alternative practices. Autumn-winter cycle.

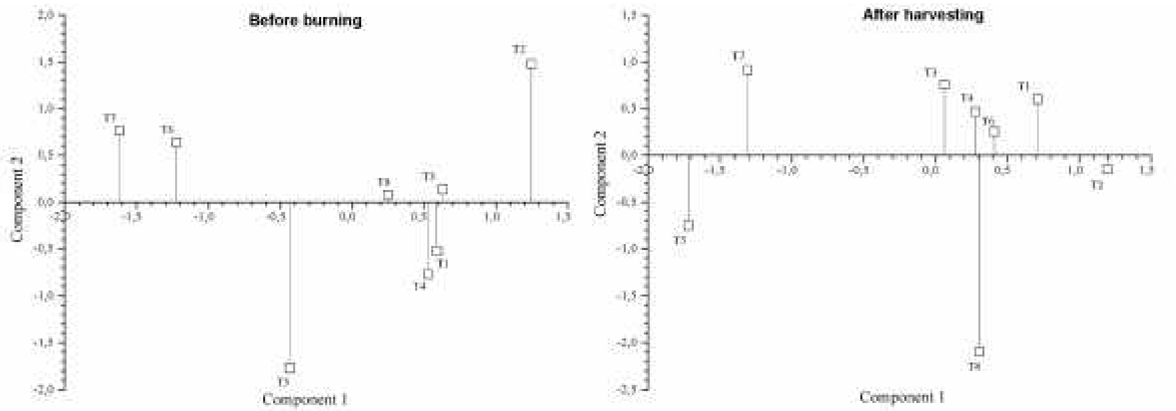

Fig. 5 Principal components of chemical properties of soils before burning and after harvesting, in *acahuales* in S-F-B agriculture. Spring-summer cycle.

Based on the results, it was determined that periods of fallow did not significantly influence soil erosion, as eroded volume did not correlate with fallow. Therefore, erosion was similar on burnt land or with no plant cover, where slope and specific topography maintained a similar geoform. Furthermore, stumps, branches and trunks scattered over the surface by the effect of S-F, which correlate positively in size with fallow, do not constitute a physical impediment reducing soil erosion. Govaerts *et al*. (2009) suggested zero tilling and retention of cuttings as an alternative practice to reduce soil loss in mountainous areas of Mexico.

The result of correlation analysis showed that slopes in the territory studied have similar mountainous conditions and that the orography does not determine the particular soil management, which is a factor needed for production of basics and generalized farming culture.

Conclusion: Agro-environmental sustainability of traditional agriculture in the Selva Region, under the S-F-B system was not seasonally affected by shortened fallow periods. But the floristic diversity, which diminishes as fallow is lengthened, due to consolidation of better adapted species. The model showed that as the number of individuals of the same species rises, the diversity index gradually lowered. Results with nescafé (*Mucuna deeringiana* Bort) as green manure on very stony land were negative, since this crop requires fertile soil, where there is less interspecies competition with endogenous weeds. The contribution of nutrients (N, P, K and organic matter), by *nescafé*, considerably increased the production capacity of the soil. Modification of the sowing density left direct positive influence on the phenological and agronomic characteristics of maize and also on weed control. Decreased distance between rows and plants, and sowing only two seeds per point had a positive effect on maize crop production. Fire used in the S-F-B system inhibited stem borer development in maize by eliminating entomophagous inocula. Treatments with long fallow periods and use of green manure showed more organic matter and nutrients in soil. Erosion from water increased in migratory agricultural systems. Steep topography and stoniness are indicators of low capacity of the territory for primary activities, in which the soil is more apt for other uses. However, the presence of thousand-year-old native societies, which base their economy on traditional agriculture, demonstrate the urgent need to establish alternative measures those respect their own cultural precepts while ensuring the basic food security of the indigenous populations, so a vision of the region's future should promote optimized soil use.

REFERENCES

Adiku, S. G. K., J. W. Jones, F. K. Kumaga, and A. Tonyigah (2009). Effects of crop rotation and fallow residue management on maize growth, yield and soil carbon in a savannah-forest transition zone of Ghana. J. Agr. Sci. 147(3): 313-322.

Brush, S. B. and H. R. Perales (2007). A maize landscape. Ethnicity and agro-biodiversity in Chiapas Mexico. Agr. Ecosyst. Environ. 1(21): 211-221.

Chambers, K. J., S. B. Brush, M. N, Grote, and P. Gepts (2007). Describing maize (*Zea mays* L.) landrace persistence in the Bajío of Mexico. A survey of 1940s and 1950s collection locations. Econ. Bot. 61(1): 60–72.

Cheruiyot, E. K., L. M. Mumera, L. N. Nakhone, and S. M. Mwonga (2003). Effect of legume managed fallow on weeds and soil nitrogen in following maize (*Zea mays* L.) and wheat (*Triticum* aestivum L.) crops in the Rift Valley highlands of Kenya. Aust. J. Exp. Agr. 43(6): 597-604.

Contreras-Benítez, J. A., I. Nikolskii-Gavrilov, L. A. Aceves-Navarro, R. Arteaga-Ramírez, M. Escalona-Maurice, and D.S. Fernández-Reynoso

(2002). Pronóstico del cambio de algunas propiedades de los suelos agrícolas al modificarse las condiciones microclimáticas. Agrociencia. 36(03): 267-277.

Daniels A. E., K. Painter, and J. Southworth (2008). Milpa imprint on the tropical dry forest landscape in Yucatan, Mexico. Remote sensing and field measurement of edge vegetation. Agr. Ecosyst. Environ. 123(4): 293–304.

De Calzadilla, J., W. Guerra, and V. Torres (2002). El uso y abuso de las transformaciones matemáticas. Aplicaciones en modelos de análisis de varianza. Cub. J. Agr. Sci. 36(2): 103-106.

Eastmond, A., and B. Faust (2006). Farmers, fires, and forests. A green alternative to shifting cultivation for conservation of the Maya forest? Landscape Urban Plan. 74(3-4): 267-284.

García-Barrios, L., and M. González-Espinosa (2004). Change in oak to pine dominance in secondary forests may reduce shifting agriculture yields experimental evidence from Chiapas, Mexico. Agr. Ecosyst. Environ. 102(3): 389-401.

García-Villalpando, J. A., A. Castillo-Morales, M. E. Ramírez-Guzmán, G. Rendón-Sánchez and M. U. Larqué-Saavedra (2001). Comparación de los procedimientos de Tukey, Duncan, Dunnett, Hsu y Bechhofer para la selección de medias. Agrociencia, 35: 79-86.

Gliessman, S. R. (2002). Agroecología. procesos ecológicos en agricultura sostenible. Ed. AGRUCO-CATIE; Turrialba (Costa Rica). 358 p.

Govaerts, B., K. D. Sayre, B. Goudeseune, P. De Corte, K. Lichter, L. Dendooven, and J. Deckers (2009). Conservation agriculture as a sustainable option for the central Mexican highlands. Soil Till. Res. 103(2): 222–230.

Granados, D., and G. F. López (2001). Ecología de poblaciones vegetales. Ed. Universidad Autónoma Chapingo; Chapingo (México). 144 p.

Hernández, E., S. Levy, and E. Bello (1995). La roza-tumba-quema en Yucatán, in: Hernández, E., S. Levy, and E. Bello (Eds.), La milpa en Yucatán. un sistema de producción agrícola tradicional. Colegio de Postgraduados, México, pp. 35-86.

Instituto Nacional de Estadística Geografía e Informática (INEGI) (2000). Anuario Estadístico del estado de Chiapas. INEGI-Gobierno del Estado de Chiapas, Tuxtla (México).

Juo, A. S. R., and A. Manu (1996). Chemical dynamics in slash-and-burn agriculture. Agr. Ecosyst. Environ. 58(1): 49-60.

Kaizzi, C. K., H. Ssali, and P. L. G. Vlek (2006). Differential use and benefits of Velvet bean (Mucuna pruriens var. utilis) and N fertilizers in maize production in contrasting agro-ecological zones of E. Uganda. J. Agri. Syst. 88(1): 44-60.

Keleman, A., J. Hellin, and M. R. Bellon (2009). Maize diversity, rural development policy, and farmers' practices. Lessons from Chiapas, Mexico. Geogr. J. 175(1): 52-70.

Kotto-Same, .J, P. L. Woomer, M. Appolinaire and Z. Louis (1997). Carbon dynamics in slash-and-bum agriculture and land use alternatives of the humid forest zone in Cameroon. Agr. Ecosyst. Environ. 65: 245-256.

Lafitte, H. (1994). Identificación de problemas en la producción de maíz tropical. Guía de campo. Ed. Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), México. 122 p.

Ochoa-Gaona, S., and M. González-Espinosa (2000). Land use and deforestation in the highlands of Chiapas, Mexico. Appl. Geogr. 20(1): 17–42.

Perales, H. R., B. F. Benz, and S. B. Brush (2005). Maize diversity and ethnolinguistic diversity in Chiapas, Mexico. PNAS. 102(3): 949–954.

Quiroga, R. R. (2000). Effects maize (*Zea mays* L.), cropping systems and tropical legumes on soil chemical and biochemical properties and suppressiveness to soilborne plant pathogens. Ph. D. Thesis (unpublished). Auburn Univ.

Rossi, J. P., L. Celini, P. Mora, J. Mathieu, E. Lapied, J. Nahmani, J. F. Ponge, and P. Lavelle (2010). Decreasing fallow duration in tropical slash-and-burn agriculture alters soil macroinvertebrate diversity. A case study in southern French Guiana. Agr. Ecosyst. Environ. 135(1-2): 148–154.

Sánchez, P. A. (1981). Suelos del trópico. características y manejo. Ed. Instituto Interamericano de Cooperación para la Agricultura; San José (Costa Rica). 660 p.

Sheng, T. (1990). Soil conservation for small farmers in the humid tropics [Spanish]. Ed. FAO; Roma. 122 p.

Uribe-Gómez, S., N. Francisco-Nicolas, and A. Turrent-Fernández (2002). Pérdida de suelo y nutrimentos en un entisol con prácticas de conservación, en los Tuxtlas, Veracruz; México. Agrociencia, 36: 161-168.

Young, A. R. (1991). Introducción a las ciencias forestales. Ed. LIMUSA; México. 636 p.