Revista Brasileira de Agroecologia
Rev. Bras. de Agroecologia. 5(2): 275-287 (2010)
ISSN: 1980-9735

Monitoring land use and plant cover on an Integrated Agroecological Production System through GIS

Monitoramento do uso da terra e da cobertura vegetal em sistema integrado de produção agroecológico por meio de Sistema de Informação Geográfica

DIAS, José Eduardo 1; ABBOUD, Antonio Carlos de Souza Abboud 1; GUERRA, José Guilherme Marinho 2; SALLES, Rodrigo dos Reis 3; FERREIRA, Vagner Gonçalves 4; SILVA, Jorge Xavier da 5

[1] Departamento de Fitotecnia, Universidade Federal Rural do Rio de Janeiro, Seropédica/ RJ, Brazil, abboud@ufrrj.br; [2] EMBRAPA-Agrobiologia, Seropédica/ RJ, Brazil; [3] Departamentos de Geologia e Recursos Naturais, Universidade Estadual de Campinas, Campinas, SP, Brazil; [4] Setores de Ciências da Terra, Universidade Federal do Paraná, Curitiba, PR, Brazil; [5] Departamento de Geociências, Universidade Federal Rural do Rio de Janeiro, Seropédica/ RJ, Brazil.

RESUMO: O presente trabalho teve como objetivo estudar em detalhe o uso da terra e a cobertura vegetal das 26 glebas que compõem o Sistema Integrado de Produção Agroecológico km 47, durante os anos de 2003 a 2005. Quatro atualizações anuais do uso agrícola das glebas foram realizadas entre janeiro de 2003 a dezembro de 2005 por meio de visitas periódicas ao campo. Documentos cartográficos e interpretação de imagem de alta resolução do Satélite Quick Bird auxiliaram na elaboração do mapeamento digital. Como resultados, foram gerados três mapas por meio de geoprocessamento: (a) riqueza de espécies cultivadas; (b) pousio agrícola e (c) intensidade de uso de leguminosas. Verificou-se alta riqueza de espécies cultivadas, encontrando-se glebas com até 40 espécies vegetais. Esta riqueza encontrava-se distribuída de forma desuniforme no terreno. Verificou-se também alta intensidade de uso da terra, sendo o período de pousio em grande parte da área, de aproximadamente três meses, durante os três anos de estudo. Nestes casos, predominaram os cultivos anuais associados a intenso preparo de solo. O uso de leguminosas para adubação verde no sistema foi menos intenso nas glebas com culturas anuais. Dado que culturas anuais demandam intensa mobilização de terra, práticas como plantio direto, maior uso de adubos verdes e de menor revolvimento do solo seriam recomendadas nessas glebas, para que o manejo do solo dentro de princípios agroecológicos seja expandido para toda área. As técnicas usadas permitiram um tratamento ágil de fenômenos agroecológicos complexos, resultando em uma análise compacta, porém detalhada e de fácil interpretação visual.
PALAVRAS-CHAVE: Agroecologia, uso da terra, riqueza de espécies, pousio agrícola, adubação verde, Processamento de imagens-GIS
ABSTRACT: The objective of this paper is to study in detail the land use and plant cover of an Integrated Agroecological Production System (IAPS) from 2003 through 2005. Four quarterly updating visits were performed on the 26 land units of the System from January 2003 to December 2005. Cartographic documents and QuickBird satellite images were also used to generate the final index maps for agrodiversity, fallow intensity and green manure use intensity. A high diversity of crops was observed. In some land units up to 40 plant species were recorded. However, this diversity was not uniformly distributed throughout the terrain. A high intensity of land use, mostly with annuals was also observed in a large part of the area. In most cases, fallow periods were up to 3 months in 3 years. Since annual crops demand intense tillage, minimum or no tillage practices are recommended for those areas to improve soil conservation. The use of legumes was less frequent on the land units used for annual crops. They were not uniformly distributed throughout the terrain. The results of this research are useful not only for those who are interested in the system itself, but also to validate the hypothesis that through GIS it is possible to summarize complex agroecological information into a visually friendly format, allowing easy interpretation of systemic analyses.
KEY WORDS: Agroecology; Land use; GIS- Image processing; Species richness; Fallow; Green manure.

Correspondências para: abboud@ufrrj.br
Aceito para publicação em 15/11/2010

Introduction

Diversity is the number of different species that make up a community in a particular location. Keeping diversity in an agroecosystem is difficult, because disturbances are more frequent and intense than in natural ecosystems (GLIESSMAN 2001; VADREVU et al. 2008). In Altieri's view (2002a), species diversity is related to the physical environment. The author suggests that a more complex, vertically structured environment in general shelters more species than less complex environments.

This study was conducted at the Sistema Integrado de Produção Agroecológica – SIPA (Integrated Agroecological Production System - IAPS), created in 1993 by a group of researchers and professors from Universidade Federal Rural do Rio de Janeiro, Embrapa-Agrobiologia, and Pesagro-Rio. The research, education, and extension programs developed at the IAPS enforce the practice of agroecology by use of organic farming techniques. This agroecosystem has been developing sequences of organic crops, overlapped on land units and their subdivisions.

From the beginning, soil classification, altitude and slope have been mapped, including land units locations. However, no systematic records of these land units use were kept for many years. Neither has soil chemical fertility been monitored in the different land units that compose the system.

A series of cash crops have followed in time and space, chosen not only for their commercial value, but also for the intention to increase diversity and maximize nutrients cycling. The research activities developed in those lands comprise a wide array of knowledge areas and professionals, who search for interrelations between apparently not related physical and biological phenomena, emphasizing the systemic aspects, and avoiding the reductionist approach (ROCHA 2004). Nevertheless, the IAPS complexity has challenged its managers, since the system places a great deal of importance on animal and plant diversity, the reduction of external inputs and the permanent pursuit of sustainability.

In view of the considerations above, the purposes of this paper are: to present multi-temporal land use and plant cover, from 2003 to 2005, of slope and soil classes; to describe the agricultural use of land units from January 2003 to December 2005; in addition, by means of GIS, to generate maps portraying cultivated species richness, fallow, and legume use intensity at IAPS.

Materials and Methods

Area of study

This work was conducted at the IAPS. It is the result of an institutional agreement between EMBRAPA (Brazilian Agricultural Research Corporation), UFRRJ (Universidade Federal Rural do Rio de Janeiro) and PESAGRO-Rio (Rio de Janeiro State Agricultural Research Institute). The study area is located in the city of Seropédica-RJ, latitude 22o45' S and longitude 43o 42' W. IAPS is an organic production unit with approximately 80 ha of area, where interactive educational, research and extension programs take place (Fig. 1).

IAPS was founded in 1993. Since then, multidisciplinary agroecological research has been conducted on the area, including not only master's and doctorate theses, but trials with cultivars and genotypes of various cultivated species. Also, it has been a site where thousands of annual visitors from all over the country and from abroad, come to develop extension and teaching activities.

Obtaining thematic maps

IAPS's land unit map was obtained in 2003 (Fig. 2). At first an analogical map, it was digitalized and incorporated to the database. Although these land units are used by the farm managers as the territorial reference for choosing the crops each year, they are frequently covered by two or more plant species every season. There are 26 land units where vegetable and fruit production and agroforestry activities are developed. This parcel of IAPS covers approximately 80 ha. The remaining area, not included on the map, are pastures and land reserves.

Georeferenced sampling points

The data was collected using two ASHTECH PROMARK2, single frequency (L1 = 1575.42 MHz), 10-channel GPS receptors, capable of delivering horizontal accuracy of ± (5 mm + 1 ppm) in post processing. The data was processed using the ASHTECH SOLUTIONS 2.6 software.

The coordinates were determined by relative static positioning. A fixed point, located at IAPS, and two mobile points, located in different land units where soil samples were collected, were used to obtain the coordinates. This procedure enabled determining the E and N plane rectangular coordinates of each sampling point in the UTM system, SAD-69.

Processing the georeferenced data and obtaining thematic maps

The cartographic data obtained from all the IAPS area refer to soil classes, level curves, land use and plant cover.

The analogical images of soil classes and level curves were converted into digital images in the tiff format using an A0 scanner. A QuickBird satellite

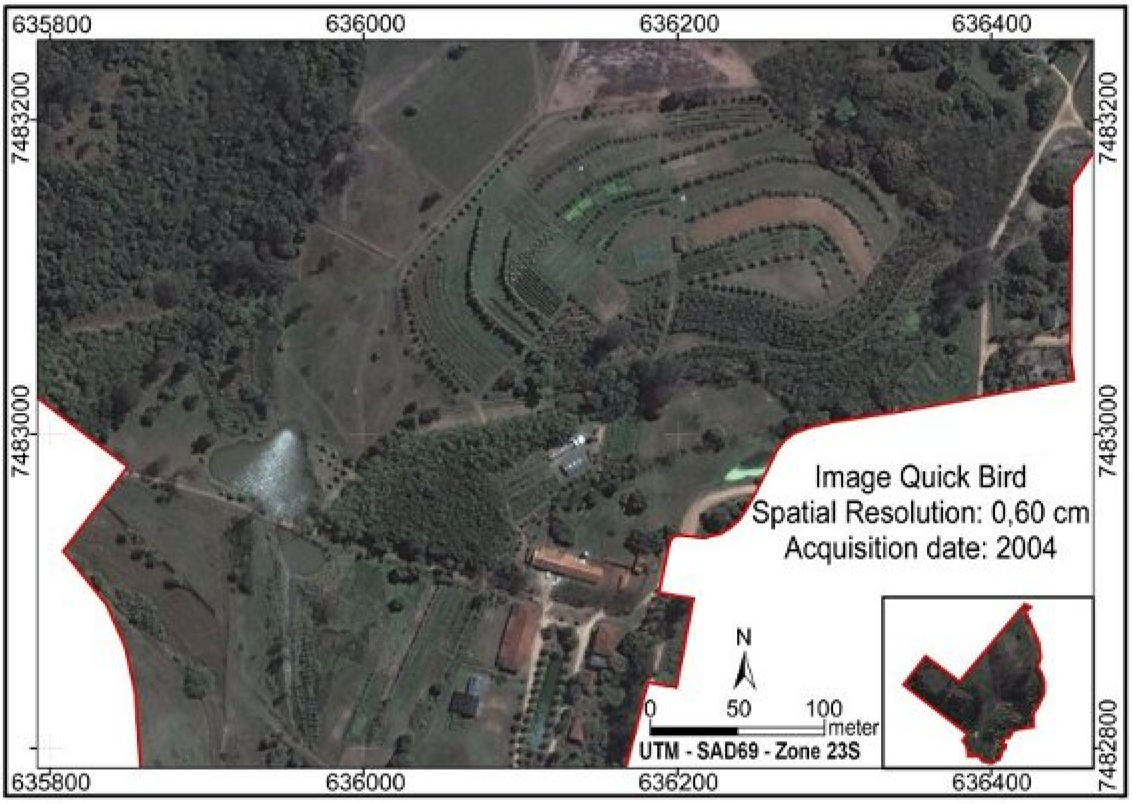

Figure 1: Study area

image of 60 cm resolution was used for redesigning the land units. The image was purchased by Instituto de Tecnologia of UFRRJ in 2004. For georeferencing the image, points were set on the field. The land features were then digitalized into a CAD system, DXF format, then imported into ESRI's ARC GIS® 9 software. The files scanned into TIFF format were converted into ERS, using the ER-MAPPER® software.

ER-MAPPER®, with a linear polynomial algorithm of linear order, was used for georeferencing the ERS format. This method is capable of converting an image without projection or whose projection is unknown. Longitudes (x) and latitudes (y) were assigned to the ERS file using the UTM coordinate system, SAD-69. The point, line and polygon vectorization process was carried out using the ARC GIS 9 software from ESRI. The vectorial files in SHAPEFILE format (.shp) were stored and matched to a table of attributes in a database file (dbf). ESRI's ARC GIS® software was used for geographic treatment of the data by GIS.

Land use maps

Land use records contained in IAPS database before the study consisted of an aerial photograph from 2000. This work enabled generating a new map of the land units, and included a new aerial parcel recently incorporated to IAPS. Quarterly updates of the maps were made in March, June, September and December from January 2003 through March 2005 to record and georeference the changes in the use of the twenty-six IAPS's

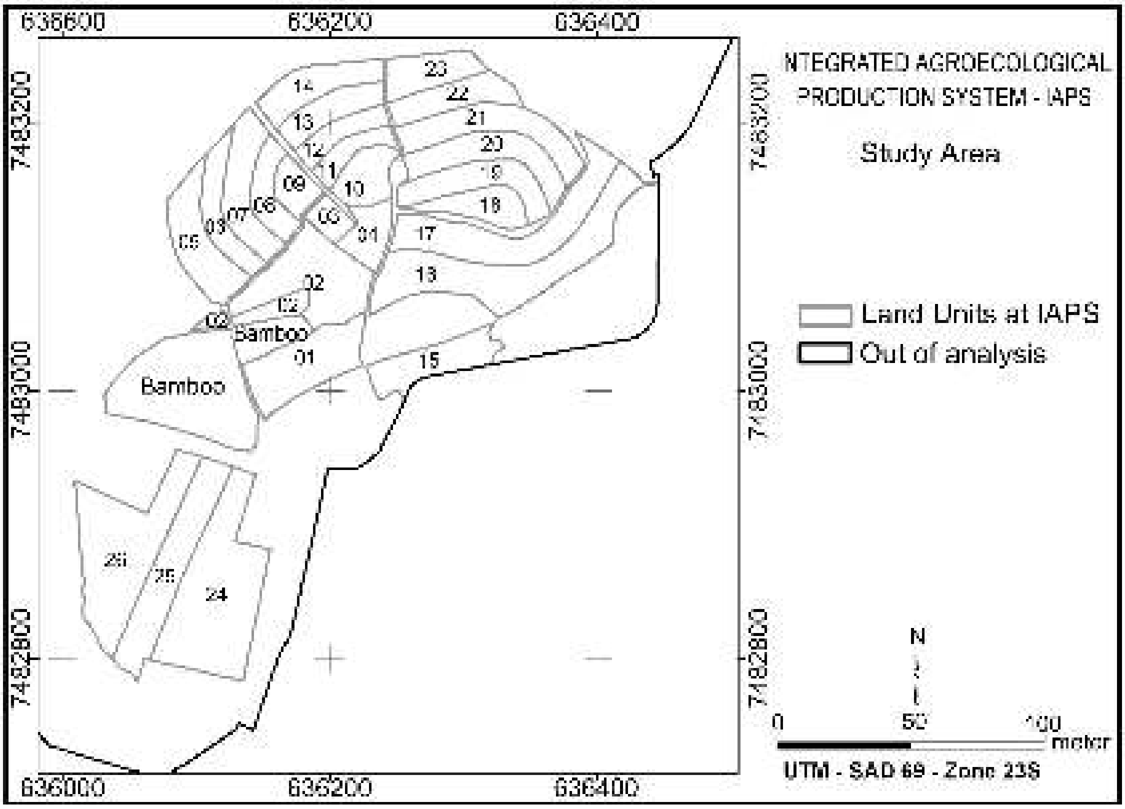

Figure 2: IAPS's land unit map

land units. The records were annotated manually on the blueprints in periodic visits. This step generated twelve digital maps of land use.

To process the images originated from land use updates, maps of cultivated species richness, fallow intensity and legume use intensity were generated from the combination of the twelve land use maps from January 2003 through December 2005, in SHAPEFILE format, using ESRI's ARC GIS® 9.

Cultivated species richness

The twelve land use maps were combined to generate a map of cultivated species richness. The cultivated species richness is the sum of cultivated species in each land unit during the period. If one species were found in the same area in different periods, it would be counted only once.

Fallow intensity

The fallow intensity map was generated from the combination of the same twelve maps. This variable refers to the number of months in which a crop was grown or not in each area.

Legume use intensity

This variable considered the number of months in which any legume was grown for green manure in a particular area. Annual and perennial legumes, manure legume trees, cash crops in rows formed between strips of legume, associated cash and legume crops, and cash crops in agroforestry systems were considered for that purpose.

Results and Discussion

Agricultural use of land units from 2003 to 2005

The twelve land use maps in the different land units updated every three months from January 2003 to December 2005 show that some land units are permanently occupied by perennial crops; others, occupied by perennial and annual crops; and some of them are occupied by annual crops. Land use was the most dynamic in the latter, since land unit management involved continuous crop rotation. This makes interpretation difficult, and requires processing information, so that all the data can be summarized in one map, as we will see next.

Before we start, below is a brief description of land use:

- Land units occupied by perennial crops:

Land unit 01 - rami (*Boehmeria nivea*); grown in part of this land unit for more then ten years. It is used as in natura protein source for egg-laying poultry. This land unit has lines of Gliricidia (*Gliricidia sepium*) separated by 6 meters, forming a crop system characterized by rows, occupied by annual crops of vegetables, corn and beans, and ginger until 2004; in 2005, tropical flowers (*heliconiaceae, musaceae, zingiberaceae*) started to be grown in the rows.

Land units 02, 15 e 16 - taken by agroforestry systems. These units show the highest plant species diversity. There are nearly 40 plant species. Among the best-known cultivated species are different banana cutivars (*Musa* sp.), papaya (*Carica papaya*), cocoa (*Theobroma cacao*), açaí (*Euterpe oleracea*), juçara palm (*Euterpe etuis*), urucum (*Bixa orellana*), star fruit (*Averrhoa carambola*), pineapple (*Ananas comosus*), acerola (*Malphigia glaba*), gliricidia (*Gliricidia sepium*), guapuruvú (*Schizolobium parahybum*), guandu (*Cajanus cajan*), coffee (*Coffea arabica*), eritrinas (*Erythrina speciosa*, *Erythrina* sp.), tahiti lime (*Citrus aurantifolia*), rangpur lime (*Citrus limonia*), leucena (*Leucaena leucocephala*), aroeira (*Schinus* sp), sabiá (*Mimosa caesalpiniaefolia*) pupunha palm (*Bactris gasipaes*), acacia (*Acacia mangium, Acacia auriculiformis*), embaúba (*Cecropia* sp.), black mulberry (*Morus nigra*), angico, eucalyptus (*Eucalyptus* sp.), pitanga

(*Eugenia uniflora*), guava (*Psidium guajava*), heliconia (*Heliconia psitacorum*), orange (*Citrus sinensis*), murici pitanga (*Banisteriopsis pubipetal*).

Land unit 03 - occupied by fig crops (*Ficus carica*).

Land unit 04 - taken by a mixed orchard including (*Malphigia glabra*), cashew (*Anacardim occidental*), breadfruit (*Artocarpus altilis*).

Land unit 05 - a strip of this land unit is taken by papaya (*Carica papaya*), gliricidia (*Gliricidia sepium*) and ponkan (*Citrus reticulata*) and soursop (*Annona muricata*); another strip was taken by custard apple (*Annona squamosa*) until 2004, and was replaced by annual crops.

Land unit 17 - taken by robusta coffee (*Coffea canephora*) and legume tree species (*Gliricidia sepium* e *Erythrina speciosa*).

- Land units occupied by annual crops:

There is intense crop rotation along time and a dynamic polygon design can still be seen within each land unit.

In land units occupied by vegetable gardens (units 1, 5, 6, 7, 9, 10, 11, 12, 21, 22, 24, 25 and 26), there is also a high diversity, because vegetable species are grown simultaneously. The following species were used in vegetable gardens during the study: lettuce (*Lactuca sativa*), leek (*Allium porrum*), chicory (*Cichorium intybus*), beet (*Beta vulgaris*), broccoli (*Brassica oleracea* var. italica), onion (*Allium cepa*), green onion (*Allium fistulosum*), carrot (*Daucus carota*), kale (*Brassica oleracea* var. acephala), New Zealand spinach (*Tetragonia expansa*), cucumber (*Cucumis sativus*), radish (*Rhaphanus sativus*), arugula (*Eruca sativa*), parsley (*Petroselium hortensis*) and Ceylon spinach (*Basella alba*). The information is important as a historic record of the crops in the study period. Data collected between January 2003 and December 2005 are georeferenced and stored at IAPS database and can be accessed by users as guidance for future crop planning. Since one of agroecology recommendations is species diversification, both in space and time, the historic record of crops is the starting point to best planning diversity management. The information in these maps can help us better understand and plan the use of any particular land unit.

Cultivated species richness

The result of combined land use maps is shown on Fig. 3. The richness ranges from zero to 40. Zero was assigned to the area where a weather forecast station is located (out of scope of the analysis). Value 40 refers to an area taken by an agroforestry system.

The agroforestry system has a complex structure, where 40 plant species, including annual and perennial plants, and shrubs and trees were found. Minor richness of cultivated species - rated 20, 15, 14 and 11 were found in crop areas of respectively tropical flowers (*heliconiaceae, musaceae, zingiberaceae*, shaded by *gliricidia*), a sequence of annual crops, associated or not, including legumes, vegetable gardens and agroforestry system. The units that presented richness ranging from 5 to 9 were the areas taken by annual and vegetable crops. Single-cropped areas were given the lowest richness values (4, 3, 2 and 1), had simpler structure and consisted of fruit trees, annual crops and vegetables.

From the point of view of functional diversity - i.e. the biodiversity that effectively serves environmental interests - agroforestry systems have a longer lasting effect than growing vegetables as an exclusive culture. This is because vegetable diversity does not occur all year long, besides being lower. This study did not measure the richness of weeds, especially during fallow periods. Certainly, those weeds contribute to the local diversity and providing environmental services, such as nutrient cycling (AUDE et al. 2003; BARRIOS 2007; GURETZKY et al. 2007), besides attracting, sheltering and feeding natural enemy insects (ZANIN et al. 1997; SMITH et. al. 1999; ALBRECHT 2003; HYVÖNEN et al. 2003; AVIRON et al. 2007).

Many authors consider that the presence of intense biological diversity in agroecosystems is one of the pillars of agroecology (ALTIERI et al. 1983; TILMAN et al. 1996; VANDERMEER et al. 1998; ALTIERI 1999, 2002b; VAN ELSEN, 2000; SYMSTAD et al. 2003; TITTONELL et al. 2005; SMITH et al. 2008). They defend the idea that the larger the number of species in a particular agroecosystem, the larger their primary production and stability (DIAS 2006). However, few studies have explored quantitatively production-oriented agroecological systems diversity; therefore, the question of how many species would be necessary to achieve a desirable degree of stability remains unsolved. Another dimly explored aspect addressed by this study is the geographical distribution of diversity within an agroecosystem.

This study verified that crops in a 14-year old organic agricultural system - therefore a mature one, guided by the principles of Agroecology when the number of species cultivated in vegetable

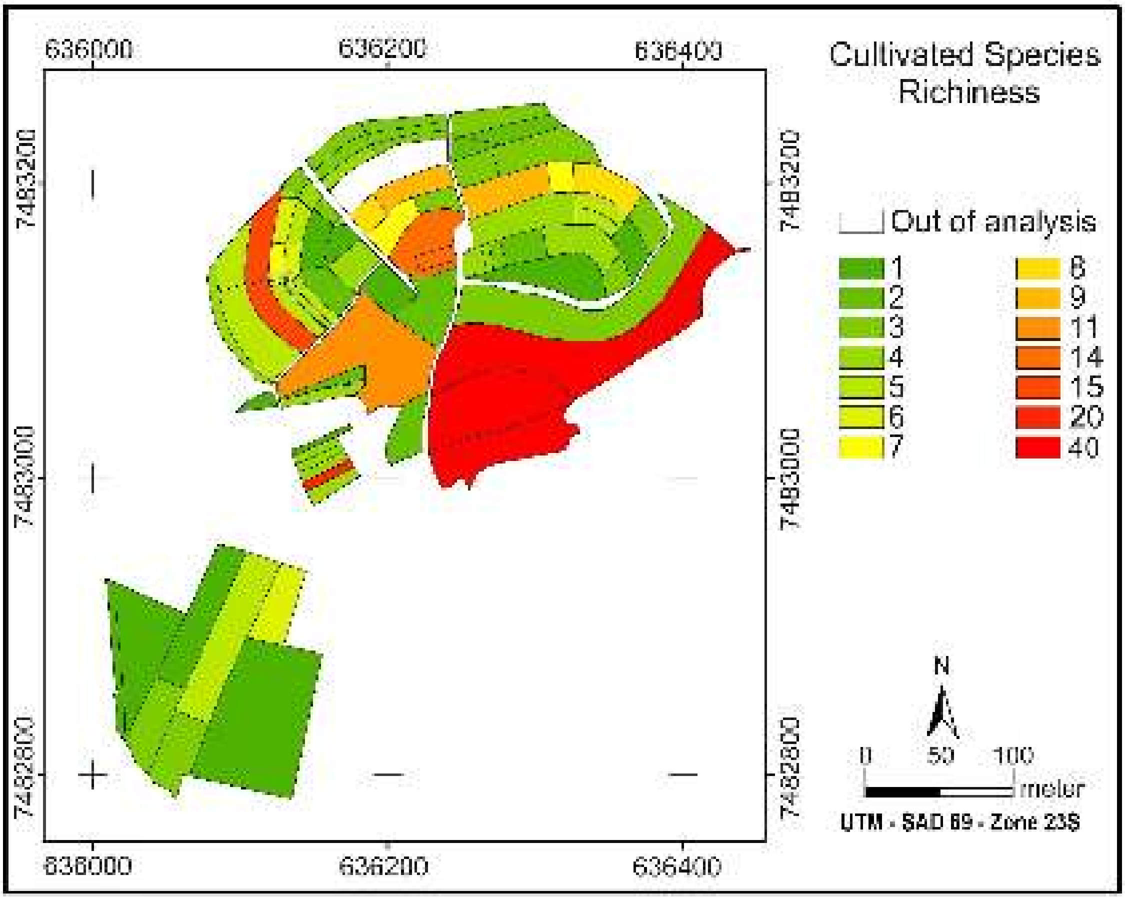

Figure 3: Cultivaded species richness

gardens and other annual cultures for 3 years is small (green and yellow areas in Fig. 3) compared to the large diversity of perennials, including agroforestry systems (areas in orange and red in Fig. 3). The cultivated species richness map indicates that high and low diversity areas are grouped and do not present homogeneous spatial distribution, as it would be desirable, so that the benefits of such diversity could be integrated to the whole area. This scenario calls for a rearrangement of land unit use to equalize low and high diversity areas, alternating agroforestry and annual crops. Alternatively, new species should be brought into low diversity areas.

Another way of looking into this variable is to increase the current diversity in annual crop areas, mainly in areas of extremely low diversity (green areas on the map). The way it is conducted presently, IAPS management is already too intensive, with high workforce demand, especially in annual crop related activities. Introducing higher diversity in these areas could be economically unviable, despite all the ecological benefits. The higher the diversity, the higher workforce demand. Looking at Fig. 2, we can notice a large portion of land used for annual crops, with cultivated species richness nearing 3. This means that, in terms of annual crops, that a single species was used per year in those areas. Other areas, such as land unit 10 (orange portion in the center) and land unit 6 (red strip at northeast), also used as vegetable gardens, showed richness values higher than 10. This unbalance suggests that the diversity of annual crops could be rearranged spatially among the areas assigned for this activity at the IAPS.

Agricultural fallow

The period of agricultural fallow between January 2003 and December 2005 is represented in Fig. 4. This map shows that the number of fallow months was 0, 3, 6, 9, 12, 30, 33 and 36.

Value -1 refers to a weather forecast station, an area out of analysis. Value 36 means that the area was not cultivated during the study period. The areas incorporated to IAPS and stony terrains were left fallow due to limitations for agricultural use.

Values 33 and 30 describe areas that were left fallow for long, also due to soil limitations. Like the other fallow areas, they could become reserves in the future. These areas cover approximately 2.5 ha.

The other areas were laid fallow for a short period. The maximum duration of the fallow period was twelve months, and did not impose any agricultural limitations.

Different from what was observed for cultivated species richness, there is a balanced distribution of use and fallow intensity in the total area. This demonstrates that even in low diversity areas, the intensity of use is high, i.e. these areas are predominantly single cropped, e.g. land unit 20, where manioc is the predominant crop.

Another aspect revealed by Fig. 4 is that many land parcels are used for intensive annual crops are grown without fallow. If on one hand a large diversity of annual species is beneficial, on the other hand intensive soil preparation is detrimental. For that reason, at IAPS a series of programs have been developed to improve the practice of direct planting of vegetables such as the tomato, cabbage, broccoli, cauliflower, taro and green pepper (PONTES 2001; MOREIRA 2003; CASTRO 2004; CASTRO et al. 2004; CESAR 2004), minimizing the effects of conventional preparation.

Legume use intensity

Legume use in an integrated agroecological production system aims to reduce external inputs, primarily nitrogen fertilizers, which are replaced by biological N_2 fixation. Cultivation of legume in grains, annual crops associated with legumes, agroforestry systems and row crops with shrub or tree legumes help reduce the use of fertilizers. All these options have been largely used in this agroecosystem.

The combination of land use maps referring to the period from January 2003 to December 2005 generated the legume use intensity map (Fig. 5), which shows the time when the area was occupied by legumes or any legume was present. These values were found: 0, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36 months.

Value -1 refers to a weather forecast station (out of analysis area). The value 36 means that the area used some sort of green fertilizer on a permanent basis. In these cases, legume was used via agroforestry system, row crops, legume and fruit production associated with legume trees.

Values 33, 30, 27 represent high legume use intensity. The predominant agricultural use was the association of annual and vegetable crops, legumes and vegetable crops.

Values 24, 21, 18, 15 represent annual legume crops, often associated with vegetables and other annual crops. Legume use was less intense (values 12, 9, 6, 3, 0) in areas of single annual crops and single vegetable crops.

The legume use map suggests a time and space unbalance in the use of this important component. Considering the 36 study months, a large neighboring portion of the green area can be

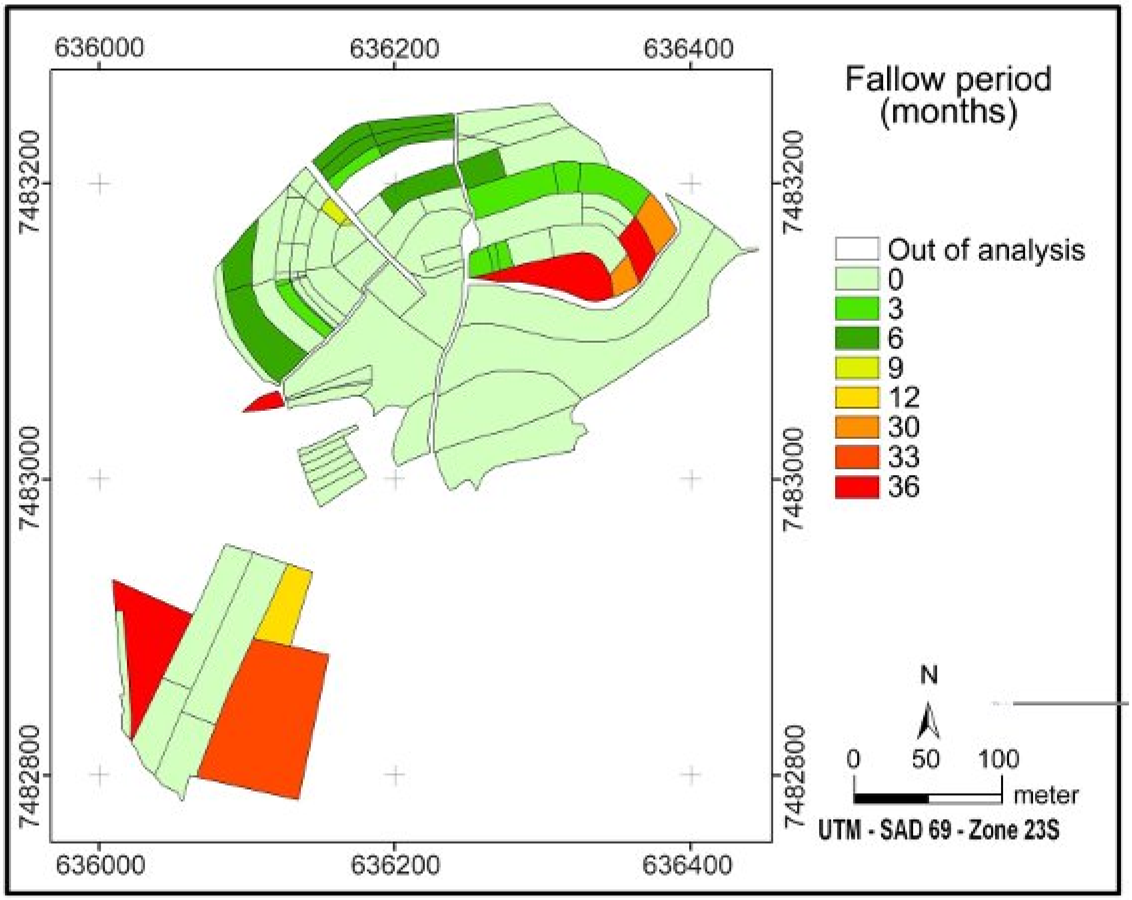

Figure 4: Fallow period

seen, i.e. with 12 months (one third of the whole period) when legumes were grown. Most of these areas are primarily intended for vegetable growing and annual crops. In contrast, there is another region where the use of legumes is concentrated: the agroforestry systems.

The same way we discussed the ideal diversity to ensure stability, the question here is to define the ideal frequency of use of legume as green manure for a particular agroecosystem. This study suggests that the in our agroecosystem, the different kinds of green manure should be spatially rearranged in the same way it was proposed for cultivated species richness.

3.5. Systemic approach

The individual information is trivial and poorly contributes to understanding how the system works. On the other hand, the three maps that resulted from the combination of these twelve maps (Figs. 3, 4 and 5) synthesize the three years of monitoring and data collection. Besides the attributive data, the geographical dimension allow for interpretations that take into consideration the natural heterogeneity of the system.

This is called systemic approach or holistic view of agroecosystem management in practical terms. This concept, although largely used in agroecology literature, includes some subjective, blurry definitions, and is not associated to any operational procedure or method. The use of GIS tool applied

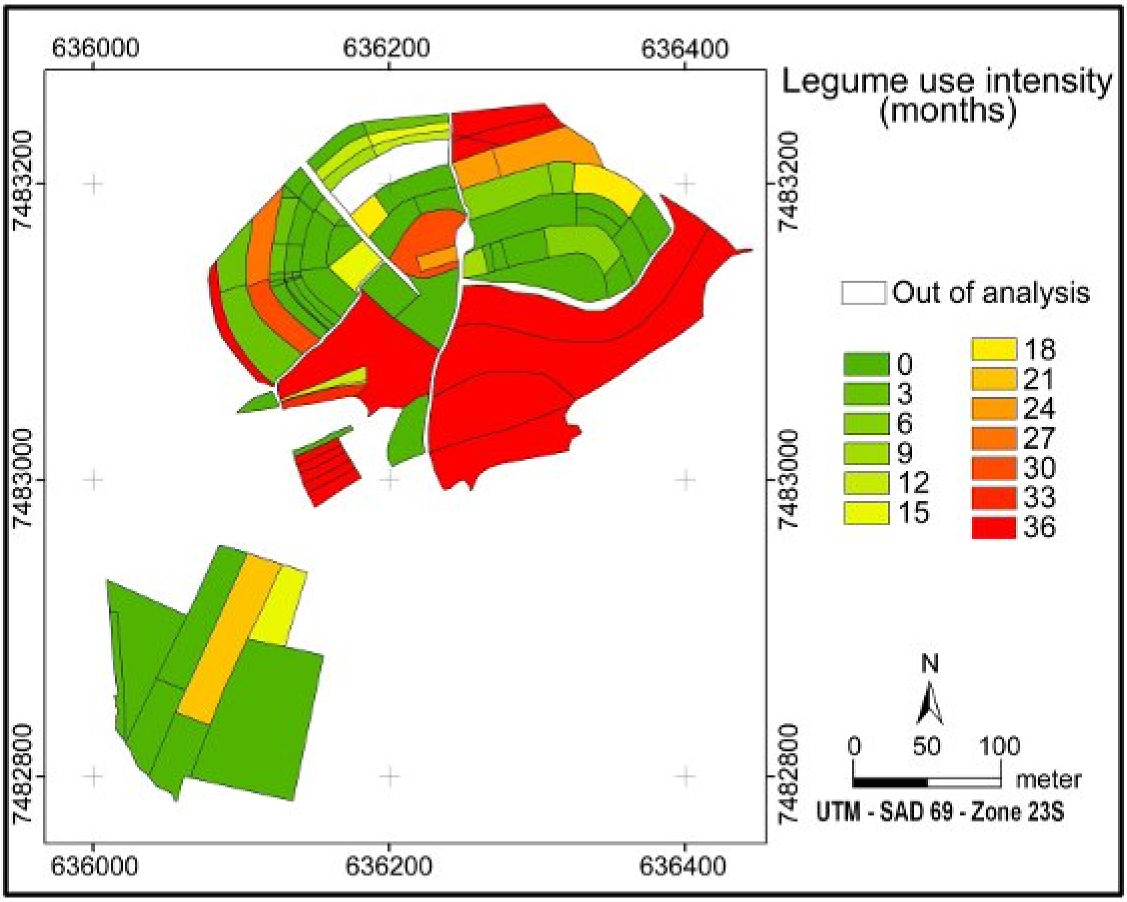

Figure 5: Legume use intensity

to the self-defined holistic science of agroecology (ALTIERI, 1998; XAVIER-DA-SILVA, 2001; COOLS et al. 2003; DALGARRD et al. 2003), is not only justifiable, but also imperative. The reason for this is that punctual studies do not take into consideration the typical heterogeneity of these systems or associate events to a geographical, component required for understand any agroecological event.

Therefore, this work has not only produced results that concern IAPS and its managers, but also validated the hypothesis that GIS enables storing a large amount of data for treatment, analysis, and continuous assessment, summarizing in a visually friendly format complex, holistic phenomena. The larger the volume of data, the safer the diagnoses and forecasts this powerful tool can help us deliver. Therefore, it is essential to monitor the space and time dynamics of land use.

Agriculture is in essence a spatial activity. The late developments of computational tools has enabled more and more users to obtain spatial solutions for problems that have traditionally been solved with analogical tools. Modern special digital models in agriculture or in natural environments may be combined with conventional methodologies, yielding attractive interpretations that could nod be performed only with one or another approach, Such combination of tools may output solutions for different problems in agricultural and natural systems on spatial, or temporal manner.

Modern spatial analysis tools, such as GIS, have been widely used in commercial agriculture areas on the so-called precision agriculture. A wide range of novel applications may be conceived for innovative agroecologial systems. They should be developed not only for research and development project purposes, but also to serve immediate growers' needs. The research presented herein is an example of such achievements. Although it has been conducted on an experimental area, similar protocol could be established for any natural system or farm environment.

Conclusion

The Integrated Agroecological Production System presents high diversity of crops, although not uniformly distributed on the land.

There is high intensity of land use, particularly in annual crops, which requires intensive soil preparation.

Legumes use for green manure is not uniformly distributed on the land, which is required for standardizing the use of this important component in space and time.

The use of GIS parameters was essential for the data acquisition and processing, and the presentation of results in academic format (maps), which can provide information to the management and use of these particular land units, and other agroecological systems in general.

Acknowledgement

The authors wish to thank Conselho Nacional de Pesquisa (CNPq) for the financial support provided to José Eduardo Dias during four years.

References

ALBRECHT, H. Suitability of arable weeds as indicator organisms to evaluate species conservation effects of management um agricultural ecosystems. Agriculture Ecosystems and Environment. 98, p. 201-211, 2003.

ALTIERI, M.A. An agroecological perspective to guide graduate educational programs in agricultural economics and rural development in Latin America of the XXI Century. Ecological Economics. 27, p. 227-236, 1998.

ALTIERI, M.A. The ecological role of biodiversity in agroecosystems. Agriculture, Ecosystems and Environment. 74, p. 19-31, 1999.

ALTIERI, M.A. Agroecologia: bases cientificas para uma agricultura sustentável. Guaíba: Agropecuária, 2002a.,529p.

ALTIERI, M.A. Agroecology: the science of natural resource management for poor farmers in marginal environments. **Agriculture, Ecosystems and Environment**. 93, p. 1-24, 2002b.

ALTIERI, M.A. et. al. Developing Sustainable Agroecosystems. **BioScience**. 33, 45-49, 1983.

AUDE, E. et. al. Vegetation diversity of conventional and organic hedgerows in Denmark. **Agriculture, Ecosystems and Environment**. 99, p.135-147, 2003.

AVIRON, S. et al.. Effects of agri-environmental measures, site and landscapes conditions on butterfly diversity of Swiss grassland. **Agriculture, Ecosystems and Environment**. 122, p. 295-304, 2007.

BARRIOS, E.. Soil biota, ecosystem services and productivity. Ecological Economics. 64, p. 269-285, 2007

CASTRO, C.M. Plantio direto e aporte de nitrogênio na produção orgânica de berinjela (Solanum melongena L.). Seropédica, 2004. 107 p. Tese (Doutorado) - Universidade Federal Rural do Rio de Janeiro,

CASTRO, C.M. et. al. Adubação verde como fonte de nitrogênio para a cultura da berinjela em sistema orgânico. **Pesquisa Agropecuária. Brasileira**. 39, p.779-785, 2004.

CESAR, M.N.Z. Desempenho de duas cultivares de pimentão (Capsicum annuunt), em sistema orgânico de produção, submetido a desbaste de ramos e consorciado com crotalária juncea. Seropédica, 2004. 57 p. Dissertação (Mestrado) - Universidade Federal Rural do Rio de Janeiro.

COOLS, N. et. al.. Towards an integration of conventional land evaluation methods and farmers soil suitability assessment: a case study in northwestern Syria. **Agriculture, Ecosystems and Environment**. 98, p. 327-342, 2003

DALGAARD, D. et. al. Agroecology, scaling and interdisciplinarity. **Agriculture, Ecosystems and Environment**. 100, p. 39-51, 2003

DIAS, S. C. Planejando estudos de diversidade e riqueza: uma abordagem para estudantes de graduação. **Acta Scientiarum.** Biological Sciences. 26 (4), p. 373-379. 2006.

GLIESSMAN, R. S. **Agroecologia: processos ecológicos em agricultura sustentável**: Porto Alegre: Universidade Federal do Rio Grande do Sul, 653p, 2001.

GURETZKY, J.A. et. al. Plant species richness in relation to pasture position, management, and scale. **Agriculture, Ecosystems and Environment**. 122, p. 387-391, 2007.

HYVÖNEN, T. et. al. Weed species diversity and community composition in organic and conventional cropping of spring cereals. **Agriculture, Ecosystems and Environment**. 97, p.131-149, 2003

MOREIRA, V.F. Produção de biomassa de guandu a partir de diferentes densidades de plantio e cultivo de brócolos em faixas intercalares sob manejo orgânico. Seropédica, 2003. 66 p. Dissertação (Mestrado)- Universidade Federal Rural do Rio de Janeiro.

PONTES, K.L.M. Avaliação da produção orgânica de tomateiro rasteiro (*Licopersicon escalentum* Mill.) em dois sistemas de plantio após pré-cultivo de sorgo consorciado com girassol. Seropédica, 2001. 165 p. Dissertação (Mestrado)- Universidade Federal Rural do Rio de Janeiro.

ROCHA, R.E. 2004. Implantação de uma base de dados georreferenciada para monitoramento e avaliação da fertilidade do solo no Sistema Integrado de Produção Agroecológica (SIPA - Fazendinha). Seropédica, 2004. 222p. Tese (Doutorado) - Universidade Federal Rural do Rio de Janeiro.

SMITH, H. et. al. Uncropped edges of arable fields managed for biodiversity do not increase weed occurrence in adjacent crops. **Biological Conservation**. 89. p. 107-111, 1999

SMITH, R.G. et. al. Effects of crops diversity on agroecosystem function: crop yield response. **Ecosystems**. 11. p. 355-366, 2008

SYMSTAD, A.J. et. al. Long-term and large scale perspectives and the relationship between biodiversity and ecosystem functioning. **BioScience**. 53. p. 89-98, 2003.

TILMAN, D. et. al. Productivity and sustainability influenced by diversity in grassland ecosystems. **Nature**. 379. p. 715-720, 1996.

TITTONELL, P. et. al. Exploring diversity soil fertility management of smallholder farmers in western Kenya II. Within farm variability in resource allocation, nutrient flows and soil fertility status. **Agriculture, Ecosystems and Environment**. 110. p. 166-184, 2005.

VADREVU, K.P. et. al. Case study of an Integrated framework for quantifying agroecosystem health. **Ecosystems**. 11. p. 283-306, 2008.

VAN ELSEN, T. Species diversity as a talk for organic agriculture in Europe. **Agriculture, Ecosystems and Environment.** 77. p. 101-109, 2000.

VANDERMEER, J. et. al.. Global change and multi-species agroecosystems: concepts and issues. **Agriculture, Ecosystems and Environment**. 7. p. 1-22,1998

XAVIER-DA-SILVA, J. **Geoprocessamento para análise ambiental.** Rio de Janeiro: Ed do autor.2001, 228 p.

ZANIN, G. et. al... Ecological interpretation of weed flora dynamics under different tillage systems **Agriculture, Ecosystems and Environment**. 66. p.177-188, 1997.