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Land evaluation for agrarian reform : a case study for Brazil

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Abbreviations

AR	Agrarian Reform
CEC	Cation Exchange Capacity
IBGE	Brazilian Institute of Geography and Statistics
INCRA	National Institute for Colonization and Agrarian Reform
FAO	Food and Agricultural Organization
GIS	Geographic Information System
LARISSA	Land Resource Information and Suitability System for Family Agriculture
LCC	Land Capability Classification
PCA	Principal component Analyses
SIATe	Land Evaluation System for Family Agriculture Suitability
SLQ	Supply of Land Quality indicators
SLQSRC	Total supply of land quality and regional condition indicators
SRC	Supply of Regional Condition indicators
MST	Landless Rural Workers Movement

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1 Introduction

Land evaluation may be defined as 'the process of assessment of land performance when used for specific purposes' (FAO, 1976), or as 'all methods that explain or predict the use potential of land' (Van Diepen *et al*., 1991). Land evaluation is a key tool for land use planning, either by individual land users, by groups of land users, or by society as a whole. There is a diverse set of analytical techniques that may be used to describe land uses, to predict the response of land to these in physical, social and economic terms, and to optimize land use in the face of multiple objectives and constraints (FAO, 1976).

Modern land evaluation has been developed historically as a practical application of soil science and soil mapping. In fact, there is a substantial overlap between soil survey and land evaluation (Dent & Young, 1981). Soil surveys normally include the evaluation of more generalized land use types. Vice versa, the process of land evaluation, which consists of a number of basic surveys, always includes soil survey. Moreover, soil maps are often the main basis for land evaluation because other environmental factors, such as climate, vary at larger scales (Van Diepen *et al*., 1991). These reasons have resulted in a dominant role of soil surveyors in land evaluation. And even though recently other disciplines have become more important, soil surveying continues to play an important role.

One of the first modern land evaluation tools was the land capability classification (LCC) system (Klingebiel & Montgomery, 1961), developed in the fifties by the United States Department of Agriculture (USDA). Originally, the LCC was developed for soil conservation planning at the farm scale in the USA. Since then many evaluation systems have been developed in different countries. Most of these systems are derived from the LCC system and supplemented with local expert knowledge (Van Diepen *et al*., 1991).

In the seventies the Food and Agriculture Organization (FAO) of the United Nations suggested the 'Framework for Land Evaluation' (FAO, 1976) to create a standard in terminology and methodology. The concepts of this framework are considered standard practice in several reference works (Dent & Young, 1981; Landon, 1984; Euroconsult, 1989). However, a weak point of the methodology is that it delivers qualitative rather than quantitative predictions of land performance. With the increasing application and capacity of computers to handle spatially distributed data sets there was growing need for more quantified predictions of land performance (Van Diepen *et al*., 1991). Yet, quantified methods require more detailed models of land performance, which usually have high data requirements. In areas of the world where adequate data is scarce, or in application areas with knowledge gaps, qualitative and semi-qualitative models based partly on expert judgment still have an important role to play (Rossiter, 1996).

The current trend is to include social and economic variables in prediction models, as most problems to achieve the integration of land use planning and land management are not technical but related to human factors (Pieri, 1997). Moreover, prediction models are designed to deliver several alternative options from which the stakeholder can choose, rather than to provide on single clear-cut solutions (Bouma, 1997).

Agrarian reform in Brazil

Brazil is characterized by an extreme unequal distribution of ownership over agricultural land that historically dates back to colonial times. Over the time, the unequal distribution became worse by local politics that mostly supported large landowners, the so-called 'latifundia', with easy access to property rights, public facilities, investments, and subsidies (Deiniger, 1998; Guanzirolli, 1999). A total agricultural area of 353 million hectares is distributed over 4.8 million landowners (IBGE, 1996). From these 4.8 million landowners, 2.4 million (50 %) possess less than 10 hectares, covering 2.2 % of the area. On the other hand, landowners possessing more than 1,000 hectares represent 1 % of the total landowners (49 thousand) while their lands occupy 45 % of the total surface area (Table 1).

Table 1: Classes of landowners and total area (IBGE, 1996)

	Farm size (ha)				
	< 10	≥ 10 and < 100	≥ 100 and < 500	≥ 500 and < 1000	≥ 1000
Number of farms	2 402 374 (49.7 %)	1 916 487 (39.6 %)	411 557 (8.5 %)	58 407 (1.2 %)	49 358 (1 %)
Area (ha)	7 882 194 (2.2 %)	62 693 586 (17.7 %)	83 355 220 (23.6 %)	40 186 297 (11.4 %)	159 493 949 (45.1 %)

The numbers mentioned above do not even take into account the roughly 4.5 million rural families without land and 25 million peasants that work in temporary agricultural jobs

(Rossetto & Alvares, 2001). Yet, according to the Landless Rural Workers Movement (MST) approximately 120 to 130 million ha of the total agricultural area is abandoned or strongly underutilized (Rossetto & Alvares, 2001; MST, 2002), while the Brazilian government estimates this area to 100 million ha (Ministry of Agrarian Development, 1999b). Regardless of the source or the exact values, these numbers underline the fact that the problem is not the lack, but rather the distribution and access to agricultural land.

In addition to the unequal distribution of agricultural lands, Brazil is also a country with an extreme unequal distribution of income with around 32 million people living below the poverty line. Poverty levels are related to wide differences in regional development, education, health, land and capital possessions, and public spending. The northeast, with 30 % of the country's population, concentrates 55 % of all the poor in Brazil. About 33 % of the population in this region is living in poverty, compared with 11 % in the richer southeast. Poverty is also unequally divided between rural and urban areas. In 1990 in rural areas, 53 % of the population lived below the poverty line in contrast to 18 % in urban areas (United Nations, 1997).

Inequality in land distribution and rural poverty and the resulting demands for land reforms led in the sixties to the start of the Agrarian Reform (AR), a process that is still current in today's Brazil. It became officially effective with the adoption of a new land reform law in 1964 (Law 4504, Art. 1º §1º). This land reform law regulates the rights and obligations concerning rural property. It states that all rural properties that do not fulfill their social functions can be expropriated by the Brazilian state for the benefits of AR. To fulfill their social functions, rural properties need to a) provide in the well-being of the owners as well those who work the land, b) maintain a satisfactorily production level, c) conserve the natural resources, and d) observe the legal laws that regulate the working relations between them who work and them who possess the land. Conform this law AR is a set of measures that aim to promote a better distribution of land by altering ownership and land use, to take care of social justice for and rights of both farmers and landless, and to increase productivity.

Since the 1960's more than five hundred thousand families have been settled within the framework of the AR (Guanzirolli, 1999; Ministry of Agrarian Development, 1999a; Bacelar de Araújo, 2000). Only in the period between 1993 and 1997 alone an area of 6.6 million hectares was expropriated for this purpose (Guanzirolli, 1999). A further 120,000 families, supported by social movements, have occupied underutilized or neglected land and are waiting for it to be handed over while living in camps in extreme poverty and poor conditions (Rossetto & Alvares, 2001).

It is understandable that AR is a controversial process and subject to an aggressive debate. After all, there are many stakeholders with different shares and diverging opinions involved. Moreover, AR is necessarily dealing with land property and expropriation of unproductive land, which are very sensitive issues in developing regions. On the other hand, the fact that the problem is the unequal land distribution rather than the lack of agricultural land makes Brazil one of the few countries, where it is still possible to redistribute land without damaging the farming sector that is responsible for the country's exportable surpluses (Guanziroli, 1999).

Current land evaluation procedure

In Brazil, the National Institute for Colonization and Agrarian Reform (INCRA) is responsible for the implementation of the AR at a national level. INCRA has two main options to obtain land for the AR. The most common way is that INCRA buys the land and reallocate it to the landless. About 62 % of land used for AR is obtained this way (INCRA, 2001). The settlers subsequently reimburse the value of land over a period of 20 years without needing to pay interest.

A substantial part (about 11 %) of the land redistributed by INCRA is land that was illegally possessed and subsequently expropriated judicatory by the Ministry of Justice (INCRA, 2001). All over the country, the total of land under suspicion of being illegally held is approximately 100 to 120 million hectares. This represents almost three times the surface area of Germany. For example in the north of Brazil no less than 55 million hectare are under suspect to be held illegally (Ministry of Agrarian Development, 1999c).

Conform the law 'Normative Instruction 31' (INCRA/DF, 1999), INCRA utilizes the LCC concepts of Klingebiel & Montgomery (1961) to evaluate land before obtaining and redistributing it. The LCC system is one of the best-known examples of interpretive groupings of soils and the one most widely used over the world and adapted to local circumstances. Soil map units are grouped on the basis of responsiveness to management and similarities in hazards, limitations, or risks. The groupings of the capability classification are defined for arable farming as the most preferred land use. Capability refers to long-term proper use of soils for crop production without land degradation (Van Diepen *et al.*, 1991).

The LCC system is attractive due to its simplified class structure: class 'I' represents the most suited land for annual crops following down to class 'VIII' representing the land unsuited for agriculture. The advantage of the system is that it easy to understand, but it has a number of important disadvantages as well. It is extremely subjective (Focht, 1998) and does not consider social, cultural and economic variables (Guanziroli *et al*., 1999). Moreover, it does not consider environmental variables except soil conditions and climate.

Focht (1998) studied how subjective the LCC system was by asking five experts with different professional background to apply the criteria of the LCC system to evaluate the same area (A sugar cane farm of 1990 ha in Piracicaba, São Paulo state). The outcomes of the different classifications showed a moderate to weak similarity (Figure 1) indicating that the evaluators' influence on the results of the classification is significant.

The limitations of the LCC system are well known within INCRA. In several publications INCRA reports of failures of settlements projects that are related to problems that could have been detected if the appropriate soil factors (e.g. plant nutrients, available water, slope) and socio-economic factors (e.g. available infrastructure and technical assistance) would have been analyzed (Guanziroli, 1992; Bittencourt *et al*., 1999; Sparovek *et al*., 2000).

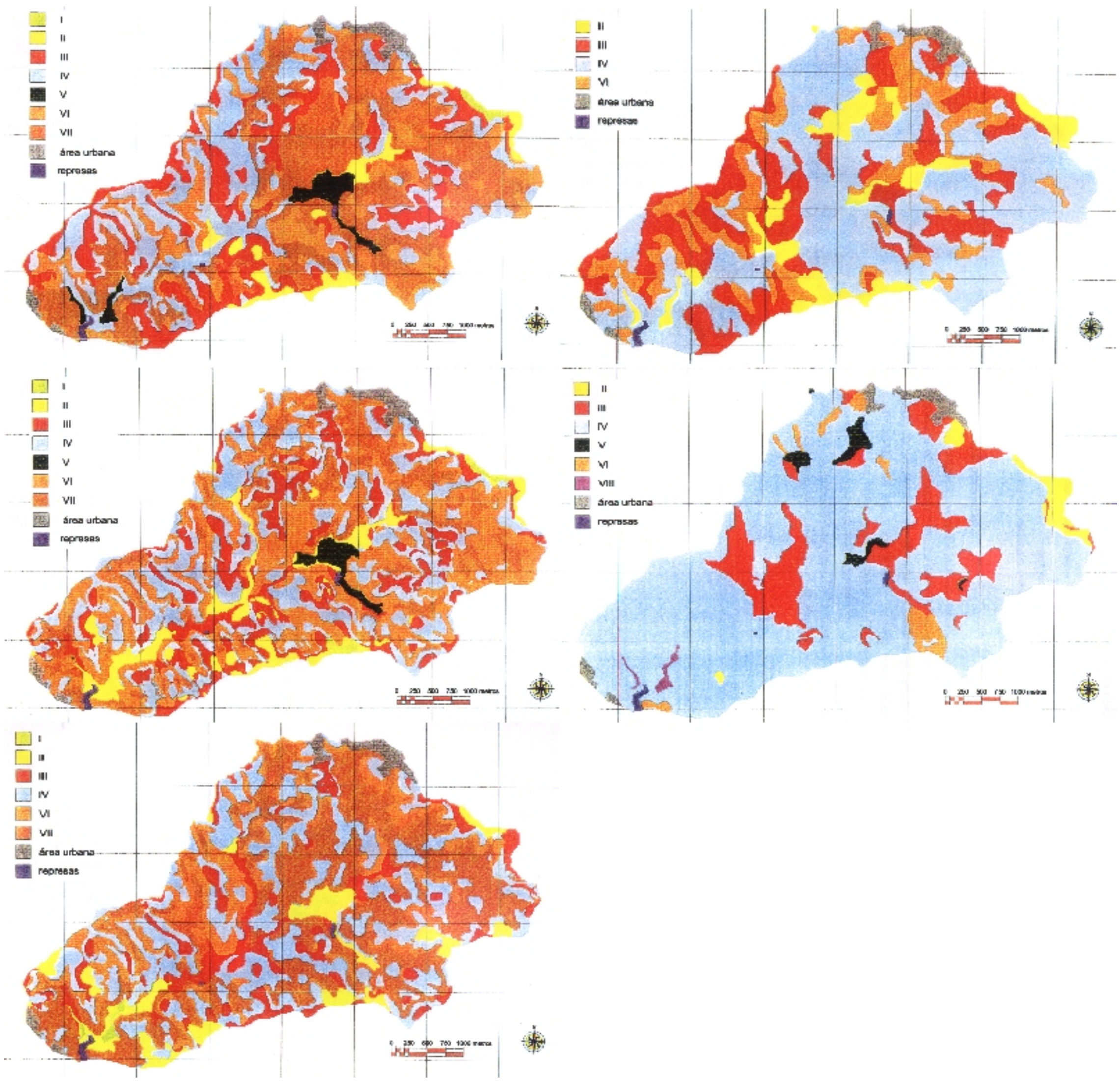

Figure 1: Five independent classification results of a sugarcane farm near Piracicaba, São Paulo state according to the Land Capability Classification system

SIATe model

To overcome some of the limitations of the LCC system, the University of São Paulo in cooperation with INCRA developed a new system, named SIATe ('Sistema de Avaliação da Viabilidade das Terras para Agricultura Familiar' or 'Land Evaluation System for Family Agriculture Suitability'). SIATe has been designed to support decisions on land evaluation for the Brazilian AR and thus to substitute the currently used methods (Sparovek *et al.*, 2000; Sparovek *et al.*, 2002). SIATe is based on the land suitability concepts developed by FAO (1976). It is a modular program with internal modules related to the supply of land quality indicators (SLQ module), the supply of regional condition indicators (SRC module), and an agronomic and economic evaluation (Analytical module). A schematic representation of SIATe is given in Figure 2. The indicators used in these modules have been defined after countrywide surveys and are chosen to represent the natural and regional resources that are most determining for agricultural production in specifically settlement projects. The system was developed to be applicable by INCRA's staff without increasing significantly the time and the resources needed in land evaluation procedures. Therefore it requires only minimal knowledge and training for its countrywide implementation (Sparovek *et al*., 2000).

To evaluate a given location, the SIATe model needs information on land quality and regional condition indicators for that particular location. In two separate modules (the SLQ and SRC modules) and using internal decision rules, this information is converted into scores for the supply of nine land quality and fourteen regional condition indicators respectively. A score can range from 1 to 5 for each of these indicators, with 1 representing very restricted conditions (i.e., a very restricted supply) up to 5 representing no restriction in supply (i.e., conditions are not restricted). The intermediate values are 2 for little restricted, 3 for moderately restricted, and 4 for restricted conditions. Next, in both the modules, the scores are integrated in an overall supply score that can range from 0 to 100. The value of 100 represents the situation in which all indicators received a score of 5, i.e., there are no restrictions in the supply of land quality or regional condition indicators. The score 0 on the other hand represents the situation in which all indicators are equal to 1, i.e., the supply of all land quality or regional condition indicators is very restricted.

A third module, the analytical module, consists out of an agronomic compatibility analyses and an economical feasibility analyses. For the agronomic compatibility analyses it uses an external database with information on the minimum requirements of the main land uses (e.g. cultivation of sugarcane, rice, corn, beans, cassava, or milk and beef production). The requirements are based on the results of the above-mentioned countrywide survey. During this survey, information was gathered about amongst others the production of these land uses by family agriculture and the regional condition and land quality indicators in which these crops prevail. They are expressed in scores for land qualities and regional conditions demands. These scores are defined in the same way as the scoring of land quality and regional condition indicators. Thus, the demands of each particular land use for the nine land quality and fourteen regional conditions indicators are expressed as scores from 1 to 5. These scores are summarized into an overall score ranging from 0 to 100. Here, 0 indicates that the crop has very low demands for all land quality and regional condition indicators. A score of 100 on the other hand indicates that the crop does not tolerate any restriction in the supply of land qualities and regional conditions.

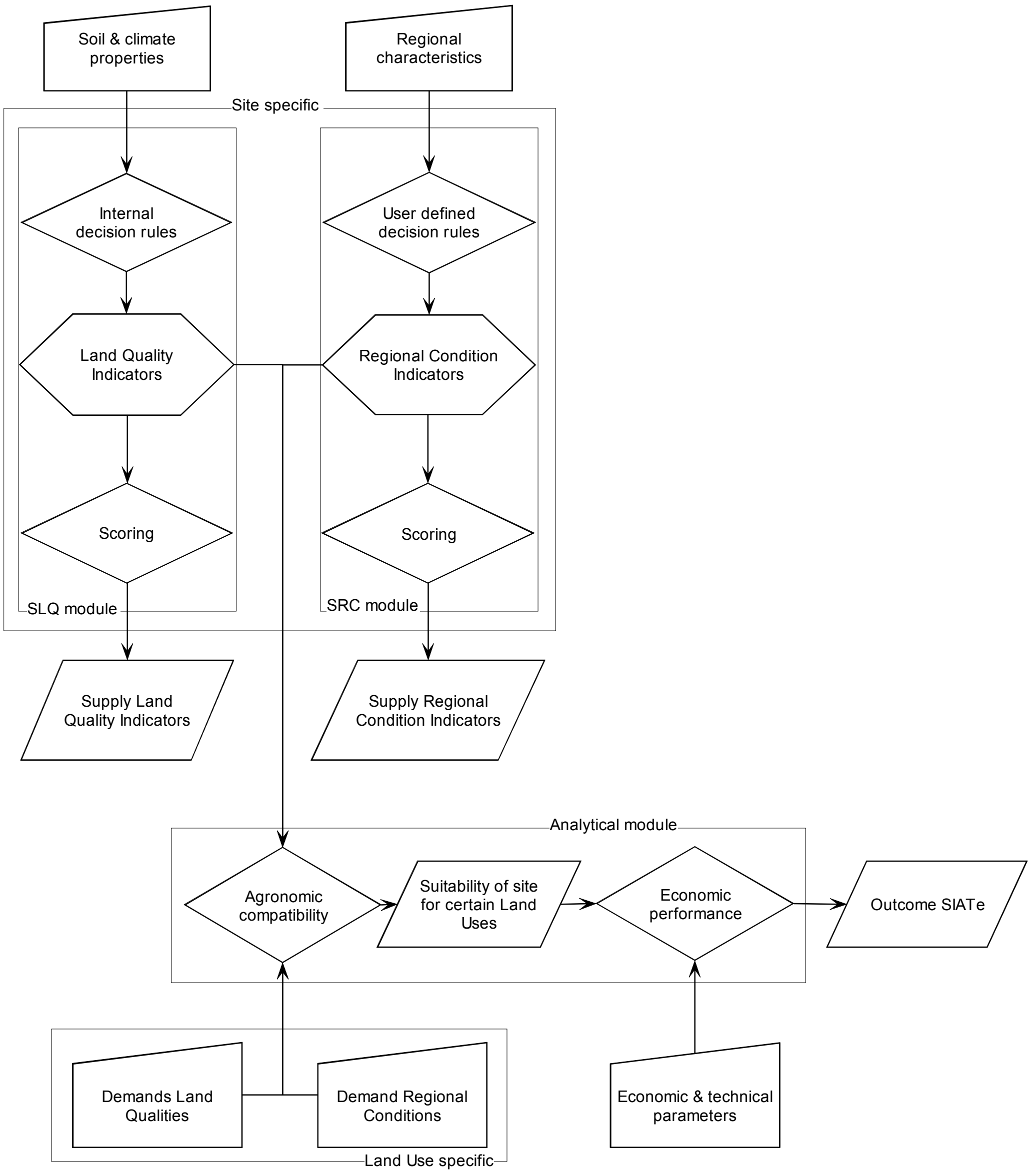

Figure 2: Schematic representation of the SIATe ('Land Evaluation System for Family Agriculture Suitability') developed by Sparovek *et al*. (2000)

The analytical module evaluates the compatibility of supplies and demands for each of the land uses. Low scores for SLQ or SRC indicate that the location under study is suitable only for commodity crops with low demands. The deviation between the supplies and demands are presented as positive or negative values. A negative value indicates that the demands of the commodity crop surpass the supplies making that location unsuited for the selected crop. A positive deviation indicates that the supplies surpass the demands of the commodity crop indicating that the location is suitable for the selected crop. Moreover, it shows that improvements or intensification of use of the selected crop is possible. A deviation close or equal to zero indicates that conditions are suitable for the selected crop, but possibilities to improve or intensify the production are limited.

Next, an analysis of the economic feasibility is carried out. This analysis is based on economical and technical parameters, e.g. expected productivity, costs and benefits of production, regional income. This economic feasibility is based on two assumptions. The expected income of a settler needs to be equal or larger than the average regional income. And the annual saving capacity of a settler should be equal or larger than the annual payments of the land to INCRA.

The final outcome of SIATe gives an suggestion on land uses that can be used for the location under investigation. Based on these land uses, SIATe reports on the area available for cultivation, the number of families that can be settled on the location, the size of property per family, and the expected income and saving capacity.

Up-scaling SIATe to regional scale

The original SIATe model was developed for farm planning at a local scale. However, there exists a strong demand for a model that can be applied at a national level and which will allow a better understanding of the most important differences in land quality and regional condition indicators as well as their influence on the process of land evaluation for AR. The research work presented in this thesis stems from this demand and aims to support and optimize the decision-making process on AR at a national scale.

For this study the SLQ and SRC modules of SIATe were adopted to be used on a national level. The new model, named LARISSA (Land Resource Information and Suitability System for Family Agriculture) was designed to detect regional differences and identify the better areas for AR. LARISSA follows a similar approach as the framework for large-scale soil map evaluations for general agricultural purposes (FAO, 1976) as suggested by Ramalho *et al*. (1978). It is also quite similar to the approach for the application of Land Capability

Classification for soil conservation planning as suggested by Lepsch *et al*. (1983). The main differences are a stronger technological support by using a computer based framework and specific attention to address family agriculture under the perspective of AR.

The main difference between the SIATe and LARISSA models is that for LARISSA, land quality and regional condition indicators are collected at the municipal and regional level while SIATe uses farm level data. In practice it proved to be impossible to work with all the indicators of SIATe at a national level. To deal with Brazil in its entirety (Figure 3) the research was carried out at reconnaissance level. This level is considered to be adequate to indicate the possibilities of large areas while being cost and time efficient (Dent & Young, 1981). An evaluation at reconnaissance level incorporates spatial generalization and classification to filter out short-range local variation in order to present general overviews (Burrough, 1989). Furthermore a number of indicators were left out because of lack of available information at the required scale. To analyze the input data, a land evaluation process similar to SIATE was performed in a Geographic Information System (GIS). The methodology is further explained in the next chapter.

An additional objective of this study was to identify and collect information that is already available. A disadvantage of working on the scale of national level is that the access to country covering data is restricted. Moreover, the regional differences related to the availability of basic information are enormous. For example, it is far easier to obtain data on socio-economic parameters for the densely populated industrialized southern part of Brazil as for the scarcely populated north. This implies that more general input data has to be used, compatible with information from those areas with more restricted information.

Creating a database with information on land quality and regional condition indicators on national level was a major challenge. The data available in Brazil are often fragmented, focused on limited areas, often only available in hard copies, and difficult to obtain. Thus, to bring together the data for this study took a considerable effort of time and labor. Decisive in this process was the establishment of collaboration with relevant institutes. Although not an easy process in itself, it opened doors to information that would otherwise not have been available. The main two partnerships were with INCRA and the Brazilian Institute of

Geography and Statistics (IBGE). INCRA made available much information on AR, while data on agricultural production was gathered in cooperation with IBGE. Both a requirement for and an additional result of the collaboration with especially INCRA was the communication about the developments and requirements for the model, thus increasing the changes of adaptation of the model by one of the main stakeholders.

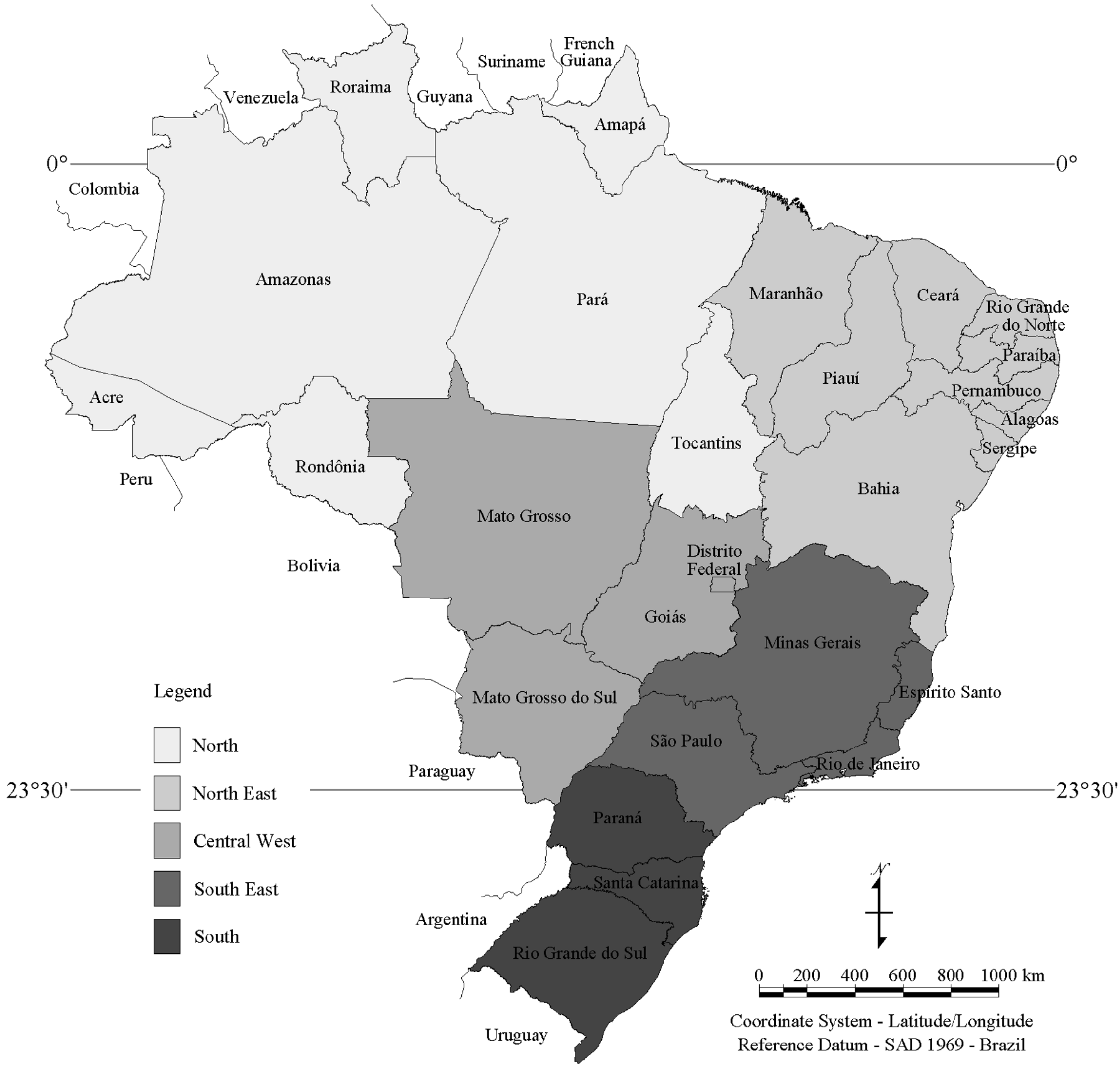

Figure 3: Brazil subdivided in regions and states

Information on land quality and regional condition indicators was derived from a diverge range of publicly available data. As a result, this study gives a rather complete overview of what data is currently available for Brazil in the public domain.

As mentioned above, the principle objective of this study was to support and optimize the decision-making process on AR at a national scale, based upon which the LARISSA model was developed. A complementary objective was to identify and collect available information useful in the development and planning of AR.

The main body of the work presented here is about the validation and evaluation of the LARISSA model, translated into the following objectives:

- To determine the regional differences in the outcome of the land evaluation system LARISSA
- To quantify the relative influence of the natural resource quality indicators on the land evaluation system LARISSA
- To investigate the relative significance of regional condition indicators for the evaluation results of LARISSA
- To study relations between the location of agrarian reform settlements projects and the evaluation results of LARISSA
- To validate land evaluation results by LARISSA.

2 Material and methods

LARISSA is based on two main modules. The first module is related to the Supply of Land Qualities (SLQ) and the other is concerned with the Supply of Regional Conditions (SRC). The major input data for the SLQ module are derived from the soil map of Brazil. Furthermore, input climate data is required. The input data derived from the soil map are described in chapter 2.1, followed by a description of the decision rules used to convert these input soil data into standardized land quality indicators. Subsequently the input climate data and the decision rules how to convert these data into a land quality indicator are described in chapter 2.2. In chapter 2.3 the input data for the SRC module and the decision rules used to convert these input data into regional conditions are presented.

The statistical analyses that were used to evaluate LARISSA and to validate the outcome of land evaluation for AR are defined in chapter 2.4 – 2.6. To evaluate the importance of the different model input variables, two different procedures were used; the Principle Component Analyses (PCA) and a stepwise exclusion procedure (chapter 2.4). PCA is a useful exploratory technique to analyze interrelations among model input indicators and their contribution to the total variance within a dataset. As such, it can be used to estimate the importance of the different indicator variables in the model. By implementing a stepwise exclusion procedure, one may produce a more direct estimate of the influence of the different variables on the model outcome. In such a procedure, model variables are excluded one by one from the model. Each time, the outcome is recalculated, thus giving an indication of the importance of these variables on the model results.

To identify the main differences between the regions in terms of regional conditions and land quality indicators, contingency tables and accompanying Chi-square statistics were employed (chapter 2.4). This statistical technique is extremely useful not only to identify if there are differences between regions, but also to explore existing differences.

Chapter 2.5 describes the method used to see in how far the selection of new areas for settlements were confirm the technical criteria used in the LARISSA model and whether this has been changed over time. To correct for possible geo-political trends (e.g., the preference in the last year for new settlements in the north east) it was examined if there was any trend in the distribution of settlements per region. Finally in chapter 2.6 the method to validate the relation between the outcome of steps of the land evaluation procedure and productivity data is described.

2.1 Soil map and derived soil properties

Brazil has only recently developed a well-described soil classification system 'O Sistema Brasileira de Classificação de Solos' (EMBRAPA, 1999), but pedologists have been using local classification systems since the beginning of the soil mapping in the fifties. As the introduction of this Brazilian classification system is recent, most data to be found on Brazilian soils still use an old classification system, which is described by Camargo *et al*. (1987) and Prado (1995). This classification system was originally based on the old American Classification System as formulated by Badwin *et al*. (1938) and the modified American Classification System as formulated by Thorp & Smith (1949). Later changes in the American System as well as many concepts of the Soil Taxonomy Classification System (Soil Survey Staff, 1975) and some ideas and criteria from the Soil Map of the World (FAO, 1974) were also incorporated in updates of the Old Brazilian Classification System.

Lenthe & Cordeiro (1985) and Camargo *et al.* (1987) related the first taxonomic level of the Brazilian soil classification system to other classification systems. An abstract of their work is given in Table 2. The comparison at the second taxonomic level or higher is not direct and it is more complicated, as the criteria to classify soils are different and typical for the Brazilian soils.

The main source of information used in this research was the soil map 'Mapa de Solos do Brasil', at scale 1: 5,000,000 (EMBRAPA, 1981). This map combines soil map data collected by several governmental agencies in the seventies and eighties. The descriptions of soil types are based on the old Brazilian classification system as described by Prado (1995). The map was digitized in 1992 by the UNEP/GRID-Sioux Falls EROS Data Center of the U.S. Geological Survey in South Dakota. The digitized soil map is distributed as an Arc/Info interchange file. The soil map is composed of 2,815 polygons representing soil-mapping units. Each soil mapping unit represents a soil association that is made out of up to four different soil types. For each polygon, the soil types are ordered decreasingly according to the percentage of occurrence. For this study, the dominant soil type of the mapping units was considered as representative for the entire unit.

Table 2: Brazilian soil classification system related to Soil Taxonomy and the Soil Map of the World (FAO)

Brazilian	Soil Map of the World, FAO	Soil Taxonomy
Latossolos	Ferralsols	Oxisols
Podzólicos	Acrisols, Luvisols, Nitosols, Planosols	Ultisols, Alfisols
Terra Roxas e Brunas	Nitosols	Alfisols, Ultisols
Podzols	Podzols	Spodozols
Brunizéns	Phaeozems	Mollisols
Rubrozéns	Acrisols, Nitosols	Ultisols
Brunos Não Cálcicos	Xerosols	Aridisols
Planossolos	Planosols, Xerosols	Alfisols, Ultisols, Aridisols
Solonetz Solodizados	Solonetz, Planosols	Alfisols, Aridisols
Solonchak	Solonchaks	Ardisols, Entisols
Cambissolos	Cambisols	Inceptisols
Plintossolos	Acrisols, Arenosols, Ferrasols, Gleysols, Planosols	Ultisols, Oxisols, Inceptisols, Entisols
Gleissolos	Gleysols, Fluvisols	Inceptisols
Vertissolos	Vertisols	Vertisols
Rendzinas	Rendzinas	Mollisols
Solos Litólicos	Lithosols	Lithic subgroup
Regossolos	Regosols, Arenosols	Entisols
Areis Quartzosas	Arenosols	Entisols
Solos Aluviais	Fluvisols	Entisols
Solos Orgânicos	Histosols	Histosols

Source: Adapted from Lenthe & Cordeiro (1985) and Camargo *et al.* (1987).

The only available information of the soil map is the classification and occurrence of soil types per mapping unit. This kind of soil map is not helpful for users who are not soil scientists or otherwise used to this specific classification system. Also, the mapping units are not linked to quantitative data describing availability of nutrients, soil physical properties or morphological features (such as depth, stoniness or slope). In this study these issues of usability were addressed by deriving additional information on soil properties for each soil type from the accompanying reports of RADAMBRASIL (1973-1978). The RADAMBRASIL project is a natural resource survey initiated by the national government in seventies in the Amazon region for colonization purposes that was later extended for other Brazilian regions. Different agencies have been involved in this project, which has passed through several revisions. It is considered as the more comprehensive countrywide natural resource survey for

Brazil. In the reports, the soil data are presented as hardcopy soils maps at scale 1:500,000 with each mapping unit described by representative profiles in an attached report.

The basic soil attributes (qualitative and quantitative) for each mapping unit, based on the dominant soil type characteristics only, were extracted from these soils profiles and converted into classes (Table 3).

Table 3: Soil properties and class distribution used in LARISSA

Soil property	Classes				
Silt percentage (%)	≤40	>40			
Aluminum saturation (%)	≤50	>50			
Drainage	Well drained	Moderate drained	Poorly drained		
Stoniness/rockiness	Without or with few stones and/or rocks	Stony and/or rocky	Many stones and/or rocks		
EC* (dS cm^{-1})	<2	≥2 and ≤4	>4		
Sodium content (%)	<8	≥8 and ≤15	>15		
Clay percentage (%)	<15	≥15 and ≤35	>35		
Depth (cm)	<30	≥30 and ≤50	>50 and ≤100	>100	
Organic matter content (g kg^{-1})	<10	≥10 and ≤30	>30 and ≤50	>50	
CEC** (mmolc dm^{-3})	<20	≥20 and ≤50	>50 and ≤80	>80	
Base saturation (%)	<30	≥30 and ≤50	>50 and ≤75	>75	
Slope (%)	<3	≥3 and ≤5	>5 and ≤15	>15 and ≤40	>40

*EC: Electric Conductivity, **CEC: Cation Exchange Capacity

The soil properties of the dominant soil type were subsequently linked to the GIS soil map coverage in the form of attribute tables.

Evaluation of land quality indicators by LARISSA

The land quality module is made up of ten different land quality indicators: current nutrient availability, capacity of maintaining nutrient availability, nutrient retention capacity, rooting conditions, soil water holding capacity, soil drainage, erosion risk, mechanization capacity, salinity and sodicity, and climate. In the following text first the conversion of the soil input data into land quality indicators described, followed by a section on the conversion of climate data.

Decision modules were defined to convert input soil data i.e. the map with soil properties into a map with these ten land quality indicators. This conversion was based on decision modules defined by the SIATe project (Sparovek *et al.*, 2000; Sparovek *et al.*, 2002). Information used to define the indicators was obtained during an extensive field survey in the whole Brazilian territory. Sixty one-week field trips were carried out, with in total 150 established settlements projects visited. Information was collected on factors that may improve or restrict family agriculture development. The data obtained during these fieldtrips was complemented with information from literature, local agronomic experiences, and expert knowledge.

The integration of different aspects of soil science together with other variables that influence crop performance in a more holistic and integrating research approach is indicated as a essential for a better understanding of soil fertility (Sparks, 2001, Jong van Lier *et al*., 2002). In developing countries user oriented soil science research normally aims to do "the right thing at the right moment and in the right place". It uses basic scientific knowledge as well as indigenous know-how. Therefore, the involvement of local partners is essential to achieve significant results (Stoops & Cheverry, 1992).

The land quality indicators defined for LARISSA were based on local research on soil fertility and plant nutrition. They were subsequently adapted to better represent the low input agricultural systems of the small holders of the settlement projects (Raij, 1983; Raij *et al*., 1985). Nutrient availability is the most restricting soil related factor in low input tropical agriculture. Several land qualities are related to the supply of plant nutrients, as these are main factors restricting crop productivity in the tropics (Fox *et al.*, 1991; Schwertmann & Herbillon, 1992). Family agriculture is usually developed with low input of nutrients in the cropping system, thus the selection of the three land quality indicators ('current nutrient availability', 'capacity of maintaining nutrient availability', 'nutrient retention capacity') are directly related to this topic. Furthermore much weight was given to the importance of soil organic matter for tropical soils (Santos & Camargo, 1999) and crop management restrictions imposed by rooting capacity, mechanization and soil drainage (Lopes, 1984; Goedert, 1987). Moreover, the main variables related to soil degradation by erosion and salinization were considered. Soil erosion, resulting mainly from agricultural land use, is associated with environmental impacts (Clark II *et al.*, 1985) and crop productivity loss (Lal, 1995; Pimentel *et al.*, 1995) which makes the understanding of the erosion process important to guarantee food security (Daily *et al.*, 1998) and environmental safety (Matson *et al.*, 1997). In tropical agro-ecosystems soil erosion may also impact crop productivity irreversibly (Sparovek & Schnug, 2001). The inclusion of soil degradation by erosion is important for the evaluation of the sustainability of the agricultural systems. This is also valid for soil salinization in semi-arid regions.

The selected land quality indicators are described conceptually in the introduction to the results and the decision modules are presented in detail in appendix A-1 till A-15. In the decision modules the input data is converted into restriction classes. These restriction classes are defined by Food and Agricultural Organization (FAO, 1976), a description of the classes is given in Table 4.

Table 4: Description of land suitability classes according to FAO (1976)

Class	Restriction level	Description
nr	Non restricted	Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.
lr	Little restricted	Land having limitations, which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land.
mr	Moderate restricted	Land having limitations, which in aggregate are severe for, sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.
r	Restricted	Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.
vr	Very restricted	Land having limitations, which appear so severe as to, preclude any possibilities of successful sustained use of the land in the given manner.

2.2 Climate

Climate is believed to be one of the determinative environmental factors for land use suitability. Traditionally it has always been included in land evaluation procedures. The land quality indicator 'climate' is defined as the water deficit as part of the water balance. To determine the land quality indicator ‘climate’ the FAOCLIM Worldwide agro-climatic database of FAO (1995) was used.

The FAOCLIM database includes both long-term averages (1961-90) and time series for rainfall and temperatures for 833 weather stations in Brazil. This corresponds with roughly one station per million hectares. Besides this low density, the weather stations are mostly located in the northeast, southeast and south of Brazil (Figure 4). As no other public sources of long-term data are available for Brazil, 246 stations that are situated in neighboring countries along the border of Brazil were used.

Figure 4: The location of long-term weather station in Brazil

The water balance was calculated according to the model of Thornthwaite & Mather (1955):

$$P = PE + R + \Delta ST$$

Where:

P	=	Precipitation (mm/month)
PE	=	Potential Evapotranspiration (mm/month)
R	=	Runoff (mm/month)

ΔST = Change in soil moisture storage (mm/month).

The estimation of the potential evapotranspiration is based on a statistical relationship method that can be described by the method of Thornthwaite (1948):

$$PE = 0.53\left(10\frac{T_n}{I}\right)^a \frac{L_d}{12} N_n$$

Where:

PE	=	Potential evapotranspiration in month n (mm/month)
T_n	=	Mean temperature of month n (°C)
N_n	=	Number of days in month n
L_d	=	Day length of the median day in month n (hours)
I	=	Heating index
a	=	Empirical coefficient.

The empirical coefficient and heating index are calculated as follow:

$$a = 0.49239 \times I^{0.49239} + 0.01792 \times I^{0.01792} - 0.0000771 \times I^{-0.0000771} + 0.000000675 \times I^{0.000000675}$$

$$I = 0.08745 \sum_{j=1}^{12} T_j^{1.514}$$

Where:

T_j = Mean temperature of month j (ºC).

The day length is calculated as follow:

$$L_d = \frac{24}{\pi} \arccos\left[-\tan(\alpha_n) \times \tan(\varphi)\right]$$

Where:

α_n	=	Solar declination (Rad)
φ	=	Latitude (Rad).

The solar declination is calculated as follow (Paltridge & Platt, 1976):

$$\alpha_n = C_0 + \sum_{i=1}^{3}\left[C_i \sin\left(\frac{2i\pi d_n}{365}\right) - D_i \cos\left(\frac{2i\pi d_n}{365}\right)\right]$$

Where:

d_n	=	Number of day of the year (Julian day)
C_0	=	Empiric parameter (0.006918)
C_i	=	Empiric parameters (respectively 0.070257, 0.000907, 0.00148)
D_i	=	Empiric parameters (respectively 0.399912, 0.006758, 0.002697).

The method of Thornthwaite & Mather assumes that changes in soil water are directly proportional to water losses due to evapotranspiration This is based on the assumption that differences in evapotranspiration are linear with soil water storage changes. There are three possibilities in the water balance of Thornthwaite:

1) The precipitation is equal to the potential evapotranspiration. Therefore all precipitation is used for evaporation, the soil moisture storage remains constant and there is no runoff.

2) The precipitation exceeds the evapotranspiration. The precipitation is first used for the potential evapotranspiration. Excess precipitation is then used to recharge soil moisture. If soil moisture reaches field capacity, runoff occurs.

The soil moisture storage (ST) is calculated with:

$$ST_n = ST_{n-1} + (P - PE)\text{, and } D_n = -Soil_{MAX} \ln\left(\frac{ST_n}{Soil_{MAX}}\right)$$

Where:

ST_n	=	Storage in month n (mm/month)
ST_{n-1}	=	Storage in month n-1 (mm/month)
D_n	=	Deficit in month n (mm/month).

The maximum soil storage capacity is assumed equal to 125 mm, as:

$$Soil_{MAX} = 10(\theta_{FC} - \theta_{PWP})d$$

Where:

θ_{FC}	=	Soil moisture content at field capacity (0.250 m^3/m^3)
θ_{PWP}	=	Soil moisture content at permanent wilting point (0.125 m^3/m^3)
d	=	Depth of rooting zone (1000 mm).

3) The precipitation is smaller than evapotranspiration. All precipitation is used for evapotranspiration and soil moisture, if available, is used to make up the difference. The water deficit and soil moisture storage are calculated with:

$$D_n = D_{n-1} + \left|(P - PE)\right|, \text{ and } ST_n = Soil_{max} e^{\frac{-D_n}{Soil_{MAX}}}$$

Where:

D_n = Deficit in month n (mm/month)

D_{n-1} = Deficit in month n-1 (mm/month).

Water balance values were calculated for all weather stations. These point-based values were subsequently interpolated with the program ANUSPLIN (Hutchinson, 1997) to generate a regular grid surface map with water balance values. Interpolation is based on the cokriging technique that uses spline functions, which, besides water balance values, use the latitude and longitude values of the points and altitude values derived from the digital elevation model (DEM) GTOPO30, a global coverage of 30-arc second elevation data (EDC, 1996).

The water deficit values were reclassified, ranging from very restrictive (large water deficit) to non restrictive (no water deficit). This reclassification was done in such way that the classes represent equal parts of the surface areas of Brazil. These restriction classes were subsequently assigned to the five water deficit classes according to Table 5.

Table 5: Restriction criteria for ‘climate’ based on water deficit

Water deficit (mm)	Surface area (%)	(Cum %)	Code
<50	20.9	20.9	nr
50 –150	18.3	39.2	lr
150 – 250	23.2	62.4	mr
250 – 400	21.7	84.1	r
>400	15.9	100.0	vr

Scoring of supply of land quality indicators

After the determination of the separate land quality indicators a map with the overall supply of land quality indicators was determined. First the qualitative level of the land quality indicators was converted into quantitative indicators. A linear increase, with 1 representing the most restricted condition (very restricted or 'vr') up to 5 for the less restricted condition (not restricted or 'nr') was used for this conversion. The polygon maps of the original indicators were subsequently transformed into raster maps, with a grid size of one by one kilometer in the program TNTmips (MicroImages, 2001). Then a percentage value was calculated for the supply of land quality indicators by combining the raster maps with the following formula:

$$\text{Supply of land quality indicators} = \frac{\sum_{i=1}^{10}(SLQ_i - 1)}{10 \times (MAX_{SLQ} - 1)} \times 100$$

Where:

SLQ_i	=	Supply of land quality indicator i
MAX_{SLQ}	=	Maximum value of land quality indicator i.

The value of 100 % represents a condition in which all supplies are equal to the maximum value of 5, and a percentage of 0 % a condition in which all supplies are equal to 1.

2.3 Integration of regional condition indicators in LARISSA

The module for the regional conditions in SIATe is made up of fourteen different regional condition indicators (Sparovek et al., 2000; Sparovek et al., 2002). In this research only three of these indicators were included in the evaluation procedure, because of data availability at regional and national level. The following indicators were used: 'accessibility', 'market', and 'possibilities for irrigation'.

The next paragraphs give an overview of the regional and social-economic condition indicators that are included in the land evaluation for AR. Subsequently the used algorithms to include the regional condition indicators in the land evaluation procedure are given.

Accessibility

The regional characteristic 'accessibility' is defined as the acceptable effort it takes for a person (or more specific a settler) to get to the nearest city. This effort is expressed in time.

To use this concept of accessibility it is necessary to take into consideration that in Brazil transport and infrastructure are not always sufficient available or may not even exist. Therefore it was assumed that for a settler the distance to the nearest road or river and the time to reach this road or river are of importance. As soon as a major road is reached, the settler will be able to sell its products to a dealer that will intermediate the delivery and sell it to the final consumer.

To determine accessibility the following input sources were used:
- Road map of DEMIS BV (2001), scale 1:1,000,000
- Location of cities from IBGE (1999a)
- River map of DEMIS BV (2001), scale 1:1,000,000.

The road map is a global data set and represents only major roads. Based on the road map, the density of the main road network for each state was calculated by dividing the total length of roads within a state by its surface area. It is expected that it will take more time to travel by boat or take a forest track in the north of Brazil than traveling by dirt road in the southern part of Brazil to get to the main road. To adjust the distance to the expected travel time, the velocity of traveling in between roads or rivers was considered as regional dependent and estimated for each state. An overview of the velocity of traveling per state is given in Appendix A-16.

To estimate the velocity of traveling in between roads and rivers for each state, the following formula was used:

$$\text{Travel velocity} = \left[\frac{(\text{Road}_{\text{density}})}{(\text{Max}_{\text{density}} - \text{Min}_{\text{density}})} \times (\text{Max}_{\text{velocity}} - \text{Min}_{\text{velocity}}) \right] + \text{Min}_{\text{velocity}}$$

Where:

$\text{Road}_{\text{density}}$	=	Density of the road network for each state (m/km^2)
$\text{Max}_{\text{density}}$	=	Maximum density of the road network, here 131.64 m/km^2
$\text{Min}_{\text{density}}$	=	Minimum density of the road network, here 0.01 m/km^2
$\text{Max}_{\text{velocity}}$	=	Maximum velocity of traveling in between major roads, assumed 30 km/h
$\text{Min}_{\text{velocity}}$	=	Minimum velocity of traveling in between major roads, assumed 5 km/h.

Next, raster files with distances to the nearest road, city and rivers were calculated in the GIS. Based on these distance maps, time maps were calculated by dividing the distance maps by the velocity of traveling per state. Figure 5 shows the percentage of the roads of Brazil (y-as) that can be reached within a certain amount of hours (x-as), the graph indicates that 80 % of the Brazilian main roads are expected to be reached within 14 hours.

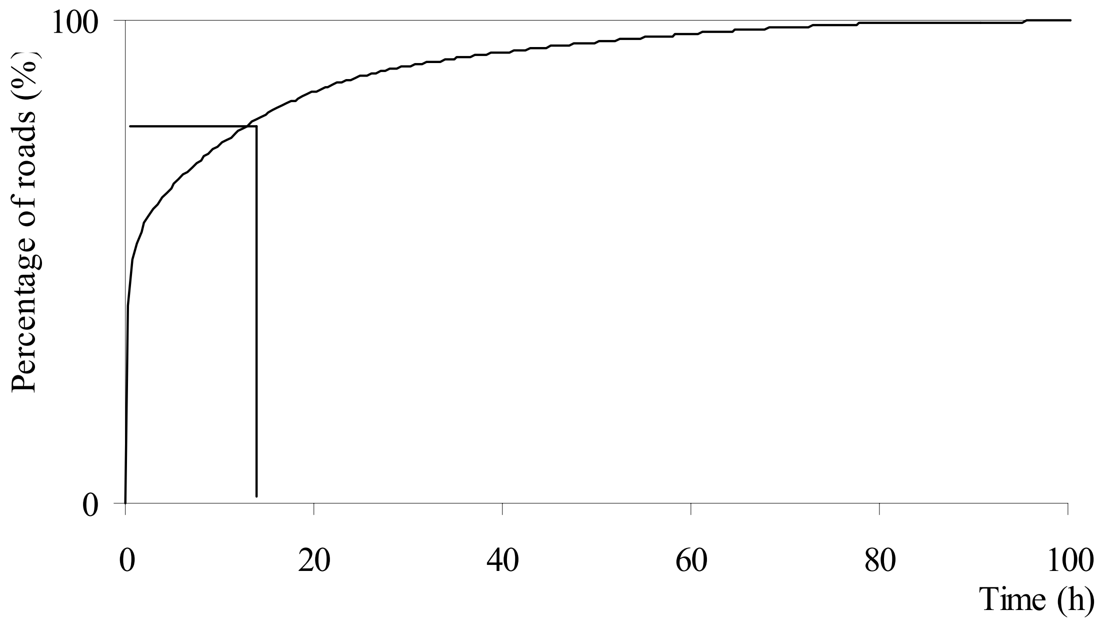

Figure 5: The amount of time (h) it takes to reach a road (% of total roads) in Brazil

Subsequently the map with 'accessibility' was calculated. For areas with a travel time of more than 14 hours, in the calculation of accessibility the travel time to reach the nearest river was included. Assuming that, as the nearest road is further away than 14 hours, a settler would try to reach the nearest road or town by boat.

'Accessibility' was calculated as follow:

$$\text{Accessibility} = T_{City} + T_{Road} \quad , \text{if } T_{Road} \leq 14 \text{ hours}$$

Where:

T_{Cities} = Travel time to reach nearest city (h)

T_{Road} = Travel time to reach nearest road (h).

And:

$$\text{Accessibility} = T_{City} + T_{Road} + T_{River} \quad , \text{if } T_{Road} > 14 \text{ hours}$$

Where:

T_{Cities} = Travel time to reach nearest city (h)

T_{Road} = Travel time to reach nearest road (h)

T_{River} = Travel time to reach nearest river (h).

Market

The regional condition 'market' is defined as the opportunity for a farmer to trade its products at a local market. A proxy measure for this requirement was calculated using population density.

The following sources were used as input data for ‘market’:
- The primary results of the demographic census of 2000 (IBGE, 2000)
- The map of the municipal districts of IBGE (1999b).

The rural population was considered self-sufficient for the majority of agricultural products; therefore in the determination of the indicator ‘market’ only the urban population was taken into account. The population density was determined by dividing the urban population of the municipal district by its surface area. The urban population data was derived from the primary results of the demographic census of 2000. The surface area of the municipal districts was derived from map of the municipal districts of IBGE.

The map with population density was reclassified in subclasses in such a way that the classes represent equal parts of the surface area of Brazil. Subsequently restriction classes were assigned to these equally divided density classes. If the urban population density of the municipal district was smaller, the indicator ‘market’ was considered more restricted for a farmer to commercialize its products. An overview of the classes and its occurrence are represented in Table 5.

Table 5: Restriction criteria for 'market' based on urban population density

Population density (Inhabitants /km^2)	Surface area (%)	(Cum %)	Population (%)	(Cum %)	Urban population (%)	(Cum %)	Rural population (%)	(Cum %)	Code
<0.25	18.3	18.3	0.4	0.4	0.2	0.2	1.3	1.3	vr
0.25-1	26.7	45.0	1.6	2.0	0.8	1.0	5.6	6.9	r
1-2.5	15.9	60.9	2.7	4.7	1.5	2.5	8.6	15.5	mr
2.5-10	21.2	82.1	11.3	16.0	7.2	9.7	30.7	46.2	lr
>10	17.9	100.0	84.0	100.0	90.3	100.0	53.8	100.0	nr

Possibilities for irrigation

The regional condition 'possibilities for irrigation' is defined as the dependence of an agricultural system to irrigation. Family agriculture systems in Brazil are described as low input systems in both supplies (fertilizer, pesticides) and modern technology (mechanization and irrigation). However, and exception is the use of supplementary irrigation. In the semi-arid northeast of Brazil, where the amount and distribution of rainfall severely restricts agricultural production, supplementary irrigation is also utilized in family agriculture. This means that the water availability (rivers or aquifers) is to be considered as an important land quality indicator. In the more humid regions, the possibility of irrigation is less important and restricted to specific crops (e.g. horticulture).

To determine 'possibilities for irrigation' the Hydrogeology map of Brazil of DNPM (1983), scale 1: 5,000,000, was used as data source. For the region where available access water is less than 400 mm, the 'possibilities for irrigation' were examined with help of the hydrogeology map for Brazil. The mapping units of the hydrogeology map represent geologic units with characteristic aquifers. For each aquifer a description is given of the discharge capacity. Based on the capacity of the aquifers the mapping units were reclassified into restriction classes. Table 6 gives an overview of the restriction classes.

Table 6: Restriction criteria for 'possibilities for irrigation' based on capacity of aquifer

Capacity	Discharge ($m^3 h^{-1}$)	Restriction
Very high	> 100	nr
Moderate to high	≥ 25 and ≤ 100	lr
Weak to moderate	≥ 3.25 and < 25	r
Very weak	< 3.25	vr

Scoring of supply of regional condition indicators

After having determined the separate regional condition indicators, one overall score for the supply of regional condition indicators was calculated based on the following formula:

$$\text{Supply of regional conditions} = \frac{\sum_{i=1}^{3}(SRC_i - 1)}{3 \times (MAX_{SRC} - 1)} \times 100$$

Where:

SRCi	=	Supply of regional condition i
MAX_{SRC}	=	Maximum value of regional condition i.

This formula results in scores from 0 up to 100. The value of 100 represents a condition in which the supply of all regional conditions are equal to the maximum value of 5, and a value of 0 a condition in which the supply of all regional conditions are equal to 1.

To be able to calculate the scores for overall supply of regional condition indicators, the maps with the three separate indicators had to be transformed from polygon maps into raster maps. The same procedure was followed as for the determination of the supply of land quality indicators, as described in paragraph 2.2. First the qualitative level of supplies was converted into quantitative indicators. A linear increase, with 1 representing the most restricted condition (very restricted or 'vr') up to 5 for the less restricted condition (not restricted or 'nr') was used for this conversion. Next raster maps were produced with a grid size of one by one kilometer using the GIS software TNTmips (MicroImages, 2001).

Total supply

As soon as the supply of land quality indicators as well as the supply of regional condition indicators was calculated, a map with the total supply was calculated following the subsequent formula:

$$\text{Total supply} = \frac{SLQ + SRC}{(MAX - 1) \times (i_{SLQ} + i_{SRC})} \times 100$$

and:

$$SLQ = \sum_{i=1}^{10}(SLQ_i - 1)$$

$$SRC = \sum_{i=1}^{3}(SRC_i - 1)$$

Where:

SLCi	=	Supply of land quality indicator i
SRCi	=	Supply of regional condition indicator i
MAX	=	Maximum value of land quality or regional condition indicators
i_{SLQ}	=	Total number of land quality indicators
i_{SRC}	=	Total number of regional condition indicators.

The value of 100 % represents a condition in which the supplies of both land quality and regional condition indicators are equal to the maximum value of 5, and a percentage of 0 % a condition in which these supplies are equal to 1.

In this research a quantitative land classification was used, in which the distinctions between classes are defined in common numerical terms. This allows us to 'perform an objective comparison between classes relating to different kinds of land use' (FAO, 1976). There are several ways to combine to individual land quality and regional condition indicators. The overall suitability was computed using equal weighting. It would have been possible to combine individual land qualities and regional conditions according to the most limiting factor, e.g. the most limiting factor determines the final outcome. This method is attractive due to its simplicity. The disadvantage however is that it does not differentiate between areas with several limitations or with areas with only one. As the study intended to study regional differences and their influences on the process of land evaluation for the AR at a national scale the algebraic combination was considered as the most suitable one.

2.4 Statistical evaluation of input indicators

<u>Principal component analyses</u>

Principal component analyses (PCA) were used to identify which combination of indicators explains the largest amount of variation in the multivariate data set, i.e. PCA were used to identify the combination of input indicators that determine the outcome of the land evaluation procedure.

The idea of PCA is to create new uncorrelated variables (principal components) that explain as much of the information in the data set as possible, in order to simplify the data set of interrelated variables. Each principal component is a linear combination of the original variables. The first principal component is chosen to explain the largest possible amount of information in the data, the second principal component is designed to be as different from the first as possible and explains the second larger amount of information, and so on. PCA produces eigenvectors and eigenvalues. Eigenvectors are sets of scores that represent the weighting of each of the variables on a principal component. They are scaled and range from –1 to +1. The closer a score is to –1 or +1, the more important the variable it represents is in terms of weighting that component. Eigenvalues are values that represent the relative contribution of each component to the explanation of the total variation in the data set. There is one eigenvalue for each principal component and the size and importance decreases with successive principal component (Fowler *et al*., 1998; Kent & Coker, 1992).

The PCA were performed with the SAS statistical package (SAS System, 2001). As input data, the raster maps of input indicators of the LARISSA model were used, after being converted to text files. The input indicators of LARISSA were:

- Current nutrient availability
- Capacity of maintaining nutrient availability
- Nutrient retention capacity
- Rooting conditions
- Soil water holding capacity
- Soil drainage
- Erosion risk
- Mechanization capacity
- Salinity and sodicity
- Climate (i.e. water deficit)
- Accessibility
- Market
- Possibilities for irrigation.

Stepwise exclusion analyses

To estimate the influence of each separate land quality and regional condition indicator on the model outcome, a stepwise exclusion analyses was employed. The evaluation results of LARISSA were determined several times (as described in paragraph 2.3), each time one of the indicators was omitted to identify its contribution to the final evaluation outcome. This contribution was quantified as the differences between the model results using all indicators (M_{all}) and the model results with the omission of indicator i (M_i).

Box plots were constructed for each region showing the differences between the model results using all indicators and the model results with the omission of indicator i. The difference is represented based on the median, quartiles (range which contains 50% of the values), highest and lowest values. These box plots show the changes in outcome of the model when excluding a certain indicator.

The stepwise exclusion procedure was performed with a representative number of point data for the five regions of Brazil. Per region point were randomly generated in the GIS. The total number of points resembled one point per thousand square kilometer. For each point the accompanying values of the land quality and regional indicators were derived from the raster maps. Based on the value of the indicators, the outcome of LARISSA was calculated as described above.

Chi-square statistic

Possible differences between the regions in terms of regional conditions and land qualities were identified. This was done by testing if (H_0) the distribution of frequency among the suitability classes were the same among the regions.

In order to compare the frequency distribution among the regions, a two-way contingency table was constructed with suitability classes and regions as descriptors. Thus, each cell of the table contained the number of observations for the corresponding pair of suitability classes and regions. Next, the expected frequency E was calculated for each cell of the table. The null hypothesis implies that the two descriptors (suitability classes and regions) are independent, which means that the probability of their joint occurrence is equal to the product of their individual probabilities. In other words, the expected frequency is equal to the product of the individual probabilities of both descriptors. This can be expressed with the following formula:

$$E_{ij} = N\left(\frac{n_i}{N}\right)\left(\frac{n_j}{N}\right) = \frac{n_i n_j}{N}$$

Where:

N = total number of observations

n_i = total number of observations in suitability class i

n_j = total number of observation in region j.

To test the null hypothesis, the Pearson chi-square statistics χ^2 (Pearson, 1900 in Legendre & Legendre, 1998) was employed:

$$\chi_V^2 = \sum \frac{(O-E)^2}{E}$$

Where:

O = observed values

E = expected values.

Note that the number of degrees of freedom use to determine the probability of accepting H_0 using a χ^2 is ν = (r-1)(c-1), where r is the number of rows (regions) and c the number of columns (suitability classes) of the contingency table.

In cases were the contingency table contained several null observed values (with corresponding very low expected frequencies), a small value (value = 1) was added to each observed value in the contingency table to lower the χ^2 statistic, i.e., to make the test more conservative (Legendre & Legendre, 1988).

2.5 Comparison with agrarian reform settlements

The results of LARISSA were compared with the location of AR settlements in order to evaluate the relationship between the number of settlements per restriction class of the SLQ indicators as well SRC indicators per region and the governmental periods. I.e. the question is if there is an increase in the selection of more suitable locations and a corresponding decrease in the selection of unsuitable locations over time. To correct for possible geo-political trends first it was examined if there was any trend in the distribution of settlements per region or state.

The data on AR projects used in this study were derived from the preliminary results of the census about the quality of the AR (Sparovek, 2002). This census was carried out between July and September 2002. During this period 4314 settlements projects of INCRA were visited and information was collected on among others the quality of life in an AR project and productivity data. For each settlement, in this study information was used on the geographical location (Figure 6) as well the period the settlement was created.

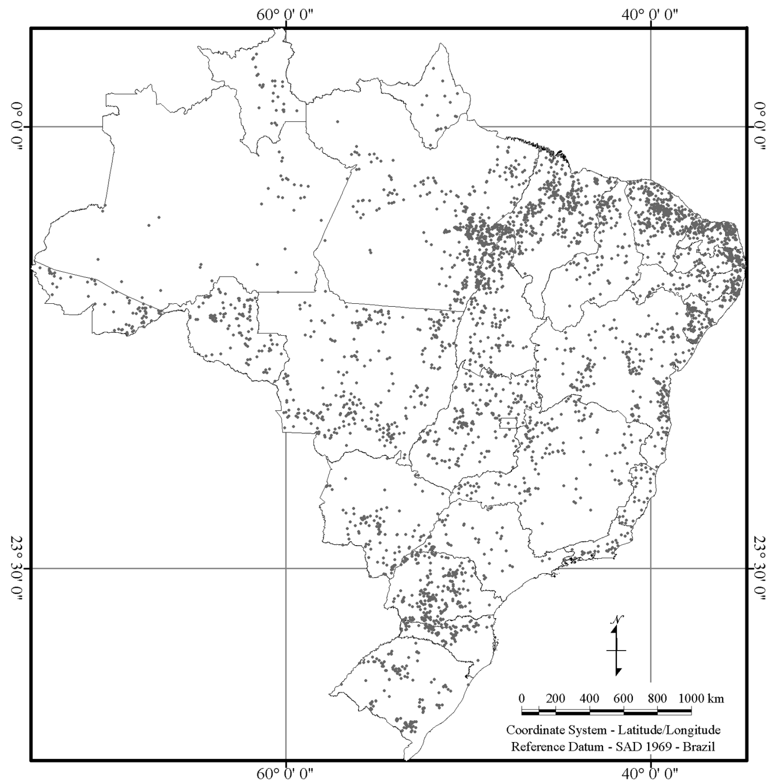

Figure 6: Location of agrarian reform settlements of INCRA in Brazil

The time since the AR was created was divided in different political periods corresponding to:

- 1964-1984: Military regime, a military dictator ruled
- 1985-1990: Government of president Sarney, first elected president after military dictatorship
- 1991-1992: Government of president Collor, impeached in 1992

- 1993-1994: Government of president Franco, vice-president of president Collor who became president after the impeachment
- 1995-1998: Government of president Cardoso, first period
- 1999-2002: Government of president Cardoso, second period after being reelected.

For each location information was extracted from the raster maps by means of simple information transfer procedure in TNTMips. I.e., for each settlement information about the scoring of the SLQ indicators and SRC indicators was extracted from the different raster maps.

Four classes from 21-40, 41-60, 61-80, and 81-100 % respectively were defined for the scoring of the SLQ and SRC indicators. The class 0-20 % did not occur. Next, the number of settlements within each of these classes was counted. Subsequently to calculate the relative frequency per class per governmental period, the number of AR settlements per class was divided by the total number of AR settlements per period.

2.6 Validation with productivity data

The Spearman Rank Correlation Coefficient (see below) was used to validate the relation between the outcome of steps of the land evaluation procedure and productivity data. Ideally, one would test this through an experimental approach. As this would require much time and resources, it was opted to carry out the model validation by comparing the model output with historical empirical production data for Brazil. The productivity data had to be operational in a wide range of conditions, e.g. from the tropical rainforest in the Amazon, to the extreme semi-arid climatic conditions in the northeastern part, up to the industrialized subtropics in the south. In line with recommendations from Guanziroli & Cardim (2000) the value of the gross agricultural production as well the value of the total agricultural cash flow was considered to be most representative for the agricultural productivity at national scale.

IBGE conducted an agricultural census in the years 1995 and 1996 (IBGE, 1996). The data available for the public gives a general description of agriculture in Brazil, but family agriculture is not distinguished from commercial agriculture. To be able to use the data for this study, a data set was compiled in collaboration with IBGE summarizing data on municipal district level. Furthermore, to be able to compare the land evaluation results with real data about family agriculture, the production and cash flow data were specified individually for family agriculture and commercial farming.

Correlation analyses

The correlation coefficient provides an index of the degree to which the two variables are related; all values are on a scale from –1 to +1. When an increase in one variable is accompanied by an increase in another, the correlation is said to be positive. When an increase in one variable is accompanied by a decrease in another, the correlation is said to be negative. The closer the value of a coefficient is to –1 or +1, the greater is the strength of the correlation, while the closer it is to 0 the weaker it is. It is essential to emphasize that the fact that variables are correlated does not necessarily mean that there is a causal relation between the two (Fowler *et al*., 98).

In this study, the Spearman Rank Correlation Coefficient (r_s) was used as this is a appropriate method when observations are indices or counts. The formula to calculate r_s is:

$$r_s = 1 - \left[\frac{6\sum d^2}{n^3 - n} \right]$$

Where:

n = the number of units in a sample

d = the difference between ranks.

3 Results

In the following chapter first the regional differences in the outcome of the land evaluation system LARISSA are described (chapter 3.1). Subsequently the relative influence of the natural resource quality indicators as well the regional condition indicators on the outcome of the evaluation results of LARISSA are described in respectively chapter 3.2 and 3.3. The relation between the location of agrarian reform settlements projects and the evaluation results of LARISSA are described in chapter 3.4, followed by a validation of the evaluation results (chapter 3.5).

3.1 Regional differences in the outcome of the land evaluation system LARISSA

Supply of land quality indicators

The map with the results of the supply of land quality indicators is presented in Figure 7. The value of 100 % represents a condition in which the supply of all land quality indicators are equal to the maximum value of 5, i.e. there are non restrictions, and a percentage of 0 % a condition in which the supply of all land quality indicators are equal to 1 (very restricted).

The results show that the regional differences in the classification of the supply of land quality indicators are not extremely distinct, although some differences can be noticed. As is represented in Figure 7, as well as in Table 8, the south of Brazil is classified as the most suitable area considering the supply of land quality indicators. The most part of the south is classified in the class interval 70 to 90 %, with an average of 73 %, which means that the greater part of the land quality indicators is non-to little restrictive. The southeast of Brazil is mostly classified in the range 50 to 80 % and the north and central west of Brazil are mostly classified in the range from 50 to 70 %. In these regions the majority of the land quality indicators are considered to be non-to moderate restrictive. The northeast is classified as relatively more restricted, with an average supply of land quality indicators of 53 %, but also for this region the majority of land quality indicators are still considered little to moderate restricted.

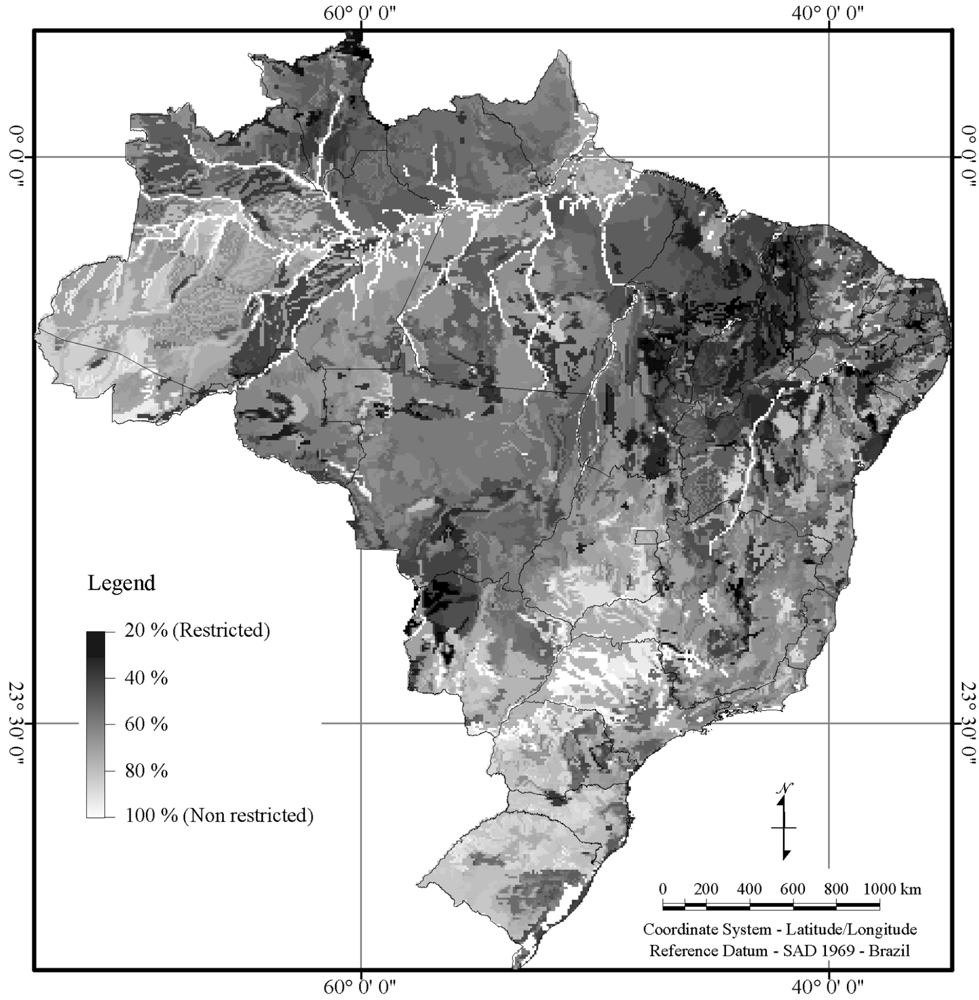

Figure 7: Distribution of the supply of land quality indicators

Table 8: Descriptive statistics of distribution of supply of land quality indicators

	North	Northeast	Central west	Southeast	South	Brazil
Mean	59.6	52.9	60.6	65.8	72.6	60.2
Median	57.5	52.5	57.5	65.0	77.5	57.5
Standard deviation	10.2	10.6	10.9	12.2	11.9	11.9
Minimum	27.5	22.5	27.5	30.0	27.5	22.5
Maximum	92.5	85.0	95.0	97.5	97.5	97.5

<u>*Supply of regional conditions*</u>

The map with the results of the supply of regional conditions is shown in Figure 8. The value of 100 % represents a condition in which the supply of all regional conditions are equal to the maximum value of 5, and a percentage of 0 % a condition in which the supply of all regional conditions are equal to 1.

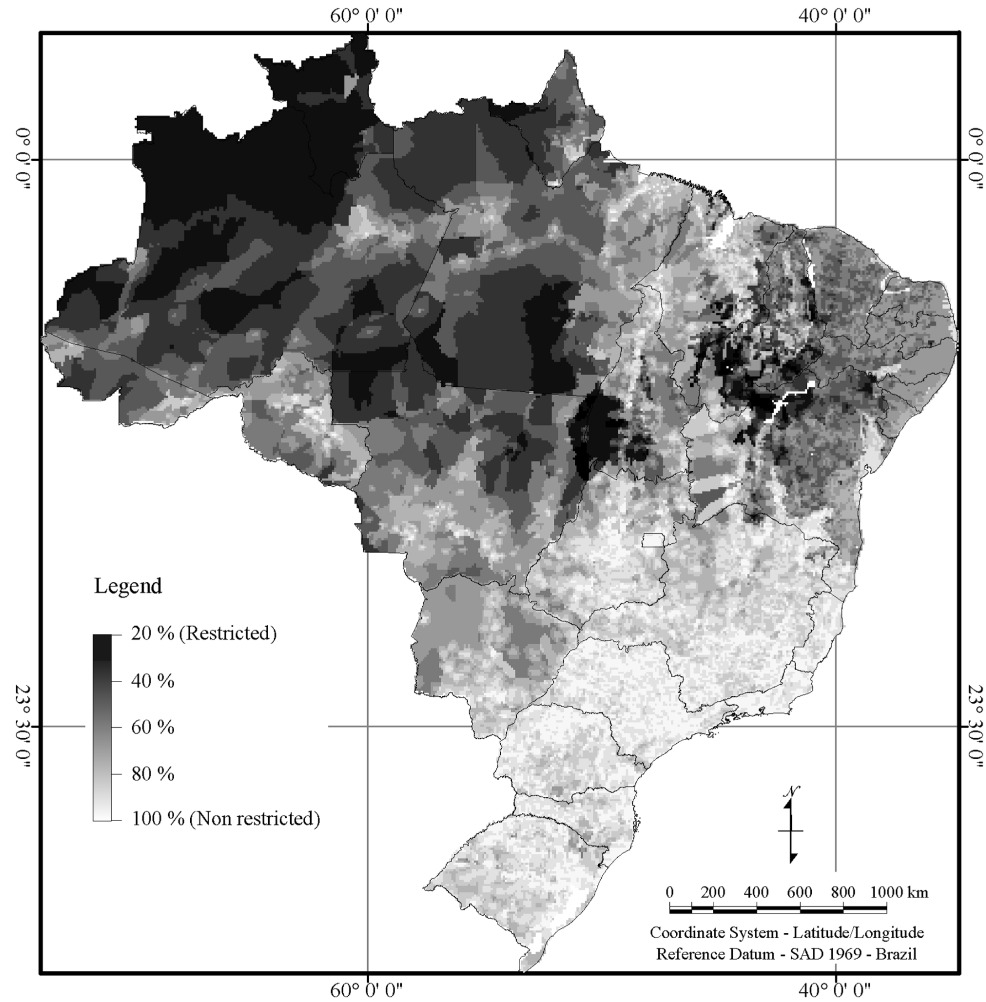

Figure 8: Distribution of the supply of regional condition indicators

Figure 8 as well in Table 9 reveal that the regional differences in the distribution of the supply of regional conditions are more distinct. The supplies of regional conditions in the south and southeast of Brazil are mainly classified as non-restricted, with a mean supply of regional conditions of 90 %. The northeast and central west of Brazil are mainly classified in the range from 50 to 70 %, indicating that the majority of the regional conditions are considered to be non-to moderate restrictive. The north of Brazil is considered more restricted, with a mean supply of regional conditions of 48 %.

Table 9: Descriptive statistics of distribution of supply of regional condition indicators

	North	Northeast	Central west	Southeast	South	Brazil
Mean	48.4	63.3	65.4	89.9	90.3	59.2
Median	41.7	66.7	66.7	91.7	91.7	56.0
Standard deviation	16.7	15.4	16.8	9.2	7.9	19.1
Minimum	13.9	16.7	16.7	33.3	58.3	13.0
Maximum	100.0	100.0	100.0	100.0	100.0	100.0

Overall evaluation of LARISSA

The map with the overall evaluation results is represented in Figure 9. Also here the value of 100 % represents a condition in which the total supplies are equal to the maximum value of 5, and a percentage of 0 % a condition in which the total supplies are equal to 1.

The overall evaluation results of LARISSA show a regional pattern, as can be seen in Figure 9 as well in Table 10. The south of Brazil is classified with a mean of 77 % for the total supplies, meaning both land quality as regional condition indicators are little to non restricted. In other words, there are little to non-significant limitations in the overall evaluation for AR. Also the southeast is classified as having little to non-significant limitations; although slightly more restricted than the south of Brazil. The north and central west of Brazil are mainly classified in the range from 50 to 70 %, indicating that the majority of the area is considered to be non-to moderate restrictive. The northeast of Brazil is considered most restrictive.

Table 10: Descriptive statistics of distribution of overall evaluation of LARISSA

	North	Northeast	Central west	Southeast	South	Brazil
Mean	57.0	55.6	61.9	71.3	77.0	60.7
Median	58.0	54.0	60.0	71.0	79.0	59.6
Standard deviation	8.6	9.1	10.7	11.1	9.6	11.3
Minimum	33.0	29.0	35.0	38.0	46.0	28.8
Maximum	91.0	89.0	94.0	94.0	94.0	98.1

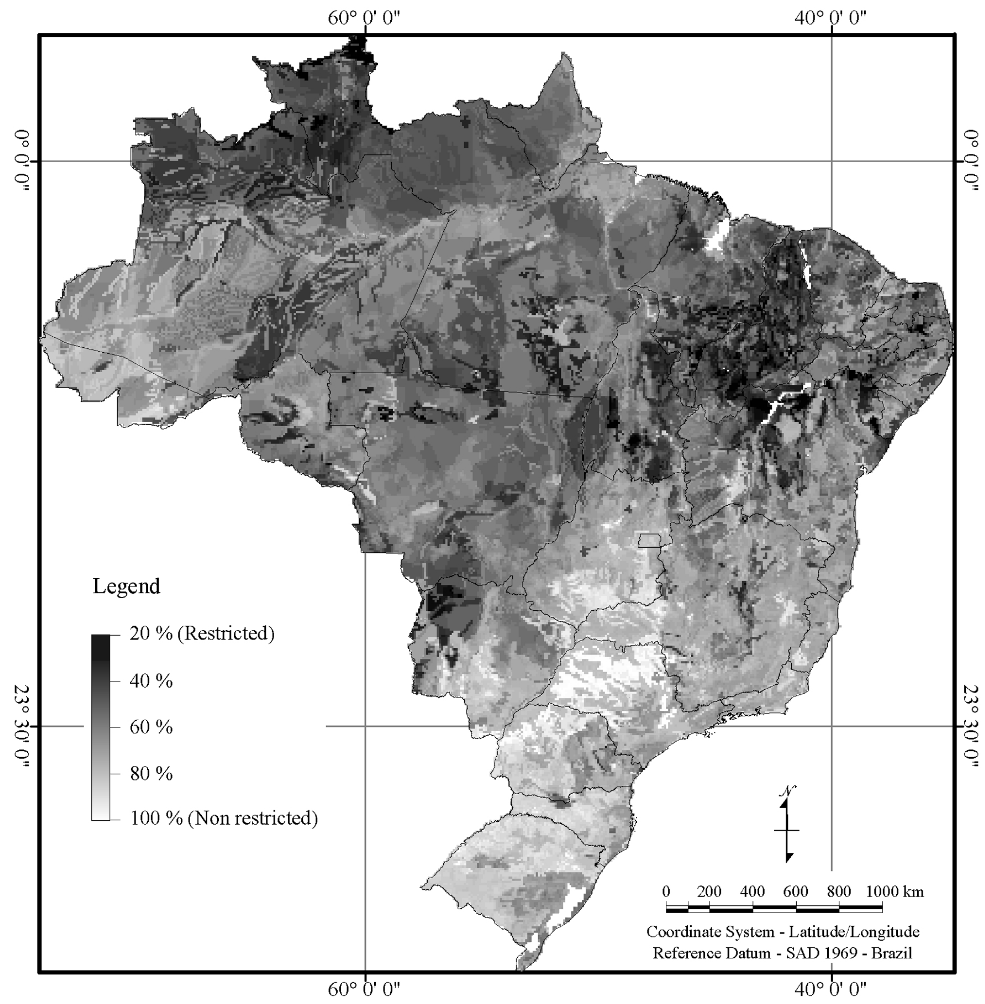

Figure 9: Spatial distribution of the evaluation results of LARISSA

Regional differences

Figure 7 and 8 reveal clearly the regional differences between the land quality and regional condition indicators. To study the heterogeneity within regions in more detail box plots (Figure 10) were created based on a stepwise exclusion analyses. These same box plots are used in the following chapters to examine the relative influence of the land quality and regional condition indicators on the land evaluation system LARISSA.

Figure 10 shows the difference between the model results using all indicators and the model results with omission of one indicator (y-as) versus the indicator, which is excluded from the model (x-as). The box plots are given for all five regions of Brazil. The figure summarizes the frequency distributions of the calculated differences based on the median, the quartiles (range which contains 50% of the values).

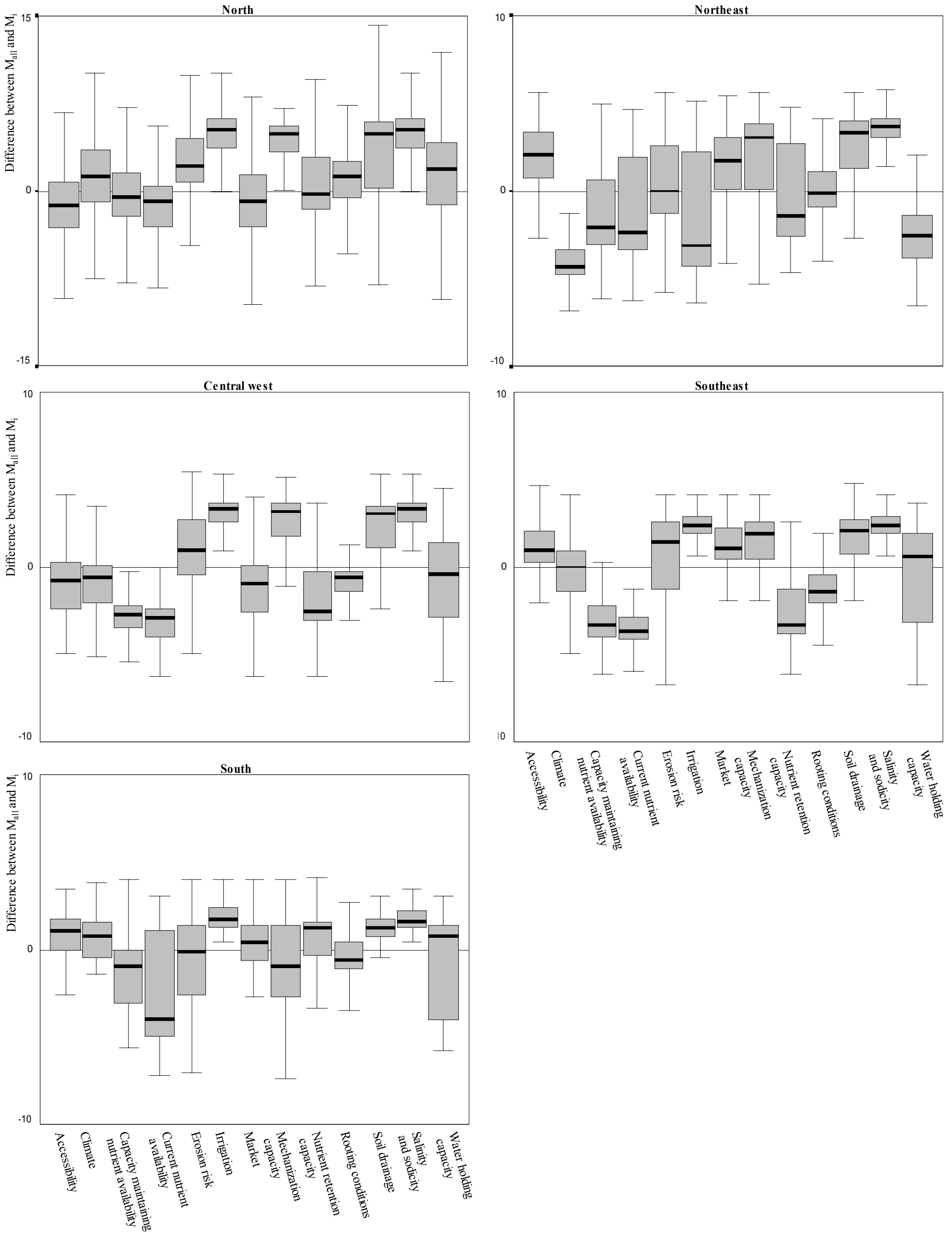

Figure 10: Box plots showing the differences between the model results using all indicators and the model results with omission of one indicator versus the indicator that is excluded from the model

Similar to the Figures 7 to 9, Figure 10 shows clearly the regional differences between the outcomes of LARISSA. Most regions of Brazil are considered to be restricted by the land quality indicators ‘current nutrient availability’, ‘capacity of maintaining nutrient availability’ and ‘nutrient retention capacity’. The southeast and south of Brazil are characterized by relative good facilities for ‘accessibility’ and ‘market’, and also ‘climate’ is not considered to be restrictive. In these regions the quality of the soil physical indicators becomes more important and is often the more restrictive factor. In the northeast the land quality indicator ‘climate’ (i.e. water availability) is classified as the most limiting factor; in this region there is insufficient rain. In this region also the regional condition indicator ‘possibilities for irrigation’ is considered to be restrictive on the evaluation results of LARISSA. The regional condition indicators ‘market’ and ‘accessibility’ are classified as more restrictive in the north of Brazil. These indicators are also considered to be a limitation in the central west, but in this region the restrictive character of certain land quality indicators (in particular ‘current nutrient availability’, ‘capacity of maintaining nutrient availability’ and ‘nutrient retention capacity’) are more significant.

As mentioned before, Figure 10 describes as well the relative influence of the individual land quality and regional condition indicators on outcome of the land evaluation system LARISSA. These relative influences are described in more detail in the chapters 3.2 & 3.3.

3.2 Relative influence of the natural resource quality indicators on the land evaluation system LARISSA

To study the relative influence of the natural resource quality indicators on the land evaluation system LARISSA three types of analyses were carried out. PCA were used to study the relative contribution of the indicators on total variance of the input dataset. Box plots were produced to identify the influence of the different indicators on the outcome per region. The third analysis (contingency tables) was used to study the differences between the regions.

As an overview to the results presented in the following chapter the results of the principal component analyses (PCA) of the land quality and regional condition indicators are summarized in Table 11 (full details in Appendix A-17).

Table 11: Principal component analyses of land quality and regional condition indicators evaluated by LARISSA

	Principal components				
	1	2	3	4	5
Eigenvalues	4.66	3.56	2.84	1.92	1.50
Percentage of total	24.1	18.4	14.7	9.9	7.8
Cumulative percentage	24.1	42.5	57.1	67.0	74.8
	Scoring of eigenvectors				
Current nutrient availability	0.310	0.150	-0.095	0.015	0.274
Capacity of maintaining nutrient availability	0.272	0.374	0.170	0.066	-0.025
Nutrient retention capacity	0.383	0.386	0.220	0.121	-0.081
Rooting conditions	0.180	0.139	-0.126	0.177	0.155
Soil water holding capacity	0.005	0.518	-0.313	-0.294	0.512
Soil drainage	-0.120	-0.166	-0.284	-0.646	0.165
Erosion risk	-0.094	0.031	-0.420	0.456	0.162
Mechanization capacity	-0.224	-0.128	-0.340	0.468	0.222
Salinity and sodicity	-0.025	0.022	-0.023	-0.104	-0.012
Climate	-0.153	0.409	-0.312	-0.049	-0.510
Market	0.444	-0.212	-0.394	-0.069	-0.237
Accessibility	0.491	-0.222	-0.355	-0.032	-0.212
Possibilities for irrigation	-0.338	0.306	-0.220	-0.022	-0.409

The first three principal components determine more than 50 % of the variance observed in the entire dataset. The first five principal components determine 75 % of the total variance of the input variables. Of the set of variables 'accessibility', 'soil water holding capacity' and 'erosion risk' had the strongest influence (highest component loadings) on the first three principal components. The results of the scoring of the eigenvectors are described in more detail in the following paragraphs.

3.2.1 Current nutrient availability

The land quality indicator 'current nutrient availability' is defined as the natural capacity of the soil to supply the plant with nutrients. This land quality indicator is primarily related to the base saturation and CEC of the upper 20 cm of the soil. The presence of organic matter in the surface layer influences the availability of microelements and phosphate. The decision module for 'current nutrient availability' is presented in appendix A-1. The threshold values of the selected variables are based on general fertilizer recommendation data used for Brazilian crops that are related to relative yields obtained from countrywide field experiences.

Table 12 shows a comparison of observed and expected frequency distributions (%) among restriction classes for the land quality indicator 'current nutrient availability' in five different regions. The values per regions are based on the number of observations per class per region, expressed as a percentage of the total number of observations per region. The last row of the table indicates the number of expected observations. The expected values are expressed as a percentage of the total number of expected observations. The contingency table for 'current nutrient availability' is given in Appendix A-18. In this table the observed counts as well the H_0 distribution (between brackets) are indicated per restriction class and per region. More information about the class distribution of the 'current nutrient availability' per state can be found in appendix A-19.

Table 12: Comparison of observed and expected frequency distributions (%) among restriction classes for 'current nutrient availability' per region

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted
North	5.2	1.4	1.6	68.6	23.1
Northeast	23.1	5.6	4.9	41.8	24.6
Central west	9.7	4.2	0.9	58.9	26.3
Southeast	17.8	1.6	1.5	61.9	17.2
South	29.6	1.0	5.6	41.9	22.0
Expected	12.4	2.7	2.3	59.3	23.3

More than 80 % of the land in Brazil is considered to be restricted to very restricted for 'current nutrient availability'. However, there are distinct differences between the regions. The Chi-square statistics indicates that the differences of frequency distribution between the regions are statistically highly significant (χ^2_{16} = 830330, P<0.00005). Table 12 shows that the most important differences are in the south, northeast and north. In the south and northeast a larger part as expected under assumption of the H_0 hypothesis is classified as non-restricted and a smaller part as restricted. In the north however, a smaller part as expected is classified as non-restricted and a larger part as restricted.

Differences within the different regions are especially pronounced in the northeast (Appendix A-19). Deviation of the H_0 distribution is especially evident for the states Ceará, Rio Grande de Norte, Paraíba, Pernambuco, Alagoas, and Sergipe. In these states less land as expected is classified as very restricted. This in contrary to the states Maranhão and Piauí, where less area is classified as non restricted and more land is classified as very restricted. In the north, deviation of the H_0 distribution is especially clear for the state Acre. In this state, a relative large part is classified as non-restricted while on the other hand a relatively small part is classified as restricted. In the states Roraima, Pará, and Amapá a relatively small area is classified as non-restricted and a large part as restricted. In the southeast, especially the state São Paulo has more non-restricted land than expected. Both the states São Paulo and Espírito Santo have less land classified as very restricted. Espírito Santo though has more land classified as restricted. In the south, variation from the H_0 distribution is especially clear for Santa Catarina. The central west has a class distribution quite similar as expected under the H_0 assumption. If one look in more detail though, more variation is shown. Mato Grosso do Sul contains more land as expected classified as little to non restricted and less land classified as restricted. The states Goiás and Distrito Federal also have more land classified as non-restricted, but these states have less land classified as very restricted. Mato Grosso, however, has less land classified as non restricted and more land as expected classified as restricted to very restricted.

As is shown in Table 11, the ‘current nutrient availability’ has a relatively moderate to low influence on the principal components. The variable is thus unimportant in terms of weighting in these components. The PCA reflects the weight of the indicator on the total variation of the input data. It suggests thereby indirectly that the ‘current nutrient availability’ has a relatively moderate to low influence on the final evaluation results of LARISSA. This result is in contrast to Figure 10. This figure indicates that ‘current nutrient availability’ is the main restricting land quality indicator and has the highest suppressive influence on the outcome of LARISSA. A possible explanation for the low scoring in the PCA is the fact that this land quality in general is considered restricted to very restricted, the regional variation as indicated in Figure 10 and Table 12 is not reflected in the PCA.

3.2.2 Capacity of maintaining nutrient availability

The land quality indicator ‘capacity of maintaining nutrient availability’ is defined as the capacity to maintain a certain supply of nutrients. This land quality indicator is affected by soil solution conditions (acidity and aluminum toxicity), but this is not taken into account as within the SIATe procedure aluminum toxicity is taken into account within the land quality indicator ‘rooting conditions’. This land quality indicator should be analyzed along with the land quality indicator ‘current nutrient availability’ to determine if a certain land exploitation is sustainable in time. The decision module for this land quality indicator (Appendix A-2) observes organic matter content and CEC of the surface layer.

Table 13 shows a comparison of observed and expected frequency distributions (%) among restriction classes for the land quality indicator ‘capacity maintaining nutrient availability’ in five different regions. The values per regions are based on the number of observations per class per region. They are expressed as a percentage of the total number of observations per region. The expected values are expressed as a percentage of the total number of expected observations. The contingency table for ‘capacity maintaining nutrient availability’ is given in Appendix A-20. In this appendix the observed counts as well the H_0 distribution (between brackets) are indicated per restriction class and per region. Additional information about the class distribution of the ‘capacity maintaining nutrient availability’ per state can be found in appendix A-21.

Table 13: Comparison of observed and expected frequency distributions (%) among restriction classes for ‘capacity of maintaining nutrient availability’ per region

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted
North	12.4	8.9	4.7	68.7	5.3
Northeast	8.8	14.5	14.3	45.2	17.2
Central west	9.8	4.8	14.1	58.4	12.9
Southeast	6.6	11.8	17.6	59.4	4.6
South	17.6	36.9	17.7	23.4	4.5
Expected	10.9	11.4	10.6	58.3	8.8

The land quality indicator ‘capacity of maintaining nutrient availability’ shows relatively small regional differences. Yet the Chi-square statistics indicates that the differences of the frequency distribution between the regions are statistically highly significant (χ^2_{16} = 1158313, P<0.00005). Table 13 reveals that the deviation of the H_0 hypothesis is most evident in the south, north, and northeast. In the south a larger part as expected under assumption of the H_0 hypothesis is classified as non to moderate restricted and a smaller part as restricted to very restricted. In the north especially a smaller part as expected is classified as very restricted and a larger part as restricted. In the northeast in particular a larger share as expected is classified as very restricted and a smaller share as restricted.

Differences within the regions are especially pronounced in the northeast. Deviation of the H_0 distribution is especially evident for the states Paraíba, Rio Grande do Norte, and Ceará. In these states a larger part as expected under the H_0 distribution is classified as little restricted and a smaller part as restricted. In Sergipe though a smaller part as expected is classified as non-restricted. In general, in the southeast a smaller part as expected is classified as non restricted. Rio de Janeiro yet has a larger part as expected classified as moderate restricted and a smaller part as restricted to very restricted. In the south, Paraná attracts attention as this state has a larger part as expected classified as little to moderate restricted and a smaller part as restricted to very restricted. In the north the variation of the H_0 hypothesis is most evident for the state of Acre.

As is shown in Table 11, the ‘capacity of maintaining nutrient availability’ has again a relatively moderate influence on the first principal component and a relatively high influence on the second principal component. The PCA reflects the weight of the indicator on the total variation of the input data and suggests thereby indirectly that the ‘current nutrient availability’ has a relatively moderate to high influence on the final evaluation results of LARISSA. This result is conform Figure 10. Figure 10 indicates that ‘capacity of maintaining nutrient availability’ is a very restrictive land quality indicator in all regions. The indicator has a high limiting influence on the outcome of LARISSA.

3.2.3 Nutrient retention capacity

The land quality indicator ‘nutrient retention capacity’ is defined as the capacity of a soil to retain additional nutrients, while avoiding excessive leaching or specific sorption. CEC is not the only variable defining ‘nutrient retention capacity’; this land quality indicator is also a function of soil solution and pH value. Considering that the addition of nutrients is done by chemical fertilizers (the most common way), measuring the CEC at a standard pH of 7.0 will be an indication of nutrient retention capacity when improving the soil with lime. Usually liming and fertilization are done together following recommendations of soil analysis. The ‘nutrient retention capacity’ defined by CEC values is thus an indicator of the suitability of the soil to improve the management to a higher input system.

This land quality indicator contributes to the definition of sustainability of a production system and should be analyzed along with the land quality indicators ‘current nutrient availability' and 'capacity of maintaining nutrient availability'. The decision module for this land quality indicator (Appendix A-3 & A-4) considers the CEC of the upper layer and subsurface.

Table 14 shows a comparison of observed and expected frequency distributions (%) among restriction classes for 'nutrient retention capacity' in five different regions. The values per regions are based on the number of observations per class per region, expressed as a percentage of the total number of observations per region. The expected values are expressed as a percentage of the total number of expected observations. The contingency table for the land quality indicator 'nutrient retention capacity' is given in Appendix A-22. In this appendix the observed counts as well the H_0 distribution (between brackets) are indicated per restriction class and per region. Additional information about the class distribution of the 'nutrient retention capacity' per state can be found in appendix A-23.

Table 14: Comparison of observed and expected frequency distributions (%) among restriction classes for 'nutrient retention capacity' per region

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted
North	20.6	4.7	13.6	59.4	1.8
Northeast	31.2	9.9	5.3	51.3	2.3
Central west	13.0	14.7	4.8	64.9	2.6
Southeast	17.1	14.5	4.1	61.0	3.3
South	68.1	4.0	10.3	16.6	1.0
Expected	23.9	8.6	9.1	56.3	2.1

The Chi-square statistics indicates that the differences of frequency distribution between the regions are statistically highly significant (χ^2_{16} = 1167882, P<0.00005). Table 14 shows that in the south, and central west the deviation of the H_0 hypothesis is most evident. In the south especially a larger part as expected under assumption of the H_0 hypothesis is classified as non-restricted and a smaller part as restricted. In the central west a fairly smaller share as expected is classified as non-restricted and moderate restricted and a larger share as little restricted and restricted.

Differences within the different regions are especially pronounced in the north and northeast of Brazil. In these regions deviation of the H_0 distribution is especially evident for the states Acre, Paraíba, Rio Grande do Norte, Ceará, and Sergipe. In these states a larger part as expected under the H_0 distribution is classified as non-restricted and a smaller part as restricted. However, in the southeast of Brazil in Espírito Santo a larger part as expected is classified as restricted and a smaller part as non-restricted. In the state of Rio de Janeiro a larger part as expected is classified as little restricted and a smaller part as moderate restricted. In the central west deviation of the H_0 distribution is especially clear for the states of Mato Grosso and Mato Grosso do Sul.

As is shown in Table 11, the 'nutrient retention capacity' has a high influence on the first two principal components. In other words, the variable is important in terms of weighting in these components. The PCA reflects the weight of the indicator on the total variation of the input data and suggests that the 'nutrient retention capacity' has a relatively high influence on the final evaluation results of LARISSA. This result is conforming the results of Figure 10. Figure 10 shows that the 'nutrient retention capacity' has a negative influence on the outcome of LARISSA. An exception on these results is the south, in this region the 'nutrient retention capacity' in general is considered to be non restricted (table 14) and has thus a positive influence on the land evaluation results.

3.2.4 Rooting conditions

The land quality indicator 'rooting conditions' is defined as the maximum depth of the soil that can be exploited by the rooting system, without obstacles, to support the plant physically and to provide it with water and nutrients. Beside the usual physical restriction for root development (soil depth, extremely hard subsurface horizons, excessive soil moisture) soil fertility may also obstruct rooting capacity in tropical soils due to aluminum toxicity or extremely low pH values in deeper soil layers (Buol & Eswaran, 2000). For this land quality indicator the decision module takes into consideration depth, base saturation, CEC, and aluminum saturation of the upper layer and subsurface horizon (Appendix A-5 & A-6).

Table 15 shows a comparison of observed and expected frequency distributions (%) among restriction classes for 'rooting conditions' in five different regions. The values per regions are based on the number of observations per class per region. They are expressed as a percentage of the total number of observations per region. The expected values are expressed as a percentage of the total number of expected observations. The contingency table for the 'rooting conditions' is given in Appendix A-24. In this appendix the observed counts as well the H_0 distribution (between brackets) are indicated per restriction class and per region. Additional information about the class distribution of the 'rooting conditions' per state can be found in appendix A-25.

Table 15: Comparison of observed and expected frequency distributions (%) among restriction classes for 'rooting conditions' per region

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted
North	5.0	10.3	65.2	17.6	1.8
Northeast	18.2	9.7	51.8	14.3	6.0
Central west	7.9	4.2	78.4	7.0	2.6
Southeast	20.7	2.6	64.1	8.5	4.1
South	22.5	43.6	28.1	4.2	1.6
Expected	10.9	10.4	62.6	13.1	3.0

The Chi-square statistics indicates that the differences of frequency distribution between the regions for 'rooting conditions' are statistically highly significant (χ^2_{16}=1491741, P<0.00005). Table 15 shows the deviation of the H_0 hypothesis is most clear for the south. In the south a larger share as expected under assumption of the H_0 hypothesis is classified as non-to little restricted for 'rooting conditions' and a smaller share as moderate restricted to restricted. In the southeast a larger part as expected is considered non restricted and a smaller part little restricted. In the central west in particular a larger part as expected is classified as moderate restricted.

Differences within the different regions are evident in all regions. Deviation of the H_0 distribution is especially evident for the states of Acre, Tocantins, Pernambuco and Santa Catarina. In Acre especially a larger part as expected under assumption of the H_0 hypothesis is classified as non-restricted and a smaller part as expected as moderate restricted. In Tocantins a smaller part as expected is classified as non-to moderate restricted and a larger part as restricted. In the state Pernambuco a larger part is considered to be little to non restricted for 'rooting conditions' and a smaller part as moderate restricted. In the state Santa Catarina a larger part is classified as little restricted and a smaller part as moderate restricted and restricted.

As shown in Table 11, the 'rooting conditions' have a relatively low scoring on the principal components. The variable is thus insignificant in terms of weighting in these components. The PCA suggests that the 'rooting conditions' has a relatively low influence on the final evaluation results of LARISSA. This result is conform the results of Figure 10, this figure shows that the indicator 'rooting conditions' has a relative small influence on the outcome of LARISSA.

3.2.5 Soil water holding capacity

The land quality indicator 'soil water holding capacity' is defined as the quantity of water a soil is able to store. This indicator concerns expectations of plant development while considering a favorable climatic environment and well-drained soils. The decision module for this land quality indictor (Appendix A-7 & A-8) considers depth of the soil, organic matter content, and texture (silt and clay percentage) of the upper layer and subsurface of the soil.

Table 16 shows a comparison of observed and expected frequency distributions (%) among restriction classes for 'soil holding capacity' in five different regions. The values per regions are based on the number of observations per class per region. They are expressed as a percentage of the total number of observations per region. The expected values are expressed as a percentage of the total number of expected observations. The contingency table for the 'soil holding capacity is given in Appendix A-26. In this appendix the observed counts as well the H_0 distribution (between brackets) are indicated per restriction class and per region. Additional information about the class distribution of the 'soil holding capacity' per state can be found in appendix A-27.

Table 16: Comparison of observed and expected frequency distributions (%) among restriction classes for 'soil water holing capacity' per region

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted
North	26.3	29.2	5.6	29.2	9.7
Northeast	7.5	7.3	10.0	42.3	32.9
Central west	27.1	7.3	22.9	30.1	12.6
Southeast	43.8	19.4	3.1	25.6	8.1
South	45.3	9.8	0.0	40.1	4.8
Expected	26.2	18.6	9.1	32.1	14.1

The Chi-square statistics indicates that the differences of frequency distribution for 'soil water holding capacity' between the regions are statistically highly significant (χ^2_{16} =1911469, P<0.00005). Table 16 shows that the deviation of the H_0 hypothesis is evident for all regions. In the south a larger part as expected under assumption of the H_0 hypothesis is classified as non-restricted. In the southeast a larger part as expected is classified as non-restricted and a smaller part as moderate to very restricted. In the central west especially a larger part as excepted is classified as moderate restricted and a smaller part as little restricted. In the northeast a smaller part as expected under the H_0 hypothesis is classified as none to little restricted and a larger part as expected is classified as restricted to very restricted. In the north in particular a larger part is classified as little restricted and a smaller part as moderate to very restricted.

Differences within the different regions are evident for the north and northeast of Brazil. Here deviation of the H_0 distribution is especially clear for the states of Amapá, Rondônia, Paraíba and Alagoas. The state Amapá has more land as expected classified as non-to little restricted and less land as restricted. In Rondônia a larger part is classified as little restricted and restricted and a smaller part as non-restricted. In Paraíba a larger part is classified as moderate restricted and a smaller part as non-restricted. In Alagoas a larger part as expected is classified as very restricted.

As shown in Table 11, the ‘soil water holding capacity’ has the highest scoring on the second principal component. The variable is thus significant in terms of weighting in this component. The PCA indicates the weight of the ‘soil water holding capacity’ on the total variation of the input data and suggests that the indicator has a relatively high influence on the final evaluation results of LARISSA. Figure 10 reveals a similar result, especially for the northeast of Brazil. The ‘soil water holding capacity’ has a relatively large influence on the outcome of LARISSA. Figure 10 indicates as well that this influence of this indicator on the land evaluation results is very variable. This can be explained by the large variation of ‘soil water holding capacity’ within and between regions.

3.2.6 Soil drainage

The land quality indicator ‘soil drainage’ is defined as the velocity of surplus water to infiltrate the soil and move through the soil profile. ‘Soil drainage’ concerns oxygen availability to the roots and salinization risk, and is associated with the permeability of the soil and the groundwater table level. The decision module for this indicator (Appendix A-9 & A-10) considers drainage, slope and texture of the soil profile.

Table 17 shows a comparison of observed and expected frequency distributions (%) among restriction classes for 'soil drainage' in five different regions. The values per regions are based on the number of observations per class per region. They are expressed as a percentage of the total number of observations per region. The expected values are expressed as a percentage of the total number of expected observations. The contingency table for 'soil drainage' is given in Appendix A-28. In this appendix the observed counts as well the H_0 distribution (between brackets) are indicated per restriction class and per region. Additional information about the class distribution of the 'soil drainage' per state can be found in appendix A-29.

Table 17: Comparison of observed and expected frequency distributions (%) among restriction classes for 'soil drainage' per region

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted
North	67.5	8.7	5.4	6.6	11.7
Northeast	66.6	14.4	5.1	4.9	9.0
Central west	77.2	2.9	4.5	2.6	12.7
Southeast	83.0	6.9	4.8	3.7	1.6
South	68.3	14.5	15.1	1.1	1.0
Expected	71.0	8.8	5.8	4.8	9.6

The greater part of Brazil (about 80 %) is considered little to non-restricted for 'soil drainage'. Yet the Chi-square statistics indicate that the differences of frequency distribution for 'soil drainage' between the regions are statistically highly significant (χ^2_{16}=467717, P<0.00005). Table 17 shows that the deviation of the H_0 hypothesis is most clear for the southeast and south. In the southeast a larger part as expected under assumption of the H_0 hypothesis is classified as non-restricted for 'soil drainage'. In the south a larger part as expected is classified as little to moderate restricted and a smaller part especially as very restricted. Differences within the different regions are most evident for the northeast and central west of Brazil. Deviation of the H_0 distribution is particularly clear for the states of Acre, Amazonas and Tocantins in the northeast and the states Mato Grosso and Mato Grosso do Sul in the central west of Brazil. All these states have a larger part as expected classified as restricted to very restricted.

As is shown in Table 11, the indicator 'soil drainage' has the highest scoring on the fourth principal component and a low scoring on the first three principal components. The variable is thus very important in terms of weighting in the fourth component. The PCA suggests thereby indirectly that the 'soil drainage' has a relatively moderate to high influence on the final evaluation results of LARISSA. Figure 10 that indicates that 'soil drainage' has a relatively large positive influence on the outcome of LARISSA underlines this result.

3.2.7 Erosion risk

'Erosion risk' is defined as the risk of soil degradation by water erosion. This land quality indicator is important to maintain fertility by preventing the removal of the fertile upper layer of soil or ashes from burning plant residuals. An adequate management of soil strata and plant residues or deforestation is an important aspect in erosion control. In general simple management measures are sufficient in extensive or semi-intensive agriculture. In case of a more intensive exploitation and mechanization it could be associated with soil coverage practices and the usage of terraces. The decision module for this land quality indicator (Appendix A-11 & A-12) considers depth, slope and texture of the soil profile.

Table 18 shows a comparison of observed and expected frequency distributions (%) among restriction classes for 'erosion risk' in five different regions. The values per regions are based on the number of observations per class per region. They are expressed as a percentage of the total number of observations per region. The expected values are expressed as a percentage of the total number of expected observations. The contingency table for the 'erosion risk' is given in Appendix A-30. In this appendix the observed counts as well the H_0 distribution (between brackets) are indicated per restriction class and per region. Additional information about the class distribution of the 'erosion risk' per state can be found in appendix A-31.

Table 18: Comparison of observed and expected frequency distributions (%) among restriction classes for 'erosion risk' per region

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted
North	22.9	35.5	24.1	12.6	4.9
Northeast	25.8	9.9	42.4	4.9	17.1
Central west	50.8	22.1	4.9	10.3	11.9
Southeast	43.1	22.2	12.6	10.9	11.3
South	45.2	12.3	36.6	3.0	2.9
Expected	32.1	24.0	27.0	8.9	8.0

The Chi-square statistics indicates that the differences of frequency distribution of 'erosion risk' between the regions are statistically highly significant (χ^2_{16} =1591625, P<0.00005). Table 18 shows that the deviation of the H_0 hypothesis is most obvious for the central west, north and northeast. In the central west a larger part as expected under assumption of the H_0 hypothesis is classified as non-restricted and a smaller part as moderate restricted. In the northeast a smaller part as expected is classified as non-to little restricted for 'erosion risk' and a larger part as moderate and very restricted. In the north particularly a larger part as expected is classified as little restricted and smaller part as non restricted.

Differences within the different regions are especially evident for the northeast of Brazil. Deviation of the H_0 distribution is especially clear for the state Paraíba. A larger part as expected of this state is classified as very restricted and a smaller part as non-to little restricted.

Table 11 shows that 'erosion risk' has the highest scoring on the third principal component. The variable is thus important in terms of weighting in this component. The PCA shows the weight of the indicator on the total variation of the input data and suggests thereby indirectly that the 'erosion risk' has a relatively high influence on the final evaluation results of LARISSA. Yet Figure 10 indicates that 'erosion risk' has a relatively small influence on the outcome of LARISSA. The high scoring on the PCA can most probably be explained by the high variation of this indicator within and between regions.

3.2.8 Mechanization capacity

'Mechanization capacity' is defined as the conditions of an area for mechanization with machinery driven by animal force. Slope and surface stoniness are considered decisive for the determination of this land quality indicator (Appendix A-13).

Table 19 shows a comparison of observed and expected frequency distributions (%) among restriction classes for 'mechanization capacity' in five different regions. The values per regions are based on the number of observations per class per region and are expressed as a percentage of the total number of observations per region. The contingency table for the 'mechanization capacity' is given in Appendix A-32. In this appendix the observed counts as well the H_0 distribution (between brackets) are indicated per restriction class and per region. Additional information about the class distribution of the 'mechanization capacity' per state can be found in appendix A-33. Note that in contrast to the other land quality indicators, this indicator has no soil input data classified in the class restricted.

Table 19: Comparison of observed and expected frequency distributions (%) among restriction classes for 'mechanization capacity' per region

Region	Non restricted	Little restricted	Moderate restricted	Very restricted
North	68.0	21.4	4.3	6.2
North East	64.6	11.7	5.1	18.6
Central West	81.8	10.2	3.2	4.7
Southeast	57.9	35.0	2.6	4.5
South	40.9	15.7	29.3	14.0
Expected	67.1	18.6	5.7	8.6

The Chi-square statistics indicates that the differences of frequency distribution between the regions are statistically highly significant (χ^2_{16}=1235166, P<0.00005). As is indicated in Table 19, the land quality indicator 'mechanization capacity' shows a slight regional distribution. Deviation of the H_0 hypothesis is especially evident for the central west and south of Brazil. More than 80 % of the central west of Brazil is considered to be non restricted for mechanization capacity, in contrast to 41 % of the south.

Differences within the different regions are evident for entire Brazil. Deviation of the H_0 distribution is especially clear for the state Amapá. A larger part as expected of this state is classified as little restricted and a smaller part as expected as non restricted. In Paraíba a larger part as expected is classified as very restricted and a smaller part as non-restricted. In Rio Grande do Sul a larger part as expected is classified as moderate restricted and a smaller part as non-to little restricted. A larger part of the state Mato Grosso do Sul as expected under assumption of the H_0 distribution is classified as non-restricted.

Table 11 shows that ‘mechanization capacity’ has a relative low scoring on the first two principal components and a high scoring on the third and fourth. The variable is thus relative important in terms of weighting in these components. The PCA suggests thereby indirectly that the ‘mechanization capacity’ has a relatively high influence on the final evaluation results of LARISSA. Figure 10 indicates that ‘mechanization capacity’ has a very variable influence on the outcome of LARISSA. In the north, northeast and central west this indicator has a positive contribution in the outcome of land evaluation results, in the south it is reducing the evaluation results.

3.2.9 Salinity and sodicity

‘Salinity and sodicity’ are defined as the presence of soluble salts and sodium in sufficient quantities to decrease the development of non-halophilous plants and comparatively retained sodium in relation to the CEC. Salinity will indicate salinization potential in the semi-arid part of Brazil; it is of no importance in more humid climates. The soils that have a high concentration of salts can have extreme limitations for agricultural use. Desalinization is difficult, especially when the evapotranspiration exceeds the precipitation. In case of irrigation there is a risk to increase the amount of salts by capillary rise or usage of saline water. The abundance of sodium can cause serious damage to plant growth. The decision module for this land quality indicator (Appendix A-14 & A-15) takes electric conductivity and sodium content into consideration.

Table 20 shows a comparison of observed and expected frequency distributions (%) among restriction classes for ‘salinity and sodicity’ in five different regions. The values per regions are based on the number of observations per class per region. They are expressed as a percentage of the total number of observations per region. The contingency table for ‘salinity and sodicity’ is given in Appendix A-34. In this appendix the observed counts as well the H_0 distribution (between brackets) are indicated per restriction class and per region. Information about the class distribution of the ‘salinity and sodicity’ per state can be found in appendix A-35. Note that in contrast to the other land quality indicators, this indicator has no soil input data classified in the class little restricted.

Table 20: Comparison of observed and expected frequency distributions (%) among restriction classes for 'salinity and sodicity' per region

Region	Non restricted	Moderate restricted	Restricted	Very restricted
North	98.4	0.2	0.9	0.5
North East	93.4	3.1	2.0	1.5
Central West	96.8	1.7	0.6	0.9
Southeast	99.8	0.0	0.1	0.1
South	97.0	0.0	1.1	1.9
Expected	97.2	0.9	1.0	0.8

The Chi-square statistics indicates that the differences of frequency distribution between the regions are statistically highly significant (χ^2_{16}=176955, P<0.00005). As is indicated in Table 20, the major part of Brazil is classified as non-restricted for 'salinity and sodicity'. In the northeast of Brazil though about 7 % of the area is classified as moderate to very restricted for 'salinity and sodicity'.

Differences within the different regions are especially evident for the northeast of Brazil. Deviation of the H_0 distribution is especially clear for the states Alagoas, Rio Grande do Norte, Pernambuco and Sergipe. A larger part as expected of these states is classified as moderate to very restricted.

As is shown in Table 11, 'salinity and sodicity' has a very low scoring on the principal components and the variable is thus unimportant in terms of weighting in these components. The PCA reflects the weight of the indicator in the total variation of the input data and suggests thereby indirectly that the 'salinity and sodicity' has a low influence on the final evaluation results of LARISSA. Figure 10 indicates as well that 'salinity and sodicity' has a relatively small influence on the outcome of LARISSA. More specific, in certain regions the variation of the indicator is so small that the contribution of this indicator on the evaluation results is like adding a constant value. In the northeast the relative influence is small, although this region is characterized by a semi-arid climate. This is most probably explained by the high variation of this indicator within this region; a relative small area is classified as moderate to very restricted.

3.2.10 Climate

The results of the determination of the spatial distribution of the land quality indicator 'climate' are represented in Figure 11. Table 21 shows a comparison of observed and expected frequency distributions (%) among restriction classes for 'climate' in five different regions. The values per regions are based on the number of observations per class per region. They are expressed as a percentage of the total number of observations per region. The contingency table for 'climate' is given in Appendix A-36. In this appendix the observed counts as well the H_0 distribution (between brackets) are indicated per restriction class and per region. Additional information about the class distribution of the 'climate' per state can be found in appendix A-37.

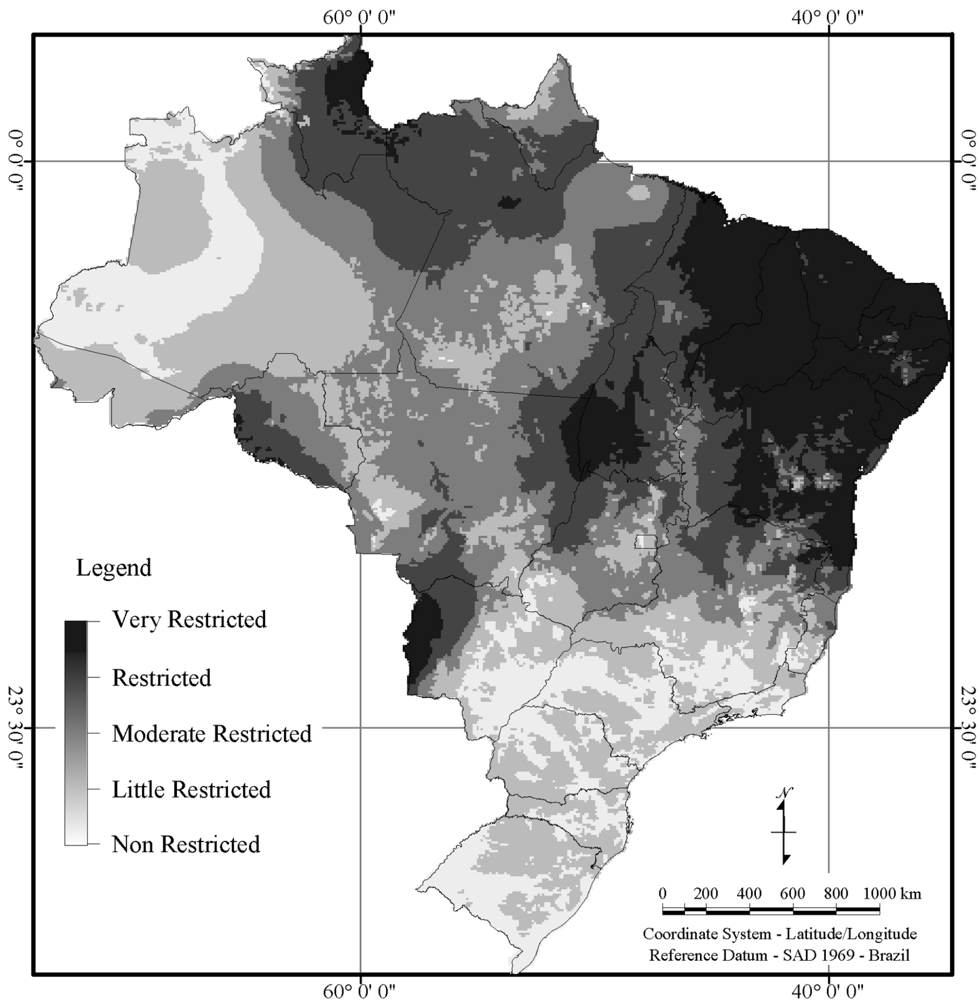

Figure 11 Climate; spatial distribution of water deficit

Table 21: Comparison of observed and expected frequency distributions (%) among restriction classes for 'climate' per region

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted
North	11.7	27.7	26.6	29.5	4.4
North East	0.0	0.2	4.7	20.4	74.7
Central West	8.1	24.5	43.5	19.6	4.3
Southeast	25.6	41.6	21.2	10.0	1.5
South	46.4	53.6	0.0	0.0	0.0
Expected	12.8	25.3	23.3	21.8	16.9

As is represented in Figure 11 and as well in Table 21, climate has strong regional distribution. The Chi-square statistics indicates that the differences of frequency distribution between the regions are statistically highly significant (χ^2_{16} = 6702039, P<0.00005) In the south and southeast of Brazil a larger part as expected under assumption of the H_0 hypothesis is considered to be little or non-restricted for climate. This in contrast to the northeast where 75 % of the surface area is classified as very restricted, a larger part as expected.

Differences within the regions are especially evident for the north and central west of Brazil. In the north deviation of the H_0 distribution is especially clear for the states Amazonas, Tocantins and Roraima. In the state Amazonas a larger part as expected is classified as non-restricted and restricted. In the states Tocantins and Roraima a larger part as expected is classified as little restricted and a smaller part as non-restricted. In the central west the state Distrito Federal a larger part as expected is classified as restricted. In the state Mato Grosso a larger part is classified as moderate restricted.

'Climate' has a modest to high scoring on principal components (Table 11). The variable is thus important in terms of weighting in these components. The PCA reflects the weight of the indicator on the total variation of the input data and suggests thereby indirectly that 'climate' has a relatively moderate to high influence on the final evaluation results of LARISSA. Figure 10 confirms that 'climate' has a high suppressive influence on the evaluation results in the northeast. In other regions the influence is less distinct.

3.3 Relative significance of regional condition indicators for the evaluation results of LARISSA

To study the relative significance of the regional condition indicators for LARISSA three types of analyses were carried out, similar as in chapter 3.2.

3.3.1 Accessibility

The results of the determination of the spatial distribution of the regional condition indicator ‘accessibility’ are represented in Figure 12.

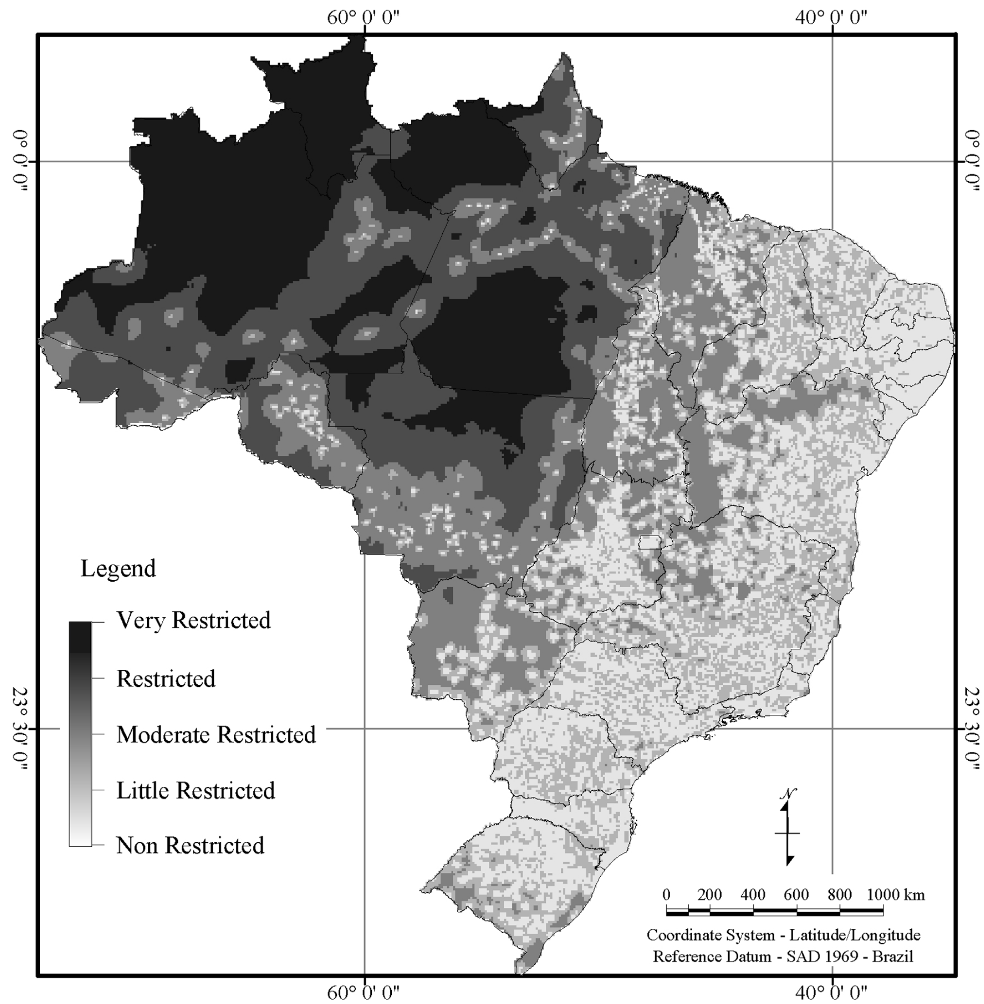

Figure 12: Spatial distribution of regional condition indicator ‘accessibility’

Table 22 shows a comparison of observed and expected frequency distributions (%) among restriction classes for ‘accessibility’ in five different regions. The values per regions are based on the number of observations per class per region. They are expressed as a percentage of the total number of observations per region. The contingency table for 'accessibility' is given in Appendix A-38. In this appendix the observed counts as well the H_0 distribution (between brackets) are indicated per restriction class and per region. Information about the class distribution of the 'accessibility' per state can be found in appendix A-39.

Table 22: Comparison of observed and expected frequency distributions (%) among restriction classes for 'accessibility' per region

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted
North	2.1	3.2	17.3	34.8	42.6
North East	41.7	35.1	23.1	0.1	0.0
Central West	12.9	17.1	38.4	24.8	6.7
Southeast	47.8	44.6	7.6	0.0	0.0
South	55.9	38.6	5.5	0.0	0.0
Expected	20.2	18.7	20.5	20.3	20.4

As is represented in Figure 12 and as well in Table 22 the regional condition 'accessibility' has a distinctive regional distribution. The Chi-square statistics indicates that the differences of frequency distribution between the regions are statistically highly significant (χ^2_{16} = 6340936, P<0.00005). For more than 55 percent of the surface area of the south and 48 % of the southeast of Brazil the settler needs to perform an acceptable effort to get to the nearest city, a larger part as expected under assumption of the H_0 hypothesis. This in contrast to the north and central west of Brazil, where a smaller part as expected is classified as non restricted and a larger part as restricted and/or very restricted.

Differences within the regions are especially evident for the north and central west of Brazil. In the north deviation of the H_0 distribution is especially clear for the states Roraima, Amazonas, Pará and Amapá. In the state Amazonas a larger part as expected is classified as very restricted. In the Roraima, Pará and Amapá a larger part is classified as restricted to very restricted, this also applies for the state Mato Grosso in the central west of Brazil.

As is shown in Table 11, 'accessibility' has the highest scoring on the first principal component. The variable is thus important in terms of weighting in this component. The PCA suggests thereby that 'accessibility' has a high influence on the final evaluation results of LARISSA. Figure 10 however shows that in the north and central west of Brazil 'accessibility' has a small limiting influence on the evaluation results. In the northeast 'accessibility' has a relatively high positive influence on the outcome of the land evaluation. Figure 10 indicates that the influence of this indicator on the evaluation results is highly variable. The high scoring on the PCA is most likely explained by the high variation within and between regions.

3.3.2 Market

The results of the determination of the spatial distribution of the regional condition indicator 'market' are represented in Figure 13.

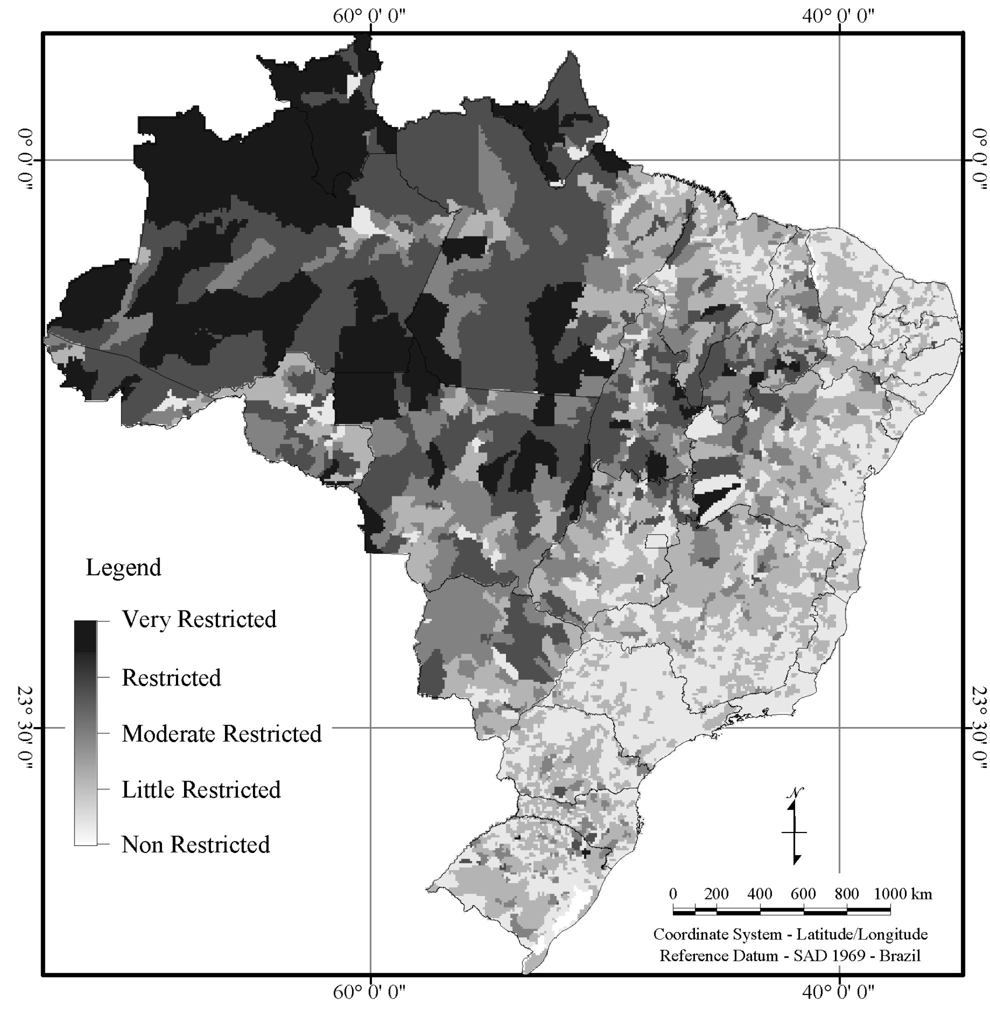

Figure 13: Spatial distribution of regional condition indicator 'market'

Table 23 shows a comparison of observed and expected frequency distributions (%) among restriction classes for 'market' in five different regions. The values per regions are based on the number of observations per class per region. They are expressed as a percentage of the total number of observations per region. The contingency table for ‘market’ is given in Appendix A-42. In this appendix the observed counts as well the H_0 distribution (between brackets) are indicated per restriction class and per region. Additional information about the class distribution of the ‘market’ per state can also be found in appendix A-43.

Table 23: Comparison of observed and expected frequency distributions (%) among restriction classes for ‘market’ per region

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted
North	2.6	40.6	12.6	9.0	35.3
North East	34.4	10.1	15.9	38.1	1.6
Central West	6.9	25.9	30.8	23.4	13.0
Southeast	51.8	1.6	5.7	40.9	0.0
South	44.0	1.3	9.6	44.9	0.2
Expected	17.5	25.2	15.7	23.0	18.6

As is represented in Figure 13 and as well in Table 23 the regional condition indicator ‘market’ has a very regional distribution. The Chi-square statistics indicates that the differences of frequency distribution between the regions are statistically highly significant (χ^2_{16} = 4941224, P<0.00005). More than 50 percent of the surface area of the southeast of Brazil and 44 % of the south is non-restricted for farmers to commercialize their products at a local market, a larger part as expected under assumption of the H_0 distribution. This in contrast to the northern and central western part of Brazil, in these regions a smaller part as expected is considered to be non restricted and a larger part as expected is considered to be restricted and/or very restricted.

Differences within the regions are especially evident for the north and central west of Brazil. In the north deviation of the H_0 distribution is especially clear for the states Roraima, Amazonas, and Amapá. In these states a larger part as expected is classified as very restricted. In the central west in the states Mato Grosso and Mato Grosso do Sul a larger part as expected in classified as moderate restricted.

Table 11 shows that ‘market’ has a relatively high scoring on the first and third principal components. The variable is thus important in terms of weighting in these components. The PCA reflects the weight of the indicator on the total variation of the input data and suggests thereby indirectly that ‘market’ has a high influence on the final evaluation results of LARISSA. Yet Figure 10 shows that in the north and central west of Brazil ‘market’ has a small limiting influence on the evaluation results. In the other regions ‘market’ has a relatively high positive influence on the outcome of the land evaluation. Figure 10 indicates that the influence of this indicator on the evaluation results is highly variable. Similar to the regional condition indicator ‘accessibility’, the high scoring of ‘market’ on the PCA is most likely explained by the high variation within and between regions.

3.3.3 Possibilities for irrigation

The results of the determination of the spatial distribution of the regional condition indicator ‘possibilities for irrigation’ are represented in Figure 14.

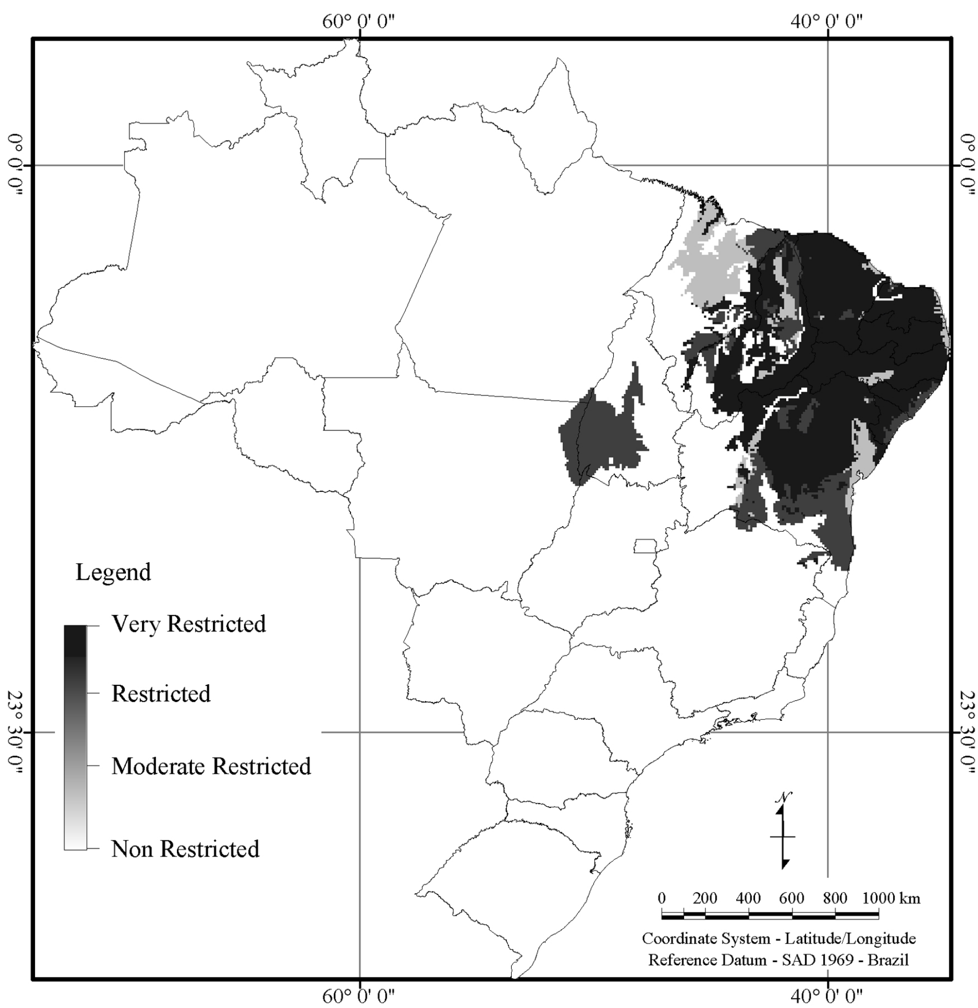

Figure 14: Spatial distribution of ‘possibilities for irrigation’

As already mentioned only the northeast was included in this study, all other regions were simply considered as non-restricted. In the northeast the potential for irrigation was estimated based on only the hydrogeology. Obviously it is also possible to use rivers for irrigation. However, there are maps with rivers, but they give no information about whether a river is perennial or seasonal. Therefore irrigation from rivers was not included in this study.

Table 24 shows a comparison of observed and expected frequency distributions (%) among restriction classes for ‘possibilities for irrigation’ in five different regions. The values per regions are based on the number of observations per class per region. They are expressed as a percentage of the total number of observations per region. The contingency table for ‘possibilities for irrigation’ is given in Appendix A-42. In this appendix the observed counts as well the H_0 distribution (between brackets) are indicated per restriction class and per region. Additional information about the class distribution of the ‘possibilities for irrigation’ per state can be found in appendix A-43. Instead of using five restriction classes, for the ‘possibilities for irrigation’ only four restriction classes were used.

Table 24: Comparison of observed and expected frequency distributions (%) among restriction classes for ‘possibilities for irrigation’ per region

Region	Non restricted	Little to moderate restricted	Restricted	Very restricted
North	97.4	0.0	2.6	0.0
North East	25.5	10.2	13.4	50.9
Central West	98.4	0.0	1.6	0.0
Southeast	100.0	0.0	0.0	0.0
South	100.0	0.0	0.0	0.0
Expected	84.0	2.0	4.1	9.9

As is represented in Figure 14 and as well in Table 24, the ‘possibilities for irrigation’ are mainly determined for the northeast of Brazil, where available access water is less than 400 mm. More than 60 % of the area of the northeast is classified as restricted to very restricted for the ‘possibilities for irrigation’.

Differences within the regions are especially evident for the northeast of Brazil. In the northeast the states Alagoas, Bahia and Sergipe have a larger part as expected under assumption of the H_0 distribution classified as very restricted. In the southeast in the state Minas Gerais a larger part as expected is classified as very restricted.

The ‘possibilities for irrigation’ has a modest to low scoring on the principal components (Table 11). The variable is thus unimportant in terms of weighting in this component. The PCA suggests that ‘possibilities for irrigation’ has a modest to low influence on the final evaluation results of LARISSA. Yet Figure 10 reveals that ‘possibilities for irrigation’ has a high limiting influence on the evaluation results in the northeast. The influence in the other regions on the outcome of the land evaluation is more limited.

3.4 Relation between the location of agrarian reform settlements projects and the evaluation results of LARISSA

Before comparing the location of the settlements with the results of the LARISSA model, first the regional distribution of these settlements was studied in order to see if there is a preference for certain regions during a certain government.

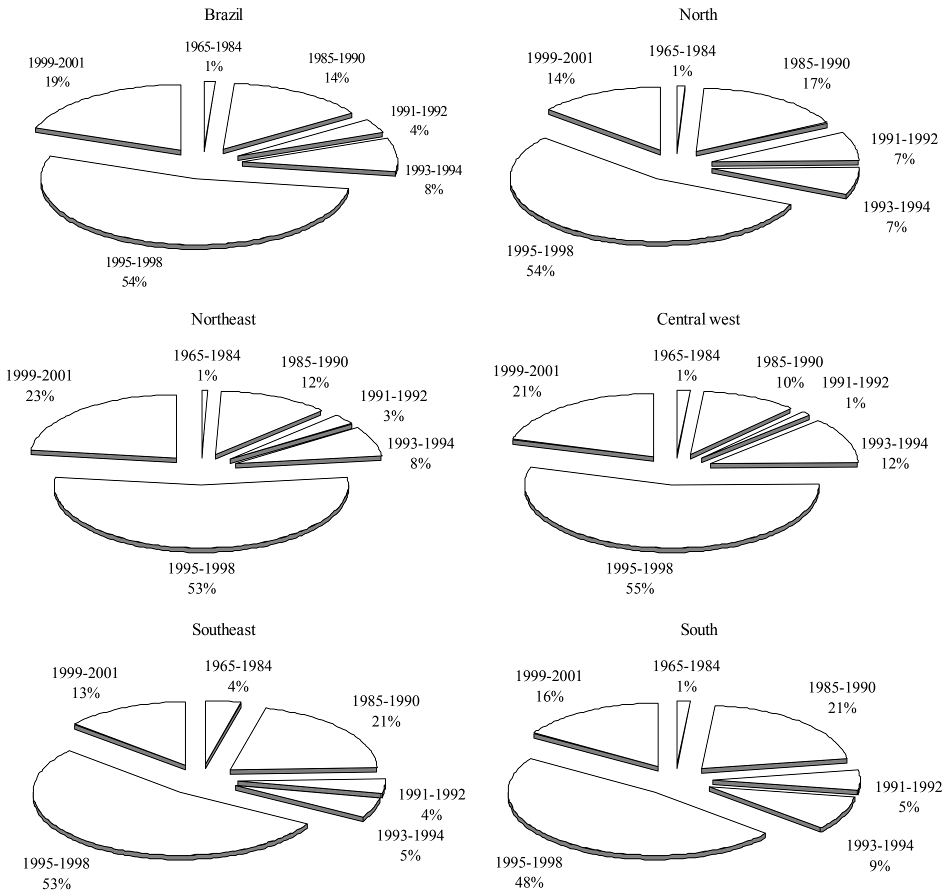

Figure 15: The relative number of new settlements created in a certain governmental period for Brazil as well as for the five regions (%)

Figure 15 shows the relative number of new settlements created in a certain governmental period per regions, it shows that the number of settlements created since 1994 increased significantly. Especially in the period 1995-1998, a large number of settlements have been created. The figure shows as well that the differences per regions are insignificant, i.e. there was no distinct relationship found between the number of new settlements in a certain region and the different governments. Appendix 44 yet shows that in certain states (especially in the north and northeast) relatively a larger number of settlements were created.

Next the results of LARISSA were compared with the location of AR settlements. A summary of the results is given in Appendix A-45. Figure 16 shows the percentage of occurrence of settlements per restriction class of the SLQ indicator scoring versus the governmental periods. Figure 17 shows the percentage of occurrence of settlements per restriction class of the SRC indicator scoring versus the governmental periods.

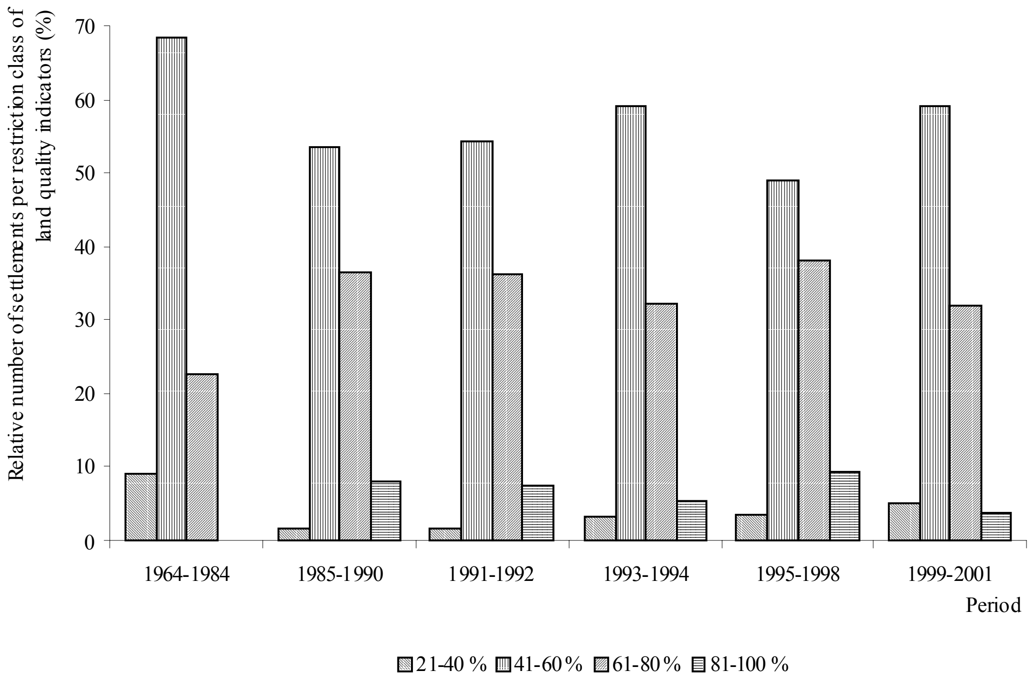

Figure 16: The number of settlements and the relative occurrence per restriction class of the supply of land quality indicators versus governmental periods

Figure 16 shows that most settlements are located there where the SLQ indicators have a scoring between 41-60 %, demonstrating that the land quality indicators on average are moderate restricted. In the last governmental period, compared to the period 1995-1998, relatively more settlements are created in the restricting class 41-60 % and less in the classes 61-80 and 81-100 %. I.e. in the last years relatively more AR settlements were created in regions that are considered to be less suitable.

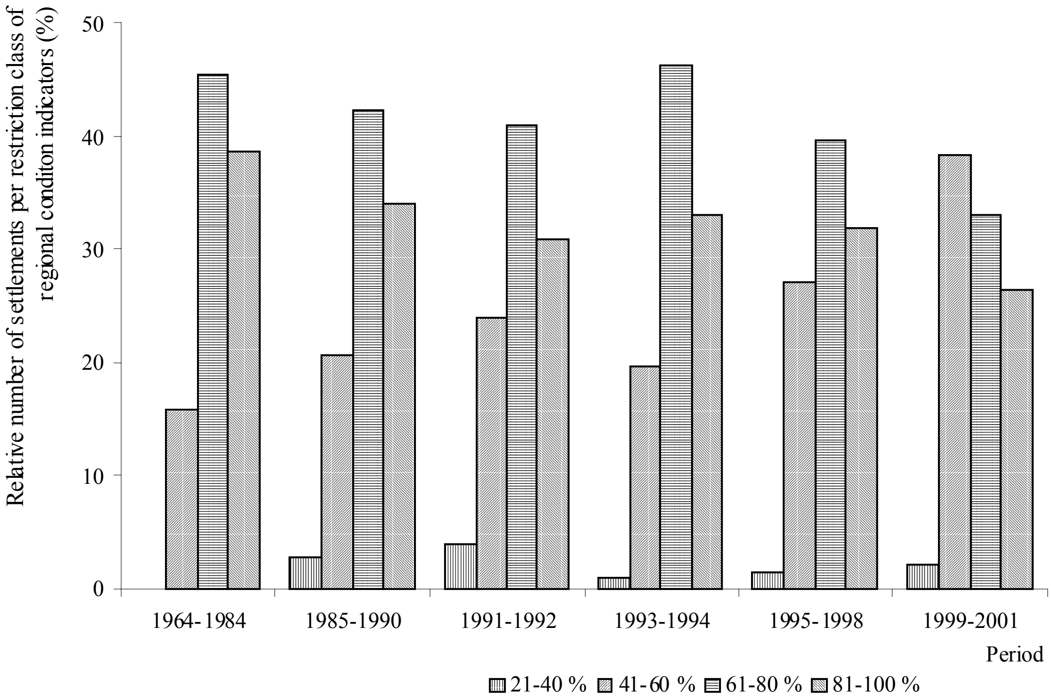

Figure 17: The number of settlements and the relative occurrence per restriction class of the supply of regional condition indicators versus governmental periods

Figure 17 shows that most settlements are located there where the SRC indicators have a scoring between 61-80 %, indicating that the majority of the regional condition indicators are considered to be moderate to little restricted. Since 1993 more settlements were created in the restricting class 41-60 % and less in the classes 61-80 and 81-100 %. These results show that during the last decade the number of settlements that were created in moderate suitable areas increased.

3.5 Validation of land evaluation results by LARISSA

Calculations of the relative importance of family agriculture were based on data provided by IBGE (1996). A summary of the data per region provided by IBGE is given in Table 25. The second column indicates the percentage of total area that is used for agriculture. The third column specifies the percentage of agricultural land that is used by family agriculture. The last column of this table shows the percentage of the value of the total agricultural production that is produced by family farmers.

Table 25: Relative importance of family agriculture in Brazil

Region	% of total area	% of agricultural area	% Production by FA
North	8.4	43.5	79.3
Northeast	30.8	41.9	54.9
Central west	67.6	13.0	16.7
Southeast	62.5	36.0	33.1
South	76.4	38.5	43.7
Brazil	41.7	31.0	38.5

As is shown in Table 25, the regional differences in family agriculture in Brazil are large. The south, central west and southeast are the main agricultural productive areas in Brazil. Yet, the relative contribution of family agriculture is most important in the north and northeast. In these regions family farms occupy a relative large share of the agricultural area as well as the total agricultural production.

Figure 18 shows the correlations between the gross production of family agriculture and a) the supply of land quality indicators, b) the supply of regional condition indicators, and c) the overall supply. Moreover, the correlations between the gross production of commercial agriculture and a, b and c are given. Figure 19 shows the correlations between the total value of agricultural cash flow of both family agriculture and commercial agriculture with a, b and c. A table with the correlation results is given in Appendix A-46. In both figures, the first column represents family agriculture, the second commercial agriculture.

As is shown in Figure 18 as well Figure 19 the correlation results of the overall supply (SLQSRC) are higher than the correlation results of only the supply of land quality indicators (SLQ), implying that reality is represented better when regional condition indicators are included in the evaluation procedure. The differences between the correlation results for the total value of agricultural cash flow and the gross production are not significant, indicating that there is no preference for one of these production measures.

The correlation of the production data with the supply of land quality indicators in the north of Brazil show a much weaker correlation with the production data than all other regions. The central west of Brazil shows a modest correlation to both the gross production and the total cash flow.

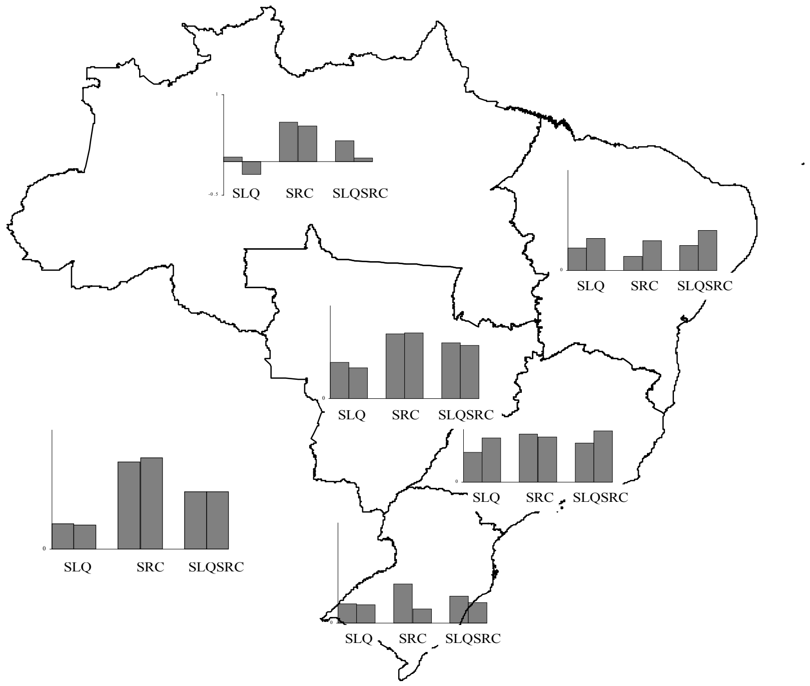

Figure 18: The correlations between the gross production and a) the supply of land quality indicators, b) the supply of regional condition indicators, and c) the overall evaluation results for both family agriculture (1st column) and commercial agriculture (2nd column)

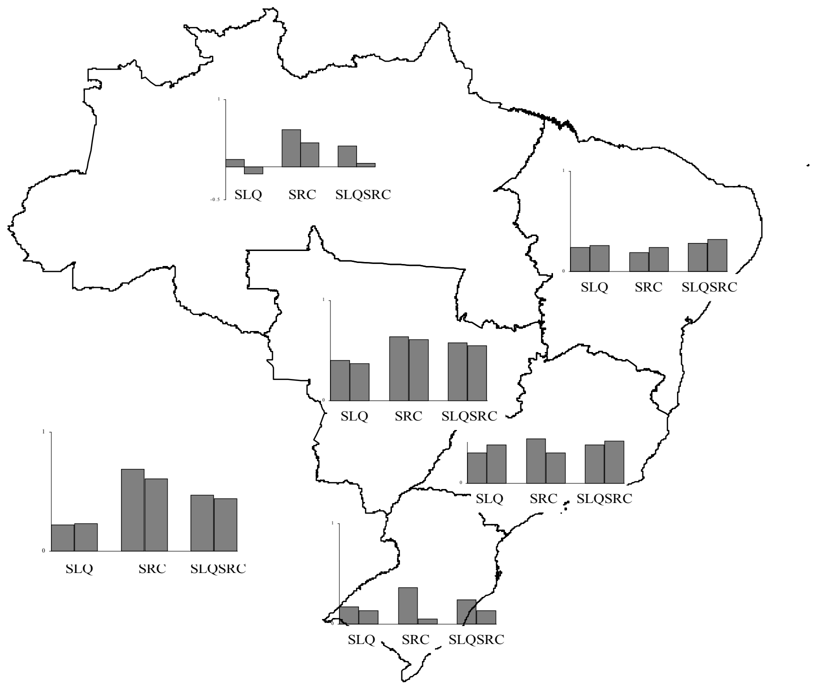

Figure 19: The correlations between the total value of agricultural cash flow and a) the supply of land quality indicators, b) the supply of regional condition indicators, and c) the overall evaluation results for both family agriculture (1st column) and commercial agriculture (2nd colum

4 Discussion

4.1 Quality of input data

To start the paragraph on quality of input data, first some general observations will be discussed. A general trend in research is a growing development of more complicated models to represent the reality. The question remains however whether these more complicated models are always more accurate than simplified methods. Independent of the model, the final results will always depend heavily on the quality of the input data. In other words, with low quality or unreliable data it will be impossible to obtain accurate and/or reliable model outputs (the garbage in - garbage out principle).

Obtaining high quality data with adequate level of detail for Brazil will take substantial time and resources. Brazil is a developing country and available resources are limited. On the other hand, there is a very urgent demand for information and research results to support (sustainable) development of amongst others the agrarian sector. This demand is a result of both internal and international developments. Examples of the latter are Agenda 21, the recent Rio+10 conference in Johannesburg, and the Convention on Biodiversity.

This implies the need of equilibrium between improving detail and data quality and being able to process the models in time to address the problem with the available resources. The approach of this study was to use already existing input data to respond to the demand to analyze regional differences in land quality indicators and regional condition indicators on national scale, and their influences on the process of land evaluation for AR at a national scale.

The first step was the compilation of a database with information on land quality and regional condition indicators, based on the principle of the best available information strategy. This strategy is based on the assumption that much of the required information is already there, although possibly not readily available. The philosophy behind this strategy is that instead of using time, money and energy in collecting new data, one should first try to use results of earlier works. Generation of new data should focus on gaps in current knowledge. In line with this approach, the project combined a dataset based on available information from Internet, research institutes and literature. Creating such a database for a country like Brazil was a major challenge. Available data are often fragmented, focused on limited areas, often only available in hard copies, and difficult to obtain. Until now there is no database similar to the extent as the one assembled for the presented study.

Soils

The soil data used in this research were derived from the soil map 'Mapa de Solos do Brasil', at scale 1: 5,000,000 (EMBRAPA, 1981). This map combines soil map data collected by several governmental agencies over a large period of time. No information is available about the exact procedures followed to combine all the data used to produce the map. In general, one need to take into account that the use of data from different sources might affect the quality and consistency of the soil map. However, it is the best information about soils in Brazil currently available on such a scale.

The above-mentioned map consists of mapping units, with for each mapping unit information about the occurrence of the different soil types and their relative importance. For LARISSA however, basic soil attributes were needed as input parameters. To be able to use this information in our analyses basic soil attributes for each mapping unit had to be determined. The information was extracted from the reports of the Projeto RadamBrasil (1973-1978). The soil data of this project is usually presented as a hardcopy map at scale 1:500,000 with each mapping unit described by representative profiles in an attached report. The information on the location of the soil profile (geographic coordinates) is not always available. However in most cases there is a general description on the location and mapping unit together with the analytical data. For each mapping unit, the soil attributes of the dominant soil types were selected and described based on representative profiles. In other words, it was assumed that each mapping unit is characterized by the soil attributes of the dominant soil type in that mapping unit. Clearly, the restriction of this method is the non-consideration of spatial variation in both soil-forming processes and in the resulting soils (Burrough *et al.*, 1997). It is for this reason that it is nowadays more common to use continuous soil classification, while using GIS to store, manipulate and interpret soil data (Gruijter *et al.*, 1997). Such soil maps are not yet available for Brazil, but when available these maps could easily serve as future input for the LARISSA model.

The soil properties were converted into land quality indicators based on decision rules, a common approach in land evaluation procedures while analyzing classified data. The advantages of using decision rules are the possibility to assess any combination of land quality indicators. Furthermore the hierarchical structure is easy to understand. In this research, the decision rules are based on literature, expert knowledge and data obtained during fieldwork (Sparovek *et al*., 2000; Sparovek *et al*., 2002).

To check the quality and correctness of these decision rules, local experts were consulted. They were asked to evaluate maps with the different land quality indicators of specific areas or regions. The results indicate that the model adequately describes the land quality indicators at both farm and regional level.

Climate

The land quality indicator ‘climate’ was based on information from the FAOCLIM database (FAO, 1995). For Brazil this database contains long-term climate information about 833 weather stations. This information was compared to several climate data sources within Brazil (Pfafstetter, 1957; Setzer, 1945; Mota, 1986), but no publicly available information about additional stations with long-term climate data was found.

Procedures from the ANUSPLIN package (Hutchinson, 1997) were used to create a climatic map. This program is a modeling package that generates interpolated grids based on smoothing splines (Hutchinson, 1991). The program was tested over several years and is used to determine elevation-dependent climate variables in numerous regions including Australia, New Zealand, Canada, Europe, South America, Africa, China and part of Southeast Asia. The program allows mean climatic conditions to be estimated reliable in remote areas. The method requires less climate knowledge compared to the hand-contouring method and provide error estimates as well as precipitation estimates that can be accessed directly by modern geographic information systems (Stillman *et al.*, 1996).

In this study the potential evapotranspiration was calculated according to the method of Thornthwaite (1948). The method is subject to criticism. Studies in arid and semi-arid regions indicate that the Thornthwaite method underestimates the potential evapotranspiration compared with the method of Penman (Michalopoulou & Papaioannou, 1991). Although the method of Penman is considered superior (Amatya *et al*. 1995), the basic data requirement for calculation the evapotranspiration is high (air temperature, wind velocity, humidity and solar radiation). The method of Thornthwaite requires measurements of temperature only. This parameter is provided by most weather stations in contrary to most other climate parameters. Although the use of the formulae of Thornthwaite is approximate, it is useful for areas in which detail meteorological data are lacking (Michalopoulou & Papaioannou, 1991; Pereira & Camargo, 1989). In Brazil, Thornthwaite´s method has been succesfully used in crop zoning, i.e. determining the potentially of a region for a crop (Paes de Camargo, 1974).

Accessibility

The regional condition indicator was based on a global road map (DEMIS BV, 2001). The quality of this road map has deficiencies as certain highways are lacking, especially in the north of Brazil. Beside, as the road map is a global data set it represents only major roads. It is possible to obtain a better dataset by 1) purchasing from a commercial company or 2) creating by means of aerial photos or satellite image interpretation. Unfortunately within the research available resources were insufficient for both options. Nevertheless, the used road map indicates clearly the present regional differences and is therefore very useful.

Accessibility, analyzed by means of GIS, is determined by using buffer and overlay tools. De Jong & van Eck (1996) criticized this approach as the existing transport network is not taken into account and as all sites within a buffer zone receive a similar weight. They suggest to use potential values based on the transport network, i.e., to use travel times measured from the existing road network. In Brazil the access to the transport network is of major importance, especially in the more remote regions. Therefore in this research travel times to a transport network were considered instead of actual travel times on the road network.

The method used to estimate the travel time to a transport network possibly results in overestimations of travel time in regions with many navigable rivers, such as the Amazon. Here, rivers might be much closer and more used than main roads, even if these roads are within a distance of 14 hours. However, empirical data about actual travel times in relation to the different transport means are not available for the whole of Brazil. Therefore an arbitrary weight to transport over the roads and rivers respectively was assigned.

Market

The regional condition indicator ‘market’ was based on population data. The population data were derived from the preliminary results of demographic census for 2000 (IBGE, 2000). As the results are still preliminary, it is difficult to make statements on the quality of the data. But it is possible to make some notes based on previous census data. Paes & Albuquerque (1999) described a significant improvement in the quality of the population data for census data for 1980 and 1990. For the 1990 census they mark the quality of data for the south, southeast and central west of Brazil as sufficient to good. The data quality in the northeast varies from regular or insufficient to good. In the north the quality of the data is insufficient to regular.

Accuracy and quality of the input data for ´market´ was considered to be adequate for this study as it identifies clearly the present regional differences.

Possibilities for irrigation

The 'possibilities for irrigation' were examined with help of the hydrogeology map for Brazil (DNPM, 1983). The mapping units of the hydrogeology map represent geologic units with characteristic aquifers, with for each aquifer a description of the discharge capacity. The map with 'possibilities for irrigation' corresponds with the area indicated by the Geological Service of Brazil (CPRM, 2002) as the area with most wells (66 % of total number of registered wells). However, by using the hydrogeology map only the potential of irrigation and not the actual irrigation situation is given.

Moreover it is also possible to use rivers for irrigation. This possibility was not included in this study as at the time no map was available that indicates whether a river is perennial or not. In the northeast most rivers fall dry for a certain period of the year, which makes it impossible to use a regular river map. At the time a river will be needed to use for supplementary irrigation, the river most probably has fallen dry. However, as soon as a map with rivers is available for that indicates which rivers are perennial and which not, it will be possible to include these data within LARISSA.

4.2 Validity of model

LARISSA is a regional system based on land suitability concepts of the Framework of Land Evaluation (FAO, 1976). In Brazil these land suitability concepts are formerly applied in another methodological approach developed by EMBRAPA and the National Center for Soil Research (CNPS), in collaboration with FAO. The methodology is based on earlier work of Bennema *et al.* (1964) and elaborated on suggestions made by Beek & Goedert (1973), Beek (1975) and Peirera *et al.* (1975). The resulting system is described by Ramalho Filho *et al.* (1978) and is used to interpret soil surveys for agricultural capability of land as a way to judge its availability for different types of land use. The system was developed to be applied on the maps of the RADAMBrasil project at reconnaissance level, but it never gained popularity in Brazil and is hardly ever applied. The SIATe model was developed to work at farm level and thus was adapted to work on a different scale. The LARISSA model is subsequently based on SIATe. As all systems are based on the Framework, they display certain similarities.

As Van Diepen *et al.* (1991) indicate the Framework organizes basic concepts, principles, and procedures for land evaluation that are applicable in any part of the world and at any scale. The Framework as such is primarily designed to provide tools for the construction of evaluation systems in support of rural land use planning, but Van Diepen *et al.* (1991) state as well that there are a number of inconsistencies and vagueness in its principles, concepts and procedures. Especially the concepts of land quality indicators are a source of confusion as the term can be interpreted in many ways. In this study the concept of land qualities according to the definition of Beek (1978) was used, i.e., land qualities were employed in order to reduce the enormous amount of data to manageable proportions and attempted to do so without losing information.

The Framework has been followed by a series of guidelines for specific land uses. These guidelines are additions to the basic concepts and details on the operational aspects of the procedures (Van Diepen *et al.*, 1991). For example, the Guidelines for Rainfed Agriculture (FAO, 1983) lists land qualities relevant for rainfed agriculture. Being build upon these guidelines, SIATe has been designed to be applicable by INCRA's, i.e., without increasing significantly the time and the resources needed in land evaluation procedures and requiring only minimal knowledge and training for its countrywide implementation (Sparovek *et al.*, 2000). This had some consequences for the decision rules and criteria in the model. For example, several land quality indicators are related to the supply of plant nutrients. These land quality indicators are not completely distinct and could as well be considered together. However, these land quality indicators were kept separately, not only because they contain unique as well as complementary information. As in the final evaluation all indicators were combined with an equal weighting, relatively more soil fertility related indicators would result in an additional weighting for soil fertility, which is of major importance to low input agriculture and is typical for the regions of Brazil where the AR is implemented.

While up scaling the SIATe model to regional scale, several adaptations needed to be made. In line with SIATe all soil related indicators were included in the LARISSA model, as well a indicator for climate. It was not feasible to include all regional condition indicators. As it was impossible to collect information on national level about local social circumstances specific for AR, like availability of technical assistance or the agrarian experiences of the settlers. The more general regional circumstances were included though.

The regional condition indicator ‘accessibility’ was included in the research as transport is essential for growth and development. In social geography accessibility is often studied in the context of transport or planning. It was beyond the scope of this research to cover all characteristics of this field of research. The aim was rather to give an indication for regional differences that influence and/or determine regional growth and development.

The regional condition indicator ‘market’ was included in the research because the opportunity for farmers to trade their products is essential for the sustainability of an AR project. Even in the situation the settlers are self-sufficient in its livelihood, they will need a certain amount of cash income for maintenance. Studies to the supply and demand in certain regions can be very complex as these normally dependent on and are related to many factors. However, in the context of this research, a general overview of the regional condition indicators, using a proxy measure 'population density' will suffice.

The regional condition indicator ‘possibilities for irrigation’ was included in this research as it is considered essential to carry out supplementary irrigation in the northeast of Brazil, even with low input family agriculture.

As expressed by Burrough (1986) land evaluation by means of map analysis techniques can be accomplished within any GIS software. This project employed the GIS software TNTMips from MicroImages (2001) to create data layers that represent the land quality and regional condition indicators with quantitative variables. A quantitative land classification was used in which the distinctions between classes are defined in common numerical terms. This allowed ‘performing an objective comparison between variables relating to different kinds of land use’ (FAO, 1976). There are several ways to combine individual land quality and regional condition indicators. The overall suitability was computed according to a formula using equal weighting. It would have been possible to combine individual land quality and regional condition indicators according to the most limiting factor, e.g. the most limiting factor determines the final outcome. This method is attractive due to its simplicity. The disadvantage however is that it does not differentiate between areas with several limitations or with areas with only one. As this study intended to examine the regional differences and their influences on the process of land evaluation for AR at a national scale, the algebraic combination was considered as the most suitable one.

4.3 Suitability of statistical methods

In this study correlation analyses were used to examine whether LARISSA is capable to predict the suitability for agricultural production. To study the relative influence of indicators on the land evaluation system LARISSA three types of analyses were carried out. PCA were used to study the relative contribution of the indicators on total variance of input data. PCA identify a smaller number of factors that explain most of the variance observed in the much larger number of variables. The analysis could thus also be used to explore the possibilities of data reduction. Stepwise exclusion analyses were applied to identify the influence of the different indicators on the outcome per region. Moreover contingency tables were used to study the differences between the regions.

PCA is one of many multivariate analyses methods. PCA is considered to be an exploratory technique that may be useful in gaining a better understanding of the interrelations among the variables, with little use of statistical tests or confidence levels (Afifi & Clark, 1984). Here, the objective was to gain a better idea of the contribution of the variables to the total variance within a dataset and thereby indirectly obtain an insight of the weight of the input variable on the final outcome of LARISSA. The analysis could also be used to explore the possibilities of data reduction. In the context of this work this did not only enable proposal improvements of the model, but will also enable the end user to better understand and interpret the outcome of the model.

The stepwise exclusion analyses were used to exclude the indicators one by one from the outcome of LARISSA, and thus giving an indication of the importance of these indicators on the model results. To interpret the results, it is important to look at the spread of the values around the median and the value of the median itself. The first gives information about the heterogeneity within a region in terms of an indicator and its influence on the final model results. A large spread around the median thus suggests that inclusion of that indicator in the model gives the model a greater distinguishing power for within-region differences. On the other hand, when all values are close or equal to the median, inclusion of the concerning indicator merely adds a constant value to the model. Here, the value of the median itself becomes important as it reveals the influence of that indicator on the between-region differences.

To perform the stepwise exclusion analyses a number of points was generated randomly. The number of points represents one point per thousand square kilometer. It was verified these random points were representative for the values of the indicators by comparing the standard error and the mean values of the raster maps of the indicators with the values of generated points.

The contingency table is a main approach for the numerical analysis of relationships among qualitative descriptors. They are widely used to test for independence of two descriptors, or the other way around, affinity or association between descriptors. (Fowler *et al*., 1998; Kent & Coker, 1992). It is also an excellent method to evaluate differences in frequency distribution, including the nature of these differences (Legendre & Legendre, 1998). All chi-square tests compare the agreement between a set of observed frequencies or distributions and those expected if some null hypothesis is true. In the case of this study, the null hypothesis implied that frequency distributions over the different suitability classes are similar for the different regions. A requirement of the test is that objects should be assigned to nominal categories. However, unambiguous intervals on a continuous scale may also be regarded as nominal for the application of the test. This is in fact what the model does, converting continuous and non-continuous input values to nominal categories (the suitability classes).

The application of the tests requires that samples are random and objects counted are independent and therefore randomly dispersed. For a study like the presented one, this would mean that X number of grid cells throughout Brazil need to be sampled random and record for each cell the region it falls in and the suitability class for each variable. However, instead of sampling, the dataset of this study covers the whole of Brazil and could therefore be considered as a 100% census.

Correlation analyses can be used for descriptive purposes, e.g. to examine the kind of relationship between variables and its strength. Correlation analyses are often helpful in obtaining a preliminary impression of the interrelationship between variables. As mentioned before, it is essential to emphasize that the method can not be used to establish cause and effect relationships, e.g. the fact that a soil property is found to be significant related to a high agricultural production does not necessarily imply that this soil property is the cause of this high production (Fowler *et al*., 1998). However, causal relations between the various land quality and regional condition indicators have been reported in research work (Fox *et al.*, 1991; Schwertmann & Herbillon, 1992). In fact, the model is based on the assumption that such causal relations exist. In this study correlation analyses were used to examine whether the model indeed is capable to predict suitability for agricultural production. In other words, the objective was not to verify if such relations exist but merely to test whether the model actually captures such relations.

4.4 Regional differences in outcome of the land evaluation system LARISSA

This study revealed clear regional differences in the results of the evaluation of land quality and regional condition indicators. Logically this has an effect on the final outcome of the land evaluation results of LARISSA.

The south and southeast of Brazil are considered to be most suitable for AR and family agriculture. The overall evaluation results of LARISSA in these regions are high, indicating that they suffer little to no significant limitations (Figure 9 & Table 10). The quality of the soil physical indicators is the more restricting factor in these regions (Figure 10). Nevertheless, in these regions both the supply of land quality and the supply of regional condition indicators are considered relatively good compared to the rest of Brazil. Conform these results INCRA should focus on these regions to create new AR projects and support the local family agriculture, as in these regions of Brazil the likelihood of settlers or small farmers to succeed is highest. In the evaluation of the land being currently expropriated, one should consider the soil indicators related to soil fertility in particular, as they are the primarily restricting factor.

Land in the south and southeast though is expensive as these are the most developed and densely populated regions. By buying land in these regions, INCRA will not be able to achieve its targeted values. Beside these regions have other opportunities for development, so people will also have chances to improve agricultural production without AR. Therefore until now the priority regions were the north and northeast, and not the south and southeast even these regions are more suitable.

The central west of Brazil is considered non to moderate restrictive in the evaluation of LARISSA, whereby the land quality indicators as well the regional condition indicators ‘accessibility’ and ‘market’ are the most restrictive indicators (Figure 10). According to these results this region is less suitable than the south and southeast to create AR projects and family farmers will need to struggle harder for survival and are less likely to be successful. When evaluating land in the expropriation process, one should pay special attention to regional condition indicators beside the traditional soil physical indicators. In case new AR projects will be created, it is advisable to focus on those municipal districts that have a good infrastructure and where the settlers will have an opportunity to commercialize their products. A dilemma though is that agrarian reform is often used as a tool to develop unexploited regions, a trend which is quite opposite to this conclusion. The latter will be discussed more elaborately in Chapter 4.7.

The LARISSA model indicates the northeast of Brazil as most restrictive (Figure 9 and Table 10). This region is in particular limited by ‘climate’ i.e. water availability (Figure 10), which results in low scores for the evaluation of regional condition indicators (Figure 8 and Table 9). Beside water availability the supply of land quality indicators is on average moderate restricted (Table 8). Conform these results, INCRA should give less priority to create AR projects in this region or focus on those areas where there are possibilities to use supplementary irrigation. Yet INCRA created a relative large number of settlements in this region (Figure 16). The northeast concentrates 55 % of all the poor in Brazil (United Nations, 1997), INCRA created these settlements in an attempt to reduce regional poverty (this subject will discussed more elaborately in the next chapters).

The north of Brazil, the Amazon region, is mainly limited by regional condition indicators ‘accessibility’ and ‘market’ (Figure 10), though the supply of land quality indicators is evaluated on average as moderate restricted (Table 8). AR was initiated in this region in the sixties to colonize the Amazon. These colonization projects were used to as base to exploit the natural resources and develop new market economies and strongly stimulated local deforestation, construction of roads and founding of villages. ‘Accessibility’ and ‘market’ are still the main constricting factors in this region. However, the results also give rise to caution because as soon as the regional condition indicators would be improved, the soil indicators related to soil fertility (Figure 10) will create restraints for the development of AR projects in large parts of the Amazon. In general the regional condition indicators are so restrictive that they hide the also fair limiting land quality indicators related to soil fertility.

There is also the more moral as well political question whether Brazil should continue to expand its agricultural frontier in areas with largely natural primary forests, while there is still more than enough unproductive land elsewhere in the country for the landless and poor. Plans to increase the accessibility of the Amazon date back to the sixties. However, currently the Brazilian government gives in for the lobby of commercial farmers and large commercial companies. With support of a number of large national and international agencies, it is reinforcing its policy of further development of the Amazon through large-scale infrastructure projects. Although more attention is given to the environmental and social impacts of such projects (Carvalho *et al*., 2001; Becker, 2002), most plans are still being heavily criticized (Laurance *et al*., 2001; Nepstad *et al*., 2002).

Up to now, the Brazilian government still focuses on the development of the north and northeast. Prioritization of these regions is considered advantageous, as the social benefits in terms of creating opportunities for the poor are largest in these areas in Brazil where poverty is highest. Another advantage of these regions is that the cost of land in these regions is lower than in the developed south and southeast. This means that for the same amount of money, it is possible to buy relatively more land and settle more families within AR projects. Or the other way around, more cash would have to be paid for land in the south, which would reduce the statistic of settled people and increase individual costs. Thus, by focusing on those regions with lower land prices, it is possible to increase the statistics on the number of settled people and efficiency of AR. However, it is important to realize is that that if such policy does not take into account the regional differences in the opportunities of the land there is no guarantee that it does reduce the actual poverty.

Moreover, the reasoning that AR in the northeast and north is more cost efficient is only valid because there are unaccounted costs (externalities) that are not included in the market price. The value of the forest or biodiversity as natural resources to be protected for the benefit of all is a clear example of externality. Market failure in taking into account externalities may be accounted to a) divergent private and social costs and benefits (the socially profitable option is privately unprofitable); b) the environmental side effects or externalities are usually unaccounted, thus private decisions are not socially optimal. Externalities need policy interventions or public incentives. I.e., the government should invest or make rules to avoid the impact of existing externalities.

In the specific case of the AR, the government should be the first to include these externalities in their decision making process. The 'Resolução Conama No 289', a environmental law, is the most representative move forwards in this context and was only established in October 2001. This law regulates conservation in relation to the creation of agrarian reform projects. Although outside the scope of this study, future editions of LARISSA could include externalities. For now, there is a lack of reliable data on unaccounted costs, but several studies are being carried out. It is good to remember that often issues related to unaccounted costs are political rather than technical issues, which makes inclusion in a model such as LARISSA complicated and will possibly impede a wide acceptance by the end users.

Chapter 3.1 shows clearly it is impossible to talk about Brazil altogether, as the regional differences are unmistakable. One policy of making AR in Brazil is unfeasible. The results show clearly that the AR should include regional differences in its policy and one should focus on the strength of each region to improve the success of AR.

4.5 Relative influence of the land quality indicators on the land evaluation system LARISSA

To study the relative influence of land quality indicators on the land evaluation system LARISSA several analyses were carried out. The PCA and the stepwise exclusion analyses (Table 11 and Figure 10) show that the soil fertility indicators ('current nutrient availability', 'capacity of maintaining nutrient availability' and 'nutrient retention capacity') have a high influence on the outcome of LARISSA and are important factors in the detection of regional differences and the identification of the better areas for AR. Climate as well has a relatively high scoring on the PCA, indicating it is explaining a significant part of the total variance of the dataset (Table 11). Climate factor has as well a moderate influence on the evaluation results (Figure 10). Inclusion of this indicator in the model is expected to have a clearly positive influence on the distinguishing power of the model, i.e., inclusion of the climate factor makes the model more sensitive for differences between areas. On national scale not all land quality indicators are needed to determine suitable regions for AR, this study concluded that indicators like 'erosion risk' and 'salinity and sodicity' are less significant on the outcome of LARISSA. Yet all land quality indicators demonstrate large regional differences within and between regions. The next text will discuss these regional variations.

Looking at Brazil in general, the land quality indicators related to soil fertility have to be considered as most restricted (Figure 10 and Table 12, 13 &14). The soil properties organic matter content, CEC, and base saturation determine these land quality indicators. Latossolos Vermelho-Amarelos (Oxisols) and Podzólicos Vermelho-Amarelos (Ultisols) are the most dominant of all soil types in the larger part of Brazil. The relevant soil properties of these soil types are considered relatively restricting. Especially Latossolos Vermelho-Amarelos on flat to undulating areas has a low nutrient fertility, although they are widely used for agricultural purposes (Oliveira *et al*. 1992).

Beside the soil fertility indicators, also ‘soil water holding capacity’ and ‘rooting conditions’ are considered to be restricting indicators (Figure 10, Table 15 & 16). Both these land quality indicators are determined by the soil property clay percentage, and Latossolos as well as Podzólicos in general have a low clay percentage (Oliveira *et al*. 1992).

The land quality indicator ‘soil drainage’ is considered to be non restricted in the land evaluation for AR on a national level (Table 17). In detail the study reveals that in the north 18 % of the area is considered restricted to very restricted, mainly because of limiting conditions in the states of Amazonas, Tocantins and Acre. These states have large areas of soils affected by hydromorphism indicating the soils are sensitive to drainage problems. This applies as well for several small states in the northeast, e.g. Ceará, Rio Grande do Norte, and Sergipe.

In the central west of Brazil 13 % of the area is considered to be very restricted for soil drainage (Table 17), mainly in the states of Mato Grosso and Mato Grosso do Sul, the Pantanal area. The Pantanal, often referred to as the world’s largest freshwater wetland system, is situated along the northernmost part of the Paraguay River and its tributaries. It is an immense alluvial plain which extends through millions of hectares of central-western Brazil, eastern Bolivia and eastern Paraguay, an estimated 80 % is located in the states of Mato Grosso and Mato Grosso do Sul. The Pantanal becomes extensively flooded during the rainy season and is characterized by widespread pastures and extensive cattle grazing.

The land quality indicator ‘mechanization capacity’ is considered limited mostly in the northeast and the south (Table 19). Soil types (Brunizéns, Solos Litólicos, and Cambissolos) with a high stoniness and/or that are located on slopes (Oliveira *et al*. 1992) characterized these areas These properties are naturally restrictive for mechanization. In addition, 17 % of the land in the northeast is considered to be very restricted due to erosion risk (Table 18). The state of Paraíba especially is considered limited due to erosion risk, with an area of 68% classified as very limited. These areas are characterized by soil types (Brunizéns, Brunos Não Cálcicos, Solos Litólicos) with a small rooting depth and little susceptible to erosion (Oliveira *et al*. 1992).

In the northeast region of Brazil the land quality indicator 'salinity and sodicity' shows a large variation, especially in the states of Alagoas, Rio Grande do Norte, Pernambuco and Sergipe. These areas are characterized by the soil types Solonetz and/or Solonchaks or have salic properties (Oliveira *et al*. 1992), soil types and soil properties that indicate possible problems with salinity and sodicity.

The land quality indicator 'climate' is mainly limiting in the northeast of Brazil (Figure 11, Table 21). The northeast is characterized by a semi-arid climate. About 75 % of the area is considered to be very restricted for this indicator, only the states of Bahia and Maranhão are classified in a lesser extend as restricted. But even these states are very restricted.

4.6 Relative significance of regional condition indicators for the evaluation results of LARISSA

To study the relative significance of regional condition indicators for the land evaluation results several analyses were carried out. One overall conclusion is that Brazil is extremely heterogeneous in both terms of land quality and regional condition indicators. Consequently, the assumption would be that the inclusion of each single one of these indicators would have a positive influence on the distinguishing power of the model. As the LARISSA model was developed for analyses on regional and national scale, it is of special interest to evaluate the actual influence of each indicator on the model outcome at these two scales, i.e., within regions and between regions.

The indicators 'accessibility' and 'market' have a relatively high scoring on the PCA, indicating that these indicators explain a large part of the total variance of the dataset (Table 11). The stepwise exclusion analyses show that inclusion of 'accessibility' and 'market' in the model has a positive influence on the distinguishing power of the model, i.e., inclusion of these indicators makes the model more sensitive for differences between areas. As a consequence of this study both ‘accessibility’ and ‘market’ should be included in the evaluation procedure for the AR and family agriculture. The regional condition indicator ‘possibilities for irrigation’ is only included in the analyses for the northeast of Brazil, a region which is characterized with a semi-arid climate. Therefore the ‘possibilities for irrigation’ have only a high influence on the evaluation results in this region (Figure 10).

The regional condition indicators ‘accessibility’ and ‘market’ are the mainly limiting indicators in the north and central west of Brazil (Table 23 & 24). Especially in the northern states of Amazonas, Roraima and Pará ‘accessibility’ is considered to be very restricted, followed by Amapá and Acre. In the central west, especially the state Mato Grosso is restricted for ‘accessibility’. For the indicator ‘market’ especially the northern states of Amazonas and Roraima are considered to be very restricted, followed by Amapá, Pará and Acre. In the central west, especially the states Mato Grosso and Mato Grosso do Sul are classified as restricted for ‘market’. These areas are the less developed regions of Brazil and covered to a large extend by the natural vegetation. Comparing these areas with the national park and other conservation areas (IBAMA, 2002), it comes out that more than 65 % of the protected areas of Brazil are located within these regions. Although this study indicates that ‘accessibility’ and ‘market’ are the most limiting indicators in these regions improvement of these indicators is not an anticipated option. As said before, there is the question whether Brazil should continue to expand its agricultural frontier in areas with largely natural primary forests when the area of agricultural land that is abandoned or under-utilized is sufficient to settle the majority, if not all rural families without land and as well as millions of peasants that work in temporary agricultural jobs.

4.7 Relation between location of agrarian reform settlements projects and the evaluation results of LARISSA

It is extremely difficult to obtain reliable numbers on AR projects. As stated by Deininger (1999), it is common practice that governments exaggerate the actual number to propagandize their policies. Since the Land Reform law was enacted, in 1964, until 1995 350,836 families had been settled in 1,626 AR and colonization projects (Guedes Pinto, 1995). The government of Cardoso claims to have settled about 372,866 families within 2,732 new AR projects from

1995 to 1999 (Ministry of Agrarian Development, 1999a). Social movements such as the MST criticize this statement by saying it is virtually impossible to be able to double the total number of settled families within the last few years. Beside, they argue that from data of the agrarian census (IBGE, 1996) appears that the numbers from INCRA until 1996 are almost 50 % exaggerated (MST, 2002). In this study the location of 3950 settlements were compared with the outcome of the LARISSA model. This number is believed to represent 92 % of the total number of settlements (Sparovek, 2002). According to this census the number mentioned above are indeed overstated. Regardless of the exact truth of AR numbers, Hoffman (1998) indicated that the extreme unequal distribution of agricultural land remained practically unaltered over the years.

This study indicates (Figure 17) that the distribution of the number of settlements per restriction class of the SRC scoring is relatively the same over the years. Until 1992 the AR settlements were mostly located in the isolated parts of Brazil as part of the colonization activities. At the time the settlements were created, there was in general hardly any infrastructure available. Nowadays these settlements are located in the more developed areas as a result of the colonization policies, so Figure 17 does not reflect the difficult situation the settlers have dealt with during the beginning. Since the government of Franco the pressure of the social movements stimulated the agrarian reform that resulted in an increase in agrarian reform projects. Figure 17 shows clearly that since 1993 more settlements are created. The figure demonstrates as well that more settlements were created on moderate restricted areas for the SRC indicators and fewer settlements are created on none to little restricted areas. Appendix A-31 shows that more settlements are created in the states of Piauí, Paraíba, Amapá, and Roraima. These states are located in the poor and less developed regions of Brazil. These results show that the AR is still used as a tool to improve the underdeveloped regions of Brazil. These results are in line with a common opinion that the AR is not a tool to change the agricultural structure of Brazil, but a reaction to the social problems related to rural poverty and migration to the cities. AR therefore focuses on those areas or regions where agriculture is underdeveloped, not modernized and not integrated in the market economy. The agricultural production is low in these regions that is always related to economical and social problems (Graziane Neto, 1994; Navarro, 2001). AR gives rural workers access to unproductive and underutilized land. This process has the potential to rise agricultural productivity and consequently have a positive effect on the regional economy and diminish social problems.

Figure 16 shows that the distribution of the number of settlements per restriction class of the SLC scoring is comparatively the same over the years. Settlements are predominantly located in areas where the land quality are considered to be moderate restricted. In the first governmental period of president Cardoso (1995-1998) a large amount of settlement were created and the land quality indicator scoring is slightly better compared to the other periods. In the second period of president Cardoso though, the distribution of the number of settlements per restriction class of the SLC scoring got worse. A likely explanation for these results is that since 1998 INCRA tries to lower the expenses for the AR by reducing the prices it is paying for land (Gasques & Villa Verde, 1998). The costs per settled family are reduced by buying land of inferior quality in terms of land quality indicators.

Until now the process of AR led to a rise of agricultural productivity of underdeveloped regions within a period of five to ten years and consequently had a positive effect on the regional economy and diminished social problems (Campos, 1994). In that sense AR can be considered to be successful. Yet the question remains whether these positive effects will continue when AR will be carried out in areas with SLQ indicators that are considered to be less suitable, as it will become more difficult for a settler to succeed to raise agricultural productivity.

4.8 Validation of the land evaluation results by LARISSA

There are large regional differences in the conditions for family agriculture (chapter 3.5). Guanzirolli & Cardim (2000) identified 4,139 thousand family agriculture farms from the Brazilian Agricultural Census of 1995-1996. From the total Brazilian rural population of 34 million people in 1996, 14 million (41 %) were occupied with family agriculture. Traditionally in Brazil, large producers were supported with property rights, subsidies, public facilities and investments (Deiniger, 19998; Guanzirolli, 1999). Nevertheless, the family farmers have managed to keep hold of their position in farm production. Despite family farmers received only 11 % of the total rural credit (FAO/INCRA, 1996) and having only 31% of the land, family agriculture provides 39 % of net total production (Table 26). In other words, family farmers produce more than the large producers, with lesser credit and land. For Brazil, as well for Latin America in general, it can be said that family agriculture is more efficient in the use of capital and land. This advantage derives from the abundant use of labor and the special characteristics of family work (De Janvry, 1981; Donner, 1992).

The results of this study were compared to an external dataset by means of correlation analyses. A data set was compiled by IBGE especially for this purpose, containing data on family agriculture and on commercial agriculture. The first conclusion drawn is that the total supply of land quality indicators is a relative weak predictor for family agriculture as well commercial agriculture (weak to moderate correlation between the scoring and the actual production, Figure 18 & Figure 19). When including the supply of regional condition indicators, the correlation increases significantly, implying that the reality is represented better when regional condition indicators are included in the model.

In fact, regional condition indicators alone show a higher correlation with agricultural production (except in the northeast), suggesting that regional condition indicators alone are in fact a better predictor than the combined overall indicators score. In reality these results are a consequence of the model setup in which all indicators have an equal weight in the final outcome. As the land quality indicators consist of ten indicators while the regional condition indicators only consist of three indicators, the lower land quality indicators score will result in a relative lower overall score.

The above-mentioned results possibly suggest that the IBGE census did not completely succeed in estimating the true gross production. The value of the gross agricultural production describes all agricultural products generated by the farmer. However, as family farmers are consuming a share, if not all, of their production gradually over the year, it is difficult to give an estimate of this measure. Especially in the more remote areas were subsistence production is more important. For similar reasons cash flow might in fact not be a very good estimator for agricultural production.

It is only fair to mention that these possibly explanation are only speculations yet. Currently, a census is being carried out in all INCRA settlements in Brazil (Sparovek, 2002). This census will also gather agricultural production data (in terms of among others actual production and profits). Unfortunately, these data are not available yet, but when available, this data will offer a much more reliable data source for the re-evaluation of the results of LARISSA.

When looking in more detail at the results, it is obvious that the results of the land quality indicators in the north show a much weaker correlation with the estimated production than in other regions. This can be explained by the historical expansion of the agricultural frontier in this area. Both planned and non-planned occupations occurred and still occur in areas that are accessible by road or river. Much less attention has been given to soil quality. As most new land occupation has take place relatively recently (since the sixties) and given the ‘ample availability’ of new lands the process of abundance of degraded land has not led to selection of the better soils for agricultural production. In practice, when the soil is exhausted, farmers tend to move to the next area.

Another region that deserves special attention is the northeast of Brazil, where the regional condition indicators show a relative weak correlation with the family production numbers. This was the only region for the indicator ‘possibilities for irrigation’ was included as a regional condition indicator. Figure 10 shows that the ‘possibilities for irrigation’ are highly suppressive on the land evaluation results, while Table 18 indicates that the share of family agriculture in the total agricultural production in this region is large. The low correlation results suggest that the inclusion of this variable decreases the predicting power of the model. So most probably the incorporation of the ‘possibilities for irrigation’ in the northeast exaggerates the restriction of suitability for family agriculture.

In the central west, where the contribution of family agriculture is lowest for the total value of the gross agricultural production, the correlation results are the highest. A possible explanation for this could be that the accumulated error for the estimation of the generated gross agricultural production in this region is lower.

Although not as presumed, in the south the correlation of the outcome of LARISSA with production numbers of both family and commercial agriculture is relatively weak. This region is considered to be very suitable for family agriculture. The quality of the soil physical indicators related to soil fertility is considered to be the more restriction factors in this region

(Figure 10), although the supply of land quality indicators is considered to be relatively good compared to rest of Brazil (Table 8). In the south of Brazil in particular the correlation of the supply of land quality with the production data is low. A possible explanation for this is the different character of family agriculture in the south of Brazil. Within this study family agriculture was characterized by low input in the cropping systems. The south though is the most developed region of Brazil. Most probably family agriculture applies more fertilizers in the cropping system than other regions of Brazil, in which case the supply of land quality indicators is not representative (i.e. an underestimate) for the suitability of the region.

4.9 Possibilities for improving land evaluation systems

Since the transition to a democracy in 1985, the demand for AR changed the policy of the Brazilian government. Until then AR was already carried out, but in the context of colonization projects to develop new agricultural productive regions. The current government assumes that promotion and support of family agriculture can result in more sustainable agriculture as more equally developed social structures (Guanziroli & Cardim, 2000). Whereby AR is interpreted as a reform of agricultural policy and land tenure. The government interprets subsidies for family agriculture and AR as being necessary since it is attempting to transform a rural worker without land into a farmer, and such a transformation could not take place if market rates were changed. The real function of land reform, according to this view, is its capacity to integrate the excluded, that is to say, to generate income and employment at a low cost, at a time of growing unemployment as a result of the adjustment of the underdeveloped economies to the world market, i.e. to the globalization of the economy (Guanzirolli, 1999). It is necessary to emphasize that these policies originate from the activities and permanent pressure of social movements as the Landless Rural Workers Movement (MST) and Confederation of Rural Works in Agriculture (CONTAC). Without the struggle of the movements the demand for a differential policy in favor for family agriculture would never have gained so much ground (Guanzirolli, 1999; Rossetto & Alvares, 2001). It's essential though to understand it has been and still is a difficult struggle. On 17 April 1996 an MST procession was marching to the capital of the state Para in the north of Brazil, when military police opened fire, killing nineteen people. Since 1985, over a thousand people have been murdered, executed or have disappeared in land occupations and protests to provoke the process of expropriating unproductive land.

The number of settlements established in the last ten years increased considerably compared to the preceding decades. Besides creating accommodations for a larger number of families INCRA made an effort to detect those factors related to failures of settlements projects (Guanziroli, 1992; Bittencourt *et al*., 1999; Sparovek *et al*., 2000). To overcome some of these problems the University of São Paulo in cooperation with INCRA developed SIATe. SIATe was developed to support decision-making of the expropriation process at a local (farm) level. It includes a wide variety of factors that are believed to be relevant for the success of creating new settlements. With help of SIATe it is possible to examine the suitability of a farm in a better and elaborated way. Moreover LARISSA was developed to support and optimize decision-making processes on AR at a national scale. It uses similar factors as SIATe, but with a focus on the detection of regional differences. Implementation of a model as LARISSA will increase the objectivity of the decision making process.

LARISSA is successful in identifying the most suitable areas for family agriculture. With the help of a simple model one can improve the efficiency of the implementation of the AR. However this study revealed that INCRA started to buy land of inferior quality in terms of land quality indicators. This means that a settler will need to struggle harder to obtain a reasonable agrarian production. Until now AR can be considered successful in the sense that it generates income and employment at a low costs. Besides, until now AR led to the development of the poor and underutilized regions of Brazil. This last achievement was one of the main aims while AR was carried out as part of colonization efforts. This study indicates that AR still is used as a tool to improve the underdeveloped regions. In line with these past results, one should assume that the current AR policies will lead to the development of a considerable part of Brazil. The question remains however whether this development will take place in case INCRA continues to but land in areas with a lower suitability of land quality indicators. In case it will be more difficult to obtain a higher agrarian production, the AR policies will not be such an effective tool to improve underdeveloped regions as in the past.

As the historical development of the AR with its failures and success stories (Bittencourt *et al*., 1999) clearly demonstrates, often it is not the availability of the appropriate tools, but the political will that determines the fait of the landless. In the last few years the Brazilian policies demonstrated a desire to support family agriculture by a number of new law and regulations.

Improved tools for the decision-making processes on AR together with an enduring social pressure can promote a better distribution of land by altering ownership and land use. One can continue to increase agrarian productivity in underdeveloped regions and can take care of social justice for and rights of both farmers and landless.

5 Summary

Inequality in land distribution and rural poverty in Brazil resulted in a demand for land reforms. As a response to this agrarian reform is performed and family agriculture is stimulated with the objective to create rural jobs, generate income and increase the agricultural productivity. The LARISSA (Land Resource Information and Suitability System for Family Agriculture) model was designed to identify the most suitable areas for family agriculture and to support the decision making process in the agrarian reform. This research examines the relative influence of several parameters on the results of land evaluation model LARISSA. The objective of this study was to gain a better understanding of the most important differences in land quality indicators and regional condition indicators as well as their influence on the outcome of the land evaluation process for family agriculture and the agrarian reform on a national scale.

A database was assembled with information on land quality indicators and regional condition indicators. The land quality indicators were based on soil data (current nutrient availability, capacity of maintaining nutrient availability, nutrient retention capacity, rooting conditions, soil water holding capacity, soil drainage, erosion risk, mechanization capacity, and salinity and sodicity) and climate data (the water deficit as part of the water balance). The regional conditions indicators describe accessibility, market and the possibilities for irrigation. Based on this database, land evaluation was carried out by means of LARISSA to determine the suitable areas for family agriculture. The land evaluation results were validated with information about the total value of agricultural cash flow and the gross production of family agriculture. The relation between the locations of agrarian reform settlement projects and the land evaluation results were examined as well as the relative importance of different indicators on the evaluation result

The investigations yielded the following results:

a) Land quality indicators and regional conditions indicators revealed clear regional differences. These differences had a significant influence on the outcome of the evaluation results by LARISSA. According to this the south and southeast of Brazil were considered as the most suitable areas for family agriculture and the realization of the agrarian reform. The land quality indicators were the most limiting factors in these regions, but did not prevail the suitability for family agriculture. The remaining part of Brazil was considered less suitable as regional conditions indicators were more restricting.

b) Land quality indicators related to soil fertility had the most accumulated influence on the outcome of the land evaluation by LARISSA. These indicators were classified also as the most restrictive of all land quality indicators. It confirms that soil fertility is of major importance to low input agriculture, which again is typical for family agriculture in Brazil and the regions where agrarian reform is implemented.

c) The regional condition indicators ‘market’ and ‘accessibility’ were considered most restricting in the north and central west of Brazil. These regions where therefore considered less suitable for family agriculture and the realization of the agrarian reform.

d) Agrarian reform settlements were located on areas indicated as suitable by LARISSA only until 1995. After that a negative trend between the location and the evaluation results of LARISSA was found, i.e. more agrarian reform settlements were created in areas that are limited by land quality and regional conditions. The reasons for this are most likely that 1) agrarian reform is used as a tool to improve the underdeveloped regions of Brazil, the areas limited by regional conditions, and 2) INCRA is lowering the expenses for the agrarian reform by reducing the prices it is paying for land. The costs per settled family are reduced by buying land of inferior quality in terms of land quality indicators.

e) The land quality indicators alone were a relative weak predictor for the success of family agricultural production. But including regional condition indicators in the evaluation model for family agriculture represented the reality much better.

f) LARISSA is successful in identifying the most suitable areas for family agriculture and to support the decision-making process in the agrarian reform. However INCRA started to buy land of inferior quality in terms of land quality indicators. This means that a settler will need to struggle harder to obtain a reasonable agrarian production. This leads to the conclusion that the current agrarian reform policies will not be such an effective tool to improve underdeveloped regions as in the past.

Zusammenfassung

Landevaluierung für die Agrarreform. Ein Fall Studium für Brasilien

Die unausgewogene Landverteilung und Armut im ländlichen Raum machten eine Landreform in Brasilien erforderlich. Daher wurden Agrarreformen durchgeführt, die das Ziel hatten, die Ansiedlung kleinbäuerlicher Betriebe zu unterstützen, Arbeitsplätze in ländlichen Regionen zu schaffen sowie die Einkommensstruktur und die landwirtschaftliche Produktivität zu steigern. Das Modell LARISSA (Land Resource Information and Suitability System for Family Agriculture) wurde entwickelt, um jene ländlichen Regionen zu identifizieren, die sich am Besten für die Ansiedlung kleinbäuerlicher Betriebe eignen und um Entscheidungsprozesse bei der Agrarreform zu unterstützen. Die vorliegenden Untersuchungen wurden durchgeführt, um den Einfluss unterschiedlicher Parameter auf die jeweiligen Ergebnisse des Landnutzungsmodells LARISSA zu untersuchen. Ziel war es, die wichtigsten Indikatoren der Landqualität sowie der regionalen Gegebenheiten zu erarbeiten und deren Einfluss auf die Nutzbarkeit der Regionen für kleinbäuerliche Betriebe und die Agrarreform auf nationaler Ebene zu ermitteln.

Es wurde eine Datenbank angelegt, die Indikatoren zur Landqualität sowie den regionalen Gegebenheiten enthält. Die Indikatoren zur Landqualität basieren auf Bodendaten (aktuelle Nährstoffverfügbarkeit, Möglichkeiten die Nährstoffverfügbarkeit zu erhalten sowie Nährstoffe im Boden zu binden, Durchwurzelungsbedingungen, Wasserhaltevermögen und Bodendrainage, Erosionsrisiko, mechanische Bearbeitbarkeit, Versalzung sowie Natriumsättigung des Bodens) und klimatischen Daten, um das Wasserdefizit des Bodens zu bestimmen. Die Indikatoren der regionalen Gegebenheiten beschreiben die Verkehrsanbindung, regionale Vermarktungspotenziale sowie Beregnungsmöglichkeiten. Auf Grundlage dieser Datenbank wurde eine Landerhebungsuntersuchung mit LARISSA durchgeführt, um die ländlichen Räume zu identifizieren, die optimal für die Ansiedlung kleinbäuerlicher Betriebe sind. Die Ergebnisse dieser Untersuchung wurden mittels Einkommensdaten sowie Daten zur Gesamtproduktion der Betriebe überprüft.

Die Beziehungen zwischen Regionen, wo in Folge der Agrarreform bereits Ansiedlungsprojekte durchgeführt wurden mit den Ergebnissen des Modells wurden

vergleichend untersucht und darüber hinaus wurde die Bedeutung der unterschiedlichen Indikatoren für die Evaluierungsergebnisse bestimmt.

Die Untersuchungen führten zu folgenden Ergebnissen:

a) Die Indikatoren der Landqualität sowie der regionalen Gegebenheiten wiesen deutliche regionale Unterschiede auf. Diese Unterschiede hatten einen signifikanten Einfluss auf die Evaluierungsergebnisse des Modells LARISSA. Danach eignen sich der Süden sowie der Südosten Brasiliens am Besten für die Ansiedlung kleinbäuerlicher Betriebe und somit für die Umsetzung der Agrarreform. Die Indikatoren der Landqualität sind dabei die limitierenden Faktoren in diesen Regionen, sprechen aber dennoch nicht gegen die Eignung dieser Gebiete. Die anderen Gebiete Brasiliens sind weniger gut geeignet, da hier die regionalen Gegebenheiten (Verkehrsanbindung, regionale Vermarktungsmöglichkeiten) unzureichend sind.

b) Die Indikatoren der Landqualität, die in Verbindung zur Bodenfruchtbarkeit stehen, hatten den grössten Einfluss auf das Ergebniss der Landerhebungsuntersuchung mit LARISSA. Diese Indikatoren wurden generell als die wichtigsten Qualitätsfaktoren identifiziert. Somit ist eine hohe Bodenfruchtbarkeit am wichtigsten für eine Landwirtschaft mit geringem Input, die charakteristisch für kleinbäuerliche Betriebe und in den Regionen, in denendie Argarreform bereits implementiert wurde, ist.

c) Von den Indikatoren der regionalen Gegebenheiten erwiesen sich die 'Vermarktungsmöglichkeiten' und die 'Verkehrsanbindung' am stärksten limitierend im Norden und zentralen Westen von Brasilien. Diese Regionen wurden daher als weniger geeignet eingestuft im Hinblick auf die Implementierung kleinbäuerlicher Betriebe und somit die Umsetzung der Agrarreform.

d) Ansiedlungen, die infolge der Agrarreform vorgenommen wurden, waren bis 1995 in Regionen lokalisiert, die auch von LARISSA als geeignete Standorte identifiziert wurden. Danach zeigte sich ein negativer Trend zwischen den aktuellen Ansiedlungsregionen und den Evaluierungsergebnissen, was bedeutet, dass vermehrt Ansiedlungen in Gebieten vorgenommen wurden, in denen die Landqualität oder die regionalen Gegebenheiten limitierend für eine profitable Landwirtschaft waren. Gründe für diese Entwicklung sind zum einen, dass die Agrarreform dazu genutzt wurde, von der Infrastruktur her unterentwickelte Regionen Brasiliens zu unterstützen und zum anderen, dass die INCRA (Nationales Institut für Ansiedlung und Agrarreformen) auf diesem Wege die Kosten der Agrarreform senken konnte, da Landankauf in diesen Gebieten preiswerter ist. Somit sind die Kosten pro angesiedelter Familie niedriger, da Land von geringerer Qualität auf Basis der Indikatoren der Landqualität angekauft wird.

e) Die Indikatoren der Landqualität allein sind relativ ungenau im Hinblick auf die Vorhersage des Erfolges der Ansiedlung eines kleinbäuerlichen Betriebes. Werden jedoch auch die regionalen Gegebenheiten berücksichtigt, so liegen die Ergebnisse des Modells für die Ansiedlung kleinbäuerlicher Betriebe sehr viel näher an der Realität.

f) LARISSA hat sich als geeignetes Modell erwiesen, um Gebiete zu identifizieren, die für die Ansiedlung kleinbäuerlicher Betriebe in Frage kommen und kann somit genutzt werden, um Entscheidungsprozesse bei der Agrarreform zu unterstützen. Da INCRA jedoch bereits Land geringerer Qualität im Hinblick auf die Indikatoren der Landqualität angekauft hat, werden es neue kleinbäuerliche Betriebe, die in diesen Regionen angesiedelt werden, schwerer haben, wirtschaftlich erfolgreich zu produzieren. Dies bedeutet letztlich, dass die derzeitige Politik in der Agrarreform bei der Wahl zu erschließender unterentwickelter ländlicher Regionen in Brasilien die vorhandenen Indikatoren zur Landevaluierung nicht in vollem Umfang berücksichtigt.

6 References

Afifi AA, Clark V (1996) Computer Aided Multivariate Analysis. Third Edition. Chapman & Hall, London, 455 p

Amatya DM, Skaggs RW, Gregory JD (1995) Comparison of Methods for Estimating Ref-ET. Journal of Irrigation and Drainage Engineering 121(6): 427-435

Bacelar De Araújo T (2000) Descentralização e participação na reforma agrária: um processo em discussão, In: Ministério De Desenvolvimento Agrário Reforma agrária e desenvolvimento sustentável. Ministéio de Desenvolvimento Agrário, Leite et al. (org.). Parelelo 15/Núcleo de Estudos Agrários e Desenvolvimento, Brasília, pp 127-143

Baldwin M, Kellogg CE, Thorp J (1938) Soil Classification. In: USDA. Agricultural Yearbook. Soils and men. Washington, pp 707-1001

Becker BK (2001) Amazonian Frontiers at the Beginning of the 21st Century. In: Hogan DJ, Tolmasquim MT Human Dimensions of Global Environmental Change. Brazilian Perspectives. Academia Brasileira de Ciências, pp 299-324

Beek KJ (1975) Recursos naturais e estudos perspectivos a longo prazo: notas metodológicas. SUPLAN, Brasília

Beek KJ (1978) Land evaluation for agricultural development. ILRI publication 23, Wageningen

Beek KJ, Goedert WJ (1973) Recursos naturais (terras) e desenvolvimento agrícola. PNUD/FAO/BRA-71-553, Brasília

Bennema J, Beek KJ, Camargo MN (1964) Um sistema de classificação de capacidade de uso de terra para levantamento de reconhecimento de solos. Ministério da Agricultura/FAO, Brasília, 50 p

Bittencourt GA, Borges de Castilhos DS, Bianchini V, Corrêa da Silva HB, Guanziroli C (1999) Principais fatores que afetam o desenvolvimento dos assentamentos de reforma agrária no Brasil. Report 4. Projeto de cooperação técnica INCRA/FAO, Brasília, 62 p

Buol SW, Eswaran H (2000) Oxisols. Advances in Agronomy 68: 151-195

Burrough PA (1986) Principles of Geographical Information Systems for Land Resource Assessment. Oxford University Press, New York

Burrough PA (1989) Matching spatial databases and quantitative models in land resource assessment. Soil Use and Management 5(1): 3-8

Burrough PA, Van Gaans PFM, Hootsman R (1997) Continuous classification in soil survey: spatial correlation, confusion and boundaries. Geoderma 77: 115-135

Bouma J (1997) The role of quantitative approaches in soil science when interacting with stakeholders. Geoderma 78: 1-12

Camargo MN, Klamt E, Kauffman JH (1987) Sistema Brasileiro de Classificação de Solos. Boletim Informativo da Sociedade Brasileira de Ciência do Solo, Campinas 12(1): 11-33

Campos R (1994) A lanterna na popa. TopbooKsEd. Rio de Janeiro

Carvalho G, Barrost AC, Moutinho P, Nepstad D (2001) Sensitive development could protect Amazonia instead of destroying it. Nature 409: 131

Clark II EH, Haverkamp JA, Chapman W (1985) Eroding soils. The off-farm impacts. The Conservation Foundation, Washington, 252 p

CPRM (2002) Programa Nacional de Hidrologia. CPRM - Serviço Geológico do Brasil <http://www.cprm.gov.br/rehi/prognh.htm>

Daily G, Dasgupta P, Bolin B, Crosson P, Guerny J du, Ehrlich P, Folke C, Jansson AM, Kautsky N, Kinzig Levin S, Mäler KG, Andersen PP, Siniscalo D, Walker B (1998) Food production, population growth, and the environment. Science 281: 1291-1292

De Javry A (1981) The agrarian question and reformism in Latin America. The Johns Hopkins University Press, Baltimore, 311 p

De Jong T, Ritsema van Eck J (1996) Location profile-based measures as an improvement on accessibility modeling in GIS. Computers, Environment and Urban Systems 20(3): 181-190

Deininger K (1999) Making Negotiated Land Reform Work: Initial Experience from Colombia, Brazil and South Africa. World Development 27: 651-672

DEMIS BV (2001) Digital Chart of the World (WMS), scale 1:1,000,000 <http://www2.demis.nl/mapserver/Mapper.asp>

Dent D, Young A (1981) Soil Survey and Land Evaluation. Allen & Unwin, London [etc.], 278 p

DNPM (1983) Mapa Hidrogeológico do Brasil, 1:5.000.000. Ministério das Minas e Energia. Departemento Nacional da Produção Mineral. (Projeção policônica)

Donner P (1992) Latin America land reforms in theory and practice: a retrospective analysis. The University of Wisconsin Press, Wisconsin

EDC (1996) GTOPO30 - Global 30 Arc-Second Elevation Data Set. U.S. Geological Survey's EROS Data Center <http://edcdaac.usgs.gov/gtopo30/gtopo30.html>

EMBRAPA (1981) Mapa de Solos do Brasil. Empresa Brasileira de Pesquisa Agropecuaria, Serviço Nacional de Levantamento e Conservação de Solos. Rio de Janeiro. Map, scale 1:5,000,000

EMBRAPA (1999) Sistema Brasileiro de Classificação de Solos. Empresa Brasileira de Pesquisa Agropecuaria, Centro Nacional de Pesquisa de Solos, Brasília, 412 p

Euroconsult (1989) Agricultural Compendium for rural development in the tropics and subtropics. Elsevier, Amsterdam, 738 p

FAO (1974) FAO-UNESCO Soil Map of the World. Vol. 1. Legend. Paris, UNESCO

FAO (1976) A Framework for Land Evaluation. FAO Soils bulletin 32. Food and Agriculture Organization of the United Nations, Rome, 72 p

FAO (1983) Guidelines: land evaluation for rainfed agriculture. FAO Soils bulletin 52. Food and Agriculture Organization of the United Nations, Rome

FAO (1995) FAOCLIM 1.2 A CD-ROM with world-wide agroclimatic data: user's manual. Agrometeorology Series Working Paper no. 11. FAO, Rome, 68 p

FAO/INCRA (1996) Perfil da Agricultura Familiar no Brasil. Projeto UFT/BRA/036/BRA, Brasilia <http://www.mda.gov.br/incra/fao/Perfil.htm>

Focht D (1998) Influência do avaliador no resultado da classificação de terras em capacidade de uso. Master thesis. Universidade de São Paulo – Escola Superior de Agricultura 'Luiz de Queiroz', Piracicaba, 110 p

Fowler J, Cohen J, Jarvis P (1998) Practical Statistics for Field Biology. John Wiley & Sons, New York, 259 p

Fox RL, Hue NV, Jones RC, Yost RS (1991) Plant-soil interactions associated with acid, weathered soils. Plant and Soil 134: 65-72

Gasques JG, Villa Verde CM (1998) Trinta anos de dispêndio da União com política fundiária. Reforma Agrária: Perspectivas para o Século XXI. INCRA/FAO. Brasília

Goedert WJ (1987) Solos sob cerrado: tecnologias e estratégias de manejo. EMBRAPA, CPAC, Ed. Nobel, São Paulo, 422 p

Graziano Neto F (1994): Recolocando a questão agrária. In: STÉDILE, J.P. (Coord.). Questão Agrária Hoje. Universidade Federal do Rio Grande do Sul. Porto Alegre

Gruijter JJD, Walvoort DJJ, Van Gaans PFM (1997) Continuous soil maps - a fuzzy set approach to bridge the gap between aggregation levels of process and distribution models. Geoderma. 77: 169-196

Guanziroli CE (1992) Principais Indicadores Sócio-Econômicos dos Assentamentos de Reforma Agrária. FAO/PNUD

Guanzirolli CE (1999) The Agrarian Reform and the Globalization of the Economy. Brazil's Case. Report 5. MDA/FAO, Brasília, 29 p

Guanziroli CE, Cardim SE (2000) Novo retrato da agricultura familiar: o Brasil redescoberto. INCRA/FAO, Brasília <http://www.incra.gov.br/fao/default.htm>

Guedes Pinto LC (1995) Reflexões sobre a política agrária brasileira no período de 1964-1994. ABRA, Boletim da Associação Brasileira de reforma Agrária, no. 1

Hoffmann R (1998) A estrutura fundiária no Brasil de acordo com o Cadastro do INCRA: 1967 a 1998. INCRA/Unicamp, Campinas

Hutchinson MF (1991) The application of thin plate splines to continent-wide data assimilation In: Jasper JD (Ed), Data Assimilation Systems, BMRC Research Report, no. 27. Bureau of Meteorology, Melbourne, pp 104-113

Hutchinson MF (1997) ANUSPLIN Version 3.2, User guide. Canberra, Australia, Center for Resource and Environmental Studies, Australian National University

IBAMA (2002) Unidades de conservação. Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis <http://www.ibama.gov.br/>

IBGE (1996) Censo Agropecuário 1995-1996. In: IBGE (2000) Base de Informaçoes Municipais, 2a edição, [CD-ROM]. Instituto Brasileiro de Geografia e Estatística, Rio de Janeiro

IBGE (1999a) Cadastro de cidades e Vilas do Brasil 1999 In: IBGE (2000) Base de Informaçoes Municipais, 2a edição, [CD-ROM]. Instituto Brasileiro de Geografia e Estatística, Rio de Janeiro

IBGE (1999b) Malha municipal digital do Brasil [CD-ROM]: situação em 1997. Instituto Brasileiro de Geografia e Estatística, Rio de Janeiro

IBGE (2000) Censo Demográfico de 2000 - Contagem da População. Instituto Brasileiro de Geografia e Estatística, Rio de Janeiro

INCRA (2001) Relatório de Gestão. INCRA, Brasília

INCRA/DF (1999) Sistemática de Desapropriação por Interesse Social. Instrução Normativa No. 31

Jong van Lier Q de, Sparovek G, Schnug E (2002) An essay on the possible improvement of soil fertility understanding by cooperation with soil physics. FAL Agricultural Research, Braunschweig 52(2): 69-73

KENT M, COKER P (1992) Vegetation description and analysis - A practical approach. John Wiley & Sons, Chichester, 363 p

Klingebiel AA, Montgomery PH (1961) Land Capability Classification. Agricultural Handbook 210. USDA, Soil Conservation Service, Washington, 21 p

Lal R (1995) Erosion-crop productivity relationships for soils of Africa. Soil Science Society America Journal. 59: 661-667

Landon JR (Ed.) (1984) Booker tropical soil manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Longman, New York, 474 p

Laurance WF, Cochrane MA, Bergen S, Fearnside PM, Delamônica P, Barber C, D'angelo S, Fernandes T (2001) The Future of the Brazilian Amazon. Science 291: 438-439

Legendre P, Legendre L (1998) Numerical Ecology, 2nd English edition. Developments in Environmental Modeling, no. 20. Elsevier, Amsterdam, 853 p

Lenthe H, Cordeiro JC (1985) Explicações sobre o sistema brasileiro de classificação de solos. Teresina, Universidade Federal do Piaui

Lepsch IF, Bellinazzi R, Bertolini D, Espíndola CR (1983) Manual para levantamento utilitário de meio físico e classificação de terras no sistema de capacidade uso. 4a aproximação. Sociedade Brasileira de Ciência do Solo, Campinas, 175 p

Lopes AS (1984) Solos sob Cerrado: características, propriedades e manejo. Potafos, Piracicaba, 162 p

Matson PA, Parton WJ, Power AG, Swift MJ (1997) Agricultural intensification and ecosystem properties. Science 277: 504-509

Michalopoulou H, Papaioannou G (1991) Reference Crop Evapotranspiration over Greece. Agricultural Water Management 20(3): 209-221

MicroImages (2001) TNTMips 6.6. MicroImages, Inc

Ministry of Agrarian Development (1999a) Balance sheet of agrarian reform and family agriculture. Brasilia, Ministry of Agrarian Development & National Institute for Colonization and Agrarian Reform, Brasilia, 51 p <http://www.incra.gov.br/>

Ministry of Agrarian Development (1999b) The Land Bank. Brasilia, Ministry of Agrarian Development & National Institute for Colonization and Agrarian Reform, Brasilia, 49 p <http://www.incra.gov.br/>

Ministry of Agrarian Development (1999c) The White Book Of Illegal Land Appropriation In Brazil. MAD/INCRA, Brasilia

Mota F Silveira da, Oliveira de Oliveira M (1986) Clima e agricultura no Brasil. SAGRA, Porto Alegre

MST (2002) Homepage of the Website of the Landless Workers Movement <http://www.mst.org.br/biblioteca/assentam/assenta1.html>

Navarro Z (2001: Desenvolvimento rural no Brasil: os limites do passado e os caminhos do futuro. Revista do Instituto de Estudos Avançados/USP 43

Nepstad D, Mcgrath D, Alencar A, Barros AC, Carvalho G, Santilli M, Diaz MD (2002) Frontier Governance in Amazonia. Science 295: 629-631

Oliveira JB de, Jacomine PKT, Camargo MN (1992) Classes gerais de solos do Brasil: guia auxiliar para seu reconhecimento. FUNEP, Jaboticabal, 201 p

Paes de Camargo A (1974) Zonemento agrícola de Estado de São Paulo, vol. 1 (Atlas with supplements). Secretaria de Agricultura, São Paulo

Paes NA, Albuquerque MEE (1999) Avaliação da qualidade dos dados populacionais e cobertura dos registros de óbitos para as regiões brasileiras. Revista Saúde Pública 33(1): pp 33-43

Paltridge GW, Platt CMR (1976) Radiative process in meteorology and climatology. Developments in Atmospheric Science, no. 5. Elsevier Scientific Publishing Company, Amsterdam, 318 p

Pereira AR, Camargo AP de (1989) An analysis of the criticism of Thornthwaite equation for estimating potential evapotranspiration. Agriculture and Forest Meteorology 46(1-2): 149-157

Pereira G, Almeida FA de, Furlani JA, Beek KJ (1975) Oferta e demanda de recursos de terra no Brasil. SUPLAN, Brasília, 106 p

Pfafstetter O (1957) Chuvas intensas no Brasil: relação entre precipitação, duração e frequência de chuvas em 98 postos com pluviógrafos. Ministerio da Viação e Obras Públicas Departamento Nacional

Pieri C (1997) Planning sustainable land management: the hierarchy of user needs. ITC Journal 3/4: 223-228

Pimentel D, Harvey C, Resosudarmo P, Sinclair K, Kurz D, Mcnair M, Crist S, Shpritz L, Fitton L, Saffouri R, Blair R (1995) Environmental and economic costs of soil erosion and conservation benefits. Science 267: 1117-1123

Prado H do (1995) Manual de classificação de solos do Brasil. FUNEP, Jaboticabal, 197 p

Projeto Radambrasil (1973-1978) Levantamento de recursos naturais. Ministério das Minas e Energia. Departemento Nacional da Produção Mineral

Raij B (1983) Avaliação da fertilidade do solo. Instituto da Potassa & Fosfato, Campinas. 2nd edition, 142 p

Raij B, Silva NM, Bataglia OC, Quaggio JA, Hiroce R, Cantarella H, Bellininazzi Jr. R, Dechen AR, Trani PE (1985) Recomendações de adubação e calagem para o Estado de São Paulo. Boletim Técnico IAC, nr. 100, Campinas, 107 p

Ramalho Filho A, Pereira EG, Beek KJ (1978) Sistema de avaliação da aptidão agrícola das terras. SUPLAN/EMBRAPA-SNLCS, Brasília

Rossiter DG (1996) A theoretical framework for land evaluation. Geoderma 72: 165-190

Rossetto N, Alvares G (2001) As long as there remains one landless there will be MST. Forests, Trees and People 45: 35-41

Santos GA, Camargo FAO (1999) Fundamentos da matéria orgânica do solo: Ecossitemas tropicais e subtropicais. Ed. Genesis, Porto Alegre

SAS (2001) The SAS System for Windows, Release 8.02. SAS Institute Inc., Cary, NY, USA.

Schwertmann U, Herbillon AJ (1992) Some aspects of fertility associated with the mineralogy of highly weathered tropical soils. In: Segoe S (Ed) Myths and science of soils of the tropics. SSSA special publication no. 29. pp 47-59

Setzer J (1946) Contribuição para o estudo do clima do Estado de São Paulo. Escolas Profissionais Salesianas, São Paulo, 239 p

Soil Survey Staff (1975) Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys. Soil Conservation Service, US Department of Agriculture, Agriculture Handbook No. 436

Sparks DL (2001) Elucidating the fundamental chemistry of soils: past and recent achievements and future frontiers. Geoderma 100: 303-319

Sparovek G (Ed) (2002) A qualidade dos projetos de assentamento do Brasil. Páginas e Letras, São Paulo (in press)

Sparovek G, Cooper M, Dourado-Neto D, Maule RF, Vidal-Torrado P, Teramoto ER, Silva AC, Lopes PP (2000) Sistema Integrado de Avaliação da Viabilidade das Terras para Agricultura Familiar (SIATe). Projeto de Cooperação Técnica INCRA/FAO - UTF/BRA/051/BRA <http://www.incra.gov.br/fao/>

Sparovek G, Cooper M, Dourado-Neto D, Maule RF, Vidal-Torrado P, Pimenta LF De M., Martins SP, Teramoto ER, Silva AC, Steeg JA van de, Schnug E (2002) The Land Resource Information and Suitability System for Family Agriculture (LARISSA), developed for the Brazilian agrarian reform. Der Tropenlandwirt: Beitraege zur tropischen Landwirtschaft und Veterinaermedizin, Zeitschrift fuer die Landwirtschaft in den Tropen und Subtropen 103(1): 47-59

Sparovek G, Schnug E (2001) Temporal erosion-induced soil degradation and yield loss. Soil Science Society of America Journal 65: 1479-1486

Stillman ST, Wilson JP, Daly C, Hutchinson MF, Thornton PE (1996) Comparison of ANUSPLIN, MTCLIM-3D, and PRISM precipitation estimates. In: Proceedings, Third International Conference/Workshop on Integrating GIS and Environmental Modeling, Santa Fe, NM, January 21-26, 1996. Santa Barbara, CA: National Center for Geographic Information and Analysis

Stoops G, Cheverry C (1992) New challenges for soil research in developing countries: a holistic approach. In: Stoops G Proceedings of the Workshop by European Community: Life science and technology for developing countries, Rennes, 22 p

Thornthwaite CW (1948) An approach towards a rational classification of climate. Geographic Review 38(1): 55-89

Thornthwaite CW, Mather JR (1955) The water balance, Drexel Institute of Technology 8(1): 1-14

Thorp J, Smith GD (1949) Higher categories for soil classification. Soil Science 67: 117-126

United Nations (1997) Implementation of agenda 21: review of progress made since the United Nations conference on environment and development, 1992. Brazil, country profile. Information Provided by the Government of Brazil to the United Nations Commission on Sustainable Development. Fifth session, 7-25 April 1997, New York United Nations Department for Policy Coordination and Sustainable Development, Division for Sustainable Development <http://www.un.org/dpcsd/earthsummit>

Van Diepen CA, Keulen H van, Wolf J, Berkhout JAA (1991) Land Evaluation: from intuition to quantification. Advances in Soil Science 15: 139-204

Table A-1: Key table for determination of land quality indicator ‘current nutrient availability’

$BS_{0-20\,cm}$ (%)	$CEC_{0-20\,cm}$ (mmol dm^{-3})	$OM_{0-20\,cm}$ (g kg^{-1})	Restriction
75	> 50	>30	nr
		≥ 10 and ≤ 30	nr
		<10	lr
	≥ 0 and ≤ 50	>30	nr
		≥ 10 and ≤ 30	nr
		<10	lr
> 50 and ≤ 75	> 50	>30	nr
		≥ 10 and ≤ 30	nr
		<10	lr
	≥ 0 and ≤ 50	>30	lr
		≥ 10 and ≤ 30	lr
		<10	mr
≥ 30 and ≤ 50	> 50	>30	mr
		≥ 10 and ≤ 30	r
		<10	vr
	≥ 0 and ≤ 50	>30	r
		≥ 10 and ≤ 30	r
		<10	vr
< 30	> 50	>30	vr
		≥ 10 and ≤ 30	vr
		<10	vr
	≥ 0 and ≤ 50	>30	r
		≥ 10 and ≤ 30	r
		<10	vr

BS: Base Saturation, CEC: Cation Exchange Capacity, OM: Organic matter content

Table A-2: Key table for determination of land quality indicator ‘capacity of maintaining nutrient availability’

$OM_{0-20\,cm}$ (g kg^{-1})	$CEC_{0-20\,cm}$ (mmol dm^{-3})	Restriction
> 50	> 80	nr
>50	> 50 and ≤ 80	nr
> 50	≥ 20 and ≤ 50	lr
> 50	< 20	lr
> 30 and ≤ 50	> 80	nr
> 30 and ≤ 50	> 50 and ≤ 80	nr
> 30 and ≤ 50	≥ 20 and ≤ 50	vr
> 30 and ≤ 50	< 20	vr
≥ 10 and ≤ 30	> 80	lr
≥ 10 and ≤ 30	> 50 and ≤ 80	vr
≥ 10 and ≤ 30	≥ 20 and ≤ 50	r
≥ 10 and ≤ 30	< 20	r
< 10	> 80	vr
< 10	> 50 and ≤ 80	r
< 10	≥ 20 and ≤ 50	vr
< 10	< 20	vr

OM: Organic matter content, CEC: Cation Exchange Capacity

Table A-3: Key table for determination of land quality indicator 'nutrient retention capacity', for soils with a depth of more than 50 cm

$CEC_{0-20\ cm}$ (mmol dm^{-3})	$CEC_{50-70\ cm}$ (mmol dm^{-3})	Restriction
> 80	> 80	nr
>80	> 50 and ≤ 80	nr
> 80	≥ 20 and ≤ 50	nr
> 80	< 20	lr
> 50 and ≤ 80	> 80	nr
> 50 and ≤ 80	> 50 and ≤ 80	nr
> 50 and ≤ 80	≥ 20 and ≤ 50	lr
> 50 and ≤ 80	< 20	mr
≥ 20 and ≤ 50	> 80	lr
≥ 20 and ≤ 50	> 50 and ≤ 80	mr
≥ 20 and ≤ 50	≥ 20 and ≤ 50	r
≥ 20 and ≤ 50	< 20	r
< 20	> 80	mr
< 20	> 50 and ≤ 80	r
< 20	≥ 20 and ≤ 50	vr
< 20	< 20	vr

CEC: Cation Exchange Capacity

Table A-4: Key table for determination of land quality indicator 'nutrient retention capacity', for soils with a depth of less than 50 cm

$CEC_{0-20\ cm}$ (mmol dm^{-3})	Restriction
> 80	nr
> 50 and ≤ 80	lr
≥ 20 and ≤ 50	mr
< 20	vr

CEC: Cation Exchange Capacity

Table A-5: Key table for determination of land quality indicator 'rooting conditions', for soils with depth of more than 50 cm

$Al_{0\text{-}20\ cm}$ (%)	$Al_{50\text{-}70\ cm}$ (%)	$CEC_{0\text{-}20\ cm}$ (mmol dm^{-3})	$CEC_{50\text{-}70\ cm}$ (mmol dm^{-3})	$BS_{0\text{-}20\ cm}$ (%)	$BS_{50\text{-}70\ cm}$ (%)	Depth >100 cm	Depth 50-100 cm
≤ 50	≤ 50	≤ 50	≤ 50	≤ 50	≤ 50	mr	r
≤ 50	≤ 50	≤ 50	≤ 50	≤ 50	> 50	mr	mr
≤ 50	≤ 50	≤ 50	≤ 50	> 50	≤ 50	lr	lr
≤ 50	≤ 50	≤ 50	≤ 50	> 50	> 50	nr	nr
≤ 50	≤ 50	≤ 50	> 50	≤ 50	≤ 50	mr	r
≤ 50	≤ 50	≤ 50	> 50	≤ 50	> 50	mr	mr
≤ 50	≤ 50	≤ 50	> 50	> 50	≤ 50	lr	lr
≤ 50	≤ 50	≤ 50	> 50	> 50	> 50	nr	nr
≤ 50	≤ 50	> 50	≤ 50	≤ 50	≤ 50	mr	mr
≤ 50	≤ 50	> 50	≤ 50	≤ 50	> 50	lr	lr
≤ 50	≤ 50	> 50	≤ 50	> 50	≤ 50	nr	nr
≤ 50	≤ 50	> 50	≤ 50	> 50	> 50	nr	nr
≤ 50	≤ 50	> 50	> 50	≤ 50	≤ 50	lr	lr
≤ 50	≤ 50	> 50	> 50	≤ 50	> 50	nr	lr
≤ 50	≤ 50	> 50	> 50	> 50	≤ 50	lr	lr
≤ 50	≤ 50	> 50	> 50	> 50	> 50	nr	nr
≤ 50	> 50	≤ 50	≤ 50	≤ 50	≤ 50	r	r
≤ 50	> 50	≤ 50	≤ 50	> 50	≤ 50	mr	r
≤ 50	> 50	≤ 50	> 50	≤ 50	≤ 50	mr	r
≤ 50	> 50	≤ 50	> 50	> 50	≤ 50	mr	mr
≤ 50	> 50	> 50	≤ 50	≤ 50	≤ 50	mr	r
≤ 50	> 50	> 50	≤ 50	> 50	≤ 50	lr	mr
≤ 50	> 50	> 50	> 50	≤ 50	≤ 50	mr	mr
≤ 50	> 50	> 50	> 50	> 50	≤ 50	mr	mr
> 50	≤ 50	≤ 50	≤ 50	≤ 50	≤ 50	r	r
> 50	≤ 50	≤ 50	≤ 50	≤ 50	> 50	mr	r
> 50	≤ 50	≤ 50	> 50	≤ 50	≤ 50	mr	r
> 50	≤ 50	≤ 50	> 50	≤ 50	> 50	mr	mr
> 50	≤ 50	> 50	≤ 50	≤ 50	≤ 50	r	r
> 50	≤ 50	> 50	≤ 50	≤ 50	> 50	mr	mr
> 50	≤ 50	> 50	> 50	≤ 50	≤ 50	mr	mr
> 50	≤ 50	> 50	> 50	≤ 50	> 50	mr	mr
> 50	> 50	≤ 50	≤ 50	≤ 50	≤ 50	r	vr
> 50	> 50	≤ 50	> 50	≤ 50	≤ 50	r	r
> 50	> 50	> 50	≤ 50	≤ 50	≤ 50	r	r
> 50	> 50	> 50	> 50	≤ 50	≤ 50	r	r

Al: Aluminum content; CEC: Cation Exchange Capacity, BS: Base Saturation

Table A-6: Key table for determination of land quality indicator 'rooting conditions', for soils with depth of less than 50 cm

$Al_{0\text{-}20\ cm}$ (%)	$CEC_{0\text{-}20\ cm}$ (mmol dm^{-3})	$BS_{0\text{-}20\ cm}$ (%)	$Depth_{<30\ cm}$	$Depth_{30\text{-}50\ cm}$
≤ 50	≤ 50	≤ 50	r	vr
≤ 50	≤ 50	> 50	mr	r
≤ 50	> 50	≤ 50	r	vr
≤ 50	> 50	> 50	lr	mr
> 50	≤ 50	≤ 50	vr	vr
> 50	> 50	≤ 50	vr	vr

Al: Aluminum content; CEC: Cation Exchange Capacity, BS: Base Saturation

Table A-7: Key table for determination of land quality indicator 'soil water holding capacity', for soils with a depth of more than 50 cm

$OM_{0\text{-}20\ cm}$ (g kg^{-1})	$Clay_{0\text{-}20\ cm}$ (%)	$Clay_{50\text{-}70\ cm}$ (%)	$Silt_{0\text{-}20\ cm}$ (%)	$Silt_{50\text{-}70\ cm}$ (%)	Depth >100 cm	Depth 50 - 100 cm
>30	>35	> 35	> 40	> 40	nr	lr
>30	>35	> 35	> 40	≤ 40	nr	lr
>30	>35	> 35	≤ 40	> 40	nr	lr
>30	>35	> 35	≤ 40	≤ 40	nr	lr
>30	>35	≥ 15 and ≤ 35	> 40	> 40	lr	mr
>30	>35	≥ 15 and ≤ 35	> 40	≤ 40	lr	mr
>30	>35	≥ 15 and ≤ 35	≤ 40	> 40	lr	mr
>30	>35	≥ 15 and ≤ 35	≤ 40	≤ 40	lr	mr
>30	>35	<15	> 40	> 40	lr	mr
>30	>35	<15	> 40	≤ 40	mr	r
>30	>35	<15	≤ 40	> 40	mr	mr
>30	>35	<15	≤ 40	≤ 40	mr	r
>30	≥ 15 and ≤ 35	> 35	> 40	> 40	nr	lr
>30	≥ 15 and ≤ 35	> 35	> 40	≤ 40	nr	lr
>30	≥ 15 and ≤ 35	> 35	≤ 40	> 40	nr	lr
>30	≥ 15 and ≤ 35	> 35	≤ 40	≤ 40	nr	lr
>30	≥ 15 and ≤ 35	≥ 15 and ≤ 35	> 40	> 40	lr	mr
>30	≥ 15 and ≤ 35	≥ 15 and ≤ 35	> 40	≤ 40	mr	mr
>30	≥ 15 and ≤ 35	≥ 15 and ≤ 35	≤ 40	> 40	lr	mr
>30	≥ 15 and ≤ 35	≥ 15 and ≤ 35	≤ 40	≤ 40	mr	r
>30	≥ 15 and ≤ 35	<15	> 40	> 40	lr	mr
>30	≥ 15 and ≤ 35	<15	> 40	≤ 40	mr	r
>30	≥ 15 and ≤ 35	<15	≤ 40	> 40	mr	r
>30	≥ 15 and ≤ 35	<15	≤ 40	≤ 40	r	r
>30	<15	> 35	> 40	> 40	nr	lr
>30	<15	> 35	> 40	≤ 40	lr	mr
>30	<15	> 35	≤ 40	> 40	lr	mr
>30	<15	> 35	≤ 40	≤ 40	mr	r
>30	<15	≥ 15 and ≤ 35	> 40	> 40	mr	r
>30	<15	≥ 15 and ≤ 35	> 40	≤ 40	mr	r
>30	<15	≥ 15 and ≤ 35	≤ 40	> 40	mr	r
>30	<15	≥ 15 and ≤ 35	≤ 40	≤ 40	mr	r

Table A-7: Continuation of key table for determination of land quality indicator 'soil water holding capacity', for soils with a depth of more than 50 cm

OM$_{0\text{-}20\ cm}$ (g kg-1)	Clay$_{0\text{-}20\ cm}$ (%)	Clay$_{50\text{-}70\ cm}$ (%)	Silt$_{0\text{-}20\ cm}$ (%)	Silt$_{50\text{-}70\ cm}$ (%)	Depth >100 cm	Depth 50 – 100 cm
>30	<15	<15	> 40	> 40	mr	r
>30	<15	<15	> 40	≤ 40	r	r
>30	<15	<15	≤ 40	> 40	r	vr
>30	<15	<15	≤ 40	≤ 40	r	vr
≥ 10 and ≤ 30	>35	> 35	> 40	> 40	nr	lr
≥ 10 and ≤ 30	>35	> 35	> 40	≤ 40	nr	lr
≥ 10 and ≤ 30	>35	> 35	≤ 40	> 40	nr	lr
≥ 10 and ≤ 30	>35	> 35	≤ 40	≤ 40	nr	lr
≥ 10 and ≤ 30	>35	≥ 15 and ≤ 35	> 40	> 40	lr	mr
≥ 10 and ≤ 30	>35	≥ 15 and ≤ 35	> 40	≤ 40	lr	mr
≥ 10 and ≤ 30	>35	≥ 15 and ≤ 35	≤ 40	> 40	lr	mr
≥ 10 and ≤ 30	>35	≥ 15 and ≤ 35	≤ 40	≤ 40	lr	mr
≥ 10 and ≤ 30	>35	<15	> 40	> 40	lr	mr
≥ 10 and ≤ 30	>35	<15	> 40	≤ 40	mr	r
≥ 10 and ≤ 30	>35	<15	≤ 40	> 40	mr	r
≥ 10 and ≤ 30	>35	<15	≤ 40	≤ 40	mr	r
≥ 10 and ≤ 30	≥ 15 and ≤ 35	> 35	> 40	> 40	nr	lr
≥ 10 and ≤ 30	≥ 15 and ≤ 35	> 35	> 40	≤ 40	nr	lr
≥ 10 and ≤ 30	≥ 15 and ≤ 35	> 35	≤ 40	> 40	lr	mr
≥ 10 and ≤ 30	≥ 15 and ≤ 35	> 35	≤ 40	≤ 40	lr	mr
≥ 10 and ≤ 30	≥ 15 and ≤ 35	≥ 15 and ≤ 35	> 40	> 40	mr	mr
≥ 10 and ≤ 30	≥ 15 and ≤ 35	≥ 15 and ≤ 35	> 40	≤ 40	mr	mr
≥ 10 and ≤ 30	≥ 15 and ≤ 35	≥ 15 and ≤ 35	≤ 40	> 40	mr	r
≥ 10 and ≤ 30	≥ 15 and ≤ 35	≥ 15 and ≤ 35	≤ 40	≤ 40	r	r
≥ 10 and ≤ 30	≥ 15 and ≤ 35	<15	> 40	> 40	mr	r
≥ 10 and ≤ 30	≥ 15 and ≤ 35	<15	> 40	≤ 40	r	r
≥ 10 and ≤ 30	≥ 15 and ≤ 35	<15	≤ 40	> 40	mr	r
≥ 10 and ≤ 30	≥ 15 and ≤ 35	<15	≤ 40	≤ 40	r	r
≥ 10 and ≤ 30	<15	> 35	> 40	> 40	lr	mr
≥ 10 and ≤ 30	<15	> 35	> 40	≤ 40	mr	r
≥ 10 and ≤ 30	<15	> 35	≤ 40	> 40	mr	r
≥ 10 and ≤ 30	<15	> 35	≤ 40	≤ 40	mr	r
≥ 10 and ≤ 30	<15	≥ 15 and ≤ 35	> 40	> 40	r	r
≥ 10 and ≤ 30	<15	≥ 15 and ≤ 35	> 40	≤ 40	r	r
≥ 10 and ≤ 30	<15	≥ 15 and ≤ 35	≤ 40	> 40	r	vr
≥ 10 and ≤ 30	<15	≥ 15 and ≤ 35	≤ 40	≤ 40	r	vr
≥ 10 and ≤ 30	<15	<15	> 40	> 40	r	vr
≥ 10 and ≤ 30	<15	<15	> 40	≤ 40	r	vr
≥ 10 and ≤ 30	<15	<15	≤ 40	> 40	r	vr
≥ 10 and ≤ 30	<15	<15	≤ 40	≤ 40	vr	vr
<10	>35	> 35	> 40	> 40	nr	lr
<10	>35	> 35	> 40	≤ 40	nr	lr
<10	>35	> 35	≤ 40	> 40	nr	lr
<10	>35	> 35	≤ 40	≤ 40	nr	lr

Table A-7: Continuation of key table for determination of land quality indicator ‘soil water holding capacity’, for soils with a depth of more than 50 cm

$OM_{0\text{-}20\ cm}$ (g kg-1)	$Clay_{0\text{-}20\ cm}$ (%)	$Clay_{50\text{-}70\ cm}$ (%)	$Silt_{0\text{-}20\ cm}$ (%)	$Silt_{50\text{-}70\ cm}$ (%)	Depth >100 cm	Depth 50 – 100 cm
<10	>35	≥ 15 and ≤ 35	> 40	> 40	lr	lr
<10	>35	≥ 15 and ≤ 35	> 40	≤ 40	lr	lr
<10	>35	≥ 15 and ≤ 35	≤ 40	> 40	lr	mr
<10	>35	≥ 15 and ≤ 35	≤ 40	≤ 40	lr	mr
<10	>35	<15	> 40	> 40	lr	mr
<10	>35	<15	> 40	≤ 40	mr	r
<10	>35	<15	≤ 40	> 40	mr	r
<10	>35	<15	≤ 40	≤ 40	mr	r
<10	≥ 15 and ≤ 35	> 35	> 40	> 40	lr	mr
<10	≥ 15 and ≤ 35	> 35	> 40	≤ 40	lr	mr
<10	≥ 15 and ≤ 35	> 35	≤ 40	> 40	lr	mr
<10	≥ 15 and ≤ 35	> 35	≤ 40	≤ 40	lr	mr
<10	≥ 15 and ≤ 35	≥ 15 and ≤ 35	> 40	> 40	mr	r
<10	≥ 15 and ≤ 35	≥ 15 and ≤ 35	> 40	≤ 40	mr	r
<10	≥ 15 and ≤ 35	≥ 15 and ≤ 35	≤ 40	> 40	r	vr
<10	≥ 15 and ≤ 35	≥ 15 and ≤ 35	≤ 40	≤ 40	r	vr
<10	≥ 15 and ≤ 35	<15	> 40	> 40	r	vr
<10	≥ 15 and ≤ 35	<15	> 40	≤ 40	r	vr
<10	≥ 15 and ≤ 35	<15	≤ 40	> 40	r	vr
<10	≥ 15 and ≤ 35	<15	≤ 40	≤ 40	vr	vr
<10	<15	> 35	> 40	> 40	mr	r
<10	<15	> 35	> 40	≤ 40	r	r
<10	<15	> 35	≤ 40	> 40	r	r
<10	<15	> 35	≤ 40	≤ 40	r	r
<10	<15	≥ 15 and ≤ 35	> 40	> 40	r	vr
<10	<15	≥ 15 and ≤ 35	> 40	≤ 40	vr	vr
<10	<15	≥ 15 and ≤ 35	≤ 40	> 40	vr	vr
<10	<15	≥ 15 and ≤ 35	≤ 40	≤ 40	vr	vr
<10	<15	<15	> 40	> 40	r	vr
<10	<15	<15	> 40	≤ 40	vr	vr
<10	<15	<15	≤ 40	> 40	vr	vr
<10	<15	<15	≤ 40	≤ 40	vr	vr

OM: Organic matter content

Table A-8: Key tables for determination of land quality indicator 'soil water holding capacity', for soils with a depth of less than 50 cm

OM $_{0\text{-}20\ cm}$ (g kg^{-1})	Clay $_{0\text{-}20\ cm}$ (%)	Silt $_{0\text{-}20\ cm}$ (%)	Depth $_{<50\ cm}$
>30	>35	>40	mr
>30	>35	≤ 40	mr
>30	≥ 15 and ≤ 35	>40	mr
>30	≥ 15 and ≤ 35	≤ 40	r
>30	<15	>40	mr
>30	<15	≤ 40	r
≥ 10 and ≤ 30	>35	>40	mr
≥ 10 and ≤ 30	>35	≤ 40	r
≥ 10 and ≤ 30	≥ 15 and ≤ 35	>40	r
≥ 10 and ≤ 30	≥ 15 and ≤ 35	≤ 40	r
≥ 10 and ≤ 30	<15	>40	r
≥ 10 and ≤ 30	<15	≤ 40	r
<10	>35	>40	vr
<10	>35	≤ 40	vr
<10	≥ 15 and ≤ 35	>40	vr
<10	≥ 15 and ≤ 35	≤ 40	vr
<10	<15	>40	vr
<10	<15	≤ 40	vr

OM: Organic matter content

Table A-9: Key table for determination of land quality indicator 'soil drainage', for soils with a depth of more than 50 cm

Drainage	Clay $_{0\text{-}20}$ cm (%)	Clay $_{50\text{-}70\ cm}$ (%)	Slope ≥ 3 %	Slope < 3 %
Good	< 15	< 15	nr	nr
		≥ 15 and ≤ 35	nr	nr
		> 35	lr	lr
	≥ 15 and ≤ 35	< 15	nr	nr
		≥ 15 and ≤ 35	nr	nr
		> 35	lr	nr
	> 35	< 15	nr	nr
		≥ 15 and ≤ 35	nr	nr
		> 35	nr	nr
Moderate	< 15	< 15	lr	mr
		≥ 15 and ≤ 35	lr	mr
		> 35	mr	r
	≥ 15 and ≤ 35	< 15	mr	mr
		≥ 15 and ≤ 35	mr	mr
		> 35	mr	mr
	> 35	< 15	mr	mr
		≥ 15 and ≤ 35	mr	mr
		> 35	r	r
Bad	< 15	< 15	r	r
		≥ 15 and ≤ 35	vr	vr
		> 35	vr	vr
	≥ 15 and ≤ 35	< 15	vr	vr
		≥ 15 and ≤ 35	vr	vr
		> 35	vr	vr
	> 35	< 15	vr	vr
		≥ 15 and ≤ 35	vr	vr
		> 35	vr	vr

Table A-10: Key table for determination of land quality indicator 'soil drainage', for soils with a depth less than 50 cm

Drainage	Clay$_{0\text{-}20\ cm}$ (%)	Slope ≥ 3 %	Slope < 3 %
Good	< 15	nr	nr
	≥ 15 and ≤ 35	lr	nr
	> 35	nr	nr
Moderate	< 15	mr	lr
	≥ 15 and ≤ 35	mr	mr
	> 35	mr	mr
Bad	< 15	vr	vr
	≥ 15 and ≤ 35	vr	vr
	> 35	vr	vr

Table A-11: Key table for determination of land quality indicator 'erosion risk', for soils with a depth of more than 50 cm

Slope (%)	$Clay_{0\text{-}20\ cm}$ (%)	$Clay_{50\text{-}70\ cm}$ (%)	$Depth_{>50\ cm}$
<6	>35	>35	nr
<6	>35	≥15 and ≤ 35	nr
<6	>35	<15	nr
<6	≥15 and ≤ 35	>35	lr
<6	≥15 and ≤ 35	≥15 and ≤ 35	nr
<6	≥15 and ≤ 35	<15	nr
<6	<15	>35	mr
<6	<15	≥15 and ≤ 35	mr
<6	<15	<15	nr
≥ 6 and ≤ 15	>35	>35	lr
≥ 6 and ≤ 15	>35	≥15 and ≤ 35	lr
≥ 6 and ≤ 15	>35	<15	lr
≥ 6 and ≤ 15	≥15 and ≤ 35	>35	mr
≥ 6 and ≤ 15	≥15 and ≤ 35	≥15 and ≤ 35	lr
≥ 6 and ≤ 15	≥15 and ≤ 35	<15	lr
≥ 6 and ≤ 15	<15	>35	r
≥ 6 and ≤ 15	<15	≥15 and ≤ 35	r
≥ 6 and ≤ 15	<15	<15	mr
>15	>35	>35	r
>15	>35	≥15 and ≤ 35	r
>15	>35	<15	r
>15	≥15 and ≤ 35	>35	vr
>15	≥15 and ≤ 35	≥15 and ≤ 35	vr
>15	≥15 and ≤ 35	<15	vr
>15	<15	>35	vr
>15	<15	≥15 and ≤ 35	vr
>15	<15	<15	vr

Table A-12: Key table for determination of land quality indicator 'erosion risk', for soils with a depth of less than 50 cm

Slope (%)	$Clay_{0\text{-}20\ cm}$ (%)	$Depth_{<50\ cm}$
<6	>35	lr
<6	≥15 and ≤ 35	lr
<6	<15	mr
≥ 6 and ≤ 15	>35	r
≥ 6 and ≤ 15	≥15 and ≤ 35	vr
≥ 6 and ≤ 15	<15	vr
>15	>35	vr
>15	≥15 and ≤ 35	vr
>15	<15	vr

Table A-13: Key table for determination of land quality indicator ‘mechanization capacity’

Slope (%)	Stoniness (≤ 20 cm)	Restriction
<16	Without or with few stones and/or rocks	nr
<16	Stony and/or rocky	mr
<16	Many stones and/or rocks	vr
≥ 16 and ≤ 40	Without or with few stones and/or rocks	lr
≥ 16 and ≤ 40	Stony and/or rocky	mr
≥ 16 and ≤ 40	Many stones and/or rocks	vr
>40	Without or with few stones and/or rocks	vr
>40	Stony and/or rocky	vr
>40	Many stones and/or rocks	vr

Table A-14: Key table for determination of land quality indicator ‘salinity and sodicity’, for soils with a depth of more than 50 cm

EC $_{0\text{-}20\ cm}$ (dS/m)	EC $_{50\text{-}70\ cm}$ (dS/m)	Na $_{0\text{-}20\ cm}$ (%)	Na $_{50\text{-}70\ cm}$ (%)	Restriction
<2	<2	<8	<8	nr
<2	<2	<8	≥ 8 and ≤ 15	lr
<2	<2	<8	>15	mr
<2	<2	≥ 8 and ≤ 15	<8	mr
<2	<2	≥ 8 and ≤ 15	≥ 8 and ≤ 15	r
<2	<2	≥ 8 and ≤ 15	>15	vr
<2	<2	>15	<8	vr
<2	<2	>15	≥ 8 and ≤ 15	vr
<2	<2	>15	>15	vr
<2	2 – 4	<8	<8	mr
<2	2 – 4	<8	≥ 8 and ≤ 15	mr
<2	2 – 4	<8	>15	vr
<2	2 – 4	≥ 8 and ≤ 15	<8	r
<2	2 – 4	≥ 8 and ≤ 15	≥ 8 and ≤ 15	vr
<2	2 – 4	≥ 8 and ≤ 15	>15	vr
<2	2 – 4	>15	<8	vr
<2	2 – 4	>15	≥ 8 and ≤ 15	vr
<2	2 – 4	>15	>15	vr
<2	>4	<8	<8	vr
<2	>4	<8	≥ 8 and ≤ 15	vr
<2	>4	<8	>15	vr
<2	>4	≥ 8 and ≤ 15	<8	vr
<2	>4	≥ 8 and ≤ 15	≥ 8 and ≤ 15	vr
<2	>4	≥ 8 and ≤ 15	>15	vr
<2	>4	>15	<8	vr
<2	>4	>15	≥ 8 and ≤ 15	vr
<2	>4	>15	>15	vr
≥ 2 and ≤ 4	<2	<8	<8	r
≥ 2 and ≤ 4	<2	<8	≥ 8 and ≤ 15	r
≥ 2 and ≤ 4	<2	<8	>15	vr
≥ 2 and ≤ 4	<2	≥ 8 and ≤ 15	<8	r
≥ 2 and ≤ 4	<2	≥ 8 and ≤ 15	≥ 8 and ≤ 15	vr
≥ 2 and ≤ 4	<2	≥ 8 and ≤ 15	>15	vr

Table A-14: Continuation of key table for determination of land quality indicator 'salinity and sodicity', for soils with a depth of more than 50 cm

EC $_{0-20\ cm}$ (dS/m)	EC $_{50-70\ cm}$ (dS/m)	Na $_{0-20\ cm}$(%)	Na $_{50-70\ cm}$ (%)	Restriction
≥ 2 and ≤ 4	<2	>15	<8	vr
≥ 2 and ≤ 4	<2	>15	≥ 8 and ≤ 15	vr
≥ 2 and ≤ 4	<2	>15	>15	vr
≥ 2 and ≤ 4	≥ 2 and ≤ 4	<8	<8	r
≥ 2 and ≤ 4	≥ 2 and ≤ 4	<8	≥ 8 and ≤ 15	r
≥ 2 and ≤ 4	≥ 2 and ≤ 4	<8	>15	vr
≥ 2 and ≤ 4	≥ 2 and ≤ 4	≥ 8 and ≤ 15	<8	vr
≥ 2 and ≤ 4	≥ 2 and ≤ 4	≥ 8 and ≤ 15	≥ 8 and ≤ 15	vr
≥ 2 and ≤ 4	≥ 2 and ≤ 4	≥ 8 and ≤ 15	>15	vr
≥ 2 and ≤ 4	≥ 2 and ≤ 4	>15	<8	vr
≥ 2 and ≤ 4	≥ 2 and ≤ 4	>15	≥ 8 and ≤ 15	vr
≥ 2 and ≤ 4	≥ 2 and ≤ 4	>15	>15	vr
≥ 2 and ≤ 4	>4	<8	<8	vr
≥ 2 and ≤ 4	>4	<8	≥ 8 and ≤ 15	vr
≥ 2 and ≤ 4	>4	<8	>15	vr
≥ 2 and ≤ 4	>4	≥ 8 and ≤ 15	<8	vr
≥ 2 and ≤ 4	>4	≥ 8 and ≤ 15	≥ 8 and ≤ 15	vr
≥ 2 and ≤ 4	>4	≥ 8 and ≤ 15	>15	vr
≥ 2 and ≤ 4	>4	>15	<8	vr
≥ 2 and ≤ 4	>4	>15	≥ 8 and ≤ 15	vr
≥ 2 and ≤ 4	>4	>15	>15	vr
>4	<2	<8	<8	vr
>4	<2	<8	≥ 8 and ≤ 15	vr
>4	<2	<8	>15	vr
>4	<2	≥ 8 and ≤ 15	<8	vr
>4	<2	≥ 8 and ≤ 15	≥ 8 and ≤ 15	vr
>4	<2	≥ 8 and ≤ 15	>15	vr
>4	<2	>15	<8	vr
>4	<2	>15	≥ 8 and ≤ 15	vr
>4	<2	>15	>15	vr
>4	≥ 2 and ≤ 4	<8	<8	vr
>4	≥ 2 and ≤ 4	<8	≥ 8 and ≤ 15	vr
>4	≥ 2 and ≤ 4	<8	>15	vr
>4	≥ 2 and ≤ 4	≥ 8 and ≤ 15	<8	vr
>4	≥ 2 and ≤ 4	≥ 8 and ≤ 15	≥ 8 and ≤ 15	vr
>4	≥ 2 and ≤ 4	≥ 8 and ≤ 15	>15	vr
>4	≥ 2 and ≤ 4	>15	<8	vr
>4	≥ 2 and ≤ 4	>15	≥ 8 and ≤ 15	vr
>4	≥ 2 and ≤ 4	>15	>15	vr
>4	>4	<8	<8	vr
>4	>4	<8	≥ 8 and ≤ 15	vr
>4	>4	<8	>15	vr
>4	>4	≥ 8 and ≤ 15	<8	vr
>4	>4	≥ 8 and ≤ 15	≥ 8 and ≤ 15	vr
>4	>4	≥ 8 and ≤ 15	>15	vr

Table A-14: Continuation of key table for determination of land quality indicator 'salinity and sodicity', for soils with a depth of more than 50 cm

EC $_{0\text{-}20\ cm}$ (dS/m)	EC $_{50\text{-}70\ cm}$ (dS/m)	Na $_{0\text{-}20\ cm}$ (%)	Na $_{50\text{-}70\ cm}$ (%)	Restriction
>4	>4	>15	<8	vr
>4	>4	>15	≥ 8 and ≤ 15	vr
>4	>4	>15	>15	vr

EC: Electric conductivity, Na: Sodium content

Table A-15: Key tables for determination of land quality indicator 'salinity and sodicity', for soils with a depth of less than 50 cm

EC $_{0\text{-}20\ cm}$ (dS/m)	Na $_{0\text{-}20\ cm}$ (%)	Restriction
<2	<8	nr
<2	≥ 8 and ≤ 15	mr
<2	>15	vr
≥ 2 and ≤ 4	<8	r
≥ 2 and ≤ 4	≥ 8 and ≤ 15	r
≥ 2 and ≤ 4	>15	vr
>4	<8	vr
>4	≥ 8 and ≤ 15	vr
>4	>15	vr

EC: Electric conductivity, Na: Sodium content

Table A-16: Velocity of traveling per state in Brazil

State	Total area (km²)	Road (km)	Road/area (km/km²)
Roraima	224118	3	0.01
Amazonas	1570947	5314	3.38
Pará	1247703	8404	6.74
Amapá	142816	1771	12.40
Mato Grosso	903386	19280	21.34
Acre	152522	3303	21.65
Rondônia	237565	5275	22.21
Maranhão	331918	16424	49.48
Tocantins	277298	13893	50.10
Minas Gerais	586552	42103	71.78
Goiás	340118	24515	72.08
Piauí	251312	18906	75.23
Mato Grosso do Sul	357140	29120	81.54
São Paulo	248177	21077	84.93
Bahia	564273	48212	85.44
Ceará	145712	12642	86.76
Rio Grande do Sul	281734	25691	91.19
Espírito Santo	46047	4299	93.35
Paraná	199282	19002	95.35
Rio de Janeiro	43797	4401	100.49
Rio Grande do Norte	53077	5431	102.33
Santa Catarina	95285	10251	107.58
Paraíba	56341	6561	116.45
Sergipe	21962	2631	119.79
Alagoas	27819	3644	130.98
Pernambuco	98527	12970	131.64
Distrito Federal	5802	1070	184.41

Table A-17: PCA of input variables of LARISSA model

	Principal components												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Eigenvalues	4.66	3.56	2.84	1.92	1.50	1.24	1.06	0.65	0.56	0.48	0.40	0.27	0.22
Percentages	24.1	18.4	14.7	9.9	7.8	6.4	5.5	3.4	2.9	2.5	2.1	1.4	1.1
Cumulative	24.1	42.5	57.1	67.0	74.8	81.2	86.7	90.0	92.9	95.4	97.4	98.9	100.0
	Component loadings												
CNA	0.310	0.150	-0.095	0.015	0.274	0.705	0.174	-0.255	-0.185	-0.028	0.372	-0.172	0.048
CMNA	0.272	0.374	0.170	0.066	-0.025	-0.057	-0.215	0.380	0.094	0.074	0.469	0.503	-0.266
NRC	0.383	0.386	0.220	0.121	-0.081	-0.015	-0.289	0.270	0.115	-0.006	-0.260	-0.608	0.166
RC	0.180	0.139	-0.126	0.177	0.155	0.309	0.018	0.092	-0.107	0.090	-0.715	0.490	0.033
WHC	0.005	0.518	-0.313	-0.294	0.512	-0.440	0.282	-0.087	0.002	-0.003	-0.040	-0.058	-0.022
SD	-0.120	-0.166	-0.284	-0.646	0.165	0.279	-0.479	0.304	0.119	0.048	-0.049	-0.063	-0.102
ER	-0.094	0.031	-0.420	0.456	0.162	-0.156	-0.635	-0.236	-0.247	-0.141	0.112	-0.001	0.053
MC	-0.224	-0.128	-0.340	0.468	0.222	0.119	0.257	0.480	0.428	0.134	0.102	-0.164	-0.019
SS	-0.025	0.022	-0.023	-0.104	-0.012	-0.033	-0.021	0.123	0.028	0.111	0.179	0.220	0.937
Climate	-0.153	0.409	-0.312	-0.049	-0.510	0.190	-0.019	-0.332	0.526	-0.139	-0.029	0.080	0.004
Accessibility	0.491	-0.222	-0.355	-0.032	-0.212	-0.184	0.015	-0.169	0.046	0.683	0.034	-0.044	-0.059
Market	0.444	-0.212	-0.394	-0.069	-0.237	-0.124	0.199	0.268	-0.125	-0.630	0.019	0.030	0.029
Irrigation	-0.338	0.306	-0.220	-0.022	-0.409	0.093	0.143	0.312	-0.615	0.227	0.034	-0.127	-0.048

Where:
CNA: Current nutrient availability
CMNA: Capacity of maintaining nutrient availability
NRC: Nutrient retention capacity
RC: Rooting conditions
WHC: Soil water holding capacity
SD: Soil drainage
ER: Erosion risk
MC: Mechanization capacity
SS: Salinity and sodicity.

Table A-18: Contingency table of land quality indicator 'current nutrient availability'

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted	Total
North	194015 (460137)	51568 (100774)	61153 (87083)	2545867 (2198408)	857505 (863705)	3710108
North East	354745 (190807)	86884 (41788)	74772 (36111)	643537 (911625)	378551 (358157)	1538489
Central West	155441 (198469)	67058 (43466)	14515 (37561)	941965 (948230)	421285 (372538)	1600264
Southeast	162603 (113433)	15009 (24843)	13902 (21468)	565829 (541954)	157277 (212922)	914620
South	165267 (69225)	5513 (15161)	30983 (13101)	233755 (330736)	122643 (129939)	558161
Total	1032071	226032	195325	4930953	1937261	8321642

Table A-19: Distribution of 'current nutrient availability' (area in km2)

	Non restricted		Little restricted		Moderate restricted		Restricted		Very restricted	
State	Area	%	Area	%	Area	%	Area	%	Area	%
Rondônia	5509	2.4	37962	16.3	849	0.4	122850	52.7	65900	28.3
Acre	94939	63.5	0	0.0	7446	5.0	38709	25.9	8509	5.7
Amazonas	70233	4.7	4398	0.3	52608	3.5	974410	64.6	406324	26.9
Roraima	0	0.0	1978	0.9	0	0.0	156845	71.7	59915	27.4
Pará	17788	1.5	5699	0.5	13	0.0	1004664	84.5	161296	13.6
Amapá	4	0.0	1531	1.1	0	0.0	110635	80.4	25518	18.5
Tocantins	5542	2.0	0	0.0	237	0.1	137753	50.4	130044	47.5
Maranhão	7418	2.3	6743	2.1	418	0.1	194941	59.9	116054	35.6
Piauí	19618	7.8	8148	3.3	6096	2.4	116041	46.3	100651	40.2
Ceará	67265	46.2	19747	13.6	14242	9.8	31575	21.7	12898	8.9
Rio Grande do Norte	23105	43.9	7563	14.4	9026	17.1	7355	14.0	5605	10.6
Paraíba	30932	55.1	1157	2.1	16435	29.3	2896	5.2	4758	8.5
Pernambuco	30127	30.8	10299	10.5	20824	21.3	27908	28.5	8785	9.0
Alagoas	9249	33.3	675	2.4	3353	12.1	13954	50.2	543	2.0
Sergipe	14041	64.1	556	2.5	0	0.0	4624	21.1	2682	12.2
Bahia	152989	27.3	31997	5.7	4379	0.8	244244	43.6	126574	22.6
Minas Gerais	69084	11.9	11787	2.0	5040	0.9	381867	65.7	113417	19.5
Espírito Santo	2789	6.1	0	0.0	3158	6.9	34701	75.7	5163	11.3
Rio de Janeiro	6456	15.2	0	0.0	4697	11.1	19636	46.4	11564	27.3
São Paulo	84273	34.4	3222	1.3	1006	0.4	129626	52.9	27132	11.1
Paraná	73176	37.1	0	0.0	0	0.0	79042	40.1	44891	22.8
Santa Catarina	7941	8.4	0	0.0	0	0.0	46234	49.0	40233	42.6
Rio Grande do Sul	84150	31.6	5513	2.1	30983	11.6	108479	40.7	37519	14.1
Mato Grosso do Sul	59227	16.7	33533	9.5	11774	3.3	120580	34.1	128941	36.4
Mato Grosso	21348	2.4	33525	3.7	555	0.1	582759	64.7	262648	29.2
Goiás	73309	21.6	0	0.0	2186	0.6	234380	69.0	29696	8.7
Distrito Federal	1557	26.8	0	0.0	0	0.0	4246	73.2	0	0.0

Table A-20: Contingency table of land quality indicator ‘capacity of maintaining nutrient availability’

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted	Total
North	458470 (404943)	329997 (421175)	174986 (392675)	2549055 (2163709)	197600 (327605)	3710108 (3710108)
North East	134759 (167920)	223508 (174651)	220655 (162832)	695644 (897236)	263922 (135850)	1538488 (1538488)
Central West	156465 (174492)	77489 (181487)	225562 (169206)	933603 (932355)	205588 (141167)	1598707 (1598707)
Southeast	60272 (99827)	107814 (103829)	160756 (96803)	543503 (533401)	42276 (80762)	914621 (914621)
South	98137 (60921)	205697 (63363)	98633 (59075)	130411 (325516)	25283 (49286)	558161 (558161)
Total	908103	944505	880592	4852216	734669	8320085

Table A-21: Distribution of ‘capacity of maintaining nutrient availability’ (area in km2)

	Non restricted		Little restricted		Moderate restricted		Restricted		Very restricted	
State	Area	%	Area	%	Area	%	Area	%	Area	%
Rondônia	11592	5.0	761	0.3	40723	17.5	158622	68.1	21372	9.2
Acre	56181	37.6	53910	36.0	804	0.5	38709	25.9	0	0
Amazonas	195248	12.9	239466	15.9	55625	3.7	973378	64.5	44256	2.9
Roraima	15690	7.2	0	0	23141	10.6	158821	72.6	21086	9.6
Pará	112241	9.4	16784	1.4	36484	3.1	985893	82.9	38057	3.2
Amapá	20908	15.2	0	0	9518	6.9	107262	77.9	0	0
Tocantins	46611	17.0	19076	7.0	8691	3.2	126369	46.2	72828	26.6
Maranhão	19133	5.9	22848	7.0	27188	8.4	180181	55.3	76222	23.4
Piauí	15206	6.1	17004	6.8	44503	17.8	119375	47.6	54464	21.7
Ceará	26595	18.2	35914	24.6	19479	13.4	51083	35.1	12657	8.7
Rio Grande do Norte	8869	16.8	16812	31.9	4769	9.1	14827	28.2	7375	14.0
Paraíba	14031	25.0	27615	49.2	4059	7.2	3310	5.9	7163	12.8
Pernambuco	8743	8.9	24901	25.4	6330	6.5	33373	34.1	24597	25.1
Alagoas	0	0	3121	11.2	5654	20.4	14758	53.1	4240	15.3
Sergipe	322	1.5	7410	33.8	5919	27.0	6068	27.7	2184	10.0
Bahia	41859	7.5	67882	12.1	102752	18.3	272670	48.7	75020	13.4
Minas Gerais	43788	7.5	40489	7.0	105199	18.1	361199	62.1	30520	5.3
Espírito Santo	5005	10.9	1250	2.7	4856	10.6	34701	75.7	0	0
Rio de Janeiro	6945	16.4	2846	6.7	12926	30.5	19636	46.4	0	0
São Paulo	4533	1.8	63229	25.8	37775	15.4	127967	52.2	11756	4.8
Paraná	13603	6.9	83321	42.3	44376	22.5	49890	25.3	5920	3.0
Santa Catarina	24049	25.5	34543	36.6	15571	16.5	17896	19.0	2347	2.5
Rio Grande do Sul	60485	22.7	87833	32.9	38686	14.5	62625	23.5	17015	6.4
Mato Grosso do Sul	16134	4.6	39543	11.2	59228	16.7	124883	35.3	114266	32.3
Mato Grosso	92513	10.3	17071	1.9	96074	10.7	608935	67.6	86242	9.6
Goiás	47818	14.1	20875	6.1	70260	20.7	195539	57.6	5079	1.5
Distrito Federal	0	0	0	0	0	0	4246	73.2	0	0

Table A-22: Contingency table of land quality indicator 'nutrient retention capacity'

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted	Total
North	762680 (885348)	175049 (320001)	504538 (337688)	2202280 (2087420)	65561 (79650)	3710108 (3710108)
North East	479458 (367132)	151896 (132697)	81351 (140031)	789781 (865600)	36002 (33029)	1538488 (1538488)
Central West	207519 (381873)	235375 (138025)	76520 (145653)	1039298 (900357)	41552 (34355)	1600264 (1600264)
Southeast	156071 (218257)	133043 (78887)	37399 (83247)	558083 (514594)	30025 (19636)	914621 (914621)
South	380077 (133195)	22389 (48142)	57614 (50803)	92567 (314038)	5513 (11983)	558160 (558160)
Total	1985805	717752	757422	4682009	178653	8321641

Table A-23: Distribution of land quality indicator 'nutrient retention capacity' (area in km2)

	Non restricted		Little restricted		Moderate restricted		Restricted		Very restricted	
State	Area	%	Area	%	Area	%	Area	%	Area	%
Rondônia	16089	6.9	34797	14.9	4528	1.9	177657	76.2	0	0.0
Acre	110091	73.6	804	0.5	19330	12.9	19379	13.0	0	0.0
Amazonas	419572	27.8	68897	4.6	264760	17.6	716358	47.5	38386	2.5
Roraima	15665	7.2	25144	11.5	0	0.0	150754	68.9	27175	12.4
Pará	121112	10.2	32197	2.7	159609	13.4	876541	73.7	0	0.0
Amapá	21915	15.9	5138	3.7	3373	2.4	107262	77.9	0	0.0
Tocantins	58236	21.3	8072	3.0	52938	19.4	154330	56.4	0	0.0
Maranhão	45502	14.0	24951	7.7	39973	12.3	193620	59.5	21527	6.6
Piauí	24750	9.9	51990	20.8	19114	7.6	151290	60.4	3409	1.4
Ceará	89744	61.6	11790	8.1	2871	2.0	30257	20.8	11066	7.6
Rio Grande do Norte	34995	66.5	1439	2.7	0	0.0	16219	30.8	0	0.0
Paraíba	45759	81.5	3544	6.3	2240	4.0	4635	8.2	0	0.0
Pernambuco	45661	46.6	707	0.7	1582	1.6	49992	51.0	0	0.0
Alagoas	8935	32.2	317	1.1	472	1.7	18050	65.0	0	0.0
Sergipe	13652	62.3	1185	5.4	2550	11.6	4517	20.6	0	0.0
Bahia	170460	30.4	55973	10.0	12548	2.2	321201	57.3	0	0.0
Minas Gerais	70008	12.0	81013	13.9	36126	6.2	374718	64.5	19331	3.3
Espírito Santo	5259	11.5	5852	12.8	0	0.0	34701	75.7	0	0.0
Rio de Janeiro	8105	19.1	14242	33.6	371	0.9	19636	46.4	0	0.0
São Paulo	72699	29.6	31936	13.0	903	0.4	129029	52.6	10694	4.4
Paraná	123575	62.7	17724	9.0	0	0.0	55810	28.3	0	0.0
Santa Catarina	74163	78.6	0	0.0	10126	10.7	10118	10.7	0	0.0
Rio Grande do Sul	182339	68.4	4665	1.7	47488	17.8	26639	10.0	5513	2.1
Mato Grosso do Sul	54921	15.5	87590	24.7	0	0.0	170360	48.1	41184	11.6
Mato Grosso	83365	9.3	109169	12.1	39579	4.4	668548	74.2	174	0.0
Goiás	67677	19.9	38616	11.4	36940	10.9	196143	57.8	194	0.1
Distrito Federal	1557	26.8	0	0.0	0	0.0	4246	73.2	0	0.0

Table A-24: Contingency table of land quality indicator ‘rooting conditions’

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted	Total
North	185648 (404810)	383318 (385638)	2418533 (2323839)	654442 (485307)	68168 (110514)	3710109 (3710109)
North East	280486 (167865)	148638 (159914)	796768 (963637)	220525 (201245)	92071 (45828)	1538488 (1538488)
Central West	126272 (174605)	66499 (166335)	1254260 (1002331)	112249 (209325)	40984 (47668)	1600264 (1600264)
Southeast	189736 (99794)	23336 (95068)	586024 (572875)	78000 (119638)	37524 (27244)	914620 (914620)
South	125833 (60901)	243181 (58017)	156702 (349605)	23311 (73011)	9133 (16626)	558160 (558160)
Total	907975	864972	5212287	1088527	247880	8321641

Table A-25: Distribution of land quality indicator ‘rooting conditions’ (area in km2)

	Non restricted		Little restricted		Moderate restricted		Restricted		Very restricted	
State	Area	%	Area	%	Area	%	Area	%	Area	%
Rondônia	12409	5.3	14907	6.4	150065	64.4	52033	22.3	3657	1.6
Acre	91976	61.5	7446	5.0	43793	29.3	6390	4.3	0	0.0
Amazonas	60266	4.0	282945	18.8	787133	52.2	359427	23.8	18203	1.2
Roraima	1978	0.9	4139	1.9	167451	76.6	20154	9.2	25016	11.4
Pará	9281	0.8	49462	4.2	1008019	84.7	103913	8.7	18784	1.6
Amapá	1531	1.1	16494	12.0	119138	86.5	524	0.4	0	0.0
Tocantins	8207	3.0	7925	2.9	142934	52.2	112001	40.9	2508	0.9
Maranhão	10566	3.2	17985	5.5	201184	61.8	92211	28.3	3628	1.1
Piauí	13420	5.4	12563	5.0	149762	59.8	45188	18.0	29620	11.8
Ceará	46583	32.0	28918	19.8	36542	25.1	22174	15.2	11511	7.9
Rio Grande do Norte	15109	28.7	17329	32.9	10502	19.9	9713	18.4	0	0.0
Paraíba	12470	22.2	22541	40.1	7136	12.7	14031	25.0	0	0.0
Pernambuco	34621	35.3	19303	19.7	29749	30.4	14270	14.6	0	0.0
Alagoas	10326	37.2	842	3.0	11635	41.9	4970	17.9	0	0.0
Sergipe	7350	33.6	1367	6.2	13186	60.2	0	0.0	0	0.0
Bahia	130040	23.2	27790	5.0	337072	60.2	17967	3.2	47313	8.4
Minas Gerais	86909	15.0	12784	2.2	394861	67.9	49807	8.6	36833	6.3
Espírito Santo	4974	10.9	2324	5.1	37243	81.3	1043	2.3	228	0.5
Rio de Janeiro	8763	20.7	2535	6.0	17689	41.8	13282	31.4	84	0.2
São Paulo	89091	36.3	5693	2.3	136231	55.5	13867	5.7	379	0.2
Paraná	53897	27.3	53938	27.4	83447	42.3	1224	0.6	4604	2.3
Santa Catarina	1390	1.5	61764	65.4	27398	29.0	0	0.0	3854	4.1
Rio Grande do Sul	70546	26.5	127479	47.8	45857	17.2	22087	8.3	675	0.3
Mato Grosso do Sul	68629	19.4	33224	9.4	249425	70.4	0	0.0	2777	0.8
Mato Grosso	7574	0.8	12684	1.4	742535	82.4	102461	11.4	35581	3.9
Goiás	50016	14.7	19087	5.6	258054	76.0	9788	2.9	2626	0.8
Distrito Federal	54	0.9	1503	25.9	4246	73.2	0	0.0	0	0.0

Table A-26: Contingency table of land quality indicator 'soil water holding capacity'

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted	Total
North	974556 (970624)	1083183 (688333)	209399 (338519)	1081591 (1191243)	361384 (521394)	3710113 (3710113)
North East	115041 (402494)	112471 (285435)	154363 (140375)	651175 (493979)	505443 (216209)	1538493 (1538493)
Central West	433687 (418656)	116260 (296896)	367121 (146012)	481572 (513814)	201629 (224891)	1600269 (1600269)
Southeast	400975 (239281)	177519 (169690)	28403 (83452)	233784 (293668)	73945 (128535)	914626 (914626)
South	252820 (146025)	54477 (103556)	1 (50928)	223798 (179215)	27068 (78440)	558164 (558164)
Total	2177079	1543910	759287	2671920	1169469	8321665

Table A-27: Distribution of land quality indicator 'soil water holding capacity' (area in km2)

	Non restricted		Little restricted		Moderate restricted		Restricted		Very restricted	
State	Area	%	Area	%	Area	%	Area	%	Area	%
Rondônia	13225	5.7	73218	31.4	6627	2.8	117215	50.3	22786	9.8
Acre	50619	33.8	64634	43.2	21410	14.3	12941	8.6	0	0.0
Amazonas	413194	27.4	546611	36.2	30280	2.0	351937	23.3	165952	11.0
Roraima	41972	19.2	18474	8.4	0	0.0	103694	47.4	54597	25.0
Pará	308698	26.0	295373	24.8	116192	9.8	399855	33.6	69343	5.8
Amapá	76544	55.6	58627	42.6	0	0.0	2516	1.8	0	0.0
Tocantins	70303	25.7	26245	9.6	34889	12.8	93433	34.2	48705	17.8
Maranhão	17418	5.3	20512	6.3	5296	1.6	204718	62.9	77630	23.8
Piauí	10104	4.0	3189	1.3	7259	2.9	128100	51.1	101901	40.7
Ceará	581	0.4	7689	5.3	49573	34.0	42258	29.0	45626	31.3
Rio Grande do Norte	3657	6.9	0	0.0	15919	30.2	17482	33.2	15595	29.6
Paraíba	224	0.4	2759	4.9	21765	38.7	23199	41.3	8232	14.7
Pernambuco	21956	22.4	5716	5.8	14549	14.9	18758	19.2	36964	37.7
Alagoas	5911	21.3	1163	4.2	1510	5.4	4067	14.6	15122	54.4
Sergipe	212	1.0	4658	21.3	0	0.0	9507	43.4	7526	34.4
Bahia	54978	9.8	66784	11.9	38490	6.9	203086	36.3	196844	35.1
Minas Gerais	181997	31.3	131342	22.6	22312	3.8	184441	31.7	61103	10.5
Espírito Santo	9999	21.8	3081	6.7	1943	4.2	30788	67.2	0	0.0
Rio de Janeiro	21726	51.3	12064	28.5	1461	3.4	6082	14.4	1021	2.4
São Paulo	187252	76.3	31031	12.7	2686	1.1	12472	5.1	11820	4.8
Paraná	117805	59.8	24795	12.6	0	0.0	53529	27.2	980	0.5
Santa Catarina	55349	58.6	8541	9.0	0	0.0	26779	28.4	3737	4.0
Rio Grande do Sul	79665	29.9	21140	7.9	0	0.0	143489	53.8	22349	8.4
Mato Grosso do Sul	140218	39.6	7962	2.2	23461	6.6	74420	21.0	107995	30.5
Mato Grosso	69358	7.7	86377	9.6	311932	34.6	346925	38.5	86242	9.6
Goiás	219812	64.7	21920	6.5	30224	8.9	60223	17.7	7392	2.2
Distrito Federal	4297	74.0	0	0.0	1503	25.9	3	0.0	0	0.0

Table A-28: Contingency table of land quality indicator 'soil drainage'

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted	Total
North	2505791 (2632936)	322731 (327742)	201294 (214376)	245313 (179407)	434979 (355647)	2505791 (2632936)
North East	1024001 (1091811)	221208 (135906)	78906 (88896)	75566 (74396)	138806 (147478)	1024001 (1091811)
Central West	1235057 (1135652)	47152 (141363)	72542 (92466)	42002 (77383)	203510 (153399)	1235057 (1135652)
Southeast	759467 (649075)	63105 (80795)	43872 (52848)	33493 (44228)	14684 (87675)	759467 (649075)
South	381265 (396107)	80917 (49306)	84224 (32251)	6030 (26991)	5724 (53505)	381265 (396107)
Total	5905581	735113	480838	402404	797703	5905581

Table A-29: Distribution of land quality indicator 'soil drainage' (area in km2)

	Non restricted		Little restricted		Moderate restricted		Restricted		Very restricted	
State	Area	%	Area	%	Area	%	Area	%	Area	%
Rondônia	183727	78.8	23862	10.2	3741	1.6	0	0.0	21741	9.3
Acre	65651	43.9	0	0.0	12941	8.6	55861	37.3	15151	10.1
Amazonas	964063	63.9	48324	3.2	91734	6.1	143988	9.5	259864	17.2
Roraima	158381	72.4	25142	11.5	6015	2.7	18153	8.3	11047	5.1
Pará	890656	74.9	197140	16.6	27102	2.3	8355	0.7	66207	5.6
Amapá	98750	71.7	16391	11.9	16494	12.0	0	0.0	6053	4.4
Tocantins	144565	52.8	11872	4.3	43267	15.8	18956	6.9	54916	20.1
Maranhão	200534	61.6	55721	17.1	12293	3.8	42354	13.0	14671	4.5
Piauí	212621	84.9	21227	8.5	0	0.0	14300	5.7	2406	1.0
Ceará	59859	41.1	45477	31.2	10120	6.9	0	0.0	30272	20.8
Rio Grande do Norte	28014	53.2	11934	22.7	2928	5.6	0	0.0	9777	18.6
Paraíba	26040	46.4	20625	36.7	879	1.6	0	0.0	8635	15.4
Pernambuco	67930	69.4	12580	12.8	4389	4.5	2134	2.2	10909	11.1
Alagoas	12616	45.4	2	0.0	8901	32.0	2983	10.7	3273	11.8
Sergipe	9739	44.5	212	1.0	5526	25.2	2447	11.2	3979	18.2
Bahia	406649	72.6	53431	9.5	33869	6.0	11349	2.0	54885	9.8
Minas Gerais	494266	85.0	35936	6.2	31082	5.3	15751	2.7	4160	0.7
Espírito Santo	36560	79.8	623	1.4	2915	6.4	2298	5.0	3415	7.5
Rio de Janeiro	23107	54.6	145	0.3	6170	14.6	8087	19.1	4845	11.4
São Paulo	205533	83.8	26400	10.8	3706	1.5	7358	3.0	2263	0.9
Paraná	137614	69.8	49805	25.3	4604	2.3	517	0.3	4569	2.3
Santa Catarina	77505	82.1	11893	12.6	3854	4.1	0	0.0	1155	1.2
Rio Grande do Sul	166146	62.3	19219	7.2	75766	28.4	5513	2.1	0	0.0
Mato Grosso do Sul	246861	69.7	0	0.0	9587	2.7	42002	11.9	55604	15.7
Mato Grosso	704651	78.2	6923	0.8	56885	6.3	0	0.0	132376	14.7
Goiás	277741	81.8	40229	11.8	6070	1.8	0	0.0	15530	4.6
Distrito Federal	5803	100.0	0	0.0	0	0.0	0	0.0	0	0.0

Table A-30: Contingency table of land quality indicator 'erosion risk'

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted	Total
North	851005 (1192743)	1318207 (888954)	893485 (1001442)	467220 (331955)	180191 (295014)	3710108 (3710108)
North East	396350 (494600)	152145 (368627)	652167 (415273)	75182 (137653)	262644 (122335)	1538488 (1538488)
Central West	464282 (294037)	202517 (219146)	44846 (246877)	93756 (81834)	109220 (72727)	914621 (914621)
Southeast	240578 (179440)	123931 (133737)	70172 (150660)	60575 (49940)	62905 (44383)	558161 (558161)
South	723066 (514460)	197092 (383428)	585529 (431947)	47830 (143181)	46747 (127247)	1600264 (1600264)
Total	2675281	1993892	2246199	744563	661707	8321642

Table A-31: Distribution of land quality indicator 'erosion risk' (area in km2)

	Non restricted		Little restricted		Moderate restricted		Restricted		Very restricted	
State	Area	%	Area	%	Area	%	Area	%	Area	%
Rondônia	79894	34.3	100870	43.3	22875	9.8	1084	0.5	28347	12.2
Acre	11120	7.4	111392	74.5	0	0.0	14151	9.5	12941	8.6
Amazonas	409513	27.2	677913	45.0	309354	20.5	93395	6.2	17798	1.2
Roraima	61173	28.0	12806	5.9	78654	36.0	41090	18.8	25016	11.4
Pará	190806	16.0	315185	26.5	377859	31.8	223067	18.8	82543	6.9
Amapá	5416	3.9	41242	30.0	17858	13.0	73171	53.1	0	0.0
Tocantins	93082	34.0	58799	21.5	86886	31.8	21263	7.8	13546	5.0
Maranhão	66251	20.3	30524	9.4	171393	52.6	0	0.0	57406	17.6
Piauí	45349	18.1	14137	5.6	119690	47.8	20627	8.2	50750	20.3
Ceará	25954	17.8	842	0.6	73215	50.2	725	0.5	44991	30.9
Rio Grande do Norte	9898	18.8	5519	10.5	18323	34.8	0	0.0	18913	35.9
Paraíba	5379	9.6	623	1.1	11725	20.9	0	0.0	38451	68.4
Pernambuco	26848	27.4	18712	19.1	23272	23.8	0	0.0	29110	29.7
Alagoas	12762	45.9	4951	17.8	8916	32.1	472	1.7	673	2.4
Sergipe	4058	18.5	10428	47.6	4767	21.8	1707	7.8	943	4.3
Bahia	199850	35.7	66410	11.9	220865	39.4	51650	9.2	21407	3.8
Minas Gerais	289644	49.8	131347	22.6	33999	5.8	58415	10.1	67790	11.7
Espírito Santo	27979	61.1	2388	5.2	9200	20.1	3330	7.3	2915	6.4
Rio de Janeiro	10071	23.8	7066	16.7	1606	3.8	17109	40.4	6502	15.4
São Paulo	136588	55.7	61716	25.2	41	0.0	14903	6.1	32012	13.1
Paraná	79541	40.4	30705	15.6	4259	2.2	31231	15.8	51374	26.1
Santa Catarina	64476	68.3	12794	13.6	821	0.9	10126	10.7	6190	6.6
Rio Grande do Sul	96561	36.2	80432	30.2	65092	24.4	19219	7.2	5340	2.0
Mato Grosso do Sul	249174	70.4	36944	10.4	59500	16.8	2288	0.6	6148	1.7
Mato Grosso	263255	29.2	111288	12.4	469566	52.1	24825	2.8	31902	3.5
Goiás	206390	60.8	48807	14.4	56463	16.6	19214	5.7	8698	2.6
Distrito Federal	4246	73.2	54	0.9	0	0.0	1503	25.9	0	0.0

Table A-32: Contingency table of land quality indicator ‘mechanization capacity’

Region	Non restricted	Little restricted	Moderate restricted	Very restricted	Total
North	2524491 (2490349)	795810 (689852)	158189 (211786)	231618 (318121)	3710108 (3710108)
North East	993984 (1032685)	180136 (286064)	78088 (87822)	286280 (131917)	1538488 (1538488)
Central West	1309524 (1074150)	163678 (297551)	51193 (91349)	75868 (137214)	1600263 (1600263)
Southeast	529389 (613924)	320049 (170063)	23786 (52210)	41397 (78424)	914621 (914621)
South	228377 (374657)	87641 (103784)	163772 (31862)	78372 (47859)	558162 (558162)
Total	5585765	1547314	475028	713535	8321642

Table A-33: Distribution of land quality indicator ‘mechanization capacity’ (area in km2)

	Non restricted		Little restricted		Moderate restricted		Very restricted	
State	Area	%	Area	%	Area	%	Area	%
Rondônia	162936	69.9	36522	15.7	1499	0.6	32114	13.8
Acre	42736	28.6	71307	47.7	21410	14.3	14151	9.5
Amazonas	1152497	76.4	210357	13.9	16786	1.1	128332	8.5
Roraima	150630	68.9	43093	19.7	0	0.0	25016	11.4
Pará	789762	66.4	320626	27.0	56100	4.7	22972	1.9
Amapá	48122	35.0	89566	65.0	0	0.0	0	0.0
Tocantins	177808	65.0	24339	8.9	62394	22.8	9033	3.3
Maranhão	234436	72.0	38941	12.0	41674	12.8	10522	3.2
Piauí	156089	62.3	2850	1.1	25446	10.2	66167	26.4
Ceará	87659	60.2	725	0.5	2431	1.7	54913	37.7
Rio Grande do Norte	28222	53.6	0	0.0	3905	7.4	20526	39.0
Paraíba	12967	23.1	6035	10.7	623	1.1	36555	65.1
Pernambuco	57686	58.9	13403	13.7	306	0.3	26548	27.1
Alagoas	22784	82.0	529	1.9	1510	5.4	2950	10.6
Sergipe	12719	58.1	2471	11.3	0	0.0	6713	30.6
Bahia	381423	68.1	115181	20.6	2193	0.4	61385	11.0
Minas Gerais	344815	59.3	182763	31.4	15527	2.7	38090	6.6
Espírito Santo	36555	79.8	8601	18.8	427	0.9	228	0.5
Rio de Janeiro	11531	27.2	30035	70.9	370	0.9	416	1.0
São Paulo	136487	55.6	98651	40.2	7461	3.0	2662	1.1
Paraná	70217	35.6	56529	28.7	24334	12.3	46030	23.4
Santa Catarina	38036	40.3	11893	12.6	25723	27.2	18755	19.9
Rio Grande do Sul	120124	45.1	19219	7.2	113715	42.6	13587	5.1
Mato Grosso do Sul	317759	89.7	14465	4.1	15631	4.4	6199	1.8
Mato Grosso	754788	83.8	74379	8.3	27869	3.1	43799	4.9
Goiás	232731	68.5	74780	22.0	7693	2.3	24367	7.2
Distrito Federal	4246	73.2	54	0.9	0	0.0	1503	25.9

Table A-34: Contingency table of land quality indicator 'salinity and sodicity'

Region	Non restricted	Moderate restricted	Restricted	Very restricted	Total
North	3649557 (3607310)	6377 (35209)	34907 (37195)	19271 (30397)	3710112 (3710112)
North East	1436589 (1495863)	48347 (14600)	30771 (15424)	22785 (12605)	1538492 (1538492)
Central West	1220572 (1225764)	21025 (11964)	7464 (12639)	11635 (10329)	1260696 (1260696)
Southeast	912683 (889282)	1 (8680)	850 (9169)	1091 (7494)	914625 (914625)
South	541516 (542698)	1 (5297)	6031 (5596)	10616 (4573)	558164 (558164)
Total	7760917	75751	80023	65398	7982089

Table A-35: Distribution of land quality indicator 'salinity and sodicity' (area in km2)

	Non restricted		Moderate restricted		Restricted		Very restricted	
State	Area	%	Area	%	Area	%	Area	%
Rondônia	233071	100.0	0	0.0	0	0.0	0	0.0
Acre	149604	100.0	0	0.0	0	0.0	0	0.0
Amazonas	1452648	96.3	4398	0.3	34906	2.3	16021	1.1
Roraima	216760	99.1	1978	0.9	0	0.0	0	0.0
Pará	1186210	99.7	0	0.0	0	0.0	3249	0.3
Amapá	137687	100.0	0	0.0	0	0.0	0	0.0
Tocantins	273576	100.0	0	0.0	0	0.0	0	0.0
Maranhão	318576	97.9	0	0.0	0	0.0	6997	2.1
Piauí	246958	98.6	3433	1.4	0	0.0	162	0.1
Ceará	125601	86.2	19508	13.4	0	0.0	618	0.4
Rio Grande do Norte	40936	77.7	7472	14.2	1770	3.4	2475	4.7
Paraíba	49073	87.4	933	1.7	2404	4.3	3768	6.7
Pernambuco	76923	78.5	7024	7.2	13177	13.5	819	0.8
Alagoas	20962	75.5	3142	11.3	3353	12.1	317	1.1
Sergipe	17428	79.6	2447	11.2	0	0.0	2028	9.3
Bahia	540131	96.4	4388	0.8	10066	1.8	5598	1.0
Minas Gerais	581196	100.0	0	0.0	0	0.0	0	0.0
Espírito Santo	45716	99.8	0	0.0	0	0.0	96	0.2
Rio de Janeiro	41359	97.7	0	0.0	0	0.0	994	2.3
São Paulo	244412	99.7	0	0.0	849	0.3	0	0.0
Paraná	195728	99.3	0	0.0	517	0.3	864	0.4
Santa Catarina	92060	97.5	0	0.0	0	0.0	2347	2.5
Rio Grande do Sul	253728	95.2	0	0.0	5513	2.1	7403	2.8
Mato Grosso do Sul	313933	88.7	21024	5.9	7463	2.1	11634	3.3
Mato Grosso	900835	100.0	0	0.0	0	0.0	0	0.0
Goiás	0	0.0	0	0.0	0	0.0	0	0.0
Distrito Federal	5803	100.0	0	0.0	0	0.0	0	0.0

Table A-36: Contingency table of land quality indicator ‘climate’

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted	Total
North	466484 (507670)	1103941 (1006765)	1059920 (925891)	1175668 (866707)	174805 (673785)	3980818 (3980818)
North East	1 (212679)	3911 (421766)	78387 (387885)	339376 (363091)	1246015 (282270)	1667690 (1667690)
Central West	135588 (212736)	409007 (421879)	725019 (387990)	326254 (363189)	72272 (282346)	1668140 (1668140)
Southeast	251858 (125542)	409736 (248965)	209111 (228965)	98667 (214329)	15051 (166621)	984423 (984423)
South	282395 (77699)	326865 (154085)	1 (141707)	1 (132649)	1 (103123)	609263 (609263)
Total	1136326	2253460	2072438	1939966	1508144	8910334

Table A-37: Distribution of land quality indicator ‘climate’ (area in km2)

	Non restricted		Little restricted		Moderate restricted		Restricted		Very restricted	
State	Area	%	Area	%	Area	%	Area	%	Area	%
Rondônia	0	0.0	56296	22.8	104015	42.2	79367	32.2	6901	2.8
Acre	5353	3.5	134014	86.8	14967	9.7	0	0.0	0	0.0
Amazonas	455217	28.2	715612	44.4	274912	17.1	166289	10.3	100	0.0
Roraima	4111	1.7	23363	9.8	18751	7.9	139679	58.5	52743	22.1
Pará	1702	0.1	153104	12.0	552535	43.2	554338	43.4	16121	1.3
Amapá	100	0.1	20759	13.6	68494	45.0	62978	41.3	0	0.0
Tocantins	0	0.0	792	0.3	26245	8.8	173017	57.9	98938	33.1
Maranhão	0	0.0	0	0.0	8987	2.6	119927	34.1	222979	63.4
Piauí	0	0.0	0	0.0	1594	0.6	25608	9.5	242126	89.9
Ceará	0	0.0	0	0.0	0	0.0	3397	2.2	154257	97.8
Rio Grande do Norte	0	0.0	0	0.0	0	0.0	0	0.0	60585	100.0
Paraíba	0	0.0	100	0.2	498	0.8	5277	8.0	60143	91.1
Pernambuco	0	0.0	99	0.1	1291	1.2	12511	11.2	98204	87.6
Alagoas	0	0.0	0	0.0	99	0.3	99	0.3	32752	99.4
Sergipe	0	0.0	0	0.0	0	0.0	0	0.0	25854	100.0
Bahia	0	0.0	3711	0.6	65917	11.1	172555	29.2	349114	59.0
Minas Gerais	92587	15.1	221370	36.0	188222	30.6	97254	15.8	15050	2.4
Espírito Santo	7812	14.8	23153	43.9	20329	38.6	1412	2.7	0	0.0
Rio de Janeiro	23950	46.9	26559	52.0	559	1.1	0	0.0	0	0.0
São Paulo	127509	47.9	138653	52.1	0	0.0	0	0.0	0	0.0
Paraná	84587	40.1	126469	59.9	0	0.0	0	0.0	0	0.0
Santa Catarina	41994	39.2	65264	60.8	0	0.0	0	0.0	0	0.0
Rio Grande do Sul	155814	53.6	135131	46.4	0	0.0	0	0.0	0	0.0
Mato Grosso do Sul	116954	31.6	116954	31.6	32931	8.9	61535	16.6	42246	11.4
Mato Grosso	6367	0.7	185714	20.0	531184	57.2	178955	19.3	26740	2.9
Goiás	11107	3.1	101795	28.1	160612	44.3	85763	23.7	3284	0.9
Distrito Federal	1160	19.4	4543	75.8	290	4.8	0	0.0	0	0.0

Table A-38: Contingency table of regional condition indicator ‘accessibility’

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted	Total
North	84490 (805004)	128130 (745968)	688614 (816286)	1387449 (808474)	1698837 (811788)	3987520 (3987520)
North East	693099 (335808)	583049 (311181)	384977 (340514)	2270 (337255)	1 (338638)	1663396 (1663396)
Central West	215233 (336017)	285272 (311374)	639066 (340726)	413294 (337465)	111566 (338848)	1664431 (1664431)
Southeast	465969 (196947)	434994 (182503)	74593 (199707)	1 (197795)	1 (198606)	975558 (975558)
South	336486 (121502)	232172 (112591)	33188 (123204)	1 (122025)	1 (122526)	601848 (601848)
Total	1795277	1663617	1820438	1803015	1810406	8892753

Table A-39: Distribution of regional condition indicator ‘accessibility’ (area in km2)

	Non restricted		Little restricted		Moderate restricted		Restricted		Very restricted	
State	Area	%	Area	%	Area	%	Area	%	Area	%
Rondônia	7281	3.0	19976	8.2	123309	50.4	94185	38.5	0	0.0
Acre	17633	10.2	5912	3.4	62025	35.8	87173	50.4	282	0.2
Amazonas	853	0.1	5687	0.4	94406	5.9	593922	36.9	914768	56.8
Roraima	0	0.0	0	0.0	0	0.0	20221	8.6	215696	91.4
Pará	8437	0.7	17633	1.4	198897	15.6	502266	39.4	547867	43.0
Amapá	1519	1.0	4368	2.9	38644	25.6	86117	57.1	20224	13.4
Tocantins	48765	16.4	74554	25.0	171333	57.5	3564	1.2	0	0.0
Maranhão	62208	17.7	96054	27.4	190122	54.2	2269	0.6	0	0.0
Piauí	88399	32.9	122739	45.7	57549	21.4	0	0.0	0	0.0
Ceará	75770	48.2	77662	49.4	3689	2.3	0	0.0	0	0.0
Rio Grande do Norte	48383	80.0	12096	20.0	0	0.0	0	0.0	0	0.0
Paraíba	61366	93.1	4525	6.9	0	0.0	0	0.0	0	0.0
Pernambuco	83008	74.4	28484	25.5	94	0.1	0	0.0	0	0.0
Alagoas	31291	95.7	1405	4.3	0	0.0	0	0.0	0	0.0
Sergipe	21677	85.0	3831	15.0	0	0.0	0	0.0	0	0.0
Bahia	220996	37.4	236253	40.0	133522	22.6	0	0.0	0	0.0
Minas Gerais	248800	40.5	293709	47.9	71060	11.6	0	0.0	0	0.0
Espírito Santo	28433	56.8	20768	41.5	891	1.8	0	0.0	0	0.0
Rio de Janeiro	34066	69.7	14209	29.1	618	1.3	0	0.0	0	0.0
São Paulo	154669	58.8	106307	40.4	2022	0.8	0	0.0	0	0.0
Paraná	124431	58.8	86677	41.0	520	0.2	0	0.0	0	0.0
Santa Catarina	72435	70.3	30392	29.5	169	0.2	0	0.0	0	0.0
Rio Grande do Sul	139619	48.6	115102	40.1	32498	11.3	0	0.0	0	0.0
Mato Grosso do Sul	54963	15.0	113846	31.1	194732	53.1	3029	0.8	0	0.0
Mato Grosso	17249	1.9	43680	4.7	347771	37.4	409350	44.0	111565	12.0
Goiás	137529	38.0	126556	35.0	96563	26.7	914	0.3	0	0.0
Distrito Federal	5491	82.2	1190	17.8	0	0.0	0	0.0	0	0.0

Table A-40: Contingency table of regional condition indicator 'market'

Region	Non restricted	Little restricted	Moderate restricted	Restricted	Very restricted	Total
North	102073 (699490)	1621308 (1007734)	504592 (626443)	358650 (919907)	1410943 (743991)	3997566 (3997566)
North East	571426 (290951)	167110 (419164)	264136 (260568)	632741 (382633)	27365 (309461)	1662778 (1662778)
Central West	115699 (291661)	431370 (420187)	513586 (261203)	389647 (383567)	216532 (310216)	1666834 (1666834)
Southeast	508772 (171993)	15813 (247784)	55932 (154031)	402223 (226189)	192 (182935)	982932 (982932)
South	259295 (103170)	7901 (148633)	56395 (92396)	264715 (135679)	1305 (109733)	589611 (589611)
Total	1557265	2243502	1394641	2047976	1656337	8899721

Table A-41: Distribution of regional condition 'market' (area in km2)

	Non restricted		Little restricted		Moderate restricted		Restricted		Very restricted	
State	Area	%	Area	%	Area	%	Area	%	Area	%
Rondônia	21789	8.8	79860	32.1	66944	26.9	69311	27.8	11042	4.4
Acre	7136	4.6	15858	10.2	17344	11.1	88506	56.7	27354	17.5
Amazonas	12714	0.8	36241	2.2	104218	6.4	580859	35.9	882001	54.6
Roraima	4913	2.1	0	0.0	1103	0.5	35797	15.0	197235	82.5
Pará	31842	2.5	171428	13.4	226702	17.7	646160	50.4	206875	16.1
Amapá	8524	5.5	0	0.0	3008	1.9	81930	52.7	61874	39.8
Tocantins	15153	5.1	55262	18.5	85271	28.5	118745	39.7	24561	8.2
Maranhão	63309	17.8	169955	47.8	64507	18.1	53822	15.1	3894	1.1
Piauí	27999	10.5	78218	29.3	87484	32.7	62176	23.3	11359	4.3
Ceará	81230	52.4	68941	44.5	4496	2.9	300	0.2	0	0.0
Rio Grande do Norte	41721	68.6	18465	30.4	599	1.0	0	0.0	0	0.0
Paraíba	44709	67.7	18421	27.9	2290	3.5	597	0.9	0	0.0
Pernambuco	66032	59.0	40711	36.4	3972	3.5	1192	1.1	0	0.0
Alagoas	26320	81.8	5739	17.8	0	0.0	0	0.0	99	0.3
Sergipe	18058	71.5	6513	25.8	691	2.7	0	0.0	0	0.0
Bahia	202047	34.3	225777	38.3	100096	17.0	49023	8.3	12011	2.0
Minas Gerais	221180	36.0	324435	52.8	52866	8.6	15812	2.6	191	0.0
Espírito Santo	35388	67.7	16847	32.3	0	0.0	0	0.0	0	0.0
Rio de Janeiro	45570	89.6	5219	10.3	93	0.2	0	0.0	0	0.0
São Paulo	206633	77.9	55721	21.0	2972	1.1	0	0.0	0	0.0
Paraná	107082	50.7	85867	40.7	15729	7.5	2378	1.1	0	0.0
Santa Catarina	43064	40.4	48235	45.2	13552	12.7	1872	1.8	0	0.0
Rio Grande do Sul	109148	40.2	130612	48.0	27113	10.0	3650	1.3	1304	0.5
Mato Grosso do Sul	25592	6.9	96724	26.2	162870	44.1	83834	22.7	0	0.0
Mato Grosso	13223	1.4	130763	14.1	271616	29.2	299728	32.3	213923	23.0
Goiás	71083	19.6	161965	44.7	79099	21.8	47807	13.2	2608	0.7
Distrito Federal	5800	96.8	193	3.2	0	0.0	0	0.0	0	0.0

Table A-42: Contingency table of regional condition indicator ‘possibilities for irrigation’

Region	Non restricted	Little restricted	Restricted	Very restricted	Total
North	3601077 (3106090)	1 (73880)	96981 (150634)	1 (367457)	3698060 (3698060)
North East	421894 (1392001)	169607 (33109)	222197 (67507)	843596 (164677)	1657294 (1657294)
Central West	924987 (776921)	1 (18479)	1 (37678)	1 (91911)	924990 (924990)
Southeast	576418 (484150)	1 (11516)	1 (23480)	1 (57276)	576421 (576421)
South	1606522 (1371736)	1 (32627)	26643 (66524)	1 (162279)	1633167 (1633167)
Total	7130898	169611	345823	843600	8489932

Table A-43: Distribution of regional condition ‘possibilities for irrigation’ (area in km2)

	Non restricted		Little restricted		Restricted		Very restricted	
State	Area	%	Area	%	Area	%	Area	%
Rondônia	23763	100.0	0	0.0	0	0.0	0	0.0
Acre	152537	100.0	0	0.0	0	0.0	0	0.0
Amazonas	1572820	100.0	0	0.0	0	0.0	0	0.0
Roraima	224193	100.0	0	0.0	0	0.0	0	0.0
Pará	1280805	99.8	0	0.0	2103	0.2	0	0.0
Amapá	142843	100.0	0	0.0	0	0.0	0	0.0
Tocantins	204115	68.3	0	0.0	94877	31.7	0	0.0
Maranhão	176546	51.1	94065	27.2	34950	10.1	39942	11.6
Piauí	56994	21.2	20526	7.6	42945	15.9	148863	55.3
Ceará	1499	0.9	3297	2.1	4596	2.9	149872	94.1
Rio Grande do Norte	1896	3.1	3693	6.1	1098	1.8	54097	89.0
Paraíba	0	0.0	3386	4.9	3386	4.9	62633	90.2
Pernambuco	0	0.0	6156	5.5	199	0.2	105552	94.3
Alagoas	0	0.0	594	1.8	6926	21.5	24638	76.6
Sergipe	0	0.0	0	0.0	6907	27.3	18354	72.7
Bahia	184957	31.7	37890	6.5	121189	20.8	239644	41.1
Minas Gerais	586900	100.0	0	0.0	0	0.0	0	0.0
Espírito Santo	46053	100.0	0	0.0	0	0.0	0	0.0
Rio de Janeiro	43800	100.0	0	0.0	0	0.0	0	0.0
São Paulo	248233	100.0	0	0.0	0	0.0	0	0.0
Paraná	199312	100.0	0	0.0	0	0.0	0	0.0
Santa Catarina	95293	100.0	0	0.0	0	0.0	0	0.0
Rio Grande do Sul	281811	100.0	0	0.0	0	0.0	0	0.0
Mato Grosso do Sul	357265	100.0	0	0.0	0	0.0	0	0.0
Mato Grosso	903199	97.1	0	0.0	26642	2.9	0	0.0
Goiás	340254	100.0	0	0.0	0	0.0	0	0.0
Distrito Federal	5803	100.0	0	0.0	0	0.0	0	0.0

Table A-44: The total number of settlements and the relative number per governmental period versus state

State	Relative number of settlements per governmental period (%)						Number
	1965-1984	1985-1990	1991–1992	1993-1994	1995-1998	1999-2001	
Rondônia	0	19	1	10	47	23	94
Acre	1	16	4	5	45	27	73
Amazonas	6	29	26	0	32	6	34
Roraima	4	4	9	24	49	9	45
Pará	0	10	5	5	67	12	385
Amapá	0	12	0	8	69	12	26
Tocantins	0	65	24	5	4	2	55
Maranhão	0	10	3	7	56	25	443
Piauí	0	4	3	5	56	32	113
Ceará	2	18	3	15	54	8	317
Rio Grande do Norte	0	9	2	7	58	23	216
Paraíba	0	16	1	4	42	37	153
Pernambuco	0	8	3	0	61	29	38
Alagoas	1	8	3	10	54	23	145
Sergipe	0	13	3	3	54	26	90
Bahia	0	16	3	5	53	24	249
Minas Gerais	0	9	5	5	66	14	137
Espírito Santo	13	33	2	2	38	13	63
Rio de Janeiro	6	48	6	10	19	10	31
São Paulo	2	19	2	5	57	16	58
Paraná	2	19	7	9	50	13	259
Santa Catarina	2	41	3	11	31	13	111
Rio Grande do Sul	0	8	4	7	56	25	142
Mato Grosso do Sul	4	12	1	2	55	26	97
Mato Grosso	1	10	2	16	50	22	325
Goiás	1	13	0	8	59	18	152
Distrito Federal	1	5	1	13	64	16	99
Brazil	1	14	4	8	53	19	3950

Table A-45: The total number of settlements per restriction class of the SLQ indicators and SRC indicators versus six governmental periods

Period	Scoring of SLQ indicators[1]					Scoring of SRC indicators[2]				
	0-20 %	21-40 %	41-60 %	61-80 %	81-100 %	0-20 %	0-20 %	21-40 %	41-60 %	81-100 %
1964 - 1984	0	4	30	10	0	0	0	7	20	17
1985 - 1990	0	9	262	179	40	0	16	118	241	194
1991 - 1992	0	10	311	207	44	0	6	35	60	45
1993 - 1994	0	5	86	47	8	0	3	63	148	106
1995 - 1998	0	74	1030	799	200	0	33	568	832	668
1999 - 2001	0	40	451	244	30	0	17	292	253	201

[1] = Supply of Land Quality indicators, [2] = Supply of Regional Condition indicators

Table A-46: Correlation of SLQ, SRC, and SLQSRC with the value of gross production as well as total value of agricultural cash flow

Region	Gross production of family agriculture SLQ	SRC	SLQSRC	Gross production of commercial agriculture SLQ	SRC	SLQSRC
North	0.07	0.59	0.31	-0.19	0.53	0.05
Northeast	0.22	0.14	0.25	0.32	0.30	0.40
Central west	0.39	0.70	0.60	0.33	0.71	0.57
Southeast	0.30	0.48	0.39	0.44	0.45	0.51
South	0.19	0.39	0.27	0.18	0.14	0.20
Brazil	0.21	0.73	0.48	0.20	0.77	0.48
	Total cash flow of family agriculture			Total cash flow of commercial agriculture		
Region	SLQ	SRC	SLQSRC	SLQ	SRC	SLQSRC
North	0.10	0.55	0.31	-0.11	0.35	0.05
Northeast	0.24	0.19	0.28	0.26	0.24	0.32
Central west	0.40	0.64	0.58	0.37	0.61	0.55
Southeast	0.30	0.44	0.38	0.38	0.30	0.42
South	0.17	0.36	0.24	0.13	0.05	0.13
Brazil	0.22	0.69	0.47	0.23	0.61	0.44

SLQ: Supply of land quality indicators
SRC: Supply of regional condition indicators
SLQSRC: Total supply of land quality and regional condition indicators

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