INRES
Institut für Nutzpflanzenwissenschaften und Ressourcenschutz
Abteilung Tropischer Pflanzenbau

Environmental Sustainability Analysis of Cashew Systems in North-east Brazil

zur
Erlangung des Grades
Doktor der Agrarwissenschaften
(Dr. agr.)

der
Hohen Landwirtschaftlichen Fakultät
der
Rheinischen-Wilhelms-Universität
zu Bonn

vorgelegt am:
18. Dezember 2008

von
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Fortaleza, Brasilien

Erscheinungsjahr: 2009

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Tag der mündlichen Prüfung:	13.02.2009

Diese Dissertation ist auf dem Hochschulschriftenserver der ULB Bonn
http://hss.ulb.uni-bonn.de/diss_online eletronisch publiziert.

Environmental Sustainability Analysis of Cashew Systems in North-east Brazil

This study aims to provide a comprehensive insight into the status and development prospects of the cashew farming systems in North-east Brazil, where thousands of small growers depend on cashew production. The smallholder units are important economic-social groups within rural areas in the north-eastern region. After the introduction of dwarf-precocious cashew, the resulting higher cashew yields in the north-eastern region brought about great expectations concerning the rural and regional development prospects due to the increasing income of growers.

This study is an inquiry into the cashew sector, focusing on the states of Ceará and Piauí, main producers of cashew in Brazil. The main goal of this research is to evaluate the cashew farming systems, identifying the main aspects that affect the yields of the cashew farming systems. Specifically, this research main focuses were on: (i) general characteristics and classification of the cashew growers and their farming systems, specially the factors that affect the cashew nut productivity in both states; (ii) litter fall production and biomass partitioning of the common and dwarf-precocious types of cashew tree and; (iii) an accounting of inputs and outputs of environmental and economic contributions to the cashew farming systems. To collect all this data, 254 farmers were interviewed and an experiment of litter fall was conducted during 24 months at EMBRAPA-Pacajus, Ceará.

The main results of this study were: (i) cashew farmers in the states of Ceará and Piauí had different characteristics and a cluster analysis helped to identify seven homogenous groups from the large number of cashew farming systems observed in this study; (ii) cashew nut production in North-east Brazil was variable across climatic, geographic and agronomic conditions; (iii) the common cashew tree had higher litter fall production. Additionally, the common type also showed better dynamic stability of litter fall production; (iv) the dwarf-precocious cashew tree demonstrated greater biomass production and accumulated more energy in terms of biomass partitioning. Beside this, higher cashew production was observed in the dwarf-precocious type; (v) the energetic assessment of inputs and outputs of farming systems is a viable tool to qualify and quantify the environmental and economic functioning of agricultural ecosystems. The environmental comparison becomes even more convincing when solar transformity is used as a common yardstick and; (vi) the homestead cashew farming system outyielded all other systems in terms of environmental performance and sustainability. The higher cashew yield of the Irrigated model could only be achieved at the expense of higher ELR (Emergy Load Ratio) and EER (Emergy Exchange Ratio).

Umweltverträglichkeits-Analyse der Cashew-Anbausysteme im Nordosten Brasiliens

Diese Studie zielt darauf ab, einen vollständigen Überblick über den Status und die Entwicklungsaussichten der Anbausysteme für Cashewbäume im Nordosten Brasiliens zu geben. Tausende von kleinen Landwirten sind vom Cashewanbau abhängig. Diese kleinen Bauern sind wichtige ökonomische Sozialgruppen innerhalb der ländlichen Gebiete im Nordosten. Nach der Einführung von schwachwachsenden Cashewbäumen eröffnen die zu erwartenden Ertragssteigerungen und die daraus resultierenden höheren Einkommen gesteigerte Erwartungen im Hinblick auf die landwirtschaftlichen und regionalen Entwicklungsmöglichkeiten.

Diese Studie analysiert das Cashew Anbausystem, besonders in den Staaten von Ceará und Piauí, den Hauptproduzenten der Cashewnuss in Brasilien. Die Hauptziele dieser Studie waren: (i) die Klassifizierung des Anbausystems für Cashewbäumen, insbesondere der Faktoren, die die Produktivität des Cashewbaumes beeinflussen; (ii) Vergleich von Blattfall und Biomasseproduktion zwischen den herkömmlichen und schwachwachsenden Cashewbäumen und; (iii) Bilanzierung von ökologischen und ökonomischen Einflussfaktoren des Cashewanbaumsystemes. In dieser Studie wurden 254 Landwirte befragt und ein Blattfallversuch in EMBRAPA-Pacajus, Ceará über 24 Monate durchgeführt.

Die wichtigsten Ergebnisse dieser Studie waren: (i) Es gab Unterschiede zwischen den Standorten, sowohl bei der Betriebsleitung und Betriebsstruktur als auch im Anbausystem. Mit Hilfe einer Blockanalyse konnten sieben homogene Gruppen gebildet werden; (ii) die Cashewnuss-Produktion im Nordosten Brasiliens schwankt entsprechend den klimatischen, geographischen und landwirtschaftlichen Bedingungen; (iii) der herkömmliche Cashewbaum weist höhere und stabilere Werte des Blattfalls auf; (iv) der schwachwachsende Cashewbaum produziert mehr Biomasse und zusätzlich konnte eine höhere Produktion von Cashewnüssen beobachtet werden; (v) die Energiebilanz der Anbausysteme ist eine geeignete Maßnahme zur Qualifizierung und Quantifizierung der ökologischen und ökonomischen Auswirkungen der landwirtschaftlichen Systeme. Dieser Vergleich wird sogar noch deutlicher wenn die "Transformity" als ein allgemeiner Maßstab verwendet wird und; (vi) das Modell "Familienbetrieb" hat die besten Ergebnisse im Bereich Umwelt und Nachhaltigkeit. Die höhere Cashewnuss-Produktion des Modells "Bewässerung" konnte nur auf Kosten von höherem ELR (Emergy Lasts-Verhaltnis) und EER (Emergy Austausch-Verhältnis) erreicht werden.

Análise Ambiental da Sustentabilidade da Cajucultura no Nordeste do Brasil

O presente estudo procura fornecer uma análise detalhada sobre a situação da cajucultura no Nordeste do Brasil, onde milhares de pequenos produtores dependem e sobrevivem desse cultivo. Pequenos sistemas agrícolas são grupos econômico-sociais importantes dentro das áreas rurais na região nordestina. Após a introdução do cajueiro tipo anão-precoce, o aumento significativo na produtividade dos pomares trouxe grandes expectativas em torno de um elevado desenvolvimento rural e regional, traduzido em um aumento na renda dos produtores.

O estudo fornece uma investigação da cajucultura nos estados do Ceará e Piauí, principais responsáveis pela produção de castanha de caju no Brasil. O principal objetivo da pesquisa foi avaliar os sistemas agrícolas do caju nos estados do Ceará e Piauí, identificando os principais fatores que influenciam o comportamento dos sistemas de cultivo. Especificamente, os esforços de pesquisa focaram (i) características gerais dos produtores de caju e seus sistemas agrícolas, principalmente os fatores que afetam a produtividade da castanha de caju e classificação de diferentes tipos de sistemas do caju em ambos os estados, (ii) medir a produção de serrapilheira e mensurar a produção de biomassa dos cajueiros tipo comum e anão-precoce e (iii) contabilizar as entradas e saídas dos fatores (recursos da natureza e da economia) que contribuem para o funcionamento do sistema. Como fonte de dados, 254 produtores de caju foram entrevistados e um experimento foi conduzido para coleta de serrapilheira durante um período de 24 meses na EMBRAPA-Pacajus, Ceará.

Os principais resultados encontrados neste estudo foram: (i) diferentes características foram encontradas entre os produtores de caju nos estados do Ceará e Piauí e uma análise de cluster classificou os produtores entrevistados em sete grupos homogêneos analisados neste estudo; (ii) a produção de castanha de caju varia significativamente sob as condições climáticas, geográficas e agronômicas; (iii) o cajueiro tipo comum produziu maior quantidade de serrapilheira. Adicionalmente, mostrou maior estabilidade na produção dinâmica durante o período observado; (iv) o cajueiro tipo anão-precoce obteve maior produção de biomassa e maior acúmulo de energia em partes vegetais. Além disso, maior produção de frutos foi observada com o tipo anão-precoce; (v) a avaliação energética de entradas e saídas de sistemas agrícolas mostrou-se uma ferramenta viável para qualificar e quantificar contribuições ambiental e econômica dentro de ecossistemas. No entanto, a análise mostra mais autenticidade quando a tranformidade solar é utilizada como uma base comum e; (vi) o sistema agrícola da pequena propriedade rural (homestead) obteve a melhor performance ambiental e mostrou-se mais sustentável comparado com os outros tipos de sistemas. A alta produtividade de castanha do modelo irrigado foi tão somente alcançado baseado em altos valores do ELR (Índice de carga ambiental) e EER (Taxa de intercâmbio emergético).

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%	Percent
%Renew	Percent Renewability
ACC	Amendoa da Castanha do Caju
Apr	April
Apud	Cited in
Aug	August
BTU	British Thermal Unit
C	Celsius
CCP	Precocious Clone of Cashew
CEAT	Centro de Estudos e Apoio ao Trabalhador e a Trabalhadora
Cm	Centimetre
CNSL	Cashew Nut Shell Liquid
CW	Centre-West
Dec	December
E	East
E.g.	Exempli gratia (for example)
EER	Emergy Exchange Ratio
EIR	Emergy Investment Ratio
ELR	Emergy Load Ratio
EMATER	Enterprise of Technical Assistance and Rural Extension
EMBRAPA	Brazilian Enterprise for Agricultural Research
EPACE	Enterprise of Agricultural Research in Ceará
Et al.	Et alii (and others)
EYR	Emergy Yield Ratio
F	Fahrenheit
FAEC	Agricultural Federation of the State of Ceará
FAO	Food and Agriculture Organization
Feb	February
G	Gram
GDP	Gross Domestic Product
H	Hour
Ha	Hectare

IBGE	Brazilian Institute of Geography and Statistics
INRES	Institut of Crop Science and Resource Conservation
IPEA	Institute of Applied Economic Research
IPECE	Institute for Research and Economic Strategy of Ceará
J	Joule
Jan	January
Kg	Kilogram
Km	Kilometre
Km^2	Square kilometre
M	Metre
Mar	March
M^2	Square metre
M^3	Cubic metre
Mg	Milligram
Mio	Million
Mm	Millimetre
N	North
NE	North-east
Nov	November
Oct	October
PADETEC	Enterprise of Technological Development
PROCAJU	Programme for the Development of Cashew System
PRONAF	National Programme of Empowerment of Familiar Agriculture
R$	Real (Brazilian currency)
S	South
SE	Southeast
Sept	September
Sej	Solar emergy joule
SI	Sustainability Index
SMA	Secretariat of Environment
SPSS	Statistical Package for the Social Sciences
STATA	Statistical software package
Tr	Transformity
UFC	Federal University of Ceará

US$	American Dollar
V_{bio}	Bio-volume
V_{eco}	Eco-volume
W	West
χ^2	Chi square
Y	Year

ACKNOWLEDGMENTS

I thank the following people and organizations that provided various types of assistance towards the completion of this study:

Prof. Dr. Marc Janssens, my first supervisor, for his patience, overall unfaltering guidance during the entire dissertation period and thoughtful suggestions and comments on the thesis. The overwhelming encouragement and support I received from him is gratefully acknowledged.

Prof. Dr. Jürgen Pohlan, my second supervisor, for his invaluable suggestions and significant comments throughout this dissertation despite his multiple occupations.

Prof. Dieter Wittmann, my third supervisor, for his generous acceptance.

Prof. Dr. Hartmut Gaese, Prof. Dr. Sabine Schlüter, Dr. Lucas Antônio de Sousa Leite and Prof. Dr. José Osvaldo Beserra Carioca for the technical support and for co-operation.

The German Academic Exchange Service, DAAD (Deustche Akademische Austaushdienst), for providing me with the needed financial support.

The EMBRAPA from Fortaleza/Pacajus and EMATER from Ceará and Piuaí for their assistance and welcoming and friendly atmosphere during the field work period and for providing logistical support.

M. Sc. Aama El Naas, Dr. Andrea Dörr, Dr. Dina Raafat, Dr. Fábio Waltemberg, Fernanda Cruz, Dr. Juan Carlos Torrico, Dr. Maurício Hunsche, Dr. Hussein Koschar and M. Eng. Silke Meilwes for helping me to survive the difficult times and for sharing enjoyable moments.

The cashew farmers for supported me to conduct the field research and advice me in designing the questionnaire.

The friendly staff and students of the Institute of Horticulture of the University of Bonn and of the Research Station of Marhof.

Marcelo Callado, my husband, for his continued encouragement, constant love and emotional support, which I enjoyed through all these years. My family, for the encouragement and support. My heartiest thanks.

The time I spent in the Ph. D. course has been the best time in my life and very fruitful in terms of knowledge and skills I acquired; the invaluable collaboration with all aforementioned people, as well as with those not listed, but nevertheless in my thoughts and heart.

1 INTRODUCTION

In the early 1970s, the majority of global cashew nut production (68%) took place in Africa, including countries such as Tanzania and Mozambique (Azam-Ali and Judge, 2001). In 2006, the world production amounted to 3,218,349 ton from a total harvested area of 3,867,385 ha. In this year, the five main cashew-producing countries were: Vietnam, Nigeria, India, Brazil and Indonesia, totalling 79% of total world prodution and covering up to 73% of the harvest area (FAO, 2008). Since the last five years, Vietnam and Nigeria have been offering a tough competition to traditional cashew producers like India and Brazil. The cashew industry ranks third in the world production of edible nuts. In 2000, the world production was about 2 million ton of cashew nuts in shell with an estimated value in excess of US$ 2 billion. India and Brazil are the major cashew exporters, with 60% and 31%, respectively, of the world market share (ITC, 2002; FAO, 2007).

In India, cashew ranks second among farms exports. India started to export cashew nut in the early 20th Century with a small quantity, which has increased along the years (ITC, 2002). In 2005, India produced more than 400,000 tons, i.e. twice the amount produced by Brazil. The major world importers of cashew kernels are the United States, the Netherlands, Germany, Japan and the United Kingdom. The cashew kernels are ranked, as either the second or the third most expensive nut traded in the United States covering a great variety of uses. Retail prices range from about US$9 to US$23 per kg depending on the quality of the nut (Azam-Ali and Judge, 2001). The traditional and extensive market connections of exporters from Brazil and India make it difficult for smaller exporters to make gains in the United States market (The Clipper, 1994). Importers may appreciate the low prices offered by small suppliers, but the lack of reliability in quality tends to make them favour the larger, more reputable suppliers. In 2005, India and Brazil were the major exporters of cashew nut in the world reaching 548 million tons. The worldwide cashew processing is very competitive and generally exploited by small-scale processors. In Brazil, cashew is a very attractive crop for small-scale producers because it requires few inputs and harvesting does not coincide with the peak labour demand for other food crops as beans and cassava, which are largely consumed domestically.

The economic value of cashew cultivation in Brazil was recognized during the Second World War, when there was a considerable demand for cashew nut shell liquid in North America. Owing to this, the expansion of the areas cultivating cashew began in the 1960s through governmental incentives. This increase in production allowed Brazil to set foot in the international market (Azam-Ali and Judge, 2001; Moreira, 2002). Cashew is predominantly a smallholder crop in Brazil with about 90% of cashew trees are grown by small-scale farmers (Azam-Ali and Judge, 2001). The smallholder units are important economic-social groups within rural areas of North-east Brazil, supplying the domestic market with cash crops such as cashew. However, its production generally spans during just four or five months per year (Sietz *et al.*, 2006). Small producers constitute 70% of the cultivated area, possesing orchards of 10 ha on average (Meilwes, 2006). Cashew production is more significant in areas near to coastal regions, where cashew trees are under optimum climate conditions. In 2006, about 11% (or 710,404 ha) of cultivated area of permanent crops in Brazil was occupied by cashew crops. In Brazil, the cultivated area with cashew trees is restricted to the North, North-east and Centre-west regions (IBGE, 2007a).

The North-east is the most important region for cashew cultivation. The cashew tree has a great importance in the economy of North-east, mainly for maintaining the employment level and income of rural producers, as well as for providing a source of external resources to Brazil. According to EMBRAPA (2002), just the production chain of cashew tree in the State of Ceará involves about 300 thousand people. In 2003, alone the cashew tree production chain, covering 372,000 ha, produced 110,000 tons of cashew nut in shell and 32,000 tons of cashew kernels, with an export volume of US$ 110 million, including US$ 2.27 million for cashew nut shell liquid (known as CNSL) (FAEC, 2004). However, the cashew production chain in North-east is considered insufficient and the production segment, presently with low productivity, could compromise the whole business not just regionally but also nation-wide. This prevents the country from competing on the international agribusiness market (Almeida and Soares, 1995).

Currently, 90% of the total cultivated area of cashew trees is characterized by the presence of the common type, considered by most experts as the main reason for low productivity in the sector (Almeida and Soares, 1995; Andrade, 2004). Among several suggestions to increase the productivity of the orchards, the substitution of the common cashew tree type for the dwarf-precocious cashew tree is advocated. The dwarf-precocious cashew tree has a productivity rate of 1,300 kg/ha of cashew nut and could eventually reach 4,000 kg/ha under irrigation, compared to 220 kg/ha for the common type of cashew tree (Barros and Crisóstomo, 1995). Therefore, possible increase in production could stabilize the national market, whilst simultaneously raising the quality of cashew products. The low productivity of the cashew systems in the North-east is an enormous problem, resulting low profitability for the producers, mainly smallholders (Leite, 1994). The irregular production can discourage agro-industry and consequently induce a demand change by final consumers (Lima, 1988; Klemenz, 2004). Furthermore, the agricultural producers might find themselves unwilling to continue working in this segment, and would start shifting to other crops, which in turn could eventually phase out cashew production in North-east Brazil. This possible trend should not be considered as an isolated factor in the rural sector.

Due to the downward spiral of cashew production, the Brazilian government established the PROCAJU project in 2000 in an attempt to stimulate and strengthen the cashew segment in the north-eastern region. The PROCAJU project involves six out of the nine north-eastern states, namely Bahia, Ceará, Maranhão, Pernambuco, Piauí and Rio Grande do Norte. In Ceará, the PROCAJU project involves 45 municipalities (Andrade, 2004). Besides the federal government, other Brazilian and foreign institutions, such as German research institutions, showed great interest in studying the problems concerning the cashew sector in the North-east region. Brazilian institutions included the Federal University of Ceará (UFC) and the Brazilian Enterprise for Agricultural Research (EMBRAPA). Whereas the German partners are the Unit of Tropical Agriculture of the Institut of Crop Science and Resource Conservation (INRES) of the University of Bonn and the Institute for Technology in the Tropics – ITT (University of Applied Sciences of Cologne).

This international partnership resulted in a common research project entitled: Potential analyses and development for an integrated utilization of cashew raw material in Ceará, Brazil. Therefore, the present study is a result of this bilateral cooperation project between Germany and Brazil. However, the main objective of the research was to assessment the cashew farming systems in the states of Ceará and Piauí, identifying main components that take part into the ecosystems. In order to accomplish this objective, it was important to:

i. To describe general information about the cashew farmers and their systems (e.g. social composition, gender, production systems and agricultural practices); to identify the factors that affect the cashew nut productivity and; to characterize different types of cashew systems in both states.

ii. To evaluate the litter fall and biomass partitioning between the common and the dwarf-precocious cashew types. In additional, to describe structure and parameters between the two types of cashew trees.

iii. To relate inputs and outputs in the cashew systems using a common yardstick as well as the efficiency of the use of natural and economic resources in the systems.

2 LITERATURE REVIEW

Agriculture has the important role of providing food for the rural and urban populations of any country. Agricultural needs are to increase annually, in order to keep up with the increasing world population. The most difficult challenges for agriculture are just beginning in spite of past improvements in food production (Pretty, 1995). In developing countries, food productivity has increased in the last decades, stirring various discussions about the process of the sustainable development in the world. The term of sustainability was earlier used in the context of productivity either as a descriptive feature of ecosystems (Becker, 1997). This author affirms also that the concept of sustainability is based on three aspects: ecological, social and economic. Sustainability is the ability of a system to maintain productivity in spite of a major disturbance (intensive stress) (Conway, 1983). In other words, this concept has a direct relationship with an agricultural potential of each country or region of the world.

2.1 Agro-ecological zones of Brazil

Brazil is a country in South America with a territory of roughly 8,514,876 km^2, of which 64% is considered potential farmland (FAO, 2004). The national territory extends from north to south over around 4,390 km (5°16'20" N to 33°44'32" S latitude) and from east to west over around 4,310 km (34°47'30" E to 73°59'32" W longitude) (IBGE, 2007b). Bounded by the Atlantic Ocean on the east, Brazil has a coastline of over 10,900 km in length. On the west side, in clockwise order from the south, the country has 15,719 km of borders with Uruguay, Argentina, Paraguay, Bolivia, Peru, Colombia, Venezuela, Guyana, Suriname and French Guyana (IPECE, 2006). Despite its vast territory, the population of Brazil is concentrated in the major cities of its coast. The population of Brazil amounts to 50 million families (or 180 million inhabitants) and 81% is concentrated in urban areas (IBGE, 2007b). Brazil has twenty-six states and one federal district, divided conventionally into five regions: North, South, North-east, South-east and, Centre-West.

According to IBGE (2007b) there are 5,564 municipalities in Brazil, which have municipal governments. Many municipalities are divided into districts, which do not have political or administrative autonomy. Each of the five major regions has a distinct ecosystem. The regional administrative boundaries do not necessarily coincide with ecological boundaries. The differences in physical environment, patterns of economic activity and population settlement vary widely among the regions. Brazil lies on the Equator and the Tropic of Capricorn. Each

Brazilian region has a typical fauna and flora for example the Amazon rain forest which is home to a vast array of natural species, flora and fauna and extensive natural resources (Appendix 1).

Soils and Vegetation. Brazil is characterized by a large diversity of soil types resulting from the interaction of climate, vegetation and associated material (Caldeiron, 1992). In Brazil, the diversity and potential uses are reflected particularly in each region of the country.

The North region covers around 45% of the surface of Brazil that comprises plains and low plateaus. The soils are deep, highly-weathered, acidic and of low natural fertility (EMBRAPA, 1999; IBGE, 1989). The soils are commonly saturated with exchangeable aluminium that is toxic for most plants species which considerably reduces the productive potential of the land (FAO, 2004). Except for the state of Tocantis, where the savannah (cerrado) plays a major role, the Amazon rain forest covers the North region. Hundreds of plant species with an economic or social value in the Amazon biome, including fruit-bearing, oil and medicinal plants were estimated (Vieira, 1999).

In the North-east, most soils possess medium to high natural fertility, but a large proportion is shallow due to a low degree of weathering. They are sometimes associated with salinity and high levels of sodium, which is the main factor limiting of productivity in the north-eastern region (Caldeiron, 1992). This region is mainly characterized by the biome of “caatinga” that extends over areas of north-eastern states (Andrade-Lima, 1981). The “caatinga” is characterized by xerophytic vegetation typical of a semi-arid climate. Various fruit species and medicinal plants have their centre of genetic diversity in the North-east and the use of local medicines is therefore common (Coimbra-Filho and Camara, 1996; Vieira, 1999). Several family species belong to the “caatinga”, e.g. Euphorbiaceae (*Sapium lanceolatum* Huber), Anacardiaceae (*Schinopsis brasiliensis* Engl.), Leguminosae (*Senna spectabilis* - DC.), Boraginaceae (*Cordia trichotoma* - Vell.) among others (Maia, 2004).

The Brazilian Central Plateau, which is a plain formed by natural erosive processes is located in the Centre-West region. Extensive areas in this region are composed of deep and well-drained soils with low fertility but easily corrected by liming and fertilization (IBGE, 1988). Most soils in this region possess favourable physical characteristics and topographical conditions which significantly contribute agriculture. The centre-western region has a low demographic density when compared to other regions. This could also be because the “Pantanal” as well as a small part of the Amazon rain forest in the north-west cover a part of its territory. The region is also covered by the "Cerrado", which is the largest savannah in the world (Kaimowitz and Smith, 1999; IBGE, 1988).

The South-east region is characterized by plateaus and highland areas and its soils are predominantly deep and usually of low natural fertility. The soil in this region is generally composed of latosols (56%) and argilosols (20%) (EMBRAPA, 1999). Its vegetation is characterized by the appearance of tropical semiciduous forests. In the North of this region there is a semi-arid area with almost no vegetation. In the West and in the North-east there is the characteristic "cerrado" (similar to savannah) (IBGE, 1990).

In the South, the soils originated both from basic rocks and sediments viz.; latosols (25%), neosols (23%) and argilosols (14%) (EMBRAPA, 1999). The vegetation of the southern region consists of rain forest along the coast, called "Mata Atlântica", with tropical semiciduous species in the North and in the West. There are also needle-leaved pine woods that cover the highlands and grasslands similar to the Argentine pampas covering the sea level plains (Caldeiron, 1992).

Climate, temperature and rainfall. More than 90% of Brazilian territory lies within the tropical zone, between the Equator and the Tropic of Capricorn. However, the climate in Brazil varies considerably from the mostly tropical North, where the Equator traverses the northern region, to temperate zones below the Tropic of Capricorn, which crosses the country at the latitude of the state of São Paulo, located in the south-eastern region (Appendix 2).

Brazil has five climatic regions: humid equatorial, tropical, tropical of altitude, tropical Atlantic and semi-arid/subtropical (Rao and Hada, 1994). The most part of North region is dominated by a humid equatorial climate and is characterized by average annual temperatures between 24°C and 26°C and annual thermal amplitude[1] of up to 3°C (Nimer, 1989). The northern region receives abundant and regular rainfall (more than 2,500 mm/y) and in the winter, the region can have cold fronts from the Antarctic polar mass (IBGE, 1989). The regions of Centre-west, North-east and South-east are dominated by a tropical climate, with hot and humid summers as well as cold and dry winters. In these areas, the temperature exceeds 20°C and the rainfall ranges from 1,000 mm/y to 1,500 mm/y (Nimer, 1979). The South region together with parts of south-eastern and of centre-western regions have a tropical altitude climate, with average temperatures between 18°C and 22°C and an annual thermal amplitude of 7°C - 9°C. The

[1] The thermal amplitude is the difference between the maximum and the minimum temperatures registered during one period.

average rainfall is similar to that observed with tropical climate (Algarve and Cavalcanti, 1994). The North-east and part of the southern region are influenced by the tropic Atlantic climate. The temperature varies between 18°C and 26°C and the amount of rainfall is about 1,500 mm/y (Kousky, 1980). The north-eastern region is also characterized by semi-arid climate, with an average temperature of 27°C and rainfall that does not exceed 800 mm/y. The subtropical climate prevails in the regions of South-east, Southern and Centre-west and is characterized by average temperatures below 18°C with rainfall amounting to 1,500 mm/y to 2,000 mm/y (Kousky, 1979; Cavalcanti, 1982).

2.2 Agricultural structure in Brazil

During the colonial period in Brazil (1500-1822), the national production was intimately linked with agricultural activities, mainly sugar cane planted along the coast using forced labour (manual slave labour), which used to be commonplace in agriculture. The first Portuguese colonialists adopted an economy based on the production of agricultural goods. Tobacco, cotton and some other agricultural products were produced but sugar cane was the main product at that time, also known in Brazilian history as the Sugar cane Cycle (16-18th Century) (Prado Júnior, 1974; Girão, 1964). Coffee was another important crop for Brazilian agriculture. It was introduced in Brazil in the early 18th Century, but was planted initially only to supply to the domestic market. Its production was concentrated in the mountain region (Mata Atlântica) near Rio de Janeiro. From the area close to Rio de Janeiro, coffee production moved along the Paraíba Valley toward the state of São Paulo which later became Brazil's largest export region in the 19th century (Prado Júnior, 1974).

Another important crop in the history of Brazilian economy was rubber, especially during the periods between 1879-1912 and 1942-1945 (during the Second War), known at the time as Rubber Boom and Second Rubber Boom, respectively. The cultivation of Rubber was concentrated in the North Region in the cities of Manaus, Porto Velho and Belém (Weinstein, 1983). Brazil has experienced in the last decades the greatest changes in the occupation of its agrarian space since the colonial period (IBGE, 2007b). In this periodo many agricultural products have been cultivated. Actually, the agriculture in Brazil is highly diversified and its impressive performance has placed the country among the world's competitive exporters of agro-industrial products (Jales *et al.*, 2006). From 1949 to 1955, the primary sector of the Brazilian economic activity contributed about a quarter of the national Gross Domestic Product (GDP). However, the Brazilian macroeconomic situation shows that the share of the primary sector declined from 21.36% in 1947 to 5.52% in 2005. This reduction in the agricultural sector is probably due to the fact that some areas of the agricultural sector are characterized by primitive and labour intensive production systems. However, other domains are producing intensively, with modern tools and dynamic processes. Nowadays, Brazil is considered one of the world's largest exporters of agricultural products.

Brazil has an immense variety of agricultural resources. Due to this, each region has specialized in producing some agricultural goods and the national agriculture model has resulted in the concentration of production to a few crops. Consequently, this process of concentration goes throughout the geographical distribution of the production, where some Brazilian states reached a remarkable agricultural situation. Table 1 lists the ten main products of permanent crops, four of them coming from the north-eastern region, particularly from Bahia state, namely cocoa, banana, coconut and sisal. Among these ten products, three (coffee beans, cocoa beans and cashew nuts) are considered the most important export commodities of Brazil. The south-eastern region has largest harvest area for coffee beans, orange and rubber. From the North and South regions, the largest proportion of cultivated area is dedicated to growing oil palms and mate tea, respectively.

Table 1. The main products of permanent crops in Brazil: 2006

Products	Area harvested (ha)	Total production (ton)	Major producer Region/State	Regional participation in the national production (%)
Coffee beans	2,312,154	2,573,368	SE/Minas Gerais	84
Orange	805,903	18,032,313	SE/São Paulo	83
Cashew nut	710,181	243,770	NE/Ceará	99
Cocoa beans	647,135	212,270	NE/Bahia	70
Banana	504,586	6,956,179	NE/Bahia	39
Coconut[1]	289,815	1,985,478	NE/Bahia	67
Sisal	279,584	248,111	NE/Bahia	100
Rubber	106,897	175,723	SE/São Paulo	62
Oil palm	96,509	1,207,276	N/Pará	85
Mate tea (leaves)	78,633	434,483	S/Rio Grande do Sul	99

Source: IBGE (2007a).

[1]Production expressed in number of fruits.

Table 2 enumerates the main temporary products in order of harvest area importance in Brazil. According to IBGE (2007b), 34.7% of the soya bean produced in the country in 2005 comes alone from the state of Mato Grosso, centre-western region (FAO, 2004). Besides soya beans, the Centre-west sets apart more than half cultivated areas of cotton and sorghum production. In spite of limited land available for agricultural expansion in the South, the southern region includes an extensive area for the production of temporary crops, such as corn, beans, rice, wheat and tobacco. Regarding temporary crops, the state of São Paulo (south-eastern region) evolved from a traditional citrus (Bolling and Suarez, 2001) into a leading producer of sugar cane, which is actually a major strategic crop for the country as a source of energy. The north-eastern region is again represented by the state of Bahia with a predominant production of the cassava crop, contributing more than one third of the national production.

Table 2. The main products of temporary crops in Brazil: 2006

Products	**Area harvested (ha)**	**Total production (ton)**	**Major producer** **Region/State**	**Regional participation in the national production (%)**
Soya bean (grain)	222,047,349	52,464,640	CW/Mato Grosso	49
Corn (grain)	12,613,094	42,661,677	S/Paraná	44
Sugar cane	6,144,286	457,245,516	SE/São Paulo	68
Bean (grain)	4,034,383	3,457,744	S/Paraná	32
Rice (in the husk)	2,970,918	11,526,685	S/Rio Grande do Sul	70
Cassava	1,896,509	26,639,013	NE/Bahia	36
Wheat (grain)	1,560,175	2,484,848	S/Paraná	89
Cotton[1]	898,008	2,898,721	CW/Mato Grosso	60
Sorghum (grain)	722,200	1,604,920	CW/Goiás	61
Tobacco (leaves)	495,706	900,381	S/Rio Grande do Sul	97

Source: IBGE (2007a).
[1]herbaceous type.

The meat market is another important activity in Brazil. In 2006, Brazil was the second country in the world in terms of number of cattle following China (FAO, 2008). This market has been supplied mainly with soya beans and corn, the main raw materials for animal feed. Besides the self-sufficient production of animal feed, Brazil has also a qualified and competitive workforce that is an indispensable resource for this economic activity (IBGE, 2008a).

2.3 North-east Brazil

North-east Brazil extends over an area of 1,554,257 km², with a total resident population of 51,507,545 inhabitants (IBGE, 2007c). The region has a coastal line of 3,306 km; latitude of -01°02'30" N, -18°20'07" S, -07°09'28" E and, -05°20'56" W and longitude of -45°50'54" N, -39°39'48" S, -34°47'30" E and -48°45'24" W. The region borders on the Atlantic Ocean, to the North and East, on the South-east region to the South and on the North and Centre-West regions, to the West (IPECE, 2005). The North-east is comprised of nine states, Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe and Bahia. This region, which covers 18.2% of the national territory, is the third largest of the five macro-regions of Brazil and it can be compared to the state of Amazonas with an area of 1,570,947 km^2 (IPECE, 2005). Most of the North-eastern state capitals are located on the Atlantic coast, where the population density is considered high, although the North-east is home to the bulk of the rural population of the country.

North-east Brazil is known as the most densely populated semi-arid region on world-wide. The region is divided into three principal physiographical sub-regions (i) the Atlantic forest zone or "zona da mata", which encompasses stretches along the coastline as far north as Rio Grande do Norte (ii) the "sertão" with an area of mixed farming and (iii) the semi-arid (cerrado) zone that is periodically affected by drought (Oakley, 1980). The North-east region is ecologically diverse but predominantly semi-arid.

Climate. The North-east is the driest region and is the hottest part of the country with a semi-arid climate. It has temperatures with an annual average between 20°C and 28°C. Occasionally, a maximum of around 40°C has been observed in the south of Maranhão and Piauí (Strahler and Strahler, 2005). During winter, mainly in June and July, minimum temperatures between 12°C and 16°C in the coastal regions (MCKnight and Hess, 2000). The rainfall regime is characterized by great inter-annual variability, increasing from less than 1,000 mm/y in the lowlands to 1,900 mm/y in the higher areas. Different rainfall regimes are identified in the North-east, with a rainy season from March to May (in the north), December to February (in the south/south-east) and May to July (in the east) (IPECE, 2005; MCKnight and Hess, 2000; Conti, 1995).

Soils. The soils supporting the main productive agricultural systems in the North-east are predominantly Latosols and Neosols, which constitute more than 58% of the North-eastern region. The argisols is found in 17% of the North-east, mainly in the foothills in the "Cerrado" region and this one can be used with perennial crops and pastures. In general, the Latosols, Neosols and Argisols are deep and well-drained, presenting some limitations for agricultural activity, such as: low natural fertility, high acidity and low water retention capacity due their porosity (EMBRAPA, 1999; Coelho *et al.*, 2002).

Natural vegetation. (i) The "caatinga" is a type of vegetation and a bioregion characteristic of the North-eastern part of Brazil which does not correspond to a single type of vegetation, but is a broad mosaic of different types. The highest areas (known as "agreste") located closer to the coast are less subject to intense droughts (Romariz, 1974; Maia, 2004). The vegetation of "caatinga" is composed mainly of palm stands: "carnaúba" stands (*Copernicia cerifera* Mart.), "babaçú" stands (*Orbignya phalerata* Mart.), "tucúm" stands (*Astrocaryum vulgare* Mart.) and "macaúba" stands (*Acrocomia aculeata*), from which lauric and oleic oils are extracted (Eiten, 1983); (ii) the "cerrado" has a plant community structure similar to the African savannah. It is seen in various states in Brazil, particularly in some North-eastern ones: Bahia, Maranhão, Piauí and Ceará. Some are evergreen while others are deciduous for variable periods of the dry season (Caldeiron, 1992). A large number of plant families are represented, including Gramineae, Compositae, Leguminosae, Myrtaceae and Rubiaceae (Ratter *et al.*, 1997) and; (iii) the forest zone or "zona da mata" is located along the Atlantic coast of North-east Brazil and extends to the states of Pernambuco, Paraíba and Sergipe. The forest zone is known as the Atlantic forest, which is a region of tropical and subtropical moist forest, tropical dry forest, savannah and mangrove forests (Coimbra-Filho and Câmara, 1996; Fundação SOS and INPE, 1993).

2.4 Farming systems in North-east Brazil

The farming systems in the North-east are strongly influenced by the immense climatic variability (IBGE, 2007b). Agricultural production is the most important economic activity in the rural areas of North-east Brazil (Herfort *et al.*, 2000). However, currently, the largest farm area is allocated for pasture with 21% (IBGE, 2007d). At the second position, the forest covers about 16% area and 14% are for perennial and annual crops (farming area).

According to FAO (2001), several factors have influenced agriculture in the North-east in the period of 1965 to 2000, including the loss of economic competitiveness of important crops like annual cotton (*G. herbaceum* L.), long periods of droughts, an exodus of rural people to urban areas or other regions and consequently, a high cost of rural labour. In spite of the loss of competitiveness, cotton production still plays an important role in the North-eastern region. Currently, the soya bean is one of the most important export crops in the region. This was introduced by large landholders from South Brazil to supply to the global market (Andrade, 1999). Today, the soya bean has the largest planted area in the state of Bahia and in the southern part of Maranhão. Crops like bean, manioc and maize (Table 3) are known as subsistence crops, having a relative importance for the North-east region. Bahia, Ceará and Maranhão are the largest producers of these crops in the region. In the case of sugar cane, about 37% of the north-eastern production is concentrated in the state of Pernambuco.

Table 3. The main products of temporary crops in North-east: 2006

Products	**Area harvested (ha)**	**Total production (ton)**	**Major producer**	**Participation in the total production of the region (%)**
			State	
Cotton[1]	302,758	885,996	Bahia	91
Rice (in the husk)	716,372	1,112,828	Maranhão	63
Sugar cane	1,120,547	63,182,425	Pernambuco	37
Fava bean	35,589	14,128	Paraíba	64
Bean (grain)	2,175,301	1,045,238	Bahia	34
Castor oil	138,497	83,280	Bahia	82
Cassava	883,529	9,614,526	Bahia	46
Maize	2,723,273	3,167,819	Bahia	35
Soja bean (grain)	1,487,915	3,467,918	Bahia	57
Sorghum (grain)	82,065	125,176	Bahia	56

Source: IBGE (2007a).
[1]herbaceous type.

Among permanent crops, nine of ten main products of permanent crops come from the state of Bahia. This state is also a leading producer of rubber, coffee beans, oil palm and sisal in North-east Brazil. Besides Bahia, crops like coconut and banana are also found in Sergipe and Ceará. Cashew nut and cocoa beans (Table 4) have a massive economic importance for the internal market and are known in the world market as cash crops. The largest planted areas with cashew crop are found in the states of Ceará and Piauí, respectively, where about 70% of the national production is concentrated. The cocoa production of the North-east comes alone from Bahia.

Other crops, such as carnauba palm (*Copernicia prunifera*) and babaçu palm (*Orbignya phalerata*) are included in the land use systems in the North-east and have an enormous economic importance for the region (IBGE, 2003). Pastures are typically found in the Agreste landscape of the North-eastern region, encompassing the annual grass *Brachiaria plantaginea* and the perennial grass *Chloris orthonoton* Doell. Besides the production of traditional crops, extensive livestock enterprises located in the semi-arid region of the North-east dominate the agricultural economy.

Table 4. The main products of permanent crops in North-east: 2006

Products	Area harvested (ha)	Total production (ton)	Major producer State	Participation in the total production of the region (%)
Banana	207,090	2,706,207	Bahia	44
Rubber	29,352	27,756	Bahia	92
Cocoa beans	539,946	148,703	Bahia	100
Coffee beans	153,449	156,106	Bahia	96
Cashew nut	706,195	241,518	Ceará	54
Coconut[1]	233,838	1,320,933	Bahia	48
Oil palm	44,783	176,089	Bahia	100
Orange	117,589	1,746,829	Bahia	52
Mango	51,339	953,217	Bahia	66
Sisal	279,584	248,111	Bahia	95

Source: IBGE (2007a).

[1]Production expressed in number of fruits.

2.5 Cashew production in North-east Brazil

In Brazil, the North-east region is the main regional producer of cashew nut with 99% of the national production. Cashew is mainly produced in the coastal region of the states of Ceará and Rio Grande do Norte and in the central region of Southeast Piauí. The states of Ceará, Piauí and Rio Grande do Norte accounts for 91% of harvested area for cashew system in the North-east (IBGE, 2007a).

The cashew nut production is concentrated on small-scale farmers in mono- or mixed production systems, which possess orchards of 50 ha on average with some subsistence families among them. According to Sietz *et al.* (2006), cashew is predominantly a smallholder crop in the North-east. Table 5 shows that more than 40% in 1996 of the cashew nut harvested area is concentrated by small farms however about 43% of the cashew apple harvested area belonged to big farms (IBGE 2007e). The main products of the cashew systems are the cashew nut and the cashew apple but only cashew nut brings incomes for the farmers because its economic value is related to the dollar price. The cashew nut production is traditionally directed at the external market, generating an average of 150 million dollars of annual exchange value (Bueno Figueiredo *et al.*, 2007).

Table 5. Cashew production in the North-east: 1996

Farm Classification	Property size	Harvested area		Production		Productivity
Cashew nut	(ha)	(ha)	%	(ton)	%	(kg/ha)
Small	≤ 50	200,097	40.72	78,488	50,54	392.25
Medium	51 ≤ 500	156,573	31.87	43,956	28,30	280.74
Big	≥ 501	134,679	27.41	32,867	21,16	244.04
Total	-	491,349	-	155,311	-	-
Cashew apple	(ha)	(ha)	%	(thousand fruits)	%	(thousand fruits/ha)
Small	≤ 50	48,690	34.05	853,760	52.63	17.53
Medium	51 ≤ 500	31,839	22.26	458,948	28.30	14.41
Big	≥ 501	62,474	43.69	309,263	19.07	4.95
Total	-	143,003	-	1,621,971	-	-

Source: IBGE (2007e).

The cashew apple is basically destined for the national and local market. Its manufacturing industry consists of drinks, sweets, condiments, flours and animal feed among others. Other uses are classified as home-made productions and can be found in small establishments, co-operative societies and associations of rural producers. Nevertheless, the use of the peduncle does not reach 6% of the production (Cavalcanti, 1998). One of the causes for the low use is related to its rapid deterioration, causing excessive losses in the field and during processing. The utilization of mixed crops in cashew systems is very common in the North-east, mainly for the subsistence families. Among small and medium cashew producers, 73% grow bean as secondary crop, 40% maize and, 27% manioc (Cavalcanti, 2003). Besides the mixed crops, animal husbandry is another economic source of aggregated value for the cashew farmers. Besides of the cashew nut kernel and the cashew apple, the cashew nut shell liquid constitutes an important and valuable by-product of the cashew nut as it is rich in phenol, one of the main input substances used in industries of plastic, varnish, insulating material, paint and automobile (Melo, 1998).

The cashew nut production varies from year to year and over the last seventeen years, it experienced a gradual increase. However, output decreased significantly due to drought in the years 1993 and 1998, by 110 kg/ha and 90 kg/ha, respectively (IBGE 2007a). Low productivity in most cashew orchards is attributed to the occurrence of a common type of cashew trees and to factors such as poor crop husbandry, pests and diseases and low producer prices. In addition, farmers are discouraged by interruptions of incentives and financial aid, linked to low internal prices and stagnation in export demands.

2.6 Cashew cropping

Cashew (Anacardium occidentale L.) is a dicotyledonous evergreen tree crop belonging to the Anacardiaceae family of plants, that includes the mango (Mangifera indica), the pistachio (Pistachia vera L.) and the poison ivy (Toxicodendron radicans) (Aguiar *et al.*, 2000; Oliveira, 2003; Deckers *et al.*, 2001). The family Anacardiaceae comprises 60 genera and 400 species of tropical and sub-tropical trees and shrubs (Nair *et al.*, 1979). The cashew tree was disseminated by the Portuguese in the 16^{th} Century to other countries in Africa, Asia and Latin America (Moreira, 2002; Melo, 2002). The actual fruit is the cashew nut, to which a thickened stem is attached, the cashew apple, which is known in botanical terms as peduncle or pseudocarp. It is well known for its nuts that are consumed worldwide and are traded as an important commodity (Alvim and Kozlowski, 1977). The cashew tree is native to north-eastern Brazil and its English name derives from the Portuguese name for the fruit of the cashew tree that is known as "caju", which in turn derives from the Tupi Indian name, acaju (Rosengarten, 1984; Davis, 1999; Maia *et al.* 2000).

2.6.1 Phenology of cashew plant

The cashew plant is a tropical tree with a number of stout primary and secondary branches. The bark is thick, resinous, round and scaly (Johnson, 1973). The cashew wood is yellow in colour, moderately soft and light (Tavares, 1959). The plant is resistant to drought and generally prefers deep and sandy soils. It grows up to 12 meters high, with a dome-shaped crown or canopy bearing its foliage on the outside, where flowers and fruits are found. It has leathery oval leaves (Nair *et al.*, 1979). Table 6 shows the phases of the cashew tree phenology in north-eastern Brazil.

Table 6. The phenology of cashew tree in Brazil

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Fruit time							X	XX	XX	XX	XX	X
Flowering	X	X			X	X	XX	XX	XX	XX	XX	X
Leaf flow				X	X	X	X	XX	XX	XX	XX	XX
Leaf fall	X	X	X	XX	XX	XX	XX	X	X	X	X	X

Source: (Oliveira, 2004).

Note (1): X - Minor intensity.
XX - Major intensity.

Note (2): the cashew phenology changes according to the climatic factors of each region or state.

Cashew flowers. Normally, the cashew tree flowers in three to five years (Rao and Hassan, 1957). However, the age at which a cashew tree starts flowering depends on the growing conditions and genetic factors (Tolla, 2004). Copeland (1961) described the inflorescence of cashew as a terminal panicle-like cluster. The flowers are produced in a panicle or corymb up to 26 cm long. The cashew flower is red, small, pale green at first then turning reddish, with five slender and acute petals 7 to 15 mm long (Masawe *et al.*, 1996).

Cashew fruit (apple and nut). The cashew apple is red or yellowish in colour (Rao and Hassan 1957; Damodaran *et al.*, 1965). At the end of each cashew apple, there is a kidney-shaped ovary, the cashew nut (seed), having a double shell (Figure 1). The cashew nut has the edible kernel or nut inside the shell. The cashew kernel (in its raw form) is soft, white and edible and changes in colour and taste when roasted (Ohler, 1979). In the cashew nut, between the shell and the nut, there is black caustic oil, the CNSL, which has various industrial benefits as it can be used in varnishes and plastics (Azam-Ali and Judge, 2001). The cashew apple is about 5 cm wide and 8 to 10 cm long that when ripe, it is pear-shaped, shiny red or yellow, soft and juicy (Morton, 1987). The nut varies in size, shape and shelling properties (Rao and Hassan, 1956), being 3 to 5 cm long and 2 to 4 cm wide (Nair *et al.*, 1979).

Leaves. The leaves are spirally-arranged, leathery-textured, obovate rounded, thickly coriaceous and entire, often notched at the apex, with pinnately formed prominent veins. The petioles are short, 1-2 cm long and the leaves are commonly crowded at the end of the branches. The leaf size varies from 4 to 22 cm in length and from 2 to 15 cm in width (Johnson, 1973).

Root system. The root system of a mature cashew tree consists of a very prominent, well-developed tap root and an extensive wide-spread system of lateral and sinker roots that penetrate deeply into the soil profile (Ohler, 1979; Nair *et al.* 1979). Agnoloni and Giuliani (1977) observed that the simple, weak tap root in the first phase of growth of the young cashew tree takes a more complex structure of strong and extensive roots both sideways and downwards later on. The same authors noticed that the primary root soon ceases to grow and even retracts while at the same time, the side roots develop gradually and extensively, achieving a space double the size of the canopy by the time the tree is eighteen months old.

Canopy growth. In agreement with Tolla (2004), the rate of canopy growth of the cashew plant planting will determine how rapidly the tree enters into the economic production phase.

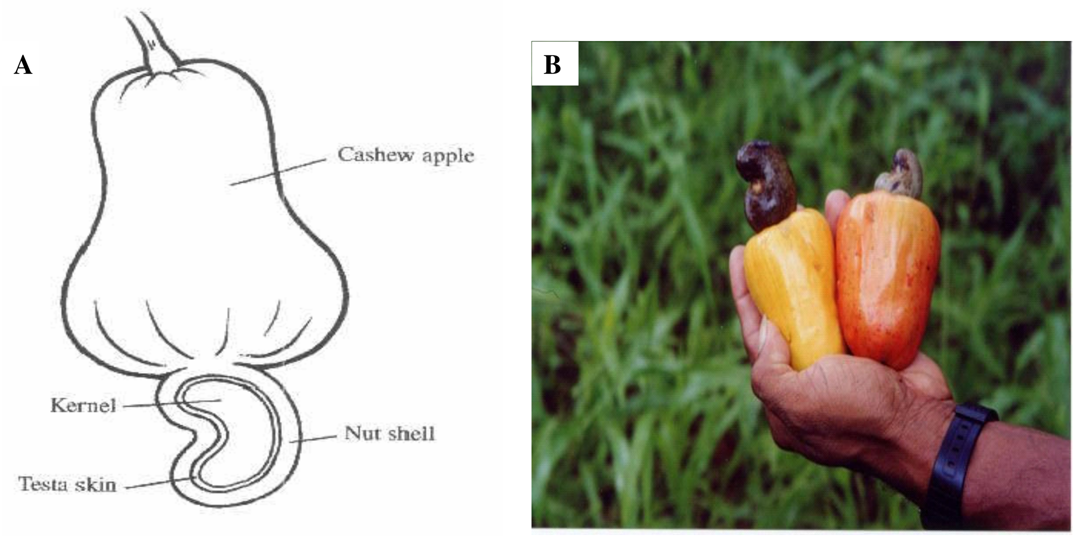


Figure 1. Cross section of a cashew fruit (A) and two different types of cashew fruit (B).
Source: Azam-Ali and Judge (A), (2001); this work (B).

2.6.2 Ecological adaptation

Climate. Nair *et al.* (1979) reached the conclusion that the main factor that can compromise the productivity of the cashew tree is a prolonged period of extreme cold or frost. The authors agreemented that: the tree is very sensitive to cold when young but becomes fairly hardy with age and can withstand light frost for short periods. The most suitable average annual rainfall for the cashew crop in Brazil lies between 800 mm and 1,600 mm within a period of five to seven months. Fruiting within the 800 mm – 1,000 mm/y range is believed to depend on droughts and might therefore be irregular (Fruitrop, 2001). The 1,000 mm/y isohyet is therefore set as limit for obtaining regular harvest. Moreover cashew crops require air humidity of 70% to 80% and an average temperature of 27°C (Oliveira, 2004).

Sunlight. The cashew tree is a sun-plant and does not grow well under condictions of excessive shade. Crisóstomo *et al.* (1992) observed during fiveyears that the production of some common cashew trees in the Research Station of EMBRAPA in Pacajus, Brazil was more favourable on the sunset side than on the sunrise side. This research has demonstrated that 30.9% of the cashew production was obtained on the west side and 29.3% on the north side, compared to 20.7% and 19.1% on the east and south sides, respectively.

Soils. The cashew tree should preferably be cultivated in deep soils, no less than 1.5 m (Oliveira, 2004). The appropriate texture of soil should be loam or sandy loam with a very slightly acidic to neutral pH (pH = 6.3 to 7.3). As the soil type varies considerably with depth, texture and other physical and chemical properties, it is difficult to classify soils/lands according to their suitability for cashew crop (Nair *et al.*, 1979).

2.6.3 Crop management

Appropriate management practices showed combine three important factors, namely optimum production potential, input efficiency, and environmental protection for a specific site in order to ensure a better sustainable basis (Tolla, 2004). Based on the study of Griffith (2001), all management practices must be considered and packaged in a cropping system.

Pruning. The practice of pruning is very important for fruit trees mainly aiming at obtaining higher yields. However, Ohler (1979) cautioned that this practice of removing the lowest branches must be limited during the first year of growth. Removing the lower branches at later stages is necessary and indispensable to get the desirable shape of the tree and to facilitate agricultural management. In addition, pruning can promote protection against diseased and infected branches (phytosanitary pruning).

Fertilizer application. In Brazil, the cashew crop has been seldom manured regularly. Indeed, cashew was not cultivated with intensive management until the new genetic potential of the dwarf-precocious type was introduced. However, cashew crop requires regular fertilizer application, particularly from fruit set onward (Nair *et al.*, 1979). In accordance with Parent and Albuquerque (1972), the combined application of potassium and phosphorus is indispensable in the first stages of cashew growth. Moreover, experiments have demonstrated that regular application of nitrogen, potassium and phosphorus is beneficial for obtaining healthy trees and increasing cashew yields (Azam-Ali and Judge, 2001).

Harvesting. Tolla (2004) reached the conclusion that the harvesting by the cashew crop involves collecting the nuts that have dropped to the ground after maturing. Nair *et al.* (1979) pointed out that this collection is normally done over a period of 10-12 weeks (during the months from November to February). If the cashew apple is not collected, it may be allowed to fall to the ground and subsequently, the adhering nuts can be collected during the first 4-6 weeks. However, the dropped nut should not remain longer than a week on the ground to get a good quality nut (Acland, 1971). Regarding the apple, Ohler (1979) recommended it should be harvested before it fell naturally.

Weeding. In North-east Brazil, the space between rows of cashew trees has been used for planting subsistence crops as for example cassava, beans and fruit crops. The weeding time depends on the age of the tree. In accordance to this, cashew management in North-eastern Brazil can be timed as follows (Table 7):

Table 7. General information about management practices of cashew crop in Ceará State

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Harvesting								X	X	X	X	X
Pruning	X											
Fertilizer application	X	X	X									

Source: Cardoso *et al.*, 2002 and fieldwork data.

2.7 Biomass related descriptors of farming systems

Biomass is defined as the total of live organic matter present in trees (including leaves, branches, twigs, main bole and bark) expressed as oven-dry tons per unit area (tree, hectar, region or country) (Keeling and Phillips, 2007; Brown, 1997). Commonly, the biomass density is expressed as mass per unit area, e.g. mg/ha.

> *The term has been widely used as a unit of yield since the 1970s as it is a more useful measure than volume as it allows comparisons to be made between different trees as well as among different tree components.*
>
> Kueh and Lim (1999), pp.1.

Biomass is an important attribute of vegetation for a variety of reasons and it is a very important yield factor of forest inventory data. The biomass survey overcomes many problems in ecological studies. Kueh and Lim (1999) found evidence that the use of biomass information in the ecosystems, will mainly: (i) provide quantitative and descriptive data of the ecosystems and indicate their available biomass resources, (ii) provide a measure of the nutrients cycle and its qualities, (iii) determine energy flux, (iv) provide estimates for carbon sequestration, (v) quantify increment in forest yield, growth or productivity and (vi) assess changes in forest structure.

Brazil is a significantly large producer of biomass world-wide (Bueno Figueiredo *et al.*, 2007). It is an advantage as an important energy source in the country. The study of biomass in Brazil is mainly focused on the reduction of carbon dioxide emission (Goldemberg, 2002; Macedo and Nogueira, 2005). Regarding the cashew biomass, the cashew nut shell is used for the production of energy (e.g. as fuel), which has been used by many cashew nut industries. In addition, biomass of crops is essential for land productivity prediction (Maraseni *et al.*, 2006).

2.8 Energy descriptors of farming systems

Energy is required for all processes of ecosystems and is essential for food production (Serrano *et al.*, 2003; Huang *et al.*, 2001). The measurement of energy dynamics is daily routine for applied sciences as physics and engineering whereas for ecological and economics sciences it is a rather unusual tool (Haden, 2003). Nevertheless, the energy analysis has been widely adopted in the last years by many ecologists, economists and other scientists in order to evaluate farming systems. Energy analysis can be divided into two different origins: thermodynamics and systems ecology (Hovelius, 1999). This author concluded that the energy analysis resolves questions regarding the size of energy flowing into the process only, without taking into account the quality of energy used or its origin in waste heat, for example.

> *Agro-ecosystems use environmental energies directly and indirectly from both renewable energy flows and from storages of materials and energies that resulted from past biosphere production.*
>
> Rodrigues *et al.* 2002, pp. 606.

> *Energy is a relevant parameter to study the sustainability of systems. It is also, essential to most human activities, including agriculture. Too much energy means wastage, global warming and other environmental pressures.*
>
> Serrano *et al.* (2003), pp. 1.

Many studies have been carried out on agricultural energy use (Pervanchon *et al.*, 2002). Therefore, energy analysis is merely a tool for the assessment of the environmental effect of human activities.

In agriculture, energy analysis can be used to assess the impact of human activity on the complexity and stability of environmental equilibria in terms of alteration of patterns of energy flows.

Giampietro *et al.* 1994, pp. 30.

By any means, energy analysis and the main laws of thermodynamic approaches to the analysis of agro-ecosystems, in general, provide a common basis between the energy flow and the input-output products allowing a mathematically sound analysis of energy flow in ecological and economic systems (Haden, 2003; Ukidwe and Bakshi, 2004).

2.9 Emergy analysis of farming systems

Emergy analysis is an environmental assessment tool that combines economic and ecological views based on the laws of thermodynamics. Emergy analysis was developed by H.T. Odum to study the ecosystems, but can also be applied to any system, including human societies. The emergy value of a product is referred to as the memory of energy that is dissipated during a transformation process (Odum, 1996; Brown and Ulgiati, 1999). In other words, emergy is the amount of available energy of one kind, which is required to produce something and which is used up in a transformation process. The unit of emergy is the emjoule (abbreviated sej). In this sense, several factors (i.e. rain, sunlight, fertilizer and irrigation) can be put on a common basis by expressing them in emjoule units based on solar energy that is required for each one as a reference yardstick (Odum, 1996; Odum, 2000).

The solar emergy of a flow or storage corresponds to the solar equivalent energy required to produce that flow or storage. After the energy content (J) of a flow has been acquired, it can be multiplied by its solar transformity (sej/J) to obtain its solar emergy (sej) (Huang *et al.*, 2001). The solar transformity is defined as the solar emergy required to make one joule of a service or product (Odum, 1996). Besides solar transformity, some indices widely used in emergy analysis are briefly reviewed below:

The Environmental Loading Ratio (ELR) is the ratio of purchased (F) and indigenous non-renewable emergy (N) to free environmental emergy (R). It is an indicator of the amount stress that a production process places on the local environmental.

Haden, 2002, pp. 8.

The Emergy Yield Ratio (EYR) is the emergy of an output divided by the emergy of those inputs to the process that are fed back from the economy.

Odum, 2000, pp.8.

Percent Renewable (%Renew) – the percent of the total energy driving a process that is derived from renewable sources.

Brown and Ulgiati 1999, pp.7.

Emergy investment ratio is the purchased EMERGY (F) feedback from the economy (services and other resources), divided by the free EMERGY inflow from the environment (I).

Odum 1996, pp.69.

Emergy exchange ratio divide the solar EMERGY flow of the yield product by the solar EMERGY of the money paid by the buyer.

Odum 1996, pp.84.

3 MATERIALS AND METHODS

3.1 Data collection

Between July and September 2006, a test questionnaire was conducted with 43 randomly-chosen cashew farmers in the State of Ceará, in order to adjust the relevance of the questions regarding economic, social and agricultural information. This exploratory information was not included in this research. Primary data and information used in this study were based on cashew farmers' characteristics. These data were collected using a fine-tuned questionnaire in the period between April and September 2007. The questionnaire survey (Appendix 3) was conducted in the municipalities of the states of Ceará and Piauí. Secondary data were collected through visits between July 2006 and September 2007 to the following institutions: IBGE, EMBRAPA, UFC and IPECE.

3.2 Study area

The state of Ceará. With the geographical coordinates 05°05'45" North-South and 04°09'51" East-West, the state of Ceará is surrounded in the north by the Atlantic Ocean, in the east by the states of Rio Grande do Norte and Paraíba and in the west by Piauí. Ceará has an area of 148,825 km^2 and comprises 184 municipalities. Fortaleza is the capital and the most important city in the state (IBGE, 2005; IPECE, 2006). The climate of Ceará is hot and humid on the coast, although tempered by the cool trade winds. In the semi-arid regions, the climate is hot and dry, with temperatures ranging between 22°C and 36°C. However, in the higher areas (Ibiapaba, Araripe and Apodi), the temperatures are lower, lying between from 14°C and 34°C (Ribot *et al.*, 1996; Nelson, 2005). The year is divided into a rainy season starting in January to March and lasting until June, as well as a dry season extending from July to December (IPECE, 2005; IPECE, 2006).

In general, the soil is thin and porous and does not retain moisture. Ceará has a variety of vegetations including mangroves, caatinga, jungle, shrub land and tropical rain forest. On the plateaus and mountains, the vegetation resembles the Atlantic rain forest, with mid-sized trees and permanent leaves (Maia, 2004). The semi-arid zone is called “sertão”, where the caatinga is dominant vegetation (Vieira, 1999; Brant, 2007). In the strip near the coast, there are numerous industrial cashew plantations in spite of the tough climate and soil conditions. Cashew crop is mostly concentrated on the coast, where most producers mainly depend on this crop for their income. The present study was carried out in nine municipalities (Figure 2 and Table 8).

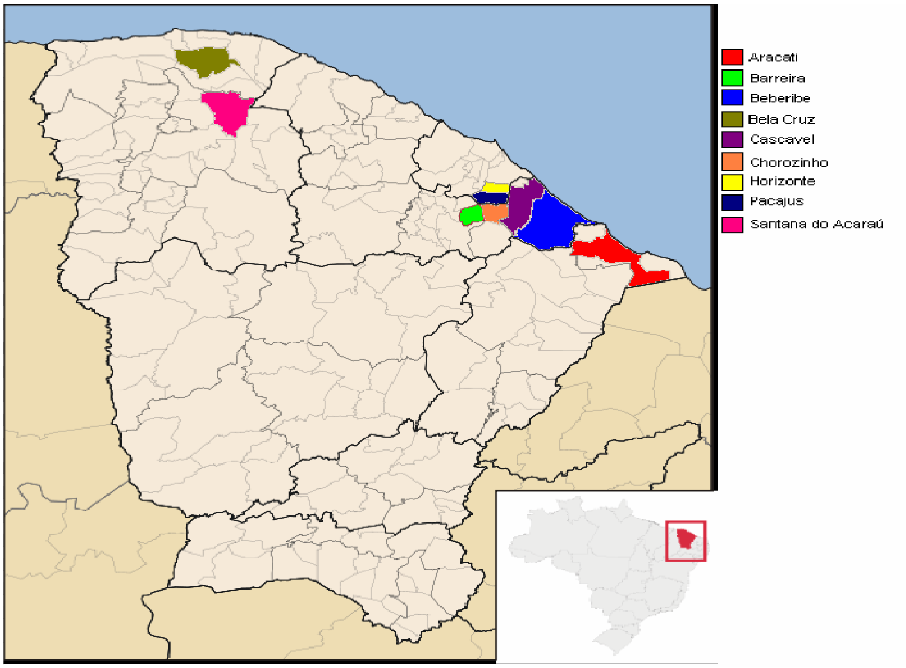


Figure 2. The studied municipalities in the state of Ceará.

Source: Adapted from Wikipedia (2007a).

Table 8. List of the studied municipalities in the state of Ceará and several informations

Municipality	Population in 2007[1]	Total area (km²)	Cashew nut in 2006[2] Planted area (ha)	Production (ton)	Productivity (kg/ha)	% of the cashew crop area
Aracati	66,049	1,229	16,020	3,845	240	13
Barreira	18,453	246	7,800	3,510	450	32
Beberibe	46,155	1,616	32,600	8,150	250	20
Bela Cruz	29,566	842	25,702	10,666	415	31
Cascavel	63,932	838	21,840	6,552	300	27
Chorozinho	18,261	278	15,300	6,885	450	55
Horizonte	48,660	160	2,534	1,444	570	15
Pacajus	54,881	254	10,189	6,317	620	40
Santana do Acaraú	28,741	969	8,570	3,085	360	9

Source: [1]IBGE (2008b); [2]IBGE (2007a).

The state of Piauí. Piauí is bounded to the west by Maranhão and to the east by Ceará, Pernambuco and Bahia. The state has a few miles of Atlantic coastline on the north and is located within the geographical coordinates 02°44'49" and 10°55'05" South and 40°22'12" 45°59'42" West (Bastos, 1994). Piauí is located in a transition zone between the semi-arid climate of the North-east and the equatorial climate of the Amazon. The state has an area of 251,529 km^2 and consists of 223 municipalities (IBGE, 2005). The state capital is Teresina, located at the confluence of the Parnaíba and Poti rivers (Rodrigues, 2001). The Parnaíba River, separating the states of Piauí and Maranhão, runs for almost 1,500 km before flowing into the Atlantic, and forms the only open-sea delta in the entire American continent (Bastos, 1994). The plateau region of Piauí is irrigated by numerous tributaries of the Parnaíba. The river valleys are separated by flat-topped plateaus called "chapadas" or "serras", including: "Serra Uruçui", "Serra Capivara" and "Chapada das Mangabeiras" (Filho, 2002).

In Piauí, two climate types are prevailing: on the one hand there is the tropical humid climate with wet autumn and summers, with temperatures varying between 25°C and 27°C; on the other hand the tropical dry semi-arid climate is characterized by winter rainfall, and consistent high temperatures, ranging between 24°C and 40°C. The North region has an annual rainfall of 1,200 mm while in the South annual rainfall reaches only 700 mm (Andrade, 2000; Krol and Bronstert, 2007). The landscape in the state is divided into three types of vegetations known as "caatinga", "cerrado" and Atlantic rain forest. In Piauí, the fieldwork was concentrated in four municipalities (Figure 3 and Table 9).

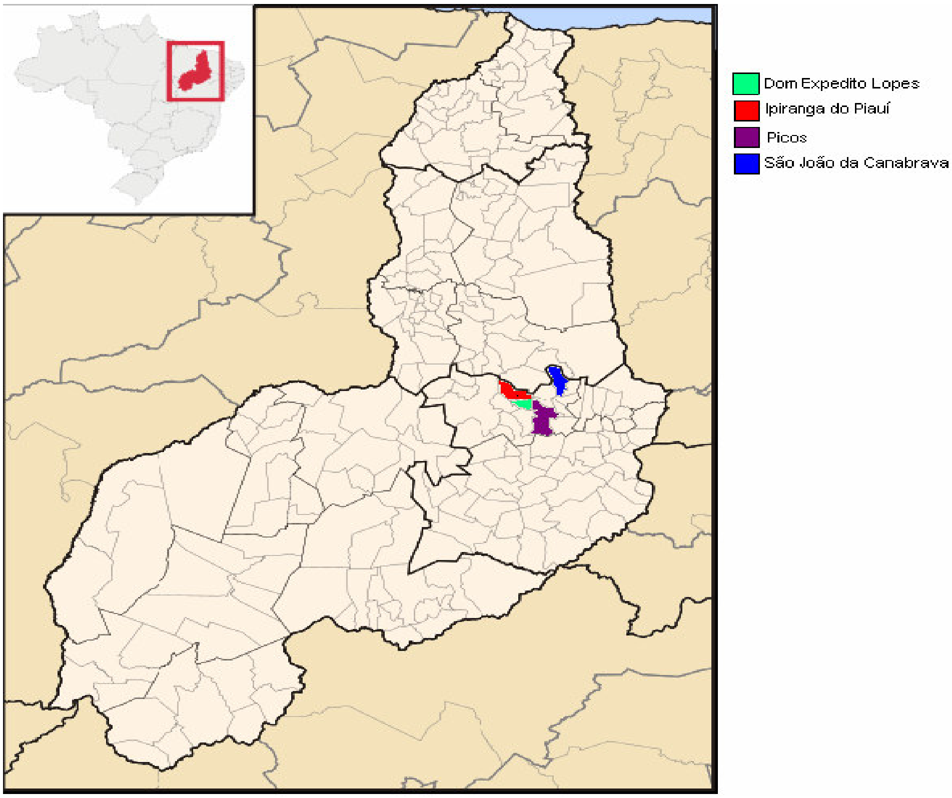


Figure 3. The studied municipalities in the state of Piauí.

Source: Adapted from Wikipedia (2007b).

Table 9. List of the studied municipalities in the state of Piauí and several informations

Municipality	Population in 2007[(1)]	Total area (km^2)	Cashew nut in 2006[(2)] Planted area (ha)	Production (ton)	Productivity (kg/ha)	% of the cashew crop area
Dom Expedito Lopes	6,532	219	3,430	1,201	350	16
Ipiranga do Piauí	9,354	528	1,562	394	252	3
Picos	70,450	803	1,845	443	240	2
São João da Canabrava	4,364	471	870	222	255	2

Source: [(1)]IBGE (2008b) and [(2)]IBGE (2007a).

3.3 Rapid appraisal of cashew based farming systems through interviews

In the state of Ceará, 194 cashew farmers were visited and included in the sample. They were scattered among 73 communities from 9 municipalities as follows: Aracati (21), Barreira (30), Beberibe (20), Bela Cruz (11), Cascavel (21), Chorozinho (30), Horizonte (21), Pacajus (20) and Santana do Acaraú (20). In the state of Piauí, 60 questionnaires were filled. A total of 14 communities from 4 municipalities were visited, as following: Dom Expedito Lopes (2), Ipiranga do Piauí (33), Picos (3) and São João da Canabrava (22). Therefore, 254 cashew farmers were successfully surveyed in total. The cashew farmers were purposely selected by an agricultural technical person of the EMATER in order to include farmers of diverse characteristics and differences in agricultural production potential. The aim was to identify the structure of cashew producers in the North-eastern region with regard to their socio-economic and environment aspects. The household survey consisted of five parts: (i) information about the farmer, (ii) identification and characterisation of the farm system, (iii) commercialisation of cashew products, (iv) public policies and (v) data concerning production of cashew fruit in 2006.

3.3.1 Determining parameters and structure of the cashew system

(i) Eco-volume

This concept was introduced in order to apprehend the relationships between species living within the boundaries of a volume (Torrico, 2006). It is defined as the product of the ground surface area[2] of agricultural systems with the eco-height (d) as follows: $V_{eco} = s \times d$ (Janssens *et al.*, 2004). It is expressed as volume in m^3/ha.

(ii) Bio-volume

It is the total volume of all living components of a plant, as follows: stems, branches, roots, rootlets, twigs and leaves. Nevertheless, allometric relations are preferred and the root system is normally not considered. On the basis of the findings of Janssens *et al.* (2006), is assumed that a plant is an assembly of tubes and that all parts could be squeeze within a cylinder formed by: $V_{bio}=basalarea \times h_{eco}$, where V_{bio} = above-ground bio-volume, $basalarea$ = diameter at soil level, h_{eco} = average height of the over a year. The main hypothesis of bio-volume is that plants mainly compete for space and is expressed in m^3/ha.

(iii) Crowding density

A factor that measures the colonized volume by any plant community, for example: crop, weeds and trees. It is defined as follows: $Ci = 100 \times V_{bio} \div V_{eco}$.

(iv) Wesenberg factor

It is the proportion between eco-volume and bio-volume gives the power of a plant community to colonise an environmental space: $Wf = V_{eco} \div V_{bio}$.

(v) Litter fall total

The experiment for litter fall (Figure 4) was conducted in the Research Station of EMBRAPA in Pacajus, Ceará, with the following coordinates: 04°11'18.50" (latitude) and 38°30'19.30" (longitude), at an elevation of approximately 63 m. Twenty 1 m^2-litter-traps were systematically positioned under cashew trees. Ten common cashew trees and ten precocious cashew trees, all in different periods of age were included for this experiment. The experiment of the common type was conducted with a good selective genetic material of cashew trees. With regard to dwarf-precocious, different clones were taked into the experiment, as follows: CCP 1001, CCP 06, CCP 09 and CCP 76.

[2] In this study, the surface area was based on the crown diameter.

Figure 4. Experiment of litter fall in Pacajus, Ceará, Brazil.
Common cashew (A) and dwarf-precocious (B) cashew types.

Litter fall was collected monthly in the period from October 2006 to September 2008. The local agricultural technical personal of the station was responsible for the collection of the contents of each trap. The litter was then sorted into: leaves, flowers, twigs, cashew nuts and cashew apples. Each fraction was weighed (ambient air-drying status) and then dried in a forced air stove at 65°C for 72 h. The present method was developed in accordance to the method described by Queiroz (2005).

(vi) Biomass

For the retrieval of biomass data, vegetation composition and structure were collected. For each cashew farm, the area included in the survey constituted about 10% of the entire plantation. Plots of approximately 16 m × 16 m were used for the survey. For biomass assessment, the following data of the cashew trees were measured: diameter at breast height, diameter of the basal area part of the crown and the tree height. Total biomass was estimated based on the bio-volume of the cashew tree and the wood density of the *Anacardium excelsum* (Nogueira *et al*., 2007) as follow: $B_t = V_{bio} \times \rho$, where ρ is the wood density (Janssens *et al.*, 2004).

3.3.2 Energy and emergy analyses

Energy and emergy analysis require systems diagrams to organize evaluations and account for all inputs and outputs into the processes (Brown and Ulgiati, 2002). The first step in emergy evaluation is to build a system diagram, which shows the organizing knowledge of all components and processes that take part in the system (Figure 5).

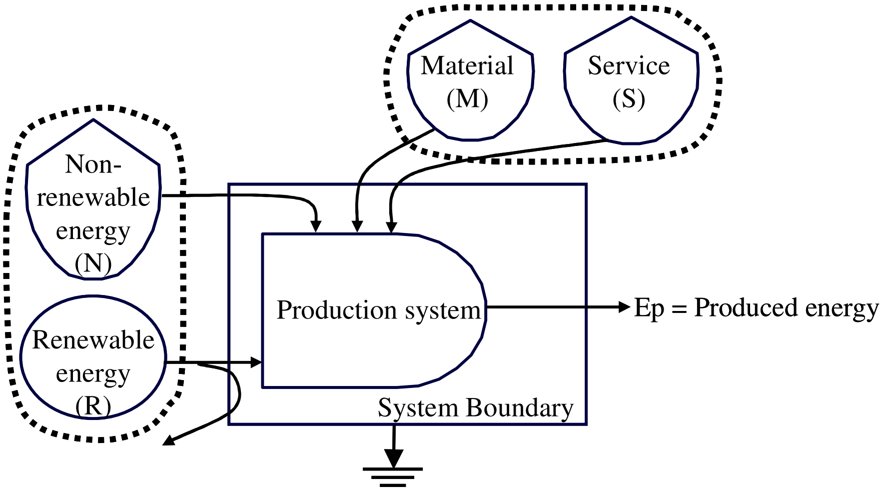


Figure 5. Diagram illustrating energy flows for a production system.

Note: renewable (N) and renewable resources (R) and others inputs (M, S).

Source: Adapted from Haden (2002); Ortega and Ribera (2005).

Odum (1996) has postulated that the diagram is drawn with the symbols of energy systems language, implying specific mathematical relationships. Each energy system diagram contains items in the order of size and turnover time from left to right. The diagram illustrates the operational relations between input and output items. Eventually, all inputs and outputs must be evaluated. In accordance with Figure 5, Table 10 shows the classification of emergy flows, considering the natural and economic contributions.

Table 10. Classification of emergy variables

Inputs	Description
I: Nature contribution	R + N
R: Renewable natural resources	Rain, sun, wind, minerals, etc
N: Non-renewable natural resources	Soil, biodiversity, etc.
F: Feedback from economy	F = M + S
M: Materials	Renewable materials from natural origin Pesticides, fertilizers, fuel, etc.
S: Services	Familiar labour (local and external) Taxes, financial costs, etc.
Y: Total emergy	Y= I + F

Source: Adapted from Ortega *et al.* (2004).

The final stage of the emergy analysis is to combine the information from the income statement into summary variables that are used in the calculations of emergy indices. The emergy indices are an important tool, which gives support in discussing about the relationship between a specific system and the social, economic and ecological ambient that supports it (Ortega *et al.*, 2004; Brown and Ulgiati, 2002; Brown and Ulgiati, 1999) (Table 11).

Table 11. Indices of emergy analysis

Name of index	Definition
Tr (solar transformity)	Y / E
Percent renewable (%Renew)	$100 \times (R + M_R + S_L) / Y$
Emergy Yield Ratio (EYR)	$Y / (M_N + S_A)$
Emergy Investment Ratio (EIR)	$(M_N + S_A) / (R + M_R + S_L + N)$
Environmental loading ratio (ELR)	$(N + M_N + S_A) / (R + M_R + S_L)$
Emergy exchange ratio (EER)	Y / [(US$) × (sej/US$)]

Y – Total emergy, E – Total energy, R – Renewable natural resources, M_R – Renewable materials, S_L – Labour services, M_N – Non-renewable materials, S_A – Additional services, N – Non-renewable natural resources.

Source: Adapted from Ortega *et al.* (2004).

3.4 Statistical methods – logit analysis

The logit analysis is among the most widely used regression of the generalized linear models, in case of a binary-dependent variable (Hahn, 2008). The model is estimated by maximum likelihood and was used to examine the effects of a set of independent variables (Xs) on the probability of success or failure of the dependent variable Prob (Yi). In this study, the cashew productivity was considered as the dependent variable, whereas independent variables included data gathered from the questionnaires as well as secondary data. The logit model is given by logistic density as follow (Anderson and Newell, 2003): $\gamma(\beta' x) = \Lambda(\beta' x)(1 - \Lambda(\beta' x))$.

The authors explain that the predicted probability from a binary choice model is given by: $E[y/x] = F(\beta' x)$, where *y* is a choice variable, *x* is a vector of explanatory variable, β' is a vector of parameter estimates and *F* is an assumed cumulative distribution function. In this model, marginal effects of continuous variables, i.e. the marginal changes in expected probability are equal to: $\partial E[y/x]\partial x = f(\beta' x)\beta$, where f is the corresponding probability density function. Several statistics should be reported routinely in any logit analysis (Wooldridge, 2002). Some measures and discussions about the parameters of the logit will be considered in the fourth chapter of this work.

4 ANALYSIS OF CASHEW SYSTEMS IN NORTH-EAST BRAZIL

A benchmark survey of cashew farming systems was conducted in North-east Brazil and a typology of these systems was created using the collected data. The data used for the analysis in this chapter were collected from field surveys undertaken in Ceará and Piauí over six months in 2007 using a structured questionnaire. A total of 254 cashew farmers were interviewed and the information is summarised in Table 12.

Table 12. Number and percentage of the interviewed farmers

State Municipality	Count (% of total)
Ceará total	194 (76.4)
Aracati	21 (8.3)
Barreira	30(11.8)
Beberibe	20 (7.9)
Bela Cruz	11 (4.2)
Cascavel	21 (8.3)
Chorozinho	30 (11.8)
Horizonte	21 (8.3)
Pacajus	20 (7.9)
Santana do Acaraú	20 (7.9)
Piauí total	60 (23.6)
Dom Expedito Lopes	2(0.8)
Ipiranga do Piauí	30 (11.8)
Picos	6 (2.3)
São João Canabrava	22 (8.7)
Total	254(100)

4.1 General characteristics of the studied cashew systems in Ceará and Piauí

The interviewed cashew farmers in Ceará were between 24 and 70 years of age, while in Piauí the farmers were 27 to 67 years old. On average, the farmers in the state of Piauí were slightly older than their counterparts in the state of Ceará. In both states, more than 87% of the farmers were male, and most were married (Table 13). Most of the farmers in both states were classified as landlords, whereas 21.1% and 15% in the states of Ceará and Piauí, respectively, were partners, settlers or resident workers. Most of the farmers in both states visited their farms at least once daily, whereas about 45% of the farmers in Piauí visited just once a week. This can probably be ascribed to the fact that some of these farmers live off their farms, sometimes several kilometres away.

The average number of years of education was higher among farmers from Piauí than in Ceará and was statistically significantly at a 10% level. Another important factor is the agricultural account control[3], which was rather common among cashew farmers, with only a small group of them conducting an accounting of their farming system, with a statistically significant difference between the groups at a 1% level. Despite the lack of account control, the cashew system was the primary source of income for the majority of interviewed farmers. Among the five income groups, there were statistically significant differences between just two (Table 13). The average size of the farms was 42.0 ha in Ceará and 19.8 ha in Piauí. Both values were statistically significant at a 10% level. The farmers in Ceará have twice the cashew farming experience as those in Piauí; the difference between these values being statistically significant at a level of 1%. No statistical difference regarding family size or percentage of labour force was shown between the groups. In Piauí, 61.7% of the farmers are members of two rural associations, indicating a higher social involvement, as compared to the farmers in Ceará, at a significance level of 1% (Table 13).

[3] In this study, agricultural account control is defined as an annual measure of the value of income generated from the production of agricultural goods and services versus the value of agricultural expenses.

Table 13. Socio-economic characteristics of the interviewed cashew farmers

Farmer characteristics	State		Test statistics (p-value)[1]	
	Ceará [194]	Piauí [60]	t-test	χ^2-test
Age (average age)	37.3	37.0	0.806	
Gender (% male)	87.1	96.6		**0.024
Marital status (% married)	97.9	100.0		0.338
Farmer occupation (% Landlord)	78.9	85.0		0.197
Visit frequency (% visiting daily)	83.0	46.7		***0.000
Education (average number of years)	5.5	6.5	*0.066	
Agricultural account control (% has control)	33.0	11.7		***0.001
Primary source of income (% agriculture)	89.7	90.0		0.582
Monthly income group – (%)				
$ 164 to $ 491	74.2	90.0		***0.006
$ 492 to $ 984	19.6	8.3		**0.028
$ 985 to $ 1,476	2.1	1.7		0.662
$ 1,477 to $ 1,968	0.5	0.0		0.764
Greater than $ 1,968	3.6	0.0		0.148
Property size (ha)	42.0	19.8	*0.090	
Owning other land property (% yes)	16.5	18.3		0.437
Cashew farm experience (average number of years)	20.8	11.7	***0.000	
Family size (average number)	4.6	4.1	0.116	
Labour force (% of family labour force)	92.3	93.3		0.520
Member of Rural Association (% taking part in two associations)	18.6	61.7		***0.000

[1]Statistically significant at 1%***, at 5%** and, at 10%*

Although cashew is one of the most important cash crops in the North-east, the equipment used by the cashew farmers is extremely simple (Table 14). In general, the cashew farmers in Ceará are better equipped than those in Piauí, except for the slightly higher percentage of irrigation pumps found in Piauí. Most of the data obtained regarding the equipment were statistically significant at a 1% level (Table 14).

Any structure on the property belonging to the cashew farmers was considered a building. Most of the properties included in the survey had a main house (farmer's residence). A labour force comprised of exclusively family members has been a predominant characteristic among cashew growers. In addition to the main house, worker's houses for temporary labour force were often found on the farms. These structures are designated for a small number of regular employees and/or a seasonal labour force, which is recruited during the cashew crop harvest time (Table 14). No statistically significant difference was shown between the groups in terms of storage places. This is probably because the cashew farm output (nut and/or apple) is sold in advance, and thus reduces the need storage. Among the buildings, there were statistically significant differences between the groups for the main house, the worker's house, the flour house and the hen house.

Table 14. Structure and composition of the farming systems

Item of cashew systems	**State**		**Test statistics (p-value)[1]**
	Ceará [194]	**Piauí [60]**	**χ^2-test**
Equipment (% yes)			
Spraying	45.4	20.0	***0.000
Weeding	6.2	0.0	**0.036
Ploughing	12.9	10.0	0.366
Grating	12.9	3.3	**0.024
Cultivator	65.5	0.0	***0.000
Irrigation pump	7.7	8.3	0.532
Transport (% yes)			
Motorized Vehicle	7.2	1.7	*0.092
Cart pulled by animal	60.3	0.0	***0.000
Buildings (% yes)			
Main house	89.7	56.7	***0.000
Worker's house	27.6	13.3	***0.017
Cowshed	6.7	8.3	0.426
Storage place	19.6	13.3	0.183
Corral	26.3	21.7	0.295
Flour house	7.8	0.0	***0.015
Pigsty	1.5	1.7	0.662
Henhouse	1.5	10.0	***0.006
Animal stock (% yes)			
Beef cattle	18.6	30.0	**0.046
Dairy cows	25.3	46.7	***0.002
Goats and sheep	13.9	30.0	***0.005
Chicken and ducks	27.8	45.0	***0.011
Fish	0.0	1.7	0.236
Pigs	0.0	1.7	0.236
Bees	1.5	0.0	0.444
Other crop (% yes)			
Cassava	54.6	73.3	***0.007
Bean	56.7	71.7	**0.026
Maize	30.4	1.7	***0.000
Grass	2.6	0.0	0.257
Sugar cane	3.6	5.0	0.433
Vegetables	0.0	1.7	0.236
Fruit trees	5.7	0.0	**0.048

[1]Statistically significant at 1%***, at 5%** and, at 10%*

As shown in Table 14, the farmers in Piauí had larger animal stock than in Ceará in all cases, except for the stock of bees. Grazing is not possible on cashew plantations year-round and during the harvest, the animals are removed from the fields. Thus the honey produced from cashew flowers constituted an additional income for the farmers for a few months. As shown in Table 14, no statistically significant difference was seen between states in terms of cattle, dairy cows, goats and sheep and chickens and ducks.

Some very small farms in the states of Ceará and Piauí do not cultivate any other crops or fruit trees (22.7% and 18.3% respectively). On the other hand, seven crops were found on most of the fields surveyed: either in crop mixes growing among the cashew trees like cassava (Table 14), maize and fruit trees such as coconut or at some difference like grass, sugar cane or vegetables. In general, a considerable part of the land designated for cashew systems is available for intercropping during the annual rainy season.

Two types of cashew trees have characterized the smallholder cashew farming systems in North-east Brazil: the common and the dwarf-precocious. The dwarf-precocious was developed by EMBRAPA and it represents a modernization of cashew cultivation. In Ceará, only 8.8% of the growers cultivate the dwarf-precocious type as compared to 45% of the growers in Piauí. Approximately one-third of the farming systems in both states grew the two types of cashews. Furthermore, more varieties of dwarf-precocious were found in Piauí, as follows: CCP 076, FAGA 11, FAGA 01, CCP 09, EMBRAPA 50, EMBRAPA 51, CAP 14, BRS 183, BRS 189 and BRS 226, while in Ceará only four of these varieties were observed. The CCP 076 variety was the most common making up 38% and 83.4% of the dwarf-precocious grown in Ceará and Piauí, respectively. In summary, more respondents in Piauí were observed to be involved in the modernisation of cashew production, then in Ceará.

Table 15. Intensification characteristics of the cashew farming systems

Item of cashew systems	**State**		**Test statistics (p-value)[1]**
	Ceará [194]	**Piauí [60]**	**χ^2-test**
Type of cashew grown (%)			
Common	59.3	16.7	***0.000
Dwarf-precocious	8.8	45.0	***0.000
Common and Precocious	32.0	38.3	0.223
Average cultivated area (ha)			
Common	11.1	4.6	***0.005
Dwarf-precocious	6.5	6.3	0.956
Irrigated area with cashew (%)	1.0	3.3	0.238
Crop management (%)			
Pruning	75.3	93.3	***0.001
Weeding	67.0	10.0	***0.000
Fertilizer application	29.4	61.7	***0.000
Pest control	0.5	0.0	0.764
Fertilizers and agrochemicals (%)			
Organic nutrients	23.7	10.0	***0.014
Chemical nutrients	12.9	61.7	***0.000
Herbicides	0.5	0.0	0.764
Fungicides	0.5	6.7	***0.012

[1] Statistically significant at 1%***, at 5%** and, at 10%*

In most cases it was observed that there is no planned spacing for the common cashew orchards and the average number of trees was about 40 to 50 plants/ha. On the other hand, two forms of planned spacing were observed for the dwarf-precocious: 7 m × 7 m, with 204 plants/ha and other spacing 6 m × 8 m, with 208 plants/ha. Table 15 shows that slightly more area in Piauí was dedicated to cultivation of the common cashew as compared to the dwarf-precocious. In Ceará, the difference is relatively greater. With respect to irrigation, it is not a commonly used type of crop management among the cashew growers. This is probably due to the higher cost with irrigation and also with the restricted market for the fresh cashew fruit in the North-eastern region.

In addition to Table 15, 15.5% and 5% of the farmers in Ceará and Piauí, respectively have not adopted any crop management. In Ceará, just 0.5% reported implementing the recommended crop management, as compared to 0% in Piauí. Thus, crop management requirements are ignored, particularly the pest control, which was not seen in either state. According to Tolla (2004), a lack of pruning, weeding, fertilizer application or pest control among the cashew growers causes a significant negative impact on the productivity of the cashew tree. In other words, these factors are very important in order to improve the productivity of cashew crop. Among groups of crop management, statistically significant difference regarding pruning, weeding and fertilizer application was observed (Table 15).

In general, fertilizers and agrochemicals were rarely used by the cashew farmers in Ceará. In Piauí, 61.7% of the farmers have used chemical nutrients. It is probably due to the predominance of cashew orchards with the dwarf-precocious, where fertilizers are most frequently used in its planting phase. In both states, statistical significance was assessed for organic nutrients, chemical nutrients and fungicides.

Table 16 presents the commercial uses of the cashew output. In addition to the cashew nut, over half of the cashew farmers in both states reported having sold cashew apples to the juice industry, though just a small percent of the overall cashew apple production has been used. As shown in Table 16 there were no statistically significant differences between the groups in terms of sales of the cashew apple. Both Oliveira (2008) and Barros *et al.* (2002) have observed that the consumption of the cashew apple has been increasing significantly in the last five years. However, this observation was not supported by the respondents of which just 3.6% of the growers in Ceará sold trays of fresh cashew apples. It was observed, however, that most of the cashew growers designated a small percentage of the cashew apples to produce products such as alcoholic drink, juice, syrup and sweets for consumption on the farm. Statistically significant difference was observed among the states for the consumption in the property.

As shown on Table 16, it was observed that cashew farmers in Ceará used more opportunities to sell their cashew outputs than those in Piauí. In Piauí only two possibilities to sell the cashew products were reported as follows: 80% went to the local market and 50% was sold through a middleman, whereas in Ceará, the growers took advantage of more opportunities such as direct export (0.5%). In spite of this, a quarter of the cashew farmers in Ceará still depended on the services of a middleman. Between the sates, statistically significant differences were observed in sales to local market, industry, middleman and national market.

Table 16. Commercialisation of cashew nut and apple production in 2006

Production of cashew apple and nut	State		Test statistics (p-value)[1]
	Ceará [194]	Piauí [60]	χ^2-test
Besides the cashew nut what parts of the cashew fruit was sold and in what manner in 2006? (%)			
Cashew apple	54.6	60.0	0.281
Cashew apple with nut (fresh fruit)	3.6	0.0	0.148
Consumption within the property (%)	66.5	96.7	***0.000
The cashew production is sold to:			
Local market (%)	39.2	80.0	***0.000
Mini-factory (%)	2.6	0.0	0.257
Industry (%)	30.4	0.0	***0.000
Middleman (%)	25.8	50.0	***0.000
Exportation (%)	0.5	0.0	0.764
National Market (%)	7.2	0.0	**0.020

[1]Statistically significant at 1%***, at 5%** and, at 10%*

Regarding technical support, eight agencies were involved with the farmers. The supply usually differed, depending on the location of the farmer. Normally, the agencies that are involved are from local or regional programmes or are connected to the local city hall. As shown in Table 17, there were statistically significant differences in support provided by EMATER, FAEC, SMA and, CEAT between the groups. It was also observed that more than 50% of the growers in both groups received financial support (rural credit). Most of the farmers reported having received rural credit from the PRONAF Programme, a national programme designed to strengthen subsistence agriculture. Other questions regarding knowledge about public policies were asked during the interviews. In this regard, 28.4% and 70% of the farmers in Ceará and Piauí respectively responded that they had knowledge of specific policies to support the cashew farming systems in the North-eastern region. Statistically significant differences were observed between the states in terms of receipt of financial support and in knowledge of public policies ($p < 0.01$, Table 17).

Table 17. Technical and financial support supplied to the cashew farmers

Support to the cashew farmers	State		Test statistics (p-value)[1]
	Ceará [194]	Piauí [60]	χ^2-test
Technical or technological support - agency (%)			
EPACE	0.5	0.0	0.764
EMATER	54.1	85.0	***0.000
EMBRAPA	1.5	1.7	0.662
FAEC	7.2	0.0	**0.020
SMA	9.3	0.0	***0.006
COOPSAT	0.5	0.0	0.764
CEAT	7.2	0.0	**0.020
SEBRAE	0.0	1.7	0.236
Financial support - rural credit (%)	51.0	76.7	***0.000
Knowledge about any public policies (%)	28.4	70.0	***0.000

[1]Statistically significant at 1%***, at 5%** and, at 10%*

4.2 Effects of different factors on the sustainability of cashew farming systems

The descriptive analyses were conducted with the help of the statistical software package SPSS and the results are displayed in the next section. Differences between the groups were compared using χ^2 and t-tests. The statistical tests were done using the null hypothesis, which assumes that there was no difference between the groups. At a 10% significance level, the null hypothesis cannot be rejected for either group. A data set was constructed for a statistical analysis, to which a logistic regression was applied. The data set was constructed based on the cashew nut productivity of the states of Ceará and Piauí in 2006 as dependent variable. Based to IBGE (2007a) and data from the questionnaires, the dependent variable was measured on a binary scale: if $Y \geq 303$ then coded "1" otherwise "0" (Table 18).

Table 18. Description of the occurrence of the cashew nut productivity

			Cashew Nut Productivity		Total
			If Y<303, Y=0	If Y≥303, Y=1	
State	Ceará	Count	64	130	194
		% within state	33.0	67.0	100.0
	Piauí	Count	25	35	60
		% within state	41.7	58.3	100.0
Total		Count	89	165	254

As summarized on Table 18, one of the objectives of this research study was to identify the variables that influence cashew nut productivity in both states. Therefore, this section discusses the determinants of cashew productivity based on a logistic analysis, which shows the relationship between the binary dependent variable and the independent variables. A statistical summary and explanation of the independent variables included in the model are provided in Table 19.

Table 19. A summary of variables used in the logistic regression model

Variables	Description	Mean ± SD	Expected sign
Precipitation[1]	Continuous scale: average precipitation from 2004 to 2006. Measurement in mm/y.	913.42 ± 91.88	+/-
Sunhours[1]	Continuous scale: average hours of sun from 2004 to 2006. Measurement in h/y.	2,902.84 ± 119.01	+
Distance to Port	Continuous scale: distance from each farm to the Port in Ceará. Measurement in kilometres.	195.02 ± 156.93	-/+
Experience with cashew crop	Continuous scale. Measurement in years.	18.68 ± 11.14	+
Fertilizer application	Measured on a binary scale: if the farmer has applied any kind of fertilizer, then coded "1"; otherwise "0".	0.37 ± 0.48	+/-
Livestock ownership	Measured on a binary scale: if the farmer is a livestock owner, then coded "1"; otherwise "0".	0.57 ± 0.49	+/-
Middleman	Measured on a binary scale: if the farmer sells cashew nut production through a middleman, then coded "1"; otherwise "0".	0.31 ± 0.46	-/+

Source: [1]INMET (2007).

Several statistical parameters were taken in to account when carrying out calculations on the data. The logistic regression was carried out using a logistic procedure with the help of STATA version 8.0. In general, the logistic regression model was robust in fitting the data, correctly classifying 73.2% of the cases (χ^2_7 = 56.31, P<0.001) (Table 20). The statistical significance of individual regression coefficients (i.e. βs) was tested using the Wald chi-square statistic. Six of the seven variables in the model were found to be significant predictors of cashew nut productivity ($p < 0.05$). The expected signs have also corresponded to the hypothesis. The CashewExperience variable was not statistically significant ($p > 0.16$), but was considered to play an important role in the cashew nut productivity and should therefore be included in the model. The intercept test on, for example, the constant merely informs whether an intercept should be included in the model and it was shown to be statistically significant ($p < 0.05$), and thus, included. Heteroscedasticity is defined as a situation in which the variance of the dependent variable varies across the data, and is common for cross-sectional data. This problem with heteroscedasticity is frequently found in regression analysis (Greene, 1997). When heteroscedasticity is severe, ignoring it may bias standard errors and p-values of the regression (Gujarati, 2000). However, in order to obtain more consistent parameters, the following regression was run with the robust command that is based on White's test.

Several tests were carried out to confirm the accuracy of the analyses. The Goodness-of-fit statistics asses how well a logistic model fits against actual outcomes and the inferential goodness-of-fit test is the Hosmer-Lemeshow (H – L) test that yielded a χ^2_7 of 9.430 and was insignificant ($p > 0.05$), suggesting that the model fit well to the data. In others words, the null hypothesis of a good model fit to data was tenable. Two additional descriptive measures of goodness-of-fit presented in Table 9 are R^2 indices, the Cox and Snell R^2 and Nagelkerke R^2, respectively. According to Bruin (2006), logistic regression does not have an equivalent to the R^2 that is found in OLS regression. In linear regression, R^2 is defined as the proportion of the variation in the dependent variable that can be explained by predictors in the model. According to Peng (2002), a research study can treat these two R^2 indices, Cox and Snell and Nagelkerke, as supplementary to other, more useful evaluative indices, such as the overall evaluation of the model, tests of individual regression coefficients and the goodness-of-fit test statistic. More statistics about the logistic regression are available in Appendix 4.

Table 20. Logistic regression analysis of cashew nut productivity in North-east Brazil

Predictor	β	**SE** β	**Wald's** χ^2	*df*	*p*	e^{β} **(Odds ratio)**
Constant	- 9.996	3.892	6.596	1	0.010	0.000
Precipitation	- 0.007	0.002	11.183	1	0.001	0.993
Sunhours	0.006	0.001	17.302	1	0.000	1.006
DistanceToPort	- 0.007	0.001	24.607	1	0.000	0.993
CashewExperience	0.022	0.016	1.920	1	0.166	1.022
FertilizerApplication	1.679	0.386	18.922	1	0.000	5.361
LivestockOwnership	- 0.670	0.310	4.662	1	0.031	0.512
Middleman	0.685	0.340	4.060	1	0.044	1.983
Test			χ^2	*df*	*p*	
Overall model evaluation						
Likelihood ratio test			56.310	7	0.000	
Wald test			22.032	7	0.000	
Goodness-of-fit test						
Hosmer and Lemeshow			9.430	7	0.307	

Cox and Snell R^2 = 0.199. Nagelkerke R^2 = 0.274. N = 254, Correctly classified = 73.2%. All statistics reported herein use 3 decimal places in order to maintain statistical precision.

Determinants of cashew productivity. Since the β coefficient in the logistic model is expressed in log units, it is not possible to directly interperate the magnitude of the change caused by a one-unit change in the independent variable. However, from the outputs of the logistic regression it was possible to calculate the marginal effect of the variables of the cashew productivity. The results are presented in Table 21.

Table 21. Marginal effect of independent variables

Variables	**Marginal effect**	**p**	e^{β} **(Odds ratio)**
Precipitation	- 0.0015273	0.001	0.993
Sunhours	0.0013165	0.000	1.006
DistanceToPort	- 0.0015363	0.000	0.993
CashewExperience	-	-	-
FertilizerApplication	0.3214799	0.000	5.361
LivestockOwnership	- 0.1405978	0.030	0.512
Middleman	0.1389458	0.030	1.983

According to Table 21, all the marginal effects have been shown to be statistically significant at a 5% level, except for CashewExperience. Marginal effects provide a good approximation of the amount of change in Y that will be caused by a one-unit change in X_k. The coefficients (βs); i.e. marginal effects of Precipitation, DistanceToPort and LivestockOwnership were negative. This means that, for a one-unit change in each of these independent variables, the marginal effect indicated a decrease in the cashew productivity of 0.15%, 0.15% and 14.06%, respectively. In the case of the Precipitation variable, it is important to note that in 16.15% of the total data, annual average precipitation varied from 1,071 mm to 1,122 mm. According to Fruitrop (2001), the upper limit for regular harvest is an annual average of 1,000 mm. Meanwhile, with respect to the DistanceToPort variable, Table 22 shows that 28% and 31.1% of 254 cashew farmers have problems due to distance from the port and transportation of the output, respectively.

Table 22. Main problems among the cashew farmers

Description of the problem	**Frequency**	**(%)**
High distance between the growers and the Port	71	28
Transportation of the cashew output	79	31.1

Regarding LivestockOwnership, a strong usage of the area under the cashew trees as a pasture was observed during the period in which the interviews were conducted, primarily in the flowering time. Overall, the most important marginal effects were seen from FertilizerAppliction and Middleman, both with statistically significant impacts. With regard to FertilizerApplication it was shown that the impact of adopting this crop management tool had a statistically significantly high probability of increasing productivity. With respect to Middleman variable and in accordance to its marginal effect is important to affirm that: in spite of problems with a low selling price, it is important to point out that the middleman service is still the best option for many cashew farmers to sell the cashew nut production.

4.3 Identifying cashew systems in North-east Brazil

This section describes the typology (i.e. system of classification) of the interviewed cashew farmers. This typology was based on a cluster analysis procedure with the help of Statgraphics software version 5.1. Cluster analysis is normally used to sort through raw data and group them into clusters, or groups of relatively homogeneous cases or observations. The cluster procedure resulted in the classification of seven groups comprised of the 254 respondents (Table 23). The cluster table is followed by a series of photos and additional information on the profile of each group.

Table 23. Cluster description for the interviewed cashew farmers in North-east Brazil

Parameters	Groups n [7]						
	Homestead	**Food crops**	**Value-added**	**Fruit tree-crops**	**Innovative**	**Irrigated**	**Agribusiness**
Number of growers n[254]	13	70	76	49	40	4	2
Scale of area (ha)	≤ 50 - small			51 ≤ 60 - medium			≥ 900 - big
Cashew system (type)	100% Common	25% Dwarf-precocious 75% Common			78% Dwarf-precocious 22% Common		
Irrigation	No					Yes	No
Participation of cashew crop in the cultivated area (%)	93	89	50	49	57	55	30
Cashew nut production (kg/ha)	529	455	340	512	412	985	161
Income from the cashew crop	Medium	Low					
Income from the farming system	Medium	Low					
Farming system	Slightly diversified	Diversified					
Use of chemical inputs	Low				Medium		
Use of organic inputs	No				Low		
Animals	Internal consumption			Livestock production			
Buildings/structures	Only residential buildings			Residential and agricultural building			
Machinery	Poorly-equipped			Satisfactorily-equipped			
Rainfall parameter	846<R<891			1,002<R<1,072	900<R<974		1,002<R<1,072

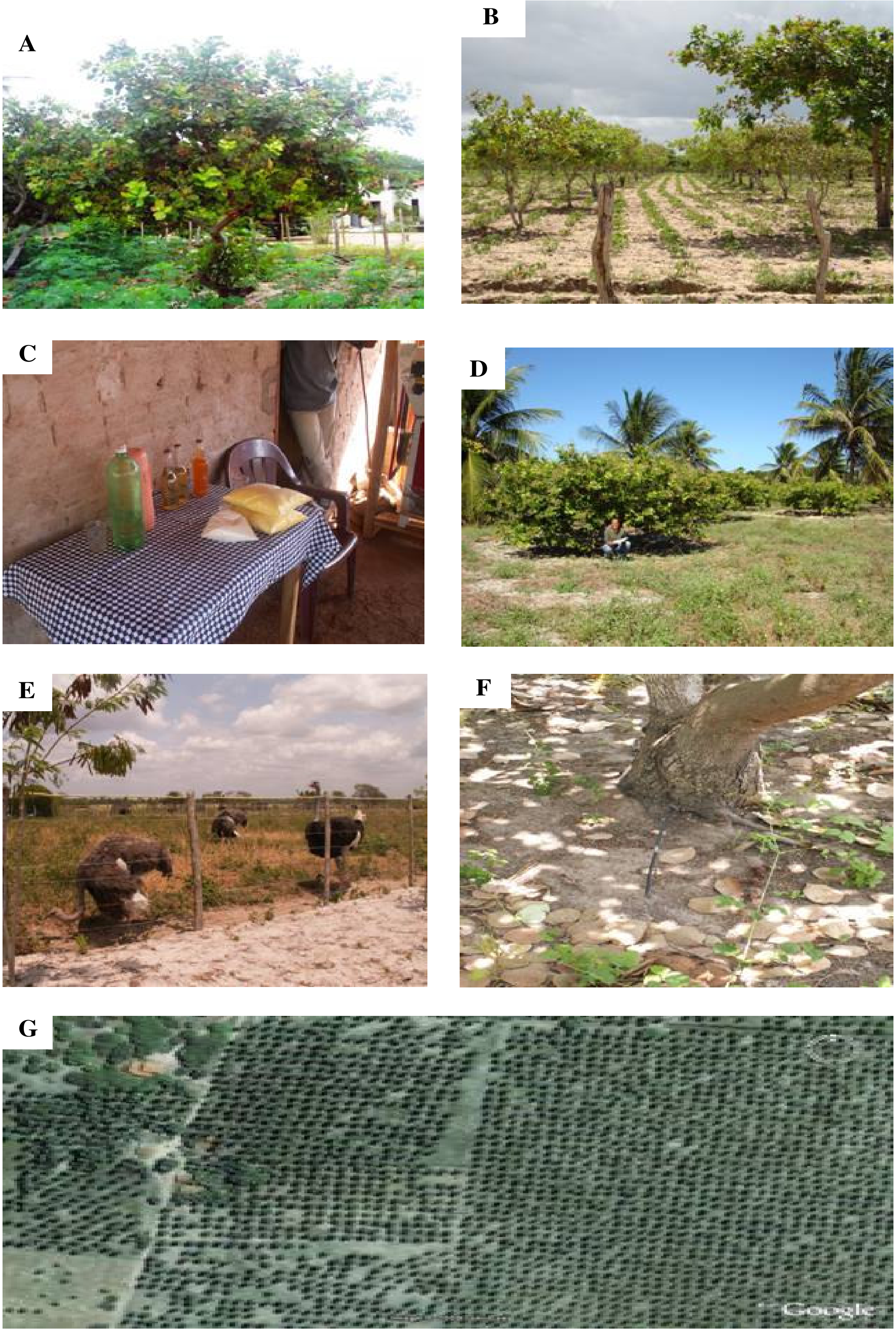


Figure 6. Cluster division: types of cashew systems.

Homestead (A); intensive intercropping with food crops (B); value-added systems (C); simultaneous fruit tree-crops (D); innovative (E); irrigated (F) and; cashew agribusiness system (G).

(A) About 5% were clustered into a homestead group that has an average cultivated area of 1.8 ha. This group was given its name due its characteristics similar to a homestead; a smallholding farm with a farmer's residence. Interesting to note in this group was the yield productivity of 529 kg/ha, which was considered very satisfactory among the groups. Among the smallholders the cashew nut is used like money in order to obtain other products and because of this they give an enormous importance to the cashew nuts.

(B) A representative number of the cashew farmers interviewed (27.56%) had the agricultural practice of cultivating two or more food crops on the same land simultaneously. The most commonly found food crops among the cashew farmers were maize, cassava, and bean during the rainy season. The primary goal of intercropping was for additional income and for home consumption.

(C) Approximately 30% of the farmers self-manufactured goods, and thus, their farms were defined as Value-added systems. For example, several of them had a flour house to produce flour from cassava for the regional market. Similarly, some cashew farmers sell the cashew nut or produce juice and wine from cashew apple. Cashew kernels are also processed by traditional cashew growers through open pan roasting.

(D) Some cashew systems simultaneously cultivate fruit tree production, e.g. coconut and cashew. Mango and guava are also suitable fruit trees partners in a cashew orchard and have very good market access in the region. Most of the fruit trees need to be planted at a sufficient distance from one-another, except for guava which can thrive directly in the shade of the cashew tree. Only 19.29% of respondent were clustered into this group.

(E) The term innovative in this research was designed for a representative group of 15.75% which is characterized with a different idea that is not normally found among the cashew farmers. During the field work, some farmers defined himself as innovative for example the idea to integrate ostrich with cashew system.

(F) The cashew tree grows normally under arid land conditions but for optimal yield quantities and good quality kernels, localized irrigation is recommended. Irrigated systems are commonly found only in dwarf-precocious orchards. The best cashew productivity (985 kg/ha) was found in group F, which represents 1.57% of the interviewed farmers.

(G) The group G is characterized by very large production units (900 ha). This is a not commonly found among cashew farmers and only 0.79% of the farmers interviewed were clustered into this group. A probable explanation for this low-productivity of this group is that the agribusiness cashew system, which 78% of the cashew systems are based on the dwarf-precocious tree, is in the initial stage of plant growth, and thus, had not yet reached its output potential.

4.4 Summary and conclusions

This chapter was divided into three parts: (i) background information on the structure of cashew farming systems i.e. from the cashew farmers and their farming systems; (ii) the key determinants of the cashew nut productivity under farm and climatic aspects and; (iii) identification of different types of cashew systems with similar characteristics (clusters). The description of the farming system in cashew producing zones has been presented in this study and provided sufficient information to develop a framework analysis of the cashew sector in the states of Ceará and Piauí.

(i) The typology developed in the first section of this chapter suggested differences among the cashew farmers and their farming systems between the states. According to the results, the cashew growers in Ceará had the following characteristics; a higher percentage of daily visit frequency; a higher percentage of agricultural account control; more cashew farming experience; more equipment for cashew farming and a form of transportation; more building structures; a preference for maize and fruit-tree crops; a larger area planted with the common cashew tree; a higher percentage of farmers that use organic nutrients; a higher percentage with crop management and; greater opportunities to sell their cashew production. Meanwhile cashew growers in Piauí had; a higher percentage of growers who earned less $ 491 per month; a higher number of farmers taking part in two rural associations; a greater preference for dairy cows, goats/sheep and chickens/ducks; a higher preference for cassava and bean crops; a larger area planted with the dwarf-precocious cashew tree; a higher percentage using chemical nutrients and fungicides; a higher internal consumption of the cashew products and; less opportunities to sell the cashew production.

(ii) The logistic model analysis showed seven variables that played an important role in cashew nut productivity: precipitation; hours of sun; distance of the farming system to the Pecém port; years of cashew farming experience; application of fertilizer; livestock ownership and; the service of middleman. Apart from the statistical insignificance of the cashew farming experience, all other variables demonstrated statistically significant influence on cashew nut productivity.

(iii) Overall, 254 cashew farmers were classified into seven groups with different characteristics, as follows; the homestead group with a small farming area; the food-crops-group based on intercropping with cassava, maize and bean crops; the value-added-group with the will to produce goods; the fruit tree-crops-group with preference for other fruit trees; the innovative-group that develops unusual ideas; the irrigated-group with a longing for better productivity; agribusiness-group with the characteristics of a big investor. On the basis of observations presented in the previous sections in this chapter, each cluster describes the group to which its members belong, providing a better understanding of the different types of homogeneous groups identified among the cashew farmers in the states of Ceará and Piuaí.

5 BIOMASS AND LITTER FALL IN MAJOR CASHEW FARMING SYSTEMS

Cashew (*Anacardium occidentale* L.), is the most widely known cultivated fruit tree in North-east Brazil. In the past, the cashew system in the North-eastern was considered to be an extensive agriculture, based on the common type. Yet, since the introduction of the dwarf-precocious type into the cashew plantations, extensive cashew agriculture was clearly distinguished from intensive cashew agriculture. Considering the genetic differences between the common and dwarf-precocious types in the region, some parameters such as the production of litter fall in the cashew orchards were measured. Litter fall is the primary process of transferring organic matter and nutrients to the soil (Brienza *et al.* 2000) and in accordance to Sonwa (2004) it is one of main indicators to monitor the sustainability of a system. Therefore, quantification of the litter fall can aid in understanding the biomass dynamics of an ecosystem. In addition, this chapter also provides information on the vegetation structure of the two different kinds of cashew trees: common and dwarf-precocious.

5.1 Structure and parameters of cashew trees

The horizontal and vertical distribution of components within a farming system is a key element in an environmental analysis. Gradually, the cashew farming systems in the North-east are being modified since the dwarf-precocious type was introduced into the cashew orchards. The first direct impact of this modernization on the cashew systems is on plant density. The cashew orchard density varied between 44 to 100 trees/ha for the common type in comparison to 156 to 277 trees/ha for the dwarf-precocious. The common type is on average taller than the dwarf-precocious and measurement values for the height were registered as: 4.60 m – 9.10 m for the common with 49 years old and 2.90 m – 8.30 m for the dwarf-precocious with 25 years old. Other parameters demonstrating the difference between the common and dwarf-precocious types were measured, as follows in Table 24. On an individual tree basis, the common type has registered the higher measurement values. The common tree is characterized by low density planting and higher cashew productivity per tree while a high density planning of the dwarf-precocious provides a better cashew yield per hectare, which has important commercial and economic impacts.

Table 24. Several measurements[4] of cashew trees in North-east Brazil

Cashew type[1]	Basal area (m^2)	DBH[2] (m)	Crown diameter (m)	Crown Depth (m)	Height (m)	Fruit yield (in kg dry matter)	
						nut	apple
Tree unit							
Common	0.11	0.35	10.94	4.95	6.25	12.40	9.77
Dwarf-precocious	0.09	0.33	9.11	4.57	5.22	6.50	5.14
Hectare unit							
Common	7.81	-	-	-	-	880.40	693.67
Dwarf-precocious	16.02	-	-	-	-	1,157.00	914.92

[1]Note: Planting density[5] – common type: 14 m × 10 m (71 trees/ha) /
dwarf-precocious: 8 m × 7 m (178 trees/ha).

[2]Note: Diameter Breast Height based on soil level height at 20 cm.

The vegetation measurement offers a wide range of information. Tree growth volume (e.g. stand basal area) is one of the main variables within forest landscape planning. Basal area is a very useful parameter for quantifying a forest stand because it is relatively easily collected and can be related to many other parameters e.g. tree volume and biomass. In this study, the estimated basal area for cashew trees was 7.81 m^2/ha for the common type and 16.02 m^2/ha for the dwarf-precocious. Based on these values, Table 25 summarizes the volume structure of the studied cashew trees measurements.

Table 25. Volume measurements of cashew systems

Cashew type	Eco-volume V_{eco} (m^3/ha)	Bio-volume V_{bio} (m^3/ha)	Crowding intensity C_i (%)	Wesenberg factor W_f
Common	31,268.28	36.61	0.12	854.09
Dwarf-precocious	56,296.30	77.77	0.14	723.88

(i) Eco-volume (V_{eco})

Eco-volume refers to soil surface multiplied by the average height of a given phytocenose or agricultural system (Marroqín, 2008). In other words, this concept refers to the above-ground quantifiable mass or volume where a single type of vegetation stands, multiplied by its height and where broad interactions between biotic and abiotic components coexist (Torrico, 2006).

[4] Note that the several measurements for plants depend on many other factors like age, crop management and climatic conditions.

[5] Due to the number of died plants in the experiment, it was considered a factor of correction of 0.75 for the common type and 0.93 for the dwarf-precocious type.

Torrico also argues that eco-volume is subject to either periodic or abrupt changes caused by climatic cycles or man-made disruptions, such as deforestation or extraction of plant materials. On the other hand, Janssens *et al.* (2004) indicated that the eco-volume also causes an effect on precipitation as well as on regulation of other ecological functions like its microclimate and water cycles.

The largest eco-volume in the studied cashew system is that of the dwarf-precocious with 56,296.30 m^3/ha (Table 25), 43.3%, which is more than the volume of the common type systems. According to Marroqín (2008), a traditional mango system offered an average V_{eco} of 11, 257 m^3/ha.

(ii) Bio-volume (V_{bio})

The main characteristic of bio-volume is the competition for space by plants (Janssens *et al.*, 2005, Diaz *et al.*, 2004, CIID, 1998, Kolnaar, 2006, Hansen, 1999 *apud* Torrico, 2006), above and below ground level where occupation of soil space is of primary importance. Bio-volume is based on the total volume of a type of plant, e.g. trees, shrubs and bushes, herbs and so on. Therefore, bio-volume of an individual plant is its biomass divided by its corresponding specific weight. Based on Deng's (2007) findings, a mango plantation in the commune of N'dali, North Ouémé, Benin, offered a V_{bio} of 61.08 m^3/ha. Other agricultural systems investigated by the same author included a cashew and mango mixed plantation, which had a bio-volume in the order of 131.24 m^3/ha.

(iii) Crowding intensity (C_i).

Crowding intensity is a factor that represents the relationship between V_{bio} and its equivalent V_{eco} and is given as a percent. C_i will be used mainly to differentiate between natural and agricultural systems. In agricultural systems, tree density, and weed control are the main factors in reducing the competition between plants, and in this case the C_i tends to decrease. A lower C_i value suggests the possibility of a lower incidence plant disease. In this case, the C_i concept is also an important factor in establishing an equilibrium between the demand and supply of finite natural resources. The C_i values for the common and dwarf-precocious were 0.12% and 0.14% respectively (Table 25). Torrico (2006) attributed a C_i value of 0.03% and 0.07% to sylvopastoral systems and citrus, respectively.

(iv) Wesenberg factor (W_f)

This factor gives an understanding about the ability of a community plants to colonise an environmental space. The lower W_f for the dwarf-precocious type means that this system colonises less space per unit bio-volume than the common type.

5.2 Total litter fall and its components

(i) Total litter fall (L_t)

The annual production of L_t for the common cashew farming system was calculated as 4.16 t/ha and around 5.83 t/ha for the dwarf-precocious, which is a difference of 40%. In a previous investigation, Mulindabigwi (2006) showed that the cashew tree litter fall total in Benin was 3.87 t/ha in Sérou and 1.93 in Dogué. In the humid zone of Cameroon, Sonwa (2004) calculated the annual litter fall to be as high as 10 t/ha for cocoa based agroforestry systems. Mosango (1991) *apud* Janssens *et al.* (2004) have reported that an annual litter fall value of 12 t/ha was reached for the primary equatorial forest in Congo-Kinshasa. Besides being impacted by climatic and geographic factors, total litter fall seems to vary according to vegetation. Details about the composition of litter fall are found next.

(ii) Components of total litter fall

From October 2006 to September 2007 (1-y) and from October 2007 to September 2008 (2-y) the litter fall of cashew trees was collected at least once monthly and separated into five components: leaves, flowers, twigs, cashew apples and cashew nuts, and then oven dried and weighed. During the period studied, a clear seasonal variability among the five components of the litter fall was observed.

Figure 7 shows that annually, litter fall had two peak-periods of production. From October 2006 to September 2007 the dominant peak was during the months of October to January with the largest litter fall production in November 2006 (306.4 g/m²), and the secondary peak was from August to September. A small spike of litter fall occurred during February and July 2007, where the total litter fall varies from 24.4 in May to 55.2 g/m² in March. In the 2-y, the dominant peak occurred during the months of October to December 2007 focusing once again on the month of November (170.5 g/m²). In this period, 55% of total annual litter fall was occurred during the months of October to December. Overall, leaves were the dominant litter fall comprising 31% of the total in both periods. The decrease of litter fall occurred during the months of February and July in the 1-y and in January to July in the 2-y, with the lowest level in both periods occurring in May. During the study period, it was observed that the percentage of flowers comprising litter fall started to increase in August, peaked in October and decreased till January.

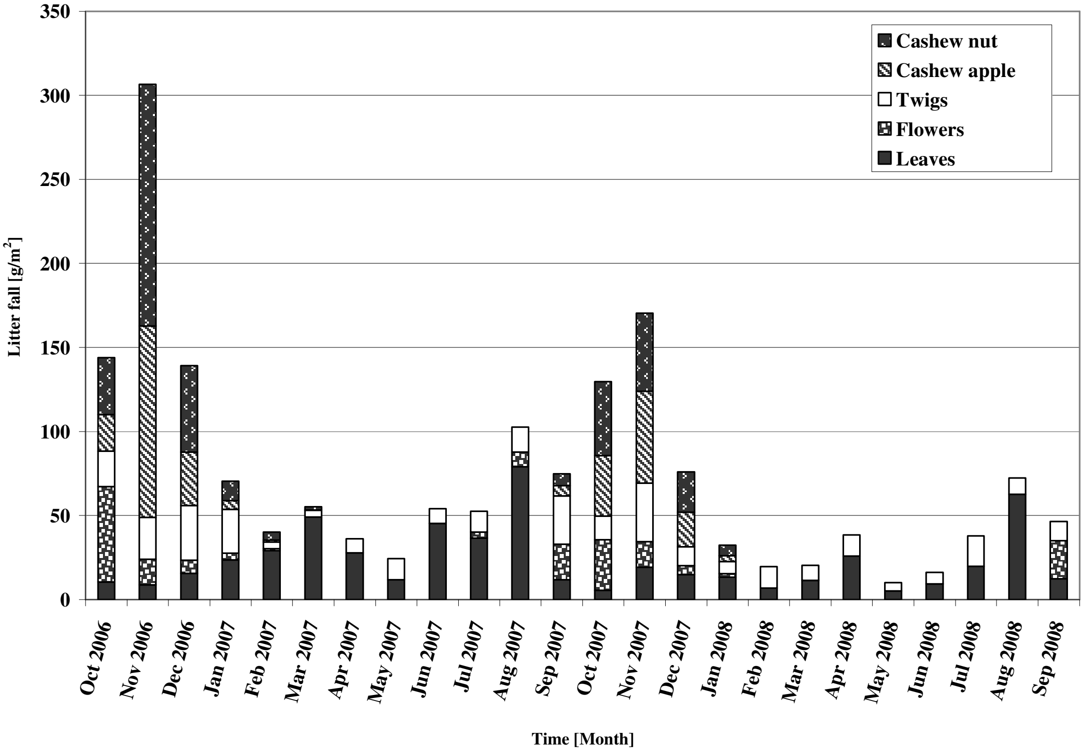


Figure 7. Mean monthly litter fall production per tree of common type in Ceará.

The litter fall of the dwarf-precocious (Figure 8) was studied at the same time as that of the common type (October 2006 to September 2008). In the 1-y, the peak-transfer of the dwarf-precocious was during the months of November to January (one month later than seen in the common type) and August to September. Between November and January, the total litter fall varied between 138.0 (in January 2007) to 153.0 g/m² (in November 2006). In the 2-y, the dominant peak occurred during October to November and as seen in the common type, the highest litter fall of the dwarf-precocious type occurred in the months of November in both periods. However, the total litter fall in November 2007 decreased by 23.5% as compared to the period before. Litter fall decreased during the months of February to July in the 1-y and between December to July in the 2-y. The litter fall components comprised an average of 48% leaf material, 12% flowers, 23% twigs, 8% cashew apple and 10% cashew nut. The percentage of flowers in the litter fall started to increase in October 2006 and declined steadily beginning the next month till February and started to increase in September 2007.

Overall, the total litter fall from the dwarf-precocious was 30.9% less than that of the common type.

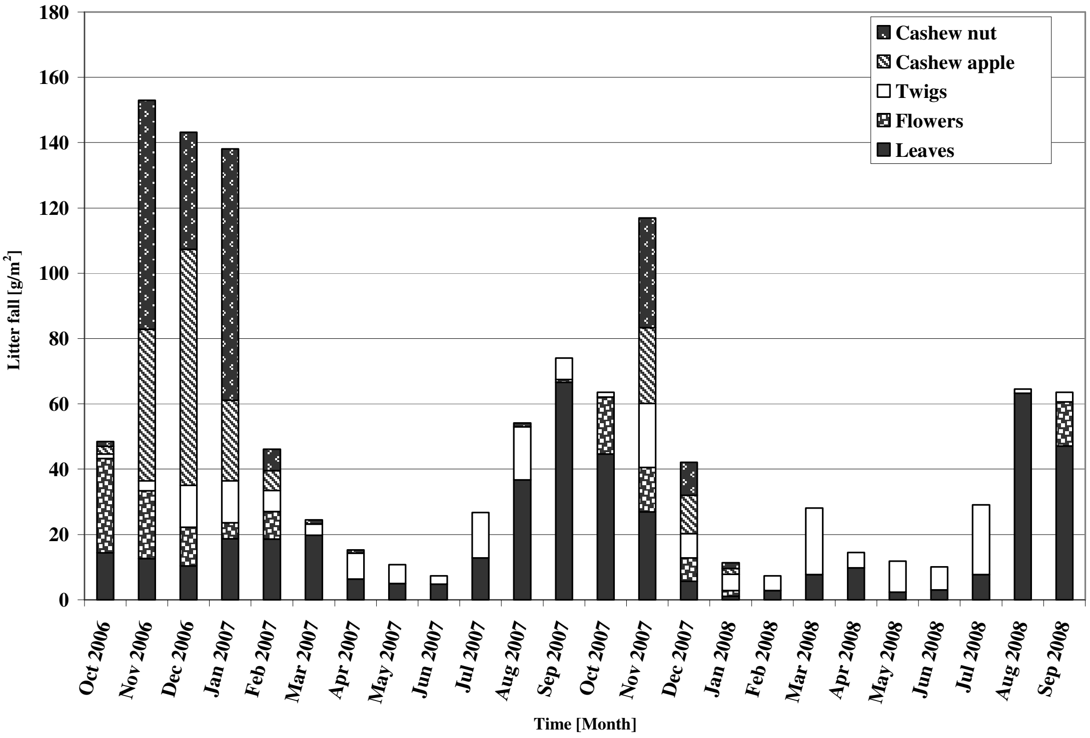


Figure 8. Mean monthly litter fall production per tree of dwarf-precocious type in Ceará.

The mean litter fall for the 1-y period of study for both types of cashew was 153 versus 94 g/m² in the 2-y period. Litter fall rates during the dry season of the 1-y period were considerably higher than in the rainy season (218 vs. 63 g/m²), with the greatest litter fall production occurring in the driest months (Figure 9). During the 2-y period, the dry season accounted for a litter fall of 123 g/m² while in the rainy season it was 38 g/m². February 2007 and April 2008 showed peak rainy season litter fall rates.

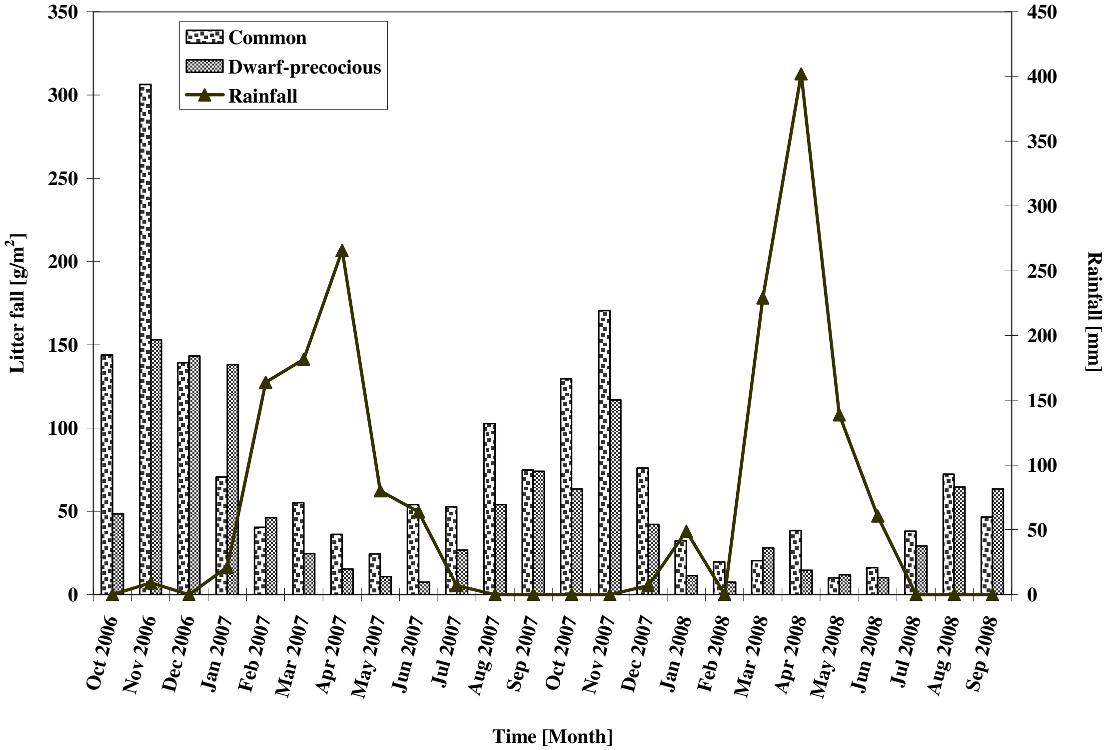


Figure 9. Dynamics of monthly litter fall and rainfall in Pacajus, Ceará.

Note: Rainfall data from FUNCEME (2008).

The observed amounts of litter fall during the two periods for both cashew types varied greatly with the density of the trees in an ecosystem. The amounts in g/m² for each litter fall component e.g. leaves, flowers, twigs, cashew apple and nut were 556, 194, 351, 295 and 375, respectively for the common type as compared to 449, 129, 198, 188 and 240, respectively for from the dwarf-precocious. The total litter fall comprised of all components accumulated during 24 months for the common type was 1,770 g/m^2 (Figure 10) and 1,204 g/m^2 for the dwarf-precocious (Figure 11).

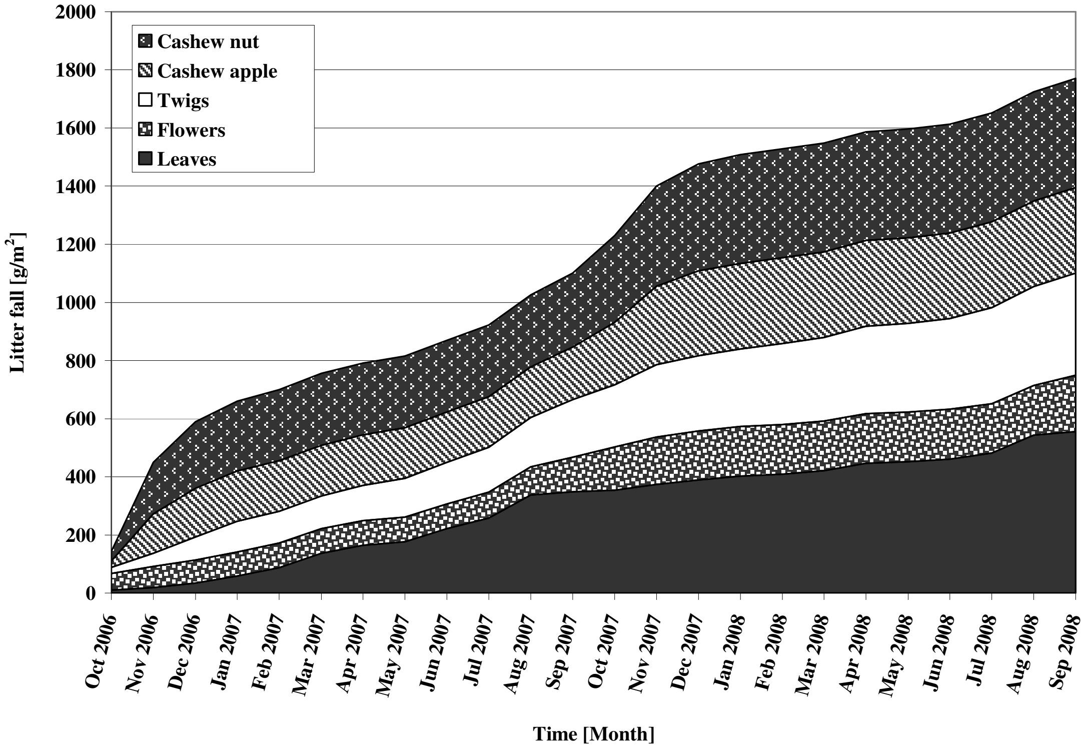


Figure 10. Accumulated litter fall per soil surface of the common type in Ceará.

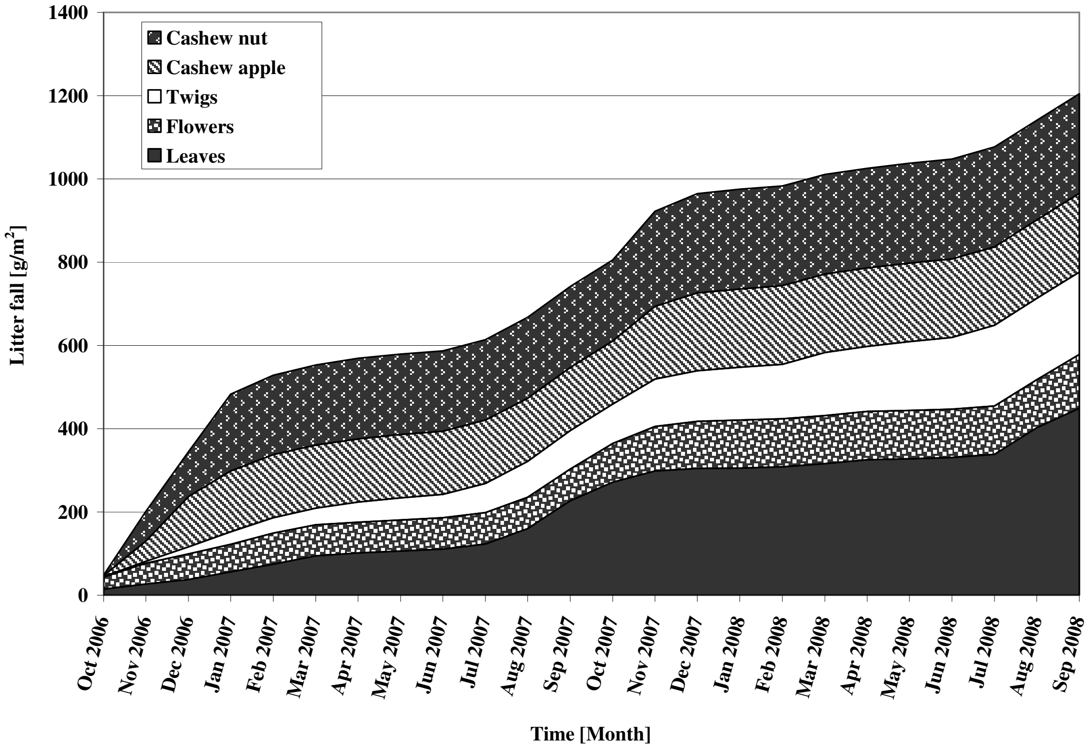


Figure 11. Accumulated litter fall per soil surface of the dwarf-precocious type in Ceará.

For both types of cashew trees, leaf fall is the primary component of total litter fall and responds rapidly to climatic changes. This component is a dominant factor in annual transfer of biomass and nutrients to the detritus pathway. In a previous study conducted by Chander *et al.* (1998), leaf fall- production and decomposition were found to be the most important components in the nutrient cycling process. With respect to the cashew in particular, compositions of nutrients found in mature leaves in Australia, Brazil and Zambia show that this litter fall component is a source of nitrogen, containing 15.0, 22.9 and 17.2 in g/kg, respectively (Crisóstomo *et al.* 2007). Crisóstomo *et al.* postulates that the cashew is erroneously considered to require low inputs of nutrients because many orchards are found in soils with low natural fertility, in which no fertilizers are applied. The leaf component is considered a suitable uptake of nutrients for the trees. Yet, during the field work it was observed that some growers remove all the litter fall mass (Figure 12), mainly before the time for harvesting. This usual practice of burning within the systems tends to contribute to the deficit of nutrients concentrations, and consequently, is one more factor of decreased yield.

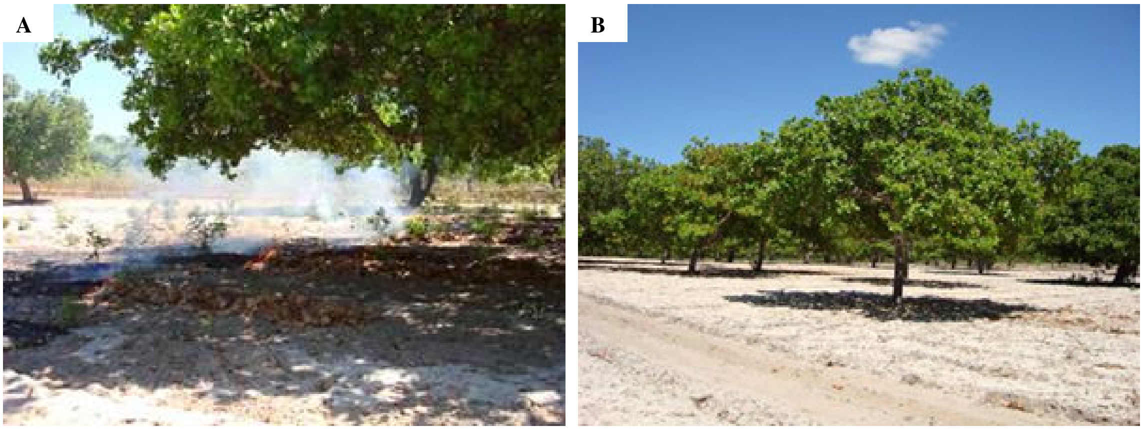


Figure 12. Cashew orchards.

Burning litter fall mass to remove it (A) and a cashew farming system after this practice (B).

5.3 Biomass and energy in cashew systems

Biomass belongs to the most important quantitative indicators of biological productivity within agricultural systems. Biomass is an important storeroom of renewable energy. The total biomass for the dwarf-precocious varied twice as much as that of the common type. Janssens *et al.* 2004 found the total biomass for anacardiaceae to be 29 t/ha in Sérou and 35 t/ha in Dogué (Table 26).

Table 26. Biomass partitioning for cashew tree

Cashew type	**Type of material (t/ha)**			
	Herbaceous[1]	**Wood**[2]	**Cashew fruit**[3]	$\mathbf{B_t}$
Common	2.59	12.76	1.6	16.95
Dwarf-precocious	3.76	29.41	2.1	35.27

[1]Leaves, flowers and twigs; [2]trun; [3]cashew apple and nut;
$\mathbf{B_t}$ = ∑ herbaceous and woody material and cashew fruit.

Biological systems that owe their existence to the photosynthesis conversion process can be seen as a storehouse of solar energy in themselves. Biomass is a versatile renewable energy source and it means that biomass is a non-exhaustible source of energy fed by solar energy. Therefore all forms of biomass can be considered to have the potential to be converted into usable form of energy. Consequently, all parts of a plant e.g. wood, leaf and fruit are considered an energy transfer in potential. In other words, energy is the basic currency of ecosystems. Therefore, an energy measurement is an important tool for better understanding an agricultural system. Additionally, energy is a relevant parameter in studying the sustainability of systems.

The main purpose of an agricultural assessment based on energy measurement is to estimate the total quantity of energy required to directly or indirectly provide a good or service to a final user (Serrano *et al.*, 2003). For the cashew systems, this energy measurement was based on biomass as an energy input within the cashew system and, for example, on the fruit production as an energy output.

Table 27. Biomass partitioning in energy units

Cashew type	**Type of material in J/ha (1.00E+09)**			
	Herbaceous[1]	**Wood**[2]	**Cashew fruit**[3]	$\mathbf{B_t}$
Common	49.20	242.00	6.50	297.70
Dwarf-precocious	71.40	559.00	8.56	638.96

Note: energy values based on Torrico (2006) and UNIFESP (2008)
[1]Leaves, flowers and twigs; [2]trun; [3]cashew apple and nut;
$\mathbf{B_t}$ = ∑ herbaceous and woody material and cashew fruit.

As shown in Table 27, the dwarf-precocious cashew system has a higher capacity to accumulate energy in the form of biomass than the common type system. Among the three forms of biomass, wood accounts for more than 80% of energy in both cases, thus, being the dominant energy storehouse. Additionally, wood is also a source of energy production in the rural and cashew farming systems context. Due to the introduction of the dwarf-precocious types into the cashew orchards, woody material of the common type appears to be used as an additional source of income for the cashew growers. It is important to observe that environmentally, this practice seems to be un-sustainable within the cashew farms due to the excessive pruning observed.

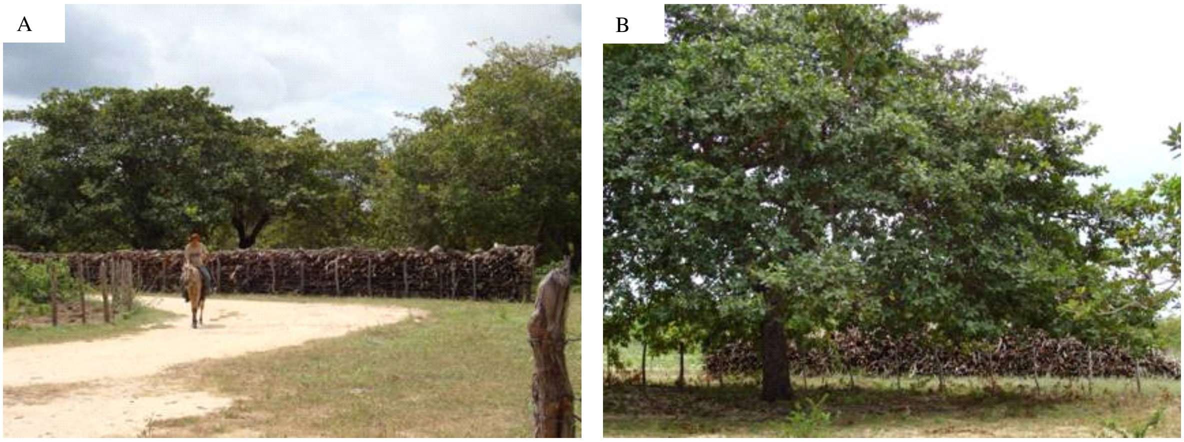


Figure 13. Stock of wood material.
Stocks of trunk and branches of cashew tree (A) and (B).

5.4 Summary and conclusions

The fifth chapter provided information and characteristics of the relevant vegetation (e.g. litter fall and biomass) and structure related to the common and dwarf-precocious types of cashew trees. The main findings discussed in this chapter were:

(i) The main factors presented in this research study in terms of the structure and parameters (e.g. vertical structure) of the cashew trees were: basal area; diameter breast height; crown diameter; crown depth; tree height and; fruit yield. In addition to the fruit yield, the tree measurement factors related to common and dwarf-precocious types suggested a strong modification of the cashew systems. The first visible difference is increased plant density in the dwarf-precocious type orchards. As a positive result of this plant density, an increased yield in the order of 31.63% was observed with the dwarf-precocious type. With regard to the volume of the cashew systems, parameters like eco-volume and bio-volume were taken into account. In both cases, the dwarf-precocious had the highest contribution for eco-volume and bio-volume, respectively. On the other hand, a side-effect of the crowding intensity factor of the dwarf-precocious could lead to a higher incidence of diseases in the system than with the common, less dense type. In spite of a lower Wesenberg factor the dwarf-precocious system occupied more space within a hectare than the common type did.

(ii) A clear seasonal pattern of litter fall was observed during the period studied. On the basis of the results available for the common and dwarf-precocious after two years of observation, the greatest intensity of litter fall was registered during the period of low precipitation (approximately, eight months per year) and the lowest values coincided with the rainy period. In other words, the litter fall pattern may change with climate change. Although leaf fall was the dominant single component of litter fall, the contribution of four other components, especially of reproductive parts (flowers and cashew nuts, for example), were also evident. Leaf fall production from the dwarf-precocious and common types was in the order of 31% and 48%, respectively of the total litter fall. The annual litter fall production from the common type (4.16 t/ha) was 40% less than that for the dwarf-precocious (5.83 t/ha).

(iii) The biomass productivity of cashew tree has been observed and discussed by other researchers (e.g. Janssens *et al.*, 2004; Mulindabigwi, 2006; Baumert, 2008). Furthermore, the results discussed in this study show that total biomass varies by vegetation structure, geographical regions and climate conditions. The total biomass in this study was based on bio-volume results and it was divided in detail through the biomass partitioning (e.g. herbaceous, wood and cashew fruit parts) for the common and dwarf-precocious types. The total biomass production of the dwarf-precocious was twice that of the common type. Nevertheless, it is important to highlight that the problem concerning the calculation of the total biomass due to the extremely limited and incomplete available data on wood density for selected species. The assessment of above-ground biomass is essential for crop conservation and management. In addition to the biomass evaluation, energy values were obtained for the respective biomass components for the different cashew tree types. The results showed that the herbaceous and wood parts seemed to be the major energy sources of the cashew tree. Generally, biomass is the major energy source of agricultural systems.

6 EMERGY EVALUATION OF CASHEW FARMING SYSTEMS

In this section emergy analysis was used to analyse the cashew farming systems. Emergy analysis was deemed appropriate for this analysis due to its ability to transform different types of inputs to a common unit known as solar energy equivalents. As first step, a traditional economic report with monetary flows was prepared. Figure 14 shows an emergy diagram, taking into account amounts of all inputs, e.g. natural and purchased resources. In addition to the inputs, the diagram also shows the outputs, e.g. cashew products, which are considered in the emergy analysis.

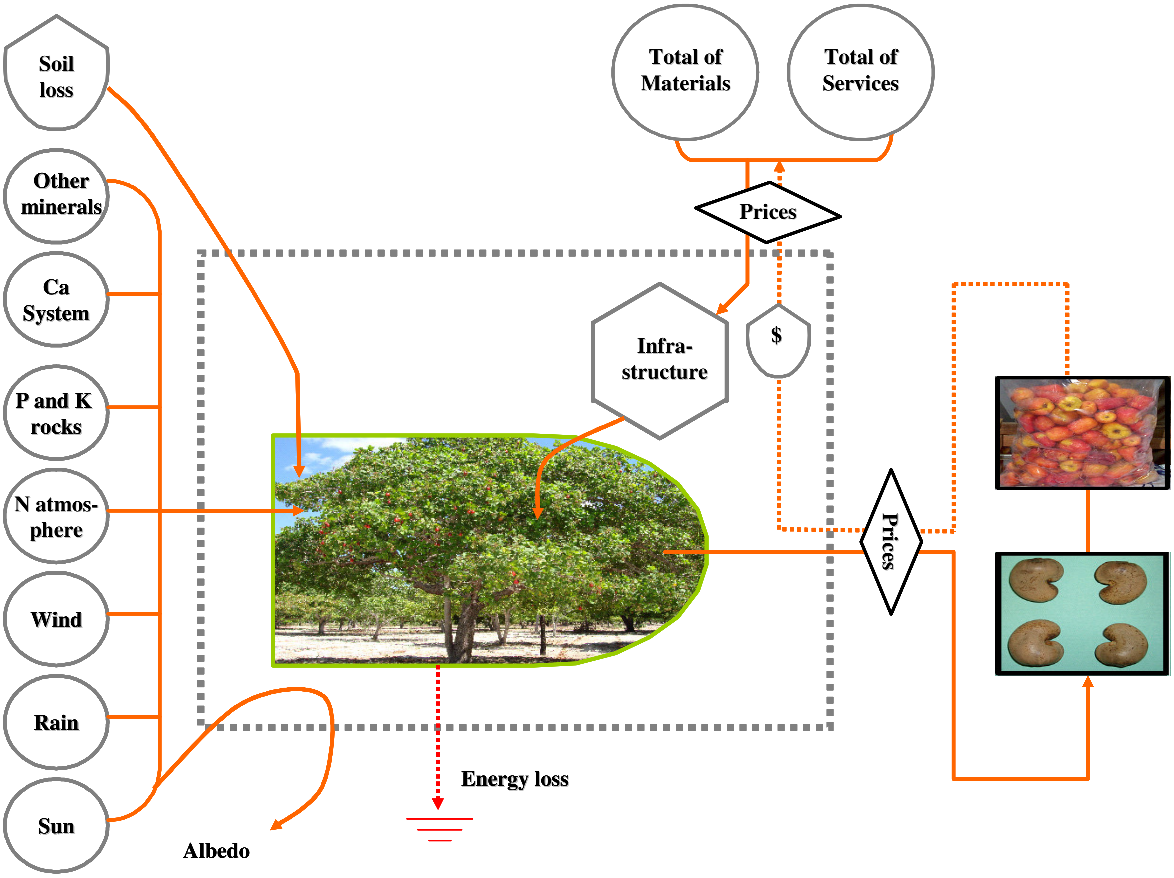


Figure 14. Overview emergy diagram of the cashew farming system.

6.1 Comparing emergy inputs of types of cashew trees in Ceará and Piauí

The emergy evaluation was used in order to analyse cashew farming systems with dwarf-precocious and common types in the states of Ceará and Piauí. All emergy indices were calculated based on one hectare of cultivated area, taking into consideration the environmental (e.g. renewable and non renewable resources) and economic (e.g. materials and services) point of views. After quantifying annual inputs to each system in raw units, e.g. kilograms, dollars, joules, these values were multiplied by specific transformities to incorporate in the huge amounts of solar emjoules required for each input (Appendixes 5; 6; 7; 8). Data for items used in order to calculate the natural and economic contributions were obtained from other papers, cashew crop manuals and from contact with farmers (Chapter 3). Table 28 shows all emergy inputs (renewable-, non-renewable, services and materials) used in cashew production on the basis of solar emjoule per hectare per year (2006).

Renewable resources. Rain input is the primary renewable emergy input per hectare (between 92% to 95%) followed by nitrogen (between 2% to 4%). Additionally, the following inputs were considered in order of increased emergy values: sun, Ca (system), other minerals, K (rocks), P (rocks), wind. In all cases, the contribution of renewable resources was mostly (more 96%) from naturally occurring inputs. From all the cashew systems studied, the common and dwarf-precocious types in Ceará had the greatest contribution of renewable resources.

Non-renewable resources. The soil loss values are based on specific soil erosion[6] calculation (in kg/ha/y) conducted for this study. Soil loss totalled amounts in the order of 3,811.72 kg/ha/y (22,316 × 10E+09 sej/ha/y) for the cashew systems in Ceará and 3,715.11 kg/ha/y (21,750 × 10E+09sej/ha/y) in Piauí, which represented 6% and 7% of the total of this environmental resource for the states of Ceará and Piauí, respectively. David (1988) reported a soil loss value of 8,130 (kg/ha/y) in Madarcos, for a five-year old cashew system with intercropping. Due to the dense cover of the cashew trees, this crop is very efficient in combating soil erosion.

Purchased resources (services and materials). Across the systems, the primary services inputs were manpower (extern and family) and maintenance (infrastructure) costs. Among the

[6] Estimated with the RUSLE equation (Aquino *et al.* 2006; Figueirêdo *et al.* 2007; Farinasso *et al.* 2006; Silva *et al.* 2003).

material inputs pesticides (fungicides and insecticides) and fertilizers (nitrogen, phosphate and potash) were the largest inputs. Among the purchased resources, between 48% to 62% came from pesticides and fertilizers inputs alone.

Table 28. Values of emergy flows (in sej/ha/y) of cashew systems in Ceará and Piauí

Contributions	Cashew Systems – Emergy flow (1E+10 sej/ha/y)			
	Ceará		Piauí	
	Common (A)	Dwarf-precocious (B)	Common (C)	Dwarf-precocious (D)
Renewable - R				
Sun	16	16	16	16
Rain	310,442	310,442	281,027	281,027
Wind	5,339	5,339	2,430	2,430
N (atmosphere)	8,702	12,968	6,603	12,641
P (rocks)	4,302	6,411	3,264	6,249
K (rocks)	1,813	2,701	1,375	2,633
Ca (system)	44	66	33	64
Other minerals	293	437	223	426
Non-renewable - N				
Soil loss	22,316	22,316	21,750	21,750
Total of enviromental resource(1)	**353,266**	**360,695**	**316,721**	**327,236**
Services - S				
Manpower (extern)	6,617	26,468	6,617	26,468
Manpower (family)	1,654	6,617	1,654	6,617
Maintenance (infrastructure)	7,271	7,999	5,090	6,544
Insurance cost	4,945	5,817	4,654	5,381
Communications cost	3,636	3,636	3,054	3,781
Taxes	2,472	2,909	2,181	2,181
Other services	3,636	5,090	2,618	4,072
Materials - M				
Fungicides	2,960	2,960	2,960	2,960
Insecticides	480	480	480	480
Nitrogen fertilizer	13,914	30,920	7,730	30,920
Phosphate fertilizer	40,365	89,700	32,890	89,700
Potash fertilizer	3,942	11,680	3,212	11,680
Electricity	16,934	21,168	13,862	15,725
Petroleum fuels	1,975	2,765	1,382	1,659
Materials for maintenance	9,889	11,634	2,472	5,817
Depreciation	6,857	7,693	5,774	6,544
Total of purchased resource(2)	**127,547**	**237,536**	**96,630**	**220,529**
Total (1+2)	**480,813**	**598,231**	**413,351**	**547,765**

After the emergy inputs were calculated, emergy diagrams summarizing the cashew systems were constructed. Figure 15 shows aggregated system diagrams that illustrate the main components and interactions of the cashew farming systems in both states. The use of environmental energies comes from direct and indirect energy flows. The emergy diagrams illustrate different kinds of energy flowing into an agro-ecosystem. To be able to compare the natural and economic inputs, the amounts of each contribution was calculated and normalised in solar emjoules per hectare per year.

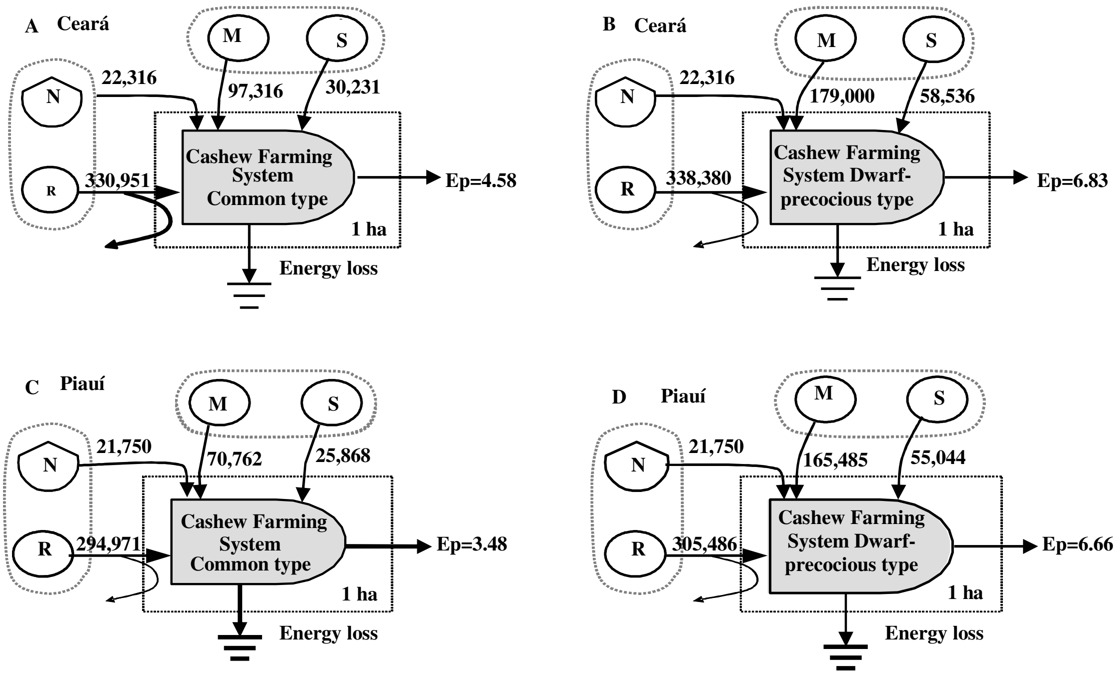


Figure 15. Summary diagrams of the emergy consumption and energy production – Ep.

Note: Emergy consumption (in 1E+10 sej/ha/y) and energy production – Ep (in 1E+09 J/ha/y). The letters R, N, M, S correspond respectively to: Renewable- and Non- renewable resources, Materials, Services.

State of Ceará. The common cashew type registered emergy consumption in the order of 27% and 73% from purchased and environmental contributions, respectively. In the case of the dwarf-precocious cashew, the primary input (61%) came from environmental contribution. On an energy basis (J/ha/y), the output for the common and dwarf-precocious was 4.58E+09 and 6.83E+09, respectively.

State of Piauí. In comparison to the state of Ceará, a similar scenario is seen in the dwarf-precocious in Piauí. In this case, the emergy consumption for purchased and environmental contributions was 40% and 60%, respectively. Meanwhile, the common cashew system received 23% of inputs purchased from a contribution and 77% from the environmental side. The main difference between the common and dwarf-precocious types stemmed from the need for more labour in the dwarf-precocious orchard. Energy output (J/ha/y) for common was 3.48E+09 while for dwarf-precocious, it was 6.66E+09.

Based on Figure 15, a series of performance indices were obtained for the cashew systems, facilitating a better understanding of different aspects in the systems. Table 29 summarizes several emergy indices for the common and dwarf-precocious types of cashew farming, in the states of Ceará and Piauí.

Yield – Y. The yield indicator is based on the total emergy (e.g. renewable, non-renewable and purchased inputs) assigned to the cashew systems (Table 29). The dwarf-precocious type consumed more emergy input than the common type.

Transformity – Tr. This value is obtained by dividing the total emergy input (*Y*) required in a cashew system by the energy of the production. It is used to evaluate the quality of the energy flows, and in general, this value is compared with other energy flows. Transformity can be seen as an inverse value to system efficiency. However, according to the literature, a higher transformity value corresponds to less efficiency in the system in producing the same output. In this study, the transformities values vary from 8.23E+05 to 1.19E+06. Among the transformities shown in Table 30, the lowest values were obtained for eco-farms, and ecological- and organic soybean. This is probably due to the weak dependency on external inputs. In terms of efficiency, the cattle system is the most inefficient (Table 30).

Table 29. Emergy indicators for the cashew farming systems (in units per ha)

	Indicators						
Type of cashew systems	**Y**[1]	**Tr**[2]	**%R**[3]	**EYR**[4]	**EIR**[5]	**ELR**[6]	**EER**[7]
Ceará							
Common	4.81E+15	1.05E+06	69	3.77	0.36	0.45	5.25
Dwarf-precocious	5.98E+15	8.76E+05	57	2.52	0.66	0.77	4.33
Piauí							
Common	4.13E+15	1.19E+06	71	4.28	0.31	0.40	5.92
Dwarf-precocious	5.48E+15	8.23E+05	56	2.48	0.67	0.79	4.62

[1]Total emergy incorporated, [2]Transformity; [3]Renewability; [4]Emergy Yield Ratio; [5]Emergy Investment Ratio; [6]Emergy Load Ratio; [7]Emergy Exchange Ratio

Table 30. Several emergy indicators from literature

General systems	Indicators						
	Y[1]	**Tr**[2]	**%R**[3]	**EYR**[4]	**EIR**[5]	**ELR**[6]	**EER**[7]
Eco-farm[a]	-	4.8E+04	66	5.34	0.23	0.51	1.23
Cattle[a]	-	6.3E+07	41	22.53	0.05	1.41	0.47
Sylvopastoral[a]	-	2.3E+05	41	19.16	0.06	1.44	0.43
Fruit vegetables[a]	-	3.1E+05	15	1.25	4.02	5.66	0.61
Leaf vegetables[a]	-	6.7E+05	12	1.19	5.26	7.28	0.92
Mixed vegetables[a]	-	4.3E+05	13	1.21	4.68	6.52	0.61
Citrus[a]	-	3.4E+05	43	2.78	0.56	1.35	1.91
Ecological soybean[b]	2.57E+15	8.8E+04	46	1.92	1.09	1.19	1.45
Organic soybean[b]	2.39E+15	8.1E+04	42	1.78	1.27	1.40	1.35
Chemical soybean[b]	3.54E+15	1.0E+05	23	1.74	1.35	3.40	2.51
Herbicide soybean[b]	3.80E+15	1.1E+05	21	1.31	3.25	3.70	2.69
Ecological [c]	4.77E+15	2.0E+05	69	3.36	0.4	0.82	0.02
Eco-farm integrated [d]	-	2.8E+05	75	11.9	0.09	-	5.52
Danish agriculture[e]	-	-	-	1.17	5.91	9.67	-

[1]Total emergy incorporated, [2]Transformity; [3]Renewability; [4]Emergy Yield Ratio; [5]Emergy Investment Ratio; [6]Emergy Load Ratio; [7]Emergy Exchange Ratio.
Source: [a]Torrico (2006), [b]Ortega (2001), [c]UNICAMP (2004), [d]Roosevelt-Agostinho (2001), [e]Haden (2003).

Renewability - %R. %R measures the sustainability of the system and it represents the percent of total emergy that comes from renewable resources, e.g. sun, rain, wind, nutrients as nitrogen and minerals. In the long run, systems with higher renewability will prevail if they were able to survive periods of economic stress (Ortega *et al.*, 2004). As compared to the dwarf-precocious cashew, the percentages of renewable resources used were relatively high in the common cashew system in Ceará and Piauí, with 69% and 71%, respectively. This means that in the long run the common cashew is the more sustainable system. Torrico (2006) observed the eco-farm depended on renewable resources for over 66% of its inputs, meaning that is also very sustainable.

Emergy Yield Ratio - EYR. This ratio of the emergy of a product to the emergy of the inputs that are received from economic sources. According to Serrano *et al.* (2003), the EYR value is always greater than one and indicates a competitive system. When the lower value is one, it means that the natural contribution was null. The EYR ratio for the cashew products varied from 2.48 in the dwarf-precocious type to 4.28 in the common one, both in the state of Piauí. The EYR values for the dwarf-precocious cashew are lower than for the common type, meaning that the natural contribution is low as compared to the supplied economic resources. Also EYR values were higher in Piauí than in Ceará in both systems (Table 29).

Emergy Investment Ratio - EIR. This index is the ratio of the emergy feedback from the economy to the emergy inputs of the nature contribution, measuring the demand of monetary investment per unit of product. A low emergy investment ratio means that environmental sources have a relatively higher contribution than economic ones e.g. goods and services. Hence, a lower EIR is associated with lower costs and higher competitiviness in the market. The EIRs for the dwarf-precocious cashew were 0.66 in Ceará and 0.67 in Piauí meaning that this kind of cashew system used more purchased contributions than environmental ones. In comparison to the dwarf-precocious, the common cashew in Ceará and in Piauí reaches larger environmental contribution, being more competitive in terms of costs with EIR values of only 0.36 and 0.31, respectively. EIR values above 3 have been defined by various authors as economically fragile agriculture due to its dependence on purchased inputs from foreign regions. In addition, the EIR can be impacted by political or socio-economical realities (Ulgiati *et al.* 1994).

Environmental Loading Ratio - ELR. This ratio measures the environmental impact of an economic activity. This index is the ratio of non-renewable emergy (N) and economic contribution (M + S) to renewable emergy (R). Environmental loading ratios above 10 suggest a greater stress on the environment and values below 3 have a relatively low environmental impact, whereas values between 3 and 10 are considered to be indicative of moderate impacts (Brown and Ulgiati, 1997). In the case of cashew systems, all the ELRs were less than 3 suggesting a slight impact of economic activities on the local environment. In the case of fruit-, leaf- and mixed vegetables, the ELRs (5.66, 7.28 and 6.52 respectively) were relatively higher indicating some environmental damage most likely from soil erosion and chemical fertilizers, which are very common among these kinds of crops (Table 30).

Emergy Exchange Ratio - EER. The emergy exchange ratio is the ratio of emergy received by the cashew trader to the emergy given to the cashew grower in any economic transaction e.g. a trade or a sale (Torrico, 2006). In 2006, the average transformity of the Brazilian currency has been estimated at 3.11E+12 (sej/US$ equivalent). In the case of the cashew system, it shows they export more emergy than they received through the payment for the products. The worst in terms of emergy exchange are the common and dwarf-precocious types in Piauí (5.92 and 4.62 respectively). In Ceará, the EERs for the dwarf-precocious and common types were 4.33 and 5.25 respectively. The EER shows that the grower does not receive a fair price for the cashew products. Further, the results show that farmers in Piauí are losing more emergy in exchange with the external market than the farmers in Ceará. In this sense, more information about the price of the cashew nut, for example and income of the cashew growers are required.

The cashew grower's main income came from the commercialisation of the raw cashew nuts, which are either exported or processed prior to export. In general, the mean price obtained in this study for the raw cashew nut in 2006 was R$ 0.94 (Table 31). As compared to earlier years, the mean price in 2006 was similar to the value observed in 1997 (R$ 0.92). In other words, over twelve years, the medium price for one kilo of raw cashew nut had a total variation of only 4.44%. The price reached its peak in 1999, when a kilo of raw cashew was sold for R$ 1.39. However, a farmer requires 372 kg cashew nut to reach a legal minimum income in 2006 i.e. thrice as much as 10 years earlier.

Table 31. Price and income evolution of raw cashew nut in Reais (R$)

Year	Minimum income in Brazilian currency[1]	Price of raw cashew nut (kg)[2]	Raw cashew nut per minimum income (kg)
1995	100	0.90	111
1996	112	0.81	138
1997	120	0.92	130
1998	130	1.18	110
1999	136	1.39	98
2000	151	1.10	137
2001	180	0.98	184
2002	200	1.10	182
2003	240	0.99	242
2004	260	1.03[3]	252
2005	300	1.03[3]	291
2006	350	0.94[4]	372

[1]IPEA, 2008a; [2]Secretaria da Agricultura e Pecuária (2004); [3]Average value; [4]This work

The raw cashew nut is the main commercial product of the cashew tree and only a small percentage (15%) of the cashew apples are destined to commercial purposes. Based on general information on the accounts control of the cashew growers collected during the fieldwork, Table 32 shows income values for the cashew systems in North-east Brazil. Better return ratios were obtained from the cashew systems with the dwarf-precocious type, meaning they represented a better income source for the growers. Among cashew systems with common type, the return ratio suggested that the growers in Piauí earned slightly better than the ones in Ceará, confirming the EYR ratios.

Table 32. Net income for cultivated area (per ha) of cashew farming system: 2006

	Ceará		Piauí	
	Common	Dwarf-precocious	Common	Dwarf-precocious
R$ (Real)	166.35	375.00	130.00	273.00
US$ (Dollar)	77.79	175.36	60.79	127.66
Return ratio = sales/costs	1.36	1.65	1.37	1.50

According to the emergy results for the states of Ceará and Piauí, an overview diagram for the cashew farming systems in North-east Brazil is presented. Figure 16 shows the emergy flows i.e. emergy inputs (environmental and purchased contributions) and energy flows (energy produced with cashew products). The overall transformity value for the cashew farming systems in North-east Brazil is 9.85E+05 on average.

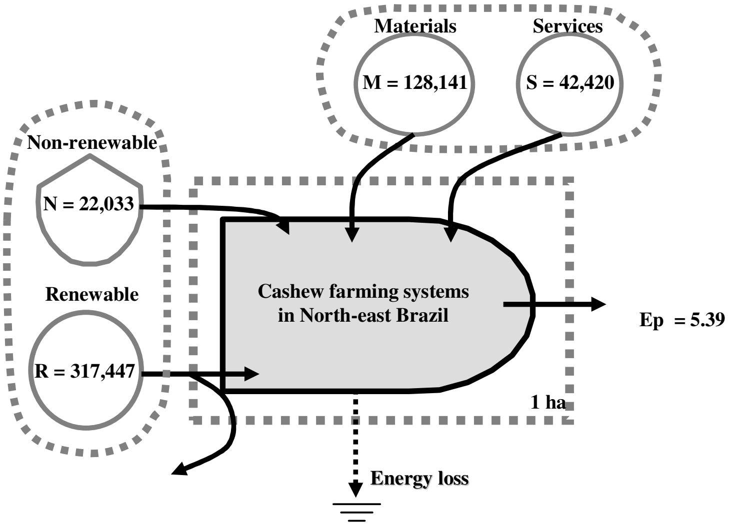


Figure 16. Diagram of emergy and energy flows of the cashew systems in North-east.

Note: Emergy consumption (N+R+M+S) in 1E+10 sej/ha/y and energy produced (Ep) in 1E+09 J/ha/y.

6.2 Emergy comparison between different cashew systems

The emergy analysis in this section was conducted based on the particularities of the seven cashew system types which were described in the fourth chapter (item 4.3). The evaluations were performed in order to gain a detailed and comparative view of the changes in the resource flows of the different types of cashew systems in North-east Brazil. Figure 17 shows the inputs in aggregated form e.g. environmental and purchased contributions included in the emergy analysis.

On the environmental side (Figure 17), the renewable input had the most variability, ranging from 45% to 78% in innovative and homestead groups, respectively. The amount of non-renewable emergy which was measured in the form of soil erosion was assumed to be equal among the systems. On the purchased side, the largest contribution came from material contribution with a variation between 9% to homestead and 46% to irrigated cashew system types, respectively.

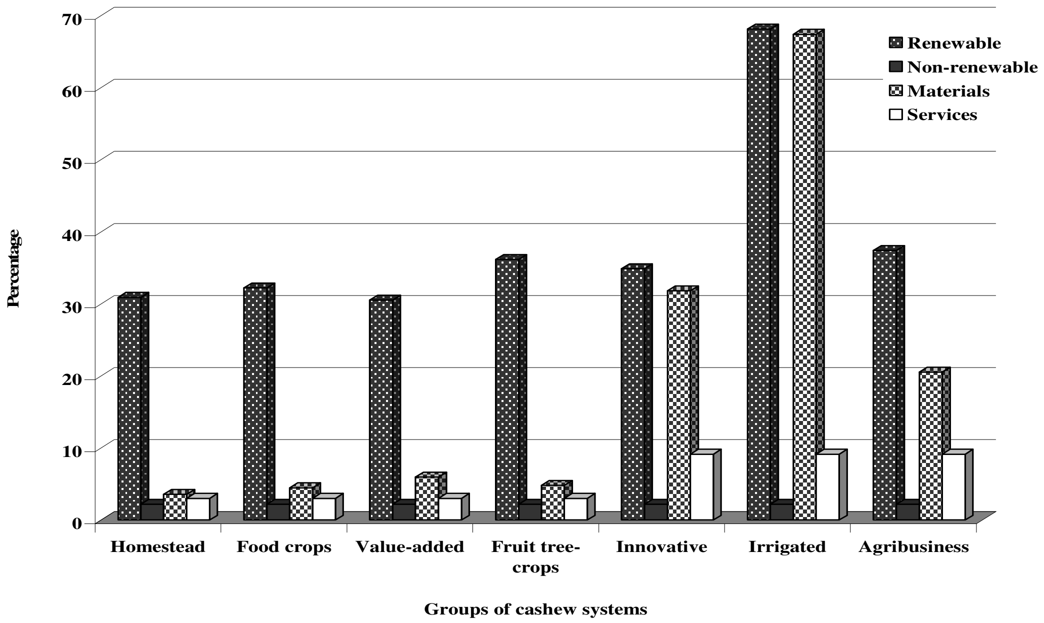


Figure 17. Emergy inputs of the seven clusters cashew systems in North-east Brazil.
Note: in 1.00E+14 sej/ha/y.

Several emergy-based indices and ratios were calculated in order to indicate performances within the ecological and economic context of the cashew systems. Table 33 presents emergy indices for the seven clusters or cashew systems.

Table 33. Emergy indicators for the seven cashew systems

	Indicators						
Farming system groups	**Y[1]**	**Tr[2]**	**%R[3]**	**EYR[4]**	**EIR[5]**	**ELR[6]**	**EER[7]**
(A) Homestead	3.97E+15	7.71E+05	78	6.03	0.20	0.28	3.10
(B) Food crops	4.19E+15	9.46E+05	77	5.59	0.22	0.30	4.89
(C) Value-added	4.16E+15	1.26E+09	73	4.68	0.27	0.36	6.36
(D) Fruit tree-crops	4.62E+15	9.28E+08	78	5.88	0.20	0.28	4.61
(E) Innovative	7.39E+15	1.95E+09	47	2.01	0.99	1.12	8.07
(F) Irrigated	1.40E+16	1.46E+06	49	2.01	1.09	1.06	8.39
(G)Agribusiness	6.79E+15	4.33E+06	55	2.40	0.71	0.81	9.34

[1]Total emergy incorporated, [2]Transformity; [3]Renewability; [4]Emergy Yield Ratio; [5]Emergy Investment Ratio; [6]Emergy Load Ratio; [7]Emergy Exchange Ratio

Table 34 provides a better understanding about the performances among groups with least and highest emergy indices related to the emergy indicators. This performance assessment is alone between the seven groups of cashew farming systems which are characterized in this study. Groups receiving similar emergy indicator values were therefore placed at the same level.

Table 34. General appraisal of the seven groups of cashew farming systems

Indicators (Keyword)	Farming system groups						
	Homestead	Food crops	Value-added	Fruit tree-crops	Innovative	Irrigated	Agribusiness
Y = I+F (Emergy consumed)……………........	-					+	
Tr = Y/E (Dependency on external input)……..	-				+		
%R = R/Y (Ecologically sustainable)…………...	+			+	-		
EYR = Y/F (Environmental contribution)………..	+				-	-	
EIR = F/I (Economically competitive)…………	+			+	-		
ELR = (N+F)/R (Environmental damage)………..........	-			-	+		
EER = Y / Total Emergy Income (Income on emergy basis).…………..	+						-

I=∑Renewable(R) and Non-renewable resources (N); F=∑Materials (M) and Services(S); Y – Total emergy (inputs), E – Total energy (output-products).

- Least; + highest.

6.3 Summary and conclusions

The sixth chapter provided general information on inputs and outputs related to the cashew farming systems. To make a comparison of different farming systems possible, an emergy analysis was required. First, the common and dwarf-precocious cashew systems were compared in Ceará and Piauí. Then, seven major cashew systems were evaluated.

Emergy findings allowed the characterisation of the four different systems of cashew production in the states of Ceará and Piauí with two types of cashew trees analysed. Undoubtedly, the dwarf-precocious type required more inputs than the common type. With regard to environmental contributions, there was a slight difference between the common and dwarf-precocious types across both states. The strongest difference was found in the purchased contributions among the cashew systems. The dwarf-precocious was observed to have a higher dependence on materials and services.

Nevertheless, apart from the economic point of view, cashew farming systems based on dwarf-precocious can be interpreted as a positive change in the cashew orchards in North-east Brazil. An input equilibrium between environmental and economic contributions means an improvement in cashew productivity and consequently, the stability of the Brazilian cashew production on the international market. In addition, high productivity means high profitability for the growers, mainly smallholders. In Ceará, the net income for the growers with dwarf-precocious was 125% more than those who grew the common type. In comparison to the growers in Piauí, the net income improved with 110%.

As discussed in this chapter, it is important to note that among all cashew systems, cashew growers do not receive a fair price for their cashew products (e.g. cashew apple and nut). When comparing the states, the farmers in Piauí are losing more emergy in emergy exchange with the market than the farmers in Ceará. In addition to the emergy exchange ratio (EER), the raw cashew nut market price was also observed. In 2006, the market price was just 4% more than in 1995. This means that, the cashew grower needed to produce three times more output in 2006 than in 1995 in order to reach the minimum national income.

With regard to the seven types of clusters, it was necessary to quantify the total of inputs required for each cashew system in order to obtain a better comprehension of them. The studied systems were: homestead; food crops; value-added; fruit tree-crops; innovative; irrigated and agribusiness. Among the systems, the lowest emergy input value (here in units of 1.00E+14 sej/ha/y) was observed in the homestead group (39.72), while the irrigated group registered the highest value (146.95).

The irrigated group had also the highest value in terms of output (9.58E+09 J/ha/y), calculated on an energy basis. Between all groups, the agribusiness systems the lowest output value (1.57E+09).

The emergy indices indicated that the homestead group showed the most positive characteristics of the groups, being more ecologically sustainable, more economically competitive and having higher environmental contribution as well as higher income on an emergy basis. With respect to these characteristics, the innovative group posted the worst results. Nonetheless, it is important to underline that these results were used to establish a comparison among the cashew systems *sensu stricto*. More studies on the differences between overall cashew based agricultural systems would be very appropriate.

In this study, the emergy methodology provided different points of view, providing important information on the cashew system structures in the states of Ceará and Piauí. However, successive emergy analyses should be conducted in the long-term. The long run perspectives of this analysis can inform local public policy makers in designing sustainable pathways for agricultural systems in general.

7 GENERAL CONCLUSIONS AND RECOMMENDATIONS

Considering the great agricultural importance of the cashew productivity to the growers in North-east Brazil, more challenges emerge and sustainable strategies are required to address the issues of sustainable economic growth. More than half of the national cashew output comes from small and medium farming systems and thousands of hectares of these farms are found in the agricultural area in the north-eastern region, particularly in the states of Ceará and Piauí. This study aimed to:

(i) To present general information about the cashew farmers and their systems; identify the factors that affect cashew nut productivity and; to characterize different types of cashew systems in the two states. These objectives serve to identify differences that allowing clustering of homogeneous groups among the cashew farmers.

(ii) To evaluate the litter fall among the common and the dwarf-precocious cashew systems and to evaluate the relationship between the biomass and annual productivity of cashew crops. The objective was to provide information about the vegetation composition and structure of the common and dwarf-precocious types and information on cashew productivity.

(iii) To compare inputs and outputs in the cashew systems by using a common yardstick. To compare efficiency of the use of natural and economic resources in these systems. The objective is to evaluate the pathway of inputs and outputs in the cashew farming systems in both states and among the groups as well as to evaluate their performance by ecological and economical standards.

The following conclusions and recommendations are proposed:

7.1 Conclusions

(i) Cashew farmers in the states of Ceará and Piauí had different characteristics and a cluster analysis helped to identify seven homogenous groups from the large number of cashew farming systems observed in this study. According to the cluster analysis, the Food-crops and Value-added were the most representative groups among the cashew systems in the North-east Brazil.

(ii) Cashew nut production North-east Brazil was variable across climatic (precipitation and sunhours), geographic (distance to the port), agronomic conditions (cashew experience of the farmer, fertilizer application, livestock ownership) and market condition (middleman).

(iii) The common cashew tree had higher litter fall production. Additionally, the common type also showed better dynamic stability of litter fall production.

(iv) The dwarf-precocious cashew tree demonstrated greater biomass production and accumulated more energy in terms of biomass partitioning. Beside this, higher cashew production was observed in the dwarf-precocious type.

(v) The energetic assessment of inputs and outputs of farming systems is a viable tool to qualify and quantify the environmental and economic functioning of agricultural ecosystems. The environmental comparison becomes even more convincing when solar transformity is used as a common yardstick.

(vi) The homestead cashew farming system outyielded all other systems in terms of environmental performance and sustainability. Nevertheless, the fruit-tree crops group seemed to have a higher economic potential in the North-east. The higher cashew yield of the Irrigated model could only be achieved at the expense of higher ELR (Emergy Load Ratio) and EER (Emergy Exchange Ratio).

7.2 Recommendations

(i) More systematic records of the resource allocation of the growers into their farming systems would provide a better understanding of the allocation processes functioning.

(ii) More information about the actual management practiced in the cashew orchards is necessary for a better knowledge of the farming systems.

(iii) Unproductive cashew trees should be eliminated and a selected material, either common or dwarf-precocious must be provided for the replanting and recycling of cashew biomass into the orchards.

(iv) More and frequent cashew tree measurement (e.g. plant inventory) should be provided.

(v) Researchers and technical agents need to join forces to better understand the needs of the farmers, and thereby develop accessible technological solutions, which fit into the cashew system setting.

(vi) The non-cashew production activities should also be submitted to an environmental/energetic appraisal. Finally, the introduction between the cashew systems and their companion components should be highlighted.

8 REFERENCES

A

ACLAND, J.D., 1971. East Africa crops: an introduction to the production of field and plantation crops in Kenya, Tanzania and Uganda. London: Food Agricultural Organization.

AGNOLONI, M., GIULIANI, F., 1977. Cashew cultivation. Library of Tropical Agriculture, Ministry of Foreign Affairs. Institute Agronomic Per L'Olhemare. 168 pp.

AGUIAR, M. de J.N. (coord.), SOUSA NETO, N.C. de, BRAGA, C.C., BRITO, J.I.B. de, SILVA, E.D.V., SILVA, F.B.R., BURGOS, N., VAREJÃO-SILVA, M.A., COSTA, C.A.R. da, 2000. Zoneamento pedoclimático para a cultura do cajueiro (Anacardium occidentale L.) no Nordeste do Brasil e Norte de Minas Gerais. Fortaleza: Embrapa Agroindústria Tropical/Recife: Embrapa-CNPS-ERP-NE. Boletim de Pesquisa, 27. 30 pp.

ALGARVE, V.R., CAVALCANTI, I.F.A., 1994. Características da circulação atmosférica associadas à ocorrência de geadas no sul do Brasil. Congresso Brasileiro de Meteorologia, 8:545-547. Belo Horizonte-MG. Anais II.

ALMEIDA, M.B., SOARES, F. A., 1995. A indústria de castanha de caju: situação atual e perspectivas. Fortaleza: SINDICAJU.

ALVES, J.M.B., 1997. Aspectos climatológicos do nordeste brasileiro com ênfase na região semi-árida: principais causas da variedade pluviométrica interanual. 1st Brazilian Rainwater Catchment Systems Conference. Proceedings, Petrolina, Empresa Brasileira de Pesquisa Agropecuária.

ALVIM, P. de T., KOZLOWSKI, T. T., (eds.) 1977. Ecophysiology of tropical crops. Academic Press. New York: San Francisco, London. ISBN 0-12-055650-2.

ANDERSON, S., NEWELL, R., 2003. Simplified marginal effects in discrete choice models. Resources for the future.Discussion paper 03-38. 9pp. Washington D.C.

ANDRADE, de C., 2000. Representações do calor em Teresina – Pi. Trabalho realizado como requisito para conclusão de mestrado em ciências geográficas pela Universidade Federal de Pernambuco. Recife.

ANDRADE, M. C. O., 1999. Atlas escolar de Pernambuco. Espaço, geo-histórico e cultural, Recife.

ANDRADE, R. A., 2004. Evolução da cultura do caju no Brasil. Available at www.todafruta.com.br.

ANDRADE-LIMA, D., 1977. Preservation of the flora of northeastern Brazil. In Prance, G. T. and Elias, T. S. (Eds.), extinction is forever: threatened and endangered species of plants in the Americas and their significance in ecosystems today and in the future. New York Botanical Garden, Bronx. Pp. 234-239.

ANDRADE-LIMA, D. 1981. The caatinga dominium. Revista Brasileira de Botanica 4: Pp.149-153.

AQUINO, C.M.S., OLIVEIRA, J.G.B., SALES, M.C.L., 2006. Estimativa da erosividade das chuvas nas terras (R) secas do Estado do Piauí. Revista Ciência Agronômica, v.37, n°3, p.287-291, 6pp.

AZAM-ALI, S.H., JUDGE, E.C., 2001. Small-scale cashew nut processing. FAO, Rome, 70 pp.

B

BAILEY, L.H., 1958. The standard encyclopedia of horticulture. Nem York: MacMillan, Vol. 1, 17th edition, 1200pp.

BARROS, L.M., CRISÓSTOMO, J.R., 1995. Melhoramento genético do cajueiro. In: Araújo, J.P.P. e Silva, V.V. Cajucultura: Modernas Técnicas de Produção. EMBRAPA\CNPAT, Fortaleza, p.73-96.

BARROS, L.M., PAIVA, J.R. de, CAVALCANTI, J.J.V., ALVES, R.E., LIMA, A.C., 2002. BRS 189 dwarf cashew clone cultivar. Crop Breeding and Applied Biotechnology, v. 2, n° 1, p. 157-158. Brazilian Society of Plant Breeding.

BASTOS, C., 1994. Dicionário histórico e geográfico do estado do Piauí. Fundação cultural Monsenhor Chaves, Teresina.

BAUMERT, S., 2008. Charakterisierung der agrarischen Landnutzungssysteme in Ketou, Benin. Diplomarbeit, Institut für Nutzpflanzenwissenschaften und Ressourcenschutz, Abteilung Tropischer Pflanzenbau der Universität Bonn, pp. 102.

BECKER, B., 1997. Sustainability assessment: a review of values, concepts, and methodological approaches. CGIAR (Consultative Group on International Agricultural Research). Washington D.C., United States, 70 pp.

BOLLING, C, SUAREZ, N.R., 2001. The Brazilian sugar cane industry: recent developments. Economic Research Service/USDA: September 2001, 5 pp.

BRANT, S., 2007. Assessing vulnerability to drought in Ceará, Northeast Brazil. Thesis of Master of Science in Natural Resources and Environment. University of Michigan. 55pp.

BRIENZA, S.jun., DENICH, M., Fölster,H., Vlek, P.L.G., 2000. Litter fall and litter in enriched fallow with fast growing trees in the eastern Amazon of Brazil. German-Brazilian Workshop on Neotropical Ecosystems, Hamburg, Germany: 939-942 pp.

BROWN M.T., 2001. Folio #3: Emergy of ecosystems. Handbook of emergy evaluation: A compendium of data for emergy computation issued a series of folios. University of Florida: Gainesville, F.I., Center for Environmental Policy.

BROWN, M. T., ULGIATI, S., 1997. Emergy-based indices and ratios to evaluate sustainability: monitoring economies and technology toward environmentally sound innovation. Ecological Engineering 9, 51-69.

BROWN, M.T., ULGIATI, S., 1999. Emergy Evaluation of the Biosphere and Natural Capital. Ambio 28, vol. 6, pp.486-493.

BROWN, M. T., ULGIATI, S., 2002. Emergy evaluations and environmental loading of electricity production systems. Journal of Cleaner Production 10, 321-334.

BROWN, S. 1997. Estimating biomass and biomass change of tropical forests. FAO Forestry Paper 134. A forest resources assessment publication, Rome.

BRUIN, J. 2006. newtest: command to compute new test. UCLA: Academic Technology Services, Statistical Consulting Group. http://www.ats.ucla.edu/stat/stata/ado/analysis/.

BUENO FIGUEIREDO, F. A., ANDRADE FIGUEIREDO, R., SÁNCHEZ, C. G., SARAIVA SÁNCHEZ, E. M., 2007. Combustion and Gasification of Cashew Nut (Anarcardium Occidentale L.) Shell: Liquid, Solid and Gas Products. 8 p. Available at: http:// www.cori.unicamp.br/centenario2008/completos.

C

CALDEIRON, S. S. (ed.), 1992. Recursos naturais e meio ambiente: uma visão do Brasil. IBGE/Departamento de Recursos Naturais e Estudos Ambientais. Rio de Janeiro, 145 pp. ISBN: 85-240-0453-3.

CARDOSO, J.E., SANTOS, A.A. dos, FREIRE, F.C.O., VIANA, F. M. P., VIDAL, J.C., OLIVEIRA, J.N., UCHOA, C.N., 2002. Monitoramento de doenças na cultura do cajueiro. Fortaleza: Embrapa Agroindústria Tropical.

CAVALCANTI, I.A, 1982: Um estudo sobre as interações entre os sistemas de circulação de escala sinótica e circulações locais. INPE 2494 TDL/097.

CAVALCANTI, J. J. V., 1998. Inventário dos recursos florestais da Mata Atlântica Anacardium occidentale – Caju. UNICAMP São Paulo.

CAVALCANTI, J. J. V., 2003. O Cajueiro: exploração, perspectivas e potencialidades no âmbito da Mata Atlântica. In Sustentável Mata Atlântica: A exploração de seus recursos florestais (SIMOES, L. L. and LINO, C. F., eds.). 2ª Edição. São Paulo: Editora SENAC, pp. 55-70.

CAVALLET, O., 2004. Análise emergética da piscicultura integrada à criação de suínos e de pesquepagues. Dissertação de mestrado. Faculdade de Engenharia de Alimentos. Unicamp. 156 pp.

CHANDER, K., GOYAL, S., NANDAL, D.P., KAPOOR, K.K., 1998. Soil organic matter, microbial biomass and enzyme activities in a tropical agroforestry system. Biol Fertil Soils 27: 168-172 pp.

COELHO, M.R., SANTOS, H.G. dos, SILVA, E.F. da, AGLIO, M.L.D., 2002. O recurso natural solo. In: C.V. Manzatto, E. de Freitas Junior and J.R.R. Peres, eds. Uso agrícola dos solos brasileiros. pp. 1–11. Embrapa Solos, Rio de Janeiro, Brazil.

COIMBRA-FILHO, A. F., CÂMARA, I. G., 1996. Os Limites originais do bioma Mata Atlântica na região nordeste do Brasil. Rio de Janeiro: Fundação Brasileira para Publ. / Field Mus. Nat. Hist., Zool. Serie: 10. Pp.187-195.

CONTI, J. B., 1995. Proposta de metodologia de estudo aplicada ao nordeste Brasileiro. Tese de Livre-Docente apresentada ao Departamento de Geografia da Faculdade de Filosofia, Letras e Ciências Humanas da Universidade de São Paulo. São Paulo-SP, Brazil.

CONWAY, G. R., 1983. Agroecosystem analysis. London: Imperial College of Science and Technology.

COPELAND, H.F., 1961. Observations on the reproductive structure of Anacardium occidentale. Phytomorphology: 315-325 pp.

CRISÓSTOMO, J. R., ALMEIDA, J.I.L., GADELHA, J.W.R. and FELIPE, E. M., 1992. Orientação para o plantio de cajueiro em relação aos pontos cardeais. Comunicado Técnico, n° 3. Fortaleza: Banco do Nordeste do Brasil S.A.

CRISÓSTOMO, L.A., SANTOS, F.J.S., OLIVEIRA, V.H., RAIJ, B. V., BERNARDI, A. C.C., SILVA, C.A., SOARES, I., 2001. Cultivo do cajueiro anão precoce: aspectos fitotécnicos com ênfase na adubação e na irrigação. Circular técnica n° 10: EMBRAPA, 8 pp.

CRISÓSTOMO, L. A., PIMENTEL, C.R.M., MIRANDA, F.R., OLIVEIRA, V.H., 2007. Fertilizing for high yield and quality. Tropical Fruits of Brazil. International Potash Institute: Switzerland. IPI Bulletim n° 18. Pp. 50-69. ISBN: 978-3-9523243-1-8.

D

DAMODARAN, V.K., ABRAHAM, J., ALEXANDER, K.M., 1965. The morphology and biology of the cashew flower (Anacardium occidentale L). 1. Flowering habit, flowering season, morphology of flower and sex ratio. Agric. Res. J. Kerala 3:23-28.

DAVID, W. P., 1988. Soil and water conservation planning: policy issues and recommendations. Journal of Philippine Development, number Twenty-Six, Volume XV, N° 1. 84 pp.

DAVIS, K., 1999. Cashew. ECHO, 17391. USA. 8 pp.

DECKERS, J., CUNDALL, E., SHOMARI, S.H., NGATUNGA, A., BASSI, G., 2001. 7. Nut crops – cashew: Anacardium occidentale L. In Crop production in tropical Africa. Edited by Romain H. Raemaekers. DGIC – Directorate General for International Co-operation. Ministry of Foreign Affairs, External Trade and International Co-operation. Brussels: Belgium. ISBN 90-806822-1-7. Pp. 691-715.

DENG, Z., 2007. Vegetation dynamics in Oueme Basin, Benin, West-Africa. University of Bonn. Germany: Bonn. Ph. D. Dissertation: Cuvillier Verlag Göttingen, 154 pp

E

EITEN, G., 1983. Classificação da vegetação do Brasil. CNPq/Coordenação Editorial, Brasília.

EMBRAPA – Embresa Brasileira de Pesquisa Agropecuária, 1999. Centro Nacional de Pesquisa de Solos. Sistema brasileiro de classificação de solos. Brasília, DF: Embrapa Produção de Informação. 412 pp.

EMBRAPA – Empresa Brasileira de Pesquisa Agropecuária, 2002. Caju: fitossanidade. Fortaleza: Embrapa Agroindústria Tropical (Série frutas do Brasil).

EMBRAPA – Empresa Brasileira de Pesquisa Agropecuária, 2008. Precocious Dwarf Cashew Tree. Fortaleza: Embrapa Agroindústria Tropical. Available at: http://www.embrapa.br/english/portfolio/fruits%20and%20vege/precocious/

F

FAEC – Federação da Agricultura e Pecuária do Estado do Ceará, 2004. Modernização da cajucultura do Ceará. Fortaleza, Junho de 2004.

FAO – Food and Agriculture Organization of the United Nations, 2001. Cactus (Opuntia spp.) as forage. Plant Production and Protection. Paper 169, ISBN 92-5-104705-7. Rome.

FAO – Food and Agriculture Organization of the United Nations, 2004. Fertilizer use by crop in Brazil. First Version, published by FAO, Rome.

FAO - Food and Agriculture Organization of the United Nations, 2007. FAO production database: http://faostat.fao.org/. Statistic Division.

FAO – Food and Agriculture Organization of the United Nations, 2008. FAO Statistics Division. Available at: http://faostat.fao.org.

FARIA, D, PACIÊNCIA, M.L.B., DIXO, M., LAPS, R.R., BAUMGARTEN, J., 2007. The response of ferns, frogs, lizards, birds and bats in forest fragments and shade cacao plantations of two contrasting landscapes in the Atlantic forest, Brazil. Biodiversity and Conservation, DOI: 10.1007/s10531-007-9189-z.

FARINASSO, M., CARVALHO JÚNIOR, O.A., GUIMARÃES, R. F., GOMES, R.A.T., RAMOS, V.M., 2006. Avaliação qualitativa do potencial de erosão laminar em grandes áreas por meio da EUPS - equação universal de perdas de solos utilizando novas metodologias em sig para os cálculos dos seus fatores na região do Alto PArnaíba -PI - MA. Revista Brasileira de Geomorfologia, Ano 7, n° 2, 73-85.

FIGUEIRÊDO, M.C.B., TEIXEIRA, A.S., ARAÚJO, L.F.P., ROSA, M. F., PAULINO, W.D., MOTA, S., ARAÚJO, J.C., 2007. Avaliação da vulnerabilidade ambiental de reservatórios à eutrofização. Artigo técnico, Vol. 12, n° 4, pp. 399-409.

FILHO, T. 2002. Teresina meu amor. COMEPI, 4° ed. Teresina.

FINAN, T., 1999. Drought and Demagoguery: A Political ecology of climate variability in Northeast Brazil. Paper from workshop on: "Public, Philosophy, Environment, and Social Justice. New York. October: 21-22.

FUNCEME – Fundação Cearense de Meteorologia e Recursos Hídricos, 2008. Monitoramento hidroambiental. Available at: http://www.funceme.br/DEPAM/index.htm

FUNDAÇÃO SOS MATA ATLÂNTICA, INPE – Instituto Nacional de Pesquisas Espaciais, 1993. Atlas da evolução dos remanescentes florestais e ecossistemas associados do domínio da Mata Atlântica no período 1985-1990. São Paulo.

FRUITROP, 2001. The cultivation of cashew. Research and methods. Suplement n° 81. 3 pp.

G

GIAMPIETRO, M., BUKKENS, S.G.F. and PIMENTEL, D., 1994. Models of energy analysis to assess the performance of food systems. Agricultural Systems 45, pp. 19-41

GIRÃO, R., 1964. História econômica geral e do Brasil. Publicação da Escola de Administração do Ceará. Tipografia Minerva: Fortaleza, 258 pp.

GOLDEMBERG, J., 2002. Energy and sustainable development. Conferência: Sustentabilidade na geração e uso de energia no Brasil nos próximos 20 anos. Unicamp: 18-20/02/2002. Available at: http://www.cgu.reiunicamp.br/energia2020/programacao.html

GREENE, W.H. 1997. Econometric analysis. 3. ed. New Jersey: Prentice-Hall.

GRIFFITH, B., 2001. Efficient fertilizer use: Maximum economic yield strategies. Available at: http://www.imcglobal.com/general/efumanual/pdf/mey.pdf.

GRUNDON, N.J., 1999. Overview of Australian Cashew Literature. Available at: http://www.clw.csiro.au/publications/techica199/tr25-99.pdf

GUJARATI, D. N., 2000. Econometria básica. São Paulo: MAKRON Books, 845 p.

H

HADEN, A.C., 2002. Emergy analysis of food production at S and S homestead Farm. S and S Center for Sustainable Agriculture 2143 Lopez Sound Rd. Lopez Island, WA 98261, pp. 33.

HADEN, A. C., 2003. Emergy evaluations of Denmark and Danisch agriculture: assessing the limits of agricultural systems to power society. Centre for Sustainable Agriculture: Swedish University of Agricultural Sciences. Uppsala.

HAHN, E.D., Soyer, R., 2008. Probit and logit models: differences in the multivariate realm. Salisbury University, the Georgy Washington University, USA. 14 pp. Available at: http:// home.gwu.edu/

HAU, J.L., BAKSHI, B.R., 2004. Promise and Problems of Emergy Analysis. Ecological Modelling 178(1-2), 215-225.

HERFORT, J., HILGER, T. H., GAISER, T., BARROS, I. de, SABOYA, L.M.F., FERREIRA, L.G.R., LEIHNER, D. E., 2000. Adaptation of the crop growth models EPIC and almanac to local cowpea and maize cropping systems in Northeast Brazil. German-Brazilian Workshop on Neotropical Ecosystems – Achievements and Prospects of Cooperative Research. Hamburg, September 3-8.

HOVELIUS, K., 1997. Energy, exergy and emergy analysis of biomass production. Report 222. Institutionen för lantbruksteknik. Swedish University of Agricultural Sciences.

HOVELIUS, K. 1999. Energy and Exergy Analysis of bioenergy crops for rapesedd oil methyl ester production. Report 237. Licentiate Thesis - Swedish University for Agricultural Sciences, Department of Agricultural Engineering, Uppsala, Sweden.

HUANG, S.L., LAI, H.Y., LEE, C.L., 2001. Energy hierarchy and urban landscape system. Elsevier, Landscape and Urban Planning 53, 145-161.

I

IBGE – Fundação Instituto Brasileiro de Geografia e Estatística, 1988. Geografia do Brasil: Região Centro-Oeste. Diretoria de Geociência. Rio de Janeiro: Volume 1, 268 pp. ISBN – 85-240-0277-8.

IBGE – Fundação Instituto Brasileiro de Geografia e Estatística, 1989. Geografia do Brasil: Região Norte. Diretoria de Geociência. Rio de Janeiro: Volume 3, 308 pp. ISBN: 85-240-0330-8.

IBGE – Fundação Instituto Brasileiro de Geografia e Estatística, 1990. Geografia do Brasil: Região Sul. Diretoria de Geociência. Rio de Janeiro: Volume 2, 420 pp. ISBN: 85-240-0317-0.

IBGE - Instituto Brasileiro de Geografia e Estatística, 2003. Produção da extração vegetal e da sivicultura. Comunicação social. Novembro de 2003, 5 pp.

IBGE – Instituto Brasileiro de Geografia e Estatística, 2004. Contas regionais do Brasil: Produto Interno Bruto do Brasil a preços correntes, segundo as Grandes Regiões e Unidades da Federação - 2001-2004. Available at November 2007, under: http://www.ibge.gov.br/home/estatistica/economia/contasregionais/2004/tabela02.pdf

IBGE - Instituto Brasileiro de Geografia e Estatística, 2005. Anuário estatístico do Brasil. Rio de Janeiro: Vol. 65. ISSN: 0100 1299, pp. 1-1 and 8 - 39.

IBGE – Instituto Brasileiro de Geografia e Estatística, 2007a. Censo agropecuário 2006. Sistema IBGE de Recuperação Automática – SIDRA. Available at: http://www.ibge.gov.br/bda/acervo.

IBGE – Instituto Brasileiro de Geografia e Estatística, 2007b. Brasil em números=Brazil in figures. Centro de Documentação e Disseminação de Informações. Rio de Janeiro, v.15, 349 pp.

IBGE – Instituto Brasileiro de Geografia e Estatística, 2007c. Censo demográfico: população residente em 1° de abril de 2007. Available at November 2007, under: http://www.ibge.gov.br/home/estatistica/populacao/contagem2007/populacao_ufs_05102007.pdf

IBGE – Instituto Brasileiro de Geografia e Estatística, 2007d. Censo agropecuário 2006 – resultados preliminares. Rio de Janeiro: 146 pp. ISSN 0103-6157.

IBGE – Instituto Brasileiro de Geografia e Estatística, 2007e. Censo agropecuário 1996. Sistema IBGE de Recuperação Automática – SIDRA. Available: http://www.ibge.gov.br/bda/acervo.

IBGE – Instituto Brasileiro de Geografia e Estatística, 2008a. Pesquisa pecuária municipal. Banco de Dados Agregados. Available at: www.ibge.gov.br

IBGE – Instituto Brasileiro de Geografia e Estatística, 2008b. O Brasil município por município. IBGE cidades @. Available at: www.ibge.gov.br

INMET – Instituto Nacional de Meteorologia, 2007. Dados climáticos no período de 2004 à 2006. Ministério da Agricultura, Pecuária e Abastecimento. Website: http://www.inmet.gov.br/

IPEA – Intituto de Pesquisa Econômica Aplicada, 2008. Dados macroeconômicos: contas nacionais. PIB agropecuário/valor adicionado/preços básicos/variação do PIB (%). Available at: www.ipeadata.gov.br

IPEA – Intituto de Pesquisa Econômica Aplicada, 2008a. Dados macroeconômicos: salário e renda. Available at: www.ipeadata.gov.br

IPECE – Instituto de Pesquisa e Estratégia Econômica do Ceará, 2005. Fisiografia: posição e extensão do território. Anuário Estatístico do Ceará. Fortaleza.

IPECE – Instituto de Pesquisa e Estratégia Econômica do Ceará, 2006. Fisiografia: posição e extensão do território: Limites-Brasil, Nordeste e Ceará. Anuário Estatístico do Ceará. Fortaleza.

ITC – International Trade Centre, 2002. International Trade Centre Common Fund for Commodities: "Cashew pricing policy and export taxation: the Indian experience". Cotonou, Bénin.

J

JALES, M.Q.M., JANK, M. S., YAO, S., CARTER, C. A., 2006. Agriculture in Brazil and China: challenges and opportunities. Institut for the Integration of Latin American and the Caribbean. Buenos Aires: 1ªed., 56 pp.

JANSSENS, M.J.J., MULINDABIGWI, V., POHLAN, J., TORRICO, J.C., 2004. Eco-volume and bio-surface interplay with the universal scaling laws both in biology and in the Mata Atlântica. Seminário: A Cooperação Brasil-Alemanha no Programa Mata Atlântica. Teresópolis, 29 November-3 December.

JANSSENS, M.J.J., DENG, Z., SONWA, D., TORRICO, J.C.MULINdaBIGWI, V., POHLAN, A.J., 2006. Relating agro-climax of orchards to eco-climax of natural vegetation. 7th International Symposium on Modelling in Fruit Research and Orchard Management; Copenhagen, 20-24 June.

JENDE, O. (2005). The conservation process of Chiapas coffee plantations through agroforestry into timber production and its ecological implications. Dissertation, 120 pp. Germany: University of Bonn/ARTS Program.

JOHNSON, D., 1973. The botany, origin and spread of cashew, Anacardium occidentale L. J. Plant.Crops1:1-7.

K

KAIMOWITZ, D. and SMITH, J, 1999. Soybean technology and the loss of natural vegetation in Brazil and Bolivia. Agricultural Technologies and Tropical Deforestation. ©CAB International 2001. 17pp.

KEELING, H.C., PHILLIPS, O.L., 2007. The global relationship between forest productivity and biomass. Global Ecology and Biogeography, 16. Journal compilation: Blackwell Publishing Ltd. PP. 618-631.

KLEMENZ, D., 2004. Gedanken zu der wirtschaftlichen und sozialen Nutzung von Cashew in Nordostbrasilien. Fachhochschule Köln: Institut für Produktion.

KOHLSCHMITT, S., 2004. The integrated utilization of the cashew plant in Brazil – Fruit Juice and its Sales Opportunities on the German Fruit Juice Market. Diplomarbeit, August 2004. 88 pp.

KOUSKY, V.E., 1979: Frontal influences on Northeast Brazil. Mon. Wea.Rev., 107, 1142-1153.

KOUSKY, V.E., 1980: Diurnal rainfall variation in Northeast Brazil. Mon. Weather Rev, 108, 488-498.

KROL, M. and BRONSTERT, A., 2007. Regional integrated modelling of climate change impacts on natural resources and resource usage in semi-Arid Northeast Brazil. Environmental Modelling and Software 22, 259-268.

KUEH, R. J. H., LIM, M. T., 1999. Forest biomass estimation in air hitam forest reserve. 7p. Available: http://www.geocities.com/EnchantedForest/Palace/1170/biomass.html

L

LEITE, L. A. S., 1994. A agroindústria do caju no Brasil: políticas públicas e transformações econômicas. Fortaleza: EMBRAPA – CNPAT.

LIMA, V. P. M. S., 1988. Origem e distribuição. In: Revista Brasileira de Economia. A cultura do cajueiro no Nordeste do Brasil. Fortaleza: Banco do Nordeste do Brasil, cap 1, p. 1-13.

M

MACEDO, I.C., Nogueira, L.A.H., 2005. Biocombustíveis. Cadernos NAE, publicação do Núcleo de Assuntos Estratégicos da Presidência da República, N° 2.

MAGALHÃES, A. R., Glantz, M. H., 1992. Socio-economic impacts of climate variates and policy response in Brazil. United Nations Environment Programme, Secretaria do Planejamento do Estado do Ceará e Fundação Esquel do Brasil.

MAIA, G. N., 2004. Caatinga – árvores e arbustos e suas utilidades. São Paulo: D and Z Computacão gráfica e Editora, 413 pp.

MAIA, J.G.S., ANDRADE, E.H.A., ZOGHBI, M.G.B., 2000. Volatile constituents of the leaves, fruits and flowers of cashew (Anacardium occidentale L.). Academic Press: Journal of Food Composition and Analysis 13, 227- 232.

MARASENI, T.N., COCKFIELD, G., APAN, A. and MATHERS. N. 2006. Estimation of shrub biomass: development and evaluation of allometric models leading to innovative teaching methods. International Journal of Business and Management Education ISSN 1832-0236. 16 pp.

MARROQUÍN, F., 2008. Sustainable management of fruit orchards in the Soconusco, Chiapas, Mexico – Intercropping cash and trap crops. Thesis, 109 pp. University of Bonn, Germany.

MASAWE, P. A. L., CUNDALL, E. P., CALIGARI, P. D. S, 1996. Distribution of cashew flower sex-types between clones and sides of tree canopies in Tanzania. Annals of Botany, v.78, p.553-558.

MCKNIGHT, T. L., HESS, D., 2000. Climate zones and types: the Köppen system, physical geography: A Landscape Appreciation. Upper Saddle River, NJ: Prentice Hall, pp. 200-1. ISBN 0-13-020263-0.

MEILWES, S., 2006. Betriebliche Situation der Cashewproduzenten in Nordost Brasilien. Fachhochschule Köln, University of Applied Sciences Cologne. Masterarbeit.

MELO, C. S., 1998. Subsídios à gestão empresarial na busca de competitividade: o caso dos derivados do caju. Fortaleza: UFC/CCA/DEA (Dissertação de mestrado).

MELO, Q. M. S. (ed.), 2002. Caju fitossanidade. Fortaleza: Embrapa Agroindústria Tropical / Brasília: EMbrapa Informação Tecnológica. 62 pp. Frutas do Brasil, 26. ISBN 85-7383-154-5.

MOREIRA, A.A., 2002.O cajueiro:vida, usos e estórias. Ceará: Fortaleza. 160 pp. ISBN: 85-902704-1-6

MORTON, J. F., 1987. Cashew apple in fruits of warm climates. Miami: Fl, 239-240. Available at: http://www.hort.purdue.edu/newcrop/morton/cashew_apple.html

MULINDABIGWI, V., 2006. Influence des systèmes agraires sur l'utilisation des terroirs, la séquestration de carbone et la sécurité alimentaire dans le bassin versant de l'Ouémé supérieur au Bénin. University of Bonn. Germany: Bonn. Ph. D. Dissertation: Cuvillier Verlag Göttingen 232 pp.

N

NAIR, M.K., BHASKARA RAO, E.V.V., NAMBIAR, K.K.N., NAMBIAR, M.C., 1979. Cashew (Anacardium occidentale L.). Central Plantation Crops Research Institute. India: Kerala, 169 pp.

NELSON, D.R., 2005. The Public and private sides of vulnerability to drought, an applied model of participatory planning in Ceará, Brazil. The University of Arizona, Tuscon, p. 217.

NIMER, E., 1979. Climatologia do Brasil. SUPREN/IBGE. Volume 4.

NIMER, E., 1989. Climatologia do Brasil. IBGE/Departamento de Recursos Naturais e Estudos Ambientais. Rio de Janeiro: 2ª Ed., 422 pp. ISBN: 85-240-0282-4.

NOGUEIRA, E.M.; FEARNSIDE, P. M.; NELSON, B.W.; FRANÇA, M.B., 2007. Wood density in forests of Brazil's 'arc of deforestation': Implications for biomass and flux of carbon from land-use change in Amazonia. Centre National de la Recherche Scientifique. 36 pp.

O

OAKLEY, P., 1980. Participation in development in N. E. Brazil. Community Development Journal and Oxford University Press, Vol. 15: 10-22, N° 1. England: Oxford: January.

ODUM, H. T., 1996. Environmental accounting: emergy and environmental decision making. John Wiley, New York, 370 pp.

ODUM, H. T., 2000. Emergy accounting. Environmental Engineering Sciences. University of Florida, Gainesville, Florida, USA. 20 pp.

ODUM, H.T., 2000a. Folio #2, Emergy of global processes. Handbook of Emergy Evaluation, Center for Environmental Policy, Environmental Engineering Sciences, University of Florida, Gainesville. 30 pp.

OHLER, J. G., 1979. Cashew. Amsterdam Koninklijk Institute voor de Tropen.

OLIVEIRA, V.H., SANTOS, F.J.S., CRISÓSTOMO, L.A., SAUNDERS, L.C.U, 2001. Manejo da irrigação na produção integrada do cajueiro anão precoce. Circular técnica n° 15: EMBRAPA, 7 pp.

OLIVEIRA, F.N.S. (ed.), 2004. Sistema de produção para manejo do cajueiro comum e recuperação de pomares improdutivos. Fortaleza: Embrapa Agroindústria Tropical.

OLIVEIRA, V.H. (ed.), 2003. Normas técnicas e documentos de acompanhamento da produção integrada de caju. Embrapa Agroindústria Tropical. Ceará: Fortaleza. 75 pp. ISSN 1677-1915.

OLIVEIRA, V.H., 2008. Cashew crop. Revista Brasileira de Fruticultura, vol. 30 n° 1, São Paulo: Jaboticabal.

ORTEGA, E.; MILLER, M.; ANAMI, M.H.; BESKOW, P.R., 2001. From emergy analysis to public policy: Soybean in Brazil. FEA/Unicamp, CP 6121 Campinas 13083-970, SP, Brasil. 18 pp.

ORTEGA, E., CAVALETT, O., BONIFÁCIO, R., WATANABE, M., 2004. Expanded emergy analysis of soybean production in Brazil. In Ortega, E. and Ulgiati, S. (editors):

Proceeding of IV Bienal International Workshop “Advances in Energy Studies”. Unicamp, Campinas, SP, Brazil. June 16-19, 285-299 pp.

ORTEGA, E., RIBERA, E.C., 2005. Símbolos usados nos diagramas de sistemas de metodologia emergética. Unicam: Faculdade de Engenharia de Alimentos/Laboratório de Engenharia Ecológica e Informática Aplicada. São Paulo. 25pp.

P

PARENTE, J.I.G., ALBUQUERQUE, J.J.L., 1972. Adubação mineral do cajueiro (Anacardium occidentale L.) em Pacajus, no litoral cearense. Ciência e Cultura, v.24, p. 372-375.

PENG, C-Y. J., LEE, K. L., INGERSOLL, G.M., 2002. An introduction to logistic regression analysis and reporting. The Journal of Education Research, 2002. 14 pp.

PERVANCHON, F., BOCKSTALLER, C., GIRARDIN, P., 2002. Assessment of energy use in arable farming systems by means of an agro-ecological indicator: the energy indicator. Agricultural Systems, 72, pp. 149-172.

PLUCKNETT, D. L., SMITH, N. J. H., 1986. Sustaining agricultural yields. BioSrience 36 (1): 40-45.

PRADO JÚNIOR, C., 1974. Histórica econômica do Brasil. Editora brasiliense: São Paulo, 355 pp.

PRETTY J., 1995. Regenerating agriculture: policies and practice for sustainability and self-reliance. Earthscan, London, National Academy Press, Washington, 320 pp.

Q

QUEIROZ, J. A., 2005. Produção de serrapilheira e ciclagem de nutrients na cultura do cajueiro anão precoce. Fortaleza: Centro de Ciências Agrárias, Universidade Federal do Ceará, 2005. Dissertação de mestrado.

R

RAO, V.B., HADA, K., 1994: Annual variation of rainfall over Brazil and atmospheric circulation over South America. Anais do VIII Congresso Brasileiro de Meteorologia, 1994: Volume 2, 81-84

RAO, V.N.M., HASSAN, M. V., 1957. Preliminary studies on the floral biology of cashew. Indian J. Agric. Sci. 27: 277-288.

RAO, V.N.M., HASSAN, M.V., 1956. A note on the variations in seed characters of cashew (Anacardium occidentale L.). Indian J. Agric. Sci. 26:211-216.

RATHKE, G., 2002. Die Energiebilanz des Winterrapsanbaus– Methodische Grundlagen u. Anwendung. Sherry L. Brandt-Williams August 2001, Revised September 2002. Center for Environmental Policy, Environmental Engineering Sciences Available from: http://landw.uni-halle.de/lfak/inst/iap/energiebil.pdf.

RATTER, J. A., RIBEIRO, J. F., BRIDGEWATER, S., 1997. The Brazilian cerrado vegetation and threats to its biodiversity. Edinburgh Journal of Botany 80: 223-230.

RIBOT, J.C., NAJAM, A., WATSON, G., RIBOT, J.C., MAGALHÃES, A.R., PANAGIDES, S.S., 1996. Climate variation, vulnerability and sustainable development in the semi-arid tropics, in ribot. J.C., Magalhães, A.R. and Panagides, S.S. (eds.), Climate Variability, Climate Change and Social Vulnerability in the Semi-arid Tropics, Cambridge University Press, Cambridge, pp. 13-54.

RODRIGUES, G.S., BROWN, M.T., ODUM, H. T., 2002. Sameframe – sustainability assessment methodology framework. In: 3rd Biennial International Workshop Advances in Energy Studies: Reconsidering de Importance of Energy. Porto Venere. Advances in Energy Studies. Padova, IT:SGEEditoriali Padova, v.3., pp. 605-612.

RODRIGUES, J., 2001. Estudos Regionais do Piauí. Haley S/A, 2°ED, Teresina, 1.p.

ROMARIZ, D. A., 1974. Aspectos da vegetação do Brasil. Instituto Brasileiro de Desenvolvimento Florestal (IBDF), Rio de Janeiro.

ROSENGARTEN, F. Jr., 1984 The book of edible nuts. Walker and Company, New York.

ROOSEVELT-AGOSTINHO, F.D., 2001. Uso de análise emergética e sistema de informações geográficas no estudo de pequenas propriedades agrícolas. Master Thesis. Unicamp. Laboratório de Engenharia Ecológica e Informática Aplicada – LEIA

S

SECRETARIA DA AGRICULTURA E PECUÁRIA – SEAGRI, 2004. Informacoes agrícolas: a agricultura na economia do Ceará. Fortaleza-Ceará: 29 pp.

SELLERS, W.D., (1965). Phisysical climatology. The University of Chicago Press, EUA. 272.

SERRANO, S., DOMINGOS, T., SIMÕES, A., 2003. Energy and emergy analysis of meat and dairy production in intensive, extensive and biological systems. Instituto Superior Técnico. Portugal: Lisboa.

SIETZ, D., UNTIED, B., WALKENHORST, O., LÜDEKE, M.K.B., MERTINS, G., PETSCHEL-HELD, G., SCHELLNHUBER, H.J., 2006. Smallholder agriculture in Northeast Brazil: assessing heterogeneous human-environmental dynamics. Department of Geography, Deutschhausstraβe 10, 35037 Marburg, Germany.

SILVA, J. M. C., TABARELLI, M., 2000. Trees species impoverishment and the future flora of the Atlantic Forest of Northeast Brazil. Nature – International weekly journal of science n° 404, 72.

SILVA, J.R.C., DIAS, A.S., 2003. Rainfall erosivity in Fortaleza, Ceará State, Brazil. II - Correlation with the rainfall coeficient and updating of factor R for the years 1962 to 2000. Revista Brasileira, Ciências Solo, 27: 347-354.

SOMBRA OLIVEIRA, F. N. (ed.), 2004. Sistema de produção para manejo do cajueiro comum e recuperação de pomares improdutivos. Sistemas de produção 2. Embrapa: Fortaleza-Ceará.

SONWA, D. J., 2004. Biomass management and diversification within cocoa agroforests in the humid forest zone of Southern Cameroon. University of Bonn. Germany: Bonn. Ph. D. Dissertation, 112 pp.

STRAHLER, A. H., STRAHLER, A. N., 2005. Physical geography: science and systems of the human environment. Wiley, New York, 794pp.

T

TAVARES, S. 1959. Madeiras do nordeste do Brasil. Universidade Rural de Pernambuco. Monografia, Recife. 5: 9-171.

THE CLIPPER, 1994. US Cashew kernel imports remain strong.

TOLLA, T. D., 2004. Effects of moisture conditions and management on production of cashew: A case study in the Lower Limpopo basin, Mozambique. International Institute for Geo-Information Science and Earth Observation Enschede, the Netherlands. Dissertation: 95 pp.

TONI, F., 2001. The Role of land tenure in strategies to reduce vulnerability to droughts in northeastern Brazil. Universidade Federal do Rio Grande do Norte, Brazil. 13 pp.

TOPPER, C.P. and KASUGA, L.J. (eds.), 2003. Knowledge transfer for sustainable tree crop development: a case history of the Tanzanian Integrated Cashew Management Programme. BioHybrids Agrisystems Ltd. ISBN 0-9545192-0-5.

TORRICO, J.C., 2006. Balancing natural and agricultural systems in the Atlantic rainforest of Brazil. University of Bonn. Germany: Bonn. Ph. D. Dissertation, 154 pp.

U

UKIDWE, N. U., BAKSHI, B. R., 2004. Thermodynamic input-output analysis of natural and economic capital – implications for LCA and supply chain management. Department of Chemical and Biomolecular Engineering, The Ohio State University, Columbus, OH 43210. 11 pp.

ULGIATI, S, ODUM, H.T., BASTIANONI, S., 1994. Emergy use, environmental loading and sustainability: an emergy analysis of Italy. Ecological Modelling 73, 215-268.

UNICAMP, 2004. A importância da análise emergética em sistemas Agro-ecológicos. IV Workshop internacional em Estudos Avançados Sobre Energia. Ecologia e Energia na América Latina. 16-19 de Junho de 2004.

UNICAMP, 2008. TABELA DE TRANSFORMIDADES - (emergia / Joule, emergia / kg, emergia/US$) de recursos naturais, insumos industriais e produtos de ecossistemas. Available at: http://www.unicamp.br/fea/ortega/curso/transformid.htm.

UNIVERSITY OF TEXAS LIBRARIES, 2008. Brazil: natural vegetation 1977. Available at: http://www.lib.utexas.edu/maps/americas/brazil_veg_1977.jpg

UNIFESP – Universidade Federal de São Paulo, 2008. Tabela de composição química dos alimentos. Departamento de informática em saúde. Available at: http://www.unifesp.br/dis/servicos/nutri/

V

VIEIRA, R.F., 1999. Conservation of medicinal and aromatic plants in Brazil. Reprinted from: Perspectives on new crops and new uses. J. Janick (ed.), ASHS Press, Alexandria, V.A. 8 pp.

W

WEINSTEIN, B. 1983. The Amazon rubber boom, 1850-1920. Stanford University Press: 356 pp.

WIKIPEDIA – A Enciclopedia Libre 2007a. Ceará. Available at: http://gl.wikipedia.org/wiki/Cear%C3%A1

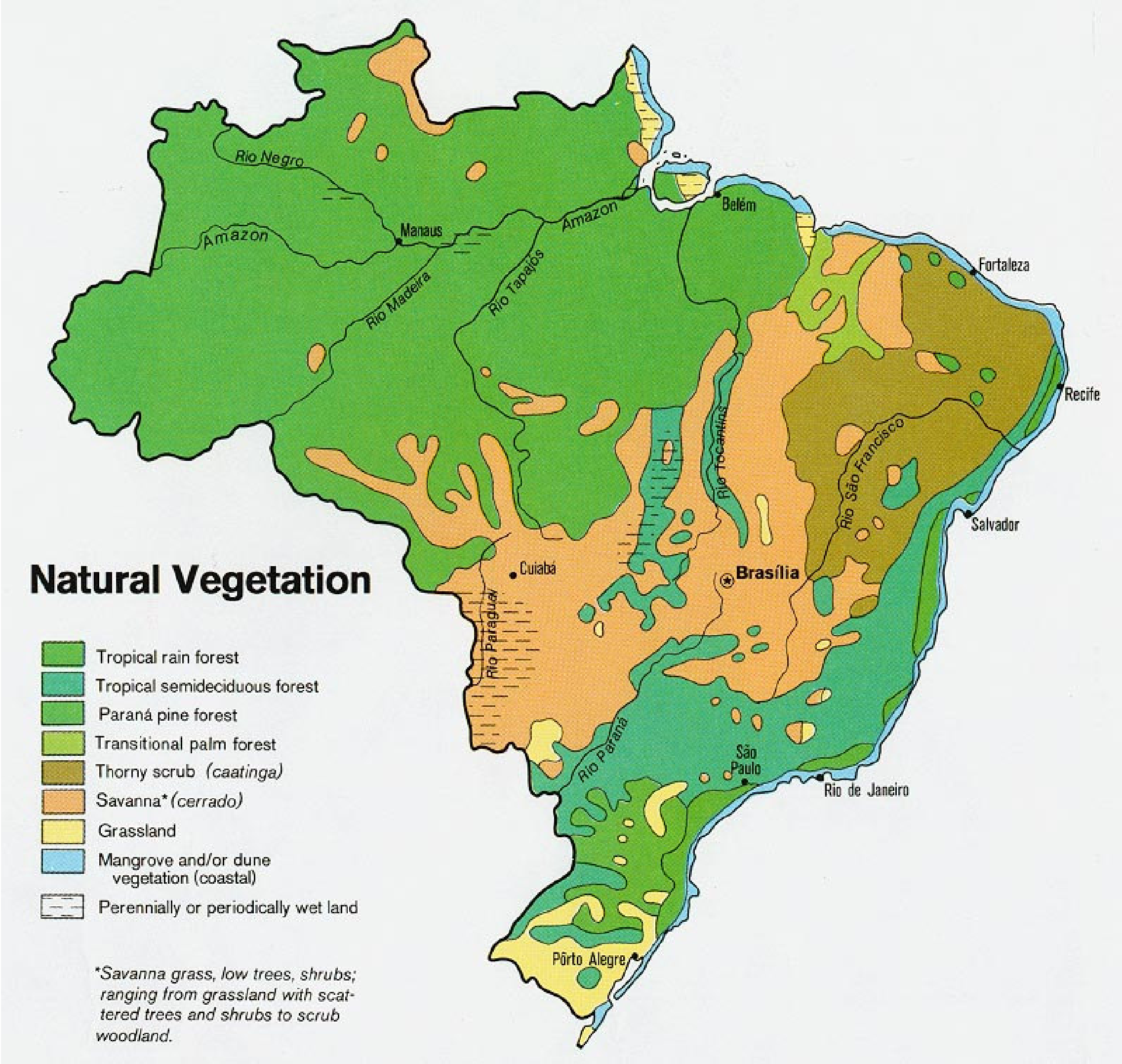
WIKIPEDIA – A Enciclopedia Libre 2007b. Piauí. Available at: http://pt.wikipedia.org/wiki/Piau%C3%AD

WOOLDRIDGE, J. M., 2002. Econometric analysis of cross section and panel data. Massachusetts Institute of Techonology/MIT. London, England. 752 pp. ISBN-10:0-262-23219-7

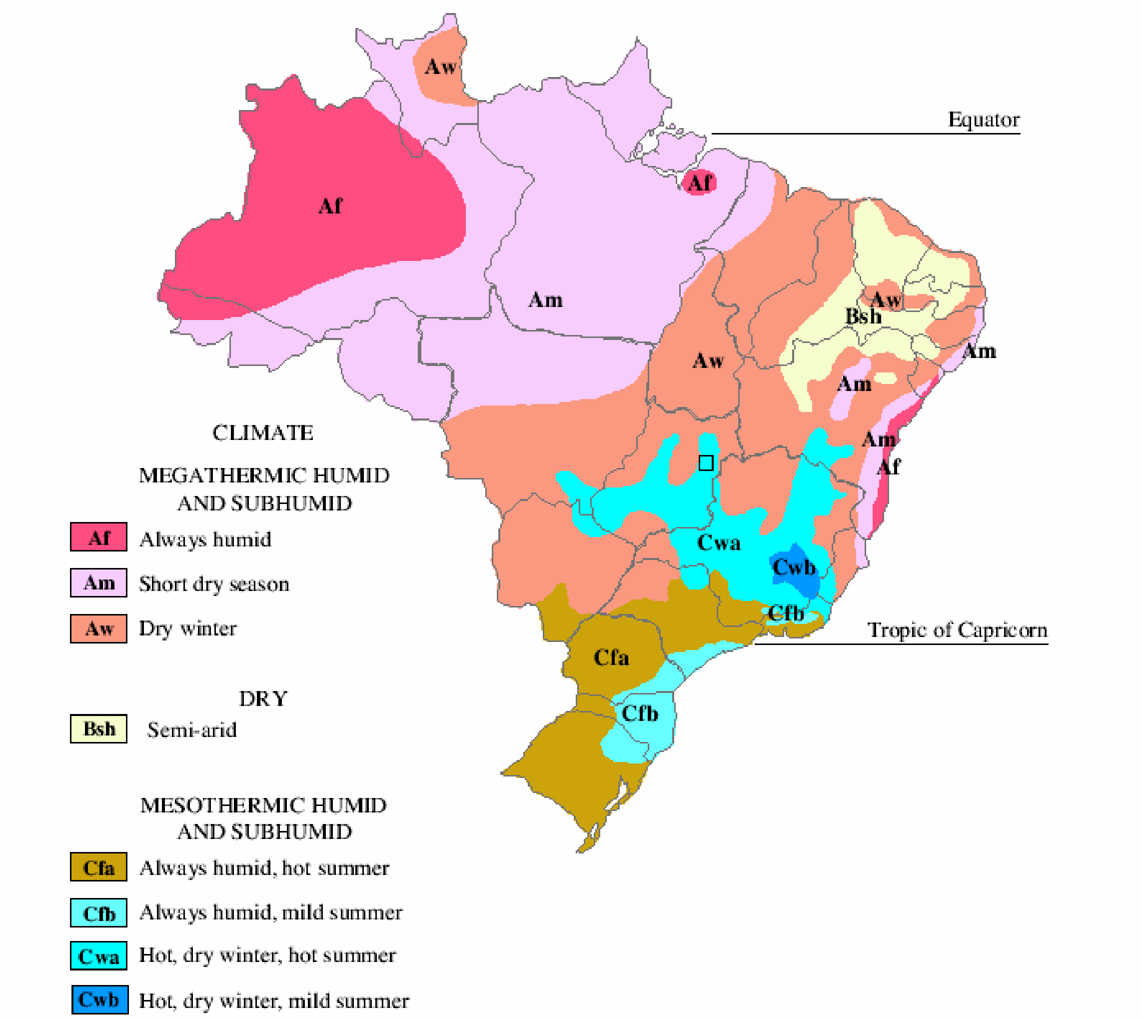
WORLD BANK, 1977. Northeast Brazil: Appraisal of Ceará Rural Development Project - Ibiapaba. Washington, D.C.: Report n° 1580a-BR. August 22, 1977. 151p.

9 APPENDIXES

Appendix 1. Map of natural vegetation in Brazil (University of Texas Libraries, 2008).



Appendix 2. Map of climate types in Brazil (FAO 2004).



Appendix 3. Questionnaire (Page n° 1/6).

Universität of Bonn – Germany

Landwirtschaftliche Fakultät
Institut für Gartenbauwissenschaft
Abteilung Tropischer Pflanzenbau

Survey to Identify the Structure of the Cashew Producers in North- East Brazil under Recognition of their Socio-Economic Environment

Sandra Callado
University of Bonn

GENERAL INFORMATIONS

Questionnaire number :	Date of Interview:
Name of Farmer or Interviewee:	Telephone number:
Municipality:	Community:
Name of Interviewer: :	Telephone number::
Company of Interviewer:	Occupation:

FARMER LOCALIZATION´S

Latitude (S)
Longitude (W)
Elevation (m):

LAND USE AND ITS DISTRIBUTION

FARMING SYSTEM STRUTUCTURE	INFRASTRUCTURE
Total Area: (ha)	Energy: ( ) Yes ( )No
Cultivated Area: (ha)	Water: ( ) Yes ( )No
Area of Preservation: (ha)	Is that enough?: ( ) Yes ( )No

APRIL, 2007

Questionnaire (Page n° 2/6).

I PART – Information of the Farmer and its Farming System

0. Identification of the farmer in terms of its occupation in the farming system:

( ) Landlord ( ) Tenant ( ) Partner ( ) Resident worker ( ) Settler

1. If the Landlord does not live in the property, how frequently he visits his farming system?

( ) Daily ( ) Weekly ( ) Each two weeks ( ) Monthly

The following questions must be answer in accordance with the position of the Interviewee in the farm system:

2. Gender: ( ) Male ( ) Female Age: _______

3. ( ) Can read and write ( ) Can not read or can not write

4. Education:

( ) Completed primary school ( ) Uncompleted primary school

( ) Secondary school ( ) College ( ) Higher level

5. Number of the Family's Farmer: _______ Women ________ Men

6. Besides crop cultivation and livestock production, do you have any other sources of income? ( ) Yes ( ) No

7. If *yes*, specify? ____________________________________

8. How much money do you get monthly from the agricultural activity?

( ) from $ 164 to $ 491 ( ) from $ 492 to $ 984

( ) from $ 985 to 1,476 ( ) from $ 1,477 to $ 1,968

( ) greater than $ 1,968

9. Do you make accounting control? ( ) Yes ( ) No

10. Has the Owner more than one property? ( ) Yes ( ) No

11. What kind of labour is predominant in the farming system?

( ) Family labour force ( ) Regular employees

12. How many regular employees' workers do you have in the Farm System? _____________

13. Do you have seasonal labourer? ( ) Yes ( ) No

If *yes*, when and how much?

Time (Month)	Amount (Persons per month)

14. Are you member of?

( ) Syndicate ( ) Cooperative ( ) Cashew farmers association
( ) Local farmers association ( ) Political group ( ) Any member

Questionnaire (Page n° 3/6).

II PART – Identification and Characterization of the Farm System

15. What kind of asset ownership is used in the cashew farming system?

Materials

Spraying	( ) Yes ( ) No
Weeding	( ) Yes ( ) No
Ploughing	( ) Yes ( ) No
Grating	( ) Yes ( ) No
Irrigation pump	( ) Yes ( ) No
Cultivator	( ) Yes ( ) No
Transport	
Vehicle	( ) Yes ( ) No
Cart pulled by animal	( ) Yes ( ) No

16. List the improvements that you have in your property:

	Amount	Size (m^2)
Main house		
Worker's house		
Corral		
Storage place		
Others		

17. Do you have livestock ownership? ( ) Yes ( ) No

18. If ***Yes***, which? ( ) Beef cattle ( ) Dairy cows ( ) Goats/sheep ( ) Chickens/ducks ( ) fish ( ) pigs ( ) others

19. Besides cashew cultivation, do you have any other crop? ( ) Yes ( ) No

20. If ***Yes***, fill the table below:

Crop	Area (ha)	Production (kg/y)	Productivity (kg/ha)

Questionnaire (Page n° 4/6).

21. Complete the table below with agricultural information's about the cultivations that exist in the farm system:
<u>TP</u> - Time to Plant (for the permanent culture)
<u>TC</u>- Time for Cultivation
<u>TH</u> – Time to Harvest

Crop	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Set	Oct	Nov	Dec

22. How many years do you cultivate the cashew culture (years of experience with cashew farming system)? ___________________

23. What kind of cashew tree do you have as crop?
( ) Dwarf-precocious cashew ( ) Common ( ) the both kind
Details – Common: _______________ Dwarf-precocious: _________________

24. Complete the next table with the following questions:

Type of cashew tree	Area (hectare)	Production (kilo/hectare)
Common		
Dwarf-precocious cashew		

25. Do you have any irrigated cashew crop area?
( ) Yes ( ) No
If ***yes***, how many hectare? __________

26. List in the table below all your management activities on the cashew culture:

Management activities	Time (per month)

27. Do you use any fertilizers and agrochemical to improve the cashew crop? ( ) Yes ( ) No

28. If ***No***, why? ____

Questionnaire (Page n° 5/6).

29. If ***Yes***, list all the fertilizers and agrochemicals in accordance with the following questions:

Agrochemicals	Name or Formula	Amount (Kilo or Litter per Hectare)	Time (per Month)
Organic nutrients			
Chemical nutrients			
Herbicide			
Fungicide			
Others			

30. In accordance with the following options, identify your(s) main problems in the cashew system:
( ) Lack of capital
( ) Lack of rural credit
( ) Transportation problems
( ) Distance between the Pecém Port and the farming system
( ) Availability of specific products for cashew
( ) Others like: ____

III PART – Commercialization of cashew products

31. Where going your cashew production?
____

32. If you sell the cashew production for any industry, it has an appropriated industrialization condition for cashew products?
( ) Yes ( ) No

33. What kind part of cashew fruit do you sell?
( ) Cashew apple ( ) Cashew nut ( ) Cashew apple with nut

34. Do you use or consume cashew fruit inside of your property?
( ) Yes ( ) No

IV PART – Public policies

35. Do you receive actually any kind of technical support? ( ) Yes ( ) No

36. What agency gives technical support?

( ) EPACE – Company of Agricultural Research in Ceará

( ) EMATER – Company of Technical Assistance and Rural Extension

( ) EMBRAPA – Brazilian Organization for Agricultural Research

( ) FAEC – Agricultural Research Federation of the State of Ceará

Others like for example: ____

Questionnaire (Page n° 6/6).

37. Do you receive agricultural financial support?
( )Yes ( )No
If ***Yes***, which: ________________________

38. Do you have knowledge about any specifically agricultural financial support for the cashew system?
( )Yes ( )No
If ***Yes***, which: ________________________

39. Do you know about any public politic to improve and to strengthen the cashew production in the North-East Brazil?
( )Yes ( ) No
If ***Yes***, which: ________________________

V PART – Production of cashew fruit

40. Complete the following table in accordance with the cashew production, which was sold in 2006:

Product	Amount (Kg)	Price per kilo
Cashew nut		
Cashew apple		
Product in nature	**Amount of trays**	**Price per tray**
Cashew apple + nut		

Thank very much for your collaboration!!!

Appendix 4. Output for the logistic regression, STATA version 8.0 (Page n° 1/2).

Output for the logistic command in STATA version 8.9

Iteration 0: log likelihood = -164.51326
Iteration 1: log likelihood = -137.59421
Iteration 2: log likelihood = -136.37654
Iteration 3: log likelihood = -136.35832
Iteration 4: log likelihood = -136.35831

Number of obs = 254
LR chi2(7) = 56.31
Prob > chi2 = 0.0000
Log likelihood = -136.35831
Pseudo R2 = 0.1711

CashewProductivity	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Constant	-9.994292	3.89249	-2.57	0.010	-17.62343	-2.365152
Precipitation	-.00712	.0021291	-3.34	0.001	-.0112929	-.002947
Sunhours	.0061371	.0014756	4.16	0.000	.0032451	.0090292
DistanceToPort	-.0071619	-.0071619	-4.96	0.000	-.0099917	-.0043322
CashewExperience	.0222104	.0222104	1.39	0.166	-.0092041	.053625
FertilizerApplication	1.679132	1.679132	4.35	0.000	.9225416	2.435722
LivestockOwnership	-.6702028	-.6702028	-2.16	0.031	-1.278567	-.0618381
Middleman	.3397139	.3397139	0.044	0.044	.0188584	1.350513

Linktest

Iteration 0: log likelihood = -164.51326
Iteration 1: log likelihood = -137.70089
Iteration 2: log likelihood = -135.02425
Iteration 3: log likelihood = -134.64968
Iteration 4: log likelihood = -134.64139
Iteration 5: log likelihood = -134.64139

Logit estimates
Number of obs = 254
LR chi2(2) = 59.74
Prob > chi2 = 0.0000
Log likelihood = -134.64139
Pseudo R2 = 0.1816

CashewProductivity	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
_hat	.7893756	.1851734	4.26	0.000	.4264423	1.152309
_hatsq	.2431378	.1373147	1.77	0.177	-.0259941	.5122697
_constant	-.1652865	.1887644	-0.88	0.381	-.535258	.204685

number of observations = 254
area under ROC curve = 0.7762

Output for the logistic regression, STATA version 8.0 (Page n° 2/2).

mfx compute
Marginal effects after logit
y = Pr(CashewProductivity) (predict) = .68837593

Variable	dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]	X
Precipitation	-.0015273	.00044	-3.47	0.001	-.00239	-.000665	913.427
Sunhours	.0013165	.00033	3.96	0.000	.000665	.001968	2902.84
DistanceTo Port	-.0015363	.0003	-5.20	0.000	-.002115	-.000957	195.024
CashewExperience	.0047645	.00371	1.28	0.200	-.002515	.012044	18.6811
FertilizerApplication	.3214799	.06356	5.06	0.000	.196895	.446065	.370079
LivestockOwnership	-.1405978	.06479	-2.17	0.030	-.26759	-.013606	.566929
Middleman	.1389458	.06409	2.17	0.030	.01334	.264552	.314961

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Appendix 5. Details of emergy accounting: common type (ha) in Ceará (Page n° 1/6).

Note	Flows	Value	Units	Transformity (sej/kg), (sej/J), (sej/$US)	Emergy Flow (sej/ha/y)
	Renewable Natural resources "R"				
1	Sun	1,58E+11	J/ha/y	1,00E+00	1,58E+11
2	Rain	6,61E+10	J/ha/y	4,70E+04	3,10E+15
3	Wind	2,18E+10	J/ha/y	2,45E+03	5,34E+13
4	underground water	0,00E+00	J/ha/y	0,00E+00	0,00E+00
5	River water	0,00E+00	J/ha/y	0,00E+00	0,00E+00
6	Forest Biomass	0,00E+00	kg/ha/y	0,00E+00	0,00E+00
7	N (atmosphere)	1,13E+01	kg/ha/y	7,73E+12	8,70E+13
8	P (rocks)	1,44E+00	kg/ha/y	2,99E+13	4,30E+13
9	K (rocks)	6,21E+00	kg/ha/y	2,92E+12	1,81E+13
10	Ca (system)	2,62E-01	kg/ha/y	1,68E+12	4,40E+11
11	Other minerals	1,72E+00	kg/ha/y	1,71E+12	2,93E+12
12	Sediments rivers	0,00E+00	J/ha/y	0,00E+00	0,00E+00
					3,31E+15
	Non-Renewable Natural resources "N"				
13	Soil loss	3,02E+09	J/ha/y	7,40E+04	2,23E+14
					2,23E+14
	Services (Econ. Resources) "S"				
14	Man power (hard)	2,13E+01	$US/ha/y	3,11E+12	6,62E+13
15	Man power (family)	5,32E+00	$US/ha/y	3,11E+12	1,65E+13
16	Maintenance (infraestructure)	2,34E+01	$US/ha/y	3,11E+12	7,27E+13
17	Insurance cost	1,59E+01	$US/ha/y	3,11E+12	4,94E+13
18	Comunications cost	1,17E+01	$US/ha/y	3,11E+12	3,64E+13
19	Taxes	7,95E+00	$US/ha/y	3,11E+12	2,47E+13
20	Other services	1,17E+01	$US/ha/y	3,11E+12	3,64E+13
					3,02E+14
	Materials (Econ. Resources) "M"				
21	Fungicides	2,00E+00	kg/ha/y	1,48E+13	2,96E+13
22	Herbicides	0,00E+00	J/ha/y	1,31E+15	0,00E+00
23	Insecticides	2,00E+00	kg/ha/y	2,40E+12	4,80E+12
24	Nitrogen fertilizer	1,80E+01	kg/ha/y	7,73E+12	1,39E+14
25	Phosphate fertilizer	1,35E+01	kg/ha/y	2,99E+13	4,04E+14
26	Potash fertilizer	1,35E+01	kg/ha/y	2,92E+12	3,94E+13
27	Calium	0,00E+00	kg/ha/y	2,08E+12	0,00E+00
28	Other minerals	0,00E+00	kg/ha/y	1,71E+12	0,00E+00
29	Manure	0,00E+00	J/ha/y	0,00E+00	0,00E+00
30	Electricity	5,04E+08	J/ha/y	3,36E+05	1,69E+14
31	Petroleum fuels	1,78E+08	J/ha/y	1,11E+05	1,97E+13
32	Materials for maintenance	3,18E+01	$US/ha/y	3,11E+12	9,89E+13
33	Vaccines and medicaments	0,00E+00	$US/ha/y	0,00E+00	0,00E+00
34	Depreciation	2,20E+01	$US/ha/y	3,11E+12	6,86E+13
					9,73E+14

Details of emergy accounting: common cashew type (ha) in Ceará (Page n° 2/6).

					Energy	Transformity	Emergy
1	**Sun**				1,584E+11	1	1,58E+11
	Solar radiation=	5,5	kWh/m^2.y	[1]			
	albedo (a) =	0,2		[2]			
	energy =	(radiation)*(1-albedo)					
	(kWh/m^2.y)*(3,6E6J/1kWh)*(1E4m^2/ha)*(1-a)						
		1,584E+11	J/ha.y				
	Transformity =	1	sej/J				
2	**Rain + ETP**				6,61E+10	4,70E+04	3,10E+15
	precipitation =	910,03	mm.y	[1]			
	ETP	411	mm.y	[1,9,10]			
	water energy =	5000	J/kg	[3]			
	Water density=	1000	kg/m^3	[3]			
	energy = (kg/m^3)*(J/kg)*(1E4m^2/ha)						
		6,61E+10	J/ha.y				
	Transformiy =	4,70E+04	sej/J	[4]			
3	**Wind**				2,18E+10	2,45E+03	5,34E+13
	air density =	1,17	kg/m^3	[1]			
	anual average velocity =	3,9	m/s	[1]			
	geotropic wind =	3,33	m/s 60% de 5,5	[5]			
	haulage coefficient =	0,001	adimensional	[5]			
	energy = (area m^2/áreaha)*(kg/m^3)*(m/s)^3*(0,001)*(3,14E7s/y)						
		2,18E+10	J/ha.y				
	transformity =	2,45E+03	sej/J	[4]			
4	**Undergroud water**				0,00E+00	0,00E+00	0,00E+00
	flow of the nascent =	0,00E+00	m^3/y				
	used water in the system =	0,00E+00	m^3/y				
	energy = (m^3/y)*(1/área total ha)*(1000kg/m3)* (5000J/kg)						
		0,00E+00	J/ha.y				
	transformity =	0,00E+00	sej/J				
5	**River water**				0,00E+00	0,00E+00	0,00E+00
	time of use of the pump =	0	h/d				
	pumped flow =	0	litro/s				
	pumped flow =	0,00E+00	m^3/y				
	energy = (m^3/y)*(1/área total ha)*(1000kg/m3)* (5000J/kg)						
		0,00E+00	J/ha.y				
	transformity =	0,00E+00	sej/J				
6	**Forest BM**				0,00E+00	0,00E+00	0,00E+00
	Forest Biomass		kgDM/y				
		0,0	kg DM/ha/y				
		0,00E+00	J/ha.y				
		0,00E+00	sej/kg				
7	**N (Atmosphere)**				5,7E+08	7,73E+12	8,70E+13
	consumption =	11,26	kg/ha.y				
	energy=	5,7E+08	J/ha.y	[6]			
	transformity =	7,73E+12	sej/kg	[7]			
8	**P (rocks)**				2,3E+07	2,99E+13	4,30E+13
	consumption =	1,44	kg/ha.y	[1]			
		2,3E+07	J/ha.y	[8]			
	transformity =	2,99E+13	sej/kg	[7]			
9	**K system**				3,1E+07	2,92E+12	1,81E+13
	consumption =	6,21	kg/ha.y	[1]			
		3,1E+07	J/ha.y	[8]			
	transformity =	2,92E+12	sej/kg	[7]			
10	**Ca system**				7,9E+05	1,68E+12	4,40E+11
	consumption =	0,26	kg/ha.y	[1]			
		7,9E+05	J/ha.y				
	transformity =	1,68E+12	sej/kg	[7]			
11	**Other mineral systems**				6,9E+06	1,71E+12	2,93E+12
	consumption =	1,72	kg/ha.y	[1]			

Details of emergy accounting: common type (ha) in Ceará (Page n° 3/6).

12	**Soil sedimentation**				0,00E+00	0,00E+00	0,00E+00
	soil added =	0	kg/ha.y				
	Organic material =	0	kg MO/kg solo				
	energy MO =	0	kcal/kg				
	energy = (kg/ha.y)*(kgmat.org./kgsolo)*(kcal/kg)*(4186J/kcal)						
		0,00E+00	J/ha.y				
	transformity =	0,00E+00	sej/J				
13	**Erosion**				3,02E+09	7,40E+04	2,23E+14
	Soil loss =	3811,72	kg/ha.y	[11,12,13,14]			
	OM =	0,035	kg MO/kg soil	[4]			
	energy OM=	5400	kcal/kg	[4]			
	energy = (kg/ha.y)*(kgmat.org./kgsolo)*(kcal/kg)*(4186J/kcal)						
		3,02E+09	J/ha.y				
	transformity =	7,40E+04	sej/J	[15]			
14	**Manpower (extern)**				1,56E+08	3,11E+12	6,62E+13
	nº persons =	0,1	persons				
	wage =	35	R$/person.month				
	expense anual =	45,5	R$/y				
		1,56E+08	J/ha.y				
	energy = (R$/y)*(US$/R$)*(1/área)						
		2,13E+01	US$/ha.y				
	transformity =	3,11E+12	sej/US$	[16]			
15	**Manpower (family)**				7,80E+07	3,11E+12	1,65E+13
	nº de persons =	0,05	persons				
	wage =	17,5	R$/person.month				
	expense anual =	11,375	R$/y				
		7,80E+07	J/ha.y				
	energy = (R$/y)*(US$/R$)*(1/área)						
		5,32E+00	US$/ha.y				
	transformity =	3,11E+12	sej/US$	[16]			
16	**Mainteinance (materials)**					3,11E+12	7,27E+13
	cost =	50,00	R$/y				
	energy = (R$/y)*(1/área)*(US$/R$)						
		2,34E+01	US$/ha.y				
	transformity =	3,11E+12	sej/US$ [i]	[16]			
17	**Taxes**						
	cost =	34	R$/y			3,11E+12	4,94E+13
	energy = (R$/y)*(1/área)*(US$/R$)						
		1,59E+01	US$/ha.y				
	transformity =	3,11E+12	sej/US$	[16]			
18	**Telephone**					3,11E+12	3,64E+13
	cost =	25	R$/y				
	energy = (R$/y)*(1/área)*(US$/R$)						
		1,17E+01	US$/ha.y				
	transformity =	3,11E+12	sej/US$	[16]			
19	**Postage**						
	cost =	17,00	R$/y			3,11E+12	2,47E+13
	energy = (R$/y)*(1/área)*(US$/R$)						
		7,95E+00	US$/ha.y				
	transformity =	3,11E+12	sej/US$	[16]			
20	**Other services**					3,11E+12	3,64E+13
	cost =	25	R$/y				
	energy = (R$/y)*(1/área)*(US$/R$)						
		1,17E+01	US$/ha.y				
	transformity =	3,11E+12	sej/US$	[16]			

Details of emergy accounting: common type (ha) in Ceará (Page n° 4/6).

21	**Fungicide**					1,48E+13	2,96E+13
	consumpstion =	2,00E+00 kg/y	[19]				
	energy =	(kg/y)(1/ área)(J/kg)					
		2,00E+00 kg/ha.y					
		3,32E+08 J/ha.y					
	transformity =	1,48E+13 sej/kg	[17]				
22	**Herbicide**					1,31E+15	0,00E+00
	expense =	0,00E+00 l/y	[13]				
	density =	0,00E+00 kg/l	[3]				
	energy =	(l/y)*(kg/l)*(1/área)					
		0,00E+00 kg/ha.y					
		0,00E+00 J/ha.y					
	transformity =	1,31E+15 sej/kg	[7]				
23	**Insecticide**				1,82E+09	2,40E+12	3,65E+09
	Quantity	2,00E+00 l/y	[19]				
		0,00E+00 kg/l					
	energy	(l/y)*(kg/l)*(1/área)					
		2,00E+00 kg/ha.y					
		1,82E+09 J/ha.y					
	transformity	2,40E+12 sej/l	[8]				
24	**Nitrogen fertilizer**				9,1E+08	7,73E+12	1,63E+10
	consumption =	0,0 kg/y					
		18,0 kg/ha.y					
	energy=	9,1E+08 J/ha.y	[7]				
	transformity =	7,73E+12 sej/kg	[8]				
25	**Phosphate fertilizer**				2,2E+08	2,99E+13	2,97E+09
	consumption =	0,00 kg/y					
		13,5 kg/ha.y					
		2,2E+08 J/ha.y	[7]				
	transformity =	2,99E+13 sej/kg	[6]				
26	**Potash fertilizer**				6,8E+07	2,92E+12	9,11E+08
	consumption =	0,00 kg/y					
		13,5 kg/ha.y					
		6,8E+07 J/ha.y	[6]				
	transformity =	2,92E+12 sej/kg	[7]				
27	**Calcium**				0,00E+00	2,08E+12	0,00E+00
	consumption =	0,00 kg/y	[13]				
		0,0 kg/ha.y					
		0,0E+00 J/ha.y					
	transformity =	2,08E+12 sej/kg	[19]				
28	**Other minerals**				0,0E+00	1,71E+12	0,00E+00
	consumption =	0,00 kg/y					
		0,0 kg/ha.y					
		0,0E+00					
	transformity =	1,71E+12 sej/kg	[7]				
29	**Manure**				0,00E+00	0,00E+00	0,00E+00
	consumption =	0,00 kg/y					
	caloric value =	0,00E+00 kcal/kg					
	energy = (kg/y)*(kcal/kg)*4186*(1/área)						
		0,00E+00 J/ha.y					
	transformity =	0,00E+00 sej/J					
30	**Eletricity**				5,04E+08	3,36E+05	1,69E+14
	consumption =	140 kWh/y					
	energy = (kWh/y)*(1/área)*(1000W/kW)*(3600s/h)						
		5,04E+08 J/ha.y					
	transformity =	3,36E+05 sej/J	[7]				

Details of emergy accounting: common cashew (ha) in Ceará (Page n° 5/6).

31	**Petroleum fuels**					1,78E+08	1,11E+05	1,97E+13
	consumption =	50	l/y					
	density =	0,85	kg/l	[18]				
	energy do combustível =	1000	kcal/kg					
	energy = (l/y)*(1/área)*(kg/l)*(kcal/kg)*(4186J/kcal)							
		1,78E+08	J/ha.y					
	transformity =	1,11E+05	sej/J	[7]				
32	**Materials for maintenance**					3,27E+00	3,11E+12	9,89E+13
	consumption =	68	R$/y					
	energy = (R$/y)*(1/área)*(US$/R$)							
		3,18E+01	US$/ha.y					
	transformity =	3,11E+12	sej/US$	[16]				
33	**Vaccines and medicaments**					0,00E+00	0,00E+00	0,00E+00
	consumption =	0,00E+00	R$/y					
	energy =	(R$/y)*(1/área)*(US$/R$)						
		0,00E+00	US$/ha.y					
	transformity =	0,00E+00	sej/US$					
34	**Depreciations**					1,36E+01	3,11E+12	3,01E+02
	depreciation =	47,15	R$/y					
	depreciation =	22,05	US$/ha.y					
	transformity =	3,11E+12	sej/US$	[16]				
			Production					
	Agricultural					4,58E+09		
		Rdto kg (Area total)		KJ/kg				
	Cashew nut	424	kg/y		5773	2,45E+09		
	Cashew apple	1041	kg/y		2052	2,14E+09		
						4,58E+09		
	Livestock production					0,00E+00	0,00E+00	0,00E+00
	Livestock Production =	0,00	ton ((80% H2O)					
	Energy (J) =	(Total production)(energy content)						
	Energy(J) =	(____ ton)*(1E+06 g/ton)*(20%)*(5.0 KCal/g)*(4186 J/KCal)						
		0,00E+00	J/ha.y					
	transformity =	0,00E+00	sej/J					
	BM Forest					0,00E+00	0,00E+00	0,00E+00
	Forest biomass	0	kg/y					
		0	kg/ha/y					
		0,00E+00	J/ha.y					
		0,00E+00	sej/kg					
	BM Regeneration					0,00E+00	0,00E+00	0,00E+00
	Regeneration biomass	0	kg/y					
			kg/ha/y					
		0,00E+00	J/ha.y					
		0,00E+00	sej/kg					
	Grass					0,00E+00	0,00E+00	0,00E+00
		0	Ton DM/y					
	energy	(Tot Production)(energy content)						
		0,00E+00	J/ha.y					
	Transformity	0,00E+00	sej/J					

Details of emergy accounting: common type (ha) in Ceará (Page n° 6/6).

References

[1] INMET (2007).
[2] SELLERS (1965).
[3] CAVALETT (2004).
[4] ODUM (2000a).
[5] RODRIGUES *et al*. (2000).
[6] RATHKE (2002).
[7] ODUM (1996).
[8] HOVELIUS (1997).
[9] CRISÓSTOMO *et al.* (2001).
[10] OLIVEIRA *et al* . (2001).
[11] AQUINO *et al*. (2006).
[12] FIGUEIRÊDO *et al* . (2007).
[13] FARINASSO *et al.* (2006).
[14] SILVA *et al.* (2003).
[15] BROWN (2001).
[16] ROOSEVELT-AGOSTINHO (2001).
[17] UNICAMP (2008).
[18] TORRICO (2006).
[19] SOMBRA OLIVEIRA (2004).

Appendix 6. Details of emergy accounting: dwarf-precocious type (ha) in Ceará.

Note	Flows	Value	Units	Transformity (sej/kg), (sej/J), (sej/$US)	Emergy Flow (sej/ha/y)
	Renewable Natural resources "R"				
1	Sun	1,58E+11	J/ha/y	1,00E+00	1,58E+11
2	Rain	6,61E+10	J/ha/y	4,70E+04	3,10E+15
3	Wind	2,18E+10	J/ha/y	2,45E+03	5,34E+13
4	underground water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
5	River water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
6	Forest Biomass	0,00E+00	kg/ha/y	3,69E+11	0,00E+00
7	N (atmosphere)	1,68E+01	kg/ha/y	7,73E+12	1,30E+14
8	P (rocks)	2,14E+00	kg/ha/y	2,99E+13	6,41E+13
9	K (rocks)	9,25E+00	kg/ha/y	2,92E+12	2,70E+13
10	Ca (system)	3,90E-01	kg/ha/y	1,68E+12	6,55E+11
11	Other minerals	2,56E+00	kg/ha/y	1,71E+12	4,37E+12
12	Sediments rivers	0,00E+00	J/ha/y	7,40E+04	0,00E+00
					3,38E+15
	Non-Renewable Natural resources "N"				
13	Soil loss	3,02E+09	J/ha/y	7,40E+04	2,23E+14
					2,23E+14
	Services (Econ. Resources) "S"				
14	Man power (hard)	8,51E+01	$US/ha/y	3,11E+12	2,65E+14
15	Man power (family)	2,13E+01	$US/ha/y	3,11E+12	6,62E+13
16	Maintenance (infraestructure)	2,57E+01	$US/ha/y	3,11E+12	8,00E+13
17	Insurance cost	1,87E+01	$US/ha/y	3,11E+12	5,82E+13
18	Comunications cost	1,17E+01	$US/ha/y	3,11E+12	3,64E+13
19	Taxes	9,35E+00	$US/ha/y	3,11E+12	2,91E+13
20	Other services	1,64E+01	$US/ha/y	3,11E+12	5,09E+13
					5,85E+14
	Materials (Econ. Resources) "M"				
21	Fungicides	2,00E+00	kg/ha/y	1,48E+13	2,96E+13
22	Herbicides	0,00E+00	J/ha/y	1,31E+15	0,00E+00
23	Insecticides	2,00E+00	kg/ha/y	2,40E+12	4,80E+12
24	Nitrogen fertilizer	4,00E+01	kg/ha/y	7,73E+12	3,09E+14
25	Phosphate fertilizer	3,00E+01	kg/ha/y	2,99E+13	8,97E+14
26	Potash fertilizer	4,00E+01	kg/ha/y	2,92E+12	1,17E+14
27	Calium	0,00E+00	kg/ha/y	2,08E+12	0,00E+00
28	Other minerals	0,00E+00	kg/ha/y	1,71E+12	0,00E+00
29	Manure	0,00E+00	J/ha/y	2,69E+04	0,00E+00
30	Electricity	6,30E+08	J/ha/y	3,36E+05	2,12E+14
31	Petroleum fuels	2,49E+08	J/ha/y	1,11E+05	2,76E+13
32	Materials for maintenance	3,74E+01	$US/ha/y	3,11E+12	1,16E+14
33	Vaccines and medicaments	0,00E+00	$US/ha/y	3,11E+12	0,00E+00
34	Depreciation	2,47E+01	$US/ha/y	3,11E+12	7,69E+13
					1,79E+15

Appendix 7. Details of emergy accounting: common type (ha) in Piauí.

Note	Flows	Value	Units	Transformity (sej/kg), (sej/J), (sej/$US)	Emergy Flow (sej/ha/y)
	Renewable Natural resources "R"				
1	Sun	1,58E+11	J/ha/y	1,00E+00	1,58E+11
2	Rain	5,98E+10	J/ha/y	4,70E+04	2,81E+15
3	Wind	9,92E+09	J/ha/y	2,45E+03	2,43E+13
4	underground water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
5	River water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
6	Forest Biomass	0,00E+00	kg/ha/y	3,69E+11	0,00E+00
7	N (atmosphere)	8,54E+00	kg/ha/y	7,73E+12	6,60E+13
8	P (rocks)	1,09E+00	kg/ha/y	2,99E+13	3,26E+13
9	K (rocks)	4,71E+00	kg/ha/y	2,92E+12	1,37E+13
10	Ca (system)	1,99E-01	kg/ha/y	1,68E+12	3,34E+11
11	Other minerals	1,30E+00	kg/ha/y	1,71E+12	2,23E+12
12	Sediments rivers	0,00E+00	J/ha/y	7,40E+04	0,00E+00
					2,95E+15
	Non-Renewable Natural resources "N"				
13	Soil loss	2,94E+09	J/ha/y	7,40E+04	2,18E+14
					2,18E+14
	Services (Econ. Resources) "S"				
14	Man power (hard)	2,13E+01	$US/ha/y	3,11E+12	6,62E+13
15	Man power (family)	5,32E+00	$US/ha/y	3,11E+12	1,65E+13
16	Maintenance (infraestructure)	1,64E+01	$US/ha/y	3,11E+12	5,09E+13
17	Insurance cost	1,50E+01	$US/ha/y	3,11E+12	4,65E+13
18	Comunications cost	9,82E+00	$US/ha/y	3,11E+12	3,05E+13
19	Taxes	7,01E+00	$US/ha/y	3,11E+12	2,18E+13
20	Other services	8,42E+00	$US/ha/y	3,11E+12	2,62E+13
					2,59E+14
	Materials (Econ. Resources) "M"				
21	Fungicides	2,00E+00	kg/ha/y	1,48E+13	2,96E+13
22	Herbicides	0,00E+00	J/ha/y	1,31E+15	0,00E+00
23	Insecticides	2,00E+00	kg/ha/y	2,40E+12	4,80E+12
24	Nitrogen fertilizer	1,00E+01	kg/ha/y	7,73E+12	7,73E+13
25	Phosphate fertilizer	1,10E+01	kg/ha/y	2,99E+13	3,29E+14
26	Potash fertilizer	1,10E+01	kg/ha/y	2,92E+12	3,21E+13
27	Calium	0,00E+00	kg/ha/y	2,08E+12	0,00E+00
28	Other minerals	0,00E+00	kg/ha/y	1,71E+12	0,00E+00
29	Manure	0,00E+00	J/ha/y	2,69E+04	0,00E+00
30	Electricity	4,13E+08	J/ha/y	3,36E+05	1,39E+14
31	Petroleum fuels	1,25E+08	J/ha/y	1,11E+05	1,38E+13
32	Materials for maintenance	7,95E+00	$US/ha/y	3,11E+12	2,47E+13
33	Vaccines and medicaments	0,00E+00	$US/ha/y	3,11E+12	0,00E+00
34	Depreciation	1,86E+01	$US/ha/y	3,11E+12	5,77E+13
					7,08E+14

Appendix 8. Details of emergy accounting: dwarf-precocious type (ha) in Piauí.

Note	Flows	Value	Units	Transformity (sej/kg), (sej/J), (sej/$US)	Emergy Flow (sej/ha/y)
	Renewable Natural resources "R"				
1	Sun	1,58E+11	J/ha/y	1,00E+00	1,58E+11
2	Rain	5,98E+10	J/ha/y	4,70E+04	2,81E+15
3	Wind	9,92E+09	J/ha/y	2,45E+03	2,43E+13
4	underground water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
5	River water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
6	Forest Biomass	0,00E+00	kg/ha/y	3,69E+11	0,00E+00
7	N (atmosphere)	1,64E+01	kg/ha/y	7,73E+12	1,26E+14
8	P (rocks)	2,09E+00	kg/ha/y	2,99E+13	6,25E+13
9	K (rocks)	9,02E+00	kg/ha/y	2,92E+12	2,63E+13
10	Ca (system)	3,80E-01	kg/ha/y	1,68E+12	6,39E+11
11	Other minerals	2,49E+00	kg/ha/y	1,71E+12	4,26E+12
12	Sediments rivers	0,00E+00	J/ha/y	7,40E+04	0,00E+00
					3,05E+15
	Non-Renewable Natural resources "N"				
13	Soil loss	2,94E+09	J/ha/y	7,40E+04	2,18E+14
					2,18E+14
	Services (Econ. Resources) "S"				
14	Man power (hard)	8,51E+01	$US/ha/y	3,11E+12	2,65E+14
15	Man power (family)	2,13E+01	$US/ha/y	3,11E+12	6,62E+13
16	Maintenance (infraestructure)	2,10E+01	$US/ha/y	3,11E+12	6,54E+13
17	Insurance cost	1,73E+01	$US/ha/y	3,11E+12	5,38E+13
18	Comunications cost	1,22E+01	$US/ha/y	3,11E+12	3,78E+13
19	Taxes	7,01E+00	$US/ha/y	3,11E+12	2,18E+13
20	Other services	1,31E+01	$US/ha/y	3,11E+12	4,07E+13
					5,50E+14
	Materials (Econ. Resources) "M"				
21	Fungicides	2,00E+00	kg/ha/y	1,48E+13	2,96E+13
22	Herbicides	0,00E+00	J/ha/y	1,31E+15	0,00E+00
23	Insecticides	2,00E+00	kg/ha/y	2,40E+12	4,80E+12
24	Nitrogen fertilizer	4,00E+01	kg/ha/y	7,73E+12	3,09E+14
25	Phosphate fertilizer	3,00E+01	kg/ha/y	2,99E+13	8,97E+14
26	Potash fertilizer	4,00E+01	kg/ha/y	2,92E+12	1,17E+14
27	Calium	0,00E+00	kg/ha/y	2,08E+12	0,00E+00
28	Other minerals	0,00E+00	kg/ha/y	1,71E+12	0,00E+00
29	Manure	0,00E+00	J/ha/y	2,69E+04	0,00E+00
30	Electricity	4,68E+08	J/ha/y	3,36E+05	1,57E+14
31	Petroleum fuels	1,49E+08	J/ha/y	1,11E+05	1,66E+13
32	Materials for maintenance	1,87E+01	$US/ha/y	3,11E+12	5,82E+13
33	Vaccines and medicaments	0,00E+00	$US/ha/y	3,11E+12	0,00E+00
34	Depreciation	2,10E+01	$US/ha/y	3,11E+12	6,54E+13
					1,65E+15

Appendix 9. Details of emergy accounting: "homestead" cashew farming system.

Note	Flows	Value	Units	Transformity (sej/kg), (sej/J), (sej/$US)	Emergy Flow (sej/ha/y)
	Renewable Natural resources "R"				
1	Sun	1,584E+11	J/ha/y	1,00E+00	1,58E+11
2	Rain	6,14E+10	J/ha/y	4,70E+04	2,88E+15
3	Wind	1,58E+10	J/ha/y	2,45E+03	3,86E+13
4	underground water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
5	River water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
6	Forest Biomass	0,00E+00	kg/ha/y	3,69E+11	0,00E+00
7	N (atmosphere)	1,26E+01	kg/ha/y	7,73E+12	9,77E+13
8	P (rocks)	1,62E+00	kg/ha/y	2,99E+13	4,83E+13
9	K (rocks)	6,97E+00	kg/ha/y	2,92E+12	2,04E+13
10	Ca (system)	2,94E-01	kg/ha/y	1,68E+12	4,94E+11
11	Other minerals	1,93E+00	kg/ha/y	1,71E+12	3,30E+12
12	Sediments rivers	0,00E+00	J/ha/y	7,40E+04	0,00E+00
					3,09E+15
	Non-Renewable Natural resources "N"				
13	Soil loss	2,98E+09	J/ha/y	7,40E+04	2,20E+14
					2,20E+14
	Services (Econ. Resources) "S"				
14	Man power (hard)	2,13E+01	$US/ha/y	3,11E+12	6,62E+13
15	Man power (family)	5,32E+00	$US/ha/y	3,11E+12	1,65E+13
16	Maintenance (infraestructure)	2,34E+01	$US/ha/y	3,11E+12	7,27E+13
17	Insurance cost	1,59E+01	$US/ha/y	3,11E+12	4,94E+13
18	Comunications cost	1,17E+01	$US/ha/y	3,11E+12	3,64E+13
19	Taxes	7,95E+00	$US/ha/y	3,11E+12	2,47E+13
20	Other services	1,17E+01	$US/ha/y	3,11E+12	3,64E+13
					3,02E+14
	Materials (Econ. Resources) "M"				
21	Fungicides	0,00E+00	kg/ha/y	1,48E+13	0,00E+00
22	Herbicides	0,00E+00	J/ha/y	1,31E+15	0,00E+00
23	Insecticides	0,00E+00	kg/ha/y	2,40E+12	0,00E+00
24	Nitrogen fertilizer	0,00E+00	kg/ha/y	7,73E+12	0,00E+00
25	Phosphate fertilizer	0,00E+00	kg/ha/y	2,99E+13	0,00E+00
26	Potash fertilizer	0,00E+00	kg/ha/y	2,92E+12	0,00E+00
27	Calium	0,00E+00	kg/ha/y	2,08E+12	0,00E+00
28	Other minerals	0,00E+00	kg/ha/y	1,71E+12	0,00E+00
29	Manure	0,00E+00	J/ha/y	2,69E+04	0,00E+00
30	Electricity	5,04E+08	J/ha/y	3,36E+05	1,69E+14
31	Petroleum fuels	1,78E+08	J/ha/y	1,11E+05	1,97E+13
32	Materials for maintenance	3,18E+01	$US/ha/y	3,11E+12	9,89E+13
33	Vaccines and medicaments	0,00E+00	$US/ha/y	3,11E+12	0,00E+00
34	Depreciation	2,20E+01	$US/ha/y	3,11E+12	6,86E+13
					3,57E+14

Appendix 10. Details of emergy accounting: "food crops" cashew farming system.

Note	Flows	Value	Units	Transformity (sej/kg), (sej/J), (sej/$US)	Emergy Flow (sej/ha/y)
	Renewable Natural resources "R"				
1	Sun	1,584E+11	J/ha/y	1,00E+00	1,58E+11
2	Rain	6,46E+10	J/ha/y	4,70E+04	3,04E+15
3	Wind	1,58E+10	J/ha/y	2,45E+03	3,86E+13
4	underground water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
5	River water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
6	Forest Biomass	0,00E+00	kg/ha/y	3,69E+11	0,00E+00
7	N (atmosphere)	1,09E+01	kg/ha/y	7,73E+12	8,41E+13
8	P (rocks)	1,39E+00	kg/ha/y	2,99E+13	4,16E+13
9	K (rocks)	6,00E+00	kg/ha/y	2,92E+12	1,75E+13
10	Ca (system)	2,53E-01	kg/ha/y	1,68E+12	4,25E+11
11	Other minerals	1,66E+00	kg/ha/y	1,71E+12	2,84E+12
12	Sediments rivers	0,00E+00	J/ha/y	7,40E+04	0,00E+00
					3,22E+15
	Non-Renewable Natural resources "N"				
13	Soil loss	2,98E+09	J/ha/y	7,40E+04	2,20E+14
					2,20E+14
	Services (Econ. Resources) "S"				
14	Man power (hard)	2,13E+01	$US/ha/y	3,11E+12	6,62E+13
15	Man power (family)	5,32E+00	$US/ha/y	3,11E+12	1,65E+13
16	Maintenance (infraestructure)	2,34E+01	$US/ha/y	3,11E+12	7,27E+13
17	Insurance cost	1,59E+01	$US/ha/y	3,11E+12	4,94E+13
18	Comunications cost	1,17E+01	$US/ha/y	3,11E+12	3,64E+13
19	Taxes	7,95E+00	$US/ha/y	3,11E+12	2,47E+13
20	Other services	1,17E+01	$US/ha/y	3,11E+12	3,64E+13
					3,02E+14
	Materials (Econ. Resources) "M"				
21	Fungicides	5,00E-01	kg/ha/y	1,48E+13	7,40E+12
22	Herbicides	0,00E+00	J/ha/y	1,31E+15	0,00E+00
23	Insecticides	7,50E-01	kg/ha/y	2,40E+12	1,80E+12
24	Nitrogen fertilizer	2,25E+00	kg/ha/y	7,73E+12	1,74E+13
25	Phosphate fertilizer	1,70E+00	kg/ha/y	2,99E+13	5,08E+13
26	Potash fertilizer	1,70E+00	kg/ha/y	2,92E+12	4,96E+12
27	Calium	0,00E+00	kg/ha/y	2,08E+12	0,00E+00
28	Other minerals	0,00E+00	kg/ha/y	1,71E+12	0,00E+00
29	Manure	5,78E+07	J/ha/y	2,69E+04	1,55E+12
30	Electricity	5,04E+08	J/ha/y	3,36E+05	1,69E+14
31	Petroleum fuels	1,78E+08	J/ha/y	1,11E+05	1,97E+13
32	Materials for maintenance	3,18E+01	$US/ha/y	3,11E+12	9,89E+13
33	Vaccines and medicaments	0,00E+00	$US/ha/y	3,11E+12	0,00E+00
34	Depreciation	2,45E+01	$US/ha/y	3,11E+12	7,63E+13
					4,48E+14

Appendix 11. Details of emergy accounting: "value-added" cashew farming system.

Note	Flows	Value	Units	Transformity (sej/kg), (sej/J), (sej/$US)	Emergy Flow (sej/ha/y)
	Renewable Natural resources "R"				
1	Sun	1,584E+11	J/ha/y	1,00E+00	1,58E+11
2	Rain	6,19E+10	J/ha/y	4,70E+04	2,91E+15
3	Wind	1,58E+10	J/ha/y	2,45E+03	3,86E+13
4	underground water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
5	River water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
6	Forest Biomass	0,00E+00	kg/ha/y	3,69E+11	0,00E+00
7	N (atmosphere)	8,12E+00	kg/ha/y	7,73E+12	6,28E+13
8	P (rocks)	1,04E+00	kg/ha/y	2,99E+13	3,10E+13
9	K (rocks)	4,48E+00	kg/ha/y	2,92E+12	1,31E+13
10	Ca (system)	1,89E-01	kg/ha/y	1,68E+12	3,17E+11
11	Other minerals	1,24E+00	kg/ha/y	1,71E+12	2,12E+12
12	Sediments rivers	0,00E+00	J/ha/y	7,40E+04	0,00E+00
					3,06E+15
	Non-Renewable Natural resources "N"				
13	Soil loss	2,98E+09	J/ha/y	7,40E+04	2,20E+14
					2,20E+14
	Services (Econ. Resources) "S"				
14	Man power (hard)	2,13E+01	$US/ha/y	3,11E+12	6,62E+13
15	Man power (family)	5,32E+00	$US/ha/y	3,11E+12	1,65E+13
16	Maintenance (infraestructure)	2,34E+01	$US/ha/y	3,11E+12	7,27E+13
17	Insurance cost	1,59E+01	$US/ha/y	3,11E+12	4,94E+13
18	Comunications cost	1,17E+01	$US/ha/y	3,11E+12	3,64E+13
19	Taxes	7,95E+00	$US/ha/y	3,11E+12	2,47E+13
20	Other services	1,17E+01	$US/ha/y	3,11E+12	3,64E+13
					3,02E+14
	Materials (Econ. Resources) "M"				
21	Fungicides	1,40E+00	kg/ha/y	1,48E+13	2,07E+13
22	Herbicides	0,00E+00	J/ha/y	1,31E+15	0,00E+00
23	Insecticides	1,40E+00	kg/ha/y	2,40E+12	3,36E+12
24	Nitrogen fertilizer	6,30E+00	kg/ha/y	7,73E+12	4,87E+13
25	Phosphate fertilizer	4,80E+00	kg/ha/y	2,99E+13	1,44E+14
26	Potash fertilizer	4,80E+00	kg/ha/y	2,92E+12	1,40E+13
27	Calium	0,00E+00	kg/ha/y	2,08E+12	0,00E+00
28	Other minerals	0,00E+00	kg/ha/y	1,71E+12	0,00E+00
29	Manure	0,00E+00	J/ha/y	2,69E+04	0,00E+00
30	Electricity	5,04E+08	J/ha/y	3,36E+05	1,69E+14
31	Petroleum fuels	1,78E+08	J/ha/y	1,11E+05	1,97E+13
32	Materials for maintenance	3,18E+01	$US/ha/y	3,11E+12	9,89E+13
33	Vaccines and medicaments	0,00E+00	$US/ha/y	3,11E+12	0,00E+00
34	Depreciation	2,20E+01	$US/ha/y	3,11E+12	6,86E+13
					5,87E+14

Appendix 12. Details of emergy accounting: "fruit tree-crops" cashew farming system.

Note	Flows	Value	Units	Transformity (sej/kg), (sej/J), (sej/$US)	Emergy Flow (sej/ha/ y)
	Renewable Natural resources "R"				
1	Sun	1,584E+11	J/ha/y	1,00E+00	1,58E+11
2	Rain	7,27E+10	J/ha/y	4,70E+04	3,41E+15
3	Wind	1,58E+10	J/ha/y	2,45E+03	3,86E+13
4	underground water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
5	River water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
6	Forest Biomass	0,00E+00	kg/ha/y	3,69E+11	0,00E+00
7	N (atmosphere)	1,22E+01	kg/ha/y	7,73E+12	9,46E+13
8	P (rocks)	1,56E+00	kg/ha/y	2,99E+13	4,68E+13
9	K (rocks)	6,75E+00	kg/ha/y	2,92E+12	1,97E+13
10	Ca (system)	2,85E-01	kg/ha/y	1,68E+12	4,78E+11
11	Other minerals	1,87E+00	kg/ha/y	1,71E+12	3,19E+12
12	Sediments rivers	0,00E+00	J/ha/y	7,40E+04	0,00E+00
					3,62E+15
	Non-Renewable Natural resources "N"				
13	Soil loss	2,98E+09	J/ha/y	7,40E+04	2,20E+14
					2,20E+14
	Services (Econ. Resources) "S"				
14	Man power (hard)	2,13E+01	$US/ha/y	3,11E+12	6,62E+13
15	Man power (family)	5,32E+00	$US/ha/y	3,11E+12	1,65E+13
16	Maintenance (infraestructure)	2,34E+01	$US/ha/y	3,11E+12	7,27E+13
17	Insurance cost	1,59E+01	$US/ha/y	3,11E+12	4,94E+13
18	Comunications cost	1,17E+01	$US/ha/y	3,11E+12	3,64E+13
19	Taxes	7,95E+00	$US/ha/y	3,11E+12	2,47E+13
20	Other services	1,17E+01	$US/ha/y	3,11E+12	3,64E+13
					3,02E+14
	Materials (Econ. Resources) "M"				
21	Fungicides	5,00E-01	kg/ha/y	1,48E+13	7,40E+12
22	Herbicides	0,00E+00	J/ha/y	1,31E+15	0,00E+00
23	Insecticides	1,50E+00	kg/ha/y	2,40E+12	3,60E+12
24	Nitrogen fertilizer	2,25E+00	kg/ha/y	7,73E+12	1,74E+13
25	Phosphate fertilizer	1,70E+00	kg/ha/y	2,99E+13	5,08E+13
26	Potash fertilizer	1,70E+00	kg/ha/y	2,92E+12	4,96E+12
27	Calium	0,00E+00	kg/ha/y	2,08E+12	0,00E+00
28	Other minerals	0,00E+00	kg/ha/y	1,71E+12	0,00E+00
29	Manure	1,93E+07	J/ha/y	2,69E+04	5,18E+11
30	Electricity	5,04E+08	J/ha/y	3,36E+05	1,69E+14
31	Petroleum fuels	1,78E+08	J/ha/y	1,11E+05	1,97E+13
32	Materials for maintenance	3,18E+01	$US/ha/y	3,11E+12	9,89E+13
33	Vaccines and medicaments	0,00E+00	$US/ha/y	3,11E+12	0,00E+00
34	Depreciation	3,58E+01	$US/ha/y	3,11E+12	1,11E+14
					4,84E+14

Appendix 13. Details of emergy accounting: "innovative" cashew farming system.

Note	Flows	Value	Units	Transformity (sej/kg), (sej/J), (sej/$US)	Emergy Flow (sej/ha/y)
	Renewable Natural resources "R"				
1	Sun	1,584E+11	J/ha/y	1,00E+00	1,58E+11
2	Rain	7,06E+10	J/ha/y	4,70E+04	3,32E+15
3	Wind	1,58E+10	J/ha/y	2,45E+03	3,86E+13
4	underground water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
5	River water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
6	Forest Biomass	0,00E+00	kg/ha/y	3,69E+11	0,00E+00
7	N (atmosphere)	9,85E+00	kg/ha/y	7,73E+12	7,61E+13
8	P (rocks)	1,26E+00	kg/ha/y	2,99E+13	3,76E+13
9	K (rocks)	5,43E+00	kg/ha/y	2,92E+12	1,59E+13
10	Ca (system)	2,29E-01	kg/ha/y	1,68E+12	3,85E+11
11	Other minerals	1,50E+00	kg/ha/y	1,71E+12	2,57E+12
12	Sediments rivers	0,00E+00	J/ha/y	7,40E+04	0,00E+00
					3,49E+15
	Non-Renewable Natural resources "N"				
13	Soil loss	2,98E+09	J/ha/y	7,40E+04	2,20E+14
					2,20E+14
	Services (Econ. Resources) "S"				
14	Man power (hard)	1,91E+02	$US/ha/y	3,11E+12	5,96E+14
15	Man power (family)	2,13E+01	$US/ha/y	3,11E+12	6,62E+13
16	Maintenance (infraestructure)	2,57E+01	$US/ha/y	3,11E+12	8,00E+13
17	Insurance cost	1,87E+01	$US/ha/y	3,11E+12	5,82E+13
18	Comunications cost	1,17E+01	$US/ha/y	3,11E+12	3,64E+13
19	Taxes	9,35E+00	$US/ha/y	3,11E+12	2,91E+13
20	Other services	1,64E+01	$US/ha/y	3,11E+12	5,09E+13
					9,16E+14
	Materials (Econ. Resources) "M"				
21	Fungicides	9,60E+00	kg/ha/y	1,48E+13	1,42E+14
22	Herbicides	0,00E+00	J/ha/y	1,31E+15	0,00E+00
23	Insecticides	9,60E+00	kg/ha/y	2,40E+12	2,30E+13
24	Nitrogen fertilizer	6,80E+01	kg/ha/y	7,73E+12	5,26E+14
25	Phosphate fertilizer	4,90E+01	kg/ha/y	2,99E+13	1,47E+15
26	Potash fertilizer	5,90E+01	kg/ha/y	2,92E+12	1,72E+14
27	Calium	0,00E+00	kg/ha/y	2,08E+12	0,00E+00
28	Other minerals	0,00E+00	kg/ha/y	1,71E+12	0,00E+00
29	Manure	2,50E+08	J/ha/y	2,69E+04	6,73E+12
30	Electricity	6,30E+08	J/ha/y	3,36E+05	2,12E+14
31	Petroleum fuels	2,49E+08	J/ha/y	1,11E+05	2,76E+13
32	Materials for maintenance	3,74E+01	$US/ha/y	3,11E+12	1,16E+14
33	Vaccines and medicaments	0,00E+00	$US/ha/y	3,11E+12	0,00E+00
34	Depreciation	2,47E+01	$US/ha/y	3,11E+12	7,69E+13
					2,77E+15

Appendix 14. Details of emergy accounting: "irrigated" cashew farming system.

Note	Flows	Value	Units	Transformity (sej/kg), (sej/J), (sej/$US)	Emergy Flow (sej/ha/y)
	Renewable Natural resources "R"				
1	Sun	1,584E+11	J/ha/y	1,00E+00	1,58E+11
2	Rain	6,53E+10	J/ha/y	4,70E+04	3,07E+15
3	Wind	1,58E+10	J/ha/y	2,45E+03	3,86E+13
4	underground water	1,93E+10	J/ha/y	1,76E+05	3,39E+15
5	River water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
6	Forest Biomass	0,00E+00	kg/ha/y	3,69E+11	0,00E+00
7	N (atmosphere)	2,35E+01	kg/ha/y	7,73E+12	1,82E+14
8	P (rocks)	3,01E+00	kg/ha/y	2,99E+13	8,99E+13
9	K (rocks)	1,30E+01	kg/ha/y	2,92E+12	3,79E+13
10	Ca (system)	5,47E-01	kg/ha/y	1,68E+12	9,19E+11
11	Other minerals	3,59E+00	kg/ha/y	1,71E+12	6,13E+12
12	Sediments rivers	0,00E+00	J/ha/y	7,40E+04	0,00E+00
					6,82E+15
	Non-Renewable Natural resources "N"				
13	Soil loss	2,98E+09	J/ha/y	7,40E+04	2,20E+14
					2,20E+14
	Services (Econ. Resources) "S"				
14	Man power (hard)	1,91E+02	$US/ha/y	3,11E+12	5,96E+14
15	Man power (family)	2,13E+01	$US/ha/y	3,11E+12	6,62E+13
16	Maintenance (infraestructure)	2,57E+01	$US/ha/y	3,11E+12	8,00E+13
17	Insurance cost	1,87E+01	$US/ha/y	3,11E+12	5,82E+13
18	Comunications cost	1,17E+01	$US/ha/y	3,11E+12	3,64E+13
19	Taxes	9,35E+00	$US/ha/y	3,11E+12	2,91E+13
20	Other services	1,64E+01	$US/ha/y	3,11E+12	5,09E+13
					9,16E+14
	Materials (Econ. Resources) "M"				
21	Fungicides	1,20E+01	kg/ha/y	1,48E+13	1,78E+14
22	Herbicides	0,00E+00	J/ha/y	1,31E+15	0,00E+00
23	Insecticides	1,20E+01	kg/ha/y	2,40E+12	2,88E+13
24	Nitrogen fertilizer	8,57E+01	kg/ha/y	7,73E+12	6,62E+14
25	Phosphate fertilizer	6,12E+01	kg/ha/y	2,99E+13	1,83E+15
26	Potash fertilizer	7,34E+01	kg/ha/y	2,92E+12	2,14E+14
27	Calium	0,00E+00	kg/ha/y	2,08E+12	0,00E+00
28	Other minerals	0,00E+00	kg/ha/y	1,71E+12	0,00E+00
29	Manure	1,44E+08	J/ha/y	2,69E+04	3,88E+12
30	Electricity	8,28E+09	J/ha/y	3,36E+05	2,78E+15
31	Petroleum fuels	4,27E+08	J/ha/y	1,11E+05	4,74E+13
32	Materials for maintenance	6,78E+01	$US/ha/y	3,11E+12	2,11E+14
33	Vaccines and medicaments	0,00E+00	$US/ha/y	3,11E+12	0,00E+00
34	Depreciation	3,96E+01	$US/ha/y	3,11E+12	1,23E+14
					6,08E+15

Appendix 15. Details of emergy accounting: "agribusiness" cashew farming system.

Note	Flows	Value	Units	Transformity (sej/kg), (sej/J), (sej/$US)	Emergy Flow (sej/ha/y)
	Renewable Natural resources "R"				
1	Sun	1,584E+11	J/ha/y	1,00E+00	1,58E+11
2	Rain	7,77E+10	J/ha/y	4,70E+04	3,65E+15
3	Wind	1,58E+10	J/ha/y	2,45E+03	3,86E+13
4	underground water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
5	River water	0,00E+00	J/ha/y	1,76E+05	0,00E+00
6	Forest Biomass	0,00E+00	kg/ha/y	3,69E+11	0,00E+00
7	N (atmosphere)	3,85E+00	kg/ha/y	7,73E+12	2,98E+13
8	P (rocks)	4,92E-01	kg/ha/y	2,99E+13	1,47E+13
9	K (rocks)	2,12E+00	kg/ha/y	2,92E+12	6,20E+12
10	Ca (system)	8,95E-02	kg/ha/y	1,68E+12	1,50E+11
11	Other minerals	5,87E-01	kg/ha/y	1,71E+12	1,00E+12
12	Sediments rivers	0,00E+00	J/ha/y	7,40E+04	0,00E+00
					3,74E+15
	Non-Renewable Natural resources "N"				
13	Soil loss	2,98E+09	J/ha/y	7,40E+04	2,20E+14
					2,20E+14
	Services (Econ. Resources) "S"				
14	Man power (hard)	1,91E+02	$US/ha/y	3,11E+12	5,96E+14
15	Man power (family)	2,13E+01	$US/ha/y	3,11E+12	6,62E+13
16	Maintenance (infraestructure)	2,57E+01	$US/ha/y	3,11E+12	8,00E+13
17	Insurance cost	1,87E+01	$US/ha/y	3,11E+12	5,82E+13
18	Comunications cost	1,17E+01	$US/ha/y	3,11E+12	3,64E+13
19	Taxes	9,35E+00	$US/ha/y	3,11E+12	2,91E+13
20	Other services	1,64E+01	$US/ha/y	3,11E+12	5,09E+13
					9,16E+14
	Materials (Econ. Resources) "M"				
21	Fungicides	6,00E+00	kg/ha/y	1,48E+13	8,88E+13
22	Herbicides	0,00E+00	J/ha/y	1,31E+15	0,00E+00
23	Insecticides	1,20E+01	kg/ha/y	2,40E+12	2,88E+13
24	Nitrogen fertilizer	4,28E+01	kg/ha/y	7,73E+12	3,31E+14
25	Phosphate fertilizer	3,06E+01	kg/ha/y	2,99E+13	9,15E+14
26	Potash fertilizer	3,67E+01	kg/ha/y	2,92E+12	1,07E+14
27	Calium	0,00E+00	kg/ha/y	2,08E+12	0,00E+00
28	Other minerals	0,00E+00	kg/ha/y	1,71E+12	0,00E+00
29	Manure	2,89E+08	J/ha/y	2,69E+04	7,77E+12
30	Electricity	6,30E+08	J/ha/y	3,36E+05	2,12E+14
31	Petroleum fuels	2,49E+08	J/ha/y	1,11E+05	2,76E+13
32	Materials for maintenance	3,74E+01	$US/ha/y	3,11E+12	1,16E+14
33	Vaccines and medicaments	0,00E+00	$US/ha/y	3,11E+12	0,00E+00
34	Depreciation	2,47E+01	$US/ha/y	3,11E+12	7,69E+13
					1,91E+15