UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"
Câmpus de Sorocaba

PROGRAMA DE PÓS-GRADUAÇÃO em
Ciências Ambientais

MARCELA PORTO COSTA

SOCIO-ECO-EFFICIENCY OF INTEGRATED AND NON-INTEGRATED SYSTEMS OF CROP, FORESTRY AND LIVESTOCK IN THE IPAMERI CITY, AT BRAZILIAN CERRADO

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Master's Thesis presented as a requirement for obtaining a Master's degree in Environmental Sciences of the Universidade Estadual Paulista "Júlio de Mesquita Filho" in the Concentration Area of Diagnosis, Treatment and Environmental Recovery

Advisor: Prof. Dr. Gerson Araújo Medeiros

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TÍTULO: Socio-Eco-Efficiency of Integrated and non-integrated systems of crop, forestry and livestock in the Ipameri city, at Brazilian Cerrado.

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I dedicate this work to all my family,
especially to my parents Marize Port Costa and
José Carlos Carneiro da Costa (in memoriam),
and my grandparents Lucia Port and Ozires Porto (in memoriam).
I also dedicate to the owners and employees of agribusiness
who seek a solution to recover their land
in an environmentally correct,
economically viable
and socially fair way.

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GLOSSARY OF LIFE CYCLE ASSESSMENT

The follow definitions were brought from a Life Cicle Assessment Glossary (Silva & Oliveira, 2014), which is a rich document of reunited terms from literature of LCA.

Abiotic Depletion

The extraction of non-renewable raw materials such ores.

Actual effect

Environmental impact which takes into account different sensitivities to pollution in different geographical areas.

Allocation

Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems.

Allocation based on economic factors

Allocation procedure in which the distribution criterion is the proportionality between the commercial value of co-products.

Allocation problem

An allocation problem occurs when several products share the same industrial process and the environmental load of the process is to be expressed in relation to only one of the products. Allocation problems can be dealt with Allocation through partitioning and System Expansion.

Allocation through portioning

Way of dealing with an allocation problem through dividing the emission and the resources use among the different products for an industrial process. The portioning can be made on for example weight basis, energy content or economic value of the process' products.

Attributional approach

System modelling approach in which inputs and outputs are attributed to the functional unit.

Boustead

Database life cycle inventory for performing LCA studies. (BOUSTEAD, 2013)

Characterization

Calculation of category indicator results.

Characterization factor

Factor derived from a characterization model which is applied to convert an assigned life cycle inventory analysis result to the common unit of the category indicator. .

Cradle-to-gate

An assessment that includes part of a product's life cycle. Including material acquisition through the production of the studied product excluding the use or end-of-life stages.

Cradle-to-grave

A cradle to grave assessment considers impacts at each stage of a product's life cycle, from the time natural resources are extracted from the ground and processed through each subsequent stage of manufacturing, transportation, product use, recycling, and ultimately, disposal.

Comparative assertion

Term used in marketing applications of LCA to denote an environmental claim regarding the superiority of equivalence of a product versus a competing product. An LCA study used to make comparative assertions requires critical review.

Completeness

Percentage of flow that is measured or estimated.

Completeness check

Process of verifying whether information from the phases of a life cycle assessment is sufficient for reaching conclusions in accordance with the goal and scope definition.

Comparative LCA

LCA study in which two or more alternative product systems are compared.

Consistency check

Process of verifying that the assumptions, methods and data are consistently applied throughout the study and are in accordance with the goal and scope definition performed before conclusions are reached.

Co-product

Any of two or more products coming from the same unit process or product system.

Cut-off criteria

Specification of the amount of material or energy flow or the level of environmental significance associated with unit processes or product system to be excluded from a study.

Critical review

Process for the quality assurance of an LCA study, involves for example evaluation of the validity of the results and the transparency of the report.

Data

Any flow of matter or energy that is an input or output the product system.

Data collection

Process of searching, collecting and documenting data in an LCA study.

Dataset review

A manual, systematic, independent, and documented process for evaluating LCI datasets in the framework of the database against established validation and review criteria.

Data quality

Characteristics of data that relate to their ability to satisfy stated requirements.

Data supplier

Person or organization that has environmental data of interest for an LCA study.

Eco-efficiency analysis

Eco-efficiency can be defined as maximizing the economic efficiency while minimizing the impact on the environment.

Ecoinvent

"The ecoinvent database is a background database that allows the LCA practioner to perform life cycle assessments (or any other type of environmental assessment) of a specific good or service, having inventory data for the complete supply chains"(ECOINVENT, 2007)

Elementary flow

Material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation.

Energy Flow

Input to or output from a unit process or product system, quantified in energy units.

Environmental impact

Consequences of pollution, e.g. eutrophication and depletion of stratospheric ozone.

Environmental aspect

Element of an organization's activities, products or services that can interact with the environment

Environmental load

Emissions of pollutants, sometimes also called environmental burden or intervention.

Expert

<audit> Person who provides knowledge or expertise to the audit team[1]. <validation or verification> person who has knowledge or expertise for the validation or verification team.

Flowchart

Visual representation of the LCA model.

Function

The function is the purpose of the product selected for the LCA goal.

Functional unit / costumer benefit

Quantified performance of a product system for use as a reference unit.

Geographic Coverage

Geographic area for which the data for each of the unit processes must be collected, aimed to meet the objectives of the study.

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[1] Note 1: Specific knowledge or experience is one that concerns the organization, process or activity to be audited, or language or culture. Note 2: An expert does not act as an auditor in the audit team. [ISO19011: 2002Note 3: Knowledge and expertise are related to the organization or project to be validated and verified, or language or culture relevant. Note 4: A technical expert does not act as a validator or verifier on the team validation or verification.

Global Warming

Increasing amounts of CO_2 and other greenhouse gases in the Earth's atmosphere are leading to increased absorption of the radiation emitted by the Earth and hence to global warming. CO_2, N_2O, CH_4 and CFCs all contribute to global warming.

Impact Category

Class representing environmental issues of concern to which life cycle inventory analysis results may be assigned.

Impact Category Indicator

Quantifiable representation of an impact category.

Input

Product, material or energy flow that enters a unit process.

Intermediate Flow

Product, material or energy flow occurring between unit processes of the product system being studied.

Intermediate Product

Output from a unit process that is input to other unit processes that require further transformation within the system.

Interested party

Individual or group concerned with or affected by the environmental performance of a product system, or by the results of the life cycle assessment.

Inventory analysis

Phase during which the LCA model is build according to the specifications determined in the goal and scope definition, data are collected and calculations indicating the environmental load of the product are made.

Life cycle thinking

A way of thinking that considers cradle-to-grave implications of different activities and products without going into the details of an LCA study

Life cycle costing (LCC)

All costs associated with the system as applied to the defined life cycle.

Life cycle inventory analysis (LCI)

Phase of Life Cycle Assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle.

Life Cycle Assessment (LCA)

Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.

Life cycle

Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal.

Life cycle management

Managerial practices and organizational Arrangement in a company or a product chain that are expressions of life cycle thinking.

Life Cycle Interpretation

Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations.

Main Flow

All flows to and from an economic process which are the goal of the process and to which allocations are made. These flows are economic flows with a positive value.

Normalization

Term used both in the context of the inventory analysis and the impact assessment to indicate relation to a reference value. Normalization in the context of the inventory analysis means to relate collected production data, which are often given on a yearly basis, to the amount of production during the same period so that the environmental loads are given relative to the amount of production. In the context of impact assessment, normalization means that the impact of a studied product is related to the total

Output

Product, material or energy flow that leaves a unit process.

Ozone Depletion

Ozone Depletion Potential is defined as the amount of CFC-11 (in kg) that would cause ozone depletion equivalent to 1 kg of the substance emitted.

Potential effect

Possible, usually meaning maximum, environmental impact of a pollutant. See also Actual effects.

Practitioner

Person conducting an LCA study and in charge of the practical work (life cycle modeling, data collection, calculations, etc).

Primary data

Data determined by direct measurement, estimation or calculation from the original source.[2]

Product Flow

Products entering from or leaving to another product system.

Process energy

Energy input required for operating the process or equipment within a unit process, excluding energy inputs for production and delivery of the energy itself.

Product

Any goods or service.[3]

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[2] NOTE: primary or original source is the source of initial physical or chemical appearance and not the initial literal appearance.

[3] NOTE 1: The product can be categorized as follows: services (e.g. transport), software (e.g. computer program, dictionary); hardware (e.g. engine mechanical part); processed materials (e.g. lubricant);

NOTE 2: Services have tangible and intangible elements. Provision of a service can involve, for example, the following: an activity performed on a customer-supplied tangible product (e.g. automobile to be repaired); an activity performed on a customer-supplied intangible product (e.g. the income statement needed to prepare a tax return); the delivery of an intangible product (e.g. the delivery of information in the context of knowledge transmission); the creation of ambience for the customer (e.g. in hotels and restaurants). Software consists of information and is generally intangible and can be in the form of approaches, transactions or procedures. Hardware is generally tangible and its amount is a countable characteristic. Processed materials are generally tangible and their amount is a continuous characteristic.

NOTE 3: Adapted from ISO 14021:1999 and ISO 9000:2005

Product System

Collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product.

Raw data

Data used in unit process inventory modelling to deliver inventory data at the end, which are extracted from various data sources, such as bookkeeping of a plant, national statistics, or journal literature.

Raw Material

Primary or secondary material that is used to produce a product.

Reference Flow

Measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit.

Releases

Emissions to air and discharges to water and soil.

Representativeness

Qualitative assessment of the degree to which the data set reflects the true population of interest (i.e. geographical coverage, time period and technology coverage).

Reviewer (independent external reviewer/independent internal reviewer)

A competent and independent person or persons with responsibility for performing and reporting on the results of a dataset review. (Independent external reviewer: A reviewer recognized by the database manager, who was not involved in the definition or development of the reviewed case and is therefore independent. The reviewer has no affiliation with dataset provider or the study commissioner. This includes both the reviewer as a person and their employer as an organization.) (Independent internal reviewer: A reviewer recognized by the database manager, who is not involved in the study to be reviewed, or quantitatively relevant parts (e.g. background data) but can be part of the organization that performed or commissioned the LCI work.)

Secondary data

Data calculated or estimated from information available in the literature.

Sensitivity Analysis

Analysis to determine the sensitivity of the outcome of a calculation to small changes in the assumptions or to variations in the range within which the assumptions are assumed to be valid. This includes changes in the process data.

Sensitivity check

Process of verifying that the information obtained from a sensitivity analysis is relevant for reaching the conclusions and for giving recommendations.

System Boundary

Set of criteria specifying which unit processes are part of a product system.

System expansion

Way of dealing with an allocation problem. System expansion means that surrounding industrial systems affected by changes in the studied product system are included in the LCA model. See also Allocation through partitioning.

Transparency

Open, comprehensive and understandable presentation of information.

Temporal Coverage

Age of data and the minimum length of time over which data should be collected.

Technological Coverage

Indicates the particular technology or set of technologies for which data should be collected.

Uncertainty analysis

Systematic procedure to quantify the uncertainty introduced in the results of a life cycle inventory analysis due to the cumulative effects of model imprecision, input uncertainty and data variability.

Unit process

Smallest element considered in the life cycle inventory analysis for which input and output data are quantified.

Unit process model

A group of mathematical relations that transforms raw data into a unit process dataset.

Unit process modeling

Procedures of defining mathematical relations and collecting raw data to obtain a unit process dataset.

Uncertainty

Quantitative definition: Measurement that characterizes the dispersion of values that could reasonably be attributed to a parameter.

Qualitative definition: A general and imprecise term which refers to the lack of certainty in data and methodology choices, such as the application of non representative factors or methods, incomplete data on sources and sinks, lack of transparency, etc.

Validation

Ensuring that data satisfy defined criteria.

Verification

Confirmation, through the provision of objective evidence that specified requirements have been fulfilled.

Waste

Substances or objects which the holder intends or is required to dispose of.

Weighting method

Method that indicate the environmental harm of pollutant or a resource relative to other pollutants and resource. Weighting methods evaluate all kinds of environmental loads or problems on a single scale and can be used to express the overall environmental impact as a single number.

Weighting

Converting and possibly aggregating indicator results across impact categories using numerical factors based on value-choices; data prior to weighting should remain available.

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LIST OF ABBREVIATIONS

ADP: Abiotic Depletion Potential

AP: Acidification Potential

AOX: Adsorbable Organic Compounds

B: Boron

BEN: National Energy Balance

Ca: Calcium

Cd: Cadmium

Cr: Chrome

CaO: Calcium oxide

CED: Cumulative Energy Demand

CH_4: Methane

CLi: Crop-Livestock integration

CLFi: Crop-Livestock-Forest integration

Co: Cobalt

CoO: Cobalt oxide

CO_2: Carbon dioxide

Cu: Copper

COD: Chemical Oxygen Demand

EDP: Environmental Damage Potential

EEA: Eco-Efficiency Analysis

EMBRAPA : Brazilian Agricultural Research Corporation

EP: Eco-toxicity Potential

FAO: Food and Agriculture Organization of the United Nations

FEE: Fundação Espaço ECO®

FU: Functional Unit

GO: Goias

GWP: Global Warming Potential

HC: Hydrocarbons

HCL: Chloridric Acid

Hg: Mercury

I: Iodine

KCl: Potassium chloride

K_2O: Potassium oxide

LCI: Life Cycle Inventory

LCA: Life Cycle Assessment

LCIA: Life Cycle Impact Assessment

LW: Live Weight

MAP: Monoammonium Phosphate

MAPA: Ministry of Agriculture, Livestock and Supply

MEC: Maximum Emission Concentration

Mg: Magnesium

MgO: Magnesium Oxide

MJ: Mega Joule

Mn: Manganese

Mo: Molybdenum

N: Nitrogen

NH_3: Ammonia

Ni:Nickel

NMVOC: Non-Methane Volatic Organic Compounds

NO: Nitrogen monoxide

NOx: Nitrogen oxide

N_2O: Nitrous oxide

NO_3: Nitrate

NOEC: No Observed Effect

NPK: Nitrogen-Phosphorus-Potassium

NSF: National Sanitation Foundation

NT: No Tillage

ODP: Ozone Depletion Potential

OM: Organic Matter

P: Phosphorus

Pb: Lead

P_2O_5: Phosphorus pentoxide

POCP: Photochemical Ozone Creation Potential

PPE: Personal Protective Equipment

R&D: Reseach and Development

S: Sulfur

SBF: Santa Brígida Farm

Se: Selenium.

SEEA: Socio-Eco-Efficiency Analysis

SI: Soil Index

SPL: Slowly Permable Layer

TRU: Technological Reference Unit

TCO: Total Cost of Ownership

UNESP: Universidade Estadual Julio de Mesquita Filho

UK: United Kingdom

USLE: Universal Soil Loss Equation

Vkm: Vehicle.Kilometer (não encontrei no texto)

VOC: Volatic Organic Compounds

ABSTRACT

In the 1970s, the occupation of the Cerrado through the expansion of agricultural frontiers and increasing productivity also brought pasture degradation, environmental and economic damage. In this context, other techniques in addition to soil and crop management have been developed for the recovery or pasture formation, such as the systems of Crop-Livestock integration (CLi) and Crop-Livestock-Forest integration (CLFi). The objective of this study was to evaluate aspects of social, environmental and economical efficiency of agricultural and cattle farm production in the productive area of the Brazilian Cerrado based on the assessment of the life cycle approach systems. The study was conducted in the municipality of Ipameri in Goiás, in the technological reference unit of Santa Brigida Farm, for the dissemination of the CLi and CLFi systems, in partnership with the Brazilian Agricultural Research Corporation - EMBRAPA, considering the CLi and CLFi systems, timber and grain cultivation, and cattle breeding by conventional methods. The analysis of social, environmental and economic efficiency was based on the socio-eco-efficiency tool (AgBalance™). This tool consists of assessing the life cycle in agriculture, supplemented by indicators of economic environmental quality, social development, and specific agricultural activity. Results show advantages when Crop-Livestock-Forest integration is prioritized followed by Crop-Livestock system comprising the three pillars – social, environmental and economic – when compared to conventional systems.

Key-Words: Socio-eco-efficiency, Crop-Livestock-Forest integration and life cycle assessment.

RESUMO

Na década de 1970 a ocupação do Cerrado, por meio da expansão de fronteiras agrícolas e do aumento da produtividade, trouxe também a degradação das pastagens e prejuízos ambientais e econômicos. Nesse contexto, técnicas e manejos de solo e culturas têm sido desenvolvidos para a recuperação ou formação de pastagens, como os sistemas de integração lavoura-pecuária (iLP) e lavoura-pecuária-floresta (iLPF). O objetivo do presente trabalho foi avaliar aspectos da eficiência social, ambiental e econômica de sistemas de produção agrícola e pecuarista em área produtiva do cerrado brasileiro baseado na abordagem da avaliação do ciclo de vida. O trabalho foi desenvolvido no município de Ipameri em Goiás, na fazenda Santa Brígida , polo de difusão tecnológica deste sistema integrados em parceria com a Empresa Brasileira de Pesquisa Agropecuária – EMBRAPA . O estudo avaliou os sistemas iLP, iLPF e o cultivo de madeira, grãos e criação de gado pelos métodos convencionais. A análise de eficiência social, ambiental e econômica foi baseada na ferramenta de sócioecoeficiência (AgBalanceTM) desenvolvida pela empresa BASF SE e certificada por agências globais independentes, como DNV Business Assurance e NSF International. Essa ferramenta consiste na avaliação do ciclo de vida na agricultura, por indicadores de qualidade ambiental, desenvolvimento social e econômico, específicos da atividade agropecuária. Os resultados mostram vantagens qundo a integração lavoura-pecuária-floresta é priorizada seguido pelo sistema lavoura-pecuária nos três pilares - social, ambiental e econômico - quando comparado com os sistemas convencionais.

Palavras-Chave: Socioecoeficiência, Integração Lavoura-Pecuária-Floresta (iLPF), Avaliação do cilo de vida (ACV) ,

SUMMARY

1. INTRODUCTION

The world demand for food, fiber and energy is increasing and recent studies indicate that the world population is expected to reach 9 billion people by 2050. According to the Food and Agriculture Organization of United Nations (FAO), this increasing demand has an impact over the global food production estimated in the order of 60% based on data from 2005 and 2007. The population growth is not solely responsible for this increase in demand, but the urbanization and rising incomes contribute to the changes that have been identified in the consumption pattern of products derived from agricultural activities (FAO, 2009).

In the recent years, changes in food consumption habits have been observed especially in emerging economies of countries in East and West Asia, North Africa and Latin America. In these countries, new food consumption patterns have been gradually replacing the consumption of roots, tubers and coarse grains of wheat, rice, sugar, vegetable oils, meat and dairy products. Besides those emerging markets, the USA market has shown substantial increase of meat consumption per capita (FAO, 2009).

Brazil occupies a prominent position in the global food production scenario. In 2010, it was the fifth largest producer of cereals and oilseeds, the second largest producer of citrus and the second largest producer of beef and bufalinas (FAO, 2014).

Comparative studies of competitive markets in the export business show that Brazil has an advantage over certain emerging countries due to its economic and social incentive policies currently in place, large extensions of degraded areas for recovery, and abundance of natural resources. In Africa, despite its high potential for food production, there are still many social and ethnic conflicts hindering its agricultural development (FAO, 2009).

Intensification of food production in Brazil to supply food demand may be associated with negative environmental effects, such as environmental impacts generated by new agricultural frontier openings, overuse of fertilizers, high degree of grassland degradation, among others (FAO, 2009). There are also economic and social factors that limit the intensification of food production, such as high interest loan rates, social conflicts, among others, which impose challenges for the increase of agricultural production in a more sustainable way while integrating the economic, social and environmental pillars.

In this context, sustainable soil management and crop techniques have been developed for the recovery of productive areas in tropical and sub-tropical environments, as is the case of integrated Crop-Livestock Systems (CLI) and Crop-Livestock-Forest (CLFi) developed by EMBRAPA (Brazilian Agricultural Research Corporation). These systems are able to recover degraded pasture at relatively low costs and produce three times the volume of grain and twice the volume of meat without the need for opening new areas by optimizing land use and incorporating social benefits (EMBRAPA, 2013).

However, studies aimed at evaluating the efficiency of systems that incorporate social, economic and environmental aspects in an integrated way are still scarce in the literature. Alternative practices combining different areas of knowledge, integrating the social, environmental and economic aspects are the Life Cycle Assessment (LCA) and, more recently, the Eco-Efficiency Analysis (EEA); Socio-Eco-Efficiency Analysis (SEEA) (Saling et al., 2002) and AgBalance^{TM} (Schöneboom et al. 2012). The last one includes not only environmental, economic and social aspects, but also considers agricultural sustainability indicators.

2. OBJECTIVE

The objective of this study was to evaluate, in an integrated manner, the social, environmental and economic efficiency of five different production systems combination for agriculture, forestry and livestock in a Brazilian biome, the Cerrado, based on the lifecycle analysis approach.

2.1. Specif objectives

- Application of the LCA approach to evaluate social, environmental and economic efficiency of Crop-Livestock-Forest integration system (CLFi), Crop-Livestock integration system (CLi) and conventional wood, livestock and crops (soybeans, sorghum and corn) production systems.
- Identify and quantify the environmental, social and economic aspects of composition of systems evaluated.
- Discussion of the application of AgBalance^{TM} tool to achieve the objectives proposed by the study.
- Identify the data that can be enhanced to a more accurately study.
- Identify the critical points of the application of LCA in the study of integrated and conventional farming system.

3. LITERATURE REVIEW

3.1. Integrated systems in Cerrado

Brazil has an area larger than 800 million hectares, of which about 200 million are intended for livestock production and 100 million to agricultural production (EMBRAPA, 2013). However, according to this reference, 82% of the 200 million hectares set aside for livestock production are under a degradation process.

Some contributing factors have been suggested for the degradation of pasture areas in various regions of Brazil and other countries. Other factors, such as the lack of nutrients, soil acidification, loss of organic matter, soil compaction, drought, overexploitation of pasture resources by animals, climate change, and low technological investment are leading to the emergence of pests, weed and erosion (PERON, EVANGELISTA, 2004, LI et al., 2011, AIDAR, KLUTHCOUSKI, 2003).

Balbino et al. (2011a) state that these aspects bring cause negative consequences to the production system, such as reduced supply of fodder, low performance of parameters, and meat and milk productivity per hectare as well as low economic return.

The advanced stage of land degradation in Brazil strongly requires the development of sustainable systems integrating no-tillage, crop rotation and consortiums.

Balbino et al. (2011b) describe these systems as a crop-livestock integration (CLi) or an agro pastoral system in which the interaction takes place between the agricultural and livestock components in rotation or consortium; Livestock-Forest integration (LFi) or silvipastoral, where livestock components (pasture and animal) interact with the forest; Crop-Forest integration (CFi) or agroforestry, in which the production system integrates the forest and agriculture components for intercropping of tree species; and Crop-Livestock-Forest (CLFi) or agrosylvopastoral production system that integrates all components, agricultural, livestock and forestry in rotation, consortium or succession in the same area.

One of the main objectives of these integrations is to allow the reform of degraded pastures using integrated systems such as the CLi system. This system has improved the physical and chemical conditions of the soil with pasture in the crop area, and the recovery of soil fertility, producing pasture, conserved forage and grain for animal feed in the dry season as well as increasing the carrying pasture capacity and the productivity of crops and pastures (ALVARENGA et al., 2007).

Such conditions lead to reduced costs in both the agricultural activity and livestock, thereby increasing producer income stability. For grazing reform model through CLi we refer the studies of the Barreirão System (KLUTHCOUSKI et al., 1991) and the Santa Fe System (ALVARENGA, 2004).

The crop and livestock integration system have various economic, social and environmental benefits, which have been studied by some authors, such as Sá et al. (2013), Loss et al. (2012), Costa (2012), Balbino et al. (2011b), Balbinot Junior et al. (2009), Albuquerque et al. (2001), Flores et al. (2007), Lanzanova et al. (2007), Salton (2014), Marchão et al. (2007).

In general, there are environmental benefits coming from the recovery of degraded land combined with less damaged biota and crop which, as a consequence, lead to reduced use of pesticides. The economic benefits include lower cost of deployment and maintenance than conventional systems, generating greater profitability and quality of product. Social benefits are associated with the jobs created directly and indirectly by the system deployment as well as the reduction in rural exodus (AIDAR et al., 2003).

The annual crop production model causes the compactness and decomposition of organic matter, modifying the physical and biological parameters leading to degradation, whereas in the Crop-Livestock integration system, the tropical forage replenish the organic matter, recycle underground nutrients, and contributes to the biological plowing due to its roots and biological activity, i.e., it is a reciprocal way of improvement of the system and the environment (Kluthcouski et al, 2004).

To include the forest component in the CLi system, benefits are added, such as the formation of favorable microclimate and increased thermal comfort for animals under the trees (GARCIA et al, 2011; SILVA et al, 2011). These systemm (CLFi and CLi) also provide flexibility according to the type of crop being developed in consortium, respecting the characteristics of the soil and the region.

The CLFi is suitable for forestry production since it can be used in smaller or larger spacing of tree planting lines for wood production or, instead, for agricultural and livestock activity. (PORFÍRIO-DA-SILVA, 2006, 2007).

Oliveira et al. (2008) analyze the carbon stock and the economic profitability of timber production from the age of seven in various silvopastoral systems. The authors conclude that the incorporation of forestry component can become attractive because of its potential for trading credits in the carbon market.

Currently, producers who practice recovery of degraded pastures by means of No Tillage system (NT), biological nitrogen fixation, planted forests, treatment of animal waste or Crop-Livestock-Forest can benefit from the government low-carbon credit line for agriculture (ABC Plan), coordinated by the Ministry of Agriculture, Livestock and Supply (MAPA).

According to EMBRAPA (2012), the CLFi system has high potential for carbon sequestration due to high accumulation of biomass, forage and forestry as well as accumulation of organic matter in the soil, contributing to the reduction of greenhouse gases (GHG) in the atmosphere. In this context, EMBRAPA aims at promoting an increase, until 2020, in the use of the system of 4 million hectares, enabling reduce CO_2 emissions in the order of 18 to 22 million tonnes.

In 2013, EMBRAPA published the case study of the Santa Brigida Farm, which is located in the municipality of Ipameri, in the state of Goiás. This area has great agricultural potential due to its clay and sandy latosol texture soils, and approximate altitude of 800 meters. However, extractive livestock prevails in pastures showing highly advanced stages of degradation. In 2006, the Santa Brigida Farm (SBF) found itself inserted in this context. With support from EMBRAPA, the farm soils were recovered through the implementation of CLi and CLFi systems, turning the farm into a Technological Reference Unit (TRU) (EMBRAPA, 2013).

The improvement of environmental soil quality in this farm through the implementation of CLi in this farm was assessed by Costa (2012). The author evaluated the soil quality by measuring physical parameters in different types of tillage, including conventional in degraded pasture, no-tillage in crop-livestock integration system and native vegetation of the Cerrado region, obtaining indicators that point to a possible improvement in soil quality in the CLi system when compared to conventional pasture.

The growing recognition of the importance of CLFi system led to the creation of the Law 12805/2013, establishing the National Policy for Crop-Livestock-Forest integration and modifying the Law 8171 of 17 January 1991 (BRASIL, 2013). The new law strengthens this practice through environmental education, encouraging research and disseminating the importance of the system in the recovery of degraded areas and the optimization of land use practices based on concepts of sustainability. According to EMBRAPA (2013), Brazil has a potential for technological and environmental progress in the agricultural production if the model that was implemented at SBF is applied to 100 million hectares of degraded area.

3.2. Life cycle assessment (LCA)

This concept is related to evaluation of the environmental performance of products throughout their life cycle, from the extraction of natural resources through every step of the production chain, from its use and to final disposal. In general terms, the Life Cycle Assessment method (LCA) aims to provide a diagnosis in a systemic scale while evaluating the quantitative nature of the environmental performance of the product for a specific function. The LCA diagnosis generates environmental impact indicators that are used in the analysis of the performance of the function under consideration. In comparisons of performance, different objects of study must accomplish the same defined function. To offer this result to the technique, in methodological terms, there are four operational phases (ISO 14040, 2006).

3.2.1.Goal and Scope

Establishing conceptual foundations of the study, in the Goal definition phase, there are some guiding aspects as to what is expected, the purposes for which the methodology will be used and what the target audience is for the LCA study. The Scope definition establishes the structural elements for the application of the defined function. These elements are: the definition of the function in the analysis and quantification by determining the functional unit for the study. The delimitations of the system under study obtained from the settlement of limits and boundaries between it and the external environment also belong to the procedure of scope definition (ISO 14040, 2006).

This stage of LCA methodology involves other steps: definition of assumptions - geographical, temporal and technological - and of the criteria that characterize and determine the process of data collection; the establishment of allocation criteria used for the allocation of environmental loads in multifunctional process, and the selection not only of the most appropriate method of impact assessment, but also of the categories of impacts that will be observed during the evaluation (ISO 14040, 2006).

3.2.2.Life Cycle Inventory Analysis (LCI)

This step compiles and quantifies input flows (materials and energy) and output flows (in the form of products, coproducts, emissions of matter and energy) for the system throughout its life cycle, referencing them to the functional unit defined for the study. Adjustments of environmental aspects generally occur through the realization of mass and energy balances. The LCI product is a group of inputs and outputs of matter and energy streams, which flows through the boundaries defined between the system under consideration and its external environment (ISO 14040, 2006).

3.2.3.Life Cycle Impact Assessment (LCIA)

This step consists of magnifying impacts caused by the system to the environment and to human beings by the function in analysis. Both streams of matter and energy that belong to the consolidated inventory are described quantitatively by category of environmental impact defined in the scope definition. In the Eco-Efficiency Analysis method (Saling et al., 2002), the potential impact categories are expressed in the Environmental Fingerprint, considering: Cumulative Energy Demand (CED), Abiotic Depletion Potential (ADP), Consumptive Water Use, Air Emissions (Global Warming Potential (GWP) , Photochemical Ozone Creation Potential (POCP), Ozone Depletion Potential (ODP) and Acidification Potential (AP), Water Emissions, Solid Waste Emissions, Land Use, Human Toxicity Potential and Occupational Illnesses and Accidents Risk Potential.

The alternative values for each impact category are normalized, i.e., the worst alternative in the category evaluated is equal to value one, and the others are represented in relation to this alternative.

The Eco-Efficiency matrix is the graphic that aggregates the calculations of environmental and economic impacts for each alternative, compared by applying each category a weighting factor. This weighting factor is calculated according to the importance of each impact category for the studied processes, with respect to the materials and energy consumption and their total emissions in comparison with the total consumptions/emissions of the country in which the process occurs, establishing the environmental importance of each effect resulting from the processes in analysis. Regarding the relevance of the economic impact, it is considered the contribution of the studied process to the Gross Domestic Product

(GDP) of the country being considered in the study. The relevance of environmental categories also takes in account the social perception for those impacts.

The environmental and economic indices are aggregated and represent a single point at the matrix.

3.2.4.LCA Interpreting

This last step of LCA allows evaluating the rigor with which the technique was applied. Therefore, not only elements such as data quality, but also convergence analysis between the executive steps taken for the purpose the study is intended, are confronted with each other and with requirements defined by ISO 14040:2006 and 14044:2006 and those recommended by the EEA method (Saling et al., 2002).

3.2.5.Eco-Efficiency

According to the concept developed in 1992 by the World Business Council for Sustainable Development (WBCSD, 2012), "Eco-efficiency is achieved through the provision of goods and services at competitive prices that satisfy human needs and bring quality of life, while that progressively reducing environmental impact and resource consumption throughout the life cycle to a level at least equivalent to the estimated carrying capacity of the Earth”.

This concept describes a vision for production of goods and services that generate economic value while reducing environmental impacts of production. It also suggests a significant link between resource efficiency (leading to productivity and profitability) and environmental responsibility. Therefore, eco-efficiency is the most efficient use of materials and energy in order to reduce the economic costs and environmental impacts.

The elements of eco-efficiency are: (WBCSD, 2012):

- Reduce material consumption on goods and services;
- Reduce energy consumption on goods and services;
- Reduce the dispersion of toxic substances;
- Enhance the recycling of material;
- Maximize the sustainable use of renewable resources;
- Extending shelf life of products;

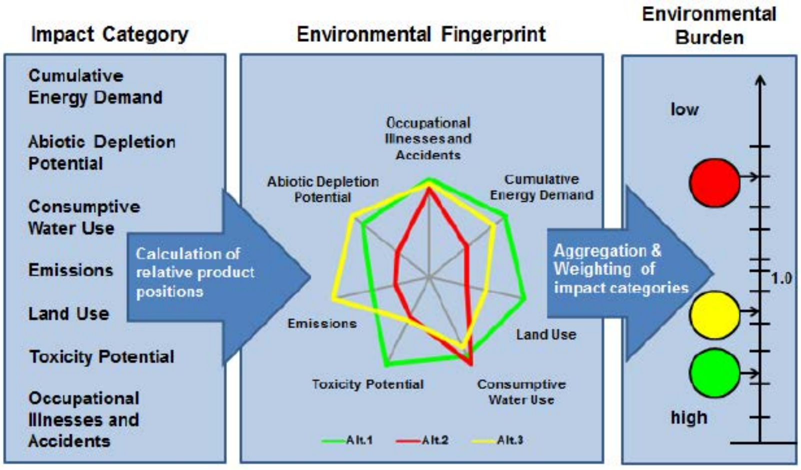
•Aggregating value to goods and services.

BASF developed the Eco-Efficiency Analysis methodology (NSF, 2013) in Germany in the 1990s. The first version of the methodology was first used in 1996 and since then it has been going through constant improvements in their modeling. It can be considered as a class management technique aimed at assessing the environmental performance of products, processes and services in order to integrate an economic evaluation. The Eco-Efficiency Analysis is based on the evaluation methodology of the life cycle as proposed at the ISO 14045 (2012) standards and is mainly used for the comparison of products that meet the same function, in order to generate information for decision making at various levels.

3.2.5.1.Environmental Impact Categories

In EEA, the consumption of natural resources and primary energy, land use, emissions and the risks are determined quantitatively. The potential toxicity is estimated semi quantitatively and determined separately. For the data achievement, the main sources of information are mapped, which determines the architecture capture, enhancement and distribution of information. The six categories are shown by a graph representation called Environmental Fingerprint (**Figure 1**). After each individual category has been evaluated, the product or process evaluated is represented through a single indicator of environmental impact, obtained by a process of weighting, normalization and re-weighting.

Figure 1: Environmental Fingerprint. (NSF, 2013)



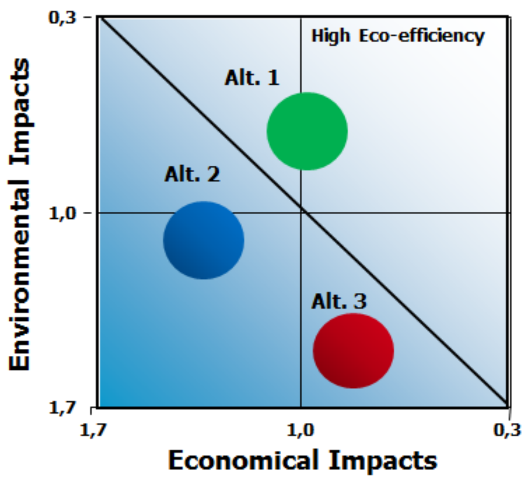
3.2.5.2. Economic Impact Categories

At this step, the costs associated with the Customer Benefit, such as production, investments, disposal, etc. - are taken into account for the economic aspects. Treatment of these data allows the calculation of the weighting and the normalization of the economic performance.

3.2.5.3.Results Reporting

The result of the analysis is presented in the Eco-Efficiency Matrix. Products or processes that have low costs and low environmental impacts would be the most eco-efficient alternatives. These alternatives are positioned in the right upper quadrant of the graph. This method provides an objective assessment of economic impacts as well as of potential environmental impacts. The eco-efficiency of products and processes can be clearly seen in the graphic making it easy for those interested in the evaluation to determine which are the best alternatives that meet the goal, as exemplified by Figure 2.

Figure 2: Eco-efficiency Matrix example. (NSF, 2013)



3.2.6.Sustainability in Agriculture and AgBalance^{TM}

The sustainability of agricultural production needs to be assessed under an integrated approach involving social, environmental and economic production systems. The concept of sustainable agriculture is defined in different ways or even with slight variations among scholars. In order to align the concepts of this sustainability with the principles of CLFi, the definition proposed by Reijntjes et al. (1992) is believed to be the most appropriate for this study since the definition refers to an ecologically balanced agriculture, economically viable, socially just, humane and adaptive.

Methodologies and tools have been developed to propitiate making inferences about sustainability in agriculture and in the food value chain, such as "Earth Assessment Tools - FAO" or other similar methods, assisting in understanding the current scenario and in decision-making on the use of land for agriculture (FAO, 1976). In contrast, Smith (1999) warns about the inconsistency of these tools, which do not lead to an adequate analysis of land use sustainability, since they do not encompass the multidimensional aspects and the multi-scale nature of agriculture.

One tool used to make inferences about sustainability in agriculture is the AgBalance^{TM} (Schoneboom, 2012). This tool involves the social, economic and environmental aspects that form the basis of socio-eco-efficiency.

The goal of the methodology is to quantify the performance of all three pillars of sustainability by means of the application of an integrated tool in order to measure sustainable development for agricultural products or processes. Thus, this tool can be used for different purposes, such as, farmers who can adopt better practices and identify options for improvement; agricultural value chain; policy makers who can assess the impact of regulations on products and farming practices and public to whom the impact of farming practices at different levels can be demonstrated, including their relationship to issues such as biodiversity or resource consumption.

AgBalance^{TM} involves analysis of the social, economic and environmental aspects that form the basis of socio-eco-efficiency. Socio-eco-efficiency includes social parameters, such as child labor, community impacts and qualification of employees with guidelines for eco-efficiency. The AgBalance^{TM} allows performing an extensive evaluation, showing no limitations concerning the geographic region or the intensity of the processes to be analyzed. With the ability to evaluate multiple systems, products and processes, AgBalance^{TM} tool makes use of over 200 criteria for the construction of 69 indicators (Schoneboom, 2012).

The judicious level sustains the credible vision and the flexibility of the tool, which is essentially based on Life Cycle Assessment and Eco-Efficiency Rating, respecting the ISO 14040 standards, 14044 (LCA) and 14045 (eco-efficiency), evaluation of economic (TCO) and social indicators of performances.

The tool emerged from pre-existing tools for sustainability analysis also developed by BASF, as is the case of Ecoefficiency Analysis and SEEBALANCE (BASF, 2001). These inspiring tools for the creation of AgBalance™ have already been successfully applied in several studies by BASF itself over 15 years since the 1990s (BASF SE 2011).

After the development of this sustainability assessment tool in the farmed environment, independent experts agencies such as DNV Business Assurance (Norway) and NSF International (United States) validated the methodology of AgBalance™ (Shoneboom et al, 2012). The purpose of the validation was to ascertain the AgBalance™ methodology with regard to coherence and transparency. Details on the scope and the results of the validation are available from the verifier's assurance statements (NSF, 2012).

3.2.6.1.Environmental and Economic Categories

AgBalance™ is based on Eco-Efficiency Analysis. The most expressive difference between the methods is that AgBalance™ replaces human toxicity by eco-toxicity indicator under environmental dimension and, on the other hand, human toxicity indicator is evaluated under the social dimension. Also, risks indicator is evaluated under social instead of environmental dimension.

On environmental dimension, impact of agricultural activity on biodiversity is assessed as a relative function, constructed from indicators of Biodiversity State, Agri-Environmental Schemes, Protected Areas, Eco-toxicity, Farming Intensity, Nitrogen Surplus, Potential for Intermixing and Crop Rotation. Additional assessment of impact from agricultural activity on soil is constructed by means of indicators of Soil Organic Matter Balance, Nutrient Balance, Potential for Soil Compaction and Potential for Soil Erosion.

LCA metrics for costs on AgBalance™ vary from study to study, according to the functional unit analyzed. In a comparison of agricultural products for the consumer, the sales price paid by the customer is used. However, when the comparison is about methods, the calculus can include expenditures with infrastructure, capital equipment, depreciation and operating costs. Cost analysis can be calculated at either a single point in time or alternatively. The indicators and categories which compose the economic dimension are shown in Figure 3.

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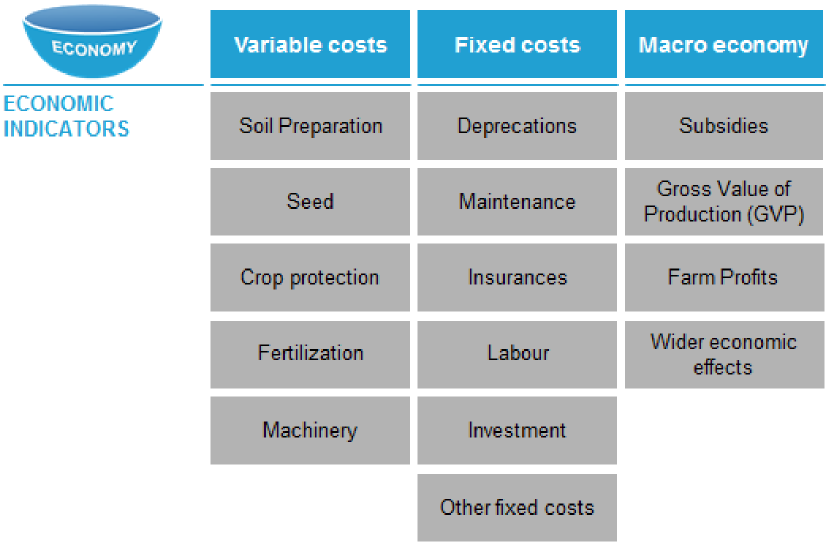
Figure 3: Economic categories and indicators analyzed at AgBalance™ (BASF,2012)



3.2.6.2.AgBalance™ – Including Social Dimension

The incorporation of the social dimension and its aspects added to the environmental and economic impacts allows a comprehensive assessment of sustainability. AgBalance™ provides this evaluation. As shown in the Figure 4, the social impacts are grouped into five categories that represent different stakeholders: farmer (employees), international community, future generations, consumers and local and national communities. For each of these stakeholders measurable indicators are considered, for example, not only the number of employees involved in work-related accidents occurring during production, but also amount of residues in feed and food when the product is used by the consumer, or for the transportation and disposal stages.

Figure 4: Social categories and indicators analyzed at AgBalance™ (BASF, 2012)

SOCIETY

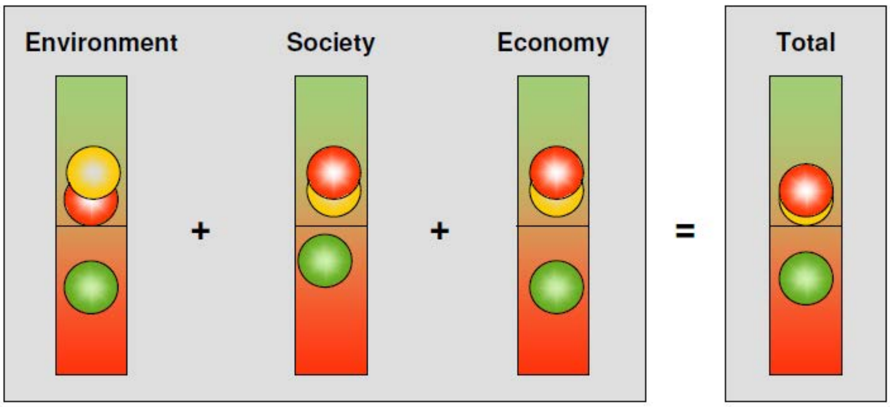
SOCIAL INDICATORS

Farmer	Consumer	Local & national community	International community	Future generation
Wages	Residues in feed & food	Access to land	Developing countries import	Trainees
Professional Training	Unauthorized / unlabeled GMO	Employment	Fair trade	Social Security
Association Membership	Toxicity Potential	Gender Equality	Child labour	R&D Expenditures
Wages and Salaries, prechain	Functional Product Characteristics	Integration	Foreign direct investment	Capital Investments
Toxicity Potential	Other risks	Qualified Employees		
Risk Potential		Employees		
Strikes and Lockouts		Part time workers		
		Family Support		

3.2.6.3.AgBalance™: Results Reporting

Similarly to EEA, AgBalance™ also applies characterization, weighting and normalization factors. Results are shown for each dimension in the respective diagram and at the end of the evaluations all dimensions can be compared, as seen in the socio-eco-efficiency diagram (Figure 5). At this diagram, the best performance can be seen when the alternative (sphere) is located at the superior region (green), and the opposite interpretation for the worst alternative.

Figure 5: Socio-eco-efficiency diagram for AgBalance™. (NSF, 2012)

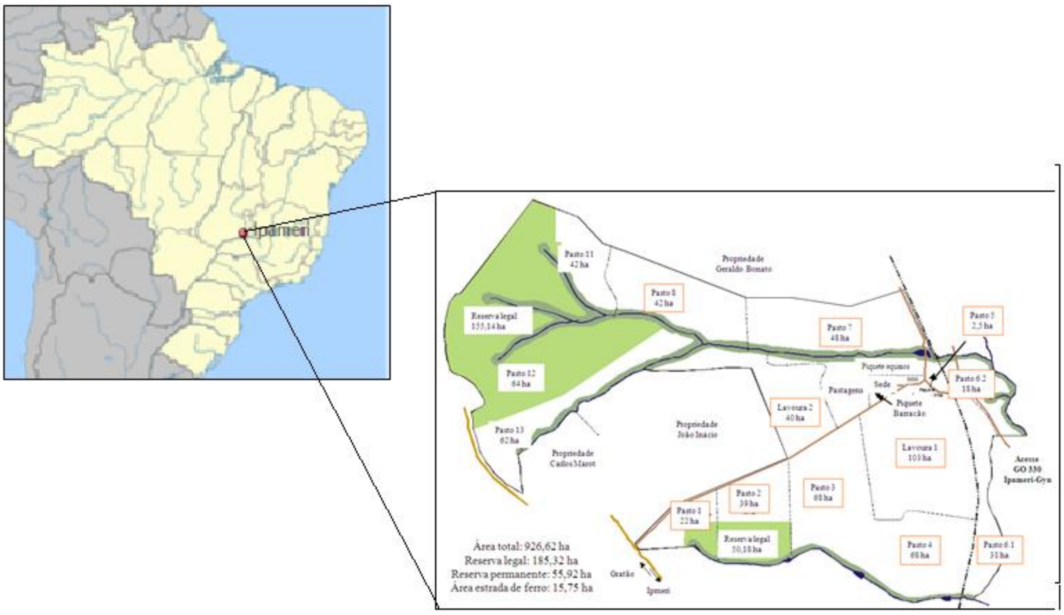


4. METODOLOGY

4.1. Location of study area

Santa Brígida Farm is located at Ipameri, a city in the State of Goiás, in the central region of Brazil (Figure 6) in the Cerrado biome, coordinates 17º39'29.47"S , 48º12'23.51" O (Headquarters), 810m above sea level. The soil of the area follows the Dark Red Latossol classification. Although it is naturally acid and low in fertility, it has good drainage, with an average clay content of 45% (OLIVEIRA, 2010; EMBRAPA, 2013).

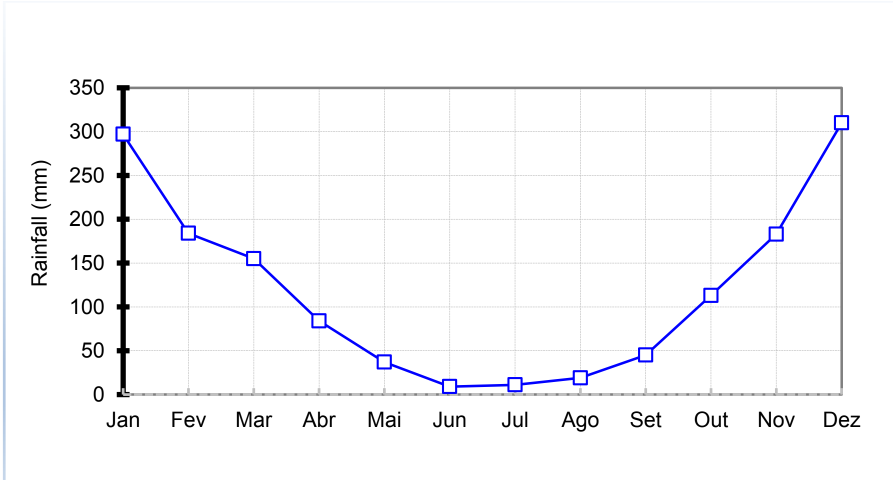
Figure 6: Location of Ipameri city, Goiás state, Brazil, and map of Santa Brígida Farm, in Ipameri – GO.



The farm became a Technological Reference Unit (TRU) established by EMBRAPA, being a diffusion hub of the Crop-Livestock-Forest Integration System. By 2005, Santa Brígida Farm had as its main activity the conventional livestock. The productivity was low, and the conditions of the soil were poor. However, since the implementation of integrated systems in 2006, the property has been producing in the same area several products such as soybeans, corn (grain and silage), sorghum, beef and wood with high productivity.

The climate, according to Köppen classification, is the AW type, tropical savanna, mesothermal (OLIVEIRA, 2010). Due to the lack of rainfall measuring instruments on the farm under study, the monthly precipitation values, as described below, refer to the municipality of Ipameri (Figure 7), which has its center located approximately 10 km far from the study area.

Figure 7: Monthly rainfall in the municipality of Ipameri-GO (ROLIM , 2003).



The work was conducted in a partnership with Fundação Espaço ECO (FEE), established by BASF S.A. in partnership with GIZ (Gesellschaft für Internationale Zusammenarbeit - Society for International Cooperation). The AgBalance^{TM} analysis method was adapted by FEE for Brazil, considering local specificities of several indicators, resulting in a robust evaluation of data collection of inputs and processes for lifecycle analysis purposes. Another key partnership was established with the farm, object of this research, for field measurements purposes, and with consultants for neighboring properties with conventional systems, making it possible to draw a comparison between these systems.

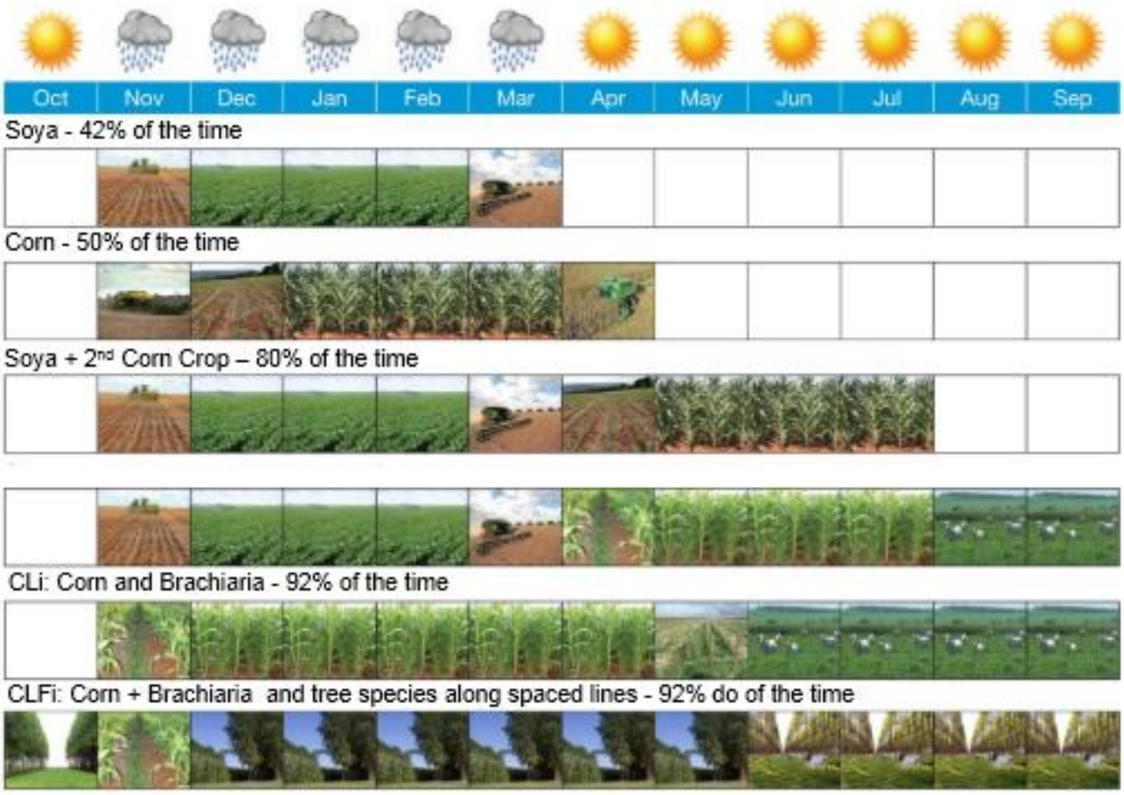
In the Cerrado biome the conventional crop model is annual, i.e., a summer crop is planted in the beginning of the rainy season (October/November) and it is can be harvested in April/May. The rest of the year is characterized by a dry season and the land stays uncovered, enabling erosion losses. Conventional livestock in the region raises cattle on pastures, usually with termite infestation. Conventional forestry usually plants eucalyptus which be harvested at a minimum age of seven years.

Integrated systems allow the combination of different components such as agriculture, livestock, and forestry in the same area through rotation, consortium and succession. At Santa Brígida farm, two types of integrated system are adopted: Crop-Livestock integration (CLi) and crop-livestock-forest integration (CLFi). CLi consists of planting forage concomitantly with a grain crop or a second grain crop, while in CLFi there is the possibility of planting tree species along spaced lines. After crop harvesting, the forage and the residues of the crop generate a fresh pasture (Figure 8a), allowing the farmer to use the land for livestock grazing in the dry season as well (Figure 8b). The forest component can promote thermal comfort for the cattle, increasing weight gain. Besides, the farmer can obtain extra income from forest logging. The comparison of land use for conventional agriculture and integrated systems in Ipameri city is shown on Figure 9. At this figure, the two first lines is related to conventional crop, the third is also related to conventional crop, but it shows when a second crop is cultivated after soya. The fourth and fifth line shows two possibilities of CLI adopted at SBF, and the last line shows CLFI, which grows at least the forest in the month of October.

Figure 8: Crop-Livestock-Forest integration system (CLFi): (a) Pasture growing after crop is harvested, (b) livestock grazing and eucalypthus in the dry season. (Foto b – Crédito: Ernesto de Souza)

(a) (b)

Figure 9: Land use in Ipameri city. (Adapted from KLUTHCOUSKI, 2012)



Thus, the different systems can generate different products: CLFi system produce grains, meat and wood, CLi produces grains and meat, Conventional Crop produces just grains, Conventional Livestock produces just meat, and Conventional Forestry just wood. Therefore, the development of a comparative study of integrated and non-integrated systems can be a hard task, considering the complexities involving those productions. In order to make it feasible, all systems need to be brought to the same basis of comparison through arrangement of system, certifying all products considered are covered by the systems.

4.2. AGBALANCE^{TM} ANALYSIS

4.2.1.Goal of the Study

This study aims at evaluating the environmental, economic and social performance of integrated and non-integrated systems (conventional systems of soy, corn, sorghum, forestry -eucalyptus for energy supply- and meat) in order to identify the amount of food necessary to meet the needs of 500 people, in average, in Brazil for a period of seven years.

The main reason for the development of this study is to offer decision making criteria for farmers when choosing farming techniques in the context of food and energy under increasingly growing demand.

Finally, the target audience of this study are farmers, who can become able to recover their lands and produce in a better socio-eco-efficient way; policy makers engaged in helping create laws providing incentives for the adoption of those systems; legislators acting on regulations of products available in the market; stakeholders of downstream and upstream processes and researchers who can improve and disseminate the most sustainable techniques around the world.

4.2.2. Scope of the Study

4.2.2.1.Functional Unit/Customer Benefit and Alternatives

The definition of customer benefit should take into account the context of a product and the technological options available in the market enabling the same or similar function of the product to be performed (Krozer and Vis, 1998). For this evaluation, it is necessary to adopt a comparative basis that considers the multiple products. In view of the possible environmental and social burden allocated for each product and in order to respect the synergistic effects of integrated systems, it was decided to establish a Functional Unit (FU) to offer soy, corn, sorghum, meat and wood sufficient enough to achieve food and energy demands of a Brazilian average population composed of 500 people for a 7-year production cycle. The determination of the proportion of these products to supply this community in Brazil was based on per capta data for Brazilian consumption over the seven years analysed, from 2007 to 2014 (FAOSTAT, 2014; EMBRAPA 2010 and BRASIL, 2014). The timeframe of 7 years was chosen due to eucalypthus clycle, and 500 people was chosen because it is the amount of people which CLFI system at SBF (50 hectares) can supply at this period.

Table 1: Average of products needs of 500 Brazilian people on a 7-year timeframe (2007 to 2014) (FAOSTAT, 2014; EMBRAPA 2010 and BRASIL, 2014).

Product	Amount (kg)
Soy	263,542
Corn	384,101
Sorghum	19,000
Meat	132,700
Wood	1,535,325

Each system has its own output and its own product proportion, as shown on Table 2.

Table 2: Output and proportion for each system in 50 hectares during 7 years.

Product (t)	**CLFi**	**CLi**	**Conventional Crop**	**Conventional Livestock**	**Conventional Livestock**
Soya	94.3	870.0	960.0	-	-
Corn	274.9	1,824.0	960.0	-	-
Sorghum	-	91.6	150.0	-	-
Meat	129.1	135.0	-	18.0	-
Wood	1,221.1	-	-	-	7,926.8

It is necessary to determine a reference flow so that the alternatives compared can produce the same quantities of soya, corn, sorghum, meat and wood consistently with the functional unit as determined. Thus, the alternatives are agricultural multiproduct arrangement in which a specific cultivation system can be interpreted as the protagonist due to its significant contribution to the final rate offered to the market. Accordingly, for the system productivity, as seen on Table 2, it was calculated the amount of hectares necessary for each system to compose each arrangement (Table 3).

Under conventional crop systems, the products of soya, corn ans sorghum were listed separately for clarity. This, however, does not imply monoculture; typical crop rotations are assumed in conventional cropping systems.

For the first alternative it was used the maximum area of CLFi without surpassing the FU to avoid allocation, preventing this system to achieve the FU. Therefore, it was used Conventional systems areas to achieve FU. For alternative 2 it was used the maximum area of CLi and Conventional Systems. The alternative 3 was composed of Conventional Systems (grains, livestock and forestry). Alternative 4 was the combination modeled with less area (in the total) to achieve the FU. Alternative 5 was a composition combining CLFi, CLi and Conventional Systems using different proportions. All alternatives are described on Table 3.

Table 3: Reference flow – Alternatives compared.

Systems	Arrangements				
	1	**2**	**3**	**4**	**5**
Crop-Livestock-Forest System (ha)	51.4	0.0	0.0	50.0	25.0
Crop-Livestock- System (ha)	0.0	10.3	0.0	1.3	6.8
Conventional System of Crop (Soya) (ha)	8.7	4.4	13.7	7.6	5.2
Conventional System of Crop (Corn) (ha)	5.3	0.0	20.0	3.1	0.0
Conventional System of Crop (Sorghum) (ha)	6.3	0.0	6.3	5.5	2.2
Conventional System of Livestock (ha)	0.0	291.7	369.3	0.0	139.0
Conventional System of Eucalyptus (ha)	1.8	9.7	9.7	2.0	5.8
Total of Area (ha)	73.5	316.2	419.0	69.6	184.0

4.2.2.2.Boundaries

The boundaries of the study includes the following unit processes: extraction of raw materials, production, manufacturing of basic intermediate products, transportation, use phase at farm level, operations at farm level until completion of truck loading before leaving the farm. For example, in case of fossil diesel, it means the extraction of crude oil, refinery, and transportation to the farm, including the truck or tractor fuel consumption while in the farm.

This study considers the processes as far as the farm gate. Further downstream activities, such as processing, distribution, consumption, and end-of-life of the products are not taken into account.

4.2.2.3.Product System

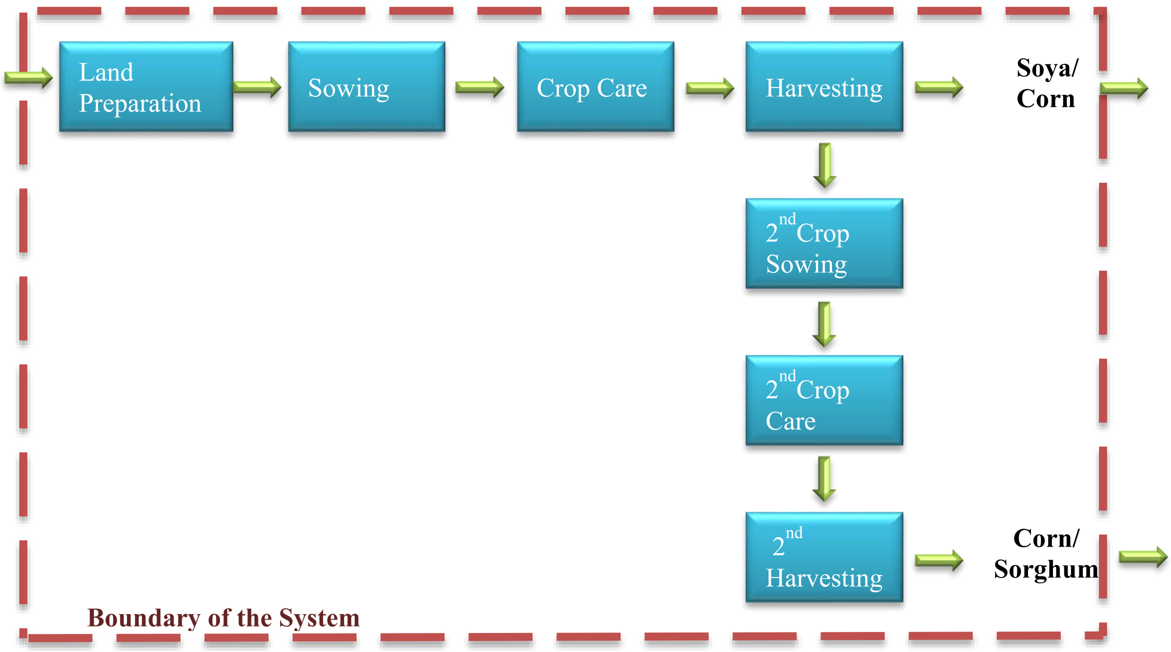
4.2.2.3.1.Product System of Conventional Systems

Conventional systems were modeled using information on techniques adopted in the region of Ipameri city. The information was provided by consultants providing services for traditional farms of the city.

a) Conventional Crop System

Conventional crop system usually initiates with the land preparation by using the tillage process. The cultivation is an annual crop of soya, corn and sorghum. Soya is planted as a summer crop. In the three first years, soya is usually planted for nitrogen fixation. From this point on, it is time to choose the crop and the seeding for a second crop (e.g., corn and sorghum). When the crop is harvested (march/may for summer crop and July for second crop) the soil remains uncovered until next crop cultivations (november). The product system for conventional crop is represented on Figure 10.

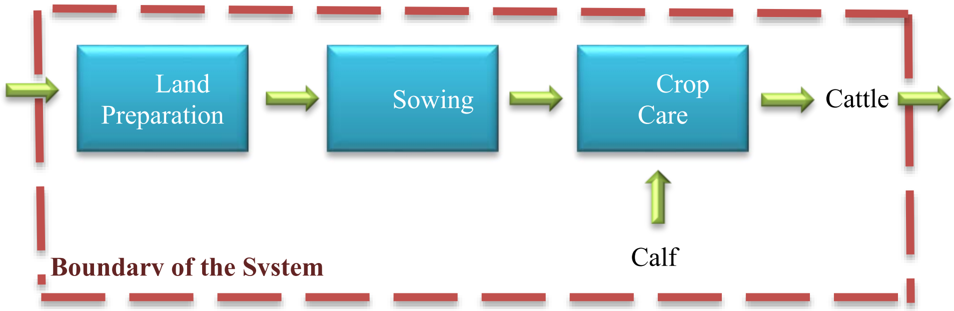
Figure 10: Product system of Conventional Crop at Farm Production Unit.



b) Conventional Livestock System

Conventional system for livestock is very simple and poor in the Cerrado region. Pastures are planted after land preparation using the tillage process and fertilization. After the forage growth, the only management provided is the control of animal units per hectare. It is very common to find pastures infested with termites and the land in advanced stage of degradation. This happens because of bad and inefficient management and overweight animal units in the area. The animal diet consists of forage, and water coming from rivers of the region. The product system for conventional livestock is represented on Figure 11.

Figure 11: Conventional Livestock product system at Farm Production Unit.

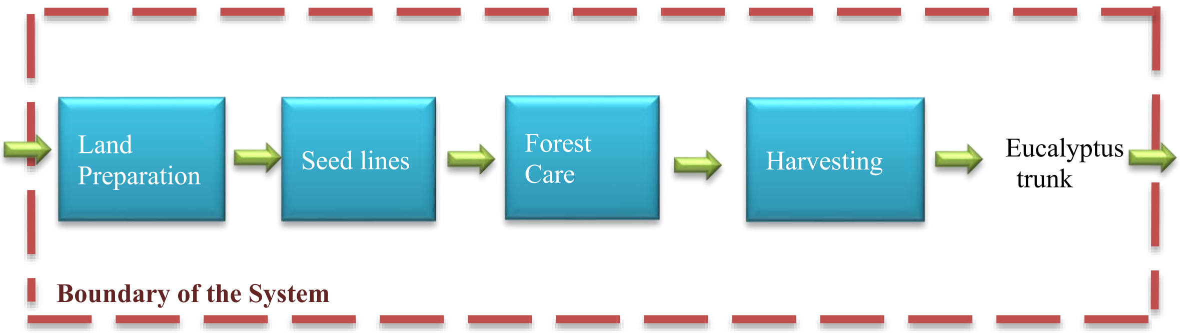


c) Conventional Forestry System

For conventional system of forestry, the land is recovered by using the conventional tillage process and eucalyptus plantation. Fertilizers and defensives are used, and the earliest harvesting cycle is 7 years. The product system for conventional forest is represented on Figure 12.

The seed lines spacing are 3 meters by 2 meters between plants. Fertilization is the first step of the planting process, followed by plant care, which consist of two or three applications of fertilizers containing micronutrients such as zinc (Zn), copper (Cu) and boron (B), KCI, and defensives for ant control. The harvesting process is outsourced.

Figure 12: Conventional forestry product system at Farm Production Unit.



4.2.2.3.2.Product System of CLi

The CL integrated system can combine different kinds of crop and forage. The most common practices of Santa Brígida Farm are discussed below.

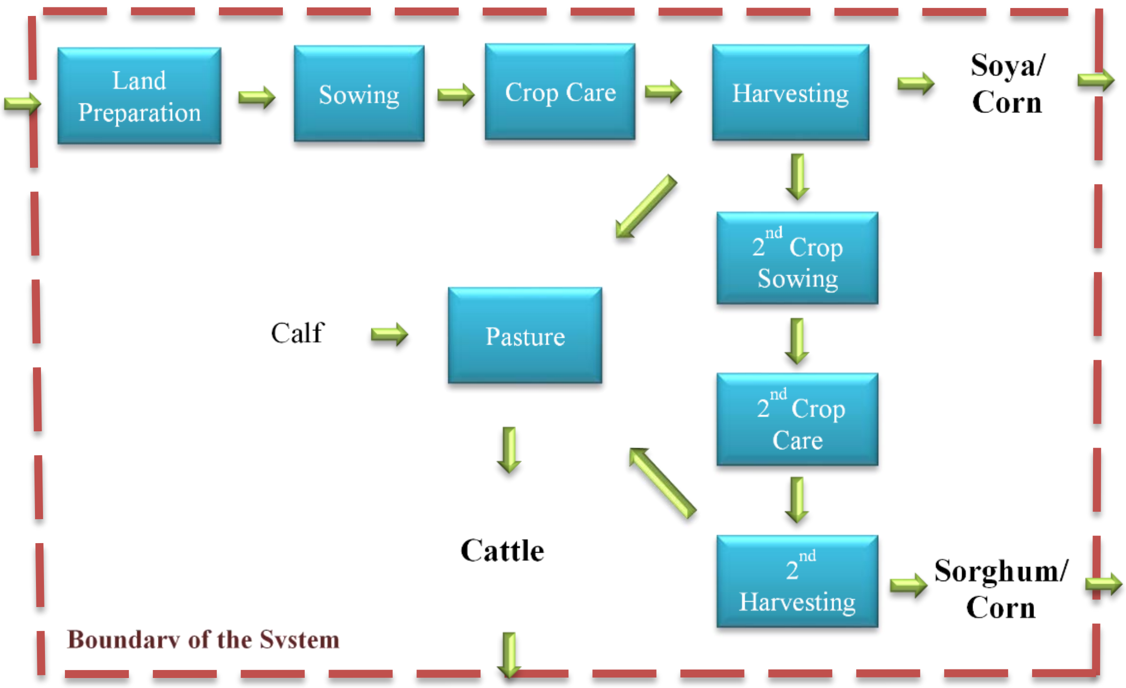
The CLi system also adopts, its first step, tillage for land preparation. This system combines Crop and Livestock in the same area during the same year. Livestock is allowed as long as brachiaria is planted intercropping with corn or sorghum crop lines occurring on summer crop or as a 2nd crop. When the crop is harvested, the forage and residues form a fresh pasture used for cattle feeding. In order to plant two crops, it is needed a planting machine with three boxes (one for the 1st kind of seed, and the other for fertilizers, and the third for the 2nd kind of seeds).

When brachiaria is planted intercropped with the 2nd crop, the Livestock is maintained on pasture areas for two months. This period is also used for replacement of calves for future for future production, or the land is left to lie fallow. When brachiaria is planted with the summer crop, the land is used for pasture during a 4-month period. During this period, approximately half of the area is selected for older and heavy cattle and for livestock finishing process. The weight gain is around 1.2 kg per animal per day. At the end of 2 months, approximately 20% of the cattle that have not gained the proper weight and are sent to the feedlot process for 45 days, and 80% are sold. The final 2 months of pasture is used for calf replacement. The other half of the area is selected to receive the cattle that are not so heavy, thus ending the process. The cattle stay for 4 months at the pasture and then they are sent to feedlots for 60 days. Further assumptions for cattle production are described in the main assumptions section.

This system also adopts supplementary feed, which is mixed at the farm for pasture and feedlot. Some compounds of this mixture, such as silage (for feedlot) and sorghum (for pasture and feedlot feeding), come from products processed in the farm.

After the end of the cattle process, the rainy season starts again and the area starts again its crop production cycle. The product system for CLi is represented on Figure 13.

Figure 13: Crop-Livestock product system at Santa Brígida Farm.



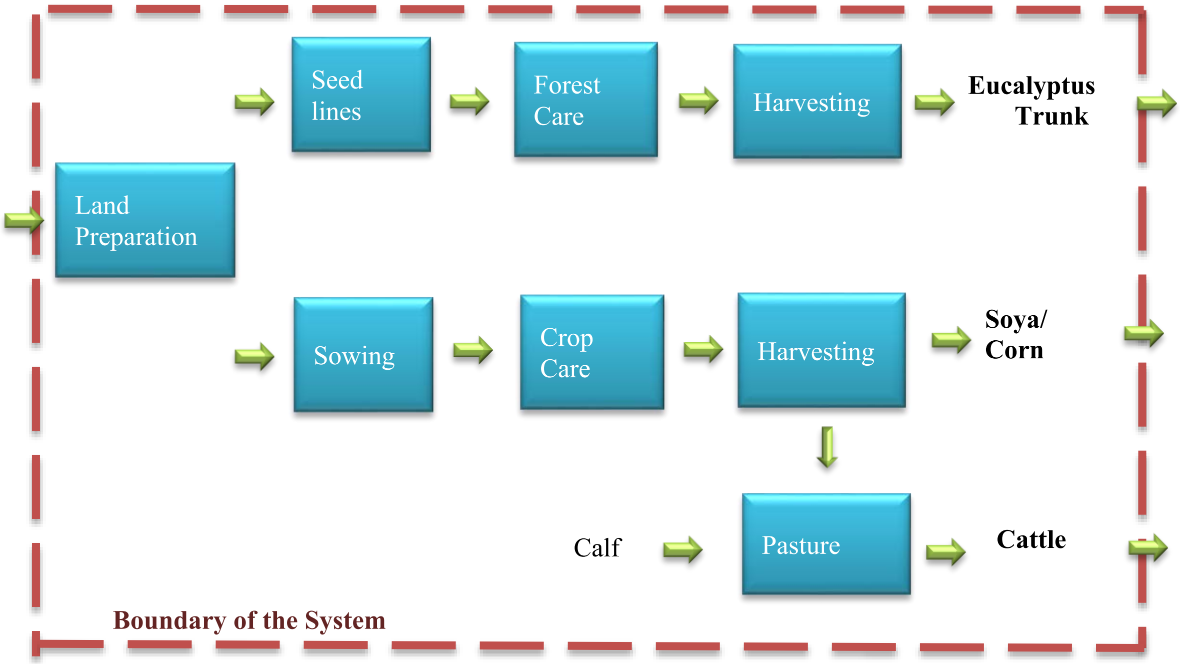
4.2.2.3.3.Product System of CLFi Systems

Similarly to the CLi system, the CLFi system also allows pasture after crop because of the seeding of corn or sorghum crop is made simultaneously with brachiaria. Since the first year of the cycle, the system uses double eucalyptus seeding lines spaced in 3 meters by 1 meter between plants, and spaced 26 meters from the crop area. Eucalyptus is planted from East to West direction for improving the amount of sun light on the crop. In this system, soya is planted in the first year, and corn and brachiaria in the second year, followed by pasture after the corn harvesting. After that, the area is used for livestock pasture and eucalyptus planted in rows.

Livestock under this system is benefited from the thermal comfort provided by eucalyptus. Cattle also counts receive supplementary feed for specific ages and seasons. This system of production avoids feedlot process. Complementary feed for cattle from 8 to 24 months of age in pasture has two types, rain season (october to march) and dry season (april-september). At the age of 24 months, cattle are considered to be at the ending process. This occurs on pasture, and the complementary feed is the same of CLi.

Eucalyptus received fertilization while being planted. For plant care it is used 2 applications of fertilizers containing micronutrients as zinc, copper and boron, pesticides against ants, and one application of KCl. The harvest process is outsourced. The product system for CLFi is represented on Figure 14.

Figure 14: Crop-Livestock-Forest product system at Santa Brígida Farm.



4.2.2.4.Inventory of elementary procees

To achieve functional unit, inputs and outputs were calculated for each alternative. Tables are available AppendixI.

4.2.2.5.Selected Approach

For the objectives of this study an attribution life cycle analysis was used, since it is aimed at producing a retrospective comparison of systems of production place on Santa Brígida Farm.

4.2.2.6.Data requirement

Since each alternative is a composition of five different production systems, data were collected from each system, and afterwards, the evaluation of the set of Arrangement was conducted. Inputs and outputs of each unit process were verified for consistency and made the reference flow correlations with the functional unit. Therefore, mass and energy balances were applied. When any inconsistency was observed, the information was reported to those responsible for providing the data, and a new assessment was conducted.

All relevant components of each system have been considered, either by collecting data from Santa Brígida farm, or by getting data from consultants from other regions farm and literature information.

For crop and forestry, the following data items were collected at the farm level:

- Yield
- Machinery use and fuel consumption;
- Soil nutrient content (from soil analysis), grain size (clay, sand or silt), organic matter content;
- Amounts and types of seeds, fertilizers (mineral and organic), crop protection applied, water for product dilution;
- Detailed technical itinerary of field work and machinery, including seeds treatment;
- Waste (packing etc.);
- By-products, e.g. straw, crop residues;
- Co-product, e.g. corn silage and sorghum for cattle feed;
- Additional environmental indicators: number of elements in crop rotation, legal reserve;
- Economic figures (direct costs);
- Social aspects;
- Distance of input suppliers, kind and capability of transport, and return transportation, etc.

For animal production phase, the following data were collected at the farm level:

- Input of calf (impact of a cow to generate calf)
- Initial and final live weight per life stage;
- Animal unit per hectare;
- Soil nutrient content (from soil analysis), grain size (clay, sand or silt), organic matter content;
- Additional environmental indicators: number of elements in crop rotation, legal reserve;
- Pasture inputs;
- Feed inputs;
- Drinking water input;

- Social aspects;
- Distance from input suppliers, round transportation capability, etc.

Additional data on the farm level process obtained from literature:

- Emissions from fertilizes, livestock and silage processes;
- Ecotoxicity of applying products;
- Trace elements on fertilizers;
- Machinery use and fuel consumption;
- Manure management system.

Social indicators collected at the farm level:

- Number of employees;
- Number of working hours;
- Time spent in professional training;
- Family support expenditures;
- Research and Development investments;
- Workers' wages (low qualification level);
- Workers' wages (high qualification level);
- Students/trainees in Dedicated Education Units/ training in agriculture;
- Operational costs (inputs, maintenance, etc.).

The economic costs were calculated for each production step, from the perspective of the farmer. Therefore, cost data were based solely on information provided by Santa Brígida Farm; cost data regarding upstream processes were not obtained.

4.2.2.7.Data quality requirement

For the definition of environmental aspects, it was decided to use primary data on processes developed on farm. Data on conventional systems were obtained from consultants providing technical advice on conventional systems for farms in the region. For upstream process unit, secondary data were used.

For social aspects, it was used only on information that could be found for all alternatives under this study, such as corporate and social reports. When available, data on wage values and remuneration, family support expenses, research and development, and professional training associated with the activity were also included. In this context, the number of qualified jobs was also investigated. For economic evaluation purposes, it was considered the inflation and the minimum salary rate as established by law.

4.2.2.8.Data source

The primary data mentioned were collected by the conductor of this study with the help of SBF and FEE technical teams. Secondary data were extracted from official publications, government technical reports and international database, such as EMBRAPA's, and from the Life Cycle Assessment database, available on BEST support software, focusing on this study area. Thus, this study made use of data collected from the international database of LCA in the case of elementary processes or subsystems for which no reliable national data source was available.

4.2.2.9.Time-related coverage

Due to eucalyptus cycle, primary data were collected for a period of 7 years, starting in 2007, when the integrated systems were implemented, and finished in 2014. As for the secondary data, recent data sources were used observing other quality requirements. Any other order of temporal variations will be introduced to complement the necessary data for the model boundaries/limits as established.

4.2.2.10.Geographical coverage

Primary data represents the farm, local soil and climate conditions as well as the conventional neighboring farms; ancillary processes were chosen since they are representative of the Brazilian conditions. Some other geographical variations were introduced, as mentioned before, to complement contours of the model in which variations are inserted.

4.2.2.11.Technology coverage

This study focuses on comparing different technologies. Traditional agricultural practices are usually adopted by farms in the neighboring region of SBF. So, SBF is a technological reference for farm in the region for integrated systems.

4.2.2.12.Cut-off Criteria

The decision on the exclusion of environmental aspects followed two criteria. First, data were excluded when sources were not reliable and when they presented low level of individual contribution to total inputs or outputs of the unit process and secondly, when the relevance of their environmental aspect was low. The first criterion is the ability to delete the environmental aspect if its value in mass or energy accounts for less than 1% of total inputs and outputs associated with the process. However, the simple percentage contribution of the environmental aspect is not sufficient to exclude it from the product system, requiring an environmental relevance analysis. Given these two criteria, the environmental aspect was disregarded in the product life cycle unless its presence were essential to the production process.

4.2.2.13.Sensitivity Analysis

Regarding the accuracy of the data in the study, it is understood that the uncertainty of results is a function of the uncertainty of the data used (primary and secondary data). According to the information requirements of this study, and to ensure the representativeness of the study results, options were selected depending on the availability of these products on the markets that supply SBF and conventional systems, and on the quality data requirements for temporal coverage, geographical and technological data, as mentioned before.

There is a 50% standard deviation for Intergovernmental Panel on Climate Change (IPCC) emission factors due to regional variation, climate, soil etc. The uncertainty of primary and Ecoinvent input data was estimated to be around 10%. In spite of the effects of uncertainty on the absolute accuracy of the LCA models, it was estimated to be relatively accurate when performing comparative analyses. However, uncertainty regarding information on individual datasets has not been evaluated systematically.

4.2.2.14.Main Assumptions

Same crop care was adopted to each crop regardless the cultivation system (tillage, fertilizer and crop protection application, seed treatment, operational machines, etc.). For crop management the averages used in applications were considered, disregarding the possibility of an atypical pest infestation scenario, since it is random events that may or may not originate in the cycle. Thus, the study considers conservative approach for applications of crop protection. All the systems were considered to have been implemented in degraded areas. So, the first step for all of them is land preparation (with tillage process) followed by the desiccation process. However, dissication process was practiced again just before planting the summer crops.

LCA environmental aspects for the manufacture of agricultural machines, such as tractors, and implementation of infrastructure were not considered. In the same context, the transportation stage was considered only for atmospheric emissions from fossil fuel burning during movements of trucks. Environmental aspects resulting from the construction of roads, manufacture of vehicles (trucks or ships), as well as their use were not considered. Also for modeling purposes, data from trucks returning to their points of origin were not included.

Crops harvested in a 7-year cycle of CLi and CLFi were considered primary data; however the assumption underlying crops harvested in a 7-year cycle of conventional systems was based on the common practice in the region, according to consultants of Santa Brígida Farm and conventional farms of the region, representing the most widely used practices.

For soya cultivation, a first application of products for crop desiccation is applied, followed by a treatment consisting of a mixture of seeds and specialized products prepared in a mixture machine. Biological products for seed treatment were not considered as inventory entries to all systems, due to lack of information on these inventories in the literature. Sowing also receives an application of fertilizer. Before sowing, an application of KCl is conducted. Crop care consists of four applications of fertilizes and crop protectants sprayed with machine. Crop harvesting is made using propped machines.

Corn crop is similar to soya. There is crop desiccation only before planting the summer crop. No desiccation process is applied before the 2nd crop planting. But, there is seed treatment with different products and sowing with fertilizer application. These are followed by one top dressing and three sprayer applications of crop protections.

Sorghum crop is simpler compared to soya and corn. No desiccation is conducted, since it is always planted as a 2nd crop without seed treatment. Fertilizer is applied at sowing time, followed by two sprayed applications of crop protection. The harvest process is similar to soy and corn.

Conventional livestock is very simple. It is planted with brachiaria and it is fertilized just once over the whole cycle. Management is only about controlling the number of animal unit per hectare.

Despite its similarity to the eucalyptus assumption, for the conventional system it was considered an application of liquid boron by airplane (kerosene fuel) that was not considered for CLFi. Also, the conventional system takes in account the space rows of 3 m per 2 m with a population density of 1,667 plants per hectare. For CLFi system the space is 3 meters by 1 meter, in double stands spaced 26 meters apart from culture, which totals 689, 6 plants per hectare. The assumption for eucalyptus density is 650 kg/m^3. On integrated system, just one third of the production remain to serve the functional unit while the rest is storage. Since no destination for the stored eucalypthus trunk has been identified, the whole impact was considered in the calculation for the eucalypthus which attends the FU.

The amount and type of seeds can change with the years and the cycles (summer or second crop). Soya and corn requires seed treatment. The energy required for this seed process comes from a seed treatment machine that is powered with a 0.5 hp engine. Therefore, in order to treat 100 kg of soya seed, 2 minutes and 17 seconds of the machine working time is needed; for corn the time needed to process 330,000 seeds is 2 minutes and 37 seconds. These values are from experimental data on Santa Brígida Farm and were used as an assumption for all systems.

To calculate the diesel necessary for the machine, the assumptions were based on diesel supply datasheet provided by Santa Brígida Farm, as the machine is not equipped with any recording device for that purpose. Data that would not make any sense to measure in amount of fuel per hectare, such loader truck, were estimated by the equipment working time.

Limestone and gypsum are discharged in the field. For a loader truck, one scoop can carry 500kg in average of limestone. It is necessary about 6.5 scoops to fully load the spreader with lime in 8 minutes. For gypsum, the scoop is able to carry 400 kg in average and the spreader gets filled up with 6.5 scoops in 8 minute.

Water truck (3000 L capacity) runs about 1 km from the field to get water at the dam. The round trip, including filling up with water, takes 20 minutes. The capacity of a Sprayer

Tractor is 3,000 liters of water plus 3,000 l of admixture product. The output is 150 L per hectare.

Fertilizers are stored and later removed by a truck belonging to the farm to the field, where the admixture is filled into a sowing machine. For truck loading a big bag rear winch is used, and for unloading on the field it is used a big bag front winch. It takes 2 minutes per big bag to load or unload the truck.

Monoammonium Phosphate (MAP) fertilizer is applied on soya. It takes the truck 15 minutes to be fully loaded with seeds and fertilizers. Its loading capacity for MAP fertilizer is 2,000 kg. Same assumptions are used for NPK fertilizer applications on sorghum and corn crops.

For top dressing fertilizer (KCl on soya and NPK on corn and sorghum) the process is similar. The two winches load and unload one big bag of fertilizers in 2 minutes. Then, the farm truck transports the fertilizers to the field (1 km to go and 1 km to return). On the field, a 3,000 km-capacity spreader is used, taking it 6 minutes to be fully loaded.

In the harvesting process, a grain tank tractor (8 ton capacity) runs besides the harvesting machine while an outsourced truck (10 ton capacity) waits for the grain tractor to unload the grains. This process takes 12; 8 and 10 minutes for soya, corn and sorghum, respectively. The amounts of grains to be commercialized are left on site and an empty truck comes to initiate the whole process again. Productivity of each culture changes according to each system, the year cycle, and the season (summer or second crop) (Table 4)

Table 4: Grain Productivity (t) per system.

Productivity (t)	year						
Conventional Crop	1	2	3	4	5	6	7
Soya summer crop	2.880	3.120	3.300	-	3.300	3.300	3.300
Corn summer crop	-	-	-	9.000	-	-	-
Corn second crop	-	-	5.100	-	-	5.100	-
Sorghum second crop	-	-	-	-	3.000	-	-
CLi							
Soya summer crop	2.880	3.120	3.600	-	3.900	3.900	-
Corn summer crop	-	-	-	10.200	-	-	10.800
Silage corn second crop	-	45.000	-	-	-	-	-
Corn second crop	-	5.400	-	-	7.200	7.200	-
Sorghum second crop	-		3.600	-	-	-	-
CLFi							
Soya summer crop	2.880	-	-	-	-	-	-
Corn summer crop	-	8.400	-	-	-	-	-

For silage harvesting, an outsourced gasoline-fueled truck (7 to 8 ton capacity) runs beside the harvesting machine. The fuel consumption of the vehicle is estimated in 10 km per liter.

The silage area is comprised of six ditches, which are dug into the ground to keep silage fresh. The silage capacity of each ditch is 300 tons, and the silage density is around 600 kg per m^3. The complete unloading of the truck occurs in the silage area. The six ditches are loaded in 24-hour operations of two tractors spreading (rear blade) and 2 tractors working on silage compaction. After compaction, the silage is covered with a polymer mantle. Silage loss during tractors operations and transportation was estimated in 15%.

After the fermentation, the amount of dry matter loss resulting is 30%. When silage is dry, the ditches are opened and the dry silage is removed by a loader tractor that carries 600 kg of silage to the wagon truck (capacity of 4 t). This process takes 3 minutes. The wagon tractor distributes the silage on feedlot.

After each tractor operation is completed, such as harvesting, fertilizer applications, etc., a washing process takes place. Jetting equipment with 1,900 watts potency and output of 6 L/min of water is used for tractor cleaning. Removal of implement dust takes about 40 minutes. The full cleaning of a single tractor takes about 20 minutes and the farm truck (5 t) about 30 minutes.

On the farm module, direct greenhouse gas emissions come from mineral fertilizers, silage process and livestock. The emission factors from fertilizers depend on local soil and climatic conditions and, therefore, are subject to considerable variations. The same happens to cattle emissions due to a variety of factors, such as climate and soil properties, and feed and cattle breed. The choice of factors considered in this study was based on calculations as proposed in the Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). In a comparative study including all alternative in a similar context, the influence of local soil and climate conditions on emissions from fertilizers seemed to affect all scenarios in the same way. For silage process the emissions were also estimated according to Schimidt et al. (2011). Evaluations of other emissions, such as those from diesel-powered equipment are considered within their entire life cycle.

For field emissions, direct and indirect emissions through volatilization are taken into account by applying the following factors (IPCC, 2006):

- direct emission of 0.01 kg N_2O-N (nitrogen as nitrous oxide)/kg fertilizer-N;
- direct emission of 0.02 kg NH_3-N (nitrogen as ammonia)/kg fertilizer-N;
- direct emission of 0.0007 kg NO-N (nitrogen as nitrogen monoxide)/kg fertilizer-N;
- indirect emission of 0.01 kg N_2O-N / kg fertilizer-N through volatilized ammonia (NH_3);
- indirect emission of 0.0075 kg N_2O-N / kg fertilizer-N through leached N;
- Water emission 0.1 kg N / kg fertilizer N.

GHG emissions due to land use change were not considered.

The generation and transmission of electricity were characterized from LCA databases, owned by BASF and Fundação Espaço ECO, which have been adapted to brazilian conditions based on composition data from the brazilian energy matrix collected from the National Energy Balance (BEN) (BRASIL, 2012) and considering the losses and efficiency conversion of the whole lifecycle. This condition can cause a degree of inaccuracy and its consequences were assessed as acceptable by the practitioners.

Ecotoxicity potential (EP) was modeled based on emission flows of crop protection substances released to the environment. Crop protection after its application is assumed to accrue 100% to soil, which is in line with the approach in Ecoinvent datasets (USEtox emission compartment ‘agricultural soil’). Emissions from fertilizer trace elements are included in the impact assessment. However, for calculation purposes it was assumed that 10% of trace elements contained in mineral fertilizers had a leaching or runoff destination (NSF, 2013). Thus this amount was considered as water emission. Premises for trace elements in fertilizers were obtained were obtained in Guilherme & Marchi (2000).

Water consumption in industrial manufacturing of fertilizers was modeled based on the following assumptions: 1% of cooling water is considered consumptive (99% returned to the river). For farming module, water comes from river and is destinated to cattle drinking, equipment washing and dilution of products. Most of its use is for washing equipment, thus for this water use, 31% was considered consumptive water. All crops are non-irrigated cultivation. So, in order to calculate the total consumptive water, the methodology considers the Water Stress Index, which shows an average consumption for Brazil in the order of 6,59 % (PFISTER et.al, 2009).

Nutrient uptake by crops was calculated by average nutrient concentrations in harvested crops (IAC, 1996).

All systems analysed which were also composed by livestock systems included cattle for fattening. So the impact of bringing a calf to the system was considered by evaluating the impacts resulting from the cow during its life (feed, pasture, water, manure, emissions, etc.) and then distributed (by mass) according to the number of calves that the cow can generate. The assumption is that the cow weighs 450 kg and eats 0.4% of LW (live weight animal). According to the data provided by Beef Point (2013), a cow generates an average of 06 calves. The raising of the calves until the age of 8 months was considered as a process for estimates purposes of conventional system.

For livestock CH_4 emissions from enteric fermentation, calculations were based on IPCC (2006). Emissions from animal manure were calculated by volatilization process, expressed in CO_2-eq. The solid fraction was considered as a co-product that returns to the pasture system serving as fertilizer (nutrient cycling). The same goes for confinement manure, for which the closed loop approach was applied. NPK balance of conventional livestock and brachiaria (pasture) follow the same concept. Despite the initial fertilizer input, applied during seven years, the solid emissions (manure) were used as fertilizers and considered as a closed loop as well.

Assumptions for the amount of water for cattle drinking including all systems are 35 L day^{-1} per bull on pasture and 40 L day^{-1} per bull on feedlot. Stocking rate is considered to decrease 12.21% per year (TEIXEIRA et al, 2012) for all systems as a whole. On conventional livestock, the premise for feed consists of just forage and the initial allotment stocking rate is 0.5 animal units per hectare. One animal unit is 450 kg of live weight animal. Cattle stay on pasture until the age of 40 months, weighing around 540 kg.

Integrated systems work with a variety of complex cattle feeding. In addition to supplementary feed, cattle are also allowed to graze on fresh pasture newly formed with brachiaria crop and crop residues on the field.

All systems start in October of year 1 (2007). The initial rate of stocking allotment under CLFi system is 2.5 animal units per hectare. Cattle receive three different kinds of supplementary feed: supplementary feed for rainy season at pasture (October – March); supplementary feed for dry season at pasture (April- September); and supplementary feed for ending process at pasture. In CLFi there is a pasture rotation but no feedlot process. The weaned calf is introduced with 8 months of age and 200 kg of weight. When reaching the age of 24 months and weighing around 400 kg, the calves stay on pasture system and are fed with seasonal feed, eating the equivalent to 0.1% of its LW (Live Weight). From 24 to 30 months of age (ending process), the cattle eat the equivalent to 0.4% of its LW, reaching 540 kg of weight.

Assumptions for the origin of micronutrients found in premix were made according to McDowell (1999): calcium from calcium oxide; cobalt from cobalt oxide; magnesium from magnesium oxide, manganese from manganese oxide, zinc from zinc oxide, phosphorus from phosphorus pentoxide, sulfur from sulfur trioxide, copper from copper carbonate and nickel from nickel oxide.

CLi system allows the introduction of livestock after the 2nd crop for a period of two months (in this study considered as fallow), and after corn crop and brachiaria summer crop for a period of four months. Since the 2nd year, the system counts with fresh pasture every year. After corn and brachiaria summer crop, the area is divided in two equally sized areas. In one half of the area, the stocking rate is 3 animal units per hectare. Cattle arrive with 30 months of age and with weight of 470 kg (78% of the cattle that arrive) and 410 kg (22% of the cattle that arrive). At the ending process, supplementary feed is added to fresh pasture and the weight gain is 1.2 kg day-1 per bull, and the eating rate is equivalent to 0.4% LW. Therefore, in two months the cattle weight reaches 542 kg (78%) and 482 kg (22%). The bull weighing around 542 kg is sold, while cattle weighing 482 kg is sent to feedlot for an intensive feeding process during 45 days, eating the equivalent to 0.4% LW.

The other half of this area, with stocking rate of 3 animal units per hectare, the cattle is introduced when reaching 24 months of age and weight around 410 kg. The cattle is kept on pasture for four months eating the equivalent to 0.4% LW. At the end of this process, the average weight is 470 kg at 28 months of age. Then, the cattle are relocated to feedlot for 60 days to reach 542 kg and be sold. At the feedlot facilities, cattle are fed with supplementary feed, eating the equivalent to 0.4% of LW.

Residues derived from packages from agriculture and livestock were collected to be recycled by suppliers; every time a new batch of raw materials is delivered in the farm, these residues are collected. This process is considered a closed loop recycling (i.e., no residues remain in the field, since they are reintroduced in the suppliers value chain).

To calculate the cow impact it was also taken into account the land use needed for the cow and calf raising until the age of 8 months, which is the approximate age the calf is introduced in the systems analyzed in this study. The modeling of this process was developed under the assumption that the cow weight is 450 kg in average; and the stocking rate is 1.8 animal units per hectare on conventional pasture system. The assumption for calf stocking rate was 1 animal unit per hectare, weighing 200 kg at the age of 8 months. Assumption for a lower rate calf stocking is conservative.

Social indicators for the farm operations were calculated by attributing the data obtained on SBF and from the local consultants. The social indicators for other processes related to all activities not carried out at the farm were based on Brazil scenario for fertilizers, crop protection, fuels and road transports (AGRIANUAL 2010, IBGE, 2012).

The process data are described on Appendix II – Assumptions.

4.2.2.15.Allocation procedures

When a unit process generates more than one product (and when the system expansion is unfeasible), it is necessary to implement the allocation of technical environmental loads between the co-products. After testing different allocation criteria (mass and energy), criterion chosen was based on smaller variations in the results. However, for this study the data were collected based on culture and year, enabling to calculate each culture load of each system. Land preparation impacts were attributed to the first culture planted. The cow total impact (pasture planting, land use, feed, and water and emission impacts) was distributed by the number of calves (six) it generated (BEEF POINT, 2013). To allocate social data on conventional system, such as wages and qualification level, the criteria was the time each crop takes between sowing and harvesting on 7-years cycle (Table 5).

Table 5: Allocation for social data at Conventional Crop system.

Allocation criteria for Conventional System	Weight
Soya	64%
Corn	29%
Sorghum	7%

4.2.2.16.Critical Review

The critical review by third parties was the responsibility NSF Consultoria em Sustentabilidade Ltda and the protocol on goning.

4.2.3.AgBalance^{TM}: Environmental LCIA method

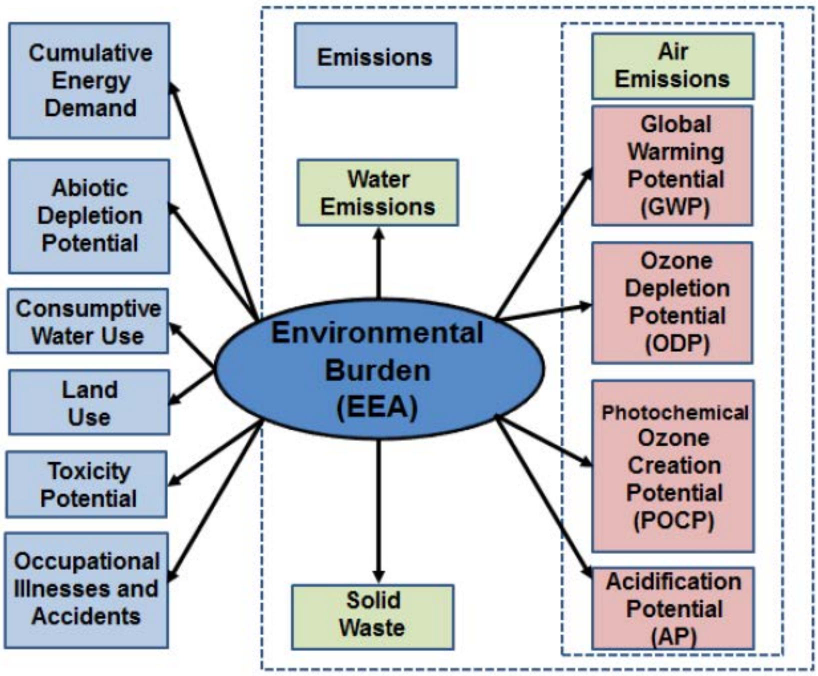
From the assumptions and boundary conditions presented, it was generated the Lifecycle Inventory (LCI) of the alternatives (systems of Arrangement) to meet the FU established. The Inventory Analysis phase corresponds to the collection of the raw data of each unit process and subsequent data treatment, so that they are correlated to the reference flow established in Goal and Scope Definition.

Next step is Life Cycle Impact Assessment (LCIA), focusing on the method selected for this study, which associates the environmental, social and economic aspects and their potential impacts.

The Eco-Efficiency Analysis (EEA) (Saling et al, 2002) determines the procedures used for grouping the assessed impact in categories, as well as the criteria for standardization and grouping. The results points to the most relevant impact categories according to the weighting factor. All values used choices regarding impact categories, characterization models, characterization factors, normalization, grouping, weighting, and use causes influencing on the results, conclusions and recommendations.

The environmental performance of each product, process or service is determined based on six impact categories: Energy Consumption, Natural Resource Consumption, Waste / Emissions, Land Use, Human Potential Toxicity and Potential Occupational Accidents and Diseases. The Waste class (or emissions) is also subdivided into three categories: Solid Waste, Wastewater and Air Emissions (which, in turn, is again subdivided into four other categories of potential impacts - Figure 15).

Figure 15: Environmental Impact Categories in EEA (BASF, 2013)



To obtain the data required to conduct the study, the main sources of information are mapped, whether technical literature (secondary data) or measurements and data available and validated by the requester of the study (primary data). The consumption of natural resources and energy, emissions and land use are determined quantitatively by Life Cycle Assessment methodology. Potential for human toxicity is estimated according to the methodology developed by BASF SE (Saling et.al, 2005). Potential occupational diseases and accidents occurring to people involved in each stage of the life cycle consider the accidents and occupational diseases arising from the activities involved in the processes under study (NSF, 2013).

The values obtained for each impact category are then normalized so that there is a comparison between alternatives. Thus, it becomes possible a preliminary assessment to identify the least favorable impact categories (with a value of one) and more favorable impact categories (with proportional values that are smaller than one) for each alternative, by the so-called Graphic "Environmental Fingerprint".

Subsequently, these six impact categories are aggregated into a single indicator through a weighting system that considers two types of factors expressed in percentages: Social Perception and Relevance Factor.

There are some changes at AgBalance™ methodology from Eco-efficiency methodology on environmental aspects. The human toxicity and potential occupational diseases and accidents (risks) indicators are analyzed under employee's category on social dimension. Also, AgBalance™ counts on additional indicators related to agricultural applications (soil and biodiversity). AgBalance™ environmental LCIA is described on the following topics. Some of indicators were developed by BASF SE for Europe context, such as coverage of protected areas, agri-environmental schemes, carbon balance, etc. To meet the purposes of comparison these indicators were adapted for the Brazilian context or were not evaluated. Explanations on how each indicator was adapted in these cases are found under the Results section.

4.2.3.1.Category Energy Consumption (MJ per FU)

Cumulative energy is used during the entire life cycle concerning raw material extraction, production, use, and disposal as well as the energy content remaining in the products by primary energy sources. While the energy from biomass feedstock is included, the sun energy that is needed to produce the biomass is excluded. (Saling et al. 2002)

4.2.3.2.Category Abiotic Resource (kg silver-eq per FU)

The quantification of this impact category follows the approach of the "Center of Environmental Science" Leiden University to determine the potential depletion of resources, known as 2001 Impact Assessment Method CML (CML, 2001). A key difference between the standard characterization factor of CML and the approach adopted in this method is that CML considers final reserves, i.e., all reservations in the earth's crust (are accessible or not), while the current method considers economic reserves, that is, those that are accessible at current prices of all raw materials. Further, the equivalence resource has the equivalent factor unity Antimony in the case of CML, and equivalent silver at EEA and AgBalance^{TM}.

Raw material consumption values are weighted with a factor that reflects the demand and exploitable reserves of the raw materials, according to estimates of the U.S. Geological Survey (USGS, 2014) and other sources. Basically, the lower the reserves of a raw material and the higher the worldwide rate of consumption, the scarcer the material, and thus, the higher the weighting factor assigned. Resource consumption is expressed in silver equivalents, covering energy-containing and other types of abiotic sources as well. As a result, renewable resources, which are assumed to have a sustainable management system and theoretically unlimited reserves, consequently have a weighting factor equal to zero. (Saling et al. 2002).

4.2.3.3.Category Emissions (per FU)

4.2.3.3.1.Emission to Air

Air emissions are calculated in terms of the mass of emissions, generated per FU (kg/FU) over the entire life cycle. At a minimum, AgBalance^{TM} considers the following chemicals: CO_2, SO_X, nitrogen oxide (NO_X), CH_4, non-methane volatile organic compounds (NMVOC), halogenated hydrocarbons (HC), ammonia (NH_3), (nitrous oxide) N_2O, and HCl. These chemicals are grouped under air emission categories (Table 7) by equivalences (Table 6).

Table 6: Equivalence for air emission. (GWP- Global Warming Potential; ODP-Ozone Depletion Potential; POCP – Photochemical Ozone Creation Potential, AP – Acidification Potential).

	GWP	ODP	POCP	AP
CO_2	1			
SO_X				1.00
NO_X				0.70
CH_4	25		0.007	
Ethene equivalents			1.000	
Hal. HC	4,750	1		
NH_3				1.88
N_2O	298	0.000		
HCl				0.88
NM-VOC average			0.42	

Table 7: Air emission categories.

Emissions to air - GWP (kg CO_2 eq.)	CO_2, CH_4, Halogenated organic compounds (HCFC), N_2O, weighted with IPCC factors (IPCC 2007) and reported as CO_2-equivalents (Saling et al. 2002).
Emissions to air – AP (kg SO_2 eq.)	SOx, NOx, NH_3, HCl, reported as SO_2-equivalents. (Saling 2002, characterization factors: CML)
Emissions to air - ODP (g CFC-11 eq.)	Halogenated compounds, reported as CFC-11-equivalents. (Saling et al. 2002, characterization factors: CML)
Emissions to air - POCP (g C_2H_4 eq.)	CH_4 and NM-VOCs (non metals volatile organic compounds), reported as ethylene equivalents. (Saling et al. 2002, characterization factors: CML)

4.2.3.3.2.Emission to Water (m^3 of Critical Volumes/ FU)

Impact on water quality is assessed through a critical volume approach, which considers both the total amount of emissions released into water as well as the environmental impact of the chemicals being emitted. Critical Volumes (CV) are calculated as the ratio of the amount of chemicals emitted, and their Maximum Emission Concentration (MEC) threshold limits. This methodology considers total water discharge, including water emissions to both wastewater treatment systems and discharges to surface waters (Saling et al. 2002).The following emissions to water are considered: Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), N-total, ammonia (NH_4) as nitrogen (N), phosphate (PO_4) as phosphorous (P), Adsorbable Oganic Halogens (AOX), hydrocarbons (to include detergents and oils). Compared to Brazilian law (CONAMA, 2011), these values (GERMAN WASTE WATER REGULATION, 2012) are more restrictive (Table 8) e and since we are dealing with a comparative study, the reference can be considered valid as baseline for weighting the different system combinations described in the scope of the study.

Table 8: limits values considered on AgBalance™ study.

Element	Concentration	Unit
COD	75	mg/l
N-total	50	mg N/l
P-total	2	mg P/l
AOX	1	mg/l
Hg	0.001	mg/l
Cd	0.005	mg/l
Cr-total	0.05	mg/l
Zn	0.2	mg/l
Cu	0.1	mg/l
Ni	0.05	mg/l
Pb	0.05	mg/l
Sn	0.2	mg/l

Direct and indirect emissions were considered in the evaluation process as well as all issues regarding waste along the life cycle of the entire chain. Despite all of the pre-chain, water emission was analyzed in the farm module as well. Emissions of trace elements from fertilizers were considered for the impact assessment. However, in order to calculate it, it was assumed that 10% of trace elements contained in mineral and organic fertilizers had a leaching or runoff destination. Thus, this amount is considered as water emission.

4.2.3.3.3.Solid Emission (kg municipal waste/FU)

Solid waste is classified as construction waste, mining waste, municipal waste, hazardous, and industrial waste according to their weight. The criterion chosen for methodological purposes considered the different types of waste based on the average cost of disposal of the same kind in Europe (Table 9). The value of this category is, therefore, the sum of the quantities of each type of waste products generated throughout the product life cycle and the weight factor corresponding to the type of waste. Recycled or re-used materials are not counted as solid waste.

Table 9: Equivalence values for solid waste in terms of costs of disposal.

Kind of waste	Weighting
Municipal Waste	1.00
Industrial/Chemical Waste	6.00
Radioactive Waste	300,000.00
Construction Waste	0.60
Mining Waste	0.00

4.2.3.4.Category Consumptive Water (L-eq per FU)

The inventory contains the fraction of water withdrawn which is not released back to the source of origin, e.g. because of evaporation, evapotranspiration, product integration or discharge into a different drainage basin or the sea (water consumption according to ISO DIS 14046).The characterization is done according to the mid-point model using the Water Stress Index (WSI) (PFISTER, 2009).This approach is in line with the ILC recommendation for impact assessment methods (EUR 25167 EN, 2012). The impact of freshwater consumption on water deprivation was calculated by multiplying the total consumptive water use (volumetric liters) by the WSI of Brazil, i.e., all water withdrawals were assumed to originate in Brazil. The final value was normalized by dividing by the global average WSI of 0.602. Thereby, the final value shows the impact of freshwater use along the life cycle relative to the impact of consumption of 1 liter of water across the globe (De Boer 2013).

According to the Water Stress Index, Brazil has the average value of 6.59%. However it is known how this index can change according to the region, representing a different significance of the impact. Regional data of watershed is not available or is not reliable.

The green water, which refers to precipitation and soil moisture consumed on-site by vegetation, e.g. evapotranspiration, is not considered.

4.2.3.5.Category Eco-toxicity Potential (EP) (points per functional unit)

The impact on water organisms from crop protection use is assessed by the USEtox ecotoxicity characterization model as described by Rosenbaum et al. (2008). This is the consensus eco-toxicity model for life cycle impact assessment derived from The United Nations Environment Programme (UNEP) and the Society for Environmental Toxicology and Chemistry (SETAC). The assumption to that category is that 100% of crop protection crops go to agricultural soil compartment.

4.2.3.6.Category General Biodiversity Impacts through Land Use (m^2 per FU)

The model of the ecosystem damage potential scheme –EDP from Köllner and Scholz (2007) includes damage functions and generic characterization factors (Table 10) for the quantification of the biodiversity damages to ecosystems resulting from land occupation and land use change.

Land occupation was calculated by using the closest characterization of systems possible to those as defined in the method (Koellner and Scholz, 2007) for the production module.

•Conventional Livestock: Less intensive pasture and meadows - Meadows mechanically harvested 2 or 3 times per year, reduced input of fertilizer, perhaps on former arable land;

•Conventional Crop: intensive arable land;

•Conventional Forest: Forests and semi-pristine areas - Intensively managed plantations with short rotation cycle with broad-leafed and coniferous trees;

•CLFi: Agro-forestry areas - Annual crops or grazing land under the canopies of forestry species;

•CLi: Cultivated areas regularly ploughed and generally under a rotation system. Artificial meadow in rotation system;

The characterization factors are on the table below.

Table 10: Characterization factors for land use occupation to the farm systems under evaluation.

System	Description	Factor
CLi	Artificial meadow	0.29
CLFi	Agro forestry	-36
Conventional Crop	Intensive arable	0.74
Conventional Pasture	Less intensive pasture	0.52
Conventional Forest	Conventional forestry	0.73

4.2.3.7.Category Impacts on Biodiversity in Agricultural Areas

In AgBalance™, individual biodiversity indicators are initially determined according to the criteria described on Equation 1 , and are then aggregated into a single Biodiversity index value. The combined score for specific impacts on biodiversity in agricultural areas (per unit of area) are calculated from all sub-indicators by multiplication.

Equation 1: Aggregation is made by multiplication of the individual indicator values:

Biodiversity index (alternative a) = BI(a) =State(a) x Schemes(a) x ProtectedAreas(a) x Ecotox(a) x Intensity(a) x N-surplus(a) x Crop rotation(a) x Intermixing(a)

The sub-indicators at the equation are described on the following topics.

4.2.3.7.1.Specific Impacts on Biodiversity in Agricultural Areas

Score calculated from number of endangered species. This reflects the vulnerability of the eco-system under study. The status of biodiversity in a particular region is assessed by the number of species that feature on the IUCN Red List for that region (IUCN, 2012) (Figure 16). The state indicator is calculated from the number of Red List species, according to a non-linear relation, where the resulting performance score as well as its derivative (slope) decreases with increasing number of endangered species (i.e., the differences are higher between regions with a smaller number of endangered species than those with higher number of endangered species).

Figure 16: IUCN Red List (IUCN, 2012)

SOUTH AMERICA

South America	EX	EW	Subtotal	CR	EN	VU	Subtotal	LR/cd	NT	DD	LC	Total
Argentina	2	3	**5**	16	49	104	**169**	0	114	153	1382	**1,823**
Bolivia	0	0	**0**	14	24	53	**91**	2	73	68	1931	**2,165**
Brazil	9	1	**10**	68	109	209	**386**	9	182	544	2903	**4,034**
Chile	0	0	**0**	17	21	66	**104**	0	67	174	707	**1,052**
Colombia	3	0	**3**	80	141	233	**454**	2	155	389	3124	**4,127**
Ecuador	6	0	**6**	78	120	220	**418**	2	127	270	2553	**3,376**
Falkland Islands (Malvinas)	1	0	**1**	0	7	11	**18**	0	12	18	138	**187**
French Guiana	0	0	**0**	6	6	28	**40**	1	28	57	1114	**1,240**
Guyana	0	0	**0**	6	9	32	**47**	2	34	73	1241	**1,397**
Paraguay	0	3	**3**	4	9	25	**38**	0	47	24	921	**1,033**
Peru	2	0	**2**	34	83	160	**277**	2	122	310	2741	**3,454**
Suriname	0	0	**0**	6	7	26	**39**	0	29	58	1112	**1,238**
Uruguay	0	0	**0**	7	24	48	**79**	0	34	47	521	**681**
Venezuela	2	0	**2**	34	59	107	**200**	1	76	230	2069	**2,578**

Table 6a: Red List Category summary country totals (Animals)
IUCN Red List Categories: EX - Extinct, EW - Extinct in the Wild, CR - Critically Endangered, EN - Endangered, VU - Vulnerable, LR/cd - Lower Risk/conservation dependent, NT - Near Threatened (includes LR/nt - Risk/near threatened), DD - Data Deficient, LC - Least Concern (includes LR/lc - Lower Risk, least concern).
IUCN Red List version 2010.4: Table 6a

4.2.3.7.2. Agri-environmental Schemes

Score calculated from financial value of funding received by farmers per hectare. Payments received by farmers for services promoting elements of biodiversity, e.g. flower strips (to support pollinators), pre-agreed timing of mowing (to improve the breeding success of meadow inhabiting birds) or the support of traditional farming practices, or others. In the Brazilian, context, this indicator is evaluated by the amount of legal reserves. For the specific purposes of this study, this indicator was not calculated because it compares Arrangement of systems and not specific farms.

4.2.3.7.3.Coverage of Protected Areas

Score calculated from percent coverage of protected areas. For EU countries, specific rating based on fraction of area under Natura 2000 status as well as fraction of UAA enrolled in agri-environmental schemes were used. For non-EU countries, the UNEP “protected area coverage” indicator (Bubb et al. 2009) is adopted by using the designated national protected areas, as recorded in the World Database on Protected Areas (WDPA, 2014). For Brazil, calculations were made according to the Protected Area biomes of each state, based on the total area of conservation units. (NSF, 2013).

4.2.3.7.4.Ecotoxicity Potential of Pesticides

Score calculated from off-target toxicity potential and amounts of active ingredients per hectare based on the product-specific data for short-term (acute) and long-term (chronic) eco-toxicity of plant protection and its lethal doses for Earthworm, Insect (Honeybee), Rodent (Rat, Mouse), Bird, Alga, Water flea (any member of the crustacean order Anomopoda - class Branchiopoda) and Fish. Analysis of short term (acute) (Figure 17) and long term (chronic, reproductively, NOEC - No Observed Effect Concentration) (Figure 18) was conducted. The final result in tox value is the average between short and long term, although if one of this value is 0,6 then the total value is 0,6, not the average (NSF,2012).

Figure 17: Calculator based on lethal doses – Short Term.

Comment

			Short-term (acute)						
		I.D.	LD50	LD50 >I.D. x	LD50 >I.D. x	LD50 >I.D. x	LD50 >I.D. x	LD50 <I.D. x	
Test Organism	Unit	Initial dose	from lab exp.	1	0,1	0,01	0,001	0,0001	
Earthworm	mg	1000	1000	X					
Insect (Honeybee)	microgram/Bee	10	100	X					
Rodent (Rat, Mouse)	mg/kg bw	2000	5000	X					
Bird	mg/kg bw	2000	2000	X					
Alga	mg/l	100	100	X					
Waterflea	mg/l	100	100	X					
Fish	mg/l	100	86,8		X				
			Pressure Factor	1	0,9	0,8	0,7	0,6	
				XXXXXX	X				Totals
			No. crosses	6	1	0	0	0	7
			Total value	6	0,9	0	0	0	6,9
								Short-term value	0,99

Figure 18: Calculator based on lethal doses –Long Term.

			Long-term (chronic, repro) NOEC						
			Long-term	LD50 >I.D. x	LD50 >I.D. x	LD50 >I.D. x	LD50 >I.D. x	LD50 <I.D. x	Relevance for
Test Organism	Unit	I.D. (OECD)	from lab. exp.	1	0,1	0,01	0,001	0,0001	"Biodiversity Element"
Earthworm	mg	1000							Function "Soil"
Insect (Honeybee)	microgram/Bee	10							Function "Pollination"
Rodent (Rat, Mous	mg/kg bw	2000	100			X			Function "Population"
Bird	mg/kg bw	2000	94			X			"Conservation Species"
Alga	mg/l	100							Function „Aquatics"
Waterflea	mg/l	100	2,2			X			Function „Aquatics"
Fish	mg/l	100	2,3			X			Function „Aquatics"
				1	0,9	0,8	0,7	0,6	
						XXXX			Totals
			No. crosses	0	0	4	0	0	4
			Total value	0	0	3,2	0	0	3,2
								Long-term value	0,80

For each alternative, the resulting values of all active ingredients EP*a* are summarized and given a sum value, which constitutes the indicator value (Equation 2).

Equation 2: Calculation of the Eco-Toxicity Potential (EP).

$$EPa = (1 / E) * M^a$$

E = Eco-toxicity value

M^a = amount of active ingredient applied in g / ha.

To calculate it under the arrangement analysis, the final result (total points) for each system (regarding the time coverage of 7 years) was multiplied by its area in the Arrangement. The final results are normalized by a linear equation between 0.6 and 1 on y axel. The angular coefficient is the maximum value of the arrangement results.

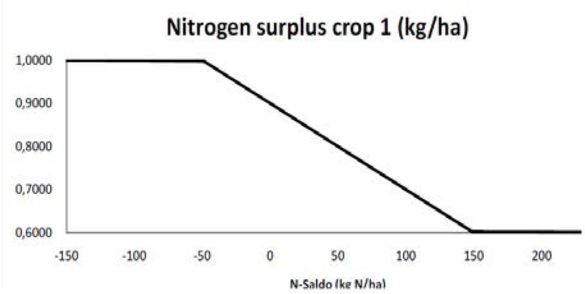
4.2.3.7.5.Nitrogen Surplus

Score calculated from nitrogen surplus per hectare. Low rates fertilizer promote biodiversity since species-rich plant societies are found on nitrogen-poor soils. The performance of this indicator is evaluated by plotting the N-balance on a linear scale with the best score (1.0) reached at minus 50 kg N/ha and the worst core (0.6) at a surplus of 150 kg N/ha (Figure 19; Table 11). The N-surplus is evaluated for each crop element in the rotation separately and a corresponding individual performance score is determined. The average of the performance scores is used to rate the complete crop rotation. Nitrogen surplus is calculated for each crop by each year. When there are two crops or more in the same year it is made the simple average for the evaluation and then the average of the 7 years of evaluation (NSF, 2012).

Table 11: Nitrogen Surplus Evaluation

N-Surplus (kg/ha)	Value
-150	0,9993
-100	0,9990
-49	0,9980
149	0,6020
200	0,6015
250	0,6012

Figure 19: Indicator Nitrogen Surplus graph evaluation.



The calculus for nitrogen surplus indicators comes from Nutrient Balance Evaluation (Topic Nutrient Balance). The Arrangement results were made by multiplying the area of each system in the Arrangement and then were divided by the total Arrangement area and then evaluated by the indicator calculus.

4.2.3.7.6.Intermixing Potential

Score calculated based on expert classification system. Crop-specific potential for intermixing with the natural vegetation was rated based on climatic conditions for growth and survival; presence of pollinators and wild-relatives, potential for pollen dispersal through wind and insects, the size of seed banks and seed persistence in soils as well as adventitious presence in machines or seed (NSF, 2012).

Intermixing Potential is evaluated as qualitatively and quantitatively arbitrary based BASF expert's opinion. The values are for Germany, but also applied to Brazil. Experts from EMBRAPA and BASF confirmed the values in the Brazilian context.

Figure 20: Intermixing potential calculus.

Category	Cross-pollination				Volunteers		Adventitious presence			
Sub-category	Pollen distance	Pollination type	Wild relatives	Foraging	Size of seed bank	Seed persistence	Mechanical	Seeds		
Score 0.6	> 2 km	open pollinator	many wild relatives	favorite forage crop	Large	> 10 years	High risk	High risk		
Score 1.0	< 25 m	strict self-pollinator	no wild relatives	no forage crop	Small	< 1 years	Low risk	Low risk	Total score	Source
Corn	0,80	0,70	1,00	0,80	0,90	0,90	0,80	0,90	0,85	Embrapa Milho
Cotton	0,90	0,80	1,00	0,70	0,90	0,80	0,80	1,00	0,86	Edilson Cotelo - BASF
Soybean	1,00	0,90	1,00	0,80	0,90	0,90	0,80	1,00	0,91	Edilson Cotelo - BASF
Wheat	0,90	0,80	0,80	0,90	0,80	0,80	0,80	1,00	0,85	Antonio Azenha - BASF
Rice	0,80	0,90	1,00	0,90	0,80	0,80	0,70	0,80	0,84	Edilson Cotelo - BASF
Potato	1,00	0,90	1,00	1,00	0,90	0,90	0,90	1,00	0,95	Dr.Martijn Gipmans - BASF
Canola/ rapeseed	0,60	0,70	0,70	0,60	0,60	0,60	0,70	0,70	0,65	Dr.Martijn Gipmans - BASF
Brachiaria	1,00	1,00	0,90	0,90	0,70	0,80	0,70	1,00	0,88	Dr.Martijn Gipmans - BASF
Eucalyptus	0,80	0,80	1,00	0,60	0,80	0,70	1,00	0,90	0,83	Dr.Martijn Gipmans - BASF
Sorghum	0,80	0,90	1,00	0,90	0,80	0,80	0,70	0,90	0,85	Dr.Martijn Gipmans - BASF

This indicator was evaluated for each year and it was made an average of the 7 years for each system. For the year when two crops were cultivated, it was made a single average between the crops total score. However, for CLFi, the calculation was made by the crops and the area, i.e., 65% is single crop average and 35% is the forest area.

To calculate the Arrangement result, the system score is multiplied by the area of each system in Arrangement, and then divided by the total area of the Arrangement.

4.2.3.7.7.Crop diversity

Score calculated from the number of different crops cultivated. This indicator quantifies the number of different crops cultivated within the production system. Crops may include inter- and co-cropping elements, catch/under sown crops. A broad variety of plant-based resources promotes biodiversity. (NSF, 2012)

Table 12: Evaluation for Crop Rotation Indicator

No. of elements in crop rotation	Value
1	0,600
2	0,800
3	1,000
4	1,100
5	1,200
6	1,300
7	1,500

This indicator was evaluated for each year and it was calculated an average of the 7 years for each system. For the Arrangement result, the system score was multiplied by the area of each system in Arrangement, and then divided by the total area of the Arrangement.

4.2.3.8.Soil

The purpose of the AgBalance^{TM} methodology is to identify the main impacts on long-term soil quality produced by human agricultural activities on arable land, associated with the functional unit/ customer benefit. The indicators to be considered in an AgBalance study are: Organic Matter balance, Nutrients (N, P, K) balance, Soil Compaction Potential, and Erosion.

The indicators are evaluated using either as dimensionless performance scores or by directly quantifying the effects, i.e., the estimated soil losses from erosion in tons per hectare and per year. The Aggregation is done by the Equation 3(NSF, 2012).

Equation 3: Aggregation of soil Indicator

Soil index (alternative a) = SI (a) = (w1 x Nutrientsnorm (a)) + (w2 x Cnorm (a)) + (w3 x Erosionnorm (a)) + (w4 x Compactionnorm (a))

At the equation above, wx are the weighting factors applied to the individual indicators (Table 13). This weighting fator was obtained by BASF SE and European specialists. The resulting Soil is dimensionless.

Table 13: Weighting Factor for soil indicator.

Nutrients, normalized	13.8%
C, normalized	13.8%
Compaction, normalized	10.3%
Erosion, normalized	62.1%

4.2.3.8.1.Soil Organic Matter

Organic soil matter is important in determining the soil quality as it influences the chemical, physical and biological functioning of soils, especially in relation to the soil's capacity to store nutrients and water, its buffering and filtering capacity, its biodiversity and structure. While it is obvious that a reduction in organic matter content will eventually impair soil quality, the reverse is also true – high organic content is not a positive development since it leads to high mineralization of nitrogenous compounds and effluxes in the hydro- and atmosphere. In this study, the soil organic carbon balance is calculated in a quality comparison. (NSF, 2012)

Carbon analysis in a 0-20 cm depth in the year 2007 and 2014 was used to calculate this indicator. CLFi and CLi data refer to Santa Brígida Farm. Data from conventional systems of crop and livestock were obtained from consultants providing services to farms in the region. For conventional forest the data used were extracted from Melo & Resck (2013).

For soil density, it was calculated the amount of soil in a 0 – 20 cm depth, and then multiplied by the percentage of organic matter in the same 0-20 cm depth, resulting in the total amount of organic matter. Each calculation was made per hectare, considering the difference of two periods (2007 and 2014). Fifty eight per cent of soil organic matter, in general, is composed of organic carbon (SCHOLLENBERGER, 1945; NELSON & SOMMERS, 1996). Based on this assumption, the amount of organic carbon (kg) was calculated for each system per hectare.

In order to obtain this number for the Arrangement, the result of each system was multiplied by the area of that system within the Arrangement and then summed, resulting in the total loss or gain of organic carbon during the seven years. These results were not subtracted from the carbon emissions to avoid restricting this study just to the first cycle of system, i.e., the recovery land cycle.

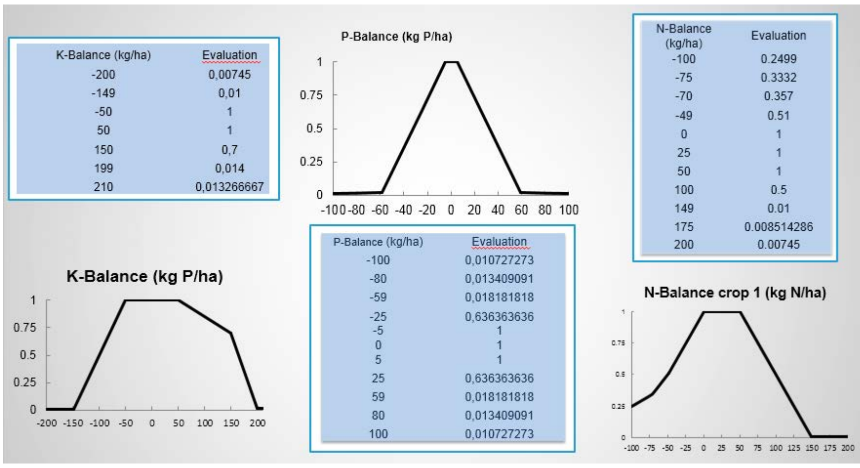
An extremely high volume of organic carbon can damage soil quality. Therefore, in order to normalize the carbon indicator, the value 1 is considered to be adapted and closer to

0.2 represents low contents or extremily high. For the purposes of this study, the normalization considers that the equation of the line is between 0.2 and 1 on y axes and between pre system higher and lower results.

4.2.3.8.2.Nutrients (N, P, K) Balance

Score calculated from nutrient balance per hectare. Nutrient balance is a function of the amount of fertilizer applied and the amount of nutrients retrieved through harvest. This balance is furthermore corrected for the ability of the soil to mineralize and thereby provide nutrients as indicated by soil nutrient supply classes. The nitrogen balance also considers different sources e.g. nitrogen fixation. The result of the nutrient balances is subsequently evaluated, using nutrients specific models with optimal scores around an equal nutrient balance of zero and decreasing scores for either nutrient deprivation or over-fertilization (Figure 21) (NSF,2012 , CHRISTEN et al. 2009).

Figure 21: Evaluation method to N, P and K balance. (NSF,2012)



K-Balance (kg/ha)	Evaluation
-200	0,00745
-149	0,01
-50	1
50	1
150	0,7
199	0,014
210	0,013266667

P-Balance (kg/ha)	Evaluation
-100	0,010727273
-80	0,013409091
-59	0,018181818
-25	0,636363636
-5	1
0	1
5	1
25	0,636363636
59	0,018181818
80	0,013409091
100	0,010727273

N-Balance (kg/ha)	Evaluation
-100	0.2499
-75	0.3332
-70	0.357
-49	0.51
0	1
25	1
50	1
100	0.5
149	0.01
175	0.008514286
200	0.00745

Evaluation of nutrients takes into account data on field crop, yield, soil nutrient supply class, other nutrient in- and output, straw (conditions on field), and crop nutrient needs (Equation 4 and Equation 5). For P and K elements, the balance of each crop is summed along the 7- year timeframe. Nitrogen is evaluated by crop in a year, then it is made the average of the evaluation for the year. The system result is the average of the 7 years of evaluation. Balance nutrient can be calculated by applying the following equations:

Equation 4: Calculus for P and K balance

Balance= Input (kg/ha nutrient) – yield (kg/ha) * content of nutrient (kg/kg) + *k*

Equation 5: Calculus for N balance

Nitrogen Balance= Input (kg/ha nutrient) – yield (kg/ha) * content of nutrient (kg/kg)

Factor *k* for P and K elements balance equation is assessed by the availability of these nutrients on the soil (class soil). For Brazil regions it is used the Table 14, adapted by specilists from EMBRAPA Meio Ambiente.

Table 14: Range of soil class for P and K elements.

Soil supply class	[content P2O5 (mg/dm3) soil]*	content K mmolc/dm3	Description	Soil supply class factor	K
Class A	0-6	0,0-0,7	Very low supply, nutrients are immobilized, double the rate in comparison to the output to the fertilized (x2)	2	K = - output x 2
Class B	7-15	0,8-1,5	Low supply, limited nutrient immobilization	1,5	K = - output x 1,5
Class C	16-40	1,6-3,0	Optimum, input = output	1	K = 0
Class D	41-80	3,1-6,0	High soil supply, lower fertilization than the output.	0,5	K = + output x 0,5
Class E	>80	>6,0	Very high soil supply, no fertilization.	0	K = + output

Data for nutrient balance evaluation has the same source. For Conventional Crop and Livestock, the class is A for P and K elements, and for conventional forestry, the factor is C. For integrated systems (CLFi and CLi), data from SBF point class B for K and P starts with class A, and in the year 4 it changes to B. The Table 15 and

Table **16** show the class soil for P and K for SBF. Conversion was considered: K mg/dm³ x 0,025641 = mmolc/ dm3.

Table 15: P data for SBF.

P mg/dm3	P_2O_5 mg/dm3	
0.8	1.832258065	A
1	2.290322581	A
1.7	3.893548387	A
2.8	6.412903226	A/B
3.9	8.932258065	B
5.8	13.28387097	B
5.8	13.28387097	B

Table 16: K data for SBF.

K mg/dm3		
39	0.999999	B
39	0.999999	B
58	1.487178	B
58	1.487178	B
52	1.333332	B
56	1.435896	B
56	1.435896	B

Regarding nutrient needs, the average nutrient contents for the different plant parts have been measured over the years and used to calculate the nutrient extraction by harvesting. Soya and Corn data came from the AgBalance™ method (State Crop Consultancy Rhineland-Palatinate, 2014), Sorghum dry matter from IPCC(2006), Eucalyptus from Melo & Resck (2013) and on other nutrient needs, from RAIJ et. al. (1996). All values can be observed on Table 17.

Table 17: Nutrient needs for each crop.

Crop	Does straw remain on field?	Dry Matter	N (kg/dt yield)	P2O5 (kg/dt yield)	K20 (kg/dt yield)
Soya	Yes	91	5,8	1,62	1,94
Corn Silage	not applicable	28	0,38	0,16	0,45
Corn Silage	Yes	86	1,38	0,8	0,5
Brachiaria	not applicable		1,30	0,23	2,17
Eucalyptus	not applicable		0,50	0,26	0,60
Sorghum	Yes	89	1,70	0,92	0,60

The results for arrangement were calculated by the final loss of P and K divided by the total area of the arrangement, then evaluated according to the AgBalance^{TM} method. For nitrogen, the evaluation according to the method per system was weighted by the area in the arrangement and then divided by the total area of arrangement.

4.2.3.8.3.Potential for Soil Compaction

Score calculated from classification scheme. Empirical relationship based on factors related to the nature of the agricultural soil (texture, depth to impermeable layer, soil organic matter content), climate (number of field capacity days), as well as a crop and a management factor. The overall risk for soil compaction is evaluated by combining all factors derived from the sub-indicators (NSF, 2012).

Source for evaluation below is BASF. Dominant soil texture (whether topsoil or subsoil compaction is being considered) is divided into classes available on Table 18.

Table 18: Soil texture evaluation.

Soil texture	Rating
Sandy and light silt soils (clay content< 15%)	1
Medium soils (clay content 15% and up to 35%)	2
Heavy clay loam and Clay soils (clay content > 35%)	3

Soils with higher content of organic matter (OM) tend to be more resistant and have lower risk of compaction, as shown the evaluation by the method on Table 19.

Table 19: Soil Organic Matter evaluation.

Soil organic matter content	Rating
>3%	1
1,5-3%	2
<1,5%	3

Intensive livestock has higher potential for soil compaction. The rate factor changes with the livestock compound OR the organic matter content (Table 20).

Table 20: Livestock compound evaluation.

Stocking rate (if livestock is considered)	Soil organic matter	Rating
<1,5 LU/ha **and** land not pre-dominantly in arable production	>3%	1
1,5 - 3 LU/ha **and** land not pre-dominantly in arable production	<3%	2
>3 LU/ha **or** land pre-dominantly in arable production	<3%	3

The presence of an impermeable or 'slowly permeable' layer (SPL) influences soil drainage and the speed at which soils can dry out, when evapo-transpiration exceeds rainfall. These soils tend to be badly drained and dry out slowly. As it is more difficult to time the use of machinery with 'low' risk periods, once soils have a tendency to become compacted. Since there are insufficient data on impermeable layer depth and on the numbers of capacity days, the same values were considered in both evaluations of the 5 systems, considering that the focus here is on a comparative analysis.The evaluation for this indicator is available on Table 21.

Table 21: Depth to impermeable layer evaluation.

Depth to impermeable / slowly permeable layer	Rating
>60 cm	1
40 - 60 cm	2
<40 cm	3

Field Capacity Days (FCD) estimates the duration of the period when the soil moisture deficit is zero. Soils usually return to field capacity (i.e. soil drainage begins) during the autumn or early winter. The field capacity period, measured in days, ends in the spring when evapotranspiration exceeds rainfall and a moisture deficit begins to accumulate. For the purposes of this study, FCD values are divided into the soil compaction risk classes (Table 22).

Table 22: Number of field capacity days evaluation.

Number of field capacity days	Rating
<90	1
90 - 150	2
>150	3

Soil bulk density tends to decrease with the age of a grass sward. When arable land is reverted to grass, the soil becomes more resilient to compression as soil organic matter contents gradually increase and soil aggregates gradually become more stable (Miller & Jazstrow, 1990, Tisdall & Oades, 1982, Tisdall, 1994). In this study, we used the following categories to define compaction risk by age of grass sward:

- Age of sward < 2 years (previous arable > five years) – High risk
- Age of sward between 2 and 5 years (previous arable > five years) – Medium risk
- Age of sward > 5 years – Low risk

Alternatively, a simplified risk categorization was applied. For each system the closest to reality alternative was chosen according to Table 23.

Table 23: Age of Grass evaluation.

Arable land, temporary or permanent grassland	Rating
Arable land	3
Temporary grassland	2
Permanent grassland	1

Certain land uses present a higher soil compaction risk than others, either due to the size of machinery used or the timing of the harvest. For example, in the UK, it is widely accepted that the growing of root crops for harvesting in the autumn can result in severely compacted arable soils (NSF, 2012). For this study, it was used the following (Table 24) general land use categories to assess soil compaction risk:

Table 24: Land Use evaluation.

Land use	Description	Rating
Category 3	Crop rotations that include maize, potatoes, sugar beet, vining peas or grazed fodder crops (e.g. stubble turnips) at least one year in seven	3
Category 2	Arable rotations (including 2-3 year grass leys) that do not include the above 'high risk' crops	2
Category 1	Grassland with swards > 3 years old	1

The overall risk for soil compaction is evaluated by a multiplication of all factors.

4.2.3.8.4. Potential for Soil Erosion

Calculated using the Universal Soil Loss Equation (USLE) (Equation 6). This equation predicts the long term average annual rate of erosion on a field, based on slope, rainfall pattern, soil type, topography, crop system, and management practices. USLE only predicts the amount of soil loss that results from sheet or rill erosion on a slope and does not take into account additional soil losses that might occur from gully, wind or tillage erosion. Where these effects have a significant impact, they have to be additionally taken into account by appropriate modeling, e.g., wind erosion through estimates by the Revised Wind Erosion Equation (NSF, 2012).

Equation 6: Universal Soil Loss Equation (USLE)

$$A = R.\ K.\ LS.\ C.\ P$$

Where R is the rainfall and runoff factor, K is the erodibility factor; LS is the slope length-gradient factor; C is the crop factor and P is the support practice.

According to the rain in the region of the study it is calculated the factor R (Figure 22). For calculate factor R, Mx is the average of monthly precipitation and P is the annual precipitation (mm). Since the geographic coverage for this study is SBF, and its neighbors (conventional farms) at the city of Ipameri – GO, the equation number 6 from Figure 22 was applied.

Figure 22: Calculus to R factor according to Brazilian Regions. (SILVA, 2004)

1	$R_x = 3{,}76 * \left(\frac{M_x^2}{P}\right) + 42{,}77$	Oliveira Jr. E Medina (1990)
2	$R_x = 36{,}849 * \left(\frac{M_x^2}{P}\right)^{1{,}0852}$	Morais et al. (1991)
3	$R_x = (0{,}66 * M_x) + 8{,}88$	Oliveira Jr. (1988)
4	$R_x = 42{,}307 * \left(\frac{M_x^2}{P}\right) + 69{,}763$	Silva (2001)
5	$R_x = 0{,}13 * (M_x^{1{,}24}$	Leprun (1981)
6	$R_x = 12{,}592 * \left(\frac{M_x^2}{P}\right)^{0{,}6030}$	Val et al. (1986)
7	$R_x = 68{,}73 * \left(\frac{M_x^2}{P}\right)^{0{,}841}$	Lombardi Neto e Moldenhauer (1992)
8	$R_x = 19{,}55 + (4{,}20 * M_x)$	Rufino et al. (1993)

Precipitation data is from (ROLIM , 2003). To Calculate K erodibility factor to Brazil there are many possibilities in literature. AgBalance^{TM} method adopts the Bouyoucos (Hudson, 1982; Bertoni e Lombardi Neto, 1990).

Equation 7: Calculus for Factor K.

Factor K = ((% sand + % silt) / (% clay))/100

For CLFi and CLi systems the same data on Santa Brigida Farm were used. For all conventional systems data on a neighboring conventional farm was used. The K factor calculation was based on the data on Table 25.

Table 25: K Factor per system.

	CLFi	CLi	Conv. Crop	Conv. Livestock	Conv. Forest
Silt (%)	5%	5%	11%	11%	11%
Very fine sand (%)	40%	40%	39%	39%	39%
Clay (%)	56%	56%	50%	50%	50%
K (erodibility factor)	0.008	0.008	0.010	0.010	0.010

The follow range is the evaluation for P factor (support practice factor) (Table 26). For all systems, the underlying assumption is UP&Down Slope pratice.

Table 26: P Factor evaluation.

P = support practice factor	
Support Practice	P Factor
Up&Down Slope	1
Cross Slope	0,75
Contour farming	0,5
Strip cropping, cross slope	0,37
Strip cropping, contour	0,25

Crop and Management Factor (C1 and C2 respectively) evaluation, according to the method, is made to the crop type and management. The crop factor shows the timeframe of soil coverage (NSF, 2012). For crop factors concerning Brazil, data from Alves et al (2013) were used. The values are available on Table 27.

Table 27: C1 and C2 Factor evaluation.

Crop	Crop factor C1
Grain Corn	0,4
Silage Corn, Beans&Canola	0,5
Cereals (Spring&Winter)	0,35
Seasonal Horticultural Crops	0,5
Trees	0,1
Hay and Pasture	0,02
Tillage type	Management factor C2
Fall Plow	1
Spring Plow	0,9
Mulch Tillage	0,6
Ridge Tillage	0,35
Zone Tillage	0,25
No-Till	0,25

Since the crop factor is about the soil coverage timeframe, for CLFi and CLi system it was adopted “Hay and Pasture” for evaluations. Management for all systems is “No-till”. The consolidated C factor is the product of Crop and Management System.

LS factor is calculated by the ramp length in meters (C) with steepness percentage (D) through the Equation 8. C value for all systems is 41 and D value is 0.25%.

Equation 8: Calculus for Factor LS.

$$LS = 0{,}00984\ C^{0{,}63}\ D^{1{,}18}$$

4.2.3.1.AgBalance^{TM}: Economic Impact

Total economic impacts are also assessed throughout the life cycle. Total economic impact of a system can reflect different concepts, depending on the purpose of the study. It corresponds to the total production costs, the sale value of the goods or services in the economy sector under study, or the profitability. As for the calculation of environmentally relevant factors, it is estimated a factor that reflects the total economic impact of a specific activity with respect to the country or region under economic study (NSF, 2012).

The economic impacts account for the actual costs that arise from the immediate activity, and the costs that will occur in the future (i.e., maintenance). Actual costs that have an environmental aspect, for example, the cost of water treatment units, are also included in the overall calculation. The costs incurred are added and combined in national currency values. This helps identify, and in some instances, optimize particularly important cost areas.

This study calculated the total cost of producing (rent of machines, employees cost, land cost) and all raw materials used. Details are available on Appendix III - Cost.

4.2.4.AgBalance^{TM}: Social Impact - Selected categories

Societal parameters are not addressed specifically in the ISO LCA standards nor in other standards that can be referenced for defining the criteria for a social LCA. AgBalance^{TM} represents BASF's best attempts to identify and utilize relevant factors bound by life cycle principles to create a social LCA framework. It takes important developments of different groups like the UNEP/SETAC working group or existing standards in the Agro-sector (NSF, 2012).

For pre-chain, data from Brazilian database were used when available (Agrianual, 2010; IBGE, 2012).

4.2.4.1.Category Farmer and Employees

4.2.4.1.1.Working Accidents (occurrences/FU)

This indicator evaluates the number of working accidents: events are considered as working accidents if the affected staff members are unable to work for more than three days. The number of working accidents is recorded in association with an activity. The numbers are expressed as the numbers of accidents, accounting for accidents of industrial workers, farm employees and farmers. This indicator was not calculated for the farm production module due to lack of reliable data.

4.2.4.1.2.Occupational Diseases (occurrences /FU)

Occupational diseases are illnesses that can be definitively attributed to occupational activity. The number of occupational disease is recorded in association with an activity (production). The numbers are expressed as the number of occupational disease cases, accounting for occupational diseases of industrial workers, farm employees and farmers. This indicator was not calculated for the farm production module due to lack of reliable data.

4.2.4.1.3.Human Toxicity (points/FU)

Impact assessment method by Landsiedel and Saling (2002); application analogous to SEEBALANCE (Kölsch et al. 2008). The assessment method is based on the classification of the H-phrases of substances with associated hazards. It accounts for human toxicity potential for industrial workers, farm employees and farmers.

Each group is given a score, ranging from 100 – 1,000 based on the severity of the toxic effects. A substance is assigned to one of these groups by its toxic properties, also described by H-phrases. When there are additional H-phrases the substance will be up-graded. However, weak effects or local effects (group 1 and group 2 respectively) and the same effect caused by an additional exposure route (e.g. oral and dermal) will not lead to an up-grade. The toxicity is evaluated not only for the final product, but also for the entire pre-chain, i.e. the chemicals needed to make the products, going all the way back to the basic raw materials that are extracted from the earth. It is quantified for the production, use, and disposal stages of the life cycle.

4.2.4.1.4.Wages (R$/FU)

Calculated as a function of the wages and the number of working hours needed to produce the Functional Unit. Accounts for income of industrial workers, farm employees as well as farmers. Note that farmer working time is included and a corresponding wage is attributed considering the highest level of qualification (NSF, 2012).

For the farm module, employment, qualification and wages were calculated based on the data available on Table 28:

Table 28: Employment, qualification and wages per hectare per system during 7 years.

qualification level	unit	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forest
Qualified	hours	98	75	17	8	2	5	269
	Wages (R$)	1.290	1.085	288	128	32	124	447
Basic Qualified	hours	405	402	114	52	14	74	162
	Wages (R$)	2.352	2.327	725	332	90	321	986

4.2.4.1.5.Professional Training (hours/FU)

Professional training is defined here as non-formal occupational education, associated with agriculture. The indicator is calculated by attributing costs for staff training hours to the product system, based on allocation by working hours per FU, accounting for professional training of industrial workers, farm employees and farmers (NSF, 2012).

For the farm module professional training calculation, it was considered the monetary value of the hours from an EMBRAPA researcher spent on SBF (20 days, 8 hours per day each year), and also the training offered by John Deere on-site, totalizing 10 courses of 16 hours for 2 employees. It was considered a monetary value of R$ 50. 00 per hour of course attendance.

4.2.4.2.Category Local Community

4.2.4.2.1.Family Support

Bonus for family support, such as, benefits for marriage and children, benefits for health care, birth, death expenditures etc. (family support in Money per functional Unit) (NSF, 2012). In Santa Brígida Farm, meal and transportation from the city to the farm is offered to all employees, and housing for 5 families at the farm site. Conventional systems offer 1 house on the farm site, and meal and transportation from the city to the farm for those not living on-site.

For monetary value calculation, it was attributed the renting value of R$ 550. 00 per house, R$10. 00 for meal per person, R$ 1. 99/l for alcohol, and R$ 2. 99/l for gasoline for 2014.

4.2.4.2.2.Employment (working hours/FU)

Quantification of number of people employed, taking into consideration the working hours for the production of the Functional Unit. In the agricultural production, no differentiation is made between the farmer working time and the employees working time. The total working time is considered as positive impacts by the community (NSF, 2012).

4.2.4.2.3.Qualified Employees (working hours/ FU)

This indicator calculates the working time that qualified employees with a formal degree dedicate to a specific product system versus no qualified worker. A higher level of qualification is associated with improved social status for the employee. Typical benefits include better job security, salary and work satisfaction (Kölsch et al. 2008).

4.2.4.3.Category Future Generations

4.2.4.3.1.Trainees (hours per FU)

This indicator assesses the number of people in formal education on the farm or in the industrial sectors associated with upstream processes. In order to meet future economic challenges, it is a key societal responsibility to educate future generations to a high standard. This particularly holds for agriculture, given the challenges that it faces, e.g., the need to increase productivity and considering that environmental impacts and education of future farmers are issues of key importance (NSF, 2012).

Santa Brigida farm counts with one full-time trainee and 60 interns on the cycle of seven years. Each intern spends around 3 months, 6 hours per day, totalizing 38,544 hours for 625 hectares of agricultural area. Conventional systems in the region do not offer programs for trainees or interns.

4.2.4.3.2.Social security (R$ per FU)

Contributions to social security systems include health insurance, contributions to public pension, old-age insurance and accidents insurance of farmers and workers (NSF, 2012). For the farm production module, these indicators were not calculated since most of them are, by law, incorporated in the wage value.

4.2.4.3.3.R&D (R$ per FU)

Internal and external expenditures of companies in research and development.

R&D Investments are seen as a positive influence for the future development of manufacturing industries. As such, it helps maintain current working environment in good conditions as well as ensure sustainability for future job opportunities (NSF, 2012). Santa Brigida Farm is a Technological Reference Unit (TRU) of integrated systems. John Deere Company invests in this farm through the CLFi Fostering Network. Over the last seven year-cycle, the company has invested R$ 3,000,000.00 in the SBF.

For the R&D assessment, the invested value was divided by the whole area of the farm (625 ha) and multiplied by the amount of hectares of CLFi and CLi of each Arrangement. In addition, the farm shares an area of 10 hectares for EMBRAPA to develop experimental researches. The average for one hectare rental was considered R$ 360.00. This value was calculated using the same approach of John Deere investments (by area). Thus, in the cycle of seven years, both integrated systems received investment of R$ 4,840.32. R&D investments in conventional systems were not relevant for this specific region.

Fostering Network comprises the following companies: EMBRAPA, John Deere, Dow AgroScience, Syngenta, Parker, Scchafler and Cocamar. This network focuses on the development and dissemination of integrated technology and on promoting and disseminating the use of these systems in farmers all over Brazil. Each company invests R$ 500,000.00 per year over a period of 5 years. Each company usually chooses a state in Brazil to make investments in integrated systems, choosing one farm as TRU.

4.2.4.3.4.Capital investment (R$ per FU)

Value of replacement and net investment, including general repair, purchase of concessions, patents and licenses (capital investment in R$ per product masses) (NSF, 2012). The the farm roduction model, this indicator was not calculated due to lack of data.

4.2.5.Social Perception Factors

Concerning these factors, BASF SA evaluated the perception of representatives of society about the relative importance of each environmental impact under this category. A survey was carried out with public opinion collection, interviews with experts, academic etc.

4.2.6.Relevance factors

The environmental relevance can be understood as the contribution to the total impact generated in a given context (in this case, the national geographic territory of Brazil) to achieve the Functional Unit established. The relevance factors taken into account are energy consumption, material resources and emissions associated with the product life cycle studied regarding the availability of regional reserves and total emissions of the region under study. The percentage of the result related to environmental relevance is given by the percentage of that particular impact considering all impacts of the category (NSF, 2012).

The Weighting Factor is determined by the geometric mean of environmental relevance factor with society's perception. These factors can be interpreted to determine the importance of each environmental impact category in relation to the priority of other categories.

For soil, biodiversity and eco-toxicity potential, there are no data available for the total amount concerning Brazil. Thus, in this case, only the society perception is taken into account, which is the final weighting factor, in which higher values are interpreted as the most critical in the context of this study.

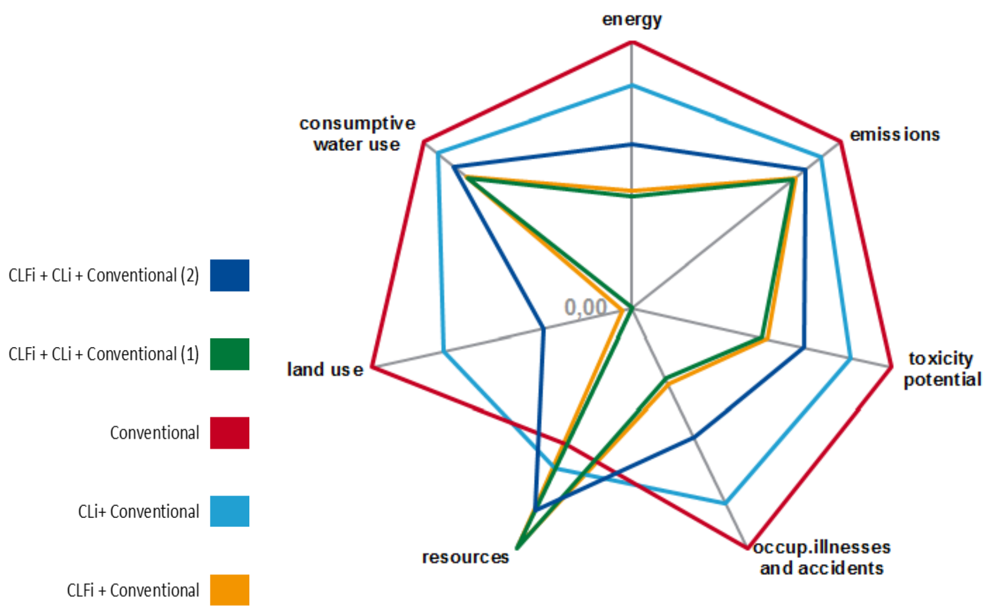
Social relevance is evaluated according to the society’s perception factors aforementioned.

5. RESULTS

5.1. Environmental Fingerprint

The values obtained for each impact category were normalized (range 0 to 1) to allow a preliminary comparison between alternatives. Thus, the worst impact category is represented by unity 1. For comparison purposes, Figure 23 is the "Environment Fingerprinting".

Figure 23: Environmental Fingerprint of Eco-efficiency Methodology.



Environmental fingerprint gives an overview of the environmental indicator evaluation. Categories of land use, consumptive water, toxicity potential, occupational illness and accidents and emissions (which contains the impact categories: acidification potential (AP), photochemical ozone creation potential (POCP), ozone depletion potential (ODP), impact on water quality (Critical Volumes method) and the creation of solid wastes) pointed to better performance of the combination which prioritizes CLFi (higher percentage) followed by CLi and then conventional systems. Resources category showed the best result to Conventional systems, due to less Zinc use. On conventional systems this element is only used on fertilizes as micronutrient while on integrated systems it is used as cattle feed as well.

5.1.1.Environmental Relevance

Relevance shows the categories that should be treated with priority (with higher relevance). The results for environmental relevance is available in Table 29.

Table 29: Relevance factors in Eco-Efficiency Study

	Environmental Relevance Factor	Social Factor	Geometric mean	Weighting Factor
Relevance Energy	8,6%	13,5%	10,8%	10,4%
Relevance Resources	10,3%	15,3%	12,6%	12,2%
Relevance Consumptive Water Use	2,4%	15,2%	6,0%	5,8%
Relevance Greenhouse Gases	9,5%	2,2%	4,6%	4,4%
Relevance AP	2,5%	1,8%	2,1%	2,1%
Relevance POCP	1,0%	1,0%	1,0%	1,0%
Relevance ODP	0,0%	1,7%	0,2%	0,2%
Relevance Water Emissions	16,1%	7,6%	11,0%	10,7%
Relevance Solid Wastes	15,9%	4,9%	8,8%	8,5%
Occupational Illnesses and Accidents	0,0%	8,6%	0,0%	8,6%
Relevance Land Use	33,7%	8,6%	17,0%	16,5%
Relevance Toxicity Potential	0,0%	19,6%	0,0%	19,6%

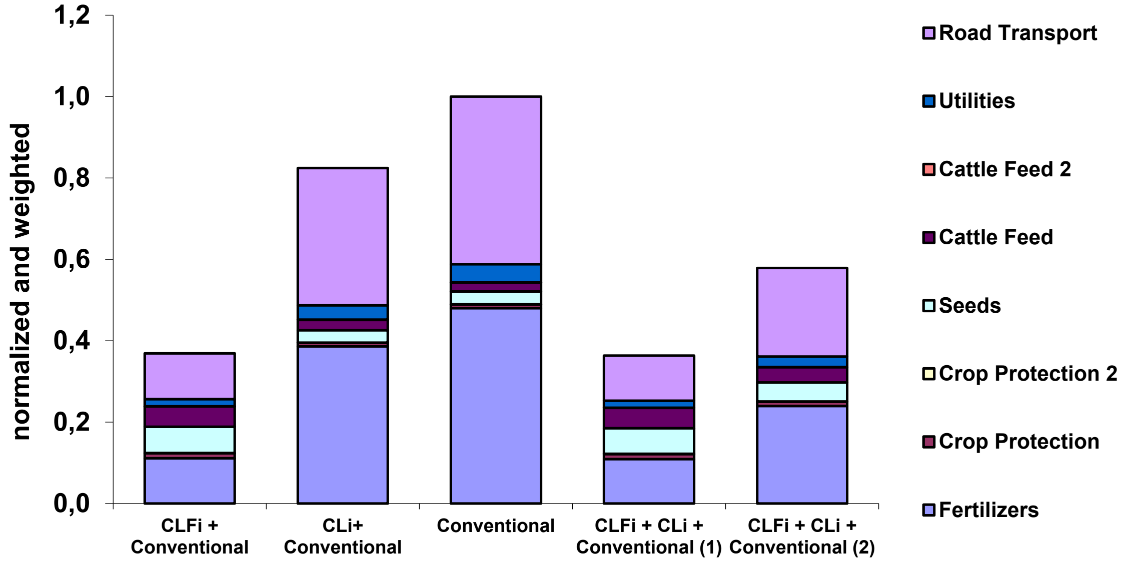
In this study, the most relevant categories would be toxicity potential and land use.

5.1.2. Environmental Impact Categories

5.1.2.1.Human Toxicity Potential

The result for human toxicity potential is showed on Figure **24**.

Figure 24: Human toxicity potential.



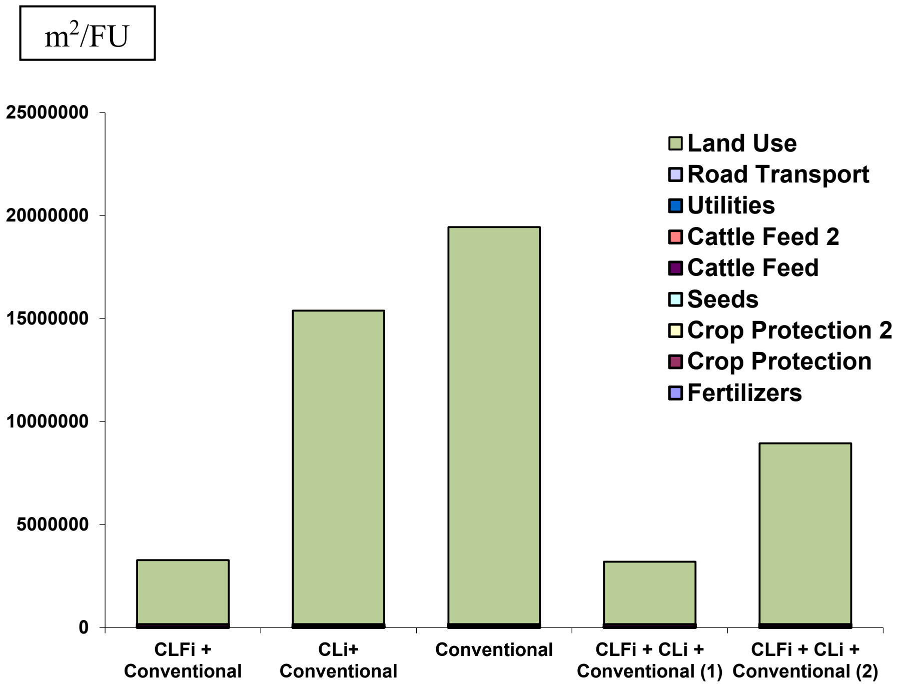
The total human toxicity potential of the most integrated Arrangement (alternative 4) is 50% lower than the conventional Arrangement (alternative 3). Fertilizer pre chain and Road Transport are major contributing factors for this result. The alternative 1 is very similar to alternative 4. This was expected to occur in all results, since the Arrangement are similar.

Cattle feed show lower results in conventional Arrangement, since these inputs are more representative in integrated Arrangement. As far as fertilizes are concerned, the major contributor for the values are calcium oxide and magnesium oxide. Calcium oxide presents high toxicity. The toxicity value of magnesium oxide comes from dolomite calcination process. In road transportation, vehicles with 14 t and 27 t capacity cause higher toxicity to conventional systems because of their high number of inputs. Utilities show high toxicity related to diesel use in the farming module.

5.1.2.2.Land Use

The results for land use (Figure 25) show major impacts related to the direct land use at farm level, which is including land use for the calf input. Second major impact is attributed to cattle feed pre-chain, especially due to soya residue.

Figure 25: Land Use Category Results.



This result is coherent, since the alternatives show very different needs of area to meet the established function unit (Arrangement composition). Despite the different size of area of the Arrangement, each system has a specific characterization (Table 10: Characterization factors for land use occupation to the farm systems under evaluation.Table 10).

Compared to conventional Arrangement, the integrated systems produce 84% less impact on biodiversity owing to its land use.

5.1.2.3.Cumulative Energy Consumption

The total cumulative energy demanded by most integrated Arrangement (alternative 4) is 58% lower than conventional Arrangement (alternative 3). This result attributed mostly to the fertilizers followed by cattle feed pre-chain than utilities (from seed treatment machine and energy of washing machine to washing equipment). The total amount demanded and the energy source can be seen on the

Figure **26** and Figure 27 respectively.

Figure 26: Cumulative Energy Consumption.

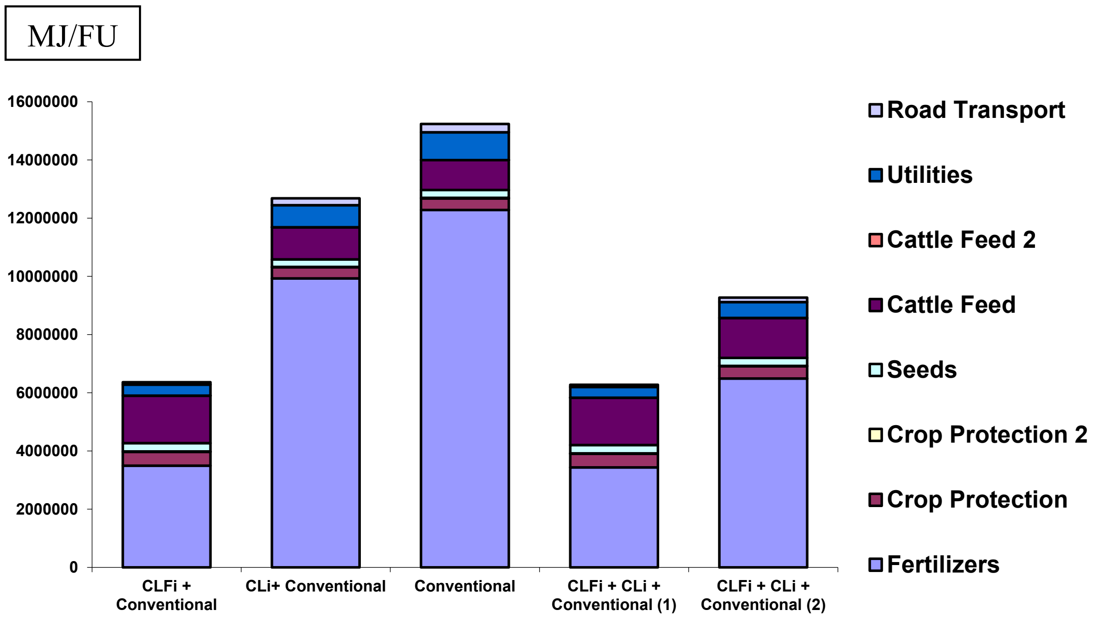
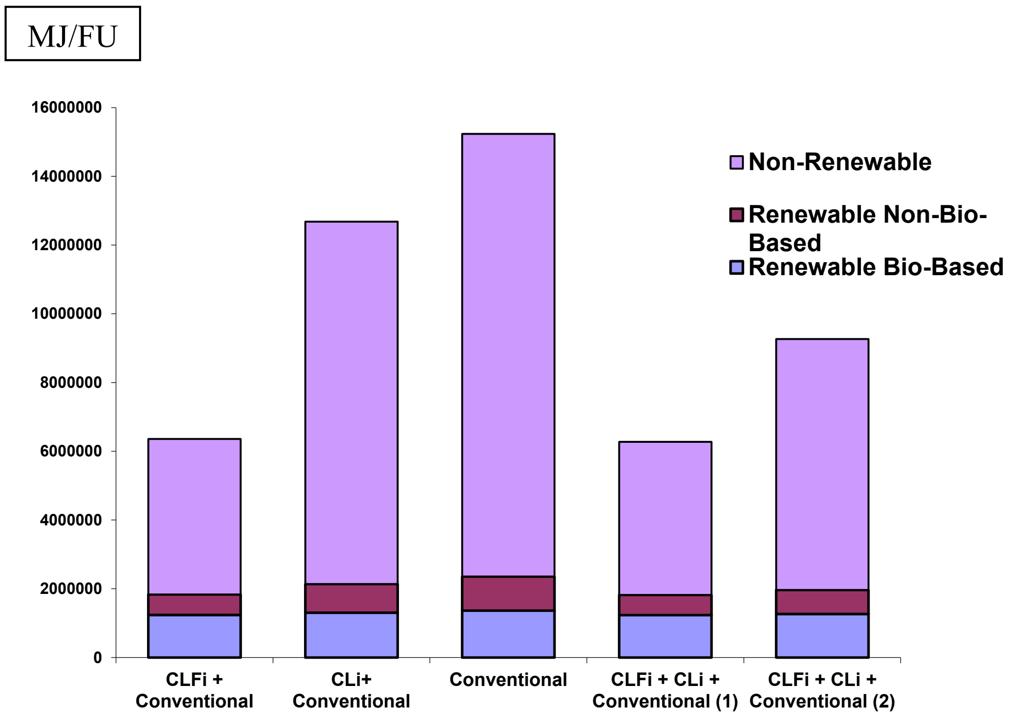


Figure 27: Total amount of the kind of the energy (renewability).



Results for cattle feed is higher to integrated system due to higher input. Regarding fertilizers, although not showing high values of energy needs (on integrated systems), their calcium and magnesium oxides (MgO and CaO) content are responsible for the high energy needs rates, which is consistent with the high rates of fertilizer uses. According to the database, it is needed 18.8 MJ (of natural gas) per 1 kg MgO; 3.2 MJ (of natural gas) per 1 kg of CaO. Boron from borax needs 66.5 MJ (of natural gas) per 1 kg. However, its input is not so high, placing it as the third most factor of impact on natural gas needs. The second energy source demanded is Oil, and the major fertilizers are CaO (1 MJ per 1 kg) and MgO (1.3 MJ per 1 kg). Cattle feed demands renewable bio-based energy from soy residue (7.5 MK per 1 kg), natural gas from urea (36.8 MJ per 1 kg), and oil from magnesium (217.7 MJ per 1 kg).

The bio-based non renewable energy shows high contribution from nitrogen fertilizers which is necessary electricity from hydreletric (39.8 MJ per 1 kg of N) and thermal source for solid biomass (21.3 MJ per 1 kg de N).

5.1.2.4.Abiotic Resources Depletion

The amount of abiotic resources and the main compounds represented in silver equivalent can be observed on the Figure 28 and Figure 29 respectivelly.

Figure 28: Resource Depletion Potential

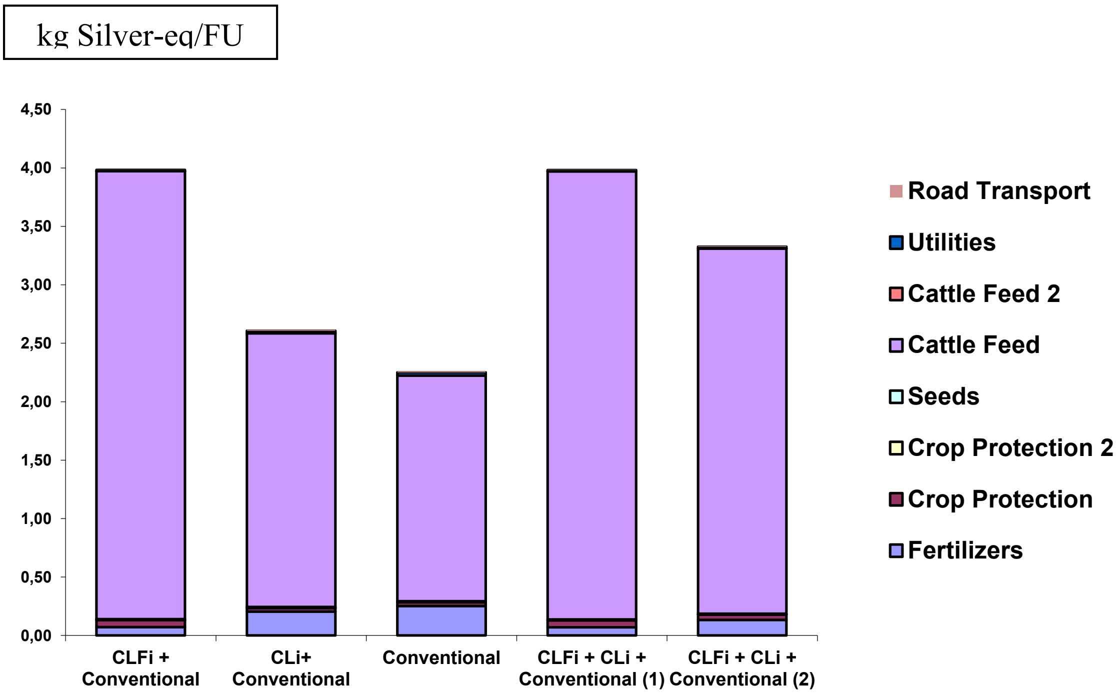
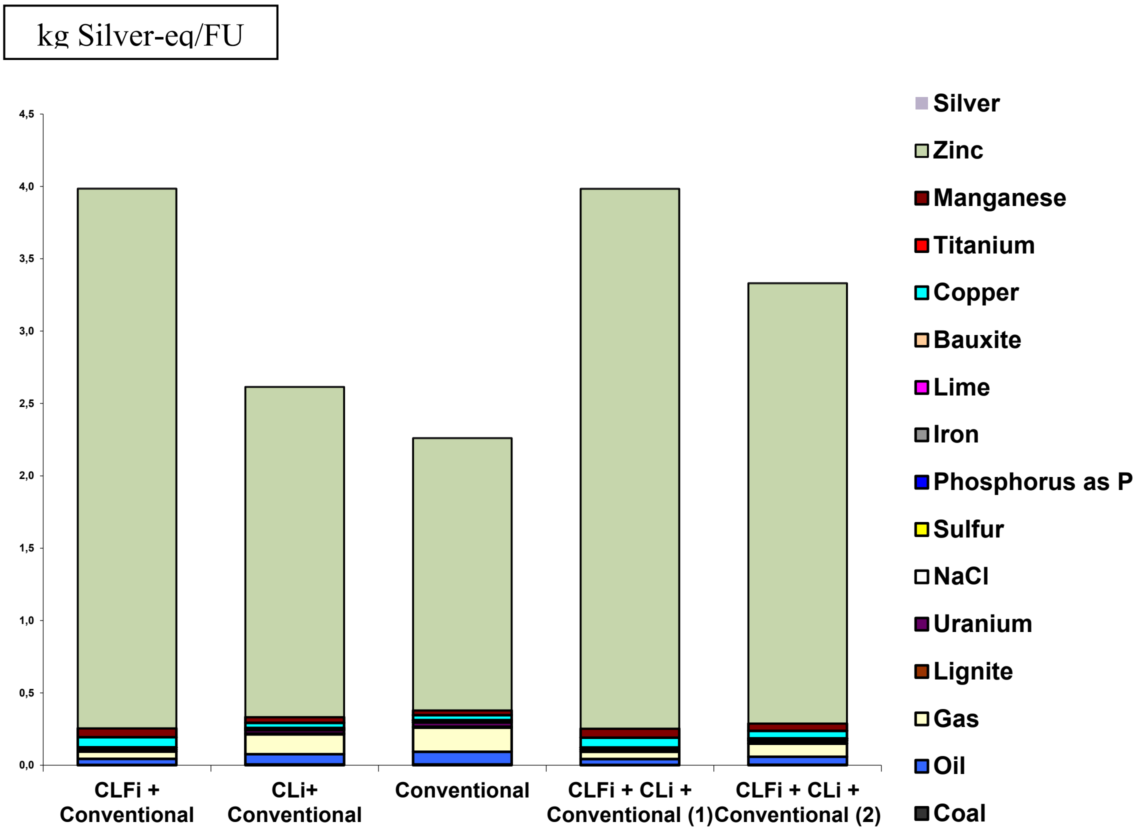


Figure 29: Main Resources Demanded.

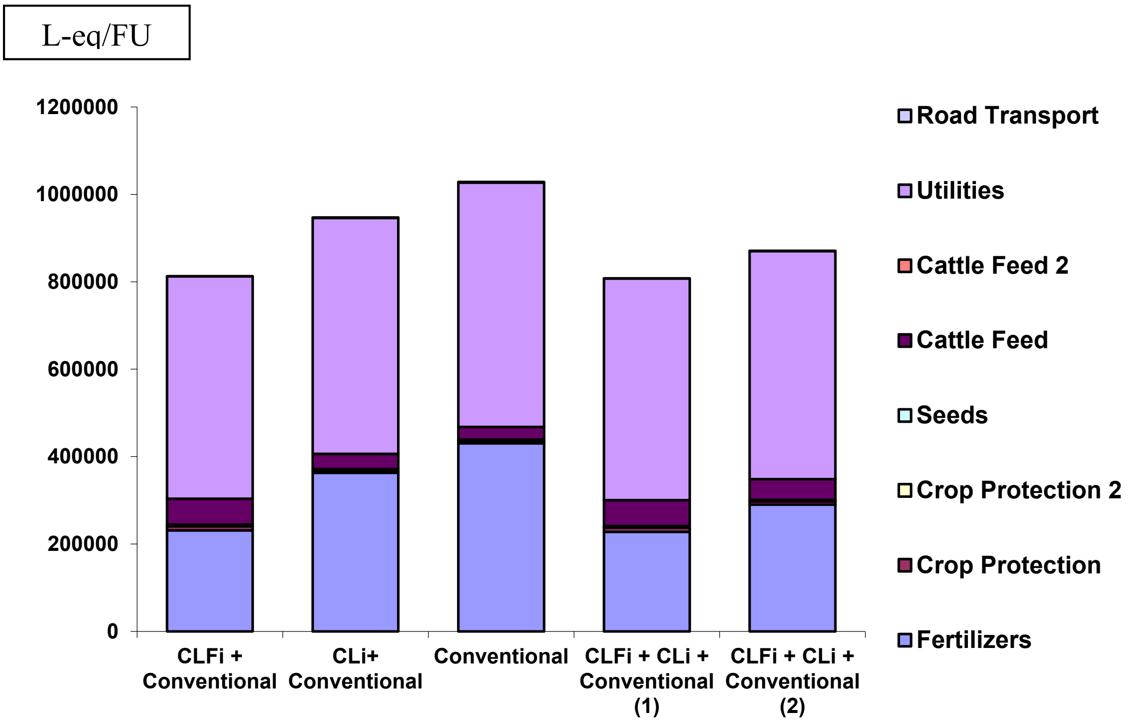


The mostly integrated Arrangement (alternative 4) have 43% more potential for resource depletion than conventional Arrangement (alternative 3). This happens due to zinc compound for cattle feed and fertilizers for forest. Although the conventional and the most integrated Arrangement do not demand high amount of zinc compound inputs (122 kg and 243 kg over 7 years), zinc compound is considered to produce high impact rates compared to other compounds analyzed.

5.1.2.5.Consumptive Water Use

Results indicate that conventional Arrangement (alternative 3) have higher impact potential (Figure 30).

Figure 30: Consumptive water.



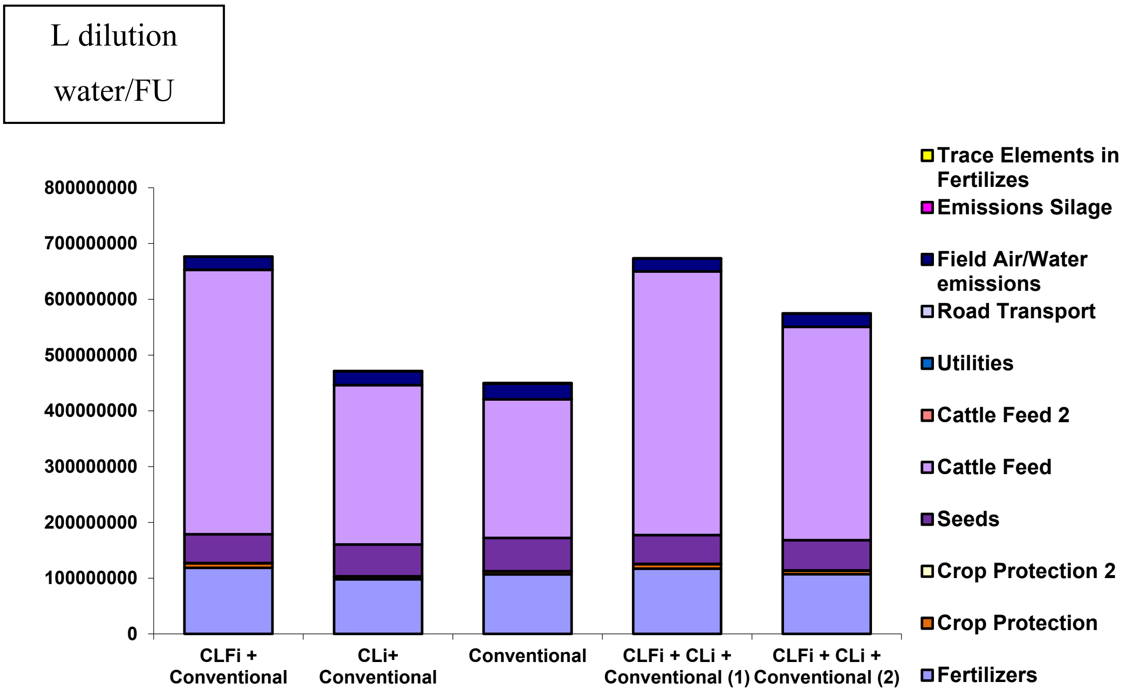
Alternative 3 showed 21% higher potential than most integrated Arrangement. The most representative contributors are consumptive water used in fertilizers pre-chain, water used in washing equipment, and water used for cattle drinking (utilities). As for alternative 4 (more integrated Arrangement), the consumptive water related to the cattle feed pre-chain is higher due to higher input demand.

5.1.2.6.Emissions

5.1.2.6.1.Water emissions

Water emission results are shown on the Figure 31.

Figure 31: Water emissions.



Cattle feed produces higher impacts on water emission category than fertilizers and seeds production pre-chain. As cattle feed input is higher on most integrated Arrangement (alternative 4), the major impact potential is attributed to this alternative.

On emission from cattle feed, the worst contribution is from Hg and unspecified trace elements associated to copper from copper carbonate life cycle. Concerning fertilizer unit processes, emissions from phosphate are the most contributing factors for this environmental impact. From the fertilizer pre-chain, Cobalt, Molybdenum, Nickel and P_2O_5 show the following amounts associated its life cycle (in mg P-eq): 670; 192,638; 14,626, 10,900, respectively, per kilogram of product. At the cattle feed, most impacts come from phosphate as P, Hg and unspecified trace elements associated to soya residue life cycle.

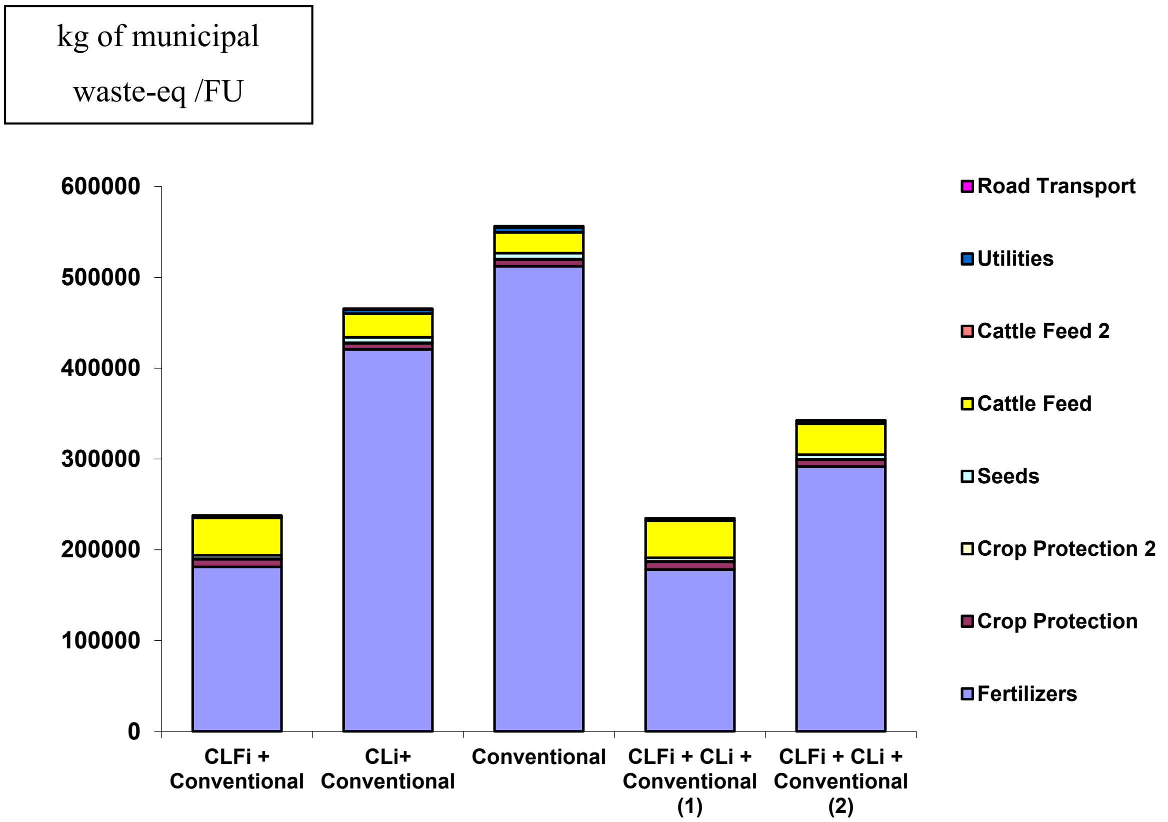
The amount of trace elements from fertilizers, calculated as 10% from leaching during the use phase, is not substantial when compared to others under the Water Emission category, as shown on Figure 31.

Figure 31 values can be checked on Appendix I. Since the inputs are higher in alternative 3 (conventional systems), based on the assumption that 10% is lost to leaching, the trace elements on the Water Emission category is also higher.

5.1.2.6.2.Solid Waste

Most of potential impacts from solid waste can be observed in Arrangement of conventional systems (alternative 3), showing 58% more impact potential than mostly integrated alternatives (alternative 4). In the farm module, all the packages of crop protection and fertilizers are returned to the supplier, which can be considered a close loop recycling. Results on Figure 32 refer to its related pre-chain.

Figure 32: Total amount of solid waste.



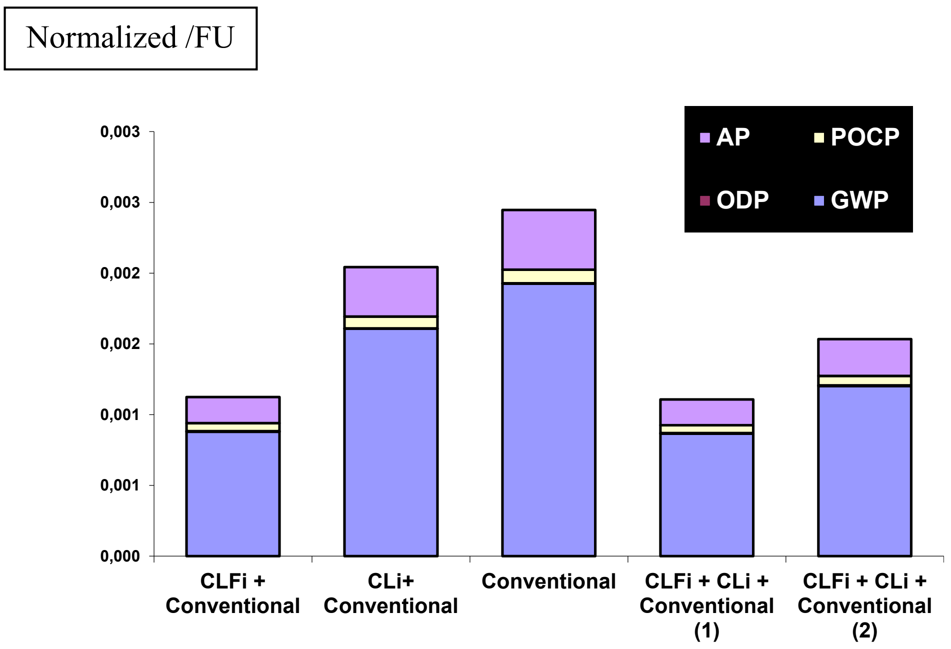
The highest impact comes from fertilizers followed by cattle feed. Regarding fertilizers, mining waste shows the highest contribution. Fertilizers compounds that produce the highest impacts are MgO, P_2O_5, K_2O. The second in the rank of major contributors is munnicipal waste from K_2O compound. As for the cattle feed pre-chain, the most relevant impact potential comes from industrial waste from copper, calcium, magnesium and soya residues.

5.1.2.6.3.Air Emissions

In the farm production module, fertilizers, silage process, diesel equipments and livestock process present high impact potential. The emission factor from the use of fertilizers depend on local soil and climatic conditions and therefore subject to considerable variations. The same happens to cattle breeding, since this process also depends on climate type and conditions, feed production and animal race-related aspects. The factors chosen for this study are based on the 'tier 1' approach in IPCC (2006). Other emissions, such those from diesel-powered equipment, are counted considering their entire life cycle, including the use phase.

For air emission, the analysis was based on the Global Warming Potential (GWP), Acidification Potential (AP), Photochemical Ozone Creation Potential (POCP), Ozone Depletion Potential (ODP). The contribution of each indicator to the normalization of the Air Emission category can be observed on the Figure 33.

Figure 33: Impacts indicators at Air emission Category.

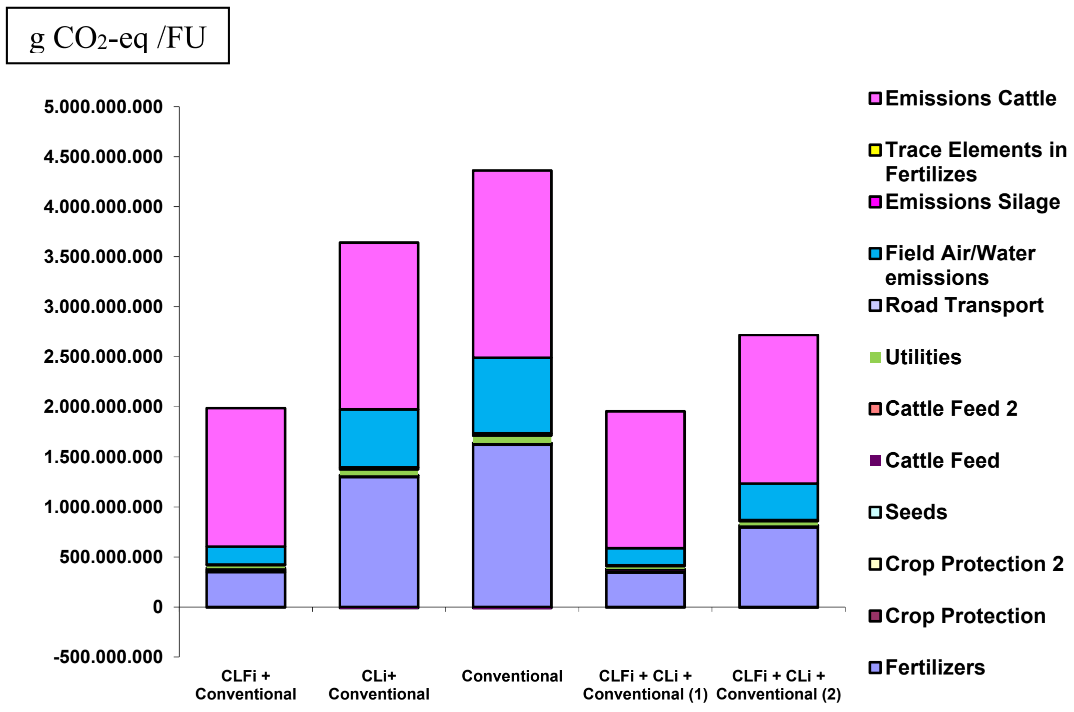


GWP is the indicator showing a major contribution to the Air Emissions, followed by the AP, POCP and ODP. ODP presents the lowest potential impact of all the Air Emission indicators analyzed in this study. Under the Air Emissions category, the highest impact comes from alternative 3 (conventional Arrangement), which is two times worse than those observed in alternative 4 (the most highly integrated Arrangement).

a) **GWP - Warming Potential**

Most of the impacts come from cattle emissions at the farm level, followed by the pre-chain of fertilizer and fertilized applied on fields. Integrated Arrangement have lower potential impact from direct cattle emission due to early cattle slaughter compared to conventional system. Emissions from cow are included in the evaluation of cattle emissions. The highest amounts were found in the following fertilizer compounds manufacturing: MgO, CaO, N and K_2O as can seen on Figure 34.

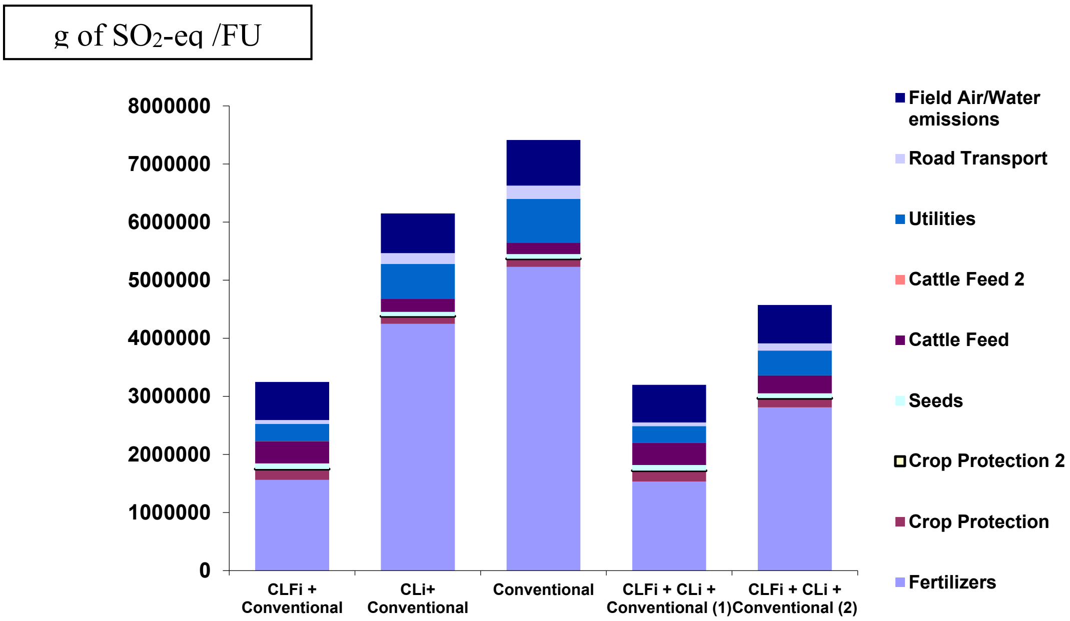
Figure 34: GWP in CO_2-eq



b) **AP - Acidification Potential**

Regarding the Acidification Potential category, the environmental aspects involved are SOx, NOx, NH_3 and HCl expressed in SO_2-eq. Results for Acidification Potential are available on Figure 35.

Figure 35: AP expressed g of SO_2-eq.

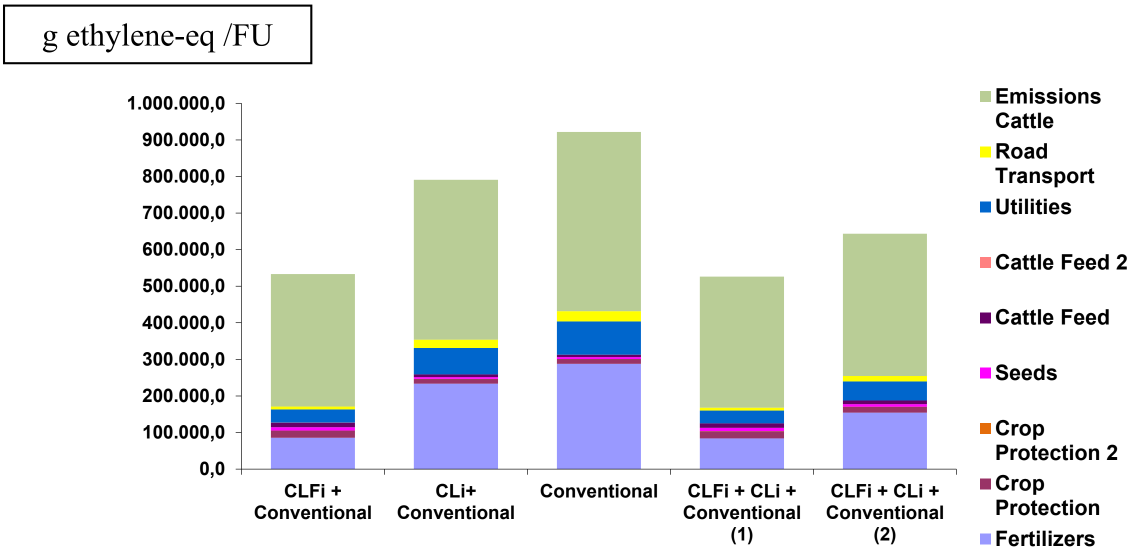


Regarding the AP category, the highest impact is observed in Arrangement 3 (conventional systems), 56% higher than most integrated Arrangement (Arrangement 4). This impact is mainly related to the fertilizer compounds pre-chain followed by the fertilized field emissions (farm module). The highest amount of SO_2 equivalent is found in the following fertilizer compounds pre-chain: MgO, P_2O_5, K_2O and N.

c) POCP - Photochemical Ozone Creation Potential

Photochemical Ozone Creation Potential has, as environmental aspects involved, CH_4 (methane) and VOCs (volatile organic compounds). These gases expressed in the ethylene-eq (Figure 36).

Figure 36: POCP expressed in ethylene-eq.



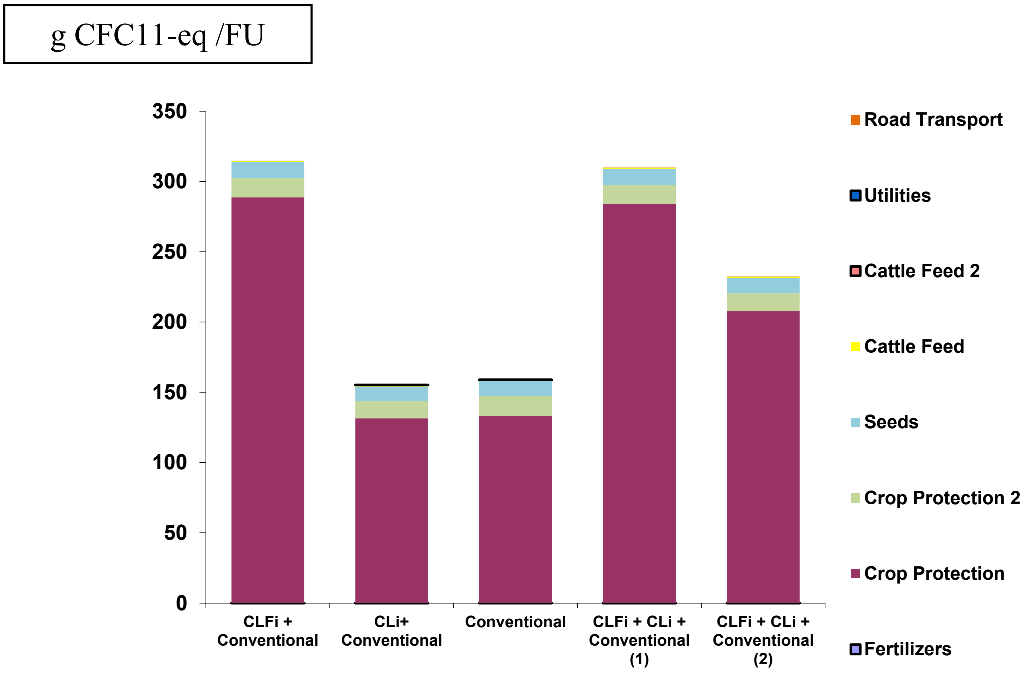
The Arrangement 3 (conventional systems) showed 42% more accumulation of POCP than most integrated alternative systems (Arrangement 4).

Fertilizers compounds, such as MgO, K_20, N, P_2O_5 and CaO, are significant due to the life cycle of their pre-chain.

d) ODP- Ozone Depletion Potential

In the Ozone layer Depletion Potential category, the environmental aspects involved are halogenated hydrocarbons. The results are expressed in g CFC11-eq (Figure 37).

Figure 37: ODP expressed in g CFC11-eq.



ODP is higher in integrated Arrangement due to an application of insecticide to corn and sorghum for cattle feed. However, a significant difference observed is attributed to a forestry insecticide for ants (pirazol chemical group), reinforcing the assumption that all production impact of forestry from CLFi system is attributed to the output of 1/3 of eucalyptus production.

5.1.2.6.4. Accidents and Occupational Diseases Potential

The result comes from pre-chain production data, since there are no primary data for occupational diseases or accidents in the farming module. This indicator will be further analyzed under AgBalance^{TM} social indicators. The normalized value of each indicator can be observed on the Figure 38 and

Figure **39**.

Figure 38: Proportion between Accidents and Occupational Diseases for Pre-Chain.

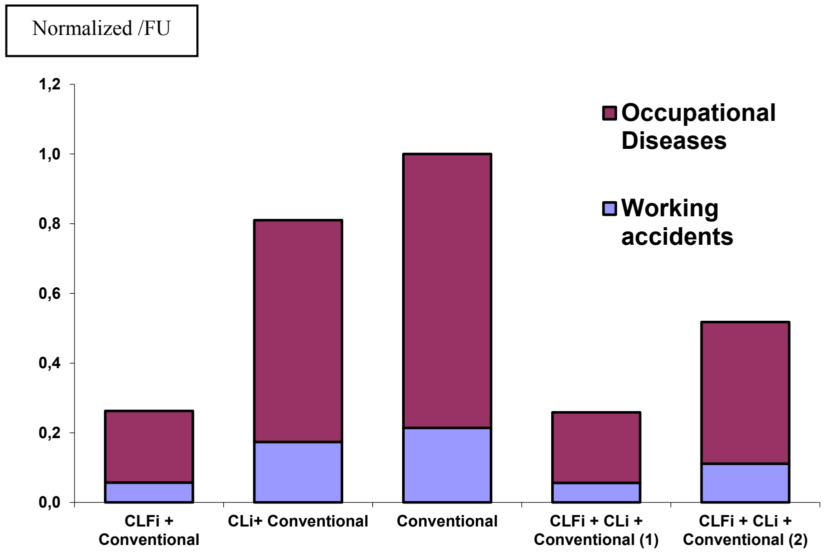
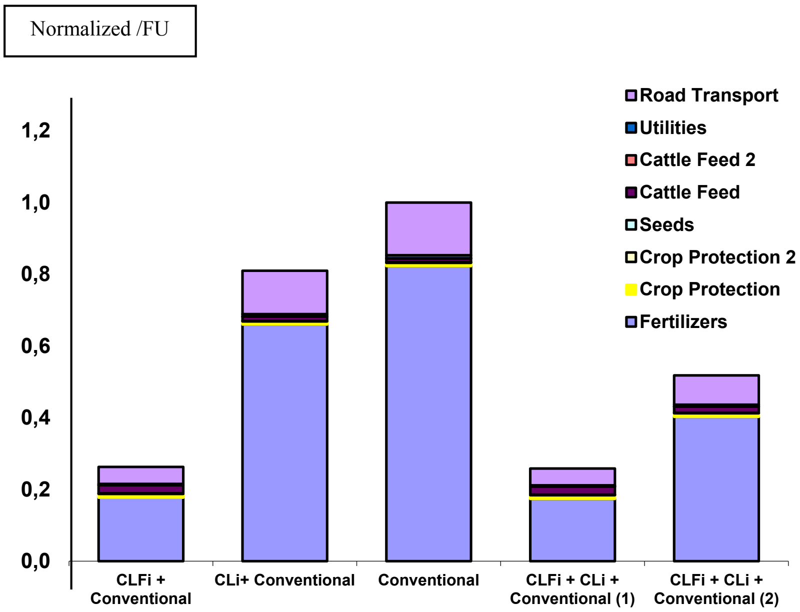


Figure 39: Accidents and Occupational Diseases potential per input.



Conventional Arrangement show higher consolidated impact potential, mostly attributed to fertilizer compounds pre-chain (MgO and CaO) used in high amounts for the recovery of degraded pastures (start condition assumption for all alternatives). Cattle feed has lower consolidated impact on conventional system due to lower inputs. As for cattle feed, the highest consolidated impacts come from soy residues.

5.2. Economic Aspect

The economic aspect was calculated using the total cost production for each alternative during the cycle of 7 years. It was considered the rise on wages and inflation for raw materials. All costs were considered as fixed costs. Equipment is usually rented (common practice in the region), so no depreciation costs were considered. Land-lease related costs were included. The total cost (R$) are available on Table 30.

Table 30: Total cost (R$) for each alternative.

Alternative 1: CLFi + Conventional	Alternative 2: CLi+ Conventional	Alternative 3: Conventional	Alternative 4: CLFi + CLi + Conventional (1)	Alternative 5: CLFi + CLi + Conventional (2)
1,019,333.61	1,748,623.33	2,160,415.96	997,368.50	1,338,208.15

In order to produce the amount of food and energy established in the functional unit as established by this study, the alternative 4 (arrangement with most integrated system) has 54% lower cost compared to conventional system arrangement (alternative 3). The alternative 4 is composed mostly by integrated systems. In this system, the land is occupied during the most part of the year and, consequently, its operational costs are higher. This Alternative 4 also has cattle-feed related costs. Although the objective of this study was to compare arrangement and not individual systems, the arrangement 4 achieved the functional unit using an area 6 times smaller than the arrangement 3.

Arrangement 3 needs to operate in a larger area, increasing its leasing costs over a period of seven years as compared to arrangement 4. Results indicated higher productivity per area achieved by integrated systems.

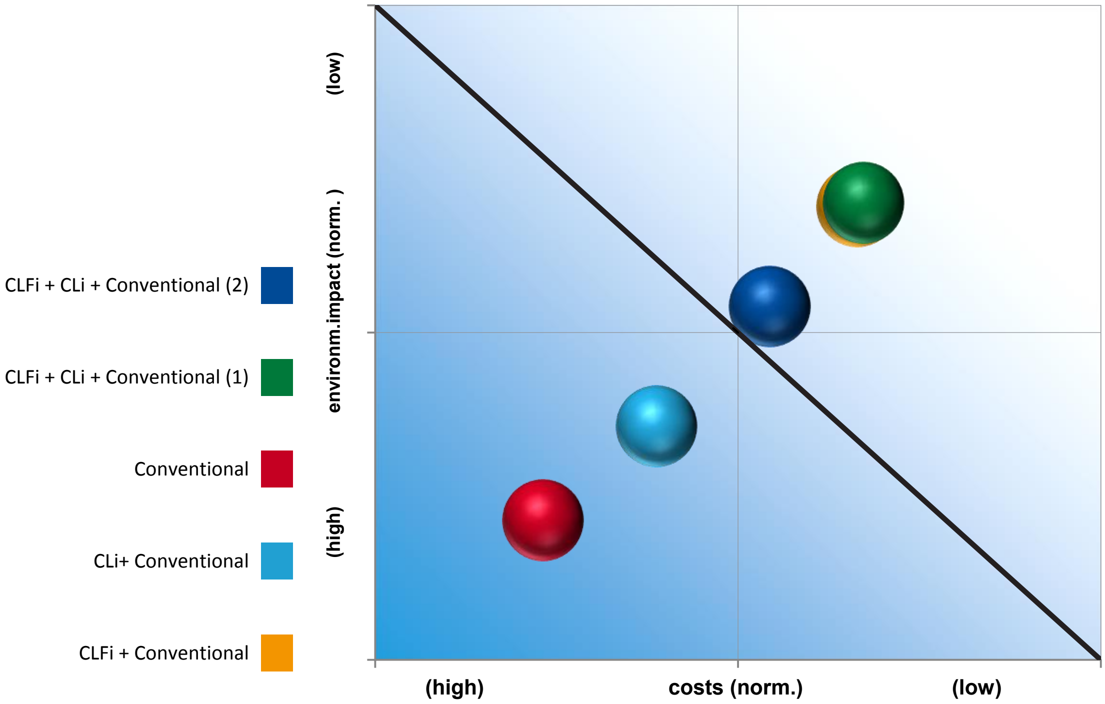
Profits were not considered in the analysis because all alternatives produce the same amount of food and energy in the same region.

5.3. Eco-Efficiency Matrix

All information obtained in the evaluation of the life cycle and the economic aspect is compiled into a single score of Eco-Efficiency (represented by spheres in the matrix associated with each alternative under study), as proposed by the Eco-Efficiency Analysis.

On the Eco-Efficiency Matrix, the axes are reverse in the range of values; thus, when sphere is directed to upper region of the graph, the better the environmental performance will be and when it is directed to the right of the graph, the better the economic performance will be (Figure 40);. The upper right quadrant is the region which has the highest eco-efficiency on the matrix. The Eco-Efficiency Matrix can be seen below.

Figure 40: Eco-efficiency Matrix



By observing Eco-efficiency Matrix it was verified that the alternative 4 is located closer to the zone of high ecological and economic efficiency, making it a more eco-efficient alternative. Conclusion shows that the most eco-efficient alternative is the one that adopts the highest amount of CLFi followed by CLi. Alternative 3, composed of conventional systems, showed the worst performance.

This result was expected since it reflects the combination of environmental and economic aspects, as already discussed. The intensification of production in the arrangement 4 optimizes in six times its land use, enabling the smaller area to produce the same amount of food and energy as established the functional unit.

5.4. Agricultural Indicators- AgBalance^{TM}

5.4.1.AgBalance^{TM} Relevance

Following the EEA logic, the relevance in AgBalance^{TM} also establish the total impact generated in a given context (in this case, the geographic territory of Brazil) in order to achieve the functional unit. The result percentage for environmental relevance is obtained by the percentage of that impact considering the impacts of all categories. The perception of society changes according to the agricultural approach adopted. Table 31 shows the weighting factors for each impact category in which higher values are interpreted as the most critical in the context of this study.

Table 31: Relevance Factors for AgBalance^{TM}.

	Environmental Relevance Factor	Social Relevance Factor	Geometric Mean	Weighting Factor
Relevance Emissions	19.9%	17.1%	18.5%	16.3%
Relevance Energy	12.0%	10.4%	11.2%	9.9%
Relevance Abiotic Resource Depletion	14.3%	12.6%	13.4%	11.8%
Relevance Land Use	50.5%	7.2%	19.1%	16.8%
Relevance Toxicity Potential	-	14.4%	-	14.4%
Relevance Water use	3.3%	13.1%	6.5%	5.8%
Biodiversity	-	13.8%	-	13.8%
Soil	-	11.3%	-	11.3%

AgBalance^{TM} relevance factors are re-distributed according to the level of impacts produced by the categories evaluated under the environmental pillar. By combining the environmental relevance with the societal perception of agriculture, no significant differences were found between them, however still prominent are land use and emissions.

5.4.2.Biodiversity

Biodiversity indicator on AgBalance^{TM} is dimensionless and it was calculated according to the product of several indicators such as, biodiversity state indicator, protected area, Eco-Tox Potential, Intermixing Potential and Nitrogen Surplus (Table 32). The biodiversity indicator is normalized by the maximum value.

Table 32: Biodiversity Indicator.

		Alternatives				
		1	2	3	4	5
1- best	Biodiversity state indicator	0.10	0.10	0.10	0.10	0.10
	Protected areas	1.00	1.00	1.00	1.00	1.00
	Crop rotation	1.00	1.00	1.00	1.00	1.00
	Eco-Tox potential	0.80	0.61	0.61	0.81	0.65
	Farming intensity	0.81	0.82	0.60	0.83	0.84
	Intermixing potential	1.00	1.00	1.00	1.00	1.00
	Nitrogen Surplus	0.867	0.874	0.875	0.866	0.872
	Result biodiversity	0.9116	0.9982	0.9980	0.9152	0.9931
1-worst	1/biodiversity	0.05	0.04	0.03	0.05	0.05
	Normalized biodiversity	0.62	0.73	1.00	0.59	0.67

The results indicated the best biodiversity to alternative 4. The main indicators that contributed to that result were crop rotation and eco-toxicity potential. Under crop rotation, the integrated system presented the best values due to its higher number of cultures under rotation and consortium.

Regarding eco-toxicity, CLFi system shows lower values because of lower crop protection inputs. In this system, crop protection inputs are most needed during in the first and second years of crop. After that, the systems is converted in pasture and forest, and crop protection is applied only on eucalyptus. Arrangement 4 is under a CLFi system for the most part, which justifies the best performance of these indicators. Calculations of each indicator are described in the following sub-sections

5.4.2.1.Biodiversity State Indicator

The status of biodiversity in a particular region is determined by the number of species featuring in the IUCN Red List. Since all system arrangement analyzed in the present study belong to the same region (Brazil), the result indicators are the same, in other words, the result indicator does not make any difference as far as the proposed comparison analysis is concerned.

5.4.2.2.Protected Areas

Score calculated from percent coverage of protected areas (conservation units). The reference area is not the farms, but the state. Since all of arrangement are located in the same state (Goias), the indicator has the same value for all alternatives.

5.4.2.3.Crop Rotation

The evaluation was made by system and by year, according to the crop assumptions for each system. The results for each system are the average of the seven years indicator (Table 33).

Table 33: Evaluation for Crop Rotation Indicator to each System

	CLFi		CLi		Conventional Crop System		Conventional Forestry System		Conventional Livestock System	
Year	No. of elements in crop rotation	Value	No. of elements in crop rotation	Value	No. of elements in crop rotation	Value	No. of elements in crop rotation	Value	No. of elements in crop rotation	Value
Year 1	3.0	1.0	1.0	0.6	1.0	0.6	1.0	0.6	2.0	0.8
Year 2	3.0	1.0	1.0	0.6	1.0	0.6	1.0	0.6	3.0	1.0
Year 3	2.0	0.8	2.0	0.8	1.0	0.6	1.0	0.6	3.0	1.0
Year 4	2.0	0.8	1.0	0.6	1.0	0.6	1.0	0.6	2.0	0.8
Year 5	2.0	0.8	2.0	0.8	1.0	0.6	1.0	0.6	3.0	1.0
Year 6	2.0	0.8	2.0	0.8	1.0	0.6	1.0	0.6	3.0	1.0
Year 7	2.0	0.8	1.0	0.6	1.0	0.6	1.0	0.6	2.0	0.8
Average		0.9		0.69		0.60		0.60		0.9

The results of evaluation of Conventional System adopted by the arrangement were considered the same regarding their segmentation in Conventional System of Soya, and Corn and Sorghum, since these crops are never cultivated isolated. To consolidate the Arrangement result, the individual result per system was multiplied by the area of that system in the arrangement. All multiplied results were summed and normalized by dividing by the total area of the arrangement.

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Table 34: Evaluation for Crop Rotation Indicator to each Arrangementment.

	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forestry		
Result per system	0.86	0.91	0.69	0.69	0.69	0.60	0.60	Sum	Result
Arrangement 1	44.07	-	5.95	3.62	4.34	-	1.06	**59.04**	**0.80**
Arrangement 2	-	9.44	3.00	-	0.02	175.05	5.81	**193.32**	**0.61**
Arrangement 3	-	-	9.41	13.72	4.34	221.57	5.81	**254.86**	**0.61**
Arrangement 4	42.86	1.23	5.21	2.15	3.78	0.01	1.19	**56.43**	**0.81**
Arrangement 5	21.43	6.17	3.53	0.01	1.52	83.39	3.50	**119.56**	**0.65**

Results assigned the best performance score to arrangement 4. This is coherent since this arrangement uses a larger area than those two types of integration systems, CLFi and CLi, which had the best evaluation scores.

5.4.2.4.Eco-Tox Potential

Similarly to crop rotation, the evaluation of Conventional System showed similar results concerning segmentation in Conventional System of Soya, Corn and Sorghum, since these crops are never cultivated isolated. The final results described below (Table 35) attribute the worst scores to conventional Arrangements.

Table 35: Evaluation for Eco-Tox Arrange.

	CLFi	**CLi**	**Conv. Soya**	**Conv. Corn**	**Conv. Sorghum**	**Conv. Livestock**	**Conv. For.**		
Eco-tox per hectar	27	9.584	9.255	9.255	9.255	-	5.307	Total sum	normalized
Arrangement 1	1386.69	0.00	80313.47	48882.35	58613.00	0.00	9366.46	**198,562**	**0.812**
Arrangement 2	0.00	98902.49	40476.76	0.00	308.52	0.00	51396.99	**191,085**	**0.819**
Arrangement 3	0.00	0.00	127031.19	185142.36	58613.00	0.00	51396.99	**422,184**	**0.600**
Arrangement 4	1348.66	12889.91	70314.36	28969.66	51014.21	0.00	10519.37	**175,056**	**0.834**
Arrangement 5	674.33	64689.13	47700.44	189.86	20477.80	0.00	30958.18	**164,690**	**0.844**

Eco-toxicity per hectare is higher in CLi systems. This happens because the system requires high levels of inputs, provided that in a 7-year cycle, crops are cultivated every year, including a 2^{nd} crop whenever feasible. CLFi system, on the other hand, allows only two years of crop and the forest; when the system is converted to pasture and forest, the pasture does not receive crop protection inputs, which is consistent with the lower eco-toxicity rates seen in the final results.

Since the value of conventional crop system was ascribed to conventional soya, corn, and sorghum, the larger areas needed for conventional Arrangements produce higher eco-toxicity rates related to the cultivation.

5.4.2.5.Intermixing Potential

This indicator presents very similar result to all alternatives. This happens because the functional unit comprises the same kinds of products, changing only the dynamics of how each Arrangement operates at the production level. Table 36 shows the result regarding each Arrangement intermixing per system.

Table 36: Intermixing Potential Evaluation for Arranges

	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forestry		
Result for each system	**0.860**	**0.879**	**0.890**	**0.890**	**0.890**	**0.875**	**0.825**		normalized
Arrangement 1	44.204	0.000	7.725	4.702	5.638	0.000	1.456	**63.72**	**0.867**
Arrangement 2	0.000	9.073	3.893	0.000	0.030	255.277	7.990	**276.26**	**0.874**
Arrangement 3	0.000	0.000	12.219	17.808	5.638	323.126	7.990	**366.78**	**0.875**
Arrangement 4	42.991	1.182	6.763	2.786	4.907	0.021	1.635	**60.29**	**0.866**
Arrangement 5	21.496	5.934	4.588	0.018	1.970	121.617	4.812	**160.44**	**0.872**

5.4.2.6.Nitrogen Surplus

Nitrogen surplus derives from nutrient balance calculation. The calculus were made on a crop and a year basis. Results for the Arrangements were obtained by multiplying the nutrient balance by the area of each system in the Arrangement and dividing by the total area of the Arrangements and, then, evaluated by the indicator (Table 37).

Table 37: Nitrogen Surplus Evaluation for the Arranges

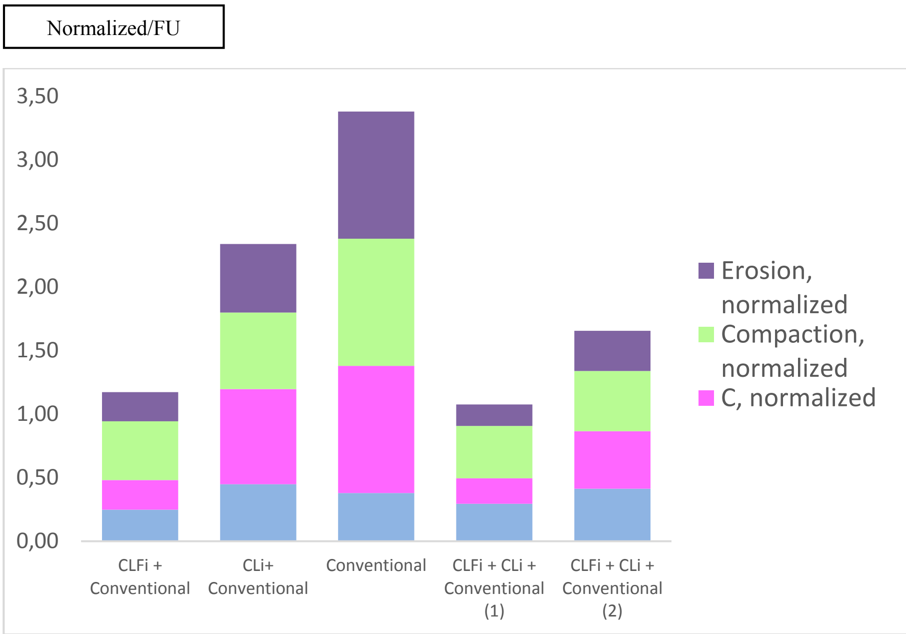
1 best	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forestry			
Nitrogen Surplus	2.52	40.97	16.73	37.68	-36.00	-48.13	-380.46	Sum	By Area	Normalized
Arrangement 1	129.33	0.00	145.19	199.02	-228.00	0.00	-671.46	-425.91	-5.8	0.912
Arrangement 2	0.00	422.79	73.17	0.00	-1.20	-14041.17	-3684.51	-17230.92	-54.5	0.998
Arrangement 3	0.00	0.00	229.64	753.80	-228.00	-17773.13	-3684.51	-20702.20	-49.4	0.998
Arrangement 4	125.79	55.10	127.11	117.95	-198.44	-1.14	-754.10	-527.74	-7.6	0.915
Arrangement 5	62.89	276.54	86.23	0.77	-79.66	-6689.37	-2219.31	-8561.90	-46.5	0.993

The highest scores for average loss of nitrogen were found in conventional forest systems. Arrangements results showed consistent rates of nitrogen loss per area of the Arrangement. After dividing by the area of the Arrangements, the alternative 3 and 5 showed higher scores of nitrogen loss. In the conventional Arrangement, livestock is the protagonist because of the area by which the indicator is multiplied, while in integrated Arrangements (1 and 4) the protagonist of nitrogen loss is CLFi due to the eucalyptus crop and the larger areas of this system in the Arrangements as a whole.

5.4.3.Soil

Results for soil quality (Figure 41) show better performance score to Arrangement 4, and the worst to Arrangement 3 in all indicators analyzed. All indicators present differences between conventional and integrated Arrangements.

Figure 41: Results for soil cathegory.



The main differences on soil quality between Arrangement 4 and 3 are attributed to erosion, carbon and compaction. The NPK balance did not show major differences.

5.4.3.1.Erosion

Soil erosion factors and its evaluation is represented by system on Table 38.

Table 38: Results for erosion Indicator per system.

	CLFi	CLi	Conv Crop	Conv Livestock	Conv forest
R (Rain factor)	51	51	51	51	51
K (erodibility factor)	0,0080	0,0080	0,0100	0,0100	0,0100
LS	8,7E-05	8,7E-05	8,7E-05	8,7E-05	8,7E-05
C1 (crop factor)	0,02	0,02	0,40	0,02	0,10
C2 (management factor)	0,25	0,25	0,25	0,25	0,25
C (crop and management factor)	0,01	0,01	0,10	0,01	0,03
P (Erosion Protection Factor)	1,00	1,00	1,00	1,00	1,00
A (annual soil loss in t/ha)	1,76E-07	1,76E-07	4,40E-06	2,20E-07	1,099E-06
Soil Erosion Class	Very Low (tolerable)	Very Low (tolerable)	Very Low (tolerable)	Very Low (tolerable)	Very Low (tolerable)

The conventional system was assigned the worst score for soil loss. The differentiating factors indicated in the comparison are crop and erosion. The erosion factor is higher in conventional systems because of the soil texture, which shows lower content of clay and slightly higher content of silt.

The most contributing factor for soil loss is the crop factor. The worst scores of the crop factor were attributed to conventional crop systems. The reason for this result is that after harvesting the soil is left uncovered.

To calculate the final results for the Arrangements, the result of the system losses were multiplied by the total area of each system on the arrangement and then summed (Table 39). The arrangement result was normalized by the highest value. For the Conventional Crop system, the same result was used for soya, sorghum and corn.

Table 39: Results for erosion Indicator per Arrange.

	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forestry		
Erosion	1.5E-07	7.9E-07	6.4E-06	6.4E-06	6.4E-06	1.1E-06	8.8E-08	Sum	normalized
Arrangement 1	7.7E-06	0.0E+00	5.5E-05	3.4E-05	4.0E-05	0.0E+00	1.6E-07	1.37E-04	0.21
Arrangement 2	0.0E+00	8.1E-06	2.8E-05	0.0E+00	2.1E-07	3.2E-04	8.5E-07	3.58E-04	0.54
Arrangement 3	0.0E+00	0.0E+00	8.7E-05	1.3E-04	4.0E-05	4.1E-04	8.5E-07	6.62E-04	1.00
Arrangement 4	7.5E-06	1.1E-06	4.8E-05	2.0E-05	3.5E-05	2.6E-08	1.7E-07	1.12E-04	0.17
Arrangement 5	3.7E-06	5.3E-06	3.3E-05	1.3E-07	1.4E-05	1.5E-04	5.1E-07	2.09E-04	0.32

Although the losses of all arrangements were considered very low and acceptable, the results seen from a comparative perspective indicate that the worst performance scores is attributed to conventional Arrangements.

5.4.3.2.Compaction

Soil compaction evaluation is the product of the evaluation of soil texture, number of fields, capacity days, depth of slowly permeable layer, age of grass, land use, and stocking rate. The result shows higher compaction of conventional system

On Table 40, it can be observed that the most contributing factor for that result is the soil organic matter content and land use.

Table 40: Compaction evaluation per system**.**

Inputs	CLFi	CLi	Conv. Crop	Conv. Livestock	Conv. Forest
Soil texture	3	3	3	3	3
Number of field capacity days	3	3	3	3	3
Depth to impermeable / slowly permeable layer	2	2	2	2	2
Soil organic matter content	1	1	3	3	2
Arable land, temporary or permanent grassland	3	3	3	3	3
Land use	2	3	3	1	1
stocking rate (if livestock is considered)	1	1	1	1	1
Value	108	162	486	162	108
Normalized	0.22	0.33	1.00	0.33	0.22

Evaluation of soil compaction under Land Use showed that the high risks are attributed to conventional crop and CLi systems. This happens because these systems allow crop cultivation every year and a 2nd crop after the second year. Other indicator of differences among systems was organic matter content. In this case, livestock and crop under conventional system present low amounts of Organic Matter (0-20 cm).

The systems results were multiplied by the area of each system in each arrangement and then, the values were summed to obtain the arrangement value. These values were normalized by divinding for the toal area of each arrangement (Table 41).

Table 41: Compaction evaluation per Arrange.

	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forestry		
Compaction	0.33	1.00	1.00	1.00	1.00	0.11	0.44	Sum	normalized
Arrangement 1	17.14	-	8.68	5.28	6.33	-	0.78	**38**	**0.45**
Arrangement 2	-	10.32	4.37	-	0.0333	32.42	4.30	**51**	**0.60**
Arrangement 3	-	-	13.73	20.01	6.33	41.03	4.30	**85**	**1.00**
Arrangement 4	16.67	1.35	7.60	3.13	5.51	0.00	0.88	**35**	**0.41**
Arrangement 5	8.33	6.75	5.15	0.02	2.21	15.44	2.59	**41**	**0.47**

The most integrated Arrangements showed better scores compared to conventional Arrangements, which showed the worst. This was expected since the Arrangement 3 is composed of a higher number of conventional crops than the other Arrangements.

5.4.3.3.Soil Organic Carbon

Based on data collected in 2007 and 2014, it was calculated the total amount of carbon per system and per hectare (Table 42). Data on density were collected from SBF and used to support all conventional systems density due to insufficient data.

Table 42: Evaluation of soil organic carbon per system.

			2007		
Alternative	density (kg/dm³)	Volume of Soil in 1 hectare (kg)	Organic Matter in Soil (% / year)	(total Organic Matter) (kg)	Organic Carbon (kg)
CLFi	1,1	2.200.000	1,8%	39.600	22.968
CLi	1,1	2.200.000	1,8%	39.600	22.968
Conv. Crop	1,1	2.200.000	1,5%	33.000	19.140
Conv. Livestock	1,1	2.200.000	1,5%	33.000	19.140
Com. Forest	1,1	2.200.000	1,5%	33.000	19.140
			2014		
Alternative	density (kg/dm³)	Volume of Soil in 1 hectare (kg)	Organic Matter in Soil (% / year)	(total organic Matter) (kg)	Organic Carbon (kg)
CLFi	1,1	2.200.000	3,2%	70.400	40.832
CLi	1,1	2.200.000	3,2%	70.400	40.832
Conv. Crop	1,1	2.200.000	0,5%	11.000	6.380
Conv. Livestock	1,1	2.200.000	0,9%	19.800	11.484
Com. Forest	1,1	2.200.000	2,8%	62.561	36.285

Results indicated that Integrated and Forest systems increase the amount of soil organic matter, while conventional systems show losses due to the intensive use of land, showing an initial value of 1.5% and a decreasing value for 0.5% at the end of the cycle. The results are consistent with the Arrangements results calculated on Table 43.

Table 43: Evaluation of soil organic carbon.

	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forestry		
C.O	17.9	17.9	-12.8	-12.8	-12.8	- 7.7	17.1	ton C/ Arrange	normalized
Arrangement 1	918	-	-111	- 67	-81	-	30	690	0.21
Arrangement 2	-	184	-56	-	- 0	- 2,234	166	- 1,939	0.75
Arrangement 3	-	-	-175	-255	- 81	-2,827	166	- 3,172	1.00
Arrangement 4	893	24	-97	- 40	-70	- 0	34	744	0.20
Arrangement 5	447	121	- 66	-0	-28	-1,064	100	- 491	0.45

For a qualitative analysis of soil quality indicator, those calculations were taken into account. However, for the calculation of carbon balance in the Arrangement there were not sufficient data since the analysis was conducted only in a 0-20 cm layer and density is an assumption. Also, for the quality soil indicator the values are represented by linear values considering the total area of the Arrangement.

Despite all limitations mentioned above, the results indicated (Table 43) that the arrangements 1 and 4 (with a high number of integrated system areas) have potential to incorporate carbon in the soil, while arrangements 2, 3 and 5 show a potential for carbon emission, especially attributed to conventional livestock.

The database used for the carbon analysis of integrated systems is from Santa Brígida Farm, i.e., the same database used by EMBRAPA (2013) research, which was discussed in the present study. However, this analysis conducted by EMBRAPA took place until 2012, and for this study, it was collected data until 2014.

5.4.3.4.Nutrient Balance

Nutrient balance was calculated by each year and by each crop for each system, since the yields changed during the period of 7 years, as already described under assumptions topic. Table 44 presents the total balance of seven years of cultivation by crop and by system. Nitrogen evaluation was done separately (Table 45, Table 46 and Table 47), and evaluated by the average of the years for conventional and integrated systems. This approach was adopted because this nutrient does not remain in the soil, thus is not possible to obtain a balance for a seven-year period.

On CLFi system, the crop value for all indicators was also weighted by the percentage of the crop occupying the system.

Table 44: Nutrient Balance for each crop by 7 years system.

	CLFi	CLi	Conv Crop	Conv Livestock	Conv forest
Crop 1	Soya	Soya	Soya	Brachiaria	Eucalyptus
Does straw remain on field?	yes	yes	yes	not applicable	not applicable
Yield (kg/ha)	2.880	17.400,00	19.200,00	4.279	158.535,0
N-input(kg/ha)	202	1.011,65	1.213,98	8	412,2
P-input (kg/ha)	46	232,45	278,94	0	47,0
K-input (kg/ha)	75	374,91	449,89	35	417,6
N-Balance (kg/ha)				-48	-380
P-Balance (kg/ha)	6	14	7	-9	-135
K-Balance (kg/ha)	5	-45,25	-168,27	-119	-375
Crop 2	Corn	Silage Corn	Corn	None	None
Does straw remain on field?	yes	not applicable	yes	None	None
Yield (kg/ha)	8.400	45.000,00	19.200,00	None	None
N-input(kg/ha)	126	126,00	378,00	0,00	0,00
P-input (kg/ha)	39	39,30	117,89	0,00	0,00
K-input (kg/ha)	81	80,90	242,71	0,00	0,00
N-Balance (kg/ha)					
P-Balance (kg/ha)	-19	-24	-16	None	None
K-Balance (kg/ha)	28,6	-171	83,39	None	None
Crop 3	Eucalyptus	Corn	Sorghum	None	None
Does straw remain on field?	not applicable	yes	yes	None	None
Yield (kg/ha)	116.992	35.400,00	3.000,00	116.992	35.400,00
N-input(kg/ha)	431	504,00	15,00	431	504,00
P-input (kg/ha)	52	157,18	32,75	52	157,18
K-input (kg/ha)	450	323,62	37,34	450	323,62
N-Balance (kg/ha)	-154	15,48	-36,00	-154	15,48
P-Balance (kg/ha)	-217	-28,29	9	-217	-28,29
K-Balance (kg/ha)	-428	103,31	7	-428	103,31
Crop 4	None	Sorghum	None	None	None
Does straw remain on field?	None	yes	None	None	None
Yield (kg/ha)	None	3.600,00	None	None	None
N-input(kg/ha)	0,00	126,00	0,00	0,00	0,00
P-input (kg/ha)	0,00	39,30	0,00	0,00	0,00
K-input (kg/ha)	0,00	80,90	0,00	0,00	0,00
N-Balance (kg/ha)	None	64,80	None	None	None
P-Balance (kg/ha)	None	10,50	None	None	None
K-Balance (kg/ha)	None	53,90	None	None	None

Table 45: Nitrogen Balance for conventional crop.

Conventional Crop System	Rain Season	Between Seasons	Dry Season		
	N balance (kg) Summer Crop	N balance (kg) 2^{nd} Crop	Dry Season	N balance (kg) average	Evaluation
Year 1	35	Uncovered Land	Uncovered Land	35	1,0000
Year 2	21	Uncovered Land	Uncovered Land	21	1,0000
Year 3	11	56	Uncovered Land	33,28	1,0000
Year 4	2	Uncovered Land	Uncovered Land	2	1,0000
Year 5	11	-36	Uncovered Land	- 12,54	0,8747
Year 6	11	56	Uncovered Land	33,28	1,0000
Year 7	11	Uncovered Land	Uncovered Land	11	1,0000
Total /Average:				17,63	0,98209

Table 46: Nitrogen Balance for crops on CLFi.

CLFi	N balance (kg) Summer Crop	N balance (kg) 2^{nd} Crop	N balance (kg) In spaced lines (Full Year)	aver N balance (kg) age	N-balance-evaluation
Year 1	35,29	Covered Land with Forrage		35,29	0,83
Year 2	10,08	Pasture		10,08	0,88
Year 3	Pasture	Pasture			
Year 4	Pasture	Pasture			
Year 5	Pasture	Pasture			
Year 6	Pasture	Pasture			
Year 7	Pasture	Pasture	-154	- 153,89	1,00
Total /Average:				- 36,17	0,90

Table 47: Nitrogen Balance for on CLi.

CLi	N balance (kg) Summer Crop	N balance (kg) 2^{nd} Crop	Dry season	N balance (kg) average	N-balance-evaluation
Year 1	35,3	Covered Land with Forage		35,3	1,0000
Year 2	21,4	-45,0	Pasture for Livestock - 2 months	- 11,82	0,8819
Year 3	-6,5	65	Pasture for Livestock - 2 months	29,17	1,0000
Year 4	-14,8	Pasture for Livestock - 4 months		- 14,8	0,8524
Year 5	-23,9	26,6	Pasture for Livestock - 2 months	1,39	1,0000
Year 6	-23,9	26,6	Pasture for Livestock - 2 months	1,39	1,0000
Year 7	-23,0	Pasture for Livestock - 4 months		- 23,04	0,7696
Total /Avarage:				2,52	0,92912

All data calculated on the tables above were used as a basis to calculate each nutrient balance. Therefore the data is discussed according to the following nutrient balance indicator

A) Nitrogen Balance

CLFi system presented positive nitrogen balance in all annual crops of the years analyzed. Regarding the forest component, approximately 35% of the system area, presents nitrogen loss. Therefore, to this system, result of the evaluation was weighted according to the area of crops and forest. CLi showed some years of nitrogen deficit in the soil, and some years of nitrogen surplus. A nitrogen loss was also observed in Conventional Livestock, which was expected due to its poor management, limited to just one application of fertilizers. Thus, the balance calculation was done by estimated productivity of brachiaria, as described under Methodology section. Conventional forest presents high levels of nitrogen loss. Nitrogen fixation by soya was estimated in 180 kg per hectare, according to Caballero (2013).

Table 48: Nitrogen balance weighted to compound the Arrangements.

	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forestry		
Nitrogenio evaluation	0,91	0,93	0,98	0,98	0,98	0,52	0,07	Sum of evaluated indicator	Evaluation normalized by Arrange area
Arrangement 1	46.69	-	8.52	5.19	6.22	-	0.12	**66.74**	**0.91**
Arrangement 2	-	9.59	4.30	-	0.03	151.33	0.64	**165.89**	**0.52**
Arrangement 3	-	-	13.48	19.65	6.22	191.56	0.64	**231.54**	**0.55**
Arrangement 4	45.41	1.25	7.46	3.07	5.41	0.01	0.13	**62.75**	**0.90**
Arrangement 5	22.71	6.27	5.06	0.02	2.17	72.10	0.38	**108.71**	**0.59**

It can be observed by Table 48 that nitrogen balance after normalization attributes better performance scores to most integrated arrangements (alternatives 4 and 1) and a the worst to conventional arrangements (alternative 3). This result was expected, since it is almost the opposite behavior to the nitrogen surplus indicator.

B) Phosphorus Balance

Phosphorus indicator was evaluated by each crop during the 7-year analysis. The value is summed, representing the total amount of P balance of each system. To calculate it for each arrangement, the value of each value was multiplied by the area of this system in the arrangement than divided by total area of arrangement, followed by the normalization of the indicator (Table 49). Eucalyptus culture is the crop presenting higher phosphorus depletion followed by corn (silage and grain) and conventional brachiaria.

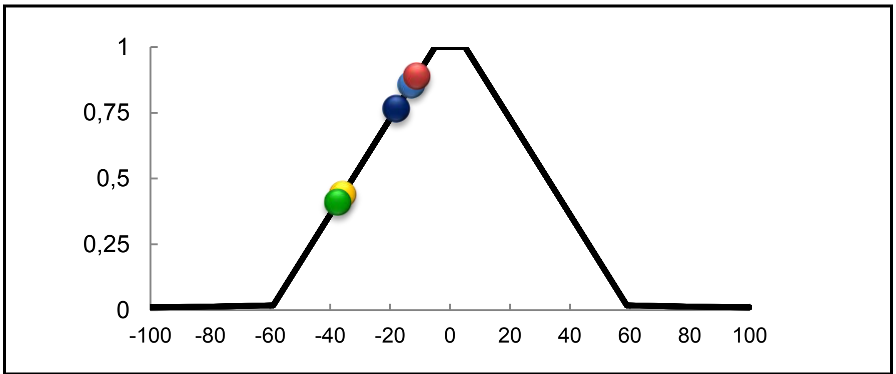
Table 49: Phosphorus balance weighted to compound the Arrangements.

	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forestry			
Nutrient Balance P	- 47	-27	7	- 16	9	- 9	-135	Sum	Loss Per Arrangement	Evaluation
Arrangement 1	-2,421	-	64	- 86	55	-	-239	- 2,626	-35.7487	0.440933
Arrangement 2	-	-284	32	-	0	- 2,497	-1,311	- 4,059	-12.8384	0.857484
Arrangement 3	-	-	101	- 325	55	- 3,160	-1,311	- 4,640	-11.0735	0.889573
Arrangement 4	-2,354	- 37	56	- 51	48	- 0	- 268	-2,607	-37.4578	0.409858
Arrangement 5	-1,177	- 186	38	- 0	19	- 1,190	-790	-3,285	-17.8568	0.76624

The arrangements present similars total amount of phosphorus depletion. In CLFi system, most depletion is caused by eucalyptus and, on CLi, it is caused by corn, thus the alternatives 1 and 4 are influenced by these depletions. In the Arrangement 3, depletion is caused by brachiaria (livestock) as it demands large areas, and from eucalyptus. Therefore, in consolidated Arrangements, the total depletion occurs in a similar way.

Although the total phosphorus loss was similar, when the indicator evaluation was done based on the area of the Arrangement, it was observed a loss in the conventional Arrangement distributed over its area, resulting in a better indicator. On Figure 42, the integrated Arrangements were scored a worse performance (closer to 0) while the conventional was scored a better performance (closer to 1).

Figure 42: Results -Phosphorus Balance for Arranges



Alternatives:	Total P-balance (kg/ ha Arrange)	N-evaluation
1	-35.75	0.44
2	-12.84	0.86
3	-11.07	0.89
4	-37.46	0.41
5	-17.86	0.77

C) Potassium Balance

Potassium indicator was evaluated by each crop during the 7-years analysis. The value was summed, representing the total amount of K balance of each system. To calculate it for the Arrangement, each system value was multiplied by the area of this particular system of the Arrangement, and the values were summed to estimate the total loss of this element for each Arrangement, followed by the normalization by the area of Arrangement and by the indicator evaluation (Table 50). The high loss rates of potassium are attributed to eucalyptus, soya, conventional livestock and corn silage crops.

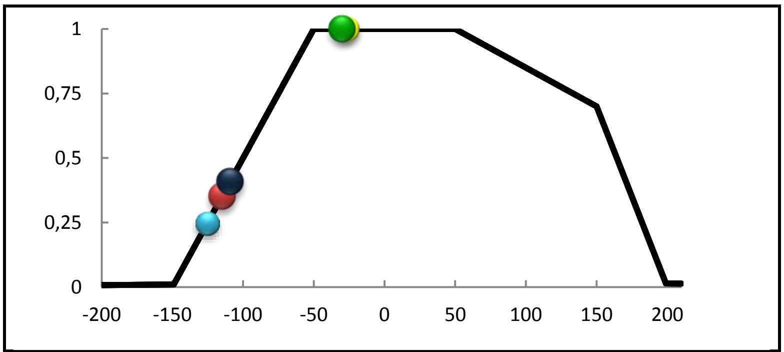
Table 50: Potassium balance weighted to compound the Arrangements.

	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forestry			
Nutrient Balance K	-6	-59	-168	83	7	-119	-375	Sum	Per Arrangement	Evaluation
Arrangement 1	-285	0	-1460	440	46	0	-662	-1,921	- 26	1.000
Arrangement 2	0	-611	-736	0	0	-34654	-3632	-39,633	- 125	0.246
Arrangement 3	0	0	-2310	1668	46	-43864	-3632	-48,092	- 115	0.352
Arrangement 4	-278	-80	-1278	261	40	-3	-743	-2,080	- 30	1.000
Arrangement 5	-139	-399	-867	2	16	-16509	-2188	-20,085	-109.18	0.4082

The Arrangements present discrepancies in the total amount of potassium depletion. In Arrangement 4 the depletion is approximately 2 thousand kilos while in Arrangement 3 it is approximately 48 thousand kilos, when achieving the same established functional unit. The depletion difference between the Arrangements 4 and 3 is 46 thousand kilos, but this value is distributed based on the difference between the areas of these Arrangements, 350 hectars.

Figure 43 shows that the alternative 1 has the best performance score (closer to 1) while the alternative 2 was rated the worst (closer to 0) in terms of potassium balance. The Arrangement 2 combines the depletion of conventional soya and eucalyptus with livestock in smaller area than Arrangement 3, producing the worst impact. The conventional Arrangement (alternative 3) shows high depletion due to livestock (larger area needed and high depletion factor), followed by eucalyptus and soya. In this Arrangement, the conventional corn crop promoted the recovery of K balance, rating it as the second worse performance.

Figure 43: Results -Potassium Balance for Arranges

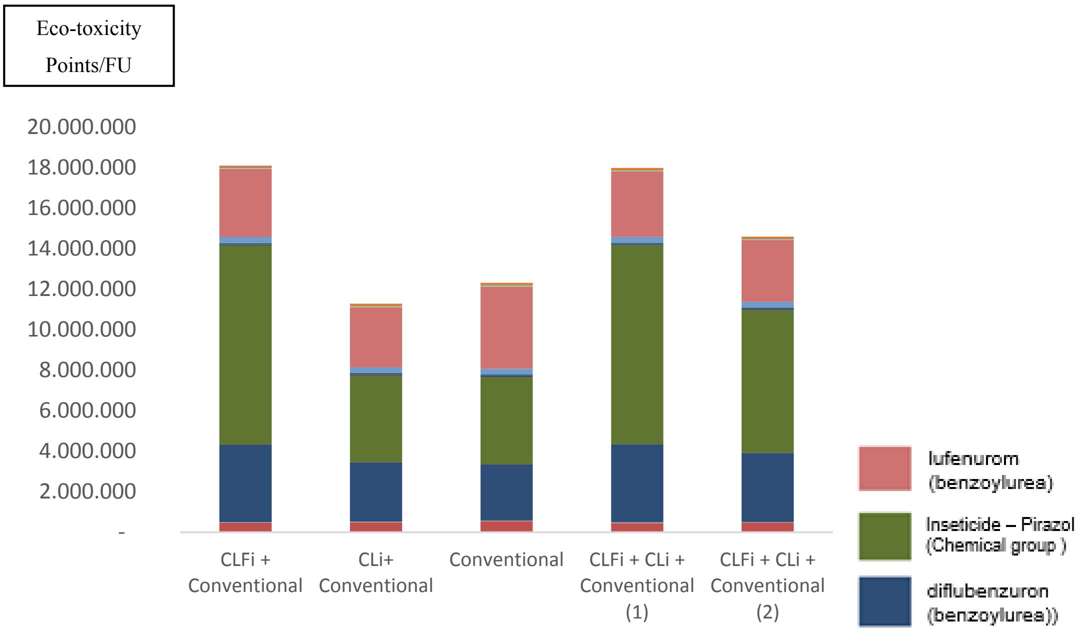


Alternatives:	Total K-balance (kg/ ha Arrange)	N-evaluation
1	-26.14	1.00
2	-125.36	0.25
3	-114.77	0.35
4	-29.89	1.00
5	-109.18	0.41

5.4.3.5.Eco-toxicity

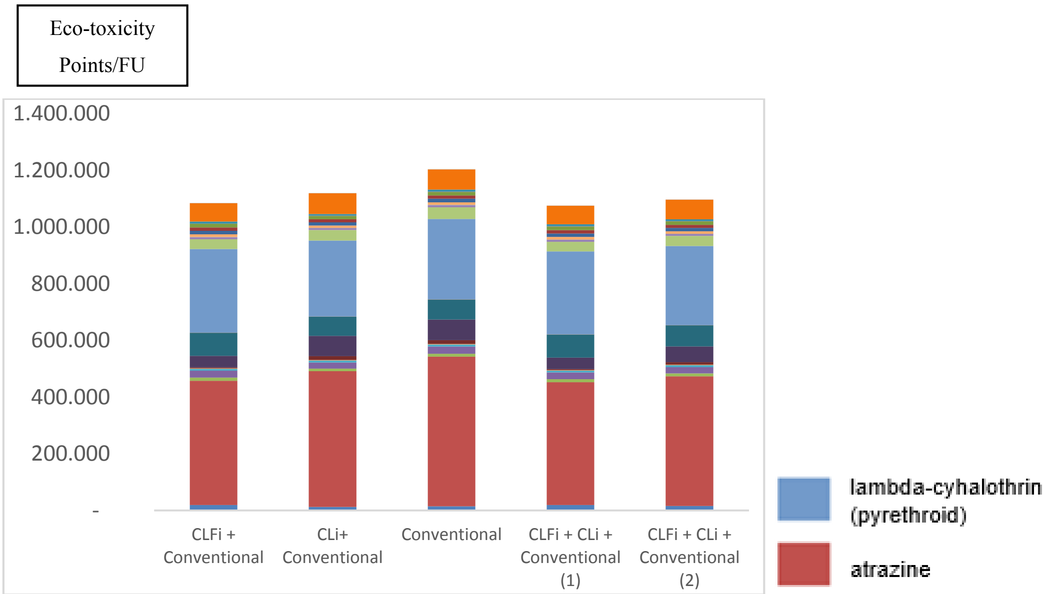
Figure 44 highest potential for eco-toxicity is represented by insecticides for ants from pirazol chemicalgroup (higly applied on eucalyptus), followed by diflubenzuron (used on soya and sorghum), and lufenuron (used on corn) .The highest eco-toxicity potential is found in the Arrangement 4, which is a highly integrated system. This happens because in integrated systems the impact of eucalyptus production is calculated as a whole, and just one third of the production is used to supply the needs of the functional unit, and the rest is stored. It also happens due to cattle feed, which needs sorghum and corn in its line of production.

Figure 44: Eco-toxicity result for the Arranges.



If the three products above had not been considered, the group of crop protection presenting high impacts would be lambda-cyhalothrin from pyrethroid chemical group (used on soya) and atrazine (used on corn); therefore the Arrangement 3 would have shown the highest impact due to the high application levels in most of its areas. (Figure 45).

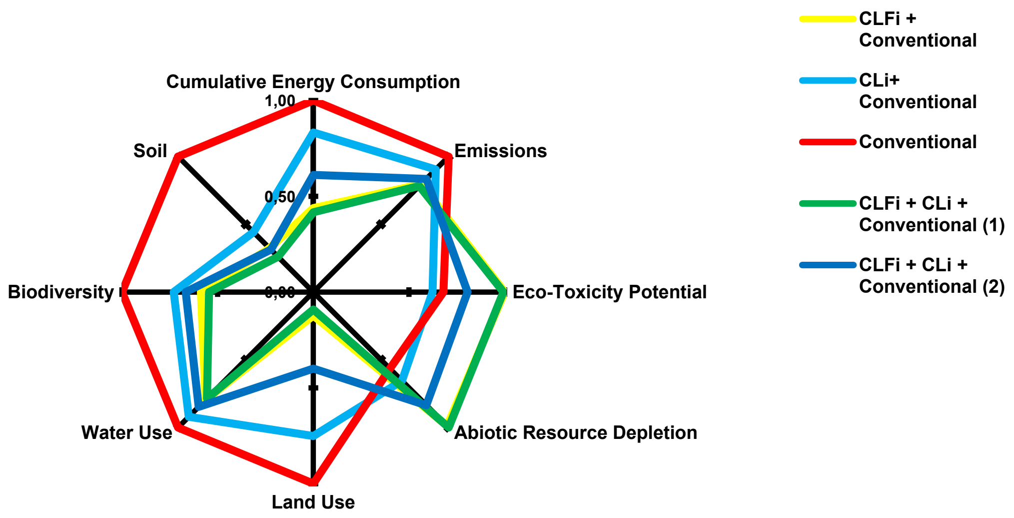
Figure 45: Eco-toxicity result for the Arranges – Secondly group of most impactive crop protection products.



5.4.4.Consolidated Environmental Fingerprint

By consolidating the Ag-Part evaluation to the Eco-efficiency previous analysis, the environmental fingerprint (Figure 46) shows that the worst performance on Eco-toxicity Potential and Abiotic Resource Depletion was found in Alternative 4 (highly integrated Arrangement). For other impact categories the results indicate that the alternative 3 (conventional Arrangement) showed the worst performance.

Figure 46: AgBalance™ Environmental Fingerprint



Soil, Biodiversity and Eco-toxicity categories were only measured at the farm level, while the other categories were measured in both, at the pre-chain and farm level.

5.5. Social impacts Categories - AgBalance™

Social impacts for AgBalance™ take in account the pre-chain and farm level, consolidating it in a unique pillar. The methodology considers a weight of 30% for the pre-chain and 70% for the Ag Part. However, in this study the equivalent weights to pre-chain and to farm level were considered to be more connected to LC thinking. The weighting factor for society was based on social perception research.

5.5.1.Pre-Chain

Indicators that are not relevant or on which there are not sufficient data were not evaluated in this study and the relevance was distributed following the logic of societal perception (Table 51).

Table 51: Weighting Factor for Social Categories – Pre Chain.

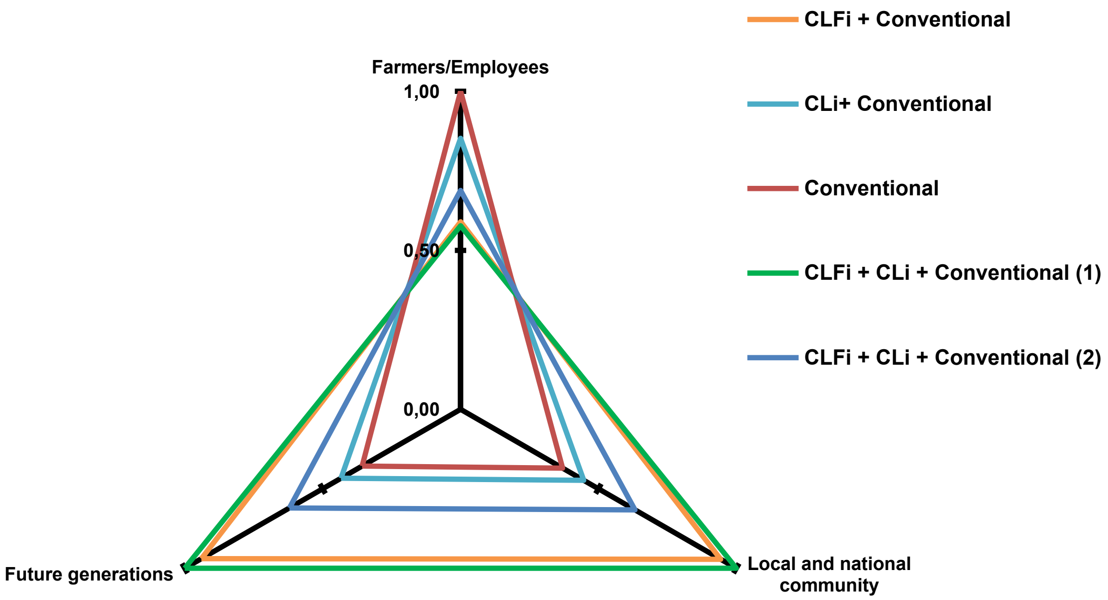
Social Categories and Indicators	Weighting Factor
Employees	36%
Working Accidents	18%
Fatal Working Accidents	24%
Occupational Diseases	18%
Toxicity Potential	29%
Wages and Salaries	12%
Local and national community	36%
Employment	83%
Family Support	17%
Future generations	29%
Capital Investments	50%
Social Security	50%

The most concerning indicators of social relevance are toxicity potential and employment. For the pre-chain, the conventional arrangement is the worst as far as the employee's category is concerned. This happens due to the fertilizers pre-chain and the number of accidents and toxicity despite the best wages associated with the input demands.

For working accidents, fatal working accidents, occupational disease and toxicity potential indicators, higher values were attributed the worst score performance under the social pillar. Indicators of wages and salary, employment, family support, capital investments and social security were rated as best performance (closer to 1) under the social pillar.

At the pre-chain social fingerprint (Figure 47) the mostly integrated arrangement (alternative 4) showed the worst score for Future Generations and Local and National Community, while the conventional the arrangement (alternative 3) was rated as best. In conventional systems more inputs are required, hence its higher positive effects on jobs, capital investments, trainees, and wages, generated in the industrial chain of production, even though the negative indicators such as human toxicity, occupational diseases and accidents are higher in this Arrangement.

Figure 47: Social Fingerprint for pre chain.



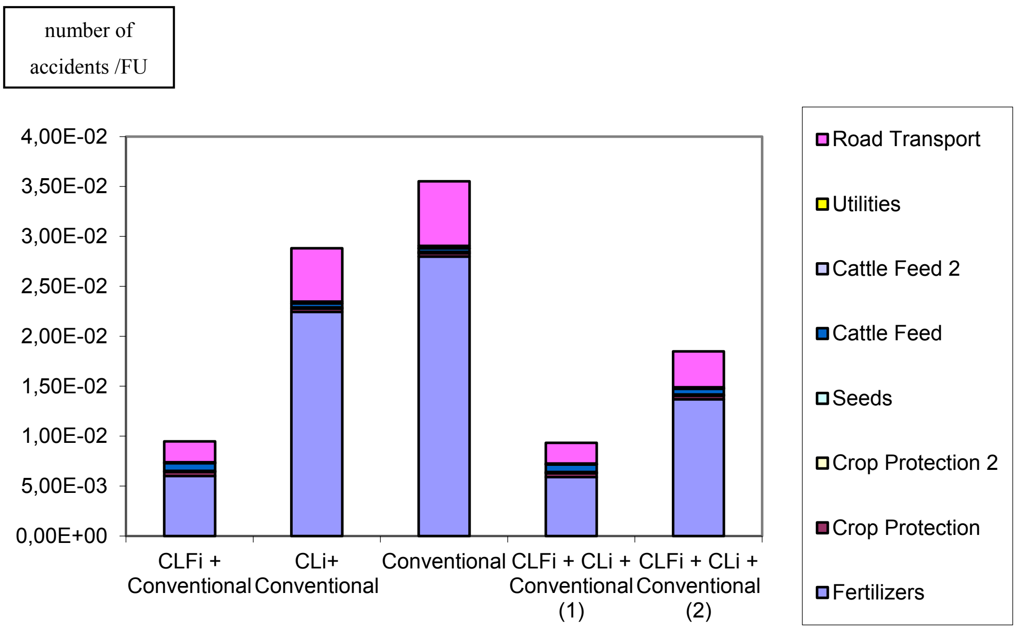
The fertilizers pre-chain, specifically regarding CaO and MgO life cycle and road transportation for 27-ton vehicles are the most contributing impacts to positive indicators, associated to salaries and employee benefits, and for negative indicators, associated to accidents, diseases, toxicity, etc. These are not only due to the ife cycle of these fertilizers and road transportation, but also they result from high input demands for a 7-year cycle. The indicators and categories can be checked below.

Human Toxicity potential has already been described under Eco-Efficiency category, and so it is not being reproduced in this section, even though it is considered under this pillar in the AgBalance™.

5.5.1.1.Employees Category

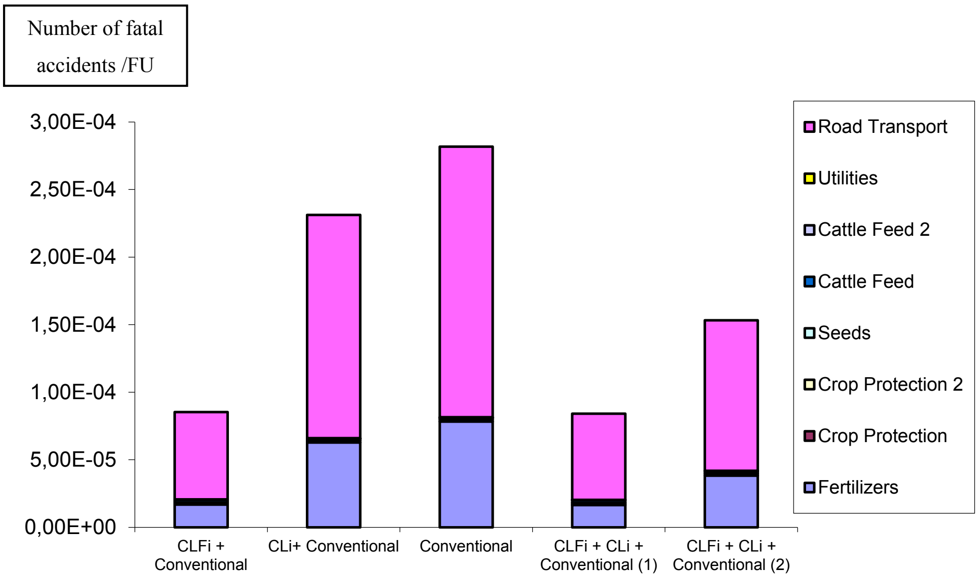
Results concerning working accidents (non-fatal) (Figure 48) indicate that conventional Arrangements present the highest impact scores. This is attributed to the fertilizers pre-chain, mainly to CaO and MgO compound production, and to road transportation operating with 27-ton vehicles carrying limestone and gypsum.

Figure 48: Non-Fatal Working Accidents along 7 years



When fatal working accidents are taken into account, the proportion observed between the two major impact contributors (27 t road transport and fertilizers compounds) change (Figure 49). Road transportation is the contributor producing the highest impacts to all alternatives, followed by fertilizers compounds (also CaO and MgO).

Figure 49: Fatal Working Accidents along 7 years



Under the Occupational Diseases category (Figure 50), the two main impact contributors are fertilizers compounds (CaO and MgO) followed by heavy vehicle transportation (27ton truck). The worst performance is attributed to alternative 3, conventional arrangements, due to its high input demand. In alternative 4, showing less impact, the cattle feed pre-chain is slightly lower than road transportation.

Figure 50: Occupational Disease along 7 years.

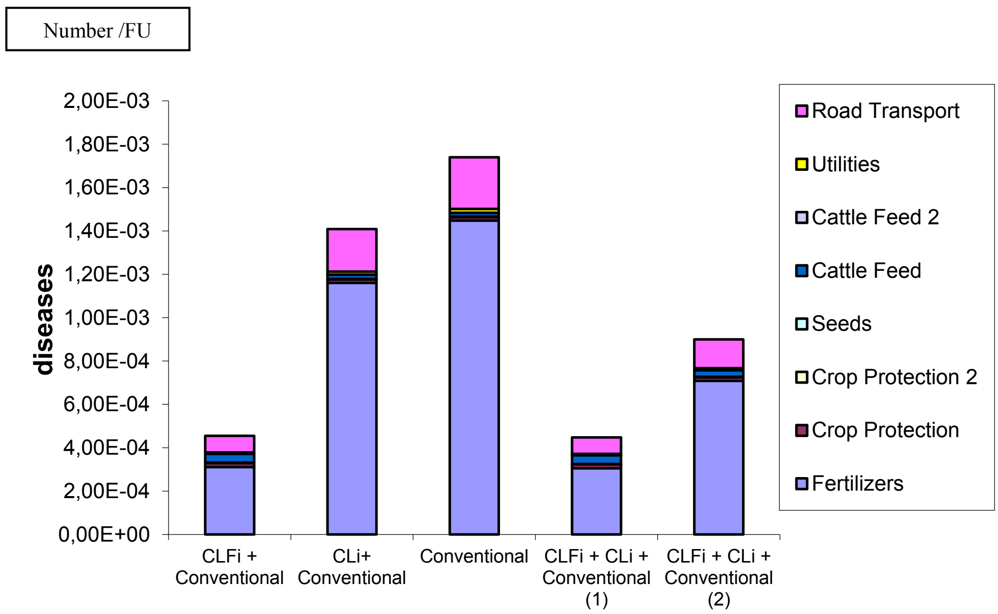
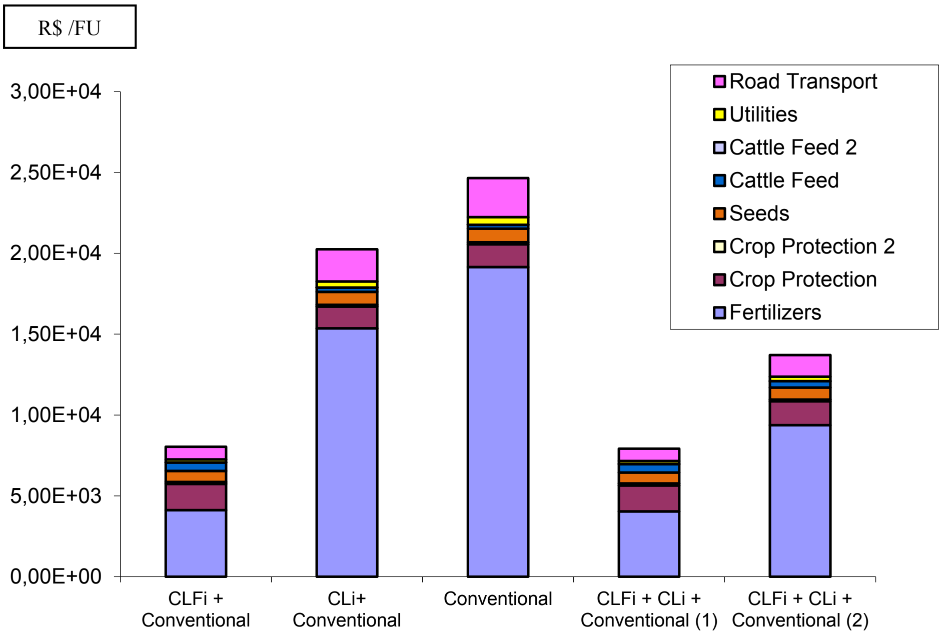


Figure 51 shows that the highest impact on wages and salary comes from the arrangement showing the best performance scores (arrangement 3). Higher input demands stimulate the production of fertilizer compounds (Cao and MgO) at the industrial level, generating more jobs and, consequently, higher wages and salaries. The second most impacting is road transport for 27-ton vehicles (arrangement 3). If alternative 4 were considered, the second better performance would be attributed to the Crop Protection pre-chain, since it presents higher input demands mainly for sorghum and corn used in cattle supplementary feed.

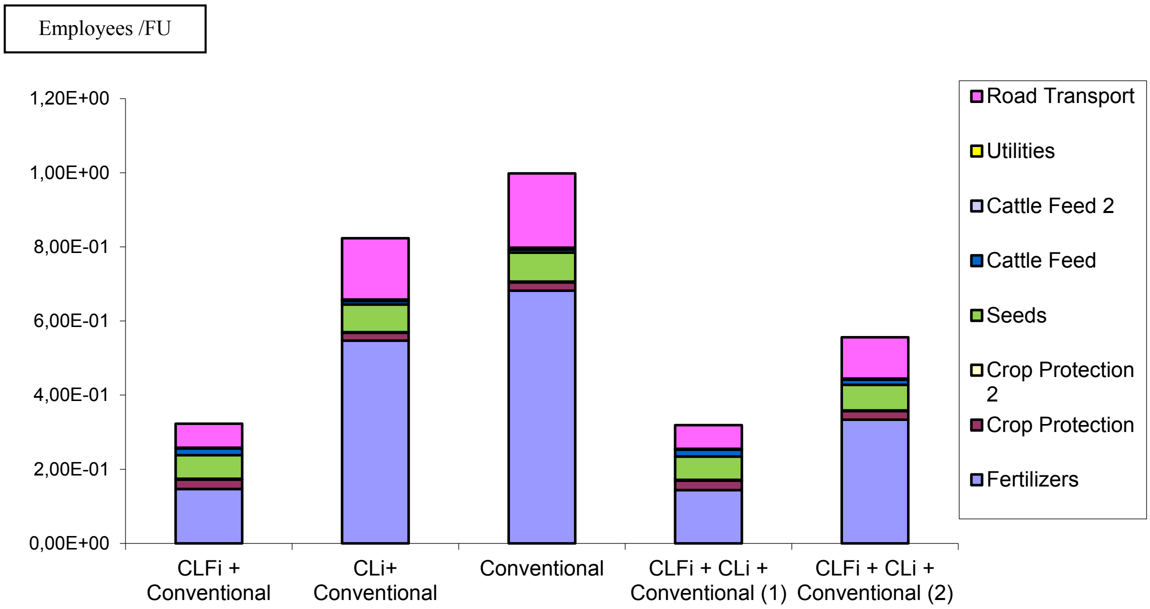
Figure 51: Wages and Salary (R$) along 7 years.



5.5.1.2.Local and National Community Category

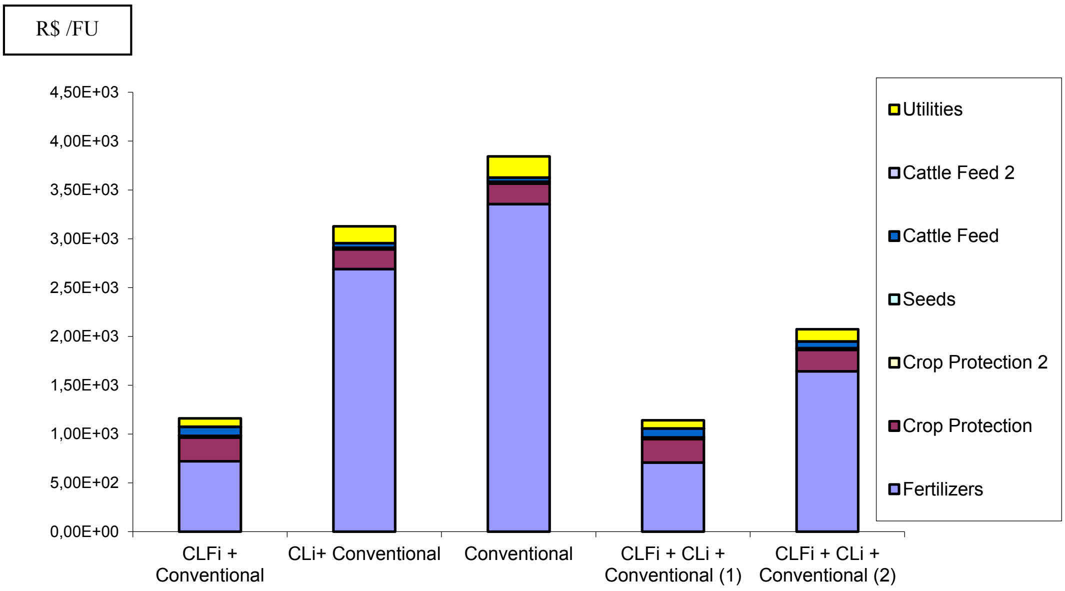
Employees, as shown on Figure 52, are highly rated in conventional arrangements due to higher inputs, such as fertilizer compounds (CaO and MgO). The best impact scores were attributed to arrangement 3, and the worst to arrangement 1. In arrangement 1, the second most important contributor is seed production, while in arrangement 3 is 27- ton vehicle transportation.

Figure 52: Employment along 7 years.



On the Figure 53, the best results refer to the conventional Arrangement (alternative 3). Major contributors are fertilizer compounds (CaO and MgO), followed by crop protection. By comparing this result with employment results, it can be concluded that the crop protection and utilities industry invest in family support while the same does not apply to the 27-ton vehicle transportation category.

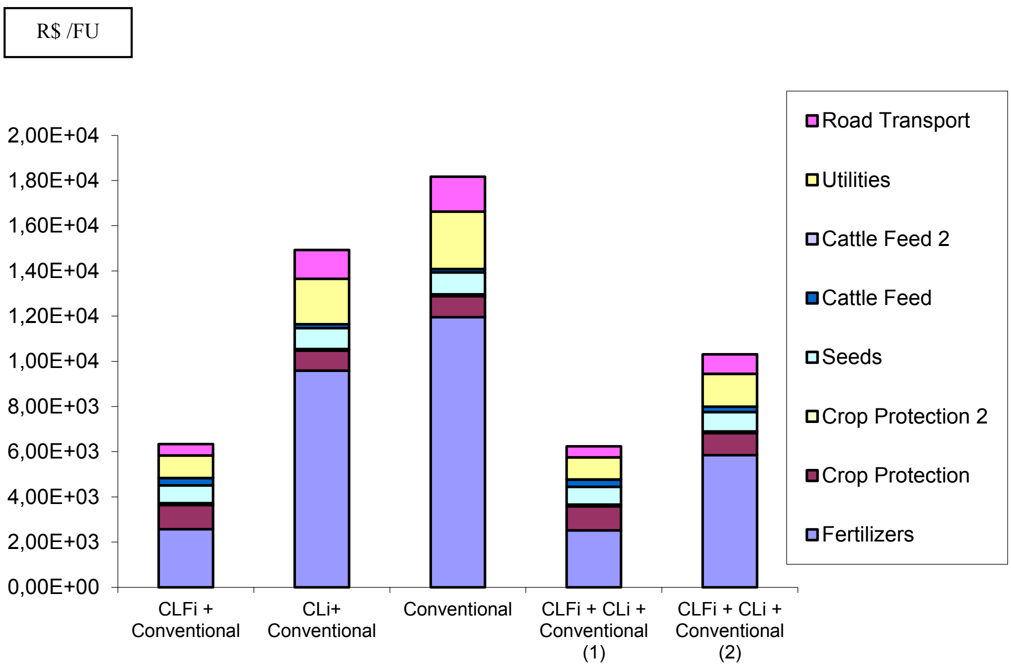
Figure 53: Family Support along 7 years.



5.5.1.3.Future Generation Category

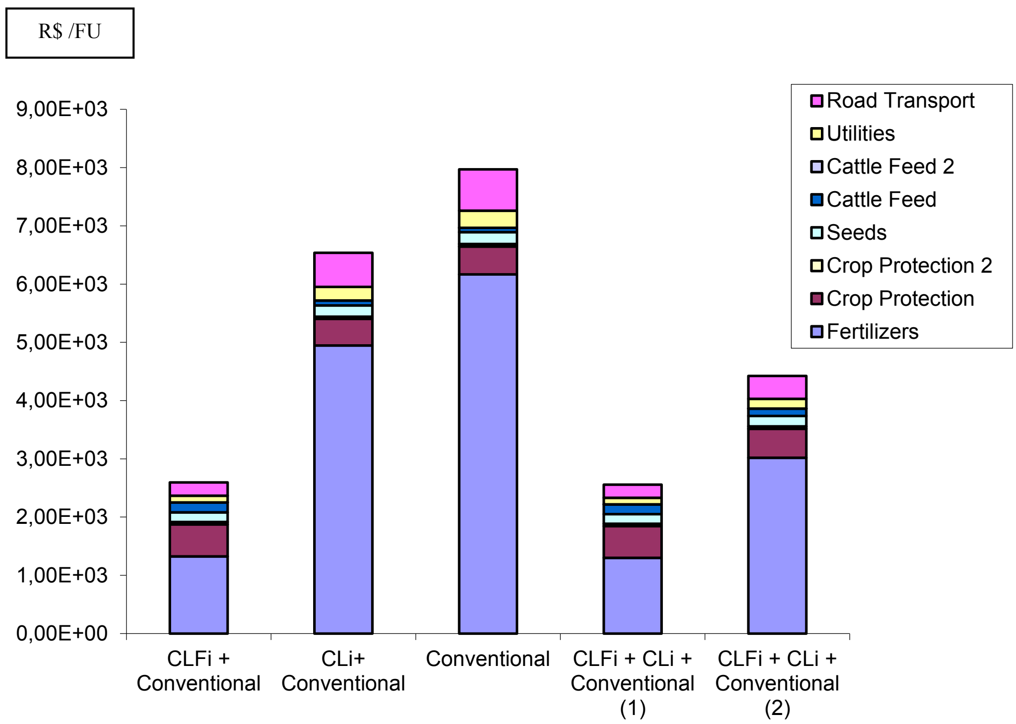
The Future Generation category shows best results for conventional (Figure 54), which is also due to higher inputs. In a comparative analysis with employment, the sectors under Future Generation Category show higher capital investments on crop protection and utilities industry.

Figure 54: Capital investments along 7 years.



Social Security had better results in conventional systems (Figure 55) due to their higher inputs. The major contributor is fertilizer compounds (mainly CaO and MgO). The second significant contributor depends on the alternative. In alternative 3, it is the 27-ton vehicle transportation road that was scored the best performance, and in alternatives 1 and 4 the best performance was attributed to cattle feed production.

Figure 55: Social Security along 7 years.



5.5.2.Agricultural module

The follow indicators, as described in Table 52 were evaluated and weighted according to the social perception research for agricultural context. The original weighting factor was distributed according to its proportion to categories and indicators evaluated at the Ag Part. The choice of the indicator to be evaluated was determined by the availability of data.

Table 52: Weighting Factor for Social Categories – Ag Part.

Farmers/Employees	46%
Wages	62%
Professional Training	38%
Local/Nat. Community	32%
Employment	48%
Qualified Employment	26%
Family Support	26%
Future Generations	22%
Trainees	50 %
R&D	50%

All indicators analyzed follow the logic of highest value/best performance, although the fingerprint on AgBalance™ methodology shows the highest impact score (1.0) as the worst alternative.

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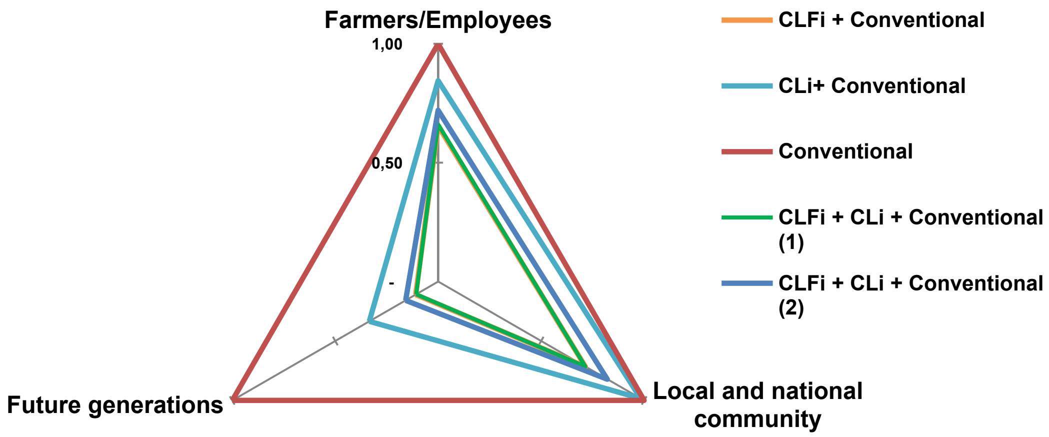
Figure 56: Social Fingerprint of Ag-Part



As can seen on Figure 56, at the farm level, the best performance is attributed to the most integrated arrangements in all categories evaluated, and the worst is attributed to conventional arrangements. The most significant differences were observed on the Future Generation category.

All social data were estimated for the time coverage of 7 years, considering 1 year with 48 working weeks due to vacations. The Integrated Systems data are concerning Santa

Brigida Farm, and the Conventional Systems data were obtained from consultants providing services to conventional farms in the region. Data were calculated per hectare than per arrangement. Wages and employees results were normalized by person equivalent. The assumption for that is that 1 person is equivalent to 14,7854 hours.

5.5.2.1.Farmer/Employees category

5.5.2.1.1.Wages

Wages indicator at farming module attributed the best performance score to arrangement 3, which is comprised of conventional systems. This performance is coherent since the area needed for this arrangement achieved the established functional unit. Usually, when a larger area is cultivated, a larger number of employees are needed. However, in integrated systems, employees work intensively during the whole year (not only on summer season) in different kinds of crops, which increases their gains.

Wages differences between the arrangement 3 and arrangement 4 (mostly comprised of integrated systems) are not high considering the extension of the areas needed by these arrangements, as can be observed on Table 53.

Table 53: Results for wages weighted per system on the Arrangements (R$).

	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forestry	
Wages per system (R$)	3,643	3,412	1,012	460	122	445	1,433	Total
Arrangement 1	187,263	-	8,783	2,427	774	-	2,529	**201,776**
Arrangement 2	-	35,216	4,427	-	4	129,775	13,877	**183,299**
Arrangement 3	-	-	13,892	9,193	774	164,268	13,877	**202,004**
Arrangement 4	182,127	4,590	7,690	1,438	673	11	2,840	**199,368**
Arrangement 5	91,063	23,033	5,217	9	270	61,826	8,359	**189,778**

In other words, wages per hectare in alternative 3 would account for approximately R$ 480.00 while R$ 2,800.00 in alternative 4.

5.5.2.1.2.Professional training

Results for professional training is available on Table 54.

Table 54: Hours of professional training per Arrangement.

	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forestry	
Professional Training (hours)	29	29	0,50	0,50	0,50	0,50	0,50	total
Arrangement 1	1,483	-	4	3	3	-	1	**1,494**
Arrangement 2	-	298	2	-	0	146	5	**451**
Arrangement 3	-	-	7	10	3	185	5	**210**
Arrangement 4	1,442	39	4	2	3	0	1	**1,490**
Arrangement 5	721	195	3	0	1	69	3	**992**

In order to keep the Integrated Systems operating intensively during the whole year in a variety of crops, as discussed above, it is a natural consequence that training hours are highly demanded. On the other hand, conventional systems usually do not offer any training, as is the case of the arrangements observed in the city of Ipameri. Therefore, the value of half an hour was attributed to Professional Training in conventional systems in this study not to make void the indicator model in the method. Consequently better performance is achieved by the most integrated arrangement.

5.5.2.2.Local and National Community Category

5.5.2.2.1.Employment

Results attributed the best performance score to conventional arrangements (Table 55). The land area for arrangement 3 is six times larger than the arrangement 4 but operates with just 20% more working hours (employees). This non-linear relation occurs due to the integrated system, which require a larger number of employees per area unit than the conventional systems and continues operating during the dry seasons as well.

Table 55: Results for employees per Arrangement.

	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forestry		
Employees	503	477	132	60	16	79	189	Person-eq	h
Arrangement 1	25,871	-	1,141	314	99	-	334	1.88	27,760
Arrangement 2	-	4,921	575	-	1	23,036	1,831	2.05	30,364
Arrangement 3	-	-	1,805	1,191	99	29,159	1,831	2.31	34,085
Arrangement 4	25,162	641	999	186	86	2	375	1.86	27,452
Arrangement 5	12,581	3,219	678	1	35	10,975	1,103	1.93	28,591

The arrangement 3 also shows best indicators due to its large areas for livestock activities. Similarly, to the environmental impacts, the social impacts were calculated in linear equations. This means that if one working hour is needed per 1 ha, the number of working hours will be needed 2 working hours per 2 hectares. In the arrangement 3 the area needed for livestock exceeds 350 hectares.

5.5.2.2.2.Qualified Employement

Santa Brigida Farm has a higher qualified staff demanded by the complexity of the integrated systems. Qualified employees are considered to have college degree. The owner of a farm (integrated or conventional) is considered to have a qualified level.

Calculations of these indicators and the indicator per system are represented on Table 56.

Table 56: Results for qualified employment per Arrangement.

Qualified	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forestry		
Qualified employement (working hours per system)	**98**	**75**	**17**	**8**	**2**	**5**	**27**	pessoa eq	h totais
Arrangement 1	5,058	-	150	41	12	-	47	**0.359**	5,308
Arrangement 2	-	771	76	-	0	1,470	260	**0.174**	2,578
Arrangement 3	-	-	237	154	12	1,861	260	**0.171**	2,525
Arrangement 4	4,919	101	131	24	11	0	53	**0.354**	5,239
Arrangement 5	2,460	504	89	0	4	701	157	**0.265**	3,915

The integrated systems bring the alternativeAlternative 4 to the best performed indicator. In the city of Ipameri, a farmer usually has a college degree, but not the employees. As far as SBF, its current staff is composed of the operational manager, who has a Master degree; the general manager, who has a thecnical college degree; the assistant officer, who as a college degree in Administration degree; the consultants for crop who also hold a Master degree; in the areas of livestock (collee degree) and forest (college degree). The ower of the farm has a Master degree.

5.5.2.2.3.Family Support

Based on SBF, arrangements with a higher percentage of integrated systems also show high values for family support (Table 57).

Table 57: Monetary value of family support per hectare per system and for Arrangements.

	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forestry	
family support	507,136	507,136	44,281	19,681	4,920	67,640	68,882	
Arrangement 1	354,873	-	5,231	1,415	424	-	1,655	363,597
Arrangement 2	-	16,554	613	-	1	62,417	2,110	81,694
Arrangement 3	-	-	1,450	940	74	59,610	1,592	63,666
Arrangement 4	364,369	9,802	4,834	885	390	23	1,962	382,265
Arrangement 5	68,919	18,608	1,241	2	59	51,105	2,184	142,118

In Ipameri's city, each conventional system mapped provides lunch for all employees and house for at least one employee, and transportation fo all others. SBF provides 5 houses to 5 families, as well as lunch and transportation for those not living in the farm.

5.5.2.3.Future Generation Category

5.5.2.3.1.Trainees

As conventional systems do not provide trainee and intern training programs, it was attributed a small number (0.0001 person equivalent) for this category due to model limitation. Thus, the results for the Trainee Category (Table 58) shows a best score to the most integrated Arrangements, as expected.

Table 58: Trainees per hectare per system and for Arrangements.

	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forestry	
Trainees	**4.17E-03**	**4.17E-03**	**1.00E-04**	**1.00E-04**	**1.00E-04**	**1.00E-04**	**1.00E-04**	
Arrangement 1	2.14E-01	0.00E+00	8.68E-04	5.28E-04	6.33E-04	0.00E+00	1.76E-04	**0.22**
Arrangement 2	0.00E+00	4.30E-02	4.37E-04	0.00E+00	3.33E-06	2.92E-02	9.68E-04	**0.07**
Arrangement 3	0.00E+00	0.00E+00	1.37E-03	2.00E-03	6.33E-04	3.69E-02	9.68E-04	**0.04**
Arrangement 4	2.09E-01	5.61E-03	7.60E-04	3.13E-04	5.51E-04	2.37E-06	1.98E-04	**0.22**
Arrangement 1	1.04E-01	2.82E-02	5.15E-04	2.05E-06	2.21E-04	1.39E-02	5.83E-04	**0.15**

The Integrated Arrangements are attractive for interns and trainees because of the complexity of this kind of system resulting from the combination of agriculture in consortium, succession and rotation, in addition to livestock production. These systems represent a great opportunity not only for hands-on training but also for formal training in the new technologies available for the development of sustainable alternatives for food production. Conventional systems, on the other hand, usually do not offer any training, at least in this region studied.

5.5.2.3.2.Research & Development (R&D)

For the evaluation of Research and Development, the indicator used for Conventional Systems was a low number – R$ 1.00 – due to model limitations. Thus, integrated Arrangements present the highest values because SBF is a TRU. Results are shown on Table 59.

Table 59: Trainees per hectare of system.

	CLFi	CLi	Conv. Soya	Conv. Corn	Conv. Sorghum	Conv. Livestock	Conv. Forestry	
R&D	**4.84E+03**	**4.84E+03**	**1.00E+00**	**1.00E+00**	**1.00E+00**	**1.00E+00**	**1.00E+00**	Sum
Arrangement 1	2.49E+05	0.00E+00	8.68E+00	5.28E+00	6.33E+00	0.00E+00	1.76E+00	**2.49E+05**
Arrangement 2	0.00E+00	5.00E+04	4.37E+00	0.00E+00	3.33E-02	2.92E+02	9.68E+00	**5.03E+04**
Arrangement 3	0.00E+00	0.00E+00	1.37E+01	2.00E+01	6.33E+00	3.69E+02	9.68E+00	**4.19E+02**
Arrangement 4	2.42E+05	6.51E+03	7.60E+00	3.13E+00	5.51E+00	2.37E-02	1.98E+00	**2.49E+05**
Arrangement 5	1.21E+05	3.27E+04	5.15E+00	2.05E-02	2.21E+00	1.39E+02	5.83E+00	**1.54E+05**

The conventional farms in the region do not invest in research and development, since they grow a single crop rotation over a wide area using the same technique.

5.5.3. Consolidated Social Fingerprint

The pre-chain and farm level fingerprints encompasses Employees, Local and National Community and Future Generation Categories, as described on Figure 57. The pre-chain performance best performance was attributed to conventional Arrangements, particularly concerning the National Community and Future Generation categories. The main reason is that higher inputs are needed, such as fertilizers. Thus, the demands for jobs and investments to increase productivity of these imputs are also high. However, the Employees Category showed opposite results due to the negative indicator associated to the production of inputs, such as toxicity, occupational diseases, and accidents.

At the farm level, the most integrated arrangement got the best performance score. Despite the larger areas of conventional Arrangement and, consequently, a higher demand for employees, the job quality is inferior than in integrated arrangements, as shown by qualified employees and professional training indicators. A major difference between integrated and conventional arrangements concerns the Future Generations indicator, especially considering the Integrated systems investments on research, development and education. When all indicators and categories from the pre-chain and farm level are analyzed together, the results show that the conventional arrangement had the worst indicator in two categories and the best score in one category. As far as the social pillar is concerned, the best social performance score was attributed to an intermediate arrangement composed of Integrated and Conventional systems (Figure 58).

To aggregate the social aspect, the weighting factor is the average of the relevance category of pre-chain and farm level (Table 60).

Table 60: Weighting Factor for social relevance.

	Pre chain	Ag-part	Average – Weighting Factor.
Farmers/Employees	0,36	0,46	41%
Local and national community	0,36	0,32	34%
Future generations	0,29	0,22	25%

Figure 57: Social Fingerprint of Pre-Chain and Ag-Part

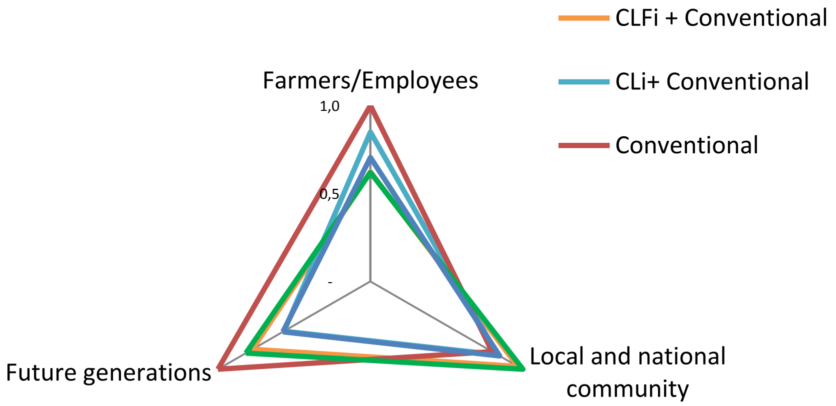
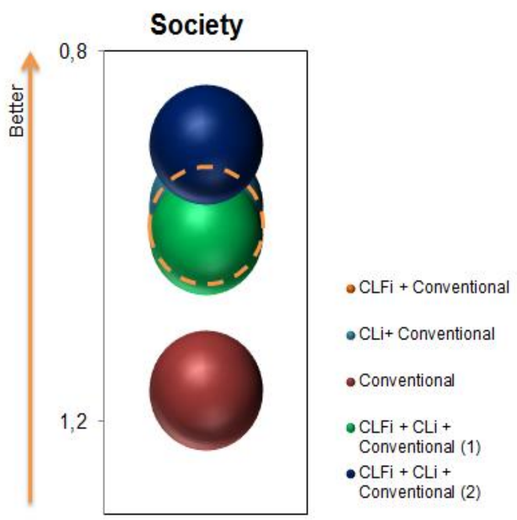


Figure 58: Social Pillar.

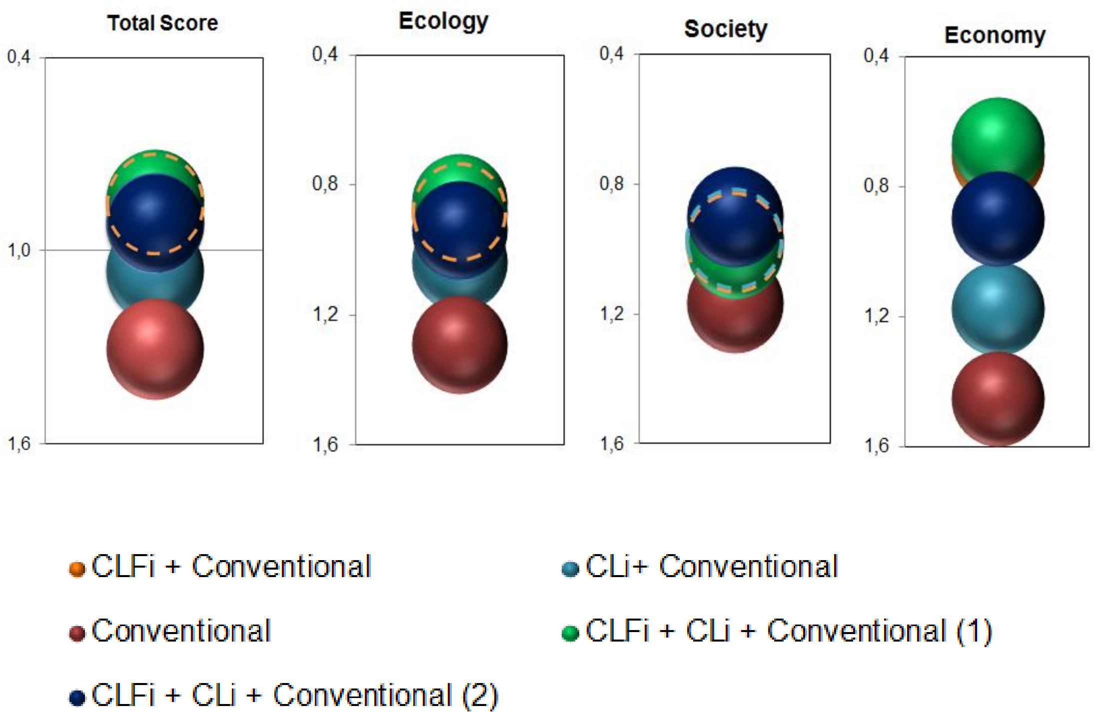


Since the pre-chain and the farm level show *quasi* opposites indicators, the consolidated results point that best indicator scores should be attributed to intermediate integrated Arrangement.

6. FINAL CONSIDERATIONS

The consolidation of the three pillars into one considers the same weighting for environment, social and economic dimensions (Figure 59). The best performance score, according to the scope determined in this study was attributed to most integrated arrangements, and the worst to conventional arrangements.

Figure 59: Socio-Eco-Efficiency Matrix Pillar.



6.1.Sensitivity Analysis

The criteria used to validate the LCI's from database was using the nearest composition possible of reality: the aim was to cover the closest technological reality possible and then the nearer geographical coverage from local production, and in case of irresolution, a sensitivity analysis would be run to choose the most conservative option (with the highest contribution to environmental impacts in CLFi system).

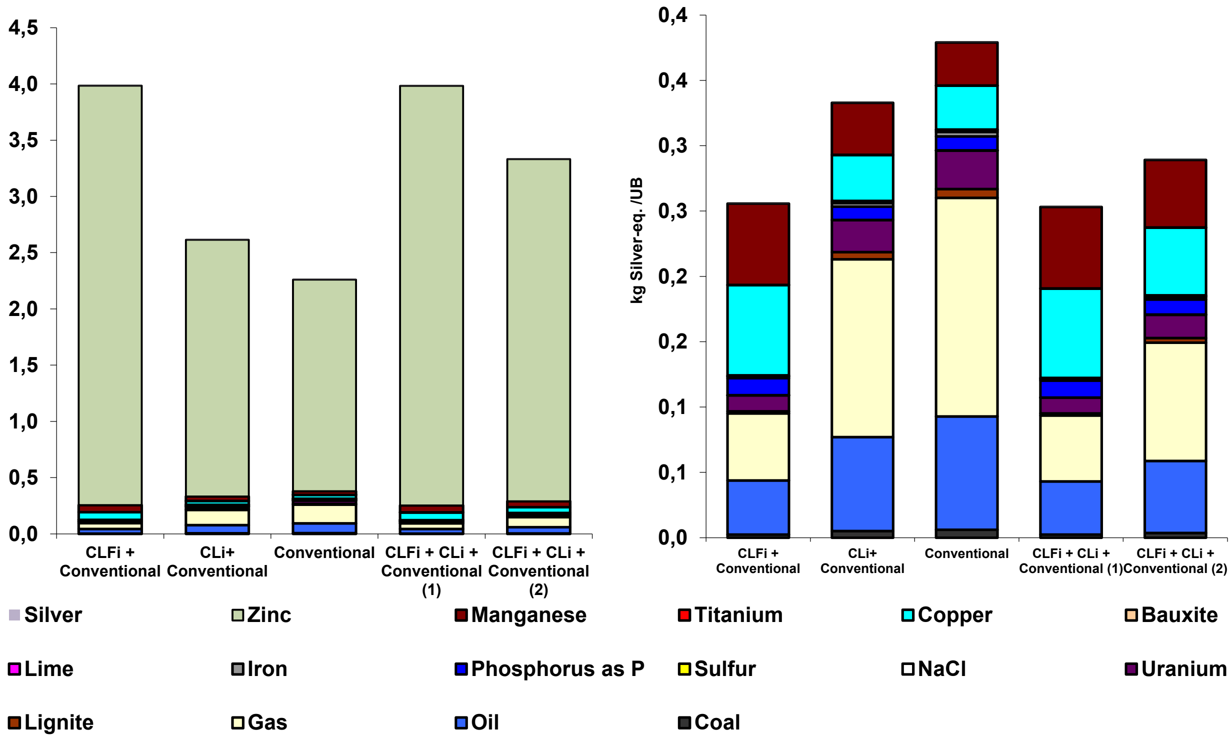
Subsequently, the coverage was chosen to be as close as possible to the period of analysis, and finally, the consistency was checked by the information on the inputs and outputs of each elementary process in order to relate the aspects of the whole production chain contained in the life cycle of each product. Thus, the interpretation of the results followed a conservative line.

Furthermore, for some specific substances no information was found to develop LCIs on the database. Therefore, similar chemical groups were chosen based on the largest consumption energy so as not to compromise the completion of the study.

6.2.Sensitivity Analysis - Zinc

The abiotic resources depletion showed impact mostly attributed to zinc compound, which has low inputs compared to fertilizers on the scope analyzed.

Figure 60: Abiotic Resources Depletion (Silver-eq.) (left) and without considering Zinc compound(right).

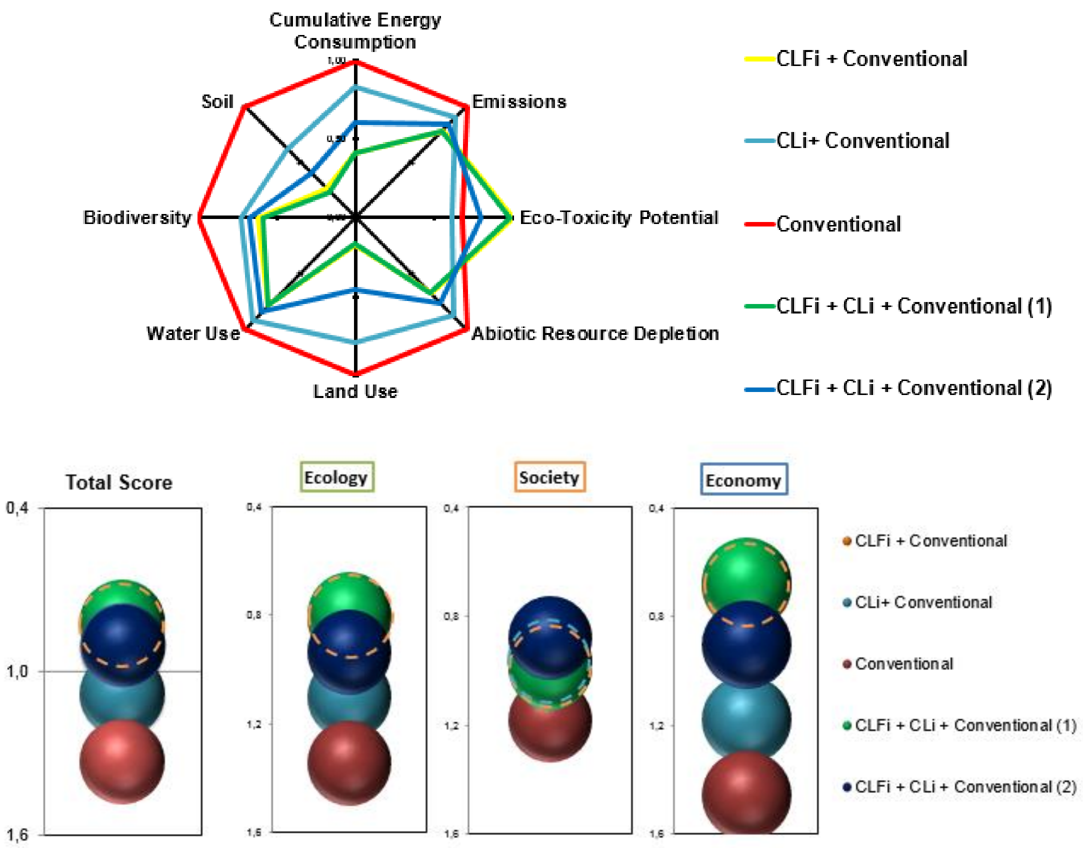


The most integrated arrangements present 43% more potential for impact on resource depletion than the conventional arrangements. This is due to zinc. Despite the low zinc inputs over the seven years of analysis, 122 kg for conventional Arrangement and 243 kg for most integrated Arrangement, this compound is sensitive to the methodology, since it considers 20 years left of world reserves. If zinc had not been considered in the process, the results would have been the opposite, and the most integrated arrangement (alternative 4) would have been rated as having the lowest impact potential.

In this context, most integrated arrangements show lower impact potential mainly attributed to oil, gas and uranium (fertilizer pre-chain) and to manganese and copper (cattle feed pre-chain). In the fertilizer pre-chain, the highest oil and gas impacts come from CaO, Nickel, MgO and P_2O_5 compounds and uranium from MgO compound.

When zinc is not considered, there is an inversion of the category result. Although the total analysis does not indicate a substantial difference, the result is maintained the same sequence (Figure 61).

Figure 61: Final results without zinc inputs

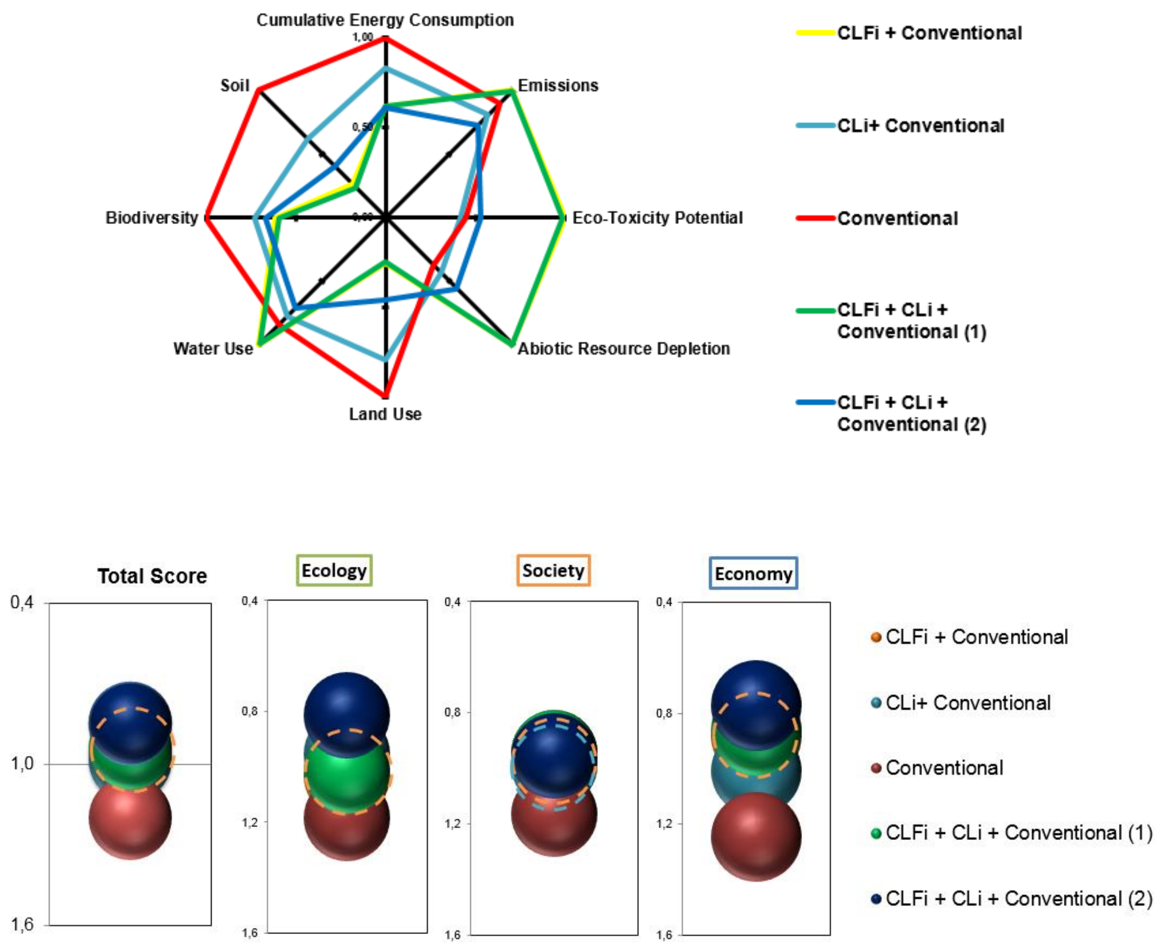


6.3. Sensitivity Analysis – higher inputs

The analysis showed high impact as contributors to the environmental pillar resulting from the conventional arrangement high inputs, such as fertilizer emissions and cumulative energy demand categories. Also, the social pillar is very affected by the input variations.

In this context, it was conducted a simulation of increase of 50% in all inputs and emissions from the farm level on the alternatives 1 and 4, which were rated the best performance in the consolidated socio-eco-efficiency analysis result. From this analysis, the alternatives 1 and 4 still presented best performance in terms of socio-eco-efficiency compared to alternative alternative 3, which represents the technological practice in the region.

Figure 62: Final results with alternative 1 and 4 with 50% higher inputs and emission.



6.4. Limitations for the use of the study

There are some methodological limitations, such as factors for emissions resulting from mineral fertilizer use, depending on local soil and climatic conditions, therefore subject to considerable variations. The factors chosen in this study were based on the 'tier 1' approach in IPCC (2006) - Guidelines for Calculation of National Greenhouse Gas Inventories, Vol. 4 (Agriculture), which is considered appropriate for the intended use of this study. In a comparative study with the same regional context of both alternatives, the influence of local soil and climate conditions on emissions from fertilizers, would affect both scenarios in the same way. Current emissions, however, may vary under local conditions, especially when forest compound in integration can create microclimate conditions.

Calculation of soil erosion rates (by USLE) in this study only predicts the amount of soil loss that results from sheet or rill erosion on a slope and does not take into account additional soil losses that might occur from gully, or wind erosion. Soil and climate conditions are modeled making use of average data. Also, changes in carbon storage due to land use have not been considered in this study. Accounting for this effect could lead to differences between the systems and arrangements.

On Eco-Efficiency Analysis, Land Use indicators refer to a comparison of biodiversity with a determined standard, a Swiss Plato. The factors are calculated for a European context and some global points, not being so representative for Brazilian comparison; however, this impact was not ignored and measured under the limitations.

There was a lack of data to measure all social indicators, If it was measured, it could consolidate the same categories from pre-chain and farm level. At the environmental fingerprint consolidation on AgBalance™ there are mixed approaches, since soil, biodiversity and eco-toxicity indicator measure only on use phase and the other on use phase and pre-chain. However, these indicators measured on use phase are focused on agriculture context.

This study was based on the function of a specific average consumption of products by a Brazilian population. If the proportion of consumption changes the results can also change since each system has its own proportion of these products. Transfer of these results and conclusions to other production methods or products is expressly prohibited. In particular, partial results may not be communicated so as to alter the meaning, nor may arbitrary generalizations be made regarding the results and conclusions.

6.5.SWOT Analysis

A SWOT analysis was applied, pointing the most strengths, weaknesses, opportunities and threats of the study:

***Strengths*:**

Primary data from Santa Brígida Farm were used; conservative assumptions and function established in a specific average consumption of products by Brazilian population. Measuring different impacts specific to agriculture context.

***Weaknesses*:**

Data collected from consultants and secondary data for assumptions and inventories, and the limitation of AgBalance^{TM} methodology.

***Opportunities*:**

Refining of data for the systems, including land use change, and extend the temporal coverage for one more cycle to measure the benefits after land recovery process. Calculate the considerations of closed loop.

***Threats*:**

The assumptions can change the result.

7. CONCLUSIONS

Results from eco-efficiency and socio-eco-efficiency presented the highest scores of socio-eco-efficiency to the arrangement with the higher area of CLFi, followed by CLi. The social analysis was not modeled linearly, and the intermediate arrangement scored as the best one, although, at this analysis, the most integrated arrangement presented better than conventional arrangement.

The most integrated arrange can improve its environmental impacts when inputs are optimized, such as fertilizers, but the inclusion of integrated systems in the arrangements highliths to some impacts caused by cattle feed pre-chain, such as abiotic resources depletion and eco-toxicity. It is suggested for future analysys the understanding of the importance of zinc on abiotic resources depletion and looking for some alternatives to replace this element on cattle feed manufacturing, or change its production way. Also it is suggested to include analysys for crop protection with lower eco-toxicity potential and calculate the carbon sequestration under GWP category, since CLFi and CLi incorporate carbon in the soil while some others conventional systems promotes carbon losses.

8. REFERENCES

AIDAR, H.; KLUTHCOUSKI, J. Evolução das atividades lavoureira e pecuária nos Cerrados. In: KLUTHCOUSKI, J.; STONE, L.F.; AIDAR, H. (Ed.).Integração lavoura-pecuária. Santo Antônio de Goiás: Embrapa Arroz e Feijão, 2003. p.25-58.

ALBUQUERQUE, J.A. et al. Efeito da integração lavoura-pecuária nas propriedades físicas do solo e características da cultura do milho. Revista Brasileira de Ciência do Solo, v.2, p.717-723, 2001

ALVARENGA,R.C.; CASTRO, A.A,D.N.; GARCIA, J.C.; NETO,M.M.G; RAMALHO, J.H.; VIANA, M.C." Sistema de Integração Lavoura-Pecuária: O modelo implantado na Embrapa Milho e Sorgo".Circular Técnica Embrapa, Sete Lagoas-MG.Dezembro de 2007. Disponível em: < http://CLFi.cnpms.embrapa.br/publicacoes/Circ_93_UD_CNPMS.pdf> Acessado em: 20/04/2013.

ALVARENGA, R. C. Integração Lavoura – Pecuária. In: SIMPÓSIO DE PECUÁRIA DE CORTE. 3. Anais... Belo Horizonte-MG: UFMG, cd rom, 2004.

ALVES, J. S; GOMES, I ; MACHADO, M.L; VIEIRA, E. M; SIMÃO, M. L.R; NAIME, U. J.Levantamento dos fatores da Equação Universal de Perdas de Solo (Eups) para o delineamento de áreas com potencial erosivo da Bacia do Rio Paranaíba (PN1 – IGAM). DIsponível em: file:///C:/Users/Marcela%20Porto/Desktop/Downloads/2%20(1).pdf . Acessado em: 20/08/2013.

ANUÁRIO DA AGRICULTURA BRASILEIRA - AGRIANUAL 2010. São Paulo. FNP Pesquisas Ltda., 2010. p. 520

BALBINO, L.C.; BARCELLOS, A.O.; STONE, L.F. (Ed.). Marco referencial: integração lavoura-pecuária-floresta. Brasília: Embrapa, 2011a.130p.

BALBINO, Luiz Carlos et al . Evolução tecnológica e arranjos produtivos de sistemas de integração lavoura-pecuária-floresta no Brasil. Pesq. agropec. bras., Brasília, v. 46, n. 10, Oct. 2011b . Disponível em: <http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0100-204X2011001000001&lng=en&nrm=iso>. Acessado em 15 Fev. 2013. http://dx.doi.org/10.1590/S0100-204X2011001000001.

BALBINO JR., A.A.; MORAES, A.; VEIGA, M. da; PELISSARI, A.; DIECKOW, J. Integração lavoura pecuária: intensificação de uso de áreas agrícolas. Ciência Rural, 2009.

BASF SE, AgBalance^{TM} - A clearer view of agricultural sustainability. 2011, Published by: BASF SE Agricultural Center – Germany. Disponível em : http://www.basf.com/group/corporate/pt/function/conversions:/publishdownload/content/sustainability/eco-efficiency-analysis/images/AgBalance_Brochure_2011.pdf

BASF, AgBalance^{TM} - Measuring sustainability in agriculture. 2012. Disponível em: <http://www.basf.com/group/corporate/pt/sustainability/eco-efficiency-analysis/agbalance>

BASF, What is the SEEBALANCE?. 2012. Disponível em: <http://www.basf.com/group/corporate/pt/sustainability/eco-efficiency-analysis/seebalance> Acessado em 25/03/2013b.

BASF – Fundação Espaço ECO. *Metodologias de Ecoeficiência*. Estudo realizado pela TÜV Anlagentechnik em setembro de 2001. Exclusivo de circulação interna da BASF.

BRASIL. LEI 12805 de 29 de Abril de 2013. Institui a Política Nacional de Integração LavouraPecuária-Floresta e altera a Lei no 8.171, de 17 de janeiro de 1991.

BRASIL. Ministério de Minas e Energia. Balanço energético nacional - BEN. Brasília: MME. Relatório final 2007 a 2014 .Available in: https://ben.epe.gov.br/. Acessed in: 20/05/2014>.

BAUMANN, T. The Hitch Hiker's Guide to LCA. *Henrikke Baumann, Anne-Marie Tillman* Studentlitteratur AB (March 12, 2004) (2004)in SILVA, G.A; OLIVEIRA, S.A; Glossário de Avaliação de Ciclo de Vida. Parceria entre a Fundação Espaço ECO® e a Associação Brasileira de Avaliação de Ciclo de Vida, 2014. Disponível em: < http://www.espacoeco.org.br/media/55031/Gloss%C3%A1rio-de-Avalia%C3%A7%C3%A3o-de-Ciclo-de-Vida-05-11-14.pdf >. Acessado em: 03/03/2015.

BEEF POINT. Maciel, R.A.P. Produção de bezerros: análise da eficiência e eficiência da análise 2013. Available in: http://www.beefpoint.com.br/radares-tecnicos/reproducao/producao-de-bezerros-analise-da-eficiencia-e-eficiencia-da-analise/. Accessed on 22/04/2015

BERTONI, J.; LOMBARDI NETO, F. Conservação do solo. São Paulo: Ícone, 1990.

BOUSTEAD CONSULTING LIMITED. The Boustead Model 5.0.12. Disponível em <http://lca.jrc.ec.europa.eu/lcainfohub/tool2.vm?tid=186>. Acesso em 2 abr. 2013.

Bubb et al. (2009) Bubb PJ, Fish L, Kapos V; Coverage of Protected Areas – Guidance for

National and Regional Use. UNEP-WCMC, Cambridge

EUR 25167 EN. Joint Research Centre – Institute for Environment and Sustainability Title: Characterisation factors of the ILCD Recommended Life Cycle Impact Assessment methods. Database and Supporting Information. Publications Office of the European Union 2012– pp 31.

Caballero, S.S.U. Fixação biológica de nitrogênio . Ageitec. Agência Embrapa de Informações Tecnológicas. Available in: <http://www.agencia.cnptia.embrapa.br/gestor/cana-de-acucar/arvore/CONTAG01_31_711200516717.html>/. Acessed on 25/04/2013.

COSTA, M.P. Avaliação da qualidade de solo do cerrado sob diferentes usos agrícolas, no município de IPAMERI – GO" (2012) 58p. Dissertação (Trabalho de graduação em engenharia ambiental)-Campus Experimental de Sorocaba, UNESP, São Paulo.

CHRISTEN et al. (2009) Christen O, Hövelmann L, Hülsbergen KJ, Packeiser M, Rimpau J,Wagner B; Nachhaltige landwirtschaftliche Produktion in der Wertschöpfungskette Lebensmittel. Schmidt Verlag, Berlin.2009.

CML-IA Characterisation Factors 3.9. Institute of Environmental Sciences, Leiden University, Netherlands, 2010.

CONAMA- Conselho Nacional do Meio Ambiente n° 430.Dispõe sobre classificação de corpos d'água e estabelece as condições e padrões para lançamento de efluentes, e dá outras providências. 2011.

DE BOER IJM, Hoving IE, Vellinga TV, Van de Ven GWJ, Leffelaar PA, Gerber PJ; Assessing environmental impacts associated with fresh water consumption along the life cycle of animal products: the case of Dutch milk production in Noord-Brabant. Int J Life Cycle Assess (2013) 18:193–203,2003.

DNV Business Assurance. DNV Assurance Statement BASF AgBalance Methodology v1.0, 2011. Available on: https://www.basf.com/documents/corp/en/sustainability/management-and-instruments/quantifying-sustainability/eco-efficiency-analysis/DNV_Assurance_Statement_BASF_AgBalance_2011_08.pdf

EMBRAPA. Cartilha: Integração lavoura-pecuária-floresta (CLFI).2012. Disponível em: < http://www.agrosustentavel.com.br/downloads/iplf.pdf>

EMBRAPA. Evolução de Sistema de Integração Lavoura-Pecuária-Floresta (CLFi): estudo de caso da Fazenda Santa Brígida, GO. Planaltina, DF. Embrapa Cerrados, 2013. 50p-(Documentos/Embrapa Cerrados, ISSN1517-5111, ISNN on line 2176-5081; 318)

EMBRAPA. Embrapa Milho e Sorgo. Mercado e Comercialização. Sistema de Produção, 2 ISSN 1679-012X Versão Eletrônica - 6ª edição. Setembro 2010.

ECOINVENT.Nemecek T, Kägi T; ecoinvent report 15, Life Cycle Inventories of Swiss and European Agricultural Production Systems. Dübendorf,2007.

FOOD AND AGRICULTURE ORGANIZATION, FAO. A Framework for Land Evaluation. FAO Soils Bulletin No. 32. FAO: Rome, 1976.

FOOD AND AGRICULTURE ORGANIZATION, FAO. 2009. How to Feed the World in 2050. (2006) Disponível em: http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf

FOOD AND AGRICULTURE ORGANIZATION, FAO. Organização das Nações Unidas para a Alimentação e a Agricultura. "FAO discute demanda mundial por alimentos." Disponível em: < https://www.fao.org.br/FAOddma.asp>. Acessado em: 15/04/2014.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS STATISTICS - FAOSTAT. Available in: http://faostat.fao.org/. Accessed in 20/06/2014.

FLORES, J. P. C.; ANGHINONI, I.; CASSOL, L. C.; CARVALHO, P. C. F.; LEITE, J. G. D. B.; FRAGA, T. I. Atributos físicos do solo e rendimento de soja em sistema de plantio direto em integração lavoura-pecuária com diferentes pressões de pastejo. Revista Brasileira de Ciência do Solo, v. 33, p. 771-780, 2007.

FRITSCH. Nährstoffgehalte in Düngemitteln und im Erntegut. Staatliche Pflanzenbauberatung Rheinland-Pfalz Germany,2007

GARCIA, A.R.; MATOS, L.B.; LOURENÇO JÚNIOR, J. de B.; NAHÚM, B. de S.; ARAÚJO, C.V. de; SANTOS, A.X. Variáveis fisiológicas de búfalas leiteiras criadas sob sombreamento em sistemas silvipastoris. Pesquisa Agropecuária Brasileira, v.46, p.1409-1414, 2011.

GLOBO RURAL. Empresas adaptam medidas mais sustentáveis nas lavouras. Disponível em: < http://revistagloborural.globo.com/Revista/Common/0,,ERT305036-18272,00.html>. 8 de Maio de 2012. Acessado em 12/04/2013.

GERMAN WASTE WATER REGULATION, 17.6.2004 (BGBl. I S. 1108, 2625); updated 24.2.2012 (BGBl. I S. 212). Abwasserverordnung in der Fassung der Bekanntmachung vom 17. Juni 2004 (BGBl. I S. 1108, 2625), die zuletzt durch Artikel 5 Absatz 8 des Gesetzes vom 24. Februar 2012 (BGBl. I S. 212) geändert worden ist

GUILHERME, L.R.G; MARCHI, G. Metais em fertilizantes inorgânicos . Avaliação de risco à Saúde apos a aplicação- tradução e adaptação do original preparado por Ther Fertilizer Institute. Translation from Health Risk Evaluation of Select Metals in Inorganic

Fertilizers Post Application prepared by The Weinberg. Group Inc. para o The Fertilizer Institute (TFI), January 2000, Available in: < http://anda.org.br/multimidia/metais_em_fertilizantes_inorganicos.pdf >

HUDSON, N., Conservacion del suelo. Barcelona: Reverté, 1982.

IBGE (Instituto Brasileiro de Geografia e Estatística). Statistics on crops and livestock. Available on http://www.ibge.gov.br/home/download/estatistica.shtm Access on March 6, 2012.

INSTITUTO AGRONÔMICO DE CAMPINAS. Boletim Técnico 100: Recomendações de Adubação e Calagem para o Estado de São Paulo. Campinas, SP. 1996. 285p.

ISO International Organization for Standardization 14040:2006 Environmental management - Life cycle assessment - Principles and framework (2006); 14044:2006 Environmental Management - Life Cycle Assessment. Requirements and Guidelines (2006);14045:2012 Environmental management — Eco-efficiency assessment of product systems — Principles, requirements and guidelines. 2012.

IUCN Red List of Threatened Species. Version 2012.1. <www.iucnredlist.org>. Downloaded on 12 July 2012.

IPCC - INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE. Egglestone S, Buendia L, Miwa K, Ngara T. K; 2006 IPCC Guidelines for National Greenhouse Inventories. Vol. 4, Agriculture, Forestry and Other Land Use, Tanabe (eds.), IGES, Japan.

KLUTHCOUSKI, J.; PACHECO, A. R. ; TEIXEIRA, S. M. et al. Renovação de pastagem do cerrado com arroz. 1- Sistema Barreirão. Goiânia-GO: EMBRAPA-CNPAF; 20p. Documentos, 33, 1991

KLUTHCOUSKI, J.; AIDAR, H.; STONE, L.F.; COBUCCI, T. Integração lavoura-pecuária e o manejo de plantas daninhas. In: SIMPÓSIO SOBRE SISTEMA AGRÍCOLA SUSTENTÁVEL COM COLHEITA ECONÔMICA MÁXIMA, 1, 2004, Piracicaba, SP. Resumos... Piracicaba: POTAFOS, 2004.

KLUTHCOUSKI, J. Estudo de Caso: Fazenda Santa Brígida. XXIII FÓRUM ABAG – INTEGRAÇÃO LAVOURA, PECUÁRIA E FLORESTA. Maringá, 18 de maio de 2012. Availale in:< http://www.abag.com.br/media/pdf-foruns/forumXXIII/joao-k-estudo-de-caso-f-s--maringa.pdf>

KÖLLNER T, SCHOLZ R; Assessment of Land Use Impacts on the Natural Environment, Part 1: An Analytical Framework for Pure Land Occupation and Land Use Change. Int. J. Life Cycle Assess. 12:16-23; 2007 . Part 2: Generic Characterization Factors for Local Species Diversity in Central Europe. Int. J. Life Cycle Assess. 13:32-48. 2007.

KÖLSCH D, Saling P, Kicherer A, Grosse-Sommer A, Schmidt I; How to measure social impacts? A socio-eco-efficiency analysis by the SEEBALANCE® method. Int. J. Sustain. Dev. 11:1 – 23.2008.

KOLZER, J.; VIS, J.C. (1998).How to get LCA in the right direction? Journal of Clean of Production, 6, p.53-61.

LANZANOVA, M.E.; NICOLOSO, R.S.; LOVATO, T.; ELTZ, F.L.F.; AMADO, T.J.C. & REINERT, D.J. Atributos físicos do solo em sistema de integração lavoura-pecuária sob plantio direto. R. Bras. Ci. Solo, v.31, p.1131-1140, 2007.

LI, X.L., GAO, J., BRIERLEY, G., QIAO, Y.M., ZHANG, J. & YANG, Y.W. Rangeland degradation on the Qinghai-Tibet Plateau: implications for rehabilitation. Land Degradation & Development, 9p, 2011.

LOSS, A.; PEREIRA, M. G.; PERIN, A.; ANJOS, L. H. C. Carbon and Nitrogen Content and Stock in No-Tillage and Crop-livestock Integration Systems in the Cerrado of Goias State, Brazil. Journal of Agricultural Science, v.4, n.8, 2012.

LANDSIEDEL R, Saling P; Assessment of Toxicological Risks for Life Cycle Assessment and Eco-efficiency Analysis. Int. J. Life Cycle Assess. 7, 261-268. 2002.

LOPES, A.S; L.R. GUIMARÃES, G.L.R; Ramos, S.J; The Saga of the Agricultural Development of the Brazilian Cerrado. *e-ifc* No. 32, November 2012. IPI 60 ANNIVERSARY ISSUE

MARCHÃO, R. L.; BALBINO, L. C.; SILVA, E. M. da; SANTOS JÚNIOR, J. D. G. dos; SÁ, M. A. C. de; VILELA, L.; BECQUER, T. Qualidade física de um Latossolo Vermelho sob sistemas de integração lavoura-pecuária no Cerrado. Pesquisa Agropecuária Brasileira, Brasília, v. 42, n. 6, p. 873-882, 2007.

McDOWELL, L. R. Minerais para ruminantes sob pastejo em regiões tropicais, enfatizando o Brasil. 3. ed. Gainesville: University of Florida, 1999. 92 p.

MELO, J. T. de; RESCK, D. V. S. Retorno ao solo de nutrientes de serrapilheira de Eucalyptus camaldulensis no cerrado do Distrito Federal. EMbrapa Cerrados, 2013.17p.

MILLER, R.M. & JASTROW, J.D. Hierarchy of root and mycorrhizal fungal interactions with soil aggregation. Soil Biol. Biochem., 22:579-584, 1990.

NELSON, D.W.; SOMMERS, L.E. Total carbon, organic carbon and organic matter. In: SPARKS, D.L. et al. (Eds).Methods of soil analysis: chemical methods. Part 3. Madison: Soil Science Society of America, 1996. p.961-1010.

NSF - "BASF's AgBalanceTM Methodology – August 2012", Available on: http://www.nsf.org/newsroom/basfs-agbalance-methodology-august-2012/

NSF - "BASF's Eco-Efficiency Analysis Methodology - May 2013", Available on: http://www.nsf.org/newsroom/basfs-eco-efficiency-analysis-methodology-may-2013 or http://www.basf.com/group/corporate/pt/sustainability/eco-efficiency-analysis/labels/index

OLIVEIRA, E.B. de; RIBASKI, J.; ZANETTI, É.A.; PENTEADO JÚNIOR, J.F. Produção, carbono e rentabilidade econômica de *Pinus elliottii e Eucalyptus grandis* em sistemas silvipastoris no Sul do Brasil. Pesquisa Florestal Brasileira, n.57, p.45-56, 2008.

OLIVEIRA, P. Consórcio de milho com adubos verdes e manejo da adubação nitrogenada no cultivo do feijão em sucessão no sistema Integração Lavoura-Pecuária no Cerrado. 2010. 126 p. Tese (Doutorado em Ciências) – Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba.

OACV – IBICT. Avaliação do ciclo de vida para a competitividade ambiental da indústria brasileira: ontologia terminológica. *Gil Anderi da Silva, Marisa Bräscher* IBICT - Instituto Brasileiro de Informação em Ciência e Tecnologia (2011) in. SILVA, G.A; OLIVEIRA, S.A; Glossário de Avaliação de Ciclo de Vida. Parceria entre a Fundação Espaço ECO® e a Associação Brasileira de Avaliação de Ciclo de Vida, 2014. Disponível em: < http://www.espacoeco.org.br/media/55031/Gloss%C3%A1rio-de-Avalia%C3%A7%C3%A3o-de-Ciclo-de-Vida-05-11-14.pdf >. Acessado em: 03/03/2015.

PFISTER S, KOEHLER A, HELLWEG, S; Assessing the Environmental Impacts of Freshwater Consumption in LCA, Environmental Science & Technology,2009.

PERON, A.J., EVANGELISTA, A.R. Pasture degradation in savanna's regions. Ciência e Agrotecnologia, v.28, n.3, p. 655-661, 2004.

PORFÍRIO-DA-SILVA, V. A integração "lavoura-pecuária-floresta" como proposta de mudança no uso da terra. In: FERNANDES, E.N.; MARTINS, P. do C.; MOREIRA, M.S. de P.; ARCURI, P.B. (Ed.). Novos desafios para o leite no Brasil. Juiz de Fora: Embrapa Gado de Leite, 2007. p.197-210.

PORFÍRIO-DA-SILVA, V. Arborização de pastagens: I. Procedimentos para introdução de árvores em pastagens. Colombo: Embrapa Florestas, 2006. 8p. (Embrapa Florestas. Comunicado técnico, 155).

PFISTER, S. KOEHLER, A. AND HELLWEG, S., Assessing the Environmental Impacts of Freshwater Consumption in LCA, Environmental Science & Technology Publication, American Chemical Society, April 23, 2009.

REIJNTJES,C., HAVERKORT,B., WATERS-BAYER, A. Farming for the future: an introduction to low-externalinput and sustainable agriculture, The Macmillan Press, London, 250p,1992.

ROLIM, S. G; SENTELHAS, P.C. Balanço Hídrico Normal de Ipameri/GO. Departamento de Física e Meteorologia. ESALQ/SP. Ano 2003. Disponível em: < http://www.leb.esalq.usp.br/bhbrasil/Goias/Ipameri.xls>.

RAIJ, B. Van ;CANTARELLA, H.; QUAGGIO, J.A & FURLANI,A.M.C. Recomendações de adubação e calagem para o Estado de São Paulo.2.ed.Campinas.Instituto Agronômico & Fundação IAC,1996, 285p. Boletim Técnico 100.

ROSENBAUM RK, Bachmann TM, Swirsky Gold L, Huijbregts MAJ, Jolliet O, Juraske R, Koehler A, Larsen HF, Macleod M, Margni M, McKone TE, Payet J, Schuhmacher M, Van de Meent D, Hauschild MZ; USEtox—the UNEPSETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in Life Cycle Impact Assessment. Int J Life Cycle.Assess 13:532–546,2008.

SÁ, J. M.; URQUIAGA, S.; JANTALIA, C. P.; SOARES, L. H. B.; ALVES, B. J. R.; BODDEY, R. M.; MARCHÃO, R. L.; VILELA, L. Balanço energético da produção de grãos, carne e biocombustíveis em sistemas especializados e mistos. Pesquisa Agropecuária Brasileira, Brasília, v. 48, n. 10, p. 1323-1331, 2013.

SALING, P.; KICHERER, A.; KRÄMER, B. D.; WITTLINGER, R.; ZOMBIK, W.; SCHMIDT, I.; SCHROTT, W. and SCHMIDT, S. ― Eco-efficiency analysis by BASF : The Method ―- Int J LCA - 2002

SALING, P; MAISCH, R;SILVANI, M; KÖNIG, N. Assessing the Environmental-Hazard Potential for Life Cycle Assessment, Eco-Efficiency and Seebalance®. LCA Journal. Ludwigshafen, 2005.

SILVA, A.M. Rainfall erosivity map for Brazil. Catena, 57:251-259, 2004.

SILVA, J.A.R. da; ARAÚJO, A.A. de; LOURENÇO JÚNIOR, J. de B.; SANTOS, N. de F.A. dos S.; GARCIA, A.R.; NAHÚM, B. de S. Conforto térmico de búfalas em sistema silvipastoril na Amazônia Oriental. Pesquisa Agropecuária Brasileira, v.46, p.1364-1371, 2011.

SMITH, C.S. Assessing agricultural land management sustainability- 1999. 400p. Tese de Doutorado (DGSPSLFS) – University of Queensland, Queensland, Australia. 1999.

SALTON, Julio *et al*. Integrated crop-livestock system in tropical Brazil: Toward a sustainable production system. Agriculture, Ecosystems & Environment, v.190, p. 70-79, 2014.

SCHOLLENBERGER, C.J. Determination of soil organic matter. Soil Science, Baltimore, v.59, p.53-56, 1945.

SCHÖNEBOOM, J; SALING, P; GIPMANS, M. AgBalance™, Technical Background Paper, BASF SE 2012. download: www.agbalance.agro.basf.com.

SILVA, G.A; OLIVEIRA, S.A; Glossário de Avaliação de Ciclo de Vida. Parceria entre a Fundação Espaço ECO® e a Associação Brasileira de Avaliação de Ciclo de Vida, 2014. Disponível em: < http://www.espacoeco.org.br/media/55031/Gloss%C3%A1rio-de-Avalia%C3%A7%C3%A3o-de-Ciclo-de-Vida-05-11-14.pdf >. Acessado em: 03/03/2015.

SCHMIDT, P.;NOVINSKI, C. O; JUNGES, D. Riscos Ambientais ourindo de compostos orgânicos voláteis e do efluente produzido por silagens. In. Jobin, C.C; Cecato, U; Canto, M.W. Simpósio dobre produção e utilizaçãode forragens conservadas,4.,2011, Maringá. Anais. Maringá UEM. P.251-270. (2011)

STATE CROP CONSULTANCY RHINELAND-PALATINATE. Staatliche Pflanzenbauberatung Rheinland-Pfalz. Available in: http://www.lwk-rlp.de/landwirtschaft/pflanzenbau/. Accessed on 22/09/214.

TISDALL, J.M. & OADES, J.M. Organic matter and water-stable aggregates in soils. J. Soil Sci., 33:141-163, 1982

TISDALL, J.M. Possible role of soil microorganisms in aggregation in soils. Plant Soil, 159:115-121, 1994.

TEIXEIRA, L.P; MELO, R.A de C.E; VILELA, L; BALBINO, L C, CORDEIRO, L.A. M. Viabilidade econômica da Integração Lavoura-Pecuária,Floresta (CLFi): Estudo em Ipameri,Go. Revista Sociedade e Desenvolvimento Rural (Revista Eletrônica SDRI), v. 6, n. 2 , set,2012.

USGS - U.S. Geological Survey. Available in: < http://www.usgs.gov/> Acessed in: 23/08/2014.

WDPA - World Database of Protected Areas. Available in: < http://www.wdpa.org/>. Acessed in 24/08/2014.

WORLD BUSINESS COUNCIL FOR SUSTAINABLE DEVELOPMENT [WBCSD]. *Eco-Efficiency:* creating more value with less impact. Geneva: WBCSD, 2000.

Appendix I – Inventory.

The input and output for seven years for each alternative can be observed on the tables below.

Table 61: Inventory of fertilizers

		Alternatives				
Fertilizers	Unit	1	2	3	4	5
B:	kg	1.51E+02	7.25E+01	7.28E+01	1.48E+02	1.10E+02
Ca:	kg	1.06E+04	5.08E+04	6.39E+04	1.03E+04	2.94E+04
CaO:	kg	6.87E+04	3.30E+05	4.15E+05	6.72E+04	1.91E+05
Co:	kg	2.83E-01	2.57E-01	2.72E-01	2.81E-01	2.67E-01
K_2O:	kg	2.04E+04	2.88E+04	3.37E+04	2.02E+04	2.41E+04
MgO:	kg	4.23E+04	2.03E+05	2.55E+05	4.14E+04	1.18E+05
Mn:	kg	2.15E+00	2.31E+00	2.45E+00	2.14E+00	2.22E+00
Mo:	kg	2.85E+00	2.59E+00	2.74E+00	2.83E+00	2.70E+00
N:	kg	1.17E+04	1.21E+04	1.40E+04	1.15E+04	1.17E+04
Ni:	kg	1.29E-01	1.17E-01	1.24E-01	1.28E-01	1.22E-01
P_2O_5:	kg	2.16E+04	1.78E+04	1.94E+04	2.14E+04	1.95E+04
S:	kg	8.59E+03	4.13E+04	5.19E+04	8.40E+03	2.39E+04

Table 62: Inventory of crop protection.

		Alternatives				
Crop Protection	Unit	1	2	3	4	5
acephate (organophosphate)	kg	7.85E+01	5.13E+01	5.88E+01	7.70E+01	6.36E+01
atrazin (triazin)	kg	3.96E+01	4.35E+01	4.80E+01	3.94E+01	4.16E+01
azoxystrobin (strobilurin)	kg	1.34E+01	1.13E+01	1.23E+01	1.33E+01	1.22E+01
Bacillus thuringiensis (biological)	kg	1.44E+00	1.31E+00	1.38E+00	1.43E+00	1.36E+00
bifenthrin (pyrethroid)	kg	4.26E+00	3.72E+00	4.41E+00	4.18E+00	3.92E+00
carboxin (carboxanilide)	kg	4.11E+00	4.63E+00	4.50E+00	4.14E+00	4.39E+00
cyproconazole (triazole)	kg	7.86E+00	6.38E+00	6.89E+00	7.77E+00	7.05E+00
diflubenzuron (benzoylurea)	kg	2.27E+01	1.71E+01	1.63E+01	2.26E+01	2.00E+01
epoxiconazole (triazole)	kg	2.54E+01	1.31E+02	1.31E+02	2.82E+01	7.95E+01
fipronil (pyrazol)	kg	3.12E+02	1.33E+02	1.34E+02	3.07E+02	2.20E+02
flumioxazin (ciclohexenodicarboximida)	kg	3.96E+00	7.11E+00	7.21E+00	4.04E+00	5.57E+00
potassium glyphosate salt (substituted glycine)	kg	4.55E+02	3.76E+02	3.92E+02	4.51E+02	4.13E+02
imidacloprid (neonicotinoid)	kg	4.95E+00	4.13E+00	5.48E+00	4.80E+00	4.41E+00
lambda-cyhalothrin (pyrethroid)	kg	2.27E+00	2.06E+00	2.18E+00	2.25E+00	2.15E+00
lufenuron (benzoylurea)	kg	7.42E+00	6.60E+00	9.00E+00	7.18E+00	6.78E+00
methomyl (methylcarbamate oxime)	kg	6.39E+00	7.01E+00	7.74E+00	6.35E+00	6.70E+00
methoxyfenozide (diacilhidrazina)	kg	5.60E+00	5.05E+00	5.86E+00	5.51E+00	5.24E+00
nicossulfurom (sulfonylurea)	kg	2.97E-01	2.64E-01	3.60E-01	2.87E-01	2.71E-01
mineral oil (hydrocarbons aliphatic)	kg	1.71E+02	1.55E+02	1.64E+02	1.70E+02	1.62E+02
Orthene 750 BR Seeds	kg	3.86E+01	3.50E+01	3.71E+01	3.83E+01	3.65E+01
Picoxystrobin (strobilurin)	kg	1.52E+01	1.37E+01	1.59E+01	1.50E+01	1.42E+01
tebuconazole (triazole)	kg	8.57E+00	7.78E+00	8.24E+00	8.50E+00	8.10E+00
thiamethoxam (neonicotinoid)	kg	3.02E+00	2.74E+00	2.90E+00	3.00E+00	2.86E+00
thiodicarb (methylcarbamate oxime)	kg	7.07E+00	5.91E+00	7.83E+00	6.86E+00	6.30E+00
thiophanate-methyl (benzimidazole (precursor))	kg	5.41E+01	4.87E+01	5.69E+01	5.32E+01	5.05E+01
tiram (dimethyldithiocarbamate)	kg	4.11E+00	4.63E+00	4.50E+00	4.14E+00	4.39E+00
sulfuramide	kg	5.32E-01	2.91E-01	2.91E-01	5.26E-01	4.08E-01
haloxyfop-P-methyl (acid ariloxifenoxipropiônico)	kg	1.70E+00	8.45E-01	8.45E-01	1.68E+00	1.26E+00

Table 63: Inventory of seeds.

		Alternatives				
Seeds	Unit	1	2	3	4	5
forage coverage - millet	kg	1.35E+03	4.13E+02	0.00E+00	1.36E+03	9.25E+02
Brachiaria brizanta	kg	1.35E+02	2.42E+03	2.95E+03	1.42E+02	1.23E+03
Brachiaria ruziziensis	kg	0.00E+00	1.35E+02	0.00E+00	1.76E+01	8.82E+01
Soy - Late cycle	kg	1.69E+03	5.88E+02	5.49E+02	1.67E+03	1.13E+03
Soy- Medium cycle	kg	1.30E+03	1.69E+03	2.06E+03	1.27E+03	1.45E+03
Soy - Early cycle	kg	1.39E+03	2.35E+03	2.20E+03	1.43E+03	1.90E+03
Corn - 2nd crop	kg	1.90E+02	4.21E+02	7.20E+02	1.68E+02	2.76E+02
Corn - Summer crop	kg	8.57E+02	4.54E+02	4.40E+02	8.48E+02	6.57E+02
Sorghum	kg	7.11E+02	5.30E+02	4.98E+02	7.09E+02	6.22E+02
Eucalyptus Seedlings	unit	3.84E+04	1.61E+04	1.61E+04	3.78E+04	2.70E+04
Eucalyptus Harvasting	m^3	6.02E+03	2.36E+03	2.36E+03	5.92E+03	4.14E+03

Table 64: Inventory of cattle complementary feed.

		Alternatives				
Cattle Feed	Unit	1	2	3	4	5
Sorghum	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Soy meal	kg	2.48E+05	1.86E+05	1.68E+05	2.48E+05	2.18E+05
limestone	kg	1.05E+05	9.47E+04	9.06E+04	1.05E+05	1.00E+05
White Salt	kg	6.70E+02	0.00E+00	0.00E+00	6.52E+02	3.26E+02
Urea	kg	1.17E+04	4.85E+02	0.00E+00	1.14E+04	6.01E+03
Calcium	kg	7.39E+03	2.86E+03	2.69E+03	7.28E+03	5.09E+03
P:	kg	6.43E+03	3.38E+03	3.28E+03	6.35E+03	4.88E+03
Mg:	kg	2.83E+03	1.74E+03	1.44E+03	2.83E+03	2.31E+03
S:	kg	1.61E+03	1.09E+03	8.20E+02	1.62E+03	1.38E+03
Mn:	kg	4.50E+03	2.61E+03	2.29E+03	4.48E+03	3.57E+03
Zn:	kg	9.64E+01	5.97E+01	4.92E+01	9.65E+01	7.90E+01
Cu:	kg	2.43E+02	1.49E+02	1.22E+02	2.43E+02	1.98E+02
Co:	kg	8.03E+01	4.72E+01	4.10E+01	8.01E+01	6.42E+01
I:	kg	5.14E+00	5.45E+00	2.62E+00	5.44E+00	5.70E+00
Se:	kg	4.82E+00	2.78E+00	2.46E+00	4.80E+00	3.81E+00
Vitamin A	kg	1.29E+00	7.42E-01	6.56E-01	1.28E+00	1.02E+00
Vitamin D	kg	0.00E+00	2.08E-01	0.00E+00	2.71E-02	1.36E-01
Vitamin E	kg	0.00E+00	2.64E-03	0.00E+00	3.44E-04	1.72E-03
Virginiamycin	kg	0.00E+00	3.62E+00	0.00E+00	4.71E-01	2.37E+00
Monensin	kg	5.14E+01	3.64E+01	2.62E+01	5.20E+01	4.51E+01

Table 65: Inventory of utilities.

		Alternatives				
Utilities	Unit	1	2	3	4	5
Water from river	m^3	2.48E+04	2.63E+04	2.73E+04	2.48E+04	2.55E+04
Electricity from network	MJ	5.38E+02	7.31E+02	8.51E+02	5.31E+02	6.21E+02
Kerosine	kg	2.82E+00	1.55E+01	1.55E+01	3.17E+00	9.33E+00
Lube oil	MJ	1.49E+00	8.17E+00	8.17E+00	1.67E+00	4.92E+00
Gasoline	MJ	0.00E+00	2.23E+01	0.00E+00	2.90E+00	1.46E+01
Diesel	MJ	3.41E+05	6.86E+05	8.66E+05	3.32E+05	4.94E+05

Table 66: Inventory of Emissions .

Emissions		Alternatives					
		Unit	1	2	3	4	5
Field Air/Water Emissions	CO_2-total	mg	1.08E+11	5.19E+11	6.52E+11	1.06E+11	3.01E+11
	NO_X	mg	1.75E+08	1.83E+08	2.10E+08	1.73E+08	1.77E+08
	NH_3	mg	2.84E+08	2.96E+08	3.41E+08	2.80E+08	2.86E+08
	N_2O	mg	2.38E+08	2.07E+08	3.46E+08	2.24E+08	2.05E+08
	Water Emissions N	mg	1.17E+09	1.22E+09	1.40E+09	1.15E+09	1.18E+09
Silage Emissions	CH_4	mg	0.00E+00	1.79E-02	0.00E+00	2.33E-03	1.17E-02
	N_2O	mg	0.00E+00	2.38E-02	0.00E+00	3.11E-03	1.56E-02
	Water Emissions DQO	mg	0.00E+00	7.20E+06	0.00E+00	9.39E+05	4.71E+06
Cattle Emissions	CH_4	mg	5.18E+10	6.24E+10	7.00E+10	5.12E+10	5.56E+10
	N_2O	mg	2.97E+08	3.59E+08	4.04E+08	2.94E+08	3.20E+08

Table 67: Inventory of trace elements emission to soil from fertilizers.

Trace Element	Unit	1	2	3	4	5
Hg	mg	3.49E-01	1.11E+00	1.05E+00	3.76E-01	7.48E-01
Cd	mg	1.86E+02	3.20E+02	3.48E+02	1.86E+02	2.51E+02
Cr	mg	7.38E+02	1.86E+03	1.80E+03	7.76E+02	1.32E+03
Zn	mg	1.10E+04	1.38E+05	1.74E+05	1.08E+04	7.11E+04
Cu	mg	1.34E+03	2.07E+03	2.43E+03	1.32E+03	1.67E+03
Ni	mg	3.65E+02	6.88E+02	7.30E+02	3.69E+02	5.25E+02
Pb	mg	7.58E+02	1.22E+03	1.47E+03	7.45E+02	9.62E+02

Table 68: Inventory of Road Transport.

Alternatives		1	2	3	4	5
Capacity of the Vehicle	Vehicle. Km*/ FU					
4	v.km	5.08E+02	3.59E+02	3.44E+02	5.05E+02	4.34E+02
5	v.km	1.37E+02	9.36E+00	2.58E+01	1.32E+02	6.93E+01
10	v.km	8.67E+01	3.04E+02	4.81E+02	7.47E+01	1.75E+02
14	v.km	1.34E+03	9.91E+02	8.77E+02	1.34E+03	1.18E+03
15	v.km	8.22E+00	5.69E+00	2.90E+00	8.45E+00	7.35E+00
27	v.km	2.94E+03	1.12E+04	1.38E+04	2.90E+03	6.80E+03

*V.km =Vehicule.Kilometer is one how much impact 1 vehicule to travel per 1 km.

Table 69: Inventory of costs.

		Alternatives				
	Unit	**1**	**2**	**3**	**4**	**5**
Total Cost	Reais	1.02E+06	1.75E+06	2.16E+06	9.97E+05	1.34E+06

Appendix II – Assumptions

Table 70: Imputs for Land Preparation

LAND PREPARATION	City of Supplier	Transport Modal	Transport Capacity (ton)	Package	AMOUNT	UNIT
LIME	PARACATU-MG	Truck	27	-	4000	kg/ha
GIBBS	CATALÃO-GO	Truck	27	-	1000	kg/ha

Table 71: Imputs for desiccation before planting crop.

DESSICATION - 1ST APLICCATION	City of Supplier	Transport Modal	Transport Capacity (ton)	Package	AMOUNT	UNIT
Zapp QI 620	CATALÃO-GO	Truck	14	Plastic Container 20L	4,5	L/ha
Flumyzin 500	CATALÃO-GO	Truck	14	Plastic bag	0,05	kg/ha
Iharol	CATALÃO-GO	Truck	14	Plastic Container 20L	0,5	L/ha
Fipronil Nortox 800 WG	CATALÃO-GO	Truck	14	Plastic bag	0,02	kg/ha

Table 72: Crops considered in 7 year's cycle of CLFi system.

CLFi	Rain Season	Dry Season	In spaced lines (Full Year)
Year 1	Soy	Covered Land with Forrage	Forestry Planting
Year 2	Corn + Brachiaria	Pasture	Forestry Care
Year 3	Pasture	Pasture	Forestry Care
Year 4	Pasture	Pasture	Forestry Care
Year 5	Pasture	Pasture	Forestry Care
Year 6	Pasture	Pasture	Forestry Care
Year 7	Pasture	Pasture	Forestry Harvesting

Table 73: Crops considered in CLi system.

Crop-Livestock System	Rain Season	Between Seasons	Dry Season
	Summer Crop	2 nd Crop	-
Year 1	Soy	Covered Land with Forrage	
Year 2	Soy	Corn + Brachiaria	Pasture
Year 3	Soy	Sorgo + brachiaria	Pasture
Year 4	Corn + Brachiaria	Pasture for Livestock - 4 months	
Year 5	Soy	Corn + Brachiaria	Pasture
Year 6	Soy	Corn + Brachiaria	Pasture
Year 7	Corn + Brachiaria	Pasture for Livestock - 4 months	

Table 74: Crops considered in Conventional Crop system.

Conventional Crop System	Rain Season	Between Seasons	Dry Season
	Summer Crop	2nd Crop	-
Year 1	Soy	Uncovered Land	Uncovered Land
Year 2	Soy	Uncovered Land	Uncovered Land
Year 3	Soy	Corn	Uncovered Land
Year 4	Corn	Uncovered Land	Uncovered Land
Year 5	Soy	Sorghum	Uncovered Land
Year 6	Soy	Corn	Uncovered Land
Year 7	Soy	Uncovered Land	Uncovered Land

Table 75: Crops considered in Conventional Forestry System.

Conventional Forestry	
Year 1	Forestry Planting
Year 2	Forestry Care
Year 3	Forestry Care
Year 4	Forestry Care
Year 5	Forestry Care
Year 6	Forestry Care
Year 7	Forestry Harvesting

Table 76: Crops considered in Conventional Pasture

Conventional Pasture	
Year 1	Planting Brachiaria
Year 2	Pasture
Year 3	Pasture
Year 4	Pasture
Year 5	Pasture
Year 6	Pasture
Year 7	Pasture

Table 77: Information for soya crop care.

SOYA CULTIVATION	City of Supplier	Transport Modal	Transport Capacity (ton)	Package	AMOUNT	UNIT
SEED TREATMENT						
Vitavax-Thiram WP	CATALÃO-GO	Truck	4	Plastic Container 20L	0,25	L/100 kg seeds
Inoculant ATMO	CATALÃO-GO	Truck	4	Plastic Container 1L/005L	0,2	L/100 kg seeds
Inoculant TUFOSO	CATALÃO-GO	Truck	4	Plastic Bag	0,6	kg/ha 100 kg seeds
Standak	CATALÃO-GO	Truck	4	Plastic Container 005L	0,2	L/100 kg seeds
APPLICATION BEFORE SOWING						
KCl	CATALÃO-GO	Truck	14	Big Bag	150	kg/ha
FERTILIZER (Sowing)						
MAP 11-52-00	CATALÃO-GO	Truck	14	Plastic Container 1L	200,00	kg/ha
CROP CARE - 2ND APLICCATION						
Zapp QI 620	CATALÃO-GO	Truck	4	Plastic Container 20L	2	L/ha
Assist	CATALÃO-GO	Truck	4	Plastic Container 20L	0,5	L/ha
Dimilin 80 WG	CATALÃO-GO	Truck	4	bag	0,02	kg/ha
TALERO Mn FOSFITO	CATALÃO-GO	Truck	4	bag	0,2	L/ha
NICOMODRY	CATALÃO-GO	Truck	4	bag	0,15	kg/ha
CROP CARE - 3RD APLICCATION						
Intrepid 240 SC	GOIÂNIA-GO	Truck	4	Plastic Container 05L	0,18	L/ha
Talstar 100 EC	CATALÃO-GO	Truck	4	Plastic Container 05L	0,25	L/ha
Priori Xtra	CATALÃO-GO	Truck	4	Plastic Container 05L/20L	0,3	L/ha
Nimbus	CATALÃO-GO	Truck	4	Plastic Container 05L	0,6	L/ha
Cercobin 500 SC	CATALÃO-GO	Truck	4	Plastic Container 10L	0,8	L/ha
Bore Acid 17%	CATALÃO-GO	Truck	4	Plastic bag	0,2	kg/ha
MAP Purificated	CATALÃO-GO	Truck	4	Plastic bag	3	kg/ha
CROP CARE -4TH APLICCATION						
Aproach Prima	CATALÃO-GO	Truck	4	Plastic Container 05L/20L	0,3	L/ha
Nimbus	CATALÃO-GO	Truck	4	Plastic Container 05L	0,6	L/ha
Dipel	CATALÃO-GO	Truck	4	Plastic Container 10L	0,5	L/ha
Engeo Pleno	CATALÃO-GO	Truck	4	Plastic Container 05L	0,25	L/ha
ac borico borosol 17% boro	CATALÃO-GO	Truck	4	Plastic Container 20L	0,2	kg/ha
Foskalium 30-20	CATALÃO-GO	Truck	5	Plastic Container 20L	1,25	L/ha
CROP CARE -5TH APLICCATION						
Horos	CATALÃO-GO	Truck	4	Plastic Container 20L	0,5	L/ha
Orthene 750 BR	CATALÃO-GO	Truck	4	bag	0,6	kg/ha
Nimbus	CATALÃO-GO	Truck	4	Plastic Container 05L	0,6	L/ha

Table 78: Information for corn crop care.

CORN CULTIVATION	City of Supplier	Transport Modal	Transport Capacity (ton)	Package	AMOUNT	UNIT
SEED TREATMENT						
Cropstar	CATALÃO-GO	Truck	4	Plastic Container 05L	0,3	L in 60 000 seeds
Rocks	CATALÃO-GO	Truck	4	Plastic Container 05L	0,3	Lin 60 000 seeds
CROP CARE - 2ND APLICCATION						
Primóleo	CATALÃO-GO	Truck	4	Plastic Container 05L/20L	2	L/ha
Nicosulfuron Nortox 40 SC	CATALÃO-GO	Truck	4	Plastic Container 05L/20L	0,15	L/ha
Assist	CATALÃO-GO	Truck	4	Plastic Container 20L	0,5	L/ha
Dimilin 80 WG	CATALÃO-GO	Truck	4	BAG	0,035	kg/ha
CROP CARE - 3RD APLICCATION						
Brilhantebr	CATALÃO-GO	Truck	4	Plastic Container 20L	0,6	L/ha
Intrepid 240 SC	GOIÂNIA- GO	Truck	4	Plastic Container 10L	0,16	L/ha
Priori Xtra	CATALÃO-GO	Truck	4	Plastic Container 05L/20L	0,3	L/ha
Nimbus	CATALÃO-GO	Truck	4	Plastic Container 05L	0,3	L/ha
CROP CARE -4TH APLICCATION						
Intrepid 240 SC	GOIÂNIA-GO	Truck	4	Plastic Container 05L	0,16	L/ha
Avant 750 SP	CATALÃO-GO	Truck	4	Plastic Container 05L	0,2	L/ha
Cercobin 500 SC	CATALÃO-GO	Truck	4	Plastic Container 10L	0,8	L/ha
Opera	CATALÃO-GO	Truck	4	Plastic Container 05L	0,75	L/ha
FERTILIZER (Sowing)						
NPK 08-20-15	CATALÃO-GO	Truck	14	Big Bag	450	kg/ha
FERTILIZER						
NPK 36-00-12	CATALÃO-GO	Truck	14	Big Bag	250	kg/ha

Table 79: Information for sorghum crop care.

SORGHUM CULTIVATION	City of Supplier	Transport Modal	Transport Capacity (ton)	Package	AMOUNT	UNIT
DESSICATION - 1ST APLICCATION						
Zapp QI 620	CATALÃO-GO	Truck	4	Plastic Container 20L	2,5	L/ha
CROP CARE - 2ND APLICCATION						
Primóleo	CATALÃO-GO	Truck	4	Plastic Container 05L/20L	2	L/ha
Assist	CATALÃO-GO	Truck	4	Plastic Container 20L	0,5	L/ha
Brilhantebr	CATALÃO-GO	Truck	4	Plastic Container 20L	0,6	L/ha
CROP CARE - 3RD APLICCATION						
Priori Xtra	CATALÃO-GO	Truck	4	Plastic Container 05L/20L	0,3	L/ha
Nimbus	CATALÃO-GO	Truck	4	Plastic Container 05L	0,6	L/ha
Dimilin 80 WG	CATALÃO-GO	Truck	4	Bag	0,3	kg/ha
FERTILIZER (Sowing)						
NPK 05-25-15	CATALÃO-GO	Truck	4	Bag	300	kg/ha

Table 80: Information for Brachiaria crop care.

BRAQUIARIA CONVENTIONAL PASTURE	City of Supplier	Transport Modal	Transport Capacity (ton)	Package	AMOUNT	UNIT
NPK 3-0-17	CATALÃO-GO	Truck	4	Bag	250	kg/ha

Table 81: Information for eucalyptus crop care.

EUCALIPTUS	City of Supplier	Transport Modal	Transport Capacity (ton)	Package	AMOUNT	UNIT
Stinger	CATALÃO-GO	Truck	14 ton /f4000	B20L	4,5	L/ha
FERTILIZER						
NPK 6-30-6 + Zn 0.4% + B 0.2% + Cu 0.3% /0.5%	CATALÃO-GO	Truck	14	Plastic bag	0,12	kg/plant
N-K : 20-00-20 + 1%B+ 0,5 Zn	CATALÃO-GO	Truck	14	Bag	0,1	kg/ Plant
N-K : 20-00-20 + 1%B+ 0,5 Zn	CATALÃO-GO	Truck	14	Bag	0,15	kg/ Plant
KCl + 1% Bore	CATALÃO-GO	Truck	14	Bag	0,1	kg/Plant
Fipronil Nortox 800 WG	CATALÃO-GO	Truck	4	Plastic bag	3	kg/ha + 100 L of Water per plant
Verdict R	CATALÃO-GO	Truck	4	Plastic Container 20L	0,7	L/ha
Bore liquid 10 % d= 1,3 (Just at Conventional System)	CATALÃO-GO	Truck	4	Plastic Container 005L	3	L/ha + 30 l of water

Table 82: Information for Seeds

SEEDS	City of Supplier	Transport Modal	Transport Capacity (ton)	Package	AMOUNT	UNIT
Soya early cycle	FORMOSA/ CATALÃO/ IPAMERI/ VIANOPOLIS-GO	Truck	14	Paper Package	80	kg/ha
Soya medium cycle		Truck	14	Paper Package	50	kg/ha
Soya long cycle		Truck	14	Paper Package	40	kg/ha
Sorghum	CATALÃO-GO	Truck	14	Paper Package	8	kg/ha
Corn	CATALÃO/ FORMOSA-GO/CATALÃO/ PIRES DO RIO	Truck	14	Paper Package	66000 - 68000	seeds/ha
2nd Crop corn		Truck	15	Paper Package	54000-56000	seeds/ha
Brachiaria brizanta	GOIÂNIA-GO	Truck	14	Paper Package	4	kg/ha
Brachiaria rumiziniense (2nd crop)	GOIÂNIA-GO	Truck	14	Paper Package	4	kg/ha
Brachiaria brizanta - conventional pasture	GOIÂNIA-GO	Truck	15	Paper Package	8	kg/ha
Millet	IPAMERI-GO	Truck	14	Paper Package	20	kg/ha
Eucalyptus	ARAGUARI-MG; ANÁPOLIS-GO;	Truck	5	Plastic Cartridge	1300	units/ha

Table 83: Information of diesel raw material.

DIESEL	City of Supplier	Transport Modal	Transport Capacity (litter)	Package
DIESEL S10	UBERLÂNDIA -MG	Truck	10 000	-

Table 84: Premises for Diesel Equipment Consumption.

Equipment	L/h of diesel	ha/h
Rear blade	12	2
Disc harrow	16	1
Intermediate disc harrow (24)	16	1,5
Leveling disc (40) opening	15	2
Leveling disc(40) closing	13	2,5
Leveling disc (36) opening	8	1,7
Leveling disc(36) closing	6,5	2,2
Millet sowing -Vincon	7	20
Sprayer	16	40
Water truck - 3000 litters	6	-
Smaller sowing (disk)	16	2,5
Smaller sowing (Chisel plow)	18	2,5
bigger sowing (disk)	22	2,5
bigger sowing (Chisel plow)	24	2,5
Big bag rear winch	9	-
Big bag front winch	5	-
Gator	1,5	-
Patrol	12	-
Mat tractor	6	1
Spreader for lime and gibbs	11	8
Spreader KCl	12	10
Rear blade for Silage	16	-
Tractor for compaction -Silage	14	-
Loader	7	-
Loader for silage	10	-
small truck 5 ton	26	-
Harvester (Soya)	30	3
Harvester (Corn)	25	2
Harvester (Sorghum)	23	4
Harvester (Forage)	30	3
Wagon tractor 400 kg	6	-
small truck 2,5 t	6	-
Grain tank tractor	12	-
Forest Subsoil	16,5	1

Table 85: Premises for Diesel intern truck consumption.

Intern Truck 5 ton	
26,0	Consumption (l/h)
40,0	Km/h – Average Speed
2,0	Distance to go and come back of the cultivation area
0,05	Time (h) to roam this distance

Table 86: Premises for Diesel Wagon tractor consumption.

Wagon tractor 4000 kg	
6,0	Consumption (l/h)
25,0	Km/h – Average Speed
2,0	Distance to go and come back of the cultivation area
0,08	Time (h) to roam this distance

Table 87: Complementary feed for the Cow

Complementary feed for the Cow	
Sorghum	62%
Soya residue	34%
Ureia	1%
Nucleus Premix	3%

Table 88: Nucleus Premix for manufacturing complementary feed to the Cow.

Nucleus Premix for complementary feed to the Cow	
Ca	40,61%
P	17,87%
Mg	10,15%
S	28,43%
Mn	0,61%
Zn	1,42%
Cu	0,51%
Co	0,03%
I	0,03%
Se	0,01%
Monensin	0,32%

Table 89: Inputs for Complementary feed.

COMPLEMENTARY FEED PRODUCTS	City of Supplier	Transport Modal	Transport Capacity (ton)	Package
PREMIX semi Feedlot	PATROCINIO-PAULISTA -SP	Truck	14	Bag 30 kg
PREMIX Feedlot	PATROCINIO-PAULISTA -SP	Truck	14	
Salt	PIRES DO RIO - GO	Truck	5	Bag 50 Kg
UREA	CATALÃO-GO	Truck	14	Bag 100 Kg
SOYA RESIDUE	PIRES DO RIO - GO	Truck	14	Bag 50 Kg
CORN SILAGE	INTERN PRODUCTION	Truck	14	-
CORN AND SORGHUM	INTERN PRODUCTION	Truck	14	-

Table 90: Complementary feed at pasture.

Complementary feed for pasture	Dry season%	Rain season (%)
Sorghum	34%	47%
Lime	0%	5%
Residue of Soya	16%	16%
Salt	23%	15%
Urea	12%	4%
Premix	15%	15%

Table 91: Complementary feed for ending process at pasture.

Complementary feed for ending process at pasture	Amount (%)
Sorghum	79%
Residue of Soya	10%
Salt	6%
Urea	2%
Premix	3%

Table 92: Premix used for manufacture the complementary and End Process feed at pasture.

Premix	Amount (%)
Ca	40,6%
P	17,9%
Mg	10,2%
S	28,4%
Mn	0,6%
Zn	1,4%
Cu	0,51%
Co	0,03%
I	0,03%
Se	0,01%
Monensin	0,32%

Table 93: Premises for Feedlot

Feedlot	Faster Feedlot 45 days (days)	Feedlot 60 days (days)	Silage (kg)	Complementary Feed (kg)
Adaptation	7	7	15,6	6
Growing	13	25	13,33	8,34
Ending Process	25	28	9,76	9,43

Table 94: Premises for Complementary Feed for Feedlot

	Adaptation	Growing	Ending Process
Complementary Feed - Feedlot	Amount per cattle per day (kg)	Amount per cattle per day (kg)	Amount per cattle per day (kg)
Silage	15,60	13,33	9,76
Sorghum	4,20	6,03	7,05
Residue of Soy	1,44	1,85	1,95
Nucleus	0,36	0,46	0,43
Total	21,60	21,67	19,19

Table 95: Nucleus to manufacture the compplementary feed to feedlot process.

Nucleus (Feedlot)	
Products	**Amount (%)**
Lime	25%
Residue of Soy	33%
Salt	7%
Urea	20%
Premix	15%

Table 96: Premix for Nucleus, used to manufacture the compplementary feed to feedlot process.

Premix for Nucleus of feedlot	
P	32,2%
Mg	30,3%
S	30,3%
Mn	1,1%
Zn	2,8%
Cu	0,6%
Co	0,03%
I	0,03%
Se	0,01%
Vitamin A	0,03%
Vitamin D	0,0003%
Vitamin E	0,5%
Virginiamycin	0,8%
Monensin	1,2%

Appendix III – Costs

All values are on monetary value of Brazil (Reais R$). The raise of prices during the time coverage was calculated by National Index of Consumer Price.

Table 97: National Index of Consumer Price raise per year.

Year	%
2014	6.39%
2013	5.91%
2012	5.83%
2011	6.50%
2010	5.90%
2009	4.31%
2008	6%
2007	4.45%

On the tables below. the values expanded with employees are included.

Table 98: Livestock compound prices

Livestock	Sell price of 15 kg of meat (@)	Cost of 1 Kg cattle feed for dry season	Cost of 1 Kg of rain season cattle feed	Diary Cost of feedlot per animal	Diary Cost of end processing at pasture (after corn and brachiaria 2 months module- CLi) per animal	Diary Cost of end processing at pasture (after corn and brachiaria 4 months module- CLi) per animal)	Diary Cost per animal end processing CLFi
Year 7	113.00	1.50	1.23	5.50	0.96	0.48	0.62
Year 6	106.32	1.41	1.16	5.17	0.90	0.45	0.59
Year 5	100.12	1.33	1.09	4.87	0.85	0.43	0.55
Year 4	93.62	1.24	1.02	4.56	0.80	0.40	0.52
Year 3	88.09	1.17	0.96	4.29	0.75	0.38	0.49
Year 2	84.30	1.12	0.92	4.10	0.72	0.36	0.46
Year 1	79.32	1.05	0.86	3.86	0.67	0.34	0.44

Table 3: Crop Prices

Crop	Land Recovery Cost/50ha	Silage Corn Cost/50ha	2nd crop corn cost/50ha	Summer corn crop cost/50ha	Soya cost/50ha	Sorghum Cost/50ha	Forage planting cost/50ha	Forest Cost CLFi/50ha of system	Conventional Forest Cost/50ha	Brachiaria 2nd crop cost/50 ha	Brachiaria summer crop cost/50 ha
Year 7	15,550	83,292	76,074	76,074	88,993	39,906	9,100	55,923	161,910	37	66
Year 6	14,631	78,370	71,578	71,578	83,734	37,548	8,562	52,802	152,875	35	62
Year 5	13,778	73,801	67,405	67,405	78,852	35,359	8,063	49,724	143,962	33	58
Year 4	12,882	69,004	63,024	63,024	73,727	33,060	7,539	46,492	134,605	31	55
Year 3	12,122	64,932	59,305	59,305	69,377	31,110	7,094	43,749	126,663	29	51
Year 2	11,600	62,134	56,749	56,749	66,387	29,769	6,788	41,863	121,204	28	49
Year 1	10,916	58,468	53,401	53,401	62,470	28,012	6,388	39,393	114,053	26	46

Table 4: Crop selling prices.

Selling Price	Soya (bag of 60kg)	Silage corn (per ton)	Corn (bag of 60kg)o	Sorghum (bag of 60kg)	m3 of eucalyptus
Year 7	60,00	100,00	22,00	16,00	29,00
Year 6	56,45	94,09	20,70	15,05	27,38
Year 5	53,16	88,60	19,49	14,18	25,78
Year 4	49,71	82,85	18,23	13,26	24,11
Year 3	46,77	77,96	17,15	12,47	22,69
Year 2	44,76	74,60	16,41	11,94	21,71
Year 1	42,12	70,20	15,44	11,23	20,43

The land lease price is R$ 3840.00 for seven years.