INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS

A Brazilian Experience for Sustainable Farming

Technical Editors
Davi José Bungenstab
Roberto Giolo de Almeida

FAMASUL
Federação da Agricultura e Pecuária de MS

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Brazilian Agricultural Research Corporation
Embrapa Beef Cattle
Ministry of Agriculture, Livestock and Food Supply

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Epigraph

"Advice is judged by results not by intentions"

Cicero (106 bC- 46 bC) – Roman author, orator and politician

Dedication

We dedicate this work to our future generations,
who will live from the land we are cultivating today.

The editors

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The editors

Foreword

Brazilian agriculture´s extraordinary advance is a case of success in a global context. The country has large territory, good soils, favorable climate and relief, added to especial efforts to consolidate an agricultural research and development network. The first milestone of the technical advances was the creation of Embrapa in the 70's, making available a set of elements that turned Brazil into an agricultural power.

Along with these favorable conditions is the will power of man and women who faced all sorts of obstacles and hostile conditions to settle themselves in the production frontiers during the last decades. The result is that Brazil no longer was a net food importer, but a global player exporter, also supplying the booming domestic demand. Brazilian population grew from 90 to almost 200 million people in this period, consequently having a drastic increase in its purchasing power.

Brazilian grains and fiber production grew 312% in the last 37 years, reaching 193 million tons in 2014, while the harvested area only grew 47% in the same period. Therefore, farmer's efficiency increased yields in 179%. The country still has 61% of its natural biomes preserved, appropriating less than 28% of its territory for agriculture.

Brazil has taken the responsibility to increase food and renewable energy production to help supply world demands based on sustainable production concepts, wisely using natural resources and preserving biodiversity.

According to the Food and Agriculture Organization of the United Nations (FAO), food production must have a 60% increase until 2050 to supply the growing global demand, due to economic development and consequent higher consumer's purchasing power. Besides population growth, higher life expectancy also contribute to raise demand.

From these results reporting the efficiency of its farming systems, Brazil ought to correspond the expectations from many other nations to help ensure the future necessary food supply.

Central-Brazil, or the Brazilian Midwest, bravely responds to this call. This region is responsible for 41% of the Brazilian agribusiness production. This ratio is increasing due to several factors, including the association of several crops in the same area, the integrated production systems, that escalate total yields in the area.

In its role of representing farmers and investing in agribusiness development, Famasul´s system promotes initiatives aiming efficiency improvements for all participants of the agricultural production chains. The system is constituted by the Agriculture and Livestock Federation of Mato Grosso do Sul State (Federação da Agricultura e Pecuária de Mato Grosso do Sul – FAMASUL), National Rural Learning Service (Serviço Nacional de Aprendizagem Rural – SENAR/MS), Soybeans Growers Association (Associação dos Produtores de Soja – APROSOJA/MS), and farmer unions. The system provides direct assistance and education for farmers and field workers, carrying out several projects to increase production efficiency. In 2013, SENAR/MS sponsored 2,400 educational activities, reaching 34.6 thousand people. Technical and practical training are major factors that assure the efficacy of Brazilian agriculture, sustainably increasing its yields.

Production and preservation are actually two sides of the same coin, having in science its reliable basis to fulfil expectations of an attentive society. Brazilian farmers find the appropriate settings to harmonically combine production and preservation, developing technologies in an environment of constant innovation. This is the scenario where publications like this one emerge, having as finger prints Embrapa´s work characteristics, which has become an international reference in tropical agriculture.

Clear, objective and didactic, this book provides technical and scientific subsides for an agricultural practice that fully represents agricultural development goals: sustainable production. Produced by a highly qualified research and development team, committed to sustainable progress through agricultural practices improvement, the following pages gather research results from many investigations on integrating crops with cattle husbandry and forestry.

At the bottom end it is clear that commercially associating two or more farming activities results not only in increased yields, but also in substantial environment preservation gains. We believe that the information here presented and the extensive technical knowledge that validates this information can be an important contribution for expanding integrated production systems worldwide, increasing not only yields, but also the positive externalities of sustainable agricultural systems.

Eduardo Corrêa Riedel

President of the Agriculture and Livestock Federation
of Mato Grosso do Sul State- FAMASUL

Preface

Agribusiness has as global mission of sustainably supplying food, fibers and energy, not negatively affecting biomes and striving for natural resources conservation. It is known that agricultural yields increase is one of the alternatives to increment the world´s food production, with no need for clearing more areas. However, systems performance improvement and increase in productivity demands systematic development of technological solutions to be transferred and adopted throughout the various sectors of the agribusiness productive chains.

This work is precisely inserted within this context, offering farmers, agriculture professionals and academics innovative technologies for integrated crop-livestock-forestry systems, since Brazil has been taking a leading position on the subject. These systems are original in the Brazilian agribusiness sector, and in this book their most relevant aspects are described and examined. It starts from a broad approach on agriculture sustainability and its assessment for ILPF systems. It goes over planning and detailed implementation and management of the different system's components to finally reach products quality and application, within the global sustainability scenario for food, fiber and bioenergy.

The book approaches also innovation, perspectives and future challenges of the Brazilian agriculture, including some silvipastoral system simulations, closing with discussions of similar systems from other countries for possible extrapolations of Brazilian systems.

This works joins knowledge from several Embrapa´s researchers and partner institutions. The experience gathered in previous editions added to contributions given by many experts from various fields, leads not only to a valuable collection of information, but it also delivers an easy to read sequence of chapters enabling a practical usage to all who search for crop-livestock-forestry systems information.

Another innovative aspect of this work is to provide spreadsheets, applications and tactical schemes that may be used by farmers, technicians and consultants in the field while planning and implementing their own integrated systems.

This is a valuable initiative on integrated systems, set to be used in Brazil, which may be adopted in other countries at tropical and sub-tropical regions around the globe.

Finally, Embrapa as a core scientific and technological institution for tropical agriculture and livestock issues, together with its partners, in the attempt to fulfill its role, provides this work as a support to all who may benefit from it, promoting sustainable development of our nation and working to supply the world with more high quality food, fiber and bioenergy.

Enjoy your reading!

Cleber Oliveira Soares

Director-General of Embrapa Beef Cattle

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Concepts and Initiatives for Sustainable Agriculture

Davi J. Bungenstab
Aziz Galvão da Silva Júnior
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Cosimo Rota

FOOD PRODUCTION AND THE SUSTAINABILITY ISSUE IN MODERN AGRICULTURE

To increase food production in order to mitigate poverty and hunger are great international challenges for agriculture in the near future. Academic discussions about the effects of population growth on world's economy formally began with Thomas Malthus' work in England 18th century, during the industrial revolution. According to him, population growth and limited natural resources, mainly arable land, would lead to economic stagnation. However, technology and industrial inputs, like mechanization and chemical fertilizers, increased yields and released a great deal of labor for the urban industry.

Positive economic impact, however, was concentrated in industrialized nations, many of them extracting raw materials from their colonies. After World War II, the systematic spread of a technology package based on genetic improvement, chemicals and further mechanization allowed significant increases in agricultural yields, remarkably in developing countries, with a new scenario for production technology, since specific inputs, machines and techniques were developed to fulfill higher demands of much more productive but vulnerable crops. Broad use of modern high energy demanding inputs, mostly based on fossil fuels, accelerated economic growth and, at the same time, increased the degradation of the environent. Developing countries, especially in Asia and Latin America, supported by public policies and international companies, adopted these technologies on a large scale especially between 1961 and 1985. Grain production more than doubled in many areas. This transformation was extremely remarkable in the Brazilian biome called Cerrados.

Today, world food production is just enough to supply the global demand. However, as a consequence of political, physical, and mostly economic frictions influencing the access to food, it is estimated that 842 million people are undernourished (FAO 2013a). Expected population growth leads to estimates that world's food production will have to increase in 60% to supply additional demand, naturally increasing pressure over natural resources.

In 1972, Meadows published the book "Limits to Growth", where results of a simulation model indicated that environmental impacts, caused by increased production to maintain high consumption levels, would lead to a collapse in the global economic system. The work had influence in both, academy and public opinion. The model was revised in 1992 and 2005, respectively published in the books "Beyond the Limits" and "Limits to Growth: The 30 year Update". The alert emphasized is: "*…the global challenge can be simply stated: to reach sustainability, humanity must increase the consumption levels of the world´s poor, while at the same time reducing humanity´s ecological footprint*". Whereas the Food and Agriculture Organization of the United Nations (FAO) defines sustainable development as "*the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such* *sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable" (FAO Council, 1989).*

When promoting sustainable agriculture, therefore, all these aspects should be taken into account, what is not necessarily easy in all circumstances. In fact, even though intimately related, economy and environment interactions are sometimes conflicting, also for the agricultural sector.

Economy-Environment Interactions

Mass conservation principles apply also to the economic activities. Any productive process is a transformation process extracting basic resources from environment in order to aggregate value for human consumption. Though using other important resources as land and water, agriculture has the great advantage of transforming "non-cost" sunlight into valuable goods in very short periods of time. However, sooner or later, all materials return to the environment, either as rests of production inputs or remains of final products. In the scope of agriculture, therefore, a system is closer to sustainability when it demands less natural resources, generates less residues and harvest highest yields per area, respecting local potentials. This cannot be obtained without extra economic resources application and therefore, remuneration for these extra investments is core in the sustainability debate.

Any productive process is a transformation process extracting basic resources from environment in order to aggregate value for human consumption.

Consumers, or at least part of them, might be aware and willing to remunerate more sustainable products. But they want to know how sustainable they are. Or at least, if they are indeed sustainable or not. However, measuring sustainability i.e. sustainable products or practices, is still a challenge not only to industry, but also for the academy. Many initiatives and assessment methods exist for the agricultural sector. There is no single definite approach, but putting together different approaches and adapting them to different situations seems to be the best alternative nowadays.

SUSTAINABILITY ASSESSMENTS FOR AGRICULTURAL SYSTEMS

To know where one stands is a principle for further progres, also towards sustainability. Analysis of strengths and weakness of an operation is essential for improvement and sometimes even for its very existence. Only what can be measured can be managed. The FAO definition for sustainable development begins with: "*the management and conservation*…". Therefore, the more accurate assessments of a system regarding sustainability are, better are the chances to achieve ***proper management*** towards it. Such assessments can encompass broader regions or single production units or products, focusing on a multitude of aspects, or just a few, according to the assessment goals and resources available.

When assessing agriculture sustainability, it is important to bear in mind that impacts are not only occurring in the production sites, but also before and after farm gates. A whole production chain approach, even if carried out in different phases, is advisable. As well as influences of parallel interests should also be considered like issues related to land tenure or economic stability, leading to land use change/deforestation in developing countries, which many times are mistakenly attributed solely to agriculture, which, in fact, uses these areas.

Integrated Crop-Livestock-Forestry Systems

Only efficient agriculture can supply world's needs for food, energy and other materials.

Only efficient agriculture can supply world's needs for food, energy and other materials. Modern technologies can have the reverse impact on environment that green revolution technologies had. Synergies among different components can be decisive for system's improvements towards sustainability. Therefore, integrated production systems can play a major role, since they gather several production systems into one, allowing many different combinations according to local potentials and needs.

Such integrated systems are not expected to be "the solution" for all situations everywhere. However, they have been proving to be a very good alternative, especially in agricultural areas with acute or gradual natural resources degradation problems, where farmer's income is compromised and other high-tech solutions for monocultures are too expensive to be adopted.

Brazil has pioneered some avant-garde agricultural technologies in the world. The no-tillage system and the combined two harvests a year using soybeans and maize or cotton in many parts of the country, the locally called "safrinha" systems, are good examples. Likewise, Brazilian integrated crop-livestock and crop-livestock-forestry systems are somehow unique in the way they operate, especially regarding component's rotation time, ability to pay-back investments for soils recuperation/improvement and revenues diversification, helping to stabilize farmer's finances.

The Brazilian model, when professionally carried out, can run a full cycle in periods as short as four years, including the forestry component. Besides soil improvement, grain crops and cattle sales provide to the farm, while timber can bring high financial returns at the end of the cycle, i.e. allowing higher and further investments with farmer's own funds.

These modern Brazilian integrated systems present many particular and innovative aspects compared to other integrated crop-livestock-forestry systems in the world and are still under development in several aspects. However, they can be considered mature enough to be presented and evaluated as an alternative for sustainable farming. Systematic evaluations of such systems are necessary to identify opportunities for improvement and adaptation to different regional circumstances.

Sustainability assessments are essential for providing feedback on these different systems performance in relation to the many different dimensions of sustainability. There are over a hundred scientifically based methods to assess sustainability or some of its aspects. None could claim to be definitive. Their application depends on the suitability of the method to the circumstances and assessment goals, as well as the data availability. A comparative analysis of many different assessment methods and their suitability for evaluating integrated systems is not possible within the scope of this chapter. Therefore a choice has been made to describe one significant sustainability assessment framework, the FAO's framework SAFA – *Sustainability Assessment of Food and Agriculture Systems*. The SAFA framework is briefly presented and its usefulness for orientating further research and development aiming system's improvements is addressed.

SAFA – SUSTAINABILITY ASSESSMENT OF FOOD AND AGRICULTURE SYSTEMS

The framework for sustainability assessment has been developed by the Natural Resources Management and Environment Department of FAO. Quoting its Guidelines – Version 3.0 (FAO, 2013b), "*SAFA is a holistic global framework for the assessment of sustainability along food and agriculture value chains*" and "*SAFA establishes an international reference for assessing trade-offs and synergies between all dimensions of sustainability… By providing a transparent and aggregated framework for assessing sustainability, SAFA seeks to harmonize sustainability approaches within the food value chain, as well as furthering good practices… SAFA aims to fill the gap between specific sustainability tools, while fostering partnerships for the long-term transformation of food systems*".

The assessment framework should be useful for members from agricultural product chains of all sizes, from a family farm to a big processing plant. It would help them evaluate their performance regarding applicable components of sustainability within their specific situation as well as to support planning and police making for whole regions. Therefore, SAFA demands adaptation regarding location, kind of operation, data availability and adoption of standards and tools.

SAFA considers four sustainability dimensions: Good Governance (G), Environmental Integrity (E), Economic Resilience (C) and Social Well-Being (S). These dimensions currently cover 21 themes which are considered core sustainability issues associated with its goals as well as they can be implemented at any level.

These themes have 58 sub-themes that are meant to help in the search for risks in the systems and possible gaps, being an institution's initiatives towards sustainability. The sub-themes, however, have 116 indicators, whose definition, quoted from the SAFA Guidelines Version 3.0 is: "…*identify the measurable criteria for sustainable performance for the sub-theme. These default indicators are examples that can be used if no other more appropriate indicators are available and*

SAFA considers four sustainability dimensions: Good Governance (G), Environmental Integrity (E), Economic Resilience (C) and Social Well-Being (S).

CHART 1.1
The 21 Themes Covered by SAFA

GOOD GOVERNANCE	ENVIRONMENTAL INTEGRITY
G1 Corporate Ethics	E1 Atmosphere
G2 Accountability	E2 Water
G3 Participation	E3 Land
G4 Rule of Law	E4 Biodiversity
G5 Holistic Management	E5 Materials and Energy
	E6 Animal Welfare
ECONOMIC RESILIENCE	**SOCIAL WELL-BEING**
C1 Investment	S1 Decent Livelihood
C2 Vulnerability	S2 Fair Trading Practices
C3 Product Quality and Information	S4 Equity
C4 Local Economy	S5 Human Safety and Health
	S6 Cultural Diversity

Source: Adapted from FAO 2013b.

are applicable at the macro level – meaning to all enterprise sizes and types, and in all contexts. Default indicators serve the purpose of providing standardized metrics to guide future assessments on sustainability. Default performance indicators for each sub-theme facilitate measuring progress towards sustainability".

The SAFA Guidelines, assessment tools, details regarding their use and liabilities as well as other resources are provided by FAO and can be downloaded from: http://www.fao.org/nr/sustainability/sustainability-assessments-safa.

SAFA implementation procedures are well described at SAFA Guidelines.

SAFA implementation procedures are well described at SAFA Guidelines, whose reading is mandatory for good implementation. Basically, implementation procedures should follow four sequential steps: Mapping, Contextualization, Indicators and Reporting, with its respective actions as described in Chart 1.2. Following the guidelines instructions carefully, should provide good assessments for farmers, companies and other institutions interested in improving sustainability of their operation or regions.

CHART 1.2
Illustration of SAFA Implementation Steps and Main Actions

STEP 1 MAPPING	STEP 2 CONTEXTUALIZATION	STEP 3 INDICATORS	STEP 4 REPORTING
Description of assessed entities	Sub-themes: review of sub-themes based on boundaries and sustainability objectives	Indicator selection	Polygon at aggregated and broken down level to illustrate sub-theme scores together with contextual issues, including risk areas (hot spot issues), boundaries and data quality, based on Accuracy Score.
Boundaries of assessment (space and time) and visual representation		Irrelevant sub-themes and indicators are not selected	Final report, where all relevant issues and scope are treated and rationale, irrelevant sub-themes and indicators are justified, areas for improvements are identified. See Appendix B of SAFA Guidelines: Performance Report Checklist.
		Guidance notes for indicators Determine Accuracy Score for each indicator	Critical Review – two levels are outlined – Level 1 for less formal SAFA assessments which involve documenting the results but this is not subject to external 3rd party audit, while Level 2 for more formal applications of SAFA includes a 3rd party audit.
What is excluded from SAFA? (cut-off criteria)		Documentation of input data and score	
Relationships of different supply chain members	Indicators: review of default (or replacement) indicators in relevant sub-themes and use of data regarding geographical, environmental, social, political and economic context to determine detailed ratings	Rating at indicator level, aggregation of results at sub-theme and theme level	

Source: adapted from FAO 2013b

SAFA Applications to Integrated Crop-Livestock-Forestry Systems

SAFA as a framework has many advantages and great potential for application in integrated systems. It can be used by farmers or farmers associations to know their current status on the subject. SAFA can provide orientation for possible certifications or applying differentiated credit from private and public institutions. Regional governments or other bodies would consider assessing local sustainability of agricultural systems and the insertion of integrated systems in this context, assessing also their importance in improving regional sustainability.

SAFA can provide an excellent framework for establishing priorities for national or institutional research on the subject.

In an Academic context SAFA prvides a very interesting conceptual framework and a guide providing directions to future research developments on sustainability. Much is still to be done regarding good governance and social well-being assessments. Naturally, when addressing single indicators, one realizes that there are investigations on all fields. However, SAFA can provide an excellent framework for establishing priorities for national or institutional research on the subject. In this sense, when other institutions overseas adopt the same approach towards directing research on the subject, suitable methodologies developed can be exchanged/adapted, allowing comparisons, and most important, creating a synergetic cooperation for world-wide improvement of more sustainable integrated crop-livestock-forestry systems.

THE SALSA PROJECT EXPERIENCE IN THE CONTEXT OF SUSTAINABLE AGRICULTURE

The SALSA Project, "Knowledge-based Sustainable vAlue-added food chains: innovative tooLs for monitoring ethical, environmental and Socio-economical impActs and implementing EU-Latin America shared strategies", is an European Union (EU) funded project aiming at the sustainable development of Latin American-EU soy and beef supply chains by improving their access to the EU and global markets for sustainable products. The project goal considers the necessity to handle the growth in the global demand for these products; it defines sustainable development strategies able to tackle the challenges that beef and soy production posed to the Latin American countries environment, economies and societies.

To this end, the SALSA project needed to enhance the knowledge of Latin American and EU environmental, economic and social contexts and assess the different dimensions of sustainability and their relevance for the beef and soy chains. A relevant part of the project took place in the Mato Grosso do Sul State, Brazil, in relation to sustainable beef chains assessment and implementation, including local integrated production systems.

Within this framework, the different supply chains structure, the set of certification schemes and regulations involving sustainable food export were investigated. The different stakeholders awareness on sustainability was also analyzed; the most relevant soy and beef chain players in different EU and Latin American countries were interviewed, and an extended survey on about 800 consumers was carried out. In a final stage, the sustainability performance of the soy and beef chain was assessed in Brazil Argentina and Mexico. Within Brazil, soybeans production and beef cattle husbandry in the Mato Grosso do Sul State were assessed, considering its relevance not only from the quantitative point of view, but also for the possibility to compare the sustainability of different beef production systems. The sustainability indicators provided by the FAO-SAFA approach were considered and adapted to the different country and regional contexts. Functional units (1 kg of boneless beef, and 1 ton of soybean meal) system boundaries (from Latin

American fields to EU ports), production systems and indicators able to capture the most relevant impacts on sustainability of the soy and beef production were selected. Both quantitative Life Cycle Assessment (LCA) based approaches and qualitative assessments were applied to score the sustainability performance. In particular for Brazil, three cases on different beef production systems were selected: specialized beef system based on pasture, integrated and organic beef systems. Following the sustainability assessment, the analysis of the impact of sustainability improvement solutions on the soy and beef chains has been carried out.

To further support the food chain agents and other stakeholders' decisions on sustainability strategies and contribute to the public debate on sustainable development, the SALSA results have been disseminated to different stakeholders (farmers, food industries, civil society and policy makers) in different areas of Latin America and the EU. This was carried out through training courses, conferences, scientific papers, newsletters and web-based resources. Successful cases of sustainable solutions in soy and beef chain sustainability have been analyzed; brochures reporting the main SALSA results were also delivered to the general public. The main difficulty that SALSA faced is to provide clear and non-misleading information on issues, which sometimes go against established and widely accepted beliefs related to sustainability.

The SALSA results on sustainability assessment showed how widely accepted opinions like the zero miles and organic intrinsic superior sustainability against more conventional systems are not so clearly confirmed. In particular the analysis of a representative integrated system used in the Mato Grosso do Sul State, Brazil, showed better performances related to land use and global warming, when compared to the other two beef production systems. These two indicators are absolutely relevant within the Brazilian context since they relate to the extremely sensitive discussion on beef contribution to global warming and soil degradation/deforestation. The latter largely contributing to Brazil overall reputation in terms of sustainability in its food production. The big players in the beef processing and retailing sector are more and more involved in sustainable beef procurement. Integrated production systems can, thus, have a huge impact on the possibility for Brazil to enhance its competitiveness in the global beef trade. The sustainability content of agricultural commodities is often promoted through guarantee systems. With this respect SALSA implemented a database containing the main certification schemes and regulations related to sustainability in the beef and soy chains. The users of the SALSA project results will be able to assess how their activites sustainability performance is in line with the main requirements included in relevant sustainability schemes. This will increase their access to the global markets for sustainable products, thus fulfilling one of the main goals of SALSA project. Moreover, SALSA performed an analysis on the degree of inclusion of the different sustainability dimensions in different certification schemes, as defined in the SAFA guidelines. These, and other SALSA results, provide support to policy makers, civil society, standard setting bodies and the consumer's discussion on new sustainability strategy implementation.

The sustainability content of agricultural commodities is often promoted through guarantee systems.

The Brazilian integrated farming system represents an excellent case, showing how sustainability is not related to a single production protocol or standard, but can be reached in different ways according to different natural, social and economic contexts.

FINAL REMARKS

The Brazilian integrated farming system represents an excellent case showing how sustainability is not related to a single production protocol or standard, but can be reached in different ways according to different natural, social and economic contexts. The complexity of assessing sustainability and interpreting the results also emerged, showing still existing limitations in objective quantitative measurements, making it necessary to integrate the debate on sustainability implementation with political, social and economic feasibility considerations. There is, consequently, room for a discussion on sustainability definition and certification among the different stakeholders, as for example is happening in the Global Roundtable for Sustainable Beef (GRSB) or the Round Table on Responsible Soy (RTRS) initiatives. The Brazilian ILPF experience for beef cattle farming is showing how, by merging sound scientific and technological research with a strong involvement of the different stakeholders from the civil society and the public and private sector, meaningful progresses towards putting sustainability into practice can be obtained. Last but not least the global dimension of projects like SALSA, the FAO-SAFA and other international initiatives, is also reducing the communication gaps between different actors and countries supporting an effective global debate on sustainable food production.

Chapter

2

Integrated Systems: What They Are, Their Advantages and Limitations

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Davi José Bungenstab
Roberto Giolo de Almeida

THE INTEGRATION OF CROPS, LIVESTOCK AND FORESTRY AS A SYSTEM

The agricultural sector has been undergoing major changes due to higher production costs and a more competitive market, requiring an increase in yields, quality and profitability, without harming the environment. In order to achieve these goals, an alternative that has gained increasing space in recent years is the use of integrated systems that incorporate crop, livestock and forestry farming in a temporal and/or spatial framework, seeking synergies among the agro-ecosystem components for the sustainability of the farm, including legal environmental compliance and valuation of natural capital (BALBINO et al., 2011).

This strategy systemic approach also incorporates other desirable attributes for the local agro-ecosystem regarding legal environmental compliance, when considering Brazil, the maintenance of Permanent Preservation Areas (PPAs) and Legal Natural Reserves (LR), recognizing the benefits of the environmental services provided by them to the production systems.

Integrated systems are currently expanding, especially grain, fiber, energy, timber, meat and dairy farming depending on the region. Using integrated systems whenever suitable can greatly help recovering degraded agricultural areas.

According to Balbino et al. (2011), integrated systems in Brazil are basically classified into four major groups:

1. **Integrated Crop-Livestock or Agropastoral System:** a production system that integrates the crop and livestock components in succession, rotation, or combined in the same area and in the same agricultural year or for several years, sequentially or alternating.
2. **Integrated Forestry-Livestock or Silvipastoral System:** a production system that integrates the livestock (pasture and animal) and forest components, in association. This production system is focused on areas where it is hard to grow crops and therefore only includes the forest and livestock components.
3. **Integrated Crop-Forestry or Silviagriculture:** a production system that integrates the crop and forest components through a combination of tree species with annual or perennial crops.
4. **Integrated Crop-Livestock-Forestry or Agrosilvipastoral:** a production system that integrates the crop, livestock and forest components in rotation, succession or combined in the same area. The crop component may or may not be restricted to the initial phase of implementation of the forest component. There are a number of institutions and scientists involved in further developing and expanding this system in Brazil. This initiative is so consolidated that the system in Portuguese called "Integração Lavoura-Pecuária-Floresta" became a concept and a trademark, as illustrated in Figure 2.1. For this reason,

Figure 2.1
Brazilian ILPF trademark.

the Integrated Crop-Livestock-Forestry systems, or agrosilvipastoral systems, which is abbreviated as ICLF systems, following the scope of this publication, sometimes can be abbreviated as ILPF, since many concepts and technologies presented are directly linked to the Brazilian experience.

The ICLF system is becoming an established technology with good perspectives of expansion in the whole country. Especially in cattle ranching areas, the use of Eucalyptus as tree component and soybeans/maize crop combinations are becoming the most popular.

This system is the main focus of this publication, since the other in regard to the implementation of these systems, there are four distinct situations: the introduction of agriculture over pasture areas, the introduction of pasture over cash crops areas and the introduction of forestry into crop or pasture areas, followed by the use of the area for animal grazing.

Periods for crop, grazing or forest cultivation will depend on the system adopted. Livestock can be used for periods of one month to five years, returning the area for crop cultivation for periods ranging from five months to five years. The forestry component can be used for one or more cuts, depending on the species used.

In regions where both soil and weather are suitable for growing grains, livestock can be used for periods of 6 to 18 months and crops for 2 to 5 years.

The main purposes of pasture introduction into predominantly cropping systems are:

- Crop rotation;
- Increased straw production for no-till crop cultivation;
- Restructuring soil physical components;
- Increased organic matter content in the soil;
- Reducing pests, diseases and weeds.

In regions with no infrastructure, unfavorable weather, marginal soil, little agricultural tradition and grain crops restrictions, it is necessary to check agricultural zoning in order to restrict cultivation to more resistant crops, like sorghum instead of maize. In these cases, livestock should remain for longer periods. In such systems, grain crops are used to recover degraded or degrading pastures. New pasture is subsequently sown, benefiting from improved soil fertility, which results in increased yields and forage quality, especially in the most critical dry periods of the year, i.e. between May and October in most Brazilian regions.

Some examples of practical alternatives for these systems are:

- Area renewal by improving the soil through a cash crop for one or more years, followed by grass seeding after harvest or mixed with the crop, using pasture for one or more years and then returning to crop for a given period;
- Pasture recovery introducing the forestry component in a region where both soil and weather are favorable for grain cultivation. In this system, cash crops are usually grown for two years allowing forest to establish, afterwards grass sowing and animal grazing are introduced for several years until trees are harvested;
- Pasture recovery solely with implementation of the forestry component. In regions technically unsuitable for grains, fiber and energy crops, the silvipastoral system is the most viable option. In this system, trees are planted in recovered or renewed grazing areas. In the first years, forage can be used to produce hay or silage until the trees are established, protecting them from animal browsing. Depending on the size of the area, electric fences can be used, allowing animals to use the area as soon as the first year. In the case of Eucalyptus for example, animals can graze already on the second year, especially by younger categories.

These integrated system models are defined based on the environmental and socioeconomic aspects of the different agro-ecosystems as shown in Figure 2.2 comprising different alternatives and solutions for the main farm problems. Expected results reflect entrepreneurial farmers immediate expectations and are focused on the development of sustainable agriculture (BALBINO et al., 2011).

With the introduction of ICLF systems, in addition to land use intensification and increased efficiency, other environmental benefits are generated.

With the introduction of ICLF systems, in addition to land use intensification and increased efficiency, other environmental benefits are generated, including higher carbon sequestration, increased soil organic matter, reduced erosion, improved microclimate conditions and animal well-being. Economic benefits generated by diversification include lower production costs, increasing yields and leveling risks inherent to agriculture especially related to weather and market variations.

Regarding research and development for sustainable production of food, fiber, energy and environmental services, according to Balbino et al. (2011), integrated systems play an essential

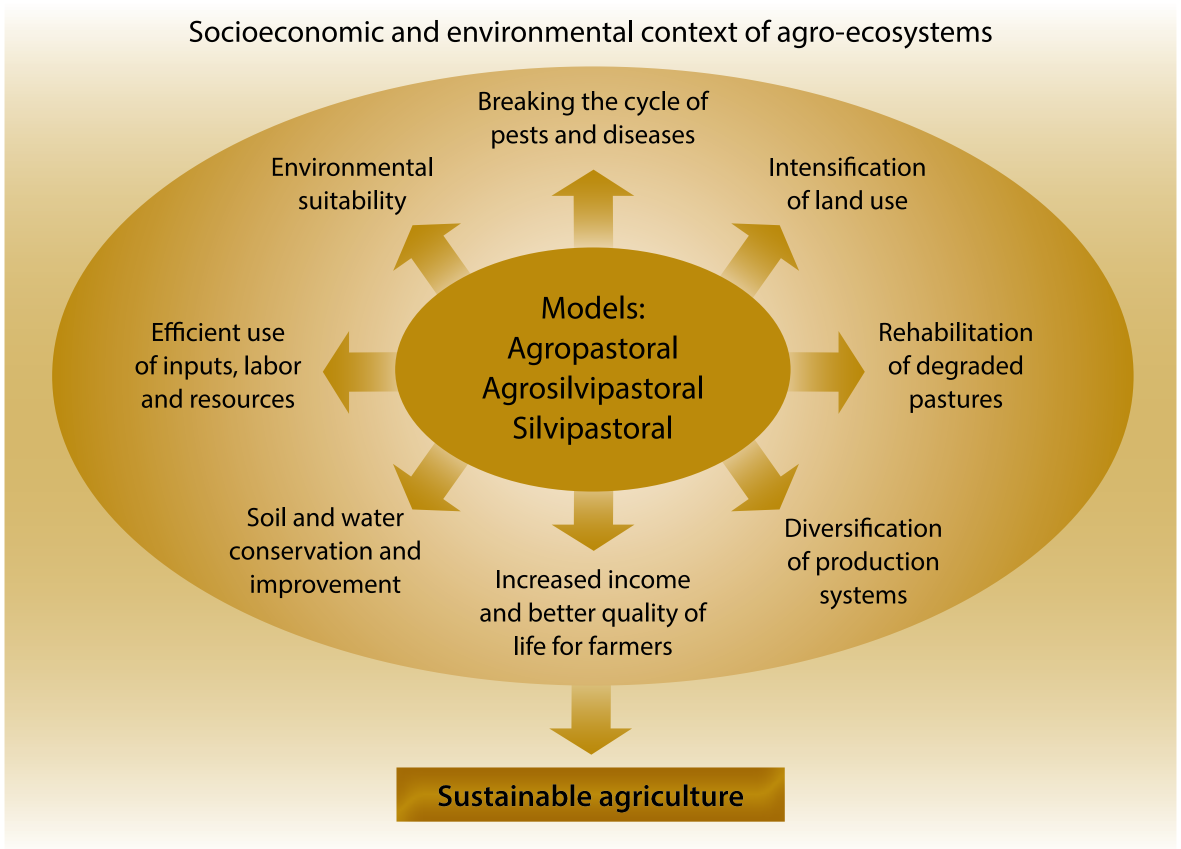

Figure 2.2
Immediate goals and results of integrated systems application in agro-ecosystems (*adapted from Balbino et al., 2011*).

role and investigation is focused on developing agricultural systems that use especially the following items:

- Economically viable farming systems, with food security assurance;
- Search for alternative environmentally safe inputs, reducing contaminants;
- High precision technologies, reducing input wastes;
- Environmental management practices and modern equipment, improving systems' efficiency and facilitating monitoring;
- Agroecological technologies, with new designs and the integration of production systems;
- Systems that increase biological diversity and internal synergies;
- Regeneration/bioremediation technologies that allow reclaiming degraded/contaminated areas.

Integrated systems can be applied to small holders, medium and large farms.

- Land use classification, improving its monitoring and optimizing use of natural resources;
- Alternative energy sources (ethanol, wood, fibers and biodiesel);
- Environmental certification and management systems that strengthen competitiveness based on preventive strategies and anticipation of environmental problems;
- New institutional arrangements, farming and management as elements for market competitiveness;
- Valuation of environmental services provided by agricultural systems and their sur roundings.

In the development process of integrated systems, support technologies and different combinations and arrangements of components, it was possible to identify and assess their various advantages as well as upcoming challenges, especially in regard to their implementation. The main benefits and challenges mentioned by Balbino et al. (2011) and Kichel et al. (2011) are listed herein. It is important to mention that because of their integrated characteristics and dependence on local conditions, all factors listed below neither are arranged by system component nor follow a hierarchy of importance.

MAIN ADVANTAGES OF INTEGRATED SYSTEMS

- Can be applied to small holders, medium and large farms;
- More efficient control of insects, diseases and weeds, leading to lower pesticide use;
- Improved microclimatic conditions thanks to the tree component reducing thermal amplitude, increasing air humidity and lowering wind intensity;
- Increased animal well-being due to improved thermal comfort;
- Possibility of using the most suitable species and cultivars for each region;
- Possibility of reducing pressure for clearing natural vegetation areas;
- Unwanted plants, which normally occur in young forest plantations, are replaced by crops and/or forage, making maintenance less expensive;
- Global warming mitigation through carbon sequestration especially by forest and forage components;
- Supporting biodiversity protection, especially due to the abundance of "border effects" or interfaces, improving synergy through new niches and habitats for crop pollinators and natural enemies of pests and diseases;
- Intensification of nutrient cycling;

- Creation of attractive landscapes that may favor rural tourism activities;
- Increased regional production of grains, beef, milk, fibers, timber and energy;
- Increased competitiveness of the beef chain in domestic and international markets, with better quality carcasses and shorter-cycle cattle raising, based on feed quality, sanitary control and genetic improvement;
- Enhanced milk yield and quality, even for grazing systems in the low season (dry period), especially for small and medium farmers;
- Higher turnover for several segments of local economy;
- Reduction of operating and market risks due to improved farming conditions and diversification of commercial activities;
- Slowing down migration processes and increasing social benefits through jobs and income generation;
- Motivation for improving professional skills;
- Facilitating participation of organized civil society;
- Diversification of farm activities, improving year-round labor demand;
- Increased soil cover from crops and pasture residues. This interaction prevents losses through erosion (soil, water sources, organic matter and nutrients), stimulating the biota and its physical recovery;
- Recovery of nutrients that have leached or drained to deeper soil layers, especially through tree and forage roots , increase of soil organic matter through litter and decaying plant residues;
- Potential for partnerships with more benefits for both, landowners and tenants.
- Lower costs for afforestation through pasture and/or annual crops cultivation;
- Alternative for introducing commercial forestry and cash crops in grazing areas with higher agricultural potential. As a result, agriculture expansion is maintained on a sustainable basis, helping reduce pressure to clear new areas for crops;
- Increased pasture carrying capacity due to improved soil fertility and more frequent maintenance;
- Encouragement to replace available forage with more productive species or cultivars;
- Compared to forestry, accelerated individual tree growth in terms of diameter, due to wider spacing;

With ICLF systems, agriculture expansion is maintained on a sustainable basis, helping reduce pressure to clear new areas.

- Financing or reducing forestry and/or pasture implementation costs, due to the lower number of trees planted (in some arrangements) and alternative income from crops and livestock components;
- Improved timber quality, due to more regular thickness of growth rings, more adequate for industrial processing;
- Possible reduction of fire accidents due to crops presence reduce straw trough animal grazing;
- Potential for high quality timber, with tree species that are little used in traditional forest plantations, but have high value in medium- and long-term ICLF projects;
- Direct and indirect benefits generated by biodiversity preservation, such as crop pollination;
- Species diversity and crop rotation help control erosion, increase soil porosity and, consequently, water infiltration to recover groundwater.

MAIN CHALLENGES OF INTEGRATED SYSTEMS

- Farmers traditionalism and resistance to adopt new technologies;
- Higher qualification and commitment demand from farmers, managers, technicians and workers;
- Higher financial investments;
- Returns in the medium to long term, especially in regard to the forestry component;
- Demand for sufficient financial available capital for investment or access to credit;
- High investments on infrastructure because of the integrated systems multiple components;
- Lack of basic regional infrastructure and local trade options; production depends on the availability and maintenance of machinery and equipment, and from factors external to the production unit, such as energy, storage and transport;
- Long distances to final consumers or processing industries. In some regions, inputs purchase such as fertilizers, seeds, seedlings, agrochemicals and animals is limited, and so it is for selling the outputs;
- Limited availability of skilled professionals, especially with formal education degrees;
- Adoption of new technologies, and in labor qualification, requires faster validation and transfer of the most suitable practices for each system;

ICLF systems demand higher qualification and commitment from people involved in the operation.

- Little emphasis on integrated systems in agriculture courses curricula;
- Government policy of incentives for adoption of integrated systems still under development;
- Increased complexity of ICLF adds risks to the system, especially due to crop component;

Despite certain initial obstacles to their adoption, ILPF systems, due to their increased management complexity, lead to the incorporation of correct attitudes by farmers, for example, in the management and disposal of the waste generated in the farm, including agrochemical packaging and waste water following legislation.

In addition to quality certifications issued by public and private institutions, trend for farms adopting integrated systems also become pioneers in the adoption of systematic improvement programs, such as Embrapa's Program for Good Agricultural Practices - Beef Cattle (http://bpa.cnpgc.embrapa.br/) and the Ministry of Agriculture, Livestock and Supply's program for the Integrated Production of Agricultural Systems (PISA), among others (http://www.agricultura.gov.br/portal/page/portal/Internet-MAPA/pagina-inicial/desenvolvimento-sustentavel).

Research and development institutions such as Embrapa work not only on developing technologies, but also on strengthening methodologies for transferring technology, knowledge, production techniques and processes, monitoring techniques and industrial processing for integrated systems. The goal is to develop systemic and continuing networks, involving research, extension services, farmers and strategic partners in a participatory manner in order to habilitate technology replicators.

The strategy which has been adopted is to continuously train extension services, financial agents, inputs dealers, farmers, managers and farm workers through the implementation of technological reference units and/or demonstration units, in addition to publications, lectures, field days and technical visits. Priority is given to participatory initiatives involving farmers, technicians, students, lecturers, industries and input traders.

In their turn, modern farmers willing to assume an entrepreneurial attitude should seek training and try to develop multidisciplinary teams to face the challenge of implementing a sustainable integrated farming project, always relying on the support of research networks and technology transfer.

Research and development institutions such as Embrapa work not only on developing technologies, but also on strengthening methodologies for transferring technology.

Chapter

3

Crop-Livestock-Forestry Integration and the Progress of the Brazilian Agriculture

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Cleber Oliveira Soares
Roberto Giolo de Almeida

THE EVOLUTION OF INTEGRATED PRODUCTION SYSTEMS

The integration of crops with livestock and forests and the association of animal husbandry with crop cultivation has been made since the beginning of agriculture. When this association is made in a planned and rational manner, it increases yields and generates environmental benefits. The concept of "Sustainable Agriculture" has been widely discussed and disseminated, but in order to be actually sustainable, it is necessary to benefit society as a whole. This means that sustainable agriculture should either maintain or improve production, with economic advantages for farmers, without harming the environment while providing food and other services.

Regarding livestock, beef cattle especially, several pasture areas have been established in succession or intercropping with annual crops. In Brazil, especially in the savannah areas that characterize the biome called *Cerrado*, the association of pastures with crops has been made since the1930s and 1940s through seeding forage grasses with annual crops or after them. The establishment of molasses grass (*Melinis minutiflora*), Guinea grass (*Panicum maximum*), jaragua grass (*Hyparrhenia rufa*) among others was made through seeds or seedlings between the rows after cultivation of corn, rice and beans, in more fertile soils (ROCHA, 1988).

This process has been intensified from the 1960s and 1970s, with the mechanized clearing of new areas in the South and Southeast regions and, especially, in the Midwest, where the *Cerrado* biome prevails. In this region, at first, these activities were stimulated by special credit programs and tax incentives. Most brachiaria areas in Brazil, and more specifically in the *Cerrado*, were established with annual crops after one or more years of crop cultivation, usually rainfed rice (KORNELIUS et al., 1979).

The replacement of native pasture with sown pasture, with or without annual crops, especially in the *Cerrado*, from the 1970s, has enabled substantial growth of the cattle herd with positive impacts in the national beef and milk yields. From 1970 to 2006, the total pasture area in Brazil increased only 12%, while the herd grew by more than 115%. Cultivated pasture areas, most of the time, were established in acid soils with low fertility, lacking mainly phosphorus, calcium and magnesium. In many situations, the soil used was marginal and even inappropriate for another cultivation (ZIMMER et al., 2011).

More than 80 million hectares were sown with grasses of *Brachiaria* genus, 90% of which occupied by two species: *Brachiaria brizantha* and *Brachiaria decumbens*.

In this context, from the 1980s, when pastures established in previous decades started do loose carrying capacity, there was the need and interest to recover them with annual crops, with several studies showing promising results. From this period on, Embrapa and other research institutions began and intensified the development of solutions and transfer of technologies to recover sown pasture areas with integrated crop-livestock systems (ILP), such as the Barreirão

System (KLUTHCOUSKI et al., 1991) and the Santa Fé System (KLUTHCOUSKI et al., 2000). More recently, interest for integrated systems has grown and, in addition to annual crops for pasture recovery, the forestry component has been introduced, leading to integrated crop-livestock-forestry systems (ICLF) (MACEDO, 2010) (Figures 3.1 A, B and C)

The reason for adopting these systems was mainly the need to recover degraded pastures and the environmental restrictions for clearing new areas of native vegetation, especially after the 1990s.

Although several studies show the benefits of having trees on pastures, such as improving landscape scene, microclimate characteristics, soil quality, animal welfare and forage quality and mitigating greenhouse gases (CARVALHO et al., 2001; CORSI., GOULART, 2006; ALMEIDA, 2010; EUCLIDES et al., 2010; MACEDO, 2010), information on how to manage the several specific components in ICLF systems is still limited.

The ILPF systems, with the appropriate management of crops, trees and pastures may increase production substantially, mainly when degraded or relatively unproductive areas are recovered. By adopting these systems, it is possible to avoid clearing new areas, resulting in environmental benefits, such as protection of native vegetation, soil and water resources conservation, in addition to promoting regional socio-economic development. By improving production processes, it is possible to reduce animals' slaughtering age, which, combined with appropriate diet, reduces methane emission by product unit, thereby helping to mitigate greenhouse gas emissions in cattle farming. Pasture, grain crops and forests will contribute to atmospheric CO_2 sequestration via photosynthesis and subsequent incorporation as organic matter.

Beef yield of degraded pastures in Brazil is around 30 kilos beef/ha/year, while in well managed recovered pastures with crop-livestock integration systems, it can reach up to 450 kilos/ha/year.

BEEF CATTLE IN BRAZIL AND THE ADOPTION OF INTEGRATED SYSTEMS

According to the Brazilian Association of Beef Exporters (ABIEC), Brazil has currently a cattle herd of 205 million head, in 2010, 43 million head were slaughtered, giving a total output of 9.3 million metric tons of beef in carcass-weight equivalent (ABIEC, 2012). Therefore, despite the large herd, average yield is estimated at only 49 kilos beef/ha/year. Overall, this figure is very low considering favorable climate and soil conditions and the genetic potential of forage species and available herd in the country.

Considering only growth and fattening phases, yield of degraded pastures is around 30 kilos beef/ha/year, while in well managed recovered pastures with crop-livestock integration systems, it can reach up to 450 kilos/ha/year.

It is estimated that standard sown pastures in the Brazilian *Cerrado* loses, on average, 6% of its production potential per year, even when correct species is appropriately implemented

Figure 3.1 A

Nelore cattle under integrated crop-livestock-forestry system.

Figure 3.1 B

Crossbred cattle under integrated crop-livestock system with brachiaria pasture after renovation with soybean.

Figure 3.1 C

Animals under and inter-seasonal bristle oat pasture cultivated over soybeans crop area.
Photos: Davi J. Bungenstab.

(MARTINS et al., 1996). This loss is mainly caused by inappropriate management and the lack of maintenance fertilization.

To help realizing the magnitude of the problem, Sparovek et al. (2004) studied three pasture renewal scenarios in Brazil, with average intervals between renovations of five, ten and fifteen years. They came to estimates of needs for renovating areas of twenty, ten and seven million hectares, for the different time spans respectively. According to Almeida et al. (2007), in Brazilian tropical cattle farming areas alone, the demand for pastures renewal is estimated at 8% of arable grazing areas, i.e. nine million hectares, with a need for between 90,000 and 135,000 tons of tropical forage seeds per year.

Cutting-edge farmers, who are still a minority, have sought to renew and maintain pastures adopting integrated systems, especially crop-livestock integration and ILPF. In these systems, the introduction of crops is not accidental, but a strategic component of production systems for beef, milk, grain, fiber, wood, energy and environmental services, which interact and complement themselves. A common example is the use of pastures interseeded with crops, which significantly improves plant cover and the organic matter in the soil, enabling no-till seeding and, consequently, increasing the potential for carbon retention, favored by larger above ground biomass and stronger root system of forages. Carbon incorporated into the soil as organic matter is protected by no-till cropping, as there is no soil inversion. This protection is expanded by the use of plant residues of tropical grasses, especially brachiarias, which have higher capacity to cover the soil, having alsolower decaying rates (Figure 3.2).

Carbon incorporated into the soil as organic matter is protected by no-till cropping, as there is no soil inversion.

With regard to animal production, grazing on previously cultivated fields, especially grain crops areas, has high forage yield and quality, with a more uniform supply, reducing the impact of seasonality on production and parasite infestations, resulting in higher animal performance than that of traditional pastures.

In order to define which options or alternatives for recovery or renewal of pastures are more suitable for each farm, it is essential to make a detailed diagnosis, with information regarding the region, the farm itself and the farmer. The diagnosis comprises local infrastructure and predominant production systems in the region, markets, farm's production system, production indices, management, suitability for cash crops and other factors.

In Brazil, with extensive grazing areas dedicated to commercial beef cattle farming, direct recovery of sown pastures is recommended when farm soil, climate, infrastructure, labor and financial resources availability are not favorable for adopting integrated systems. In this case, all investments on recovering pastures will have to be paid back by animal production alone.

When the diagnosis is favorable for grain, fiber or energy cropping, pasture renovation through ILP or ILPF may be recommended. With these systems, a large share of the investments will be returned by crop and/or forest production.

Figure 3.2

Inter-season maize crop (safrinha) intercropped with *Brachiaria* for cattle grazing after harvest and to be followed by no-till soybeans seeding in a Brazilian Midwestern farm. *Photo: Davi J. Bungenstab.*

According to Kichel., Miranda (2002), the potential for adoption of ILPF systems in different Brazilian ecosystems is mainly subject to the following factors:

- Availability of favorable soil and climate;
- Infrastructure for the production and storage of products and inputs;
- Own funds or access to credit;
- Mastery of technology for grain cropping, cattle-farming and forestry;
- Easy market access to purchase inputs and trade production;
- Access to technical assistance;
- Possibility to lease the land or to establish partnerships with experienced crop, livestock or forestry farmers.

Regarding the improvement of technology, products and processes for integrated production systems in Brazil, in an analysis carried out to identify future research and technology transfer needs, the formal research group "***Sustainable production systems and beef cattle production chains***" from Embrapa Beef Cattle, identified the following priorities:

- To continue evaluating new options of forage grasses for ILP and ILPF systems, especially the new cultivars under development by research institutions;
- To give greater emphasis to the selection and evaluation of legume species for ILP and ILPF systems, aiming to break the cycle of pests and diseases, and to increase nitrogen incorporation into the systems, consequently reducing production costs. These could also improve animal diets and consequently yields.
- To further study and carefully evaluate the effect of transgenic Bt crops, such as corn, in ILP and ILPF systems, which aim at controlling several caterpillar species.Because these caterpillars do not attack corn, they may migrate to the forage, causing severe damage. It is worthy to remind that transgenic crops, such as Bt maize, are produced through the transfer of gens of a bacterium (*Bacillus thuringiensis*) to the plant. These genes cause the maize to produce toxic proteins that kill the caterpillar when it feeds on the plant;
- To select forage cultivars, soybean, maize and other crops with increased tolerance to shade and better adapted to integrated production systems;
- To select tree species and varieties to expand viable options beyond eucalyptus;
- To select crop systems that facilitate the implementation of tree species on degraded pastures without the need for annual grain crops. This is a demand for systems where cash crops are not possible due to soil and climate limitations, but it can also serve as encouragement for cattle farmers who are not interested in crop farming;
- To enhance studies on pests and diseases in ILP and ILPF systems, to estimate risks of increasing some of them or causing suppressing effects through use of certain crop rotation or combination.
- To enhance studies on carbon balance and lifecycle assessments for products from ILP and ILPF systems;
- To evaluate the effects of ILP and ILPF systems on soil and water potential for soil conservation and improvement;
- To improve long-term ILP and ILPF experiments in strategic locations to evaluate carbon dynamics and changes in soil quality;
- To deepen studies on environmental impacts and energy accounting in ILP and ILPF systems and compare their carbon or ecological footprints with those of traditional systems in use;

One important research goal is to select crop systems that facilitate the implementation of tree species on degraded pastures without the need for annual grain crops.

- To expand technology transfer and economic assessment activities of ILP and ILPF systems, especially in commercial systems used by farmers in different regions;
- To propose regional zoning for the use of ILP and ILPF systems based on the local soil, climate and infrastructure.

INTEGRATED SYSTEMS IN THE POLICIES FOR BRAZILIAN AGRIBUSINESS DEVELOPMENT

According to Almeida et al. (2012), ILPF systems are viable alternatives from technical, environmental and socio-economic perspectives to recover and intensify the use of pastures. However, they are more complex, require interaction of several fields of knowledge as well as higher initial investments. Therefore, the prospect of public-private funds for the payment of environmental services is an important incentive towards the adoption of these production systems.

Initiatives already in progress to recover pastures in Brazil will bring several direct and indirect benefits. The programs already established have potential to optimize production in areas occupied by agricultural activities and to stimulate new crops and livestock farming, such as pork and poultry, due to increase in grain production.

It is necessary that universities implement specific disciplines on the subject, both in undergraduate and graduate levels (ALMEIDA et al., 2012).

In order to reach the goals of these programs, in addition to funds and basic infrastructure, it will be necessary to take the technology generated by research to all agents involved in the agribusiness production chains. The initiatives of the Brazilian Ministry of Agriculture, Livestock and Supply (MAPA), with credit availability from 2008, for implementing ILP and ILPF systems, through the Program for Sustainable Production in Agribusiness (Produsa) and, more recently, the Program for Low Carbon Emission Agriculture (ABC Program) have increased the Brazilian farmers' interest in adopting these technologies. However, demand for qualified professionals to plan and execute projects is an issue that should be observed, as is the need for encouraging universities to implement specific disciplines on the subject, both in undergraduate and graduate levels (ALMEIDA et al., 2012). This is of utmost importance to generate knowledge on production systems and to develop good technology transfer processes with qualified and effective technical assistance.

In 2009, the Brazilian government created a program to voluntarily reduce greenhouse gas emissions in the agriculture sector, called the ABC Program, based on the commitments made at the Conference of the Parties (COP-15, Copenhagen). This program aims to offer funds to recover 15 million hectares of degraded pasture and implement ILPF systems in four million hectares by 2020, aiming to improve sustainability in the Brazilian livestock sector.

Therefore, the efforts and commitment of federal, state and municipal agencies, unions, cooperatives, financial agents, input suppliers, public and private technical assistance providers, professional associations, specialized media and other participants of the chain are essential. With the planned work of these agents, Brazilian agricultural sector can more than double national output of food, fiber, wood and energy in a sustainable manner, improving jobs, income and development levels, without the need to clear pristine areas.

CLOSING REMARKS

In this environment of innovation and sustainability, there are excellent alternatives for farmers to adopt a more entrepreneurial attitude, transforming challenges into opportunities, through the use of integrated systems, which are efficient options due to their competitiveness compared with monospecific or specialized systems. Consequently, since the basic technological package for integrated systems is already consolidated, the sooner farmers adopt integration, the faster they will benefit from this opportunity, supporting Brazilian agriculture in its quest for sustainability.

Integrated production systems will support Brazilian agriculture in its quest for sustainability.

Chapter

4

Integrated Crop-Livestock-Forestry Systems and the Innovation System in Brazilian Agriculture

Renato Roscoe

INTRODUCTION

Success of any economical sector lays on its capacity to innovate and continuously introduce new technologies. Brazilian modern agriculture is a clear example of that.

A combination of good environmental conditions (climate, topography, water supply), government programs and entrepreneurial farmers has built the foundations for a tremendous development in rural areas of Brazil. Important governmental programs provided funding, storage, and trade. The construction of Brasilia launched new infrastructure towards the Midwest Region. But the turning point was the creation of Embrapa and the agricultural graduate and post-graduate courses in the early 70s, inaugurating the agricultural innovation system in Brazil and providing the necessary technologies to rationally explore the typical acid soils of the region.

Brazilian farmers have had tremendous improvements in their production systems in the last 40 years, increasing the productivity of land and labor, as a result of new products (improved seeds, fertilizers, pesticides etc.) and new processes (no tillage system, double cropping, integrated systems, management etc.). Farmers, supported by governmental policies and the agricultural innovation system, transformed the country from net importer to one of the most important suppliers of agricultural products to global markets. The capacity of farmers for absorbing and adapting new technologies to their activities was decisive in this process.

Now, farmers face new challenges, that ranges from local (land degradation and pollution; new pests and diseases; soil exhaustion; reduction in available water) to global scales (population growth and urbanization; increasing demand for food, fibers and energy; increasing fossil fuel prices; climate change). The new communication age, where the connectivity makes instantaneous the information flow, provides tools for society vigilance, narrowing the distance between farms and consumers. Farmers have to be more efficient than ever. They have to obtain high productivity of land and labor, providing food, fibers and energy to a growing population. At the same time they have to preserve the environment, reduce greenhouse gases (GHGs) emissions and maximize the use of natural resources. And what is even more complex: farmers have to face all those challenges also in a changing climate, with possible variation in temperatures and rainfall patterns.

The Brazilian Cerrado has been occupied more intensively in the last 40 years. At the beginning, pastures used to dominate all the explored areas. Gradually annual crops (mainly soybeans, maize, rice, and cotton) were successfully introduced, spreading over the most fertile soils. No tillage system has improved soil management, resulting in very efficient production systems. On the other hand, low investments and overgrazing made pastures systems to degrade and reduce yields. Although expressive advances in cattle production system have been obtained (genetics, health, nutrition), extensive grazing with low investments is becoming unsustainable, especially because of limitation to horizontal expansion (land prices, environmental concerns).

The agricultural innovation system is again important to face the new challenges, introducing new technologies to improve cattle production systems in Brazil. The integration of annual crops, pastures and forestry in the same areas has been developed as a solution to improve land productivity, reducing risks and environmental impacts.

The objective of this chapter is to discuss the context of technological changes in the agricultural sector in Brazil and its implications to the development of innovations on crop-livestock-forestry integrated systems.

AGRICULTURE DEVELOPMENT AND THE AGRICULTURAL INNOVATION SYSTEM IN BRAZIL

Agriculture has always been an important component of Brazilian economy since colonial times. Sugarcane plantations dominated the country exports until the XIX century, when coffee took the lead. By that time, agriculture was concentrated close to the coast. Only after 1850s some movement toward the west of São Paulo State was observed, mainly following new railroads structures. Coffee was still the major crop and grains were marginal, mainly to feed workers in cattle ranches, mines and plantations (Costa, 2010).

In the late XIX century, a significant flux of European immigrants colonized the West of São Paulo and parts of Rio Grande do Sul, Santa Catarina and Paraná States. Agriculture was still based on traditional technologies, like shift cultivation, slash-and-burn, animal-drawn plows. Grain production was incipient and attended mainly local needs. Very little was traded to supply the urban demand (Costa, 2010).

In 1940, Brazil was typically a rural country. Almost 70% of the population was rural. Close to 13 million people was resident in urban centers (Brito & Pinho, 2010). Between 1940 and 1970, a significant change occurred as a result of the government incentives to industrialize the country. In 1970, the rural population was only 45% of the total, and 52 million people were in cities. The direct consequence of urbanization and population growth was an increase in food demand. In early 1970s, Brazil was a net importer of food and inflation was a great concern (Barros, 2006).

Up to that point, agriculture in Brazil has developed in the most fertile soils, spreading first along the coast and the clay soils originally covered by forests in Minas Gerais, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul States. Although some modern equipment and fertilizers began to be imported in the 1950s, it was not before the 1970s that the modernization of agriculture started.

Government policies were designed to face the increasing demand for food and also to provide the resources to the incipient industrial sector. The challenges were to increase food supply to the internal market and also provide enough exports to keep positive the commercial balance.

In Brazil, although some modern equipment and fertilizers began to be imported in the 1950s, it was not before the 1970s that the modernization of agriculture started.

Supplies to the internal market would reduce food prices in urban areas, helping to control inflation and reduce the labor costs for the industrial sector. A positive commercial balance would provide enough resources to import equipments and technologies to modernize the industrial sector (Barros, 2006).

Official policies package included subsidies and credit (to farmers, cooperatives, and agro-industries), infrastructures (roads, storage) and the agricultural innovation system (Alves et al., 2012). Creating Embrapa was fundamental to that process, as well as the new graduate courses, with high quality masters and doctoral programs in agricultural sciences at public universities. Many researchers were also sent to high standard agricultural universities in the United States and Europe. New infrastructure was built and high-tech equipments imported to modernize the laboratories. High education in many agricultural disciplines formed an increasing group of qualified human resources (Alves et al., 2012).

Innovation came in two different ways to agriculture. The introduction of new fertilizers, pesticides and machinery to the production systems made possible its intensification. Those were typically imported technologies. At the same time, the return of well qualified researchers to Embrapa and universities, along with the new graduate students, and the implementation of a good research infrastructure provided the favorable environment to adapt those products and technologies to Brazilian conditions. Improved seeds were a good example. Genetic materials were imported, but a great portion of the development came from the effort of the Brazilian innovation system (Embrapa, 2004).

The acid soils of Cerrado were studied and new technologies were developed to explore those soils. This was a turning point in the agricultural development in Brazil.

The acid soils of Cerrado were studied and new technologies were developed to explore those soils. This was a turning point in the agricultural development in Brazil. The Cerrado, with more than 2 million km^2, has good topography, rainfall, temperature, and soils with good physical properties. The difficulty was to dominate the techniques to correct soil acidity and increase nutrient contents. The development of no-tillage system was also extremely important to maintain organic matter and improve soil fertility (Roscoe et al., 2006). The success of the agricultural innovation system can be illustrated by the fast progress of soybeans towards the Cerrado after 1970 (Figure 4.1). More than the adaptation to acid soils, poor in nutrients, soybean was also adapted to low-latitudes (Embrapa, 2004).

In the period between 1977 and 2014 (Figure 4.2), cultivated area in Brazil increased 48%, from 37 to 55 million ha (CONAB, 2014). At the same time, total grain production boosted 319%, coming from 47 million metric tons in 1977 to 197 million t in 2014. If we consider the average yield observed in 1977 (1,258 kg ha^{-1}), to obtain the same value of 197 million t of grains per year, the agricultural sector of Brazil would need 156 million ha. It means that the increment of productivity due to technological advances spared about 100 million ha of land in the last 37 years.

Livestock productivity also enlarged significantly after 1970. From 1970 to 2006, pasture areas increased 12%, whereas the number of animals rose 115% (Kichel et al. 2012). According to

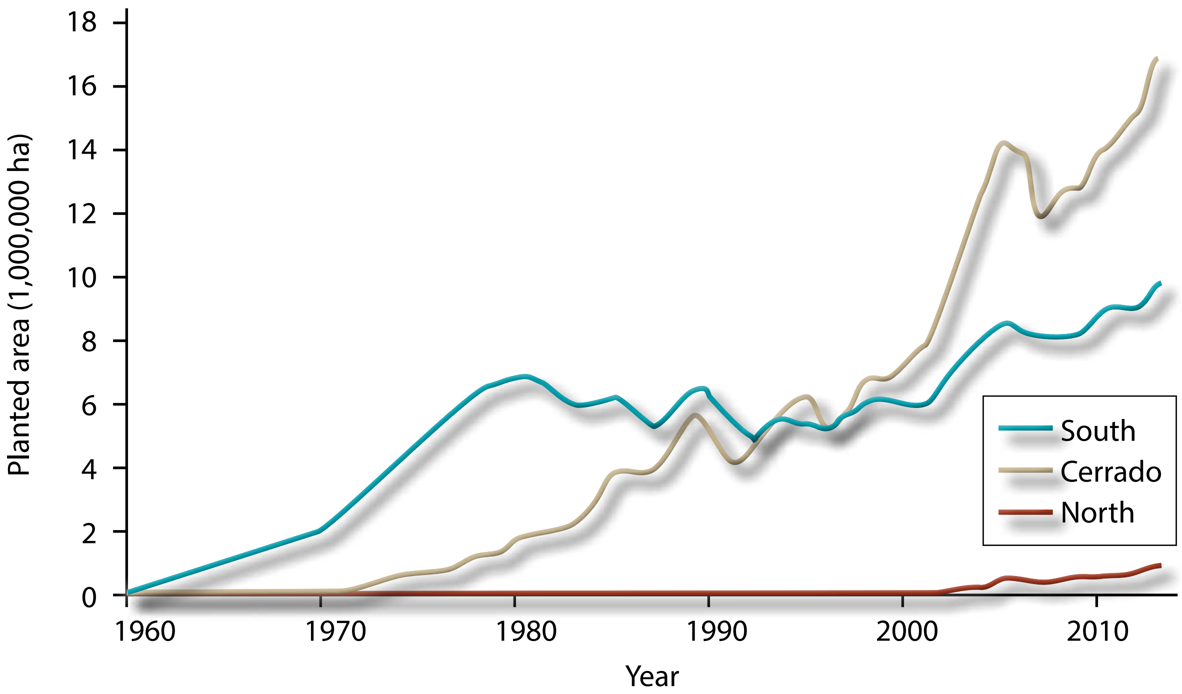

Figure 4.1

Planted area of soybean in three different regions of Brazil: South, Cerrado, and North.

Macedo & Araújo (2012), before 1970, the average carrying capacity of a pasture in Cerrado was 0.3 to 0.4 animal/ha. The introduction of new technologies as the *Brachiaria spp*. grasses increased the carrying capacity of pastures to 0.9 to 1.0 animal/ha and multiplied by 2 or 3 the beef production per area.

Studying the evolution of agriculture in Brazil, Alves et al. (2012) showed that in the census of 1995/1996, labor and land explained, respectively, 31.3% and 18.1% of the total gains in production. Complementarily, technology explained 50.6% of the variation. Appling their model to 2006, they found out that the components labor, land and technology explained, respectively, 23.1%, 9.5% and 67.4% of yield increase. The results of Alves et al. (2012) agree with the trajectories observed for land and production increases from 1976 to 2014 (Figure 2). Data were also in agreement with the decrease in rural population and the number of people employed in agriculture observed during the period. In 1985, 23.4 million people were employed in agriculture. This number decreased to 16.4 millions in 2006 (Alves & Marras, 2009).

Entrepreneur farmers were an important component in that development. According to Viera-Filho (2010), innovation in agriculture has three perspectives: generation, adoption and diffusion. Farmers migrated to the agricultural frontiers and, for many times, started the activities without a good technological support from research institutions. They actually would create the demand for new technologies and even give physical support for the official research structure. A good

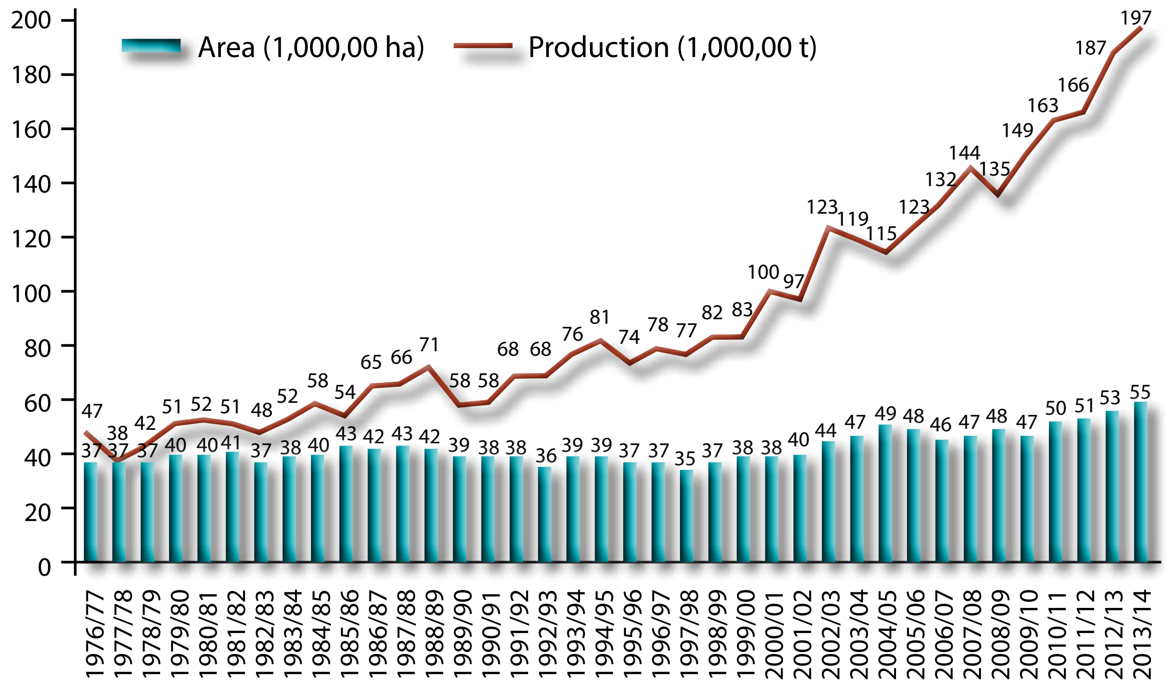

Figure 4.2

Evolution of the planted area and production of grains in Brazil.

example is the development of no-tillage innovations. Before the official research started systematic studies, farmers took the lead and adapted machinery and developed their own processes. They literally "learned by doing" (Casão-Júnior et al. 2012).

The agricultural innovation system in Brazil was the major driver to the extraordinary development of agriculture in the last 40 years. The question is: Would the system be prepared to face the new challenges? How could crop-livestock-forestry systems help to face those challenges?

THE NEW CHALLENGES

The new challenges for the Brazilian agricultural sector ranges from local to global! In terms of technology, development was not homogeneous in the whole country and two agricultural realities are found in Brazil: the highly developed agricultural systems and the low-production inefficient systems. The first is high-tech, dynamic, capitalized, and directly connected to the agricultural innovation system. In 2006, they comprised 0.5 million farmers and were responsible for 87% of the total gross production of agriculture (Alves et al. 2012). The remaining 3.9 million farmers produced only 13% of the total gross production of agriculture. This large portion of the farmers has little access to new technologies and did not participate of the high evolution of Brazilian agricultural sector in the last 40 years. Incorporating this group in the innovation system will not be an easy task.

Beef cattle production also faces important challenges. Although significant advances on animal genetics, sanitary and nutritional management have been observed in the last 40 years, an important part of the pastures were overgrazed and nutrients were not replaced by fertilizations. As a result, the majority of the sown pastures is degraded and has a very low productivity. If for one side this is a challenge to be faced, reclaiming degraded pastures with crops and more efficient livestock production constitutes an important opportunity to increase agricultural production, without clearing new natural areas. The intensification of those areas based on integrated systems will allow increases in grain and wood production, keeping or even improving livestock production.

Looking at the global challenges, the world is changing in a velocity never faced by mankind. Human society confronts more than environmental changes, but also deep socio-economic transformations. As summarized recently by Thomas Friedman, the Earth is getting hotter, flatter, and crowded (Friedman, 2008). Climate change is warming up our plant. The technological revolution and the communication age push globalization and intensify the information flow, flattening cultures and markets. Population growth significantly increases the need for food, fibers, shelter, and energy.

Global climate change is largely accepted by the international scientific community (Ciais et al., 2013). Emissions of greenhouse gases have significantly increased in the last 250 years, as a result of land use change and burning fossil fuels for energy. In the last decade (2000-2009), emissions due to fossil fuels summed up 7.8 GtC per year. Land-use change emissions are more uncertain and were estimated in 1.1 GtC per year. Emissions of methane and nitrous oxides also increased significantly, and are more associated to agriculture (Ciais et al. 2013).

The increasing concentration of GHGs in the atmosphere is correlated to increases in the atmospheric temperature, which is related to changes in rainfall pattern and the frequency of extreme events (as droughts, floods, hurricanes, tornados) (Ciais et al., 2013). Reductions in rainfall and changes in temperatures are expected in the central part of Brazil, where most of the modern agriculture and the available areas for expansion in the Cerrado region are concentrated (Pellegrino et al., 2007).

Then, global climate change may impact negatively agriculture and requires adaptations. At the same time, systems that reduce emissions per unit of food, fiber or energy produced are important strategies to mitigate global climate change. Adaptation and mitigation are dependent on an efficient agricultural innovation system. Integrated crop-livestock-forestry systems have the potential for reducing GHGs emission, by increasing carbon stocks in the soil and vegetation and increase productivity per area (Watson et al., 2000).

Global climate change may impact negatively agriculture and requires adaptation. This adaptation depends on an efficient agricultural innovation system.

The flatness of the World as advocated by Friedman (2008) implies in almost instantaneous flow of information, integration of markets and cultures. The technological revolution brought the Internet and smartphones, which made cheaper the information flow and technology transference. Integrated market allowed specialization of commodities suppliers, which placed Brazil as an important source of food and energy to the growing global population. At the same time, connectivity raised the society control on production processes and quality, with consequent pressure for environmental and social responsibility on the production level. On the other side, cultural flatness has popularized occidental consumption standards over developing countries, with remarkable consequences in China and India, where increasing *per capita* income and urbanization have demanded more and more food, fibers and energy (Friedman, 2008).

And last but far from being the least, the growing population perspectives. Estimates from the United Nations (UN) showed an increase in global population from the current 7.2 billion to 9.6 billion people by 2050 (United Nations, 2013). According to the UN Report, most of this population growth will take place in developing countries, mainly in Africa and Asia. On top of that, urbanization and relative improvements in income indicates that the demand for agricultural products should increase even more than the population growth. According to FAO (United Nations Food and Agriculture Organization), the demand for agricultural products will increase 60% until 2050 (Alexandratos & Bruinsma, 2012). According to the International Energy Outlook 2013 (IEO, 2013), global energy consumption will grow by 56% between 2010 and 2040. Total world energy will rise from 524 quadrillion British thermal units (Btu) in 2010 to 820 quadrillion Btu in 2040. The report also highlights that most of the growth in energy consumption will occur in countries outside the Organization for Economic Cooperation and Development (OECD). In non-OECD countries, energy demand will increase by 90% and, in OECD countries, by 17%.

Worldwide, the stock of land for agriculture is close to limit.

Worldwide, the stock of land for agriculture is close to limit. Apart from some countries in Africa, where structural and political problems many times hamper a boost in agriculture, only Brazil still have significant arable land to be incorporated or intensified to attend global demand for food, fibers and energy (FAO, 2000).

INTEGRATED SYSTEMS: INNOVATION TO FACE CHALLENGES

Crop-livestock-forestry integration has many of the elements necessary for a new approach towards rural development in Brazil. Most of sown pastures cover marginal areas for crops, mainly with light texture or climatic restrictions. There are also situations where environmental concerns limit land use for crops (e.g. buffering zones of national parks).

The combination of annual crops and pastures already represents an important tool to improve productivity of the vast area of degraded pastures (Macedo & Araújo, 2012). The benefits are clear for both annual crops and pastures. Agricultural land, even when no-tillage system is used, still faces the shortage of organic matter for the system (Roscoe et al., 2006). Cycles of pastures in those areas improve significantly the supply of organic matter and increase soil quality. On the other hand, cycles of annual crops may significantly increment soil fertility, since the cash flow of these crops allows investments on limestone and fertilizers. This technology has been used even in traditional areas of agriculture to improve the efficiency of no-tillage systems.

But the larger contribution of the integrated systems lays on marginal areas for agriculture and environmentally fragile regions. The restrictions in those areas are mainly soil texture (sandy soils) or climate restrictions (long droughts or climate instability). Pastures lose carrying capacity as a result of overgrazing and decrease in soil fertility. Annual crop production in those areas has high risks, but may mitigate the costs of improving soil fertility in the first 2 or 3 years. The introduction of the forest component into the integrated systems improves carbon stock, diversify and increase revenues, reduce risks (climate and market), and provide a better microclimate for livestock.

The larger contribution of the integrated systems lays on marginal areas for agriculture and environmentally fragile regions.

Such systems help to solve local challenges, recovering degraded land and increasing the income of at least part of the marginalized 3.9 million low-income farmers, which includes many cattle ranchers. Allow the increment on livestock production (better pastures and microclimate), at the same time that provide grains and wood production. Reduce risks, by diversifying farmers' options, including drought tolerance of forestry systems, even in an eventually unfavorable environment caused by climate change. In a global scale, crop-livestock-forestry systems contribute to mitigate GHGs emissions, by increasing cattle productivity (reducing emissions per unit of beef produced), carbon storage in the system (forest component and soil), and reducing pressure for deforesting new areas. The intensification of the systems would also increase the production of grains, beef, milk, and wood, helping to feed the growing population.

FINAL REMARKS

As summarized by Diamandis & Kutler (2012), the current development and the future of technological innovations are placing humanity in a period of "abundance". The incredible speed of the technological development is providing new disruptive innovations to all the economic sectors. Agriculture has the benefit not only from the intrinsic technological development, but also from other sectors of the economy. The revolution on biotechnology, with sharp cost reduction on methods, will increase its potential to help in answering many agricultural challenges. The convergence of the exponential advance on information technologies (IT), development of new materials (including biogenic) and the new universe of nanotechnology are changing dramatically the costs of automation and development of new products. This convergence is not only affecting energy efficiency, but also providing technologies to use alternative sources. Machin-

Collaborative development of new technologies is already creating a new environment for innovation, reducing costs and increasing accessibility.

ery and equipments are getting cheaper and more independent, saving labour force on farm. Remote sensing and geographic information systems are popularizing precision agriculture and natural resource management. High capacity for data acquisition and processing is increasing the understanding of climate and refining weather forecast. Automatic meteorological stations placed on farm and connected to farmers' mobile are giving real-time information and helping them in making technical and commercial decisions.

The other disruptive trend, stimulated by the new technological paradigm, is the fantastic flow of information and technology transference. Collaborative development of new technologies (open source, free content in the Internet, and voluntary work) is already creating a new environment for innovation, reducing costs and increasing accessibility. Knowledge and technology will probably get cheaper and accessible to a greater number of farmers. All the dimensions of innovation (generation, adoption and diffusion) will certainly be impacted by this new environment.

Brazilian agricultural innovation system is inserted in this new environment and will be prepared to convert all these fantastic advances into farmers' benefits. Integrated crop-livestock-forestry systems represent one of those opportunities that will not be missed.

Chapter 5

Entrepreneurship for Sustainability With Crop-Livestock-Forestry Integration

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Davi José Bungenstab
Paulo Henrique Nogueira Biscola
Camilo Carromeu
Ademar Pereira Serra

BRAZILIAN AGRIBUSINESS

The progress of Brazilian economy in recent years is unquestionable. A combination of factors, including the strengthening of democracy, economic growth and control over inflation, together with its abundance of natural resources and progress on the knowledge front, have created a favorable platform, enabling Brazil to finally cease being "the country of the future" and, at present, reap the benefits of its enormous productive potential.

In an article published in the international press few years ago, Brazil was seen as a strong candidate for the world's fifth largest economy, leaving behind countries such as France and England (THE ECONOMIST, 2009). Currently in sixth place, Brazil has agribusiness as one of its main growth pillars – in less than 30 years, the country has evolved from a net importer to one of the world's major food suppliers.

Between 1996 and 2006 Brazilian crop production grew by 365% to R$108 billion (THE ECONOMIST, 2010). Total grain production from the 2011/12 harvest was estimated at 165.9 million tons (CONAB, 2012), 1.9% higher than the previous harvest, being a new record, even though unfavorable weather conditions led to losses in some regions of the country. As for livestock, Brazil currently has the world's largest commercial beef cattle herd, with more than 209.5 million head (IBGE, 2010). In the last decade, beef exports have increased tenfold and the country is now among the world's leading beef exporters.

Although they represent excellent results, these figures are still modest given global demand for food production in the coming years. Projections indicate that in 40 years the world's population will exceed 9 billion inhabitants and although the U.N's Food and Agriculture Organization (FAO) has recently reduced demand forecasts for 2050, global food output will still have to move up by an estimated 60% to ensure food security (FAO, 2011). Increasing production is a challenge in itself, which becomes even more difficult given the need to produce more in potentially more adverse weather conditions, while, at the same time, being required to reduce environmental impacts.

In this context, Brazil has several advantages that put it in a privileged position. It has the largest amount of arable land in the world – around 300 million hectares (THE ECONOMIST, 2010) and the availability of fresh water, an extremely valuable resource in general, is not a major concern for Brazil in the short and medium term (UNESCO, 2009). It has also recorded an excellent performance in terms of agricultural production under minimum governmental subsidies (OECD, 2009; THE ECONOMIST, 2010). Also, investments in science and technology have enabled the implementation of revolutionary crop and livestock production techniques, with reduced environmental impacts and excellent results.

However, it is important to notice that Brazilian outstanding agribusiness figures are not only the result of the current political and economic scenario, its natural resources abundance or the scientific and technological advances; they also reflect the attitude and initiative of thousands of entrepreneurs from across the country who refused to become complacent. They actively pursued business opportunities with the necessary human, financial and technological resources to lead one of the biggest agricultural transformations in the history of the world.

ENTREPRENEURSHIP IN BRAZILIAN AGRIBUSINESS

Entrepreneurship and innovation are recognized as important drivers of income and job creation, productivity and competitiveness, as well as for economic growth and development of any country.

By definition, entrepreneurship comprises the willingness and ability of individuals to identify and create new business opportunities and introduce these ideas into the market, together with a willingness to compete for market share despite uncertainties, risks and other obstacles (WENNEKERS et al., 1997).

Strictly speaking, entrepreneurship is a characteristic of people rather than organizations; therefore, it is natural for entrepreneurs (including rural entrepreneurs) to be influenced by cultural aspects related to their personal history or background (LUNDSTRÖM; STEVENSON, 2001). Thus, in regions where there is a more favorable and open perception of factors such as risk, competition and the use of new technologies, entrepreneurship is more widespread than in regions with a more conservative outlook.

Strictly speaking, entrepreneurship is a characteristic of people rather than organizations.

Brazilians have a very strong entrepreneurial profile (GRECO et al., 2010). In 2009, there were 4,846,639 organizations constituted as legal entities (IBGE, 2009). Agricultural establishments summed up almost 5.2 million in 2006, 17% of which accounting for 60% of the country's agricultural production (IBGE, 2007). Farmers' interest in learning about and implementing new technologies, such as integrated crop-livestock (ICL) and integrated crop-livestock-forestry (ICLF) systems is a clear example of entrepreneurial behavior.

Rural entrepreneurs are aware that the more they know of the area in which they operate, the more likely they are to succeed. This knowledge can be obtained from specialized publications, courses, trade shows, exhibits, field trips, radio and TV programs and the Internet. It is important to notice, however, that, especially in the agricultural sector, farmers' knowledge and mastery of technology usually result from their own practical experience or exchanging information with their peers.

Entrepreneurs have to invest time and money to evaluate the opportunity, thereby helping reduce risk and increasing a project's chance of success.

CHARACTERISTICS OF A GOOD BUSINESS OPPORTUNITY

Identifying and evaluating business opportunities are among the most important aspects of entrepreneurship. Without a potentially viable opportunity, any business will only obtain mediocre results at best. At this point, therefore, entrepreneurs have to invest time and money to evaluate the opportunity, thereby helping reduce risk and increasing a project's chance of success.

As technology advances, questions arise regarding where new business opportunities can be identified in the agribusiness sector. Sector specialists and entrepreneurs discuss which criteria are the most important for evaluating the potential of a project or technology. However, recent changes in the business environment, such as unexpected announcement of government investments and new lines of credit, certainly represent an excellent source of opportunities. In the case of the ICLF systems, for example, incentives of the Low Carbon Agriculture Program, also known as the ABC Program, introduced by the Brazilian government in 2010, represent a good opportunity for introducing such systems in regions with degraded pastures where cattle farming have been losing profitability.

Changes in the way a certain production chain, sector or market is organized, such as the ones that have been taking place in the Brazilian agribusiness sector, may also present interesting opportunities. The need for solutions addressing local problems, demographic changes, changes in perception or new technologies also represent investment possibilities (DRUCKER, 2008).

When evaluating the business opportunity potential of a project or technology, the most important aspect to be taken into consideration is probably value creation. The product must be clearly perceived as valuable by consumers, and also distributors and retailers when involved (MUZYKA, 1997).

Although it is not easy to add value to commodities, it is known that the market tends to perceive as of higher value the products obtained through more efficient and less environmentally aggressive processes.

Other important factors that should be taken into consideration when evaluating a business opportunity include:

- **The existence of a real market need –** if there is known demand for a product or technology chances of success are substantially higher.
- **Good timing –** aspects such as product seasonality or a possible dependence on other technologies for delivering the product should be taken into consideration.
- **Time horizon attractiveness –** the business should be explored for a period that allows returns to levels that justify the investment.

- **Clearly defined management focus –** facilitates the management process and favors goals achievement (e.g. costs, brand, logistics).
- **Development of sustainable competitive advantages (SCAs) –** SCAs are strategies to add value that are not being used by current or potential competitors because they cannot easily duplicate them.
- **Healthy profitability potential –** although profitability potential is a highly relative concept, all opportunities must be examined for their ability to generate financial returns.
- **Good compatibility with the entrepreneur –** the opportunity should be explored by someone with the appropriate skills and experience and who has the critical resources needed to support the business.
- **Development of other business skills –** good opportunities are usually excellent learning opportunities, allowing individuals or organizations to develop skills that allow them to explore new ideas.
- **Gateway to further opportunities –** good opportunities usually lead to the identification of other investment possibilities.

ILPF SYSTEMS AS A BUSINESS OPPORTUNITY

When analyzing ILPF systems discussed in this session, with regard to each item in the above list, we can see that there is a ***real market need*** for the different resulting products. In the usual ILPF systems, the main direct products are beef and/or mutton, milk, soybeans, maize, sorghum and timber, all commodities with a well-established market. The system also produces several environmental services that are still not compensated for most farmers, although they do help increase system's profitability.

Demand for commercial outputs of the most usual ILP and ILPF systems in Brazil is constant and the technologies for implementing and conducting them have been successfully established. Currently there is also a trend regarding increase on demand for products with an environmentally and socially fair production process, making this a ***good moment for expanding*** integrated production systems. ILPF systems rationally combine crops to ensure a more effective distribution of production during the project's duration, thereby mitigating weather and market variations. The system also reduces the cost of implementing the tree and forage components with annual grain cultivation.

In the main model here discussed, the minimum ILPF cycle is around seven years and it could reach more than 20, depending on the type of trees used. Animal production indices from silvipastoral systems alone are normally similar to – or higher than – those of traditional beef pro-

Currently there is also a trend regarding increase on demand for products with an environmentally and socially fair production process, making this a good moment for expanding integrated production systems.

Integrated crop-livestock-forestry systems are not suitable for all situations or farmer profiles, creating a differential for those who adopt them.

duction. In addition, the crop component drastically reduces cost of implementing the forestry component, making the system ***highly attractive in a longer time horizon***.

Because it has several components, the adoption of an integrated production system requires a ***clearly defined management focus***, which permits management of the various interacting components, reciprocally leveraging their results and reducing risks for the entrepreneurs.

A lot more than traditional production systems, ILPF systems permit the ***development of sustainable competitive advantages***, thereby adding value to products, especially in terms of environmental services. ILPF systems are complex and require more technical knowledge and professional management, including meticulous long-term planning. They are not suitable for all situations or farmer profiles, creating a differential for those who adopt them. Environmental services generated by the system are one of its main advantages, also due to future remuneration prospects. This aspect of the system is so important that the issue is discussed in more detail in a specific chapter of this book.

Representing SCAs, ILPF systems, due to the synergies between the several components, have ***excellent profitability potential***, with a favorable cost-benefit ratio in a wide range of situations. This issue is also addressed in a specific chapter.

Because of their characteristics, Brazilian ILPF systems are usually adopted by those with a need to improve their production system or by other investors who want to enter the agricultural sector. In both cases, however, ***entrepreneurs have a good compatibility with the project***, with experience in the activity or funds available to hire specialized assistance.

An issue which is also discussed in a specific chapter, ILPF systems ***favor development of other business skills***, such as the sale of environmental services or other outputs to be created. The complexity of the system, requiring closer monitoring and control provided by more professional management, leads farmers to better analyze their activity, allowing them to see opportunities that external observers would not be able to realize, ***providing a gateway to other business opportunities***.

PLANNING – THE FORCE OF ENTREPRENEURS

The most well-known characteristics of successful entrepreneurs are visionary attitudes, self-confidence, persistence, determination, interest in exploring new opportunities, willingness to take risks and uncertainties as well as the ability to plan ahead.

If in the past planning was regarded only as a desirable characteristic for success, nowadays it is essential. In a globalized and highly competitive world where information and knowledge are widely disseminated, planning is critical for the success of any business. Studies show that “lack of planning” is still the second main cause for the failure of new projects, behind only of “lack of entrepreneurial behavior" (SEBRAE, 2008; DORNELAS, 2008). Several authors recognize that entrepreneurs who value the planning of their activities are much more likely to be successful than those who do not so. A study carried out with former students of the Harvard Business School concluded that careful planning increases any business' chance of success by up to 60% (DORNELAS, 2008). Although we are not aware of a similar study involving farmers as a class, we have no reason to believe they would be an exception.

ILPF systems have three plant components and at least one animal component, therefore they are substantially more complex than single crop systems. For this reason, meticulous planning is essential. Often it is more prudent to delay implementation, postponing, for example, the planting of trees for a year to refine the system's planning, than to risk choosing the wrong species or not having sufficient local labor available for cultivation practices like controlling weeds and ants for example.

One of the most interesting aspects of planning is that by analyzing their business in detail, farmers have the opportunity to learn more about their activity/project or the technology they intend to adopt. By doing so, they are able to consider different 'business possibilities' from the perspective of 'business opportunities'. Additionally, they can also better evaluate risks involved and increase chances of success.

ILPF systems have three plant components and at least one animal component, therefore they are substantially more complex than single crop systems. For this reason, meticulous planning is essential.

Chapter

6

Integrated Crop and Livestock Systems as Alternative to Recover Degraded Pastures

Manuel Claudio Motta Macedo
Alexandre Romeiro de Araújo

INTRODUCTION

Rational and environmentally exploitation of natural resources, sustainable production and clean development mechanisms (CDM) are highly debated issues in the agricultural development scenario in Brazil. The country has experienced a major technological and productive development in agribusiness, with growing exports and farmer's income.

Two relevant aspects, however, draw attention when discussing sustainable agricultural production: degraded pastures and the use of soil for traditional agricultural practices, with continuous soil tillage.

Cattle husbandry in Brazil is based on grazing systems. Extensive cattle ranching is more prevalent than any other system, though sometimes grazing is combined with supplements, such as dry feed, silage, chopped sugarcane or hay. The main forage grasses used in Brazil were brought from Africa and belong mostly to the genera *Brachiaria, Panicum and Andropogon*.

Sown pastures are concentrated in the *Cerrado* ecosystem, representing 49.5 million hectares from a total of 208 million hectares grazing areas (SANO et al., 2001). The region accounts for about 50% of the beef produced in the country.

Pasture soils are often given less importance compared to those used for cash crops farming. Frequently they may present problems of natural fertility, acidity, topography, surface stoniness or drainage limitations (ADAMOLI et al., 1986). Soils better suited for agriculture are planted with annual grain crops or high value cultivations for industrial processing like biofuels, fibers, resins, sugar etc.

In this context, beef cattle ranching areas are in some extent marginal and therefore expected to present issues regarding yields and sustained production.

In Brazil, stocking rates were 0.3-0.4 animals/ha before the introduction of sown pastures in the *Cerrado*, and cattle could reach slaughtering maturity only after 48 to 50 months of age (ARRUDA, 1994). In the early 1970s, the *Brachiaria* species, especially *Brachiaria decumbens*, was introduced in the region, easily adapting to the *Cerrado* biome, with its acid soils and natural low fertility. The initial average stocking rates increased from 0.9 to 1.0 animals/ha and daily live weight gains also increased 2 to 3 times in average. Higher yields have significantly expanded both beef cattle farming and the agricultural frontier in Brazil.

Until early 1990s, more than 50% of the sown pasture areas were seeded with *Brachiaria decumbens*. However, an important aspect grew in importance over the last 15 years – the reduction of the area covered with *Brachiaria decumbens* cv. Basilisk, which was replaced with *Brachiaria brizantha* cv. Marandu and an increase in *Panicum maximum* area using Tanzania and Mombaça cultivars. Marandu is currently a key cultivar in the seeds market, accounting for about 70% of total sales volume, including exports to other Latin American countries. Its expansion is due to its greater resistance to spittlebugs and enabling better animal performance. In the *Cerrado*, *Brachiaria* still represents the largest sown area, with approximately 85% of the total, compared with around 12% sown with *Panicum* varieties (MACEDO, 2005).

Pasture degradation is currently the most important factor affecting sustainable cattle husbandry in the country, representing a dynamic process of proportional yield decreases. Likewise, traditional annual agricultural crop systems, with excessive soil tillage and continuous monocultures without crop rotation, have compromised soil physical and chemical quality and also contributed to increase pest, disease and weed problems.

These issues have been mitigated with the use of important technologies, such as the no-tillage or no-till seeding system (NTS), which includes not only minimum soil preparation, but also crop rotation and integrated crop-livestock (ICLS) and integrated crop-livestock-forest systems (ICLFS).

No-tillage is a growing technology used in more than 40% of the cropping areas in the *Cerrado* region in 2003 (DUARTE et al., 2007). This figure is estimated to have exceeded 75% in 2013. The breakthrough was enabled by the agronomic, economic and environmental advantages of NTS compared to traditional tillage cultivation systems. In a report addressing NTS evolution from the beginning of the 1970s until the early 1990s, Puríssimo (1997) noted a number of difficulties, from lack of equipment to high dependence on chemical weed control.

The adoption of NTS in its fullness, in different weather and soil conditions, requires suitable crops for production and maintenance of straw covering the soil, making the system efficient and cost-effective. Various crops have been tested and used as cover crops, rotation and pasture in the autumn-winter season, of which the most promising are: maize, millet, grain and forage sorghum, forage radish and tropical forage grasses, especially the *Brachiaria*, whether in intercropping or not.

The adoption of no-till system in its fullness requires suitable crops for production and maintenance of straw covering the soil, making the system efficient and cost-effective.

Yield losses due to pasture degradation, plant health problems related to large areas of soybean monoculture, social pressure regarding land use, farmers high debt levels, input and product prices, and increased global competition, have increasingly required farmers to be more efficient. Therefore, ICL and ICLF systems may be the key for reversing certain problems on extensive cattle farming, serving as an alternative to reclaim degraded pastures while fostering cash crops and NTS, especially with straw production, improvement of soil properties, full use of equipment, job creation and increasing farmers' income.

LIMITATIONS ON PASTURE BASED BEEF PRODUCTION

Among the most important factors related to pasture degradation are improper animal management and the lack of nutrient replacement. An excessive non adjusted stocking rate

An excessive non adjusted stocking rate according to local carrying capacity and the lack of maintenance fertilization has accelerated pasture degradation process in Brazil.

according to local carrying capacity and the lack of maintenance fertilization has accelerated pasture degradation process in Brazil.

An example of how to maintain sustainable livestock production through proper management of savanna regions is presented by Lascano et al. (1989, 1995) in Figure 6.1. These authors have shown that, by adjusting the stocking rate to 1.0 animal/ha in the dry season and 2.0 animals/ha in the rainy season, with application of 10 kg of phosphorus (P), 13 kg of potassium (K), 10 kg of magnesium (Mg) and 16 kg of sulfur (S) per hectare every two years, it was possible to keep an average yield, in live weight (LW), of 139 kg/animal/year, and production per area of approximately 250 kg of LW beef per hectare after 16 years of grazing in Colombia's savannas. As explained by the authors, in some years there were production losses due to excessive rainfall and spittlebug infestations.

On the other hand, Cardoso (1987, personal communication) and Bianchin (1991) provide examples of decline in pasture vigor and productivity towards degradation. In the first case (Figure 6.2), fixed stocking rates of 1.5 and 2.5 head/ha of Nellore heifers, 18-24 months old, were used for five consecutive years in a clayey Oxisol (Distroferric Red Latosol) in Campo Grande, Mato Grosso do Sul State, Brazil, on *Brachiaria decumbens* cv. Basilisk with no maintenance fertilization. In the second example (Figure 6.3), fixed stock ratings of 1.4 and 1.8 Animal Units per ha (AU/ha)

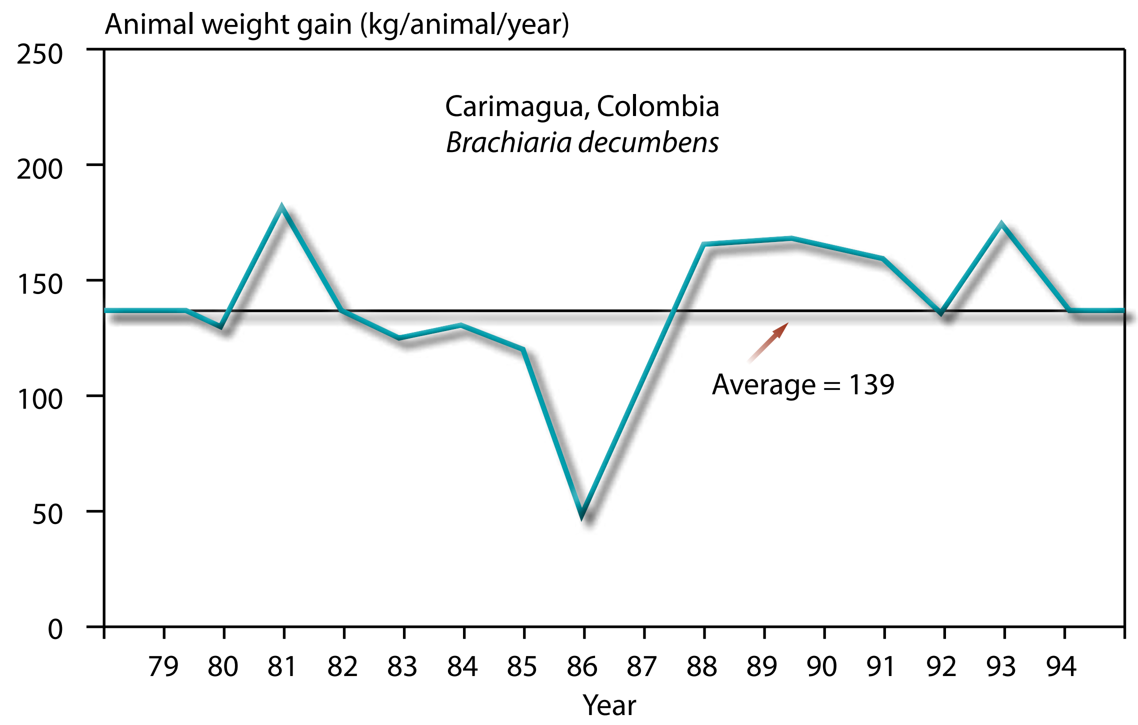

Figure 6.1

Animal production (kg LW/animal/year) in *Brachiaria decumbens* pastures in the Carimagua savannas, Colombia. Data collected by Lascano et al. (1989, 1995) for 16 years. 0 = years with spittlebug infestation.

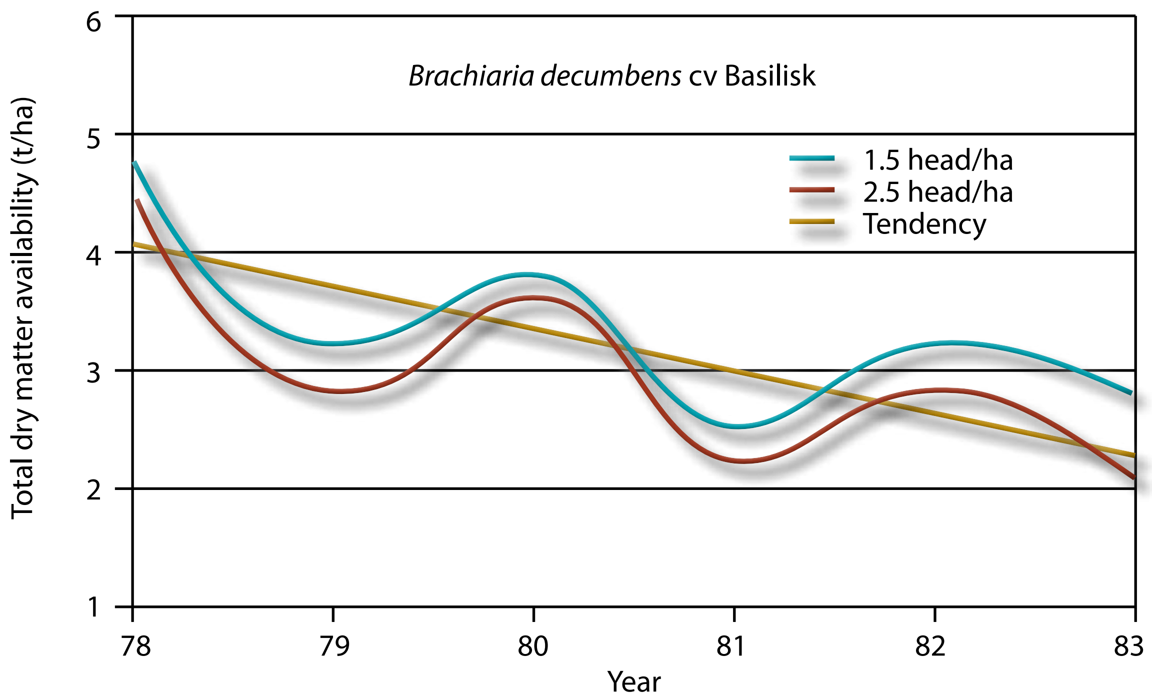

Figure 6.2

Evolution in total dry matter supply (t/ha) on a *Brachiaria decumbens* pasture in Campo Grande-MS, Brazil, with a fixed animal stocking rate. Adapted from Cardoso, 1987 (personal communication).

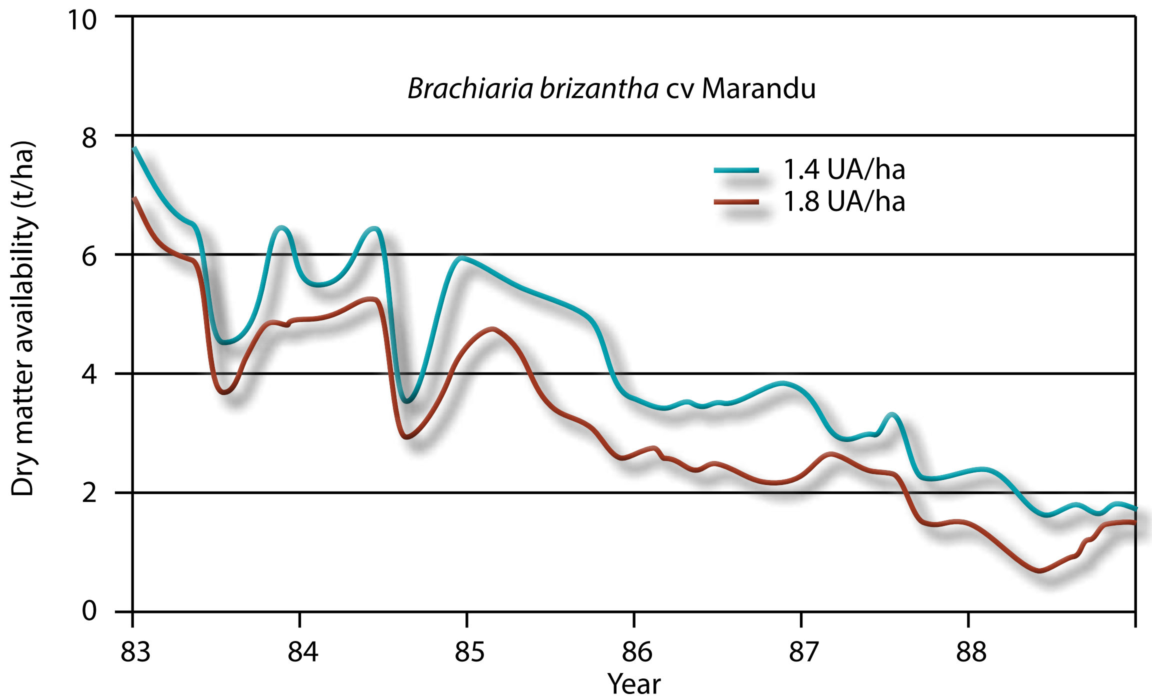

Figure 6.3

Evolution in total dry matter supply (t/ha), on a *Brachiaria brizantha* pasture in Campo Grande-MS, Brazil with a fixed animal stocking rate. Adapted from Bianchin, 1991.

of weaned Nellore calves were used for six consecutive years on a clayey Oxisol (Distroferric Red Latosol), also in Campo Grande, on *Brachiaria brizantha* cv. Marandu also with no maintenance fertilization. While in the first case animals were used for breeding, in the second, animals were reared for finishing. Figure 6.4 shows cattle production (kg LW/ha) in *Brachiaria brizantha* in the dry and rainy seasons, in three cycles of two years, followed by decline in forage availability. As of the second dry season, lower stocking rates led to higher production compared with higher stocking rates, showing the needed adjustments to maintain carrying capacity of forages.

Figures 6.2 and 6.3 show the downward trend in total dry matter supply, limiting animal feeding and causing pasture degradation.

According to other results from the same region, obtained by Euclides et al. (1994a), total dry matter supply of species such as *Brachiaria decumbens* and *Brachiaria brizantha* should be kept at around 3.0 t/ha over time to allow an adequate supply of green forage, mainly leaf blades, providing adequate animal feeding.

Among other goals, Cardoso (1987, unpublished data) and Bianchin (1991) works aimed to measure pasture carrying capacity under a fixed stocking rate, and without nutrient replacement, which was proved unsustainable. The graphs herein presented are like snap shots of the real panorama of million hectares of Brazilian sown pastures without nutrient replacement or adjustments in management.

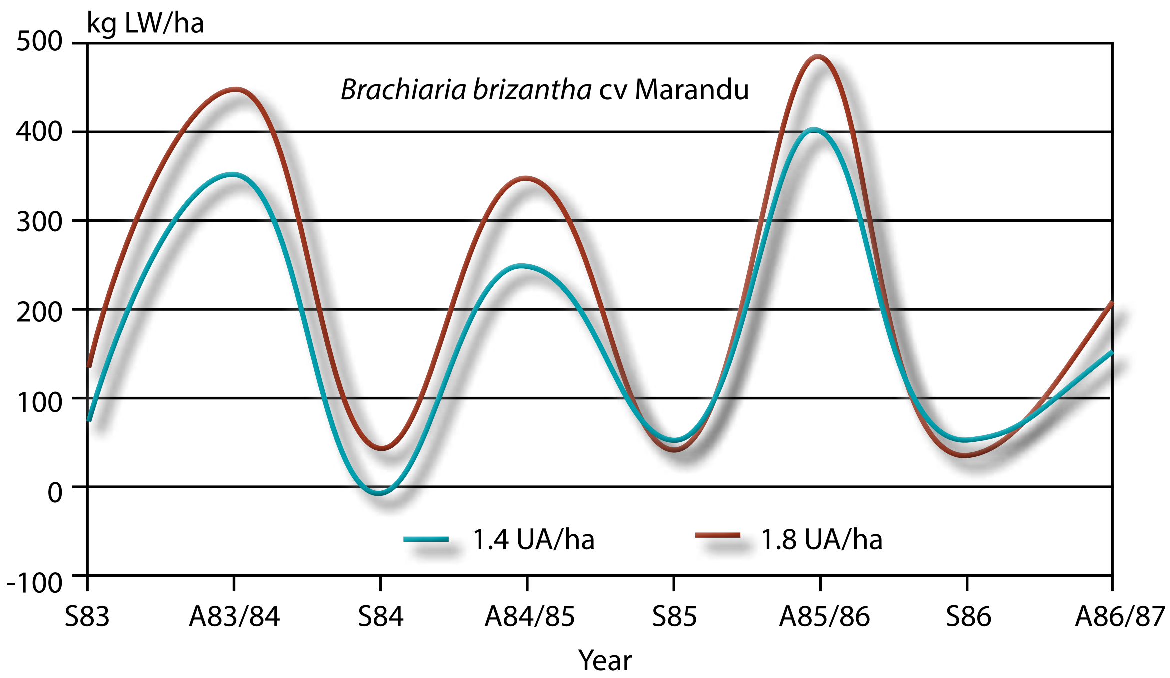

Figure 6.4

Evolution of animal production (kg LW/ha) for weaned Nellore calves raised on a *Brachiaria brizantha* cv. Marandu pasture, in Campo Grande-MS, Brazil, with a fixed animal stocking rate, during three cycles of two years. Adapted from Bianchin, 1991.

PASTURE DEGRADATION

Pasture degradation is perceived and interpreted in different ways by producers and experts, as are the obstacles to reverse their condition.

After first seeding or rehabilitation of a pasture, yield is typically higher in the first and possibly also in the second year of exploration. Forage and animal production is estimated to be in average 30-40% higher in the first year than in the third or fourth year of exploration, as long as production potential is not limited by climate, soil or improper animal management. If no management practice is implemented to maintain production, yields naturally decline over time, going intensely downwards at the beginning until later reaching a kind of balance. This balance is usually reached when beef yields barely cover animal maintenance costs, compromising farmer's capital and sometimes even leading them to leave the business.

Some authors consider that grazing pressure and constant plant defoliation cause changes in plant growth, mainly changing dossel structure altering the number of plant shootings, size and number of leaves, and the dossel/root ratio. This new morphological profile leads to different physiological and nutritional relations in the plants, that, when not correctly managed for each situation, will lead to altered soil-plant-animal balance, leading to pasture degradation.

It is recommended to start management practices before the beginning of degradation process in order to keep satisfactory yields. This can be done through animal management, especially by adjusting stocking rates and changing pasture management, or through cultivation practices, such as limestone, gypsum and fertilizers application.

In this work, pasture degradation is defined as "the advancing process of loss of plant vigor, yield and capacity for natural recovery of pastures necessary to economically ***sustain*** the levels of production and quality required by animals, as well as to overcome the adverse effects of pests, diseases and weeds, culminating with the advanced degradation of natural resources due to inadequate management."

Degradation is the result of an ongoing process of change in pastures which begins with the decline of vigor and productivity. It could be compared to a stair (Figure 6.5), in which the highest yield would be the top and the degradation process would advance top-down as the pastures are explored. To a certain extent or degree, the decline in production could be halted and productivity could be maintained with simpler, more direct actions and lower operating costs. From that point on, the actual degradation process would begin, where only pasture reclaiming actions, often more drastic and costly, would lead to appropriate results.

The end of the process would lead to a disruption of natural resources, represented by soil degradation with changes in its structure, evidenced by compaction and consequent decrease

It is recommended to start management practices before the beginning of degradation process in order to keep satisfactory yields.

in infiltration rates and water-retention capacity, causing run-off and erosion, with sediments compromising springs, lakes and rivers. At this stage, rehabilitation of the area becomes much more expensive than in previous stages.

These remarks on the degradation process, presented in a logical sequence, are not so simple and do not always occur in the same order. Instead, they may take place in different sequences at different degrees, depending on the ecosystem and adopted management practice. Even the limit between the maintenance phase and the start of actual degradation is still under research, as each production system can be experiencing a different situation. It is reasonable to assume that these limits, established by indicators, are different and fall into ranges instead of fixed and punctual values.

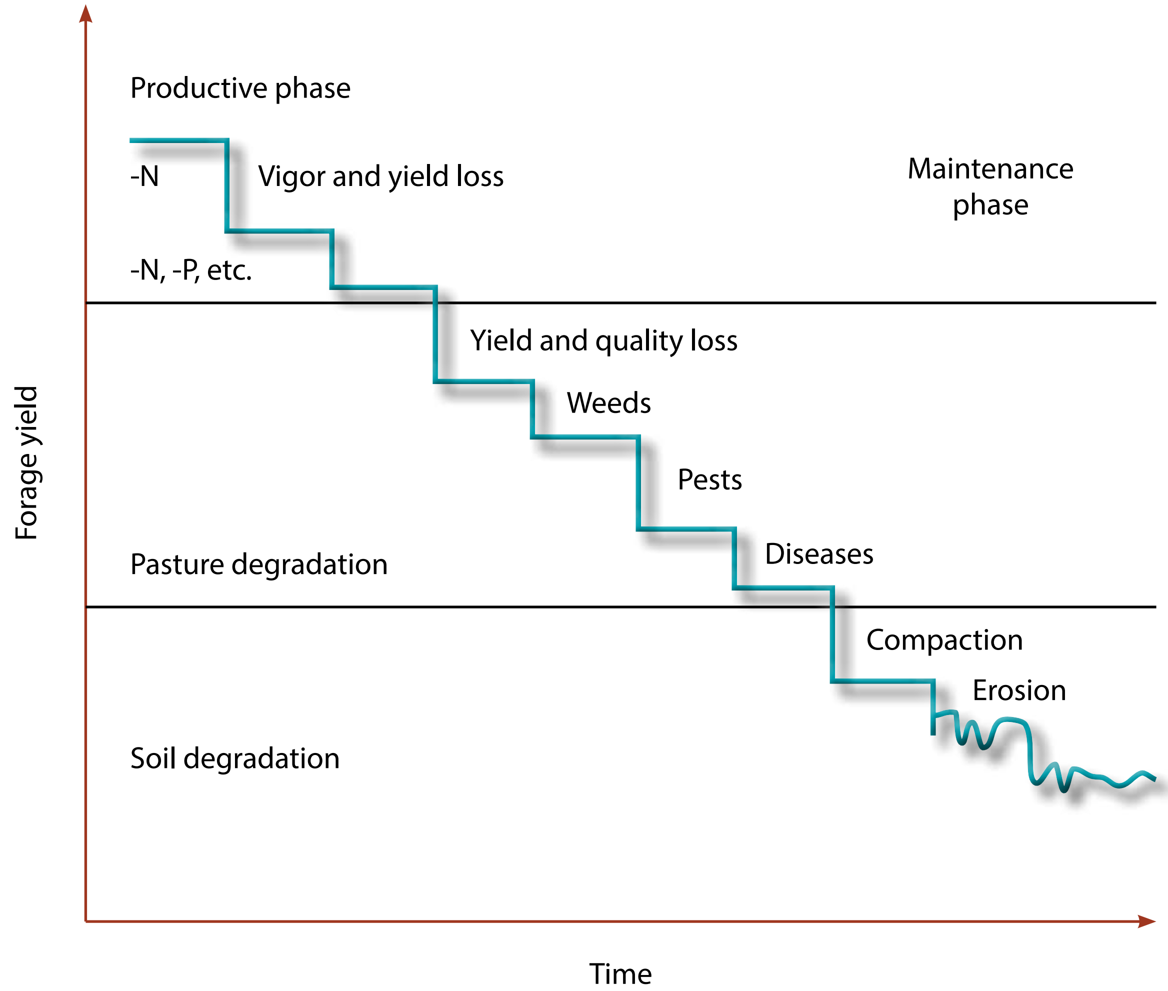

Figure 6.5

Simplified graphical representation of the degradation processes of sown pastures with different stages over time. Source: Macedo, 1999.

CAUSES OF PASTURE DEGRADATION

The main causes of pasture degradation include:

1. Forage species inappropriate to the site;
2. Poor initial pasture development caused by the absence or misuse of soil conservation practices, soil preparation, limestone application and/or fertilization, cultivation systems and methods, animal management during initial pasture development;
3. Crop management and practices, such as frequent use of fire; methods and frequency of tillage; no fertilization or inappropriate maintenance fertilization practices;
4. Pests, diseases and weeds;
5. Improper animal management, especially with excessive stocking rates and inadequate grazing systems;
6. No use or incorrect use of soil conservation practices while managing the system.

Assessments and determination of sustainability indicators for pasture yields and animal performance indicators have been the focus of several research projects, since they are essential for decision making regarding prevention and/or reversion of decreasing yields. Producers often get carried away by the momentary aspect of the pastures and fail to use important tools to predict production decrease, such as components of fertility, soil physical properties and plant nutritional status.

One of the most indicative evidences of pasture degradation process is the carrying capacity over time. When the system is systematically monitored, it is common to observe an initial decrease on the carrying capacity for the same forage availability. That is, after a fallow period, pasture growth is not enough to sustain the previous stocking rate.

Subsequently, if no management action is taken, volume and quality of forages decrease simultaneously, reflecting more intensely on animal individual performance. At this stage, the dossel may no longer be uniform, where spots without forage and exposed soil become more frequent. Weeds and pests can also occur, since the introduced sown pasture begins to lose its natural recovery ability due to the competition with native species. This process is presented in Figure 6.6.

Therefore, a careful monitoring of carrying capacity allows the anticipation of more severe degradation stages. However, even with reduced carrying capacity, farmers often do not adopt regular maintenance practices, leading to the later need of rehabilitation alternatives which are technically, financially and logistically much more expensive and difficult to execute.

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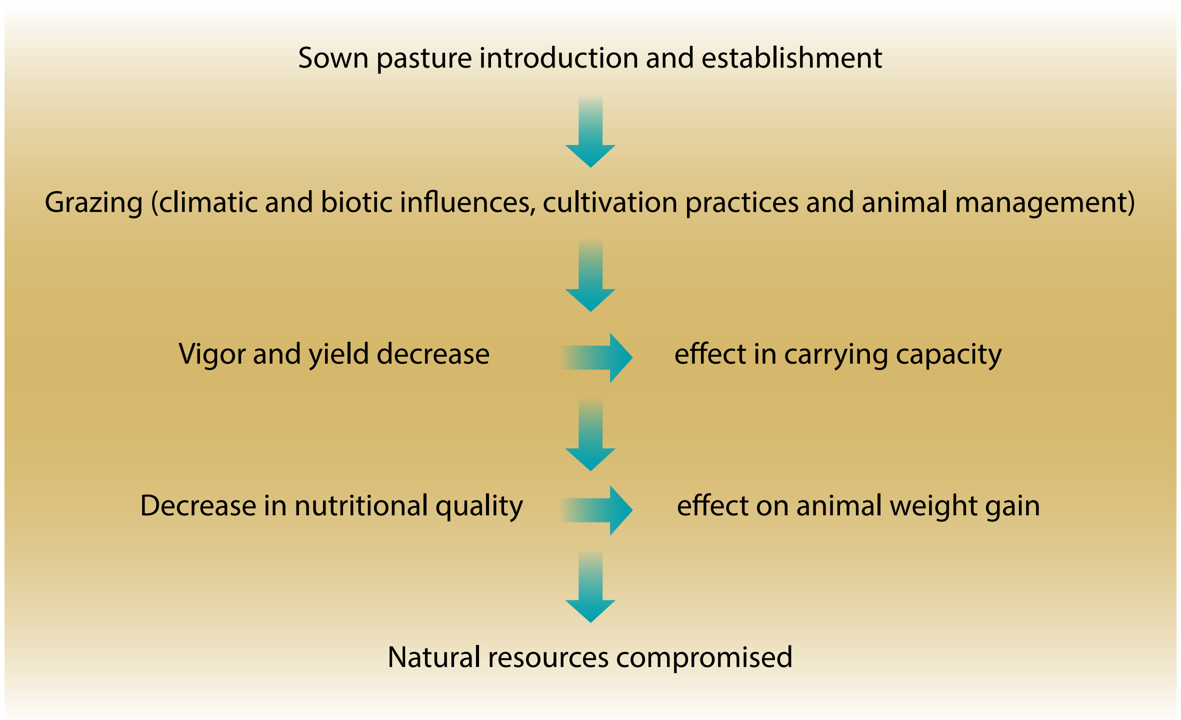


Figure 6.6
Illustration of the main stages of the pasture degradation process.

PASTURE RECOVERY AND RENEWAL METHODS

In general, pasture recovery and renewal methods, also called pasture reclamation or rehabilitation, can be classified as direct and indirect. **Direct pasture recovery** refers to mechanical and chemical practices applied to a pasture in order to revitalize it, **without replacing** the existing grass species.

The mechanical practices include surface application of inputs and tillage practices like scarifying, subsoiling, harrowing, disking, plowing etc. The chemical options include the application of limestone, gypsum and fertilizers. The most appropriate operation depends mainly on the stage of pasture degradation. The more advanced is the degradation process, the more drastic mechanical action should have to be. In this context, pastures with laminar erosion, high incidence of tall invasive species, mound-building termites and low vegetation coverage may require soil tillage operations with grids, plows, terracers and/or use of subsoilers (SPERA, et al., 1993; MACEDO, 2001a).

On the other hand, pastures at the initial stage of degradation, presenting only loss of vigor and yield, can be recovered with a simple broadcast application of limestone and fertilizers and/or scarifying and subsoiling. In the case of typical *Cerrado* soils, which are acid and have low fertility, certain nutrients play a key role in sustainable production. One of the most important nutrients is phosphorus. Research conducted by Embrapa Beef Cattle have shown that in most cases low initial P levels or the reduction in P levels after some time of exploration affect production directly. Once the P level is recovered, by the simultaneous application of other essential nutrients, nitrogen begins to play a key role in sustainable production (CADISH et al. 1993; MACEDO, 1997).

Direct pasture renewal consists of agronomic practices applied on degraded pastures to **replace** the existing forage species and reverse the degradation process through the introduction of a new species, being mainly characterized by replacing the grazing forage without carrying out an intermediate crop cultivation to improve the area.

This alternative usually presents operational and economic limitations, since tropical forage species have a high seed bank in the soil and high relative growth rates, even when pasture is degraded. Therefore, mechanical actions involving tillage or plant desiccation with herbicides are not always effective to inhibit the original forage, in order to allow establishment of the new species or variety. Competition can be high in the initial phase of establishment or during grazing phase, especially if animals are selective.

Brachiaria is one example of aggressive species with large soil seed banks. A direct pasture renewal technique that has been used recently is the replacement of *Brachiaria* by *Cynodon* (Coastcross, Tifton, etc.). As the latter are cultivated through vegetative propagation (seedlings), the use of trifluralin herbicides has proved very effective in slowing new *Brachiaria* growth from seeds in the soil, allowing a faster closing of *Cynodon* stand.

The **indirect recovery** of degraded pastures consists of mechanical and chemical cultivation practices using an annual forage species (millet, oat) or an annual grain crop (maize, soybeans, rice) for a certain period of time *to reinvigorate the existing forage species*.

Agronomic techniques may vary from pasture desiccation with herbicides and no-till seeding of an annual pasture or crop using minimum tillage, to soil preparation and conventional crop seeding. After use of the annual pasture or grain harvesting, the pasture is let to grow, from the existing seed bank or a complementary seeding, is carried out to assure sufficient plant population.

The main objective of this technique is to recover the existing pasture species at a lower cost by taking advantage of the residual fertilizer used on annual pasture or crop. Beef or dairy productions from intensive farming in annual pastures or sale of cash crops help remunerate part of the pasture recovery/renewal costs.

Indirect pasture renewal, consists of mechanical and chemical cultivation practices using an annual forage species (millet, oat) or an annual grain crop (maize, soybeans, rice) for a certain period of time *with the objective of replacing the existing forage species* by other species of higher nutritional value or with different characteristics from the former one.

ICL and ICLF systems are suitable alternatives for both, indirect pasture recovery and indirect pasture renewal, as shown in Figure 6.7. However, one must bear in mind that they should be implemented according to the limits of the pasture degradation stage, being more efficient and successful in initial phases of vigor loss, maintenance, and in early pasture degradation stages.

Pastures in advanced degradation stages must have their soil fertility and structure recovered in the first place, which in most cases requires soil conservation practices, terracing and

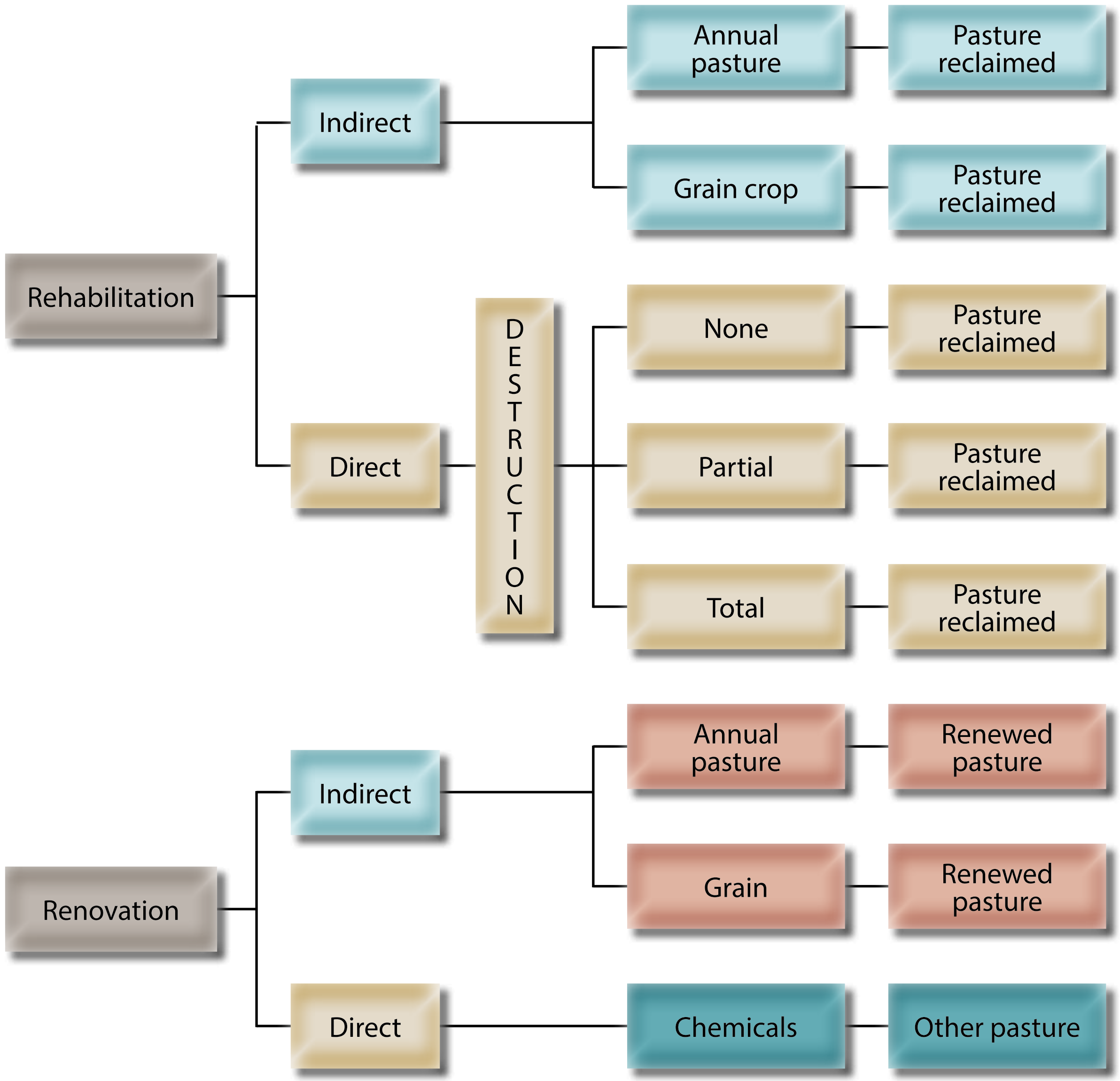


Figure 6.7

Simplified scheme of pasture recovery and renewal alternatives. Source: Macedo, 2001a.

incorporation of limestone and fertilizers. Once soils are recovered, integration systems may be implemented through introduction of annual pasture forage, using possible intercropping with a perennial forage, or through a direct perennial forage introduction. When the system is implemented with an annual grain crop, its establishment requires caution, especially regarding crop nutritional requirements and its adaptation and yield potential for the site, mainly if the grain is being cultivated for the first time in the area.

Figure 6.8 presents a diagram illustrating possible operations and sequences of activities when using ICLS for pasture recovery.

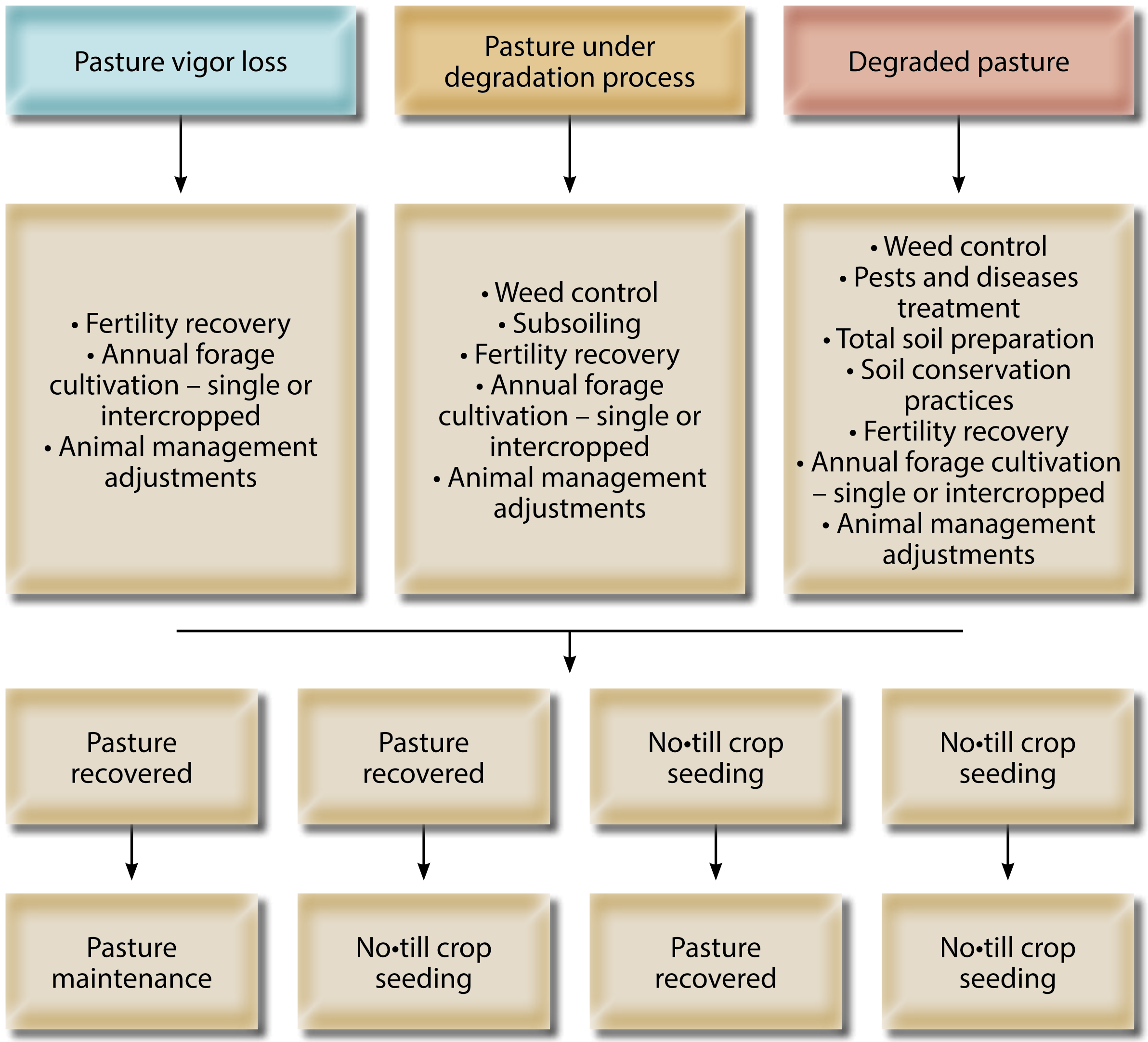


Figure 6.8
Simplified diagram of pasture recovery and renewal alternatives with the use of integrated crop-livestock system.

INTEGRATED CROP-LIVESTOCK SYSTEMS AS AN ALTERNATIVE FOR DEGRADED PASTURES RECOVERY

Grain crops and annual pastures have been used as cultural practices in the process of recovery or renewal of sown pastures. Occasional implementation of these activities by producers or by partners and tenants may be only a strategy to reduce costs and quickly return to their core activity, animal production (MACEDO., ZIMMER, 1990; KLUTHCOUSKI et al., 1991; ZIMMER et al., 1999).

However, a unique and highly efficient, though more complex, alternative to maintain productivity and indirectly recover or renew pastures has emerged recently – ICL systems, in which the introduction of crops is not occasional, but part of an integrated grain and animal production system, whose components interact and complement themselves biologic and economically. Note that the introduction of this system requires a detailed diagnosis of the farm and its regional insertion to ensure suitability.

There are certain requirements to implement integrated systems, such as more diversified machinery park, roads and storage infrastructure, skilled labor, mastering grain crops and livestock husbandry technologies.

This system allows more efficient use of inputs, machinery and labor in the farms and diversifies production and cash flow. Obviously there are certain requirements to implement the system, such as more diversified machinery park, roads and storage infrastructure, skilled labor, mastering cash crops and livestock husbandry technologies, and in-depth understanding of the related market. ICL comprehends systems in rotation schemes, alternating years or periods of livestock husbandry with grain or fiber cultivation, use of products and by-products in animal feed etc., all in the same area (ZIMMER et al., 1999; EUCLIDES et al., 1994b; 1994c; MACEDO, 2009).

From the agricultural point-of-view, integrated systems present several benefits, while monoculture and inadequate cropping practices have reduced yields and caused soil and natural resources degradation.

Continuous monoculture cropping systems favor spreading pests and diseases, such as *Scaptocoris castanea*, stem canker, root-knot nematodes and cyst nematode, causing substantial losses to soybeans production (YORONORI et al., 1993; MENDES, 1993). According to MENDES (1993), cyst nematodes were mostly identified in areas with 10-12 years of soybeans monoculture.

Another serious problem of monoculture associated with poor soil management is the concentration of soil fertility in the upper layers. Under these conditions, base saturation is excessively high, causing deficiency of micronutrients, such as manganese, in soybeans. Root distribution in the soil profile is also more intense on the surface, consequently turning crops more vulnerable to unexpected short dry periods in the cropping season.

On the other hand, ICLS has been adopted for years in several countries. Use of crop residues for animal feeding or crop stubble grazing is a common practice in various regions across Brazil, especially in the south. In terms of physical and chemical soil properties, these systems present

CHART 6.1

Evolution of Animal Production, Pasture Area and Crops in an Integrated Crop-Livestock System[1]

	NUMBER OF ANIMALS	STOCKING RATE	PASTURE AFTER *CERRADO*	PASTURE AFTER CROP	CROP
YEAR	N° HEAD	ANIMALS / HA	% OF TOTAL AREA*		
1983	1094	1.1	100	0	0
1988	821	1.9	58	29	13
1992	1150	2.3	0	41	59
1996	1200	3.2	0	36	64

[1]Total area of 1014 ha.
Source: Adapted from Vilela et al., 2001.

higher fertility rates thanks to the nutrient cycle and efficient use of fertilizers, resulting from the different needs of crops used for rotation. Improvements in soil physical properties include higher aggregated stability, lower soil bulk density, compaction and higher water infiltration rates.

For example, Vilela et al. (2001) presented positive results for animal production and soil properties improvement after the implementation of ICLS at Santa Terezinha farm, in Uberlândia municipality, Minas Gerais State. After introducing the system, they evaluated land use evolution, stocking rates and animal production from 1983 to 1996. Chart 6.1 presents some of the results.

The authors also emphasized the improvement in soil physical properties, such as aggregate stability. Pastures planted after soybean crops presented a rapid increase in aggregate stability, even more than natural vegetation would, demonstrating the important role of forage grasses extensive and deep root system for aggregating soil particles. (Figure 6.9). Organic matter content in soils under rotational cultivation also improved, increasing from 0.84 - 0.94% under continuous cropping system to 1.23% under rotational crop-pasture systems.

Embrapa Beef Cattle has been carrying out a long term experiment, started in 1993/1994 to study integrated crop-livestock rotational systems. These alternatives are compared to continuous cattle and crop systems, aiming to investigate differences on agronomic and economic efficiency as well as to assess sustainability of the different production systems. The experiment also aims to determine certain soil quality and sustainability indicators.

It is important to notice that this project was implemented in a degraded pasture area with sown *Brachiaria decumbens*, where plots were directly recovered or renewed using different treatments for fertilization, limestone application and tillage; were renewed with *Brachiaria decumbens* replacement by *Brachiaria brizantha* and *Panicum maximum* also using cash crops cultivation like

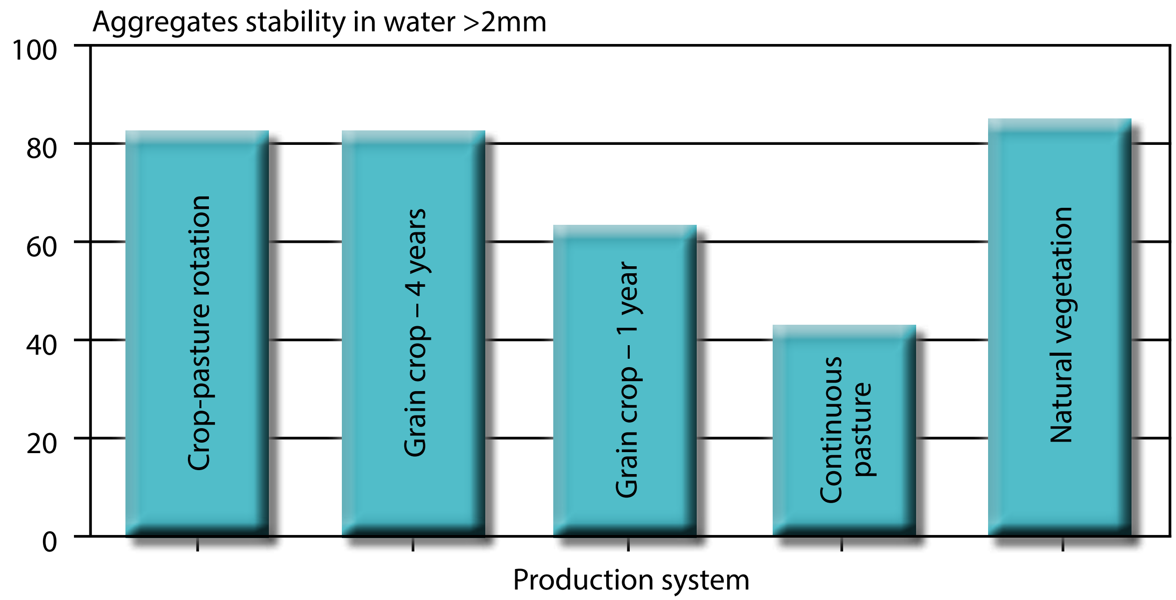


Figure 6.9

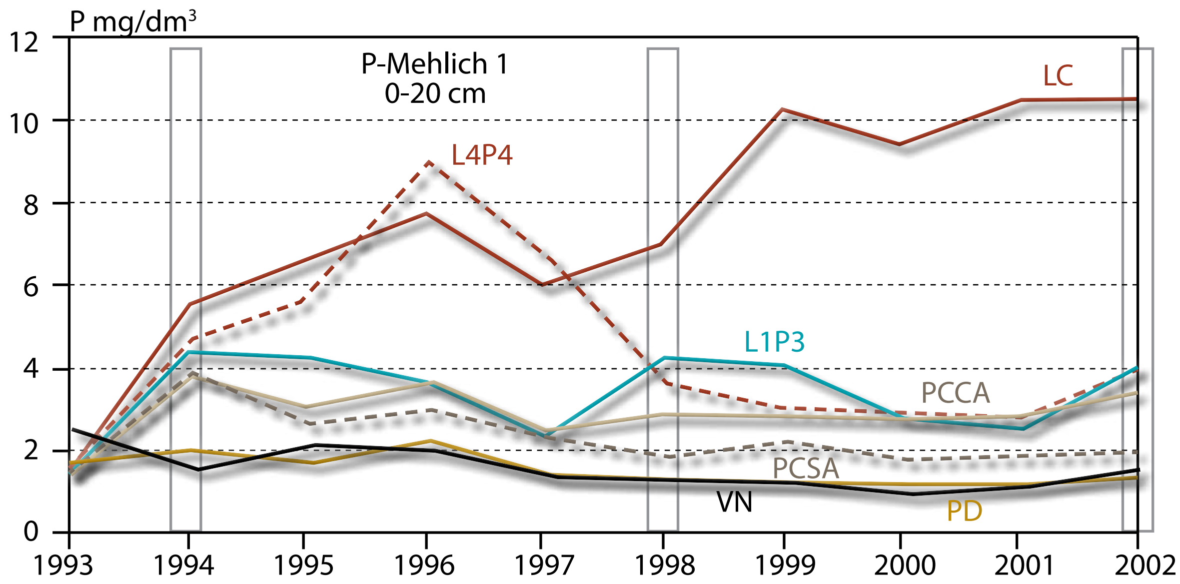
Percentage of aggregate stability in water (> 2 mm) in different production and management systems in medium texture latosol soils, in Uberlândia, MG. Source: Vilela et al., 2001.

soybeans or maize, depending on treatment. A natural vegetation plot and a degraded pasture plot were kept as references for comparison.

The main treatments consist of five production systems: **S1**- Continuous grazing; **S2**- Continuous crop cultivation; **S3**- 4-years grazing – 4-years crops; **S4**- 4-years crop – 4-year Pasture; **S5**- 1-year crop – 3-years grazing (forage introduced in the second year with and without maize cultivation). These systems are divided into subsystems that comprise soil management methods and conventional or no-till seeding systems, only summer crop or summer + inter-seasonal maize or sorghum crop, in Brazil called winter crop or "safrinha". Other sub-treatments include different maintenance pasture fertilization and alternative forage legumes intercropping, totaling 12 treatments.

The results of soil fertility analysis regarding evolution of phosphorus availability by Mehlich-1 in traditional and ICLS systems are presented in Figure 6.10, which shows that, although continuous crop systems (LC) considerably increase soil's P levels, ICL systems, such as S4 and S5, can also do it cost-effectively, especially with moderate maintenance pasture fertilization (this practice was not used in the example presented).

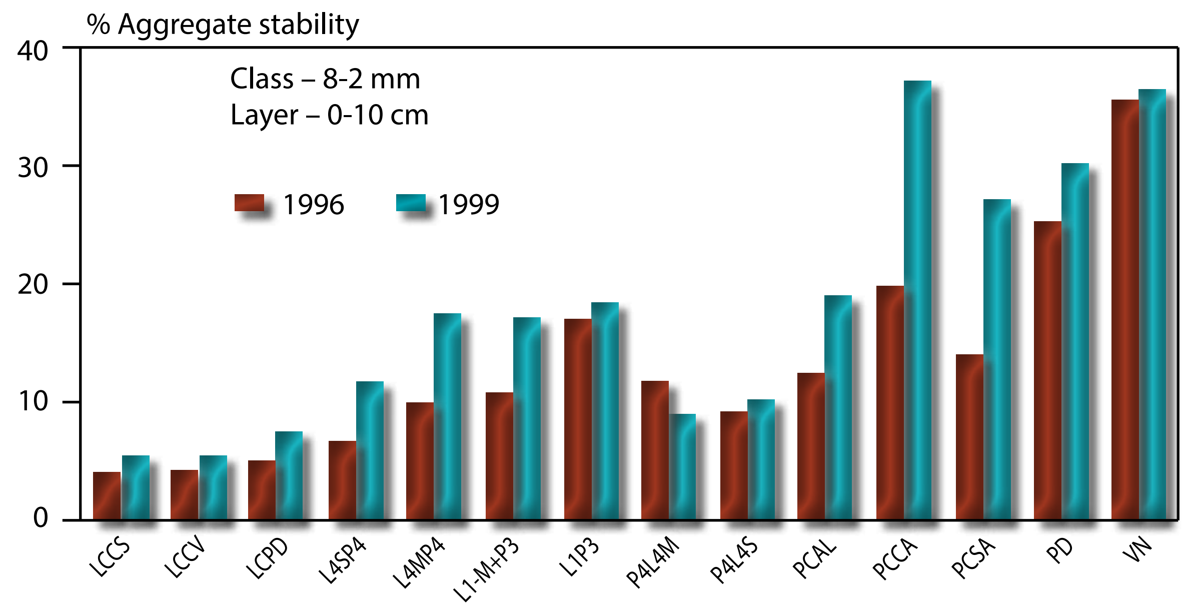
Analyses results of given physical soil properties, e.g. aggregate stability, penetration resistance and water infiltration rates, showed the key role of forage grasses to improve these properties. It has been observed that only one year (1999) after pasture introduction that followed 4 years of crop production, the grasses' root system substantially increased soil aggregate stability (Figure 6.11).



LC: continuous crop; L4P4: ICL 4 years crop-4 years cattle; L1P3: ICL 1 year crop 3 years cattle; PCCA: continuous pasture with maintenance fertilization; PCSA: continuous pasture without maintenance fertilization; VN: natural vegetation; PD: degrade pasture.

Figure 6.10

Dynamics of soil phosphorus content (Mehlich-1) in 0-20 cm layers of conventional and integrated crop-livestock systems in a Oxisol (Dstrophic Red Latosol in Campo Grande, MS. Source: Macedo, 2005.



LC: continuous crop; L4P4: ICL 4 years crop-4 years cattle; L1P3: ICL 1 year crop 3 years cattle; PCCA: continuous pasture with maintenance fertilization; PCSA: continuous pasture without maintenance fertilization; VN: natural vegetation; PD: degrade pasture.

Figure 6.11

Percentage of water-stable soil aggregates (8-2 mm diameter) in 0-10 cm deep layers in a Oxisol (Red Clayed Latosol, under different management conditions, in continuous pasture-crop systems and integrated crop-livestock systems in Campo Grande, MS. Source: Macedo, 2009.

CHART 6.2
Organic Carbon Storage in a Oxisol (Red Clayed Latosol) in Campo Grande, MS, Submitted to Management Systems for 11 Years

	C-CP[1]	C-DS[2]	S1P3[3]	S4P4[4]	PP[5]	PP+L[6]	NV[7]
DEPTH (CM)	MG HA^{-1}						
0-2.5	4.8 d	6.2 cd	7.8 c	7.2 c	6.6 c	12.0 a	10.0 b
2.5-5	5.1 d	5.5 cd	7.0 b	6.2 bc	7.2 b	8.7 a	6.7 b
5-10	135 abc	12.2 bc	12.8 abc	11.8 c	14.3 a	13.8 ab	13.6 abc
10-20	23.0 a	23.5 a	22.9 a	22.7 a	25.4 a	24.1 a	23.7 a
0-20	46. 3d	47.4 d	50.5 bcd	47.9 cd	53.5 abc	58.6 a	540 ab

[1]C-CP: crops in conventional tillage systems;
[2]C-DS: crops in no-till systems;
[3]S1P3: rotation - soybeans for 1 year – pasture (*B. brizantha*) for 3 years;
[4]S4P4: rotation - soybeans for 4 years – pasture (*P. maximum*) for 4 years;
[5]PP: permanent pasture (*B. decumbens*);
[6]PP+L: permanent pasture (*B. decumbens*) in intercropping with legumes;
[7]NV: natural vegetation
Average figures for 3 repetitions. Identical letters indicate a difference below LSD 5% for the same layer. Source: Salton, 2005.

An experiment carried out by Salton (2005) demonstrated the benefits of ICL systems in terms of carbon storage and soil aggregation. It highlights the importance of forage grasses in rotation and no-till systems associated with ICLS in the *Cerrado* region (Chart 6.2 and Figure 6.12.). ICL systems present intermediate carbon storage capacity in relation to natural vegetation and continuous-use pasture, provided there is proper nutrient reposition and adjustments in stocking rates. At that point, pastures with legumes established in 1993/94 already presented higher carbon storage than the native vegetation (Chart 6.2).

In another long-term experiment on ICL systems, which is being carried out at Embrapa *Cerrados*, in Planaltina, Federal District (VILELA et al., 2001), Marchão (2007) investigating soil physical properties, carbon storage and macrofauna to assess soil quality in these systems compared to traditional systems and continuous crop and pasture systems, including different tillage methods and no-tillage systems, with two maintenance fertilization levels. A native vegetation plot was kept as reference. The author concluded that ICL systems change certain physical-hydric properties of the soil, increasing penetration resistance and bulk density by animal trampling during the grazing phase in the rotational system, though these were not yield limiting factors for subsequent annual crops. ICL systems contribute to increasing water storage and soil porosity, especially in no-till systems. Soil use and tillage systems impacted carbon and nitrogen storage,

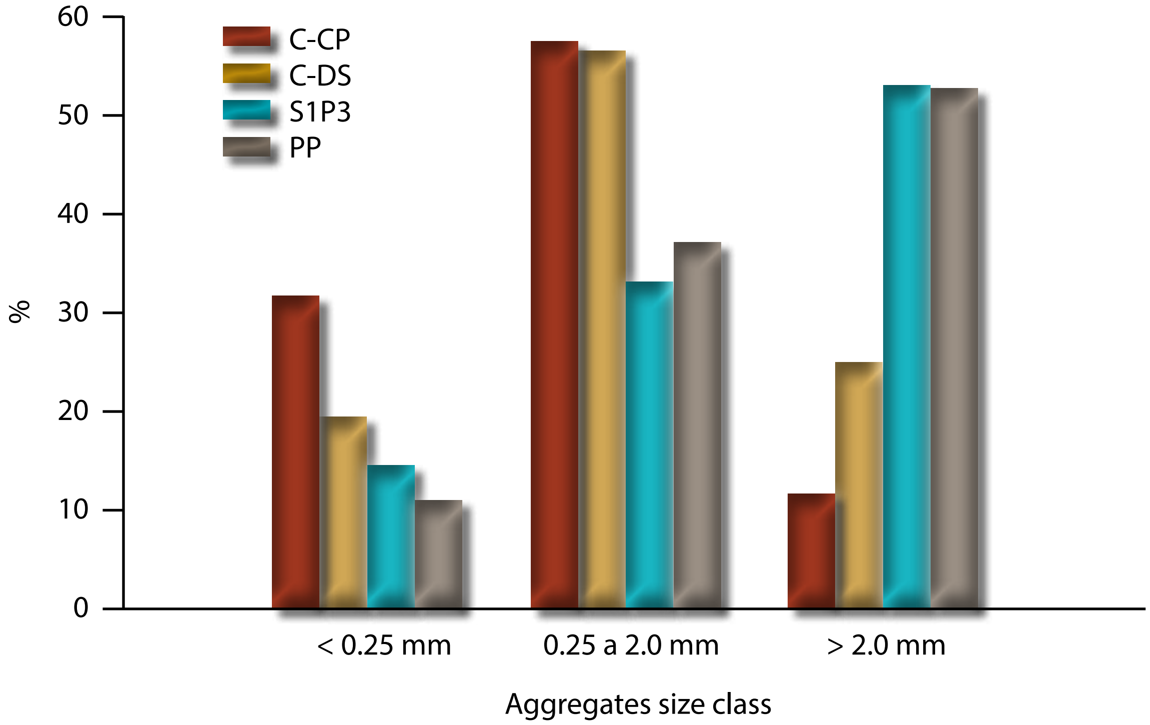


Figure 6.12

Distribution of aggregates in the 0-5 cm deep layer, grouped into three size classes for crop systems under conventional preparation (C-CP); crop under no-till system (C-DS); soybean rotation for 1 year - pasture (*B. brizantha*) for 3 years (S1P3); permanent pasture (*B. decumbens*) (PP). Source: Salton, 2005.

especially in no-tillage, with no effect of fertilization level. Regarding soil macrofauna, ICL systems based on no-tillage and on rotation with pastures in intercropping with legumes presented higher density and species biodiversity, providing better conditions for improving sustainable soil quality. Among macrofauna communities benefitted by the use of ICLS are the *Oligochaeta* (earthworms) and *Coleoptera* (scarab beetles), which play a key role in soil structuring. Macrofauna evaluation proved to be a useful soil quality indicator (Chart 6.3).

Regarding the interaction between physical and chemical soil properties with macrofauna density and richness, Lourente et al. (2007) observed in a farm in Mato Grosso do Sul, which has been using ICLS and no-tillage for several years, that there was no correlation between density of individuals and soil physical properties, though the latter was influenced by some chemical properties. Among these positive correlations are soil P levels (Mehlich-1), earthworms and *Coleoptera* (aquatic beetles) larvae with organic matter content.

Certain studies available in the literature, including Costa and Macedo (2001), Cobucci et al. (2007), Muniz (2007), Martha Jr. et al. (2008), show the economic advantages of ICL systems compared to continuous traditional systems and their ability to support pasture recovery. Most of these works shows that ICL systems present advantages in several economic viability indicators, including the internal rate of return (IRR) and net present value (NPV).

CHART 6.3

Density (individuals/m²), Species Richness (Number of Morphospecies) of the Invertebrates' Macrofauna in Integrated Crop-Livestock Rotation Systems, Continuous Systems and Natural Cerrado Vegetation in Planaltina, Federal District

	SPECIES	
SOIL USE AND PREPARATION SYSTEM	DENSITY (IND./M²)	RICHNESS (NO.)
Natural Vegetation	4,792	51
Continuous pasture	1,653	38
Continuous crop w/ soil prep.	501	4
Continuous crop w/o soil prep.	827	46
Pasture – Crop w/ soil prep.	616	22
Pasture – Crop w/o soil prep.	992	21
Crop – Pasture w/ soil prep.	1,144	26
Crop – Pasture w/o soil prep.	3,456	52

Source: Adapted from Marchão, 2007.
In a similar study Carried out at Embrapa Western Region Agriculture, in Dourados, MS, Silva et al. (2008) obtained similar results in a long-term experiment also for ICL systems evaluation. The work concluded that ICLS allows community recomposing of invertebrate macrofauna in the soil.

Benefits related to animal performance in integrated systems are also relevant. Chart 6.4 presents results of live weight gain in a long-term experiment carried out at Embrapa Beef Cattle, where different production systems are being tested in an Oxisol (Red Clayed Latosol) of the *Cerrado* region, which began with the recovery of degraded pastures to later include ICL as a rehabilitation alternative.

According to Costa; Macedo (2001), this experiment being carried out by Embrapa Beef Cattle shows that, although traditional grazing systems are maintenance fertilizer-responsive, they are not as economically efficient as ICL systems (L1P3 and L4-P4) when compared to non-fertilized systems and degraded pastures. In ICLS, the combination of beef and grain production increases efficiency of integrated systems. Secondary effects, such as improvement in soil properties, are also beneficial for ICLS, though they have not been directly assessed.

Social and economic evaluation studies should include methodologies that take into account environmental accounting in ICL systems, as they are an alternative for reclaiming degraded areas, which affect a vast portion of the Brazilian grazing areas. Their adoption on a larger scale

CHART 6.4

Animal Production in Traditional Systems with Continuous Grazing Integrated Crop-Livestock System and Degraded Pasture in the *Cerrado* Region, in Campo Grande, MS

SYSTEMS	YEARS												
	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	TOTAL	MÉDIA
	kg/ha												
TRADITIONAL SYSTEMS *B. decumbens*													
PCSA	342	556	404	360	325	235	353	249	212	270	297	**3603**	**328**
PCCA	385	497	379	497	464	278	358	289	267	340	432	**4186**	**381**
PCAL	399	542	456	513	399	321	441	374	326	396	408	**4575**	**416**
INTEGRATED CROP-LIVESTOCK SYSTEMS Soybeans/sorghum – *P. maximum* Tanzania													
L4-P4	–	–	–	–	686	414	399	–	483	464	522	**2968**	**495**
Soybean/sorghum – Corn + *B. brizantha* Marandu													
L1-P3	–	842	522	–	–	358	393	–	–	484	486	**3085**	**514**
DEGRADED PASTURE *B. decumbens*													
DP	68	90	116	111	177	73	185	127	178	201	224	**1550**	**141**

PCSA: continuous grazing with no maintenance fertilization; PCCA: continuous grazing with maintenance fertilization; PCAL: continuous grazing with maintenance fertilization and use of legume species; L4-P4: 4 years of crop cultivation, followed by 4 years of grazing; L1-P3: 1 year of crop cultivation with 3 years of grazing with forage introduced in intercropping with maize; PD: degraded pasture; Source: Macedo; Zimmer, 2007.

could help to prevent clearing new areas, especially in the *Cerrado* and Amazon regions. ICLS intensify and increase soil efficiency, resulting in higher yields within a shorter period of time and in a smaller area, besides reducing greenhouse gas emission rates per product unit.

CLOSING REMARKS

The new trend for crop-livestock integration is the incorporation of trees in the system. The initial work carried out by Carvalho et al. (1997) at Embrapa Dairy Cattle, aiming to adjust tropical forages that best adapt to shading in silvipastoral systems, has evolved into agroforestry systems, with tree rows design already considers the space needed for crop cultivation (SOARES et al., 2009).

The installation of pulp and paper mills in soils with lower fertility, where extensive cattle ranching is the main activity, like in northeastern Mato Grosso do Sul, for example, among other initiatives to supply wood for the steel industry, especially in Minas Gerais, have encouraged introducing forestry into cattle systems. Trees are planted in double or triple rows, with spacing of 8 to 14 meters between rows, depending on systems main purpose.

It is important to notice that distances wider than 14 meters favors forage growth and consequently animal production, though wood production per area will be lower. ICLF systems have made possible to integrate forestry with crops and livestock, consequently diversifying farmers' income.

Finally, statistics on areas covered with integrated systems in Brazil are scarce, becoming rather difficult to precise their extension. However, it is estimated that about 5% of the area cultivated with annual crops in Brazil uses this technology to some extent. Practical examples of on-farm use of these technologies can be found and visited in various different regions of the country like in Maracaju-MS, Rio Verde-GO, Campo Mourão-PR, Rondonópolis-MT, Luis Eduardo Magalhães-BA, Uberlândia-MG, Pedro Afonso-TO and Assis-SP.

Chapter 7

Fundamentals of Implementing Integrated Crop-Livestock-Forestry Systems with Eucalyptus Trees

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IMPLEMENTING INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS

The use of integrated crop-livestock-forestry systems (ICLF or ILPF) in farms is an alternative that offers several advantages, including environmental benefits, for pasture renovation and/or recovery of areas under some stage of degradation.

ILPF systems improve soil's chemical, physical and biological properties, help to prevent erosion, promote carbon capture and the conservation of water resources and biodiversity, in addition to several other technical, economic and social benefits.

ILPF systems are inherently more complex than grain crops and their cycle duration depends mainly on the tree component. In this context, it is essential to correctly implement the system avoiding later management problems that are often irreversible. Attention to the several planning details and caution when defining each implementation step, for each system components can determine success and failure in such initiatives.

This chapter presents and discusses several aspects related to the implementation of ILPF systems having eucalyptus as tree component, with particular emphasis on area preparation, planting and initial management of trees.

AREA SELECTION AND PREPARATION

When defining an area for implementing an ILPF system, it is necessary to bear in mind that the site should provide minimum conditions for cultivating annual crops, such as soybeans, maize and sorghum, which require greater soil fertility than most tropical grasses and eucalyptus trees demand. In cases when temporary crops have low viability due to soil fertility, climate or infrastructure issues, silvipastoral systems might be the best option, combining only forage species and the forest component.

Soil Preparation and Fertilization for Implementing ILPF Systems

After ensuring that the area has good potential for implementing an ILPF system, including viability for harvesting, transportation, storage and outputs trade, such as grain and timber, it is important to observe if the area has a sharp slope, requiring terraces to be built and the adoption of other measures to prevent erosion and soil conservation.

Particularly in the Brazilian *Cerrado*, soils usually have chemical properties which are unfavorable for cash crops without prior fertilization, once they usually present high levels of exchangeable aluminum (Al) and high active acidity (low pH). In addition to these two factors, other common problems are low phosphorus (P) content and exchangeable bases, such as calcium (Ca), magnesium (Mg) and potassium (K).

For an integrated and sustainable development of plant and animal production systems, it is necessary to sample and analyze the soil for better assessment of fertilization needs. In Brazil, soil acidity is usually corrected by the application of limestone and gypsum.

Necessary amounts of limestone and fertilizers should be determined by chemical and physical soil analysis and interpretation, based on the nutritional requirements of the crops to be cultivated.

Samples should be collected to depths of 0-20 cm and 20-40 cm, properly prepared, packed, identified and sent to laboratory. Results should be submitted to an agronomist, who will provide technical recommendations.

After defining amounts of lime and/or gypsum as well as other fertilizers that will be applied in the selected area, the next step is its uniform distribution and deep incorporation using heavy tillage equipment (Figure 7.1).

Figure 7.1

Heavy tillage for lime incorporation on the total area where the ILPF system will be implemented. *Photo: Ademar P. Serra.*

The area can be tilled through conventional systems, using plows, subsoilers and/or harrows. These practices are particularly important for implementing ILPF systems in more degraded areas, as they allow a quicker incorporation of lime and levelling the soil for crop cultivation (Figures 7.1, 7.2 and 7.3). In systems with recent crop harvesting, it is possible to adopt no-till practices (Figure 7.5), which should be prioritized whenever possible.

Lime should be incorporated into the soil to a depth of 20 cm with a heavy harrow or plow. Gypsum (calcium sulfate) can also be applied if required. In this case, aluminum saturation should be taken into consideration in the 20-40 cm deep layer, as well as nutritional requirements of crops intended to be cultivated in the area.

After lime is spread throughout the area where the ILPF system will be implemented, the eucalyptus (*Eucalyptus* spp.) planting rows are marked (Figures 7.2, 7.3 and 7.4). It is important to remember that future mechanization should be considered when defining distances between tree rows, especially taking into account the use of wide sprayers and combines for annual crops.

Figure 7.2

Soil tillage with levelling harrow in the space between eucalyptus rows.
Photo: Ademar P. Serra.

Figure 7.3

Detail of marked rows for planting eucalyptus seedlings before seeding annual crops. *Photo: Ademar P. Serra.*

Figure 7.4

Detail of marked rows for planting eucalyptus seedlings and newly emerged soybeans. *Photo: Ademar P. Serra.*

Figure 7.5
No-till soybeans cultivation.
Photo: Ademar P. Serra.

Once tree rows are marked, soil tillage with intermediate and levelling harrows is restricted to the space between these rows when necessary (Figures 7.2 and 7.3). It is recommended to use marking poles to guide machine operators in field operations (Figure 7.4). In addition to this suggested model, other possibilities include planting eucalyptus seedlings before soil preparation for annual crops. For the second grain crops season and subsequent cultivation, no-till systems are always recommended whenever possible. No-till offers several advantages, including soil preservation, improving its physical, chemical and biological properties as well as enhancing carbon storage (Figure 7.5).

Weed Control

Weed competition can slow tree growth, requiring therefore a weed management plan in advance. The area where the system will be implemented must be evaluated for defining herbicides to be used and their application plan.

The combination of cultivations, such as soybean and eucalyptus, for example, is inherent for ILPF. Currently it can be a little difficult to find registered herbicides for eucalyptus that do not affect soybean, maize, sorghum, rice and other grain crops. One possible strategy when implementing ILPF systems is to use glyphosate-resistant soybeans, with eucalyptus seedlings being planted after the last herbicide application (Figures 7.6 and 7.7).

Figure 7.6

Effect of glyphosate 20 days before seedlings introduction on GMO soybeans and stripes ready for eucalyptus planting. *Photo: Ademar P. Serra.*

Figure 7.7

Furrow preparation with phosphate and planting fertilizer for eucalyptus in single rows. *Photo: Ademar P. Serra.*

When fertilizing tree seedlings, fertilizers should be applied 10-15 cm from the stems.

The use of genetically modified (GMO) soybeans in the system can generate several benefits related to weed control. Glyphosate applications reduce weeds that compete with both, annual crops and trees.

In Brazil, some farmers plant eucalyptus seedlings in May (early dry season), before starting cultivation for the next summer crop, with the possibility to seed maize with forage through the so called Santa Fé system.

The main advantage of this model is to establish eucalyptus seedlings in the dry season, which leads to a better water and nutrient absorption by older trees during the rainy season. It also decreases weed-tree competition, thanks to the faster growth of eucalyptus in the rainy season. However, this system has a higher implementation cost, since it will require irrigation and whenever possible, the use of special gel to retain moisture for seedlings at transplanting.

EUCALYPTUS SEEDLING PLANTING AND FERTILIZATION TECHNIQUES

Furrow Preparation and Fertilization

Furrowing should be carried out preferably on the transplanting day (Figure 7.8), though it can be carried out earlier when necessary. In the case of Central Brazil, fertilization with phosphorus at 40 to 50 cm depth at furrowing is very important.

Amounts of fertilizer to be applied will depend on soil chemical and physical analysis, allowing recommendations according to eucalyptus' nutritional requirements. Notice that calcium, magnesium and sulfur are used as soil improvement, previously applied and incorporated in the full area.

Seedlings fertilization usually requires macronutrients such as nitrogen (N), phosphorus (P) and potassium (K), as well as micronutrients, such as boron (B), zinc (Zn) and copper (Cu), which can be applied on the day of planting or in the following five days in parallel fertilizing holes with the half of the amount in each side of the seedlings.

Approximately 90 days and 12 months after seedlings were planted, the first and second top-dressing fertilization should be respectively carried out to complement nutrients supply, especially nitrogen, potassium and micronutrients.

Top-dressing fertilizer is applied in parallel holes to both sides of seedlings. Optimal distance is 10-15 cm from the stem, with caution so that fertilizer is not applied too close to the seedlings. For older Eucalyptus trees, top-dressing fertilization is recommended at canopy projection area.

Figure 7.8

Eucalyptus seedlings planted in double rows after the application of the glyphosate on GMO soybeans. *Photo: Ademar P. Serra.*

Seedling Planting

Seedlings should present good quality for proper tree development. Attention to certain aspects while on nursery is very important so that defective seedlings are not transplanted to field. Seedlings must present a good phytosanitary aspect. Root system should have no coiling or awry tap-root. Additionally, they must be young and reach from 20 to 35 cm high (Figures 7.9 A and 7.9 B).

Seedling hardening off process, i.e. leaving seedlings exposed to direct sunlight and controlled irrigation before they are transplanted to field is extremely important, as it substantially improves survival rates after transplanting.

At the time of planting, in the case of deficient rainfall (less than 30 mm) or if soil moisture is not above field capacity, it is recommended to irrigate seedlings at planting, using around 2 liters water per seedling to ensure a satisfactory survival rate (Figure 7.10.).

In addition to controlling ants and termites in the entire area before planting, it is necessary to perform a pretreatment of the seedlings with Fipronil-based insecticide to mitigate losses during their early stage of development.

In case of planting seedlings grown in tubes, the work can be done manually or by using specialized seedling transplanter machines. In hand-planting, holes should have the tube's

Figures 7.9 A and B

Eucalyptus seedlings in tubes; Detail of Eucalyptus seedling rooting in tubes. *Photos: Ademar P. Serra and David J. Bungenstab.*

Figure 7.10

Planting and irrigating eucalyptus seedlings in double rows. *Photo: Ademar P. Serra.*

width and seedlings should not be placed too deep, which could kill them. An adequate depth is the one which positions the stem base at soil surface level (Figure 7.11 A and B and Figure 7.12).

It is fundamental to gently compress the soil around seedling to prevent air bubbles which hinder root system development. Seedling losses should not exceed 5%. Percentages above this amount indicate the need for replanting and should be carried out within 30 days from transplanting.

Spatial Arrangement of Trees

Besides meeting the system's goals and wood destination/quality, tree spacing should facilitate transit of machinery and equipment. It is necessary to consider the minimum distance between tree lines and keep them proportional to machines or larger equipment width, such as combines and sprayers thereby optimizing field operations and costs.

It is more common to arrange trees in single, double or triple rows (Figures 7.13 A, B and C), though it is also possible to use more rows per line of trees, according to system's primary purpose.

Figures 7.11 A and B

Eucalyptus seedlings with indication of stem base. *Photos: Ademar P. Serra and Davi J. Bungenstab.*

When topographical conditions allow, rows should be east-west oriented to ensure greater sunlight incidence between tree rows, where grain crops and forages are cultivated. In slopes, levelled planting is necessary to control erosion. Tree arrangement must then follow terraces direction. Trees should not be planted over them to avoid structure damage.

To define spacing between trees and between rows, one must consider the end-use of wood, like saw timber, lamination, firewood, fence poles, pulp and charcoal. Broader spacing trees grow faster, resulting in logs with wider diameters at the end of the ILPF cycle. Spacing usually adopted for eucalyptus in ILPF systems is usually 1.5 to 5 m between trees and 9 to 50 m between single rows. For planting in double and triple rows, the most widely combinations used are 3 m between rows, 2 m between trees in the rows, and 14 or 24 m between lines of trees. It is important to emphasize that tree arrangements should always consider characteristics of owned and contracted machines and equipment that will be used in the field.

Figure 7.12

Eucalyptus seedlings planted with stem base at soil surface level. *Photo: Ademar P. Serra.*

Figures 7.13 A, B and C

(A) single row, (B) double row, and (C) triple row of eucalyptus trees after three months of planting in an ILPF system.
Photos: Ademar P. Serra.

Initial Care for Tree Seedlings

In early tree development of eucalyptus and other species, control of surrounding weed is necessary to avoid competition, especially because in ILPF, fast tree growth is critical to allow animal grazing as early as possible, optimizing land use. Weed control can be done by hand or using pre- and post-emergent herbicides, keeping seedlings clear from weeds in a circle of at least one meter radius (Figure 7.14).

When non-selective herbicides are used, it is necessary to use mechanisms to prevent drifting. Two active principles of pre-emergent herbicides allowed in Brazil – Isoxaflutole and Oxyfluorfen – are selective for eucalyptus.

Weed control on eucalyptus is recommended for two years after planting. It is important to remind that especially at the beginning, herbicides sprayed over annual crops presents toxicity risks for eucalyptus, while herbicides recommended for trees can affect annual crops if not used carefully. A specialist should always be consulted.

Figure 7.14

Hand weed control.
Photo: Ademar P. Serra.

USE OF ANNUAL GRAIN CROPS AT ILPF IMPLEMENTATION

The tree component in ILPF systems has medium to long term economic return. Therefore, annual crops in the first and second years amortize part of the initial investment on trees and pasture renovation.

Choosing which annual crop to use will depend on local and regional agricultural potential. In the Brazilian *Cerrado*, traditional crops like soybeans, maize, sorghum and rice have been successfully used as crop component in the system.

In ILPF, annual crop management like seeding season, spacing, population, fertilization and cultivation techniques follow regional recommendations.

In larger systems, maize is usually intercropped with grass for silage or grain (Santa Fé system). Soybeans can also be used, usually requiring a better regional infrastructure. Both have presented excellent economic results in several Brazilian regions. Soybeans have been also cultivated in the first and second year of the system with good results (Figure 7.15 and Figure 7.16).

Figure 7.15

Soybeans crop in an ILPF system under implementation, with newly planted eucalyptus in single rows.
Photo: Ademar P. Serra.

It is also possible to include annual crops – preferably soybeans – into the system every four years for improving soil fertility, nutrients recycling and residual fertilization for forages. In this case, it is necessary to trim trees to increase sunlight incidence on annual crops and subsequent forage. No-till drilling should be used whenever possible.

ANNUAL CROPS ON ILPF AS MULCH

When selecting species for mulch, it is important to consider above ground biomass yield and decomposition time in order to ensure a good soil cover. Species with high decomposition rates are not suitable, unless when used to fix nitrogen, as in the case of legumes.

Millet (*Pennisetum glaucum*) is one of the most used species as mulch in the *Cerrado* region (Figure 7.17 and Figures 7.18 A and B). This species is seeded in the fall, after soybean harvest, or early spring, to form straw for the next soybean no-till drilling.

In addition to millet, other good options to be used as soil coverage include *Brachiaria* sp., grasses especially *Brachiaria ruziziensis*, which can be grown alone or intercropped with *Crotalaria*

Figure 7.16

Soybean harvesting in an ILPF system under implementation. *Photo: Ademar P. Serra.*

sp. or gandule bean, also known as pigeon peas (*Cajanus cajan*), whose most suitable cultivar for ILPF in Brazil is the "Mandarin" (Figures 7.19 A and B). These species have provided good results in straw production and permanence on soil surface.

SEEDING AND INITIAL MANAGEMENT FOR GRAZING FORAGE

Forage cultivation should follow recommendations for the species/cultivar to be introduced in the area. *Brachiaria brizantha* cvs. Marandu, Piatã and Xáraes, *B. decumbens* cv. Basilisk, *Panicum maximum* cvs. Aruana, Mombaça and Tanzânia, and *Panicum* spp. cv. Massai, are good options for ILPF systems in Brazil due to their good shade tolerance.

Grazing forage is usually introduced in the system in the second year. It is no-till drilled over previous crop residues. In certain regions, forage can also be intercropped with off-season maize or sorghum (Santa Fé system). After grain harvest, grass root system is established, enabling the plant to better absorb water and nutrients and consequently to enhance its growth and development.

Figure 7.17

No-till seeded millet over soybean harvest residues for mulch. *Photo: Ademar P. Serra.*

Figures 7.18 A and B

Millet used as mulch in an ILPF system.
Photos: Ademar P. Serra and David J. Bungenstab.

Figures 7.19 A and B

Gandule bean (*Cajanus cajan*) used as soil cover in an ILPF system. *Photos: David J. Bungenstab.*

Once soil was fertilized for the annual crop, usually there is no need to apply fertilizers when introducing forages (Figure 7.20) reducing costs.

As before mentioned, the remaining fertilizer is usually sufficient to meet forage nutritional requirements during early stage of development. However, it is important to regularly monitor soil fertility and plant nutrition to assure proper maintenance fertilization. If using forage for silage or hay, it is important to use fertilizers according to production goals.

OTHER IMPORTANT MANAGEMENT ASPECTS

Ant Control

Leaf cutting ants, especially *Atta* sp. and *Acromyrmex* sp., are common pests in Brazil that harm eucalyptus growth. Inadequate ant control can limit ILPF systems implementation, even when controllable factors such as tree species, variety or clone, soil preparation, fertilization and planting season are correctly used. Success on eucalyptus cultivation, therefore, depends on good monitoring and preventive ant control in the area and its surroundings. Ant control is necessary in a minimum radius of 100 m around the field and should begin at least two months

Figure 7.20

Brachiaria brizantha cv. Marandu seeded in no-till system in cross slot drilling. *Photo: Ademar P. Serra.*

prior transplanting seedlings. When eucalyptus seedlings are planted after or intercropped with annual crops, such as soybean, soil preparation combined with seed treatment using Fipronil-based insecticides will help.

Granular ant baits, which can be used for ant control in the dry season, are a treatment with low environmental impact and good results. However, it is not recommendable for the rainy season, when direct application of powder insecticide on anthills is recommended.

Fire Control

It is extremely important to make firebreaks bordering the area to prevent fire accidents (Figure 7.21), which could cause great harm to the system.

A firebreak is a 4 to 5 m wide gap in vegetation, preferably on both sides of fences (Figure 7.22), usually made with disk harrows. They fully incorporate straw and debris, preventing fire propagation, especially in the dry season.

Figure 7.21

Fire caused by accidental fire in an ILPF system two years after implementation. *Photo: Roberto Giolo de Almeida.*

Pruning and Thinning

Pruning or trimming, i.e. the removal of the lower tree branches and twigs, must be carried out before introducing animals in the system, since browsing can damage trees and spoil timber quality.

The first pruning is done when tree trunk reaches an average diameter of 6 cm at breast height (DBH), using adequate saws and shears (Figure 7.23) to remove a maximum of one third of the tree canopy. The cut should be levelled with the trunk, making sure not to leave tips or splinters. Proper time for further pruning will depend on timber destination, an issue addressed in a specific chapter of this book.

The first thinning, i.e. the removal of a proportion of trees from the system, is usually done 4 to 5 years after system implementation. In this case, trees are removed alternately in a row, prioritizing, however, the removal of those with defective growth, which can be used for charcoal, firewood or construction props. In addition to providing cash flow from timber sales, this practice increases light incidence for forage or annual crops in the system. Second and third thinning can

Figure 7.22
Firebreak in an ILPF system.
Photo: Davi J. Bungenstab.

Figure 7.23

Pruning a 17-month eucalyptus tree in an ILPF system.
Photo: Roberto Giolo de Almeida.

be done between 8-9 years and 12-14 years respectively, after system's implementation. Finally trees will be clear-cut and the system can restart.

CLOSING REMARKS

The steps presented in this chapter provide initial guidelines for introducing an ILPF system with eucalyptus trees. Many of the recommendations related to management, especially for the tree component also apply to silvipastoral systems, in which there is no grain crop cultivation. Likewise, many of the recommendations related to eucalyptus should also be followed when using other tree species.

In this context, it is fundamental for entrepreneur farmers to be acquainted with the main phases of the system implementation and their associated risks and difficulties, they should also become familiar with available techniques for better planning their undertaking. All orientations

It is essential that farmers design a detailed plan for the entire project, considering each stage of each culture and the various interactions among them as well as their reciprocal effects.

presented in this section should be part of a set of guidelines that form a comprehensive project for implementing the ILPF system. Therefore, it is essential that farmers design a detailed plan for the entire project, considering each stage of each culture and the various interactions among them as well as their reciprocal effects.

The next chapter addresses efficient planning methods and tools, presenting practical examples based on the presented information, aiming to make them even more useful, and, thereby, increasing chances of success for leading entrepreneurs who decided to invest on integrated crop-livestock-forestry systems.

Chapter

8

Planning Tools for Crop-Livestock-Forestry Integration

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PRINCIPLES FOR PLANNING AND ESTABLISHING WORK PROCESSES

Recently, concern with planning and especially its formalization in companies and individual projects has forced people to ask themselves what their objectives really are. The first question should always be: **what are we?** Followed by the question that will move them forward: **what would we like to be?** More often than not, the answer to these two questions is not the same. This mismatch leads entrepreneurs to the most important question of all and to seek the resulting answers and solutions: **how do we get from what we are to what we would like to be?** (ANTONIALLI, 2000).

Planning is specifying the objectives to be reached and deciding in advance the necessary and appropriate actions that must be undertaken to achieve them. Entrepreneurs are responsible for collecting and analyzing the information on which the plans and projects are based, establishing objectives to be achieved and deciding what needs to be done (BATEMAN, SNELL, 1998).

It is important to bear in mind that, as when building a house, flying a plane, taking an extended trip or transplanting an organ, **implementing a new agricultural production system** requires a well-defined plan in the form of a project with a detailed breakdown of all stages of the process.

Planning takes up farmers' time and usually entails expenses, including those related to specialized professionals. However, this can be considered as an investment because it results in a series of benefits, including:

- Clarifying the project's objectives, including for themselves;
- Thinking in advance about the various stages and preparing for the future, including in financial terms;
- Identifying in advance several fundamental requirements that will need to be met;
- Evaluating if the actions to be taken are indeed feasible;
- Allowing for the best use of the available resources;
- Motivating employees by transmitting the confidence of those who know what they are doing.

PLANNING TOOLS

The first step when implementing integrated crop-forest-livestock systems (ICLF or ILPF) is to diagnose the business current situation, considering farmer profile and regional characteristics where the farm is located. This diagnosis includes, for example, predominant production systems in the region, local markets and access to other markets, transport and storage infrastructure, the production system of the farm in question, production indices and type of management employed. In this chapter, we assume that the situation of the farmer-entrepreneur, and farm conditions are suitable for implementing an ILPF system.

Project planning can only begin when diagnosis demonstrates favorable conditions. This diagnosis already provides initial information for planning and helps establishing actions that should be taken to change the existing production system into an ILPF system. Within this planning process, these actions should be prioritized, given their importance for the success of the system and the farmers' capacity to implement them.

Project planning can only begin when diagnosis demonstrates favorable conditions.

Priority actions should then be submitted to an analysis method that leads entrepreneurs or those in charge of the project to answer the questions: what?, who?, where?, when? why?, how? and how much?.

The answers to these questions give an overview on how system implementation actions should be carried out. This is an interactive and simplified method that facilitates forward planning. The answers to these questions distribute the tasks among those who will execute them, register where, when and how they will be executed and the necessary materials to execute them, as well as the costs involved. By formalizing planning, this method also helps monitoring what each person is doing and, consequently, allows results to be assessed.

- WHAT – What needs to be done? (detailing of the action)
- WHO – Who is responsible for the action? (who will be to blame if the action is not successfully executed)
- WHERE – Where will the action be implemented? (in which place)
- WHEN – When will it be implemented? How often? At what strategic moment?
- WHY – Why is this action necessary? What is the benefit? What are the losses if it is not implemented?
- HOW – How will the action be performed? (Which method will be used? Which resources will be necessary? Which machinery and equipment? How many people will be needed?)
- HOW MUCH – How much will the farmer have to spend or invest to execute this action? How will the payment schedule be?

In order to use this tool, a chart has to be prepared with the seven questions in the columns and the actions to be executed in the rows. Especially when using electronic spreadsheets, this chart can be gradually expanded by inserting new rows as larger actions are broken down into more detailed tasks.

After detailed planning, each action should be monitored by the designated responsible person.

As a practical example of the use of this method, we have designed a planning model of the first and most important steps for the real implementation of an ILPF system with eucalyptus in Brazil (Chart 8.1). As a result, only the following columns were included in the model: what?, when?, why? and how? The columns with the questions who?, where? and how much? were left open intending to provide motivation and initial support for the effective use of this planning tool by those interested. An MS-Word file with the chart presented herein can be downloaded from www.ilpf.cnpgc.embrapa.br.

Agricultural entrepreneurs usually determine the "who" and the person(s) in charge of the action may be themselves, their employees or some outsourced company or person. Most of the time, the "here" is the farm itself or the part of it allocated for implementing the ILPF system. The "how much" usually varies considerably because it depends on the system's size and the resources already available to implement it, especially in regard to the acquisition or leasing of machinery, implements and equipment.

It is important to stress that this template is based on a real case, but only includes the main steps for implementing the system. At the planning stage, it is recommended that actions are broken down into details, adjusting them to the reality of each farm and the resources locally available.

After detailed planning, each action should be monitored by the designated responsible person. Both models, the one available here and the one presented in the next section, will be very useful tools for organizing and determining necessary actions. Obviously there are also several other methods, including more complex ones, for performing this task. Agricultural entrepreneurs need to be able to monitor, control and intervene whenever necessary to ensure the appropriate execution of the activities and, consequently, the success of the project. As with any business, the success of ILPF system largely depends on careful planning and the commitment of those involved.

USE OF THE GANTT CHART TO PLAN AND CONTROL THE ACTIVITY SCHEDULE

A complete ILPF system cycle with eucalyptus can last more than twelve years, requiring a series of management activities that need careful long-term planning to reduce project risks. For example, loss of the ideal period or date for executing a given activity can lead to delays in the entire cycle or even irreversible losses for the system. There are several project management techniques that can be adapted and applied to ILPF system implementation and execution, one of which – the **Gantt chart** – is a relatively simple tool for designing a project activity schedule, which will be dealt with in this section.

CHART 8.1
Planning Model for the Implementation of an ILPF System with Eucalyptus in Brazil

WHAT?	WHEN?	WHY?	HOW?
Checking if the area is suitable for implementing the system	Before system implementation	To avoid problems with the implementation of annual crops and allocation of system's outputs	Farm diagnosis inserted in its regional context, using the guidance of specialized professionals.
Soil sampling and chemical and physical analysis	Before initial soil preparation and annually thereafter.	To monitor soil fertility and to define soil improvement and maintenance and replacement fertilization recommendations.	Ten soil sub-samples should be taken from a homogenous plot, at depths of 0 to 20 cm and 20 to 40 cm, which should then be homogenized, forming a sample of approximately 400 grams, which afterwards is sent to a soil analysis laboratory. The results will subsequently be interpreted by an agronomist or agricultural technician.
Application of limestone and gypsum	During initial soil preparation and subsequently whenever necessary	To correct soil acidity and supply crops with calcium and magnesium	Fertilizers applied and incorporated from 0 to 20 cm using heavy harrows or plows
Monitoring and control of leaf-cutter ants	At least two months before planting and afterwards during the entire production cycle	To prevent damage to annual crops, and especially to eucalyptus.	Searching for active ant-hills in the area itself and within a radius of at least 100 meters surrounding it. When they are found, Fipronil- based insecticide in powder form or granular ant bait should be applied if the season is favorable.
Summer crop cultivation (e.g. soybean)	Year 0 (November) to Year 1 (March) Year 1 (November) to Year 2 (March) Year 5 (November) to Year 6 (March) Year 9 (November) to Year 10 (March)	To provide financial returns in the short term by reducing ILPF system's implementation costs. Because soybean is a legume that supports atmospheric nitrogen fixation in the soil	Definition of the annual crop and crop management will depend on specific technical recommendations for each region and farm, what can be made by specialized professionals. It is recommended that area-specific crop details be inserted in this chart. An additional chart can be created for the crop alone.
Eucalyptus planting	Year 1 (January)	Among the tree species available for the ILPF systems, the advantages of the eucalyptus clone (*chosen by the farmer*) include its rapid growth cycle, and suitable timber (*clone suitability*). I.e. with a guaranteed market in the region and sufficient available seedlings.	Appropriate selection of clone seedlings. Irrigation on the day of planting and every 6 days thereafter until the seedlings are stable. If more than 5% of the seedlings are lost, replanting is required. It is recommended that area-specific planting details be inserted in this chart. An additional chart can be created for the tree component.

CHART 8.1 (cont.)

Planning Model for the Implementation of an ILPF System with Eucalyptus in Brazil

WHAT?	WHEN?	WHY?	HOW?
Implementation of the Santa Fé System (maize or sorghum with *Brachiaria* intercropped)	Year 1 (February to August)	Growing brachiaria with corn or sorghum helps preserve the soil with vegetal coverage, improves the condition of the soil through residual fertilizers and nutrient cycling and generates economic returns with the income obtained from the grains.	Year 1: the autumn/winter crop should be implemented with a direct seeding system when possible. The sorghum or corn should be ensilaged.
	Year 2 (February to August)	From year 2, the forage plants are established for the livestock component.	Year 2 and thereafter: Year 1 actions can be repeated; the forage plant should be chosen based on its tolerance to shade.
	Year 6 (February to August) Year (?) (February to August)		It is recommended that area-specific planting details be inserted in this chart. An additional chart can be created for the crop.
Eucalyptus management	Year 2 (August)	Weeding to prevent competition.	Clearing eucalyptus through manual weeding or herbicides around the young trees.
Eucalyptus management	Year 2 (August)	Top dressing to meet the plants' nutritional needs.	Top dressing is carried out 90 days and one year after planting.
Eucalyptus management	***Year*** ***Height*** Year 2 0 to 2 m Year 3 2 to 4 m Year 4 4 to 6 m	Pruning to improve plant growth and timber quality and to avoid the damage caused by animal browsing when they enter the system.	Initial pruning when the diameter of the trunk is greater than 6 cm at a height of 1.30 m.
Introducing weaned calves into the system	Year 2 (September) and Year 5 (August)	Because they are small, calves cause less damage to young trees. They also require higher quality pasture provided by recently established forage.	When animals are introduced to the system, tree stems must have a diameter greater than 6 cm at a height of 1.30 m. Strategic control of animal parasites is vital to prevent contamination of the recently implemented pasture.
Harvesting 1/3 of trees	Year 5 (August) Year 9 (August) Year 13 (August)	Increase light incidence between tree rows, improving development of the annual crop and, subsequently, the forages. Providing additional cash flow.	Trees will be alternately harvested in the rows, prioritizing those with insufficient growth and/or damaged log, which will jeopardize quality for timber.

The Gantt chart was created in 1917 by the industrial engineer Henry Laurence Gantt to help the U.S. army and navy control war services. The charts were subsequently used to sequence industrial production line activities. In this technique, the schedule of activities is presented as a set of horizontal bars in a timeline. As a result, it is possible to visually monitor the completion of tasks involved and the dependence between the various activities.

One of the chart's advantages is that it allows one to rapidly visualize progress of the activities in relation to the plan, therefore allowing improved logistical organization of the project. The chart facilitates visualizing activities that should occur at the same time or in sequence, highlighting those that require the same resource.

For example, if a farmer has only one tractor to irrigate recently planted eucalyptus seedlings and to spray pesticides on the grain crop area, he/she should focus on resolving this possible logistical problem because these two activities can occur at the same time and any minor delay in either of them could lead to major losses.

Consequently, the Gantt chart, together with the previously presented method , helps to prevent problems, especially regarding labor availability, material resources and time, which would otherwise often only be realized at the moment the action is being conducted, causing disruption for farmers and their teams and, in extreme cases, even rendering the process unfeasible.

Many farmers and rural entrepreneurs are able to store information and plan effectively without the need to formalize details on paper or in computer applications. However, even these people are often surprised by the usefulness of these tools because through analysis and description of the various phases and actions of the process, they are forced to answer questions and observe details that enable them to identify problematic aspects that would not have been perceived if they had planned everything only in their minds.

Several project management software solutions using the Gantt chart can be found in the market. Several easy-to-use versions can be downloaded from the Internet at no cost and installed in a personal computer. In this example, we used GanttProject, available at no cost from **http://www.ganttproject.biz/.**

It is a free open source software with a very intuitive interface. In order to illustrate how the tool can be used in the implementation of ILPF systems, each activity mapped and described in the previous chart was inserted in the Gantt chart together with its execution period (Figure 8.1).

Among the various activities, there are several tasks that have to be performed at the same time. The Gantt chart helps planning and executing these actions, as it allows visualization of the execution period.

Another advantage of this chart is that there is a red vertical bar crossing activities in the column related to the current day. As a result, it is easy to identify tasks that are behind schedule. Figure 8.2 shows this functionality considering, as an example, January 15, 2014 as the current date.

Through analysis and description of the various phases and actions of the process, farmers and managers are forced to answer questions and observe details that enable them to identify problematic aspects on their plan.

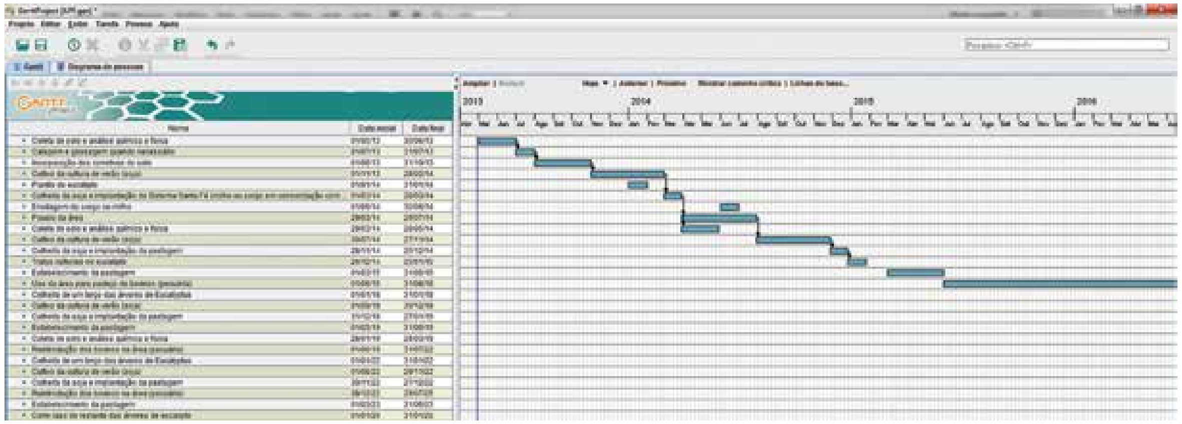

Figure 8.1

Illustration of the visual interface screen of the GanttProject software for an ILPF project with eucalyptus in Brazil.

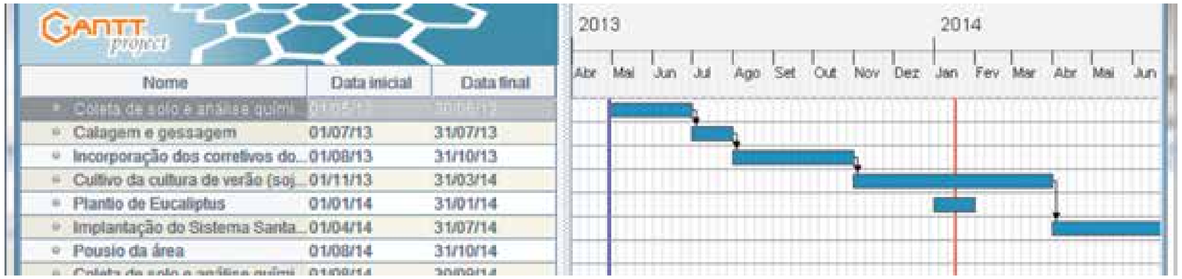

Figure 8.2

View of the Gantt chart for an ILPF project with a vertical bar indicating the current day.

HOW TO OBTAIN GANTTPROJECT?

In order to obtain this tool, go to http://www.ganttproject.biz/download from any web browser and execute the file following typical steps for installing a Windows application, as shown in Figure 8.3. All the available components should be selected, as shown in the eighth chart in Figure 8.3.

HOW TO USE GANTTPROJECT IN THE IMPLEMENTATION OF AN ILPF SYSTEM

After installing the application, it can be used as support software for the implementation of an ILPF project (or any other project for that matter). In order to help farmer-entrepreneurs, technicians and consultants map the implementation of an ILPF system, the example shown in this book is available for download at: www.ilpf.cnpgc.embrapa.br. After downloading the file, double click on it to open it automatically in GanttProject. In the system interface, the activities are shown in a column on the left and the Gantt chart is shown on the right. The activities available in the example are as follows:

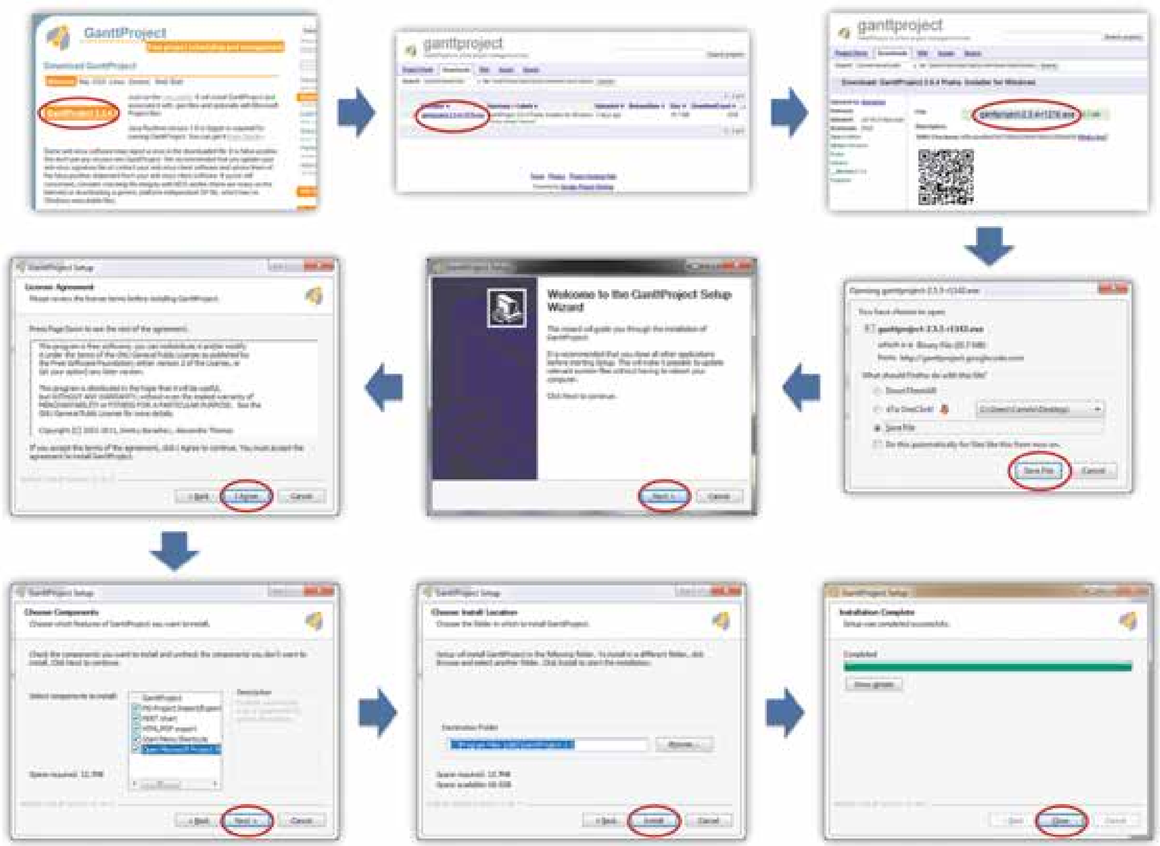

Figure 8.3
Step-by-step illustration for installing the GanttProject software.

- From 5/1/13 to 6/30/13: Soil sampling; chemical and physical analysis;
- From 7/1/13 to 7/31/13: Application of limestone and gypsum whenever necessary;
- From 8/1/13 to 10/31/13: Fertilizers incorporation;
- From 11/1/13 to 2/28/14: Summer crop cultivation (soybeans);
- From 1/1/14 to 1/31/14: Eucalyptus planting;
- From 3/1/14 to 3/28/14: Soybean harvest and implementation of the Santa Fé System (maize or sorghum in intercropping with Brachiaria grass);
- From 6/1/14 to 6/30/14: Sorghum or maize ensilage;
- From 7/1/14 to 10/31/14: Fallow period;
- From 8/1/14 to 9/30/14: Soil sampling, chemical and physical analysis and fertilization when necessary;

- From 10/31/14 to 2/28/15: Summer crop cultivation (soybeans);
- From 2/1/15 to 2/28/15: Soybeans harvest and pasture seeding;
- From 3/1/15 to 5/31/15: Establishment of pasture;
- From 6/1/15 to 8/31/18: Use of the area as pasture for livestock (cattle or small ruminants);
- From 8/1/15 to 8/31/15: Eucalyptus cultivation management;
- From 1/1/18 to 1/31/18: Harvest of one third of the eucalyptus trees;
- From 10/31/18 to 2/28/19: Summer crop cultivation (soybeans);
- From 2/1/19 to 2/28/19: Soybeans harvest and pasture seeding;
- From 3/1/19 to 5/31/19: Establishment of pasture;
- From 6/1/19 to 7/31/19: Soil sampling, chemical and physical analysis and fertilization when necessary;
- From 6/1/19 to 7/31/22: Reintroduction of livestock ;
- From 1/1/22 to 1/31/22: Harvest of one third of the eucalyptus trees;
- From 10/31/22 to 2/28/23: Summer crop cultivation (soybeans);
- From 2/1/23 to 2/28/23: Soybean harvest and pasture implementation;
- From 3/1/23 to 5/31/23: Establishment of pasture;
- From 6/1/23 to 12/31/25: Reintroduction of livestock ;
- From 1/1/26 to 1/31/26: Clear cutting the remaining eucalyptus trees.

If you wish to further use this same chart, there is a button with a clock symbol to create a new activity in the upper bar of the GanttProject interface (Figure 8.4). After clicking on the clock, a task with a generic name and without a defined period will appear in the task column.

If you wish to exclude an activity, select it and click on the "X" button, which is also in the program's main interface, as shown in Figure 8.4.

In order to change name and period of an existing activity in the example or in another file that the user is using, just double click on the activity line. The program will then show a form with the activity's properties, in which you can change any information necessary to adjust the example to your situation. As shown in Figure 8.5, the system offers the possibility of changing the activity's name, the period in which it will be carried out, its priority and the appearance of the activity bar in the Gantt chart (shape and color). It is also possible to insert additional information as pure text in the "Edit Notes" field.

Figure 8.4

Illustrations indicating the buttons in the GanttProject interface used to create and exclude tasks.

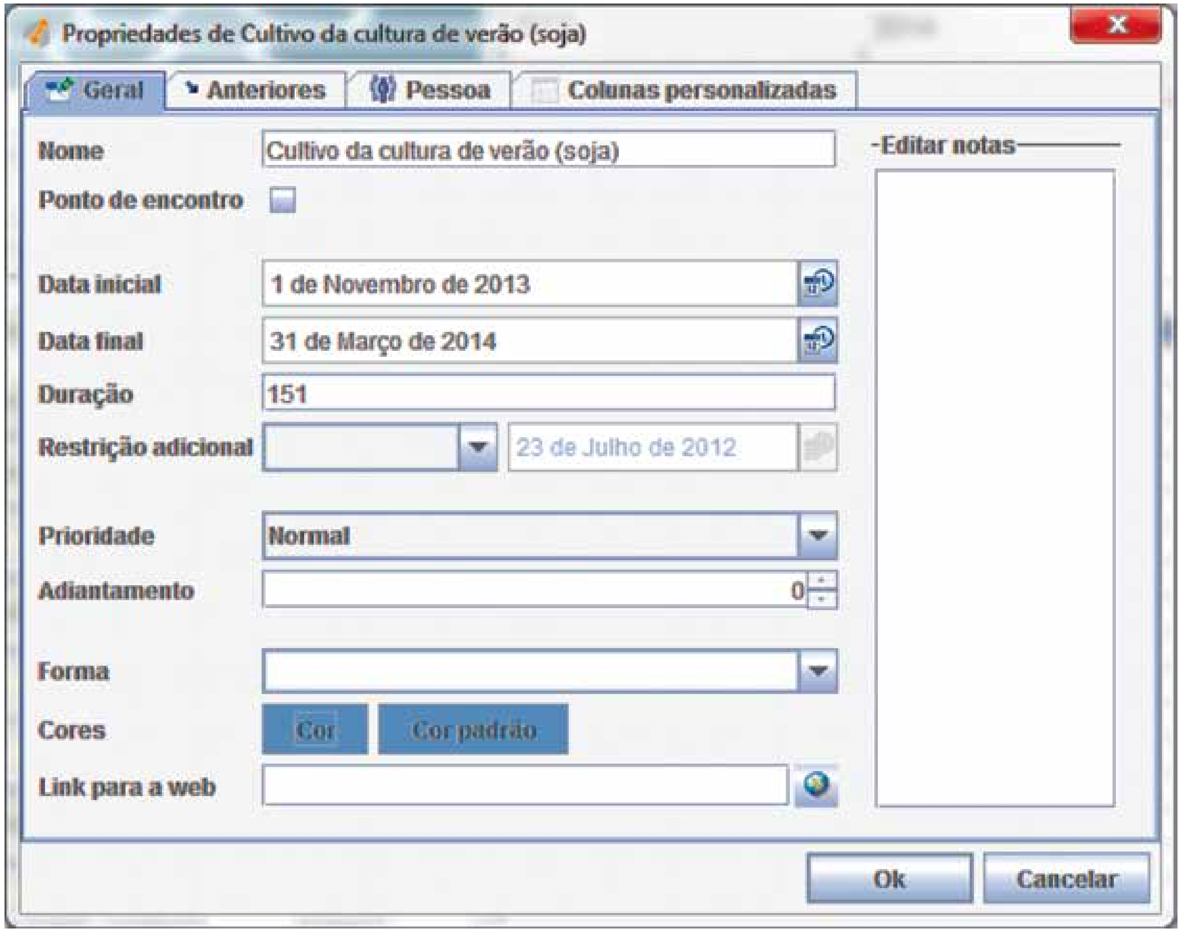

Figure 8.5

Editing properties of an activity in a project for implementing an ILPF.

You can also link dependencies among activities. When you link two activities, for example, the second one can only begin after its predecessor is completed. In order to create such dependence, select two activities and click on the chain button, as shown in Figure 8.6. In the available model, there are several activities with dependence, which are indicated by an arrow linking the predecessor to the successor.

In addition to the functionalities here presented, there are others available in GanttProject that allow more detailed control of the project implementation process. It is possible, for example, to allocate human and financial resources to each activity, allowing control and distribution of their use, usually limited, in line with the time available. Figure 8.7 shows the allocation of two resources to "Soil sampling and chemical and physical analysis". In this example, the "Farmer" and "Soil Sampling Laboratory", which are responsible for executing the activity, have first been inserted into the system through the "Person" option in the main menu. Subsequently, these persons were linked to the activity on the editing form by double clicking on the activity and then clicking on the "Person" tag of the window that opened.

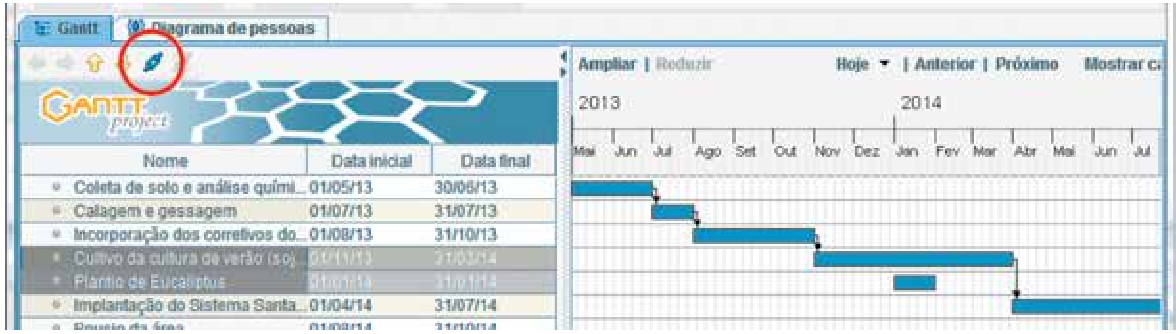

Figure 8.6

Illustration of the tool for creating dependence between two activities in a project for the implementation of an integrated system.

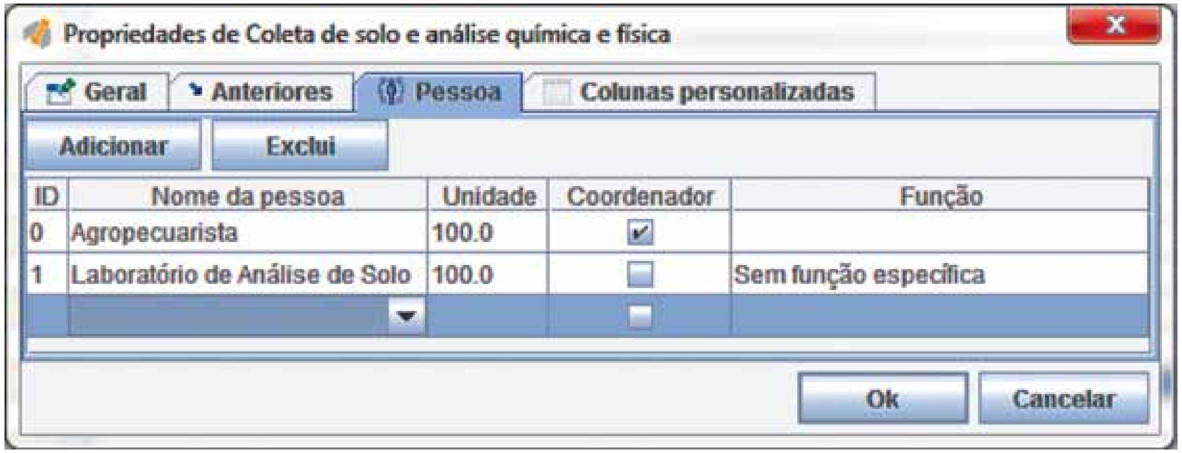

Figure 8.7

Illustration of the allocation of people and responsibilities to the activities of the integrated system implementation project.

Thanks to the easy visualization and user friendliness of the GanttProject interface, this software is an excellent support option for the implementation of an ILPF system. Its use at no additional cost allows farmers to organize and coordinate all the activities needed in a complete cycle of the system.

GanttProject is an excellent support tool for the implementation of an ILPF system.

CLOSING REMARKS

The clear and written definition of the system's objectives, scope and main characteristics, as well as the use of tools for formalizing and describing each step of planning in detail, combined with the use of specific software for managing projects, allows the formal mapping of the process and its methodical and documented execution, optimizing the use of time and resources and contributing to the success of the project as a whole.

Chapter

9

Forage Grasses in Integrated Cattle Production Systems

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Armindo Neivo Kichel

THE POTENTIAL OF INTEGRATED PRODUCTION SYSTEMS IN BRAZIL

Embrapa has intensified technology development and transfer for pastures rehabilitation with integrated crop-livestock (ICL or ILP) systems, such as the Barreirão and Santa Fé Systems, and recently, the integrated crop-livestock-forestry systems (ICLF or ILPF).

With the international growing demand for agricultural products, combined with increased concerns on environmental impacts of farming systems, technologies are increasingly required to boost efficiency of land use with less negative externalities. The consequence of this demand in Brazil, one of the few global players capable to respond to it, is the potential for cash crops and forestry advance of over degraded sown pastures areas. In this sense, despite indications of reduction in sown pastures areas in Brazil, national beef herd and yields are showing slight increase due to more efficient use of remaining sown pasture areas fostered by adoption of appropriate technologies, especially ILP and ILPF systems.

Use of crops for pasture renewal and/or recovery (ILP) is a well-established technology in Brazil (KLUTHCOUSKI et al., 2003). However, introduction of the forestry component is not yet widely used, even though several studies have shown the benefits of trees in pastures. These include improvement of microclimatic characteristics, soil quality, animal welfare, forage quality and mitigation of greenhouse gas emissions (ALMEIDA et al., 2013), in addition to improvement of the scenic beauty of landscapes.

Since information on forage management in ILPF systems is still limited, this chapter will discuss strategies and alternative uses of different forages in integrated production systems.

ALTERNATIVE USES OF FORAGES IN ILPF SYSTEMS

The selection of forages for ILPF systems must be based on their shade tolerance, given that in this condition, forages will prioritize aerial part growth before root system, delaying the onset of flowering. However, under shade, forages tend to have better nutritional value, with higher crude protein content and dry matter digestibility.

In general, forage grasses are more sensitive to shading in the initial growth/ establishment phase than in the grazing phase. The grasses *Brachiaria brizantha* (palisade grasses Marandu, Xaraés and Piatã), *B. decumbens* (cv. Basilisk), *Panicum maximum* (Guinea grasses Aruana, Mombaça and Tanzânia) and *Panicum* spp. (cv. Massai) are considered shade tolerant, having a satisfactory yield under ILPF systems with 30% to 50% shading levels. Thus, the establishment of forage grasses in ILPF systems tends to be more efficient when carried out at the first year of afforestation, since in mature systems tree shading might limit grasses deepening their root systems.

Forages should be carefully managed in ILPF, emphasizing that to allow greater accumulation of reserves and stimulate regrowth, forage grazing height should never be lower than recommended for the species/cultivar.

Leguminous forages in general tend to be less tolerant to shade than grasses. These species hardly resist to shading periods longer than two years. Leguminous forages with reasonable shading tolerance include *Calopogonium mucunoides*, *Centrosema pubescens*and the tropical kudzu (*Pueraria phaseoloides*). Pinto peanut (*Arachis pintoi*) is considered tolerant to shading, despite its slow establishment process, while stylo (*Stylosanthes* sp.) and siratro (*Macroptilium atropurpureum*) are considered little tolerant. Therefore, leguminous forages should be used in early stages of ILPF systems, as monoculture to improve soil fertility or intercropped with grasses to improve feed quality.

Leguminous forages in general tend to be less tolerant to shade than grasses.

USE OF FORAGE GRASSES IN ILP

Crops can be used at the initial phase of ILPF implementation to support degraded pastures recovery or renewal. They can be grown in single cultivation or intercropped with forage for grazing after grain harvest. Crops can be also brought into the cattle farming system in cycles of two or more years, depending on local conditions and system's goals.

During pasture productive phase, when animals are introduced for grazing, forage and animal yields are estimated to be 30% to 40% higher on average in the first year of establishment compared to the three or four subsequent years, considering no limitations by climate and soil issues or inadequate livestock management. For soil fertility improvement and carrying capacity maintenance, regular introduction of cash crops in the system is recommended (MACEDO, 2001; ZIMMER et al., 2004).

In the 1980s a technology to recover degraded pastures in the Cerrado region was developed - the so called Barreirão System. It consisted of complete tillage, fertilization especially limestone application before introducing grain crops, such as rice, maize, millet or sorghum, intercropped with perennial forage grasses, mainly Brachiaria and Andropogon grasses. This technology saves time, since it allows animal grazing almost immediately after grain harvest. Besides, revenues from cash crop production provides partial or even total amortization of investments for pasture recovery. Usually, amortization after recovery is lower for crops with higher costs, such as maize, though they usually boost yields of pastures in sequence, due to residual effect of fertilizers.

The use of annual forages, such as millet and sorghum for harvesting or grazing, is also common in this ILP system. These forages can be introduced as monocultures or intercropped with perennial forage grasses, usually of the genera *Panicum* and *Brachiaria*, both in summer or interseasonal crops, the Brazilian "safrinha". Annual forage crops support animal grazing 30 to 60 days before perennial forage grasses are ready for grazing. This increases beef production as a whole, helping to partially amortize pasture rehabilitation costs. However, this additional income is usually lower than incomes from grain crops sold to the market. .In the 1990s, a new technology package for reclaiming pastures, called Santa Fé System, was developed. Here the main focus is crop production, not cattle like in Barreirão system. It is based on introducing tropical forage grasses intercropped with annual crops under no-till or conventional seeding systems. The objective is to produce forages in the intercrop season as well as to leave substantial amounts of straw to improve no-tillage seeding for the subsequent grain cropping season. Naturally it can also be used with the purpose of pasture recovery/renewal. Such systems are more intensive and specialized, as they are usually focused on cash crops. They support higher yielding forages, including the genus *Panicum*. However, such grasses are more susceptible to mismanagement. For this reason, farmers usually prefer Brachiaria grasses, given its easier management practices, including more flexibility for grazing and harvest heights. Brachiaria species have also higher regrowth rates, are less bushy, with better potential for soil coverage and are easier to desiccate. To keep the system in optimum conditions, it is important to increase sowing rates and combine high grazing intensity and frequency in order to change tiller density, modifying plant structure and improving soil coverage.

Prior to introducing forages in more complex integrated systems, with intensified production of value-added goods, a meticulous diagnosis of local conditions should be carried out.

Prior to introducing forages in more complex integrated systems, with intensified production of value-added goods, a meticulous diagnosis of local conditions should be carried out. Appropriate techniques should be followed to establish and manage the system, so that results are closer to expectations. Special attention should be given to species or cultivars selection, seed quality, sowing rates, season and sowing methods.

An important aspect that favors annual crops intercropped with perennial forage grasses is the fact that forages present slow biomass accumulation in the period in which annual crops would suffer from competition. Under favorable soil and climate conditions, however, perennial forage grasses can compete with annual crops, reducing yields or even limiting production. In this context, to mitigate forage competition, some strategies can be effective, such as the strategic use of herbicides in small doses at early stages of forages development, forage sowing at deeper layers with fertilizers, or sowing forages only after grain crop is established.

According to studies carried out at Embrapa Beef Cattle involving several perennial forage grasses intercropped with maize and sorghum for grain production cultivated in the main and secondary season (“safrinha”), Piatã and Massai palisade grasses offered less competition to crops, while Mombaça grass required sub doses of herbicides to suppress its growth (KICHEL et al., 2009). These grasses can also be used for silage when cultivated in intercropping, especially in the main season (summer). However, as these grasses are harvested earlier, suffering a higher impact, the necessary regrowth period before grazing is longer than after grain harvesting. Higher harvest heights and larger fertilizer doses to compensate increased nutrient uptake for silage production are fundamental to assure good pasture implementation under this system.

Under Cerrado conditions, use of Brachiaria intercropped with maize in the secondary season (safrinha), do not jeopardize maize yields and provides necessary straw for superior no-tillage in the next soybeans cultivation in the summer. Increases in soybean yields from 180 to 720 kg/ha have been reported in areas previously cultivated with maize intercropped with perennial forage grasses (KICHEL et al., 2012).

According to Macedo (2009), ILP systems having three-years grazing cycle after one year crop production or for four-year grazing cycle after four years crop production, resulted in higher beef production and also improved soil quality, confirming their higher economic efficiency compared to extensive beef farming systems or even systems that used regular maintenance fertilization and/or legumes as fertilizers.

USE OF FORAGE GRASSES IN ILPF

As the tree component remains for a longer period in the system, substantially affecting yields of other components (crops, forages and animals), tree species must be carefully selected, based on careful local diagnosis. Of same importance is defining tree rows orientation and spatial arrangement according to system's goals.

Tree rows should follow local relief to promote soil and water resources conservation. If terraces are used, trees should be planted in their lower third. In flat to very slightly hilly sites, tree rows should be East-West oriented, allowing greater incidence of sunlight into understory. If local conditions demand North-South orientation, wider spacing is recommended between rows.

Spacing between tree rows or alleys can vary from 9 to 50 m, bearing in mind that shorter distances between trees limit yields of other components.

During tree initial growth, a one-meter stripe should be kept free of vegetation on each side of the row, using mechanical or chemical weeding, caring to avoid tree injuries. In this phase trees will have small impact on crops and forage yields.

When trees reach the proper height to allow animal grazing, their branches should be pruned to prevent damages. Depending on the system's priorities, trees can be thinned or selectively cut to increase light incidence in the understory, with consequent benefit to associated components, besides providing intermediate cash income for farmers.

Selection of forage species for ILPF and silvipastoral systems is focused on their adaptability to shading, which can alter their morphology and physiology. Low light incidence promotes morphological changes to forage dossel, allowing greater light interception with a lower leaf area index (LAI) through the increase of specific leaf area (PACIULLO et al., 2007).

Spacing between tree rows or alleys can vary from 9 to 50 m, bearing in mind that shorter distances between trees limit yields of other components.

Costs with ILPF systems implementation should not be a limiting factor for beef farmers since they don't have to invest in specific infrastructure for cattle, like fences, handling facilities and purchasing the animals.

The tree component can provide benefits to integrated systems also by increasing nitrogen content of forage grasses under shade, which reflects on higher yields from livestock. However, forage growth can be limited not only by excessive shading, but also, by soil characteristics, like low moisture and nutrient availability, as in traditional systems.

In an experiment carried out at Embrapa Beef Cattle, in Campo Grande, MS, two ILPF systems were implemented as a strategy to reclaim degraded Brachiaria pastures. Tillage operations were performed and soybean was sowed in October 2008. In January 2009, *Eucalyptus urophylla x E. grandis* (clone H-13) was planted at densities of 227 trees/ha (ILPF1) and 357 trees/ha (ILPF2) (Figures 9.1 A and B). Piatã palisade grass (*Brachiaria brizantha* cv. BRS Piatã) was sowed over soybean crop residues in April 2009.

At the time, raw material and services costs amounted to Brazilian Reais (BRL) R$ 2,074.00 and R$ 2,218.00 for ILPF1 and ILPF2, respectively. Soybeans harvest (yield of 2,100 kg/ha) and hay from the subsequent forage harvest (yield of 4,000 kg/ha) corresponded to amortization of 85% and 79% of ILPF1 and ILPF2 implementation costs, respectively. If a new soybeans crop had been sown in 2010, or even a maize crop for grains instead of hay had been carried out in the 2009 inter-season (safrinha), implementation costs for the ILPF systems would possibly have been fully amortized when the cattle component was introduced in the system (15 months after planting Eucalyptus), benefiting from a significantly improved pasture. These data show that costs with ILPF systems implementation should not be a limiting factor for beef farmers since they don't have to invest in specific infrastructure for cattle, like fences, handling facilities and purchasing the animals (ALMEIDA, 2010).

In the same experiment, the Piatã palisade grass pasture was evaluated in the dry season (August 2010), showing that crude protein content in forage leaves and stems was higher in shaded areas than in areas exposed to sun light. Leaves also presented higher *in vitro* organic matter digestibility when from shaded (63.2%) than from unshaded areas (54.1%), indicating the pastures under ILPF present better nutritional value. Additionally, animals showed preference for grazing in shaded areas due to the thermal comfort.

In the first grazing year, during the rainy season, (162 days), these systems had stocking rate of 1.75 animal units per ha (AU/ha) with live weight gains of 428 g/animal/day and 115 kg live weight per hectare (OLIVEIRA et al., 2012). In the third grazing year, animal individual performance did not show differences between the systems, with 376 g/animal/day. However, weight gains per hectare were higher under the system with lower tree density (ICLF1), 1.3 AU/ha and 459 kg live weight/ha, against 0.9 UA/ha and 334 kg live weight/ha, for the ICLF2. This lower yield per area is related to lower forage availability caused by higher shading intensity of ICLF2 (OLIVEIRA et al., 2013).

This project is planned to have three grazing cycles of four years each, having intermediary pasture recovery using soybeans between tree rows. In the 8^{th} year, selective thinning will harvest

Figures 9.1A and B

ILPF system experiment with Piatã palisade grass pasture managed under two different grazing heights; Eucalyptus trees planted in single rows and spacing of 14 and 22 meters between rows.
Photos: Davi J. Bungenstab

Fundamentals of forage behavior under shading conditions are well known, although studies on the interactions with other components of ILPF systems are still limited.

50% of the trees, generating revenues and increase sunlight incidence in the system to allow soybeans and forage growth. After 12 years, the remaining trees will be cut for sawlog and possible use in furniture industry.

CLOSING REMARKS

The main forage grasses currently used in Brazil are suitable for use in local ILPF systems, although they have not been selected for this specific purpose. Fundamentals of forage behavior under shading conditions are well known, although studies on the interactions with other components of ILPF systems are still limited.

ILPF systems have a great potential to recover pastures and increase yields. They are proving to be viable from the technical, environmental, social and economic perspectives. However, due to their complexity, they will require more detailed and long-term multidisciplinary studies covering all their different aspects.

Chapter

10

Tree Species in Integrated Production Systems

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INTEGRATED SYSTEMS

Various regions of the globe present high potential for implementing agroforestry systems (AFS), which combine forestry with crops, as well as silvipastoral systems (SPS), which integrates animal husbandry with forestry. Both systems are part of the comprehensive concept of integrated agricultural production systems, and the principles and technologies applied to them are perfectly applicable to more complex integrated crop-livestock-forest systems (ICLF or ILPF). AFS and SPS are suitable for a wide range of applications, including pasture recovery on low fertility soils, extensive beef cattle farming and even for feed production in high yielding dairy systems. Other uses include formation of windbreaks, protein banks and shading for animals in any type of farm.

FORESTRY IN BRAZIL

The forestry sector has a prominent position among agribusiness activities established in Brazil. The country currently ranks sixth worldwide in terms of planted forest area, which, in 2007 summed 5.6 million hectares producing Timber Forest Products (TFP) and another 6.5 million hectares producing Non-Timber Forest Products (NTFP). These afforested areas are the main sources of raw material for important segments of the forest industry, such as pulp and paper, furniture and charcoal production for the steel, food and natural rubber industries.

The whole Brazilian forestry related industry, in 2007, used nearly 150 million cubic meters TFP and more than 41 million tons NTFP. In this context, Mato Grosso do Sul State is currently considered one of the most promising states to expand forest production in the country, given its suitable climate for highly productive tropical species (STCP/SEBRAE/SEPROTUR, 2009).

In most Brazilian states, natural conditions allow afforestation under much more favorable conditions than European countries, which are traditional timber producers. Climatic conditions of virtually the entire country indicate high potential for forestry activities growth. The countries in Northern Europe have dense natural forests that are explored rationally. However, a tree removed from the region, as in the case of birch, requires at least 50 years to be replaced, producing an average 3 m^3/ha/year. In contrast, Brazil has achieved a technological development level that allows eucalyptus plantations to yield more than 40 m^3/ha/year, with cutting within just seven years and total wood production of 280 m^3/ha within a period of seven years. In this context, Brazil presents an extraordinary competitiveness factor. Additionally, the forestry sector generates a high number of permanent jobs. In 2011, for example, the sector generated approximately 4.7 million jobs (ABRAF, 2012).

IMPLEMENTATION OF AGRISILVIPASTORAL SYSTEMS

Silvipastoral and agrisilvipastoral systems are substantially more complex than conventional farming, as they require simultaneous planning and management of at least three components: livestock, pasture and trees. In addition to the higher complexity, one of the major problems in these systems is tree species selection. One should look for the most suitable according to local conditions. Their choice requires caution, especially regarding spatial distribution, to optimize wood production and use of pasture. Therefore, selecting suitable tree species, using good quality seedlings and careful planning according to the objectives of production and market demand are key factors for the success of AFS and SPS.

Embrapa has already implemented more than 190 Technology Reference Units (TRU) for integrated crop-livestock (ICL or ILP), ILPF and silvipastoral systems across Brazil. One of the main demands in the queries received by Embrapa Beef Cattle on these systems regards the best combinations between number of trees and their spatial arrangement, followed by the suitable type of forage for each region.

Aiming to meet these demands, studies on native forest species planted on pasture have been conducted since 2004, which have highlighted species from Midwestern Brazil with potential for use in silvipastoral systems, such as *Peltophorum dubium*, *Guazuma ulmifolia* and *Tabebuia* (MELOTTO et al., 2007).

Another example of the importance of careful planning ILPF is the study carried out by Balandier and Dupraz (1999), who compared growth of wide row spacing planted trees (50 to 400 plants/ha) at the initial period (5-8 years), in agroforestry systems (60% of which were planted in silvipastoral systems), with commercial forestry (600-1,400 plants/ha). The authors concluded that the growth problems observed were related to choosing species not adapted to local conditions. These authors also observed that trees in silvipastoral systems, in terms of height, developed well, with growth rates comparable to pure forestry plantations. Considering the objective of obtaining straight, cylindrical, branchless sawlogs, 4-6 m long, within 10 to 15 years, less dense plantations provided better results in most fertile and protected spots. Higher tree density is recommended for low fertility soils, subject to strong winds and water stress. This is important to compensate higher initial loss rates, resulting in final harvesting of 50 to 80 trees/ha.

Some studies showed that tree growth problems observed were related to choosing species not adapted to local conditions.

A positive aspect of forestry integrated with cattle farming is the possibility of harvesting according to variable profitability of timber in market peaks. In agrisilvipastoral systems, the optimal rotation age, thinning intensity or harvest scheduling are flexible, as opposed to crops, whose harvesting seasons cannot be changed.

As for species selection, SPS and AFS implementation should follow the system's objectives. For example, in the case of saw timber, tree distribution can affect wood quality. Diameter growth

Trees can be randomly distributed on pastures or set in pre-defined spacing, from afforestation or natural regeneration management.

for certain individuals can be improved if competition with neighboring trees is reduced during growth period. When trees are introduced at pasture renovation, or in areas previously used for agriculture, tree seedlings can initially be planted simultaneously with annual crops, leaving forages to be introduced one or two years later, in order to reduce costs with tree protection.

The most common types of tree distribution for ILPF are briefly described in this chapter, remembering that variations and combinations of them may occur according to local conditions and system's goals.

Trees can be randomly distributed or set in pre-defined spacing, from afforestation or natural regeneration management. Planting trees in lines produces tree strips across the field, preferably following contour lines in hilly areas. Trees can be planted in a single row, or in lines with two or more rows. Trees in rows/lines facilitate mechanization. Trees should be pruned and thinned as they grow, in order to maximize production and allow sunlight on pasture (MONTOYA et al., 2000).

If the goal is creating windbreaks, selected species should be resistant to winds, pests and diseases, have deep roots, fast growth with dense canopy. Distribution design must be well planned to maximize their benefits. In general, tree windbreaks provide a protection range around 10 to 20 times their height. They should be long, extending over at least 20 times their height, and preferably be connected to adjacent forests and protected areas (ABEL et al., 1997, MEDRADO, 2000; WILKINSON and ELEVICH, 2000).

Brushes or tree plots can be created by planting in spacings of 3m × 2m, 3m × 3m or 4m × 4m, or using remains of native trees left on pasture (MONTOYA et al., 2000). Narrow planting favors natural pruning as well as shading between trees allows them to grow higher. In the case of forage/protein banks, planting is also homogeneous, using high density of high nutritional value species, resulting in high biomass yield with high total crude protein and digestible crude protein for direct browsing or fodder harvesting. Among the most widely used woody shrub species for fodder are leucaena (*Leucaena leucocephala*), gliricidia (*Gliricidia sepium*) and cratylia (*Cratylia argentea*).

SELECTING TREE SPECIES

Additionally to the implementation design, selecting tree species is a critical point in planning of ILPF systems and their variations. It is essential to consider susceptibility to diseases and pests, dominant and harmful potential effect that trees could have on pasture, including excessive shading, excessive leaf litter deposition and allelopathic effects. There is also a risk associated with planting species that may become economically unattractive over time, because of changes in market potential or even due to possible environmental restrictions on exploiting these species.

As there is no general rule for selecting the appropriate species for use in silvipastoral and agrisilvipastoral systems, it is crucial to consider regional peculiarities and SPS and AFS arrangements adopted in the region. In addition to wood, species commonly available can also provide by-products such as fruits, seeds, tannin etc., which can be sold in local markets or used as raw material for export products, such as cosmetics and pharmaceuticals. They can also offer social and environmental benefits to the community. Considering these aspects, certain native and exotic tree species with potential for use in ILPF systems in Brazil are listed and briefly described in this chapter. Intention is to provide options for a more accurate selection, increasing chances of success. Naturally, this is a list of the most popular species usually available in Brazil. The fact that other species are not listed does not exclude them from being good options. The key point is always selecting the most appropriate species according to local conditions and goals.

BRAZILIAN NATIVE SPECIES

Peltophorum dubium (Sprengel) Taubert (Canafístula)

This species can reach up to 20 m and 90 cm diameter at breast height (DBH). It can be damaged by frosts, recovering subsequently, as observed in the South region of Mato Grosso do Sul (Amambaí), where commercial forests located in regions near water streams were affected, with consequent reduction in growth due to frost damage. Despite their rectilinear growth, pruning is necessary to remove twigs and increase commercial sawlogs length, which is the part of the trunk located between the ground and the first branches.

Similarly to eucalyptus, a major economic advantage of this species is that its stub easily grows back, allowing the formation of a new settlement without re-planting (CARVALHO, 1994). Martins et al. (2007) indicated the species for silvipastoral systems, especially due to its rapid growth and for having presented a survival rate of 100%, in Santa Catarina State.

In pure, commercially managed forest, lumber can be harvested nine years after planting, with average annual increase of 25 m^3/ha/year, totaling 225 m^3 at the end of the first cycle. Wood can be used for furniture, beams as well as internal and external construction structures. In silvipastoral systems, with smaller number of plants per hectare, harvest occurs later, but with higher final value.

In Mato Grosso do Sul State there are now over 100 hectares of "canafístula" cultivated in sandy soils, with up to 2,500 tree/ha density (Figure 10.1). They were exclusively afforested in areas of degraded pasture. Minimum tillage and soil conservation practices were used, having required base fertilization. These practices are similar to those necessary for pasture renovation, being recommended the introduction of trees on pastures for an integrated system.

In pure, commercially managed Peltophorum dubium forest, lumber can be harvested nine years after planting.

Figure 10.1

Commercial planting of *Peltophorum dubium* in Mato Grosso do Sul. *Photo: Alex M. Melotto.*

This species can be used in both, afforestation and silvipastoral projects, as the plant grows fast, reaching four meters height and five centimeters of DBH at ten months of age, allowing immediate introduction of sheep in the area, since the species is not palatable to these animals and there are no records of browsing or sawlogs damage.

Its sparse crown and rectilinear growth, combined with planned pruning and thinning, allows Brachiaria grass growth. Cattle grazing can be introduced from the 15th month and kept until forest harvest.

Another positive factor of the species in integrated systems is its ability to fix nitrogen (DIAS et al., 2007), to improve soil macro fauna, increasing insect population under its crown (DIAS et al., 2006). This species can be introduced through seeds (MATTEI and ROSENTHAL, 2002) or through seedlings (Figure 10.2), which can be easily found due to high seed production, easy germination and rapid growth in commercial nurseries.

Figure 10.2

Peltophorum dubium seedling 30 days after transplanting in Camapuã, MS. *Photo: Alex M. Melotto.*

Schizolobium amazonicum Ducke ("Paricá")

Trees of this species can reach from 15 to 40 m, with 0.5 to 1.0 m DBH and having sawlogs reaching up to 25 m. It is not resistant to low temperatures (SOUZA et al., 2005; CARVALHO, 2006), adapting more easily to regions with regular rainfall, though it tolerates up to five months drought. Since its wood is considered soft, it is of easy processing, good workability and good finishing, but has low natural durability (COSTA et al., 2005). It is used for wood veneer, door fillings, toys and shoes. In the fifth year after planting, Tonini et al. (2005) observed an average annual increase of 31.3 m^3/ha/year, and the species is highly suitable for SPS due to its excellent silvicultural characteristics (LIMA et al., 2003; SOUZA et al., 2005). Additionally, its stub grows back and its survival rate in the field is up to 97.8% (MARQUES, 1990).

In a silvipastoral system with *Brachiaria humidicola* in Pará State, *Schizolobium amazonicum Ducke* reached a height of 18 m, commercial sawlogs of 13 m and DBH of 0.18 m at five years of age, confirming that the species is highly suitable for these systems (LIMA et al., 2003; SOUZA et al., 2005; MANESCHY, 2009). For such, it is recommended to use densities up to 700 trees per hectare (spacing of 4 m × 4 m), introducing animals around 15 months after planting, thinning on the seventh and eleventh years and final cutting at 15 years, with the wood price in Brazil currently estimated at around BRL 60.00/m^3.

Azevedo et al. (2009) emphasize a promising combination of *Schizolobium amazonicum* and *Brachiaria brizantha* cv Marandu (Marandu palisade grass) for silvipastoral systems, because of tree high growth rate associated with high yielding and good quality pasture using 600 trees per hectare and grazing beginning in the second year of implementation.

Cedrella fissilis Vell. (Cedro rosa)

This is a tall and leafy tree, reaching above 0.5 m diameter, and growing fast, easily reaching 3 m in height in the first year. The plants have high potential to produce seeds, with easy seedlings production, which makes them easy to be found in the market (Figure 10.3).

***Cedrella fissilis* use in SPS is recommended through intercropping with insect repellent species.**

There is, however, a restriction on planting this species, as it susceptible to shoot borers (*Hypsiphylla grandella*), which are difficult to control and affect wood quality. Their use in SPS is recommended through intercropping with insect repellent species or species that do not allow hatching of moth eggs, as is the case of Australian red cedar (*Toona ciliata*), both of which with excellent potential as saw timber.

When planted on pastures, Melotto et al. (2007) observed growth of 0.6 m in the first year, which can be accelerated if the plants are shaded with other forest species that grow faster – in other words, forming an agroforestry system (PAIVA e POGGIANI, 2000). The species responds well to foot and dressing fertilizations, which, associated with other silvicultural practices (mostly weed control), significantly accelerate initial growth.

An agroforestry system with *Cedrella fissilis* introduced in a Gandule beans area used for grazing was implemented at Embrapa Beef Cattle in 2007. Good initial survival rates were obtained for the species, with no records of shoot borers infestation. This system has the advantage of enabling the use of Gandule beans as harvested fodder, being a protein source for ruminants while animals cannot graze the area.

Dipteryx alata Vogel (Baru)

In Brazil known as Baru or Cumbaru (Figure 10.4), this is a secondary species from the Cerrado, being more suitable for well-drained and dry soils and little demanding in terms of fertility (CARVALHO, 1994).

Figure 10.3

Cedrella fissilis introduced in typical cattle pasture in the Brazilian Cerrado. *Photo: Alex Marcel Melotto.*

Its wood is heavy and durable, compact, resistant to fungi and termites, suitable for building external structures such as poles and railroad ties, as well as for use in civil and naval construction (ALMEIDA et al., 1998). Baru grows at a slow to moderate rate, responding well to phosphorus and nitrogen fertilization and reaching a survival rate of over 80% in the field. Its leaves, which grow back at a satisfactory rate after browsing, provide livestock with forages, and its nuts are edible for human consumtion, mainly when roasted (CARVALHO, 1994; ALVARENGA and JORGE, 2008) (Figure 10.5).

Human consumption has been supplied by fruit gathering, but it is demanding new areas for nut production. These can be well introduced in pastures as SPS. However, animals should be kept out of the area when fruits ripe, in order to prevent their consumption. In the other hand, their palatability for animals could also be an important feature of the species for ILPF.

Current demand for fruits is supplied by isolated baru trees on pastures, since they have not been cleared due to their robust and deep root system. Many trees can still be found on pastures in Central Brazil, providing shade for animals in a very simple silvipastoral system.

Figure 10.4

Adult Baru tree in a pasture area in the Brazilian Midwest. *Photo: Davi J. Bungenstab.*

Figure 10.5

Baru tree bearing fruit in the Brazilian Midwest. *Photo: Davi J. Bungenstab.*

Grass usually doesn't grow under their crowns, a fact that is sometimes attributed to the presence of allelochemicals in roots or leaves. However, the presence of few trees providing a much liked fodder to livestock, causes overpopulation under them, with consequent trampling hindering grass growth.

According to a research conducted by Oliveira (1999), the presence of baru on *Brachiaria decumbens* pastures expanded moisture maintenance in the soil and increased nutrient supply for the pasture as well as total nutrient content in forages compared to regular pastures. Amounts of organic carbon were significantly higher (about 50%) under tree crowns compared to open areas. Also soil nitrogen content under the crowns was 18% higher than in open areas.

The presence of baru in pastures is desirable, because it provides shelter to animals as well as high quality fodder, since its pulp is rich in calories, potassium and phosphorus. Several studies have been carried out for genetic improvement of Cumbaru, for both, growth parameters and quality of its leaves as forage. This is expected to generate significant advances and new possibilities for commercial use of this species.

The presence of baru in pastures is desirable, because it provides shelter to animals as well as high quality fodder.

In this context, baru presents extremely favorable features for use in SPS, thanks to the improvements in pastures and nut market, which has high value (NEPOMUCENO, 2006).

Cordia trichotoma Vell. (Louro pardo)

This species presents rapid growth, reaching 1.34 m at 14 months of age (PEDROSO et al., 2003). Despite relatively scarce studies, ILPF systems with this species when rigorously managed, usually present positive results, especially because of its timber is traditionally used in some regions of Brazil, facilitating its access to the market.

Its wood is light to moderately dense, with 0.43 to 0.78 g/cm^3 at 15% moisture and basic density of 0.65 g/cm^3. It also features high workability and good finishing properties (MELO; PAES, 2006). It is highly resistant to xylophage organisms, especially termites (PAES et al., 2007) and presents low permeability to preservation solutions in treatments under pressure. Drying requires caution, as cracks can easily occur on log surface and ends. It has good stability for indoor use and it can be well used for bending because of high flexural strength.

EXOTIC SPECIES FOR BRAZIL

Eucalyptus

Introduced from Australia, afforestation with eucalyptus is a common practice in Brazil. The species have been systematically studied in the country for over 40 years. Today, Brazil has technical expertise on management and advanced genetic improvement for the species, providing farmers easy access to high quality seedlings, affordable prices and a range of species for different purposes in different regions of the country. These factors put eucalyptus in a prominent position for afforestation, being a major option for silvipastoral systems.

As an example, SPS with eucalyptus trees can be used to produce saw wood for furniture, which, despite being a finer application and consequently having better prices, it is still little explored in Brazil. Seedlings of suitable species and clones for this purpose include *Corymbia citriodora* (previously known as *Eucalyptus citriodora*), *Eucaliptus urophyla* and hybrid eucalyptus called urograndis (*E. urophylla* + *E. grandis*) (Figure 10.6).

Producing logs suitable for multiple uses are suggested for integrated systems, fitting different arrangements, plot sizes and fertility.

As a whole, logs suitable for multiple uses are suggested for integrated systems, fitting different arrangements, plot sizes and fertility, unless specific demand for a certain kind exists. Preference should be given to species that can be used and sold in different markets, such as saw timber, fence poles or construction. Whenever possible, finer applications, which add more value to the products generated in SPS or ILPF systems, should be prioritized, especially due to the fact that such systems have lower tree densities (between 200 and 600 trees/ha).

Figure 10.6

ILPF system with urograndis Eucalyptus in Campo Grande, MS.
Photo: Davi J. Bungenstab

Melotto and Laura (2011, unpublished data) in experiments using Nelder wheels, Nelder (1962), showed that planting orientation (North, South, East or West) had no impact on tree growth. However, forages located under trees in North-South orientation suffered etiolation, presenting higher growth. They also observed that under tree densities more commonly used in SPS (200-400 trees/ha), trees were 15% lower and had a diameter 8% larger than in pure forests, contributing to quality and therefore value of logs extracted.

Brachiaria Brizantha (palisade grass) cultivars Marandu (Figure 10.7) and *Piatã* (Figure 10.8) presented good development when planted in integrated systems. With densities up to 600 trees per hectare, dry matter production fell by less than 10% compared to plain grass systems, what can be considered a good result. In its turn, massai grass (*Panicum* spp. cv. Massai) (Figure 10.9) presented satisfactory dry matter yields only at densities below 300 trees per hectare.

With regard to animal thermal comfort, higher temperatures were observed at dawn and lower temperatures in the afternoon at densities between 400 and 600 trees per hectare, thus, temperature extremes were reduced. On average, relative humidity in the shaded area was 15% higher compared to the open area, benefiting animals and forage.

Given the importance of the species for ILPF systems in Brazil, main management practices and wood properties of Eucalyptus will be addressed in a specific chapter of this book.

Palisade grass *cvs. Marandu and* Piatã *presented good development when planted in integrated systems.*

Figure 10.7

Experimental silvipastoril system in a Nelder Wheel with eucalyptus (density of 150 to 1,300 trees per hectare) and palisade grass in Ribas do Rio Pardo, MS.
Photo: Alex Marcel Melotto.

Figure 10.8

Experimental silvipastoril system in a Nelder Wheel with eucalyptus (density of 150 to 1,300 trees per hectare) and piatã palisade grass in Ribas do Rio Pardo, MS. *Photo: Alex Marcel Melotto.*

Figure 10.9

Experimental silvipastoril system in a Nelder Wheel with eucalyptus (density of 150 to 1,300 trees per hectare) and massai guinea grass in Ribas do Rio Pardo, MS. *Photo: Alex Marcel Melotto.*

Grevillea robusta Cunn

Grevillea is a native tree species from subtropical coastal areas of Australia. It was introduced in Brazil by the end of the eighteenth century, in São Paulo State, for shading coffee plantations. In silvipastoral systems with warm temperatures, it presents easy adaptability and rapid growth in various soil types, well enduring cattle presence (MARTINS; NEVES, 2003; NEPOMUCENO, 2007; LUSTOSA, 2008). Its wood is used for railroad ties, panels, plywood and even simple furniture such as beds and chairs.

Silva (1998) concluded that the presence of *Grevillea robusta* in pastures in Northwestern Paraná impacted microclimatic variables, such as temperature and air humidity, as well as water steam pressure deficit, with positive consequences over pasture development, favoring growth through transpiration, in addition to improved animal thermal comfort.

Microclimatic effects on SPS with *Grevillea*, which were observed in Paraná by Porfirio da Silva (1998), are also important. Tree rows changed sunlight incidence and wind patterns in the plot, as well as influenced thermal patterns, water steam pressure and heat flow, increasing air temperature in winter, mitigating pasture degradation and increasing thermal comfort for animals. At night, air temperature was higher among tree rows and during the day it was lower under tree shades. Also, water content in the soil was higher under trees, providing better conditions for forage and animals consequently.

Water content in the soil was higher under trees, providing better conditions for forage and animals consequently.

In 1979, a pasture shading experiment was implemented in the region called Arenito Caiuá in Paraná State, with *grevillea* cultivated in the terraces spaced 20-22 m with 2.5 m space between trees. Pasture was introduced in 1982 with star grass (*Cynodon plectostachyus*). According to the results, the system supported 2.1 animals/ha (50% more than plain grass system), suffered only 10% damage from frost, compared with 90% in traditional systems, and produced a surplus output of 122 m^3 of wood/hectare, using only 198 trees per hectare (PORFÍRIO da SILVA, 1994).

For this species, stripes with double or triple tree rows are preferable, avoiding isolated trees. This is important to reduce the natural conic shape of the species and the formation of vigorous lateral branches in isolated trees, when there is no competition for light. Isolated and single row trees will result in reduced log yield and quality, especially because of large nodes from branches.

Toona ciliata M. Roem. (Australian Red Cedar)

The Australian red cedar (*Toona ciliata*) was introduced in Brazil in the late 1980s in southern Bahia, where it presented rapid growth, having expanded in afforestation projects in the country since then. Trees are large, reaching 1.0 m diameter and up to 40 m in height, with straight sawlogs and few bifurcations.

Toona ciliata ***is considered a transitional species, tolerating either intense radiation or shading.***

Propagation is easy, though seeds are still imported from Australia. Main reasons for its rapid expansion are timber similarity to *Cedrella fissilis* and its resistance to *Hypsiphylla grandella*, a pest responsible for failure of afforestation projects with other species of the Meliacea family, such as mahogany (*Swietenia macrophylla*) and pink cedar (PAIVA et al., 2007).

It is a fast-growing species, with a wood density of 450 kg/m^3 (LAMB and BORSCHMANN, 1998), featuring physical-mechanical properties of great value for furniture, veneer and construction industries, having intermediary characteristics compared to mahogany and pink cedar in terms of quality and uses. It can also be used to build boats and luxury furnishings, interior ornaments, musical instruments, boxes and crates, among other uses. Extraction of tannins, components used for production of insecticides and essences for the perfume, cosmetics and pharmaceutical industries has also been reported.

It is considered a transitional species, tolerating either intense radiation or shading. However, the plants require high average radiation levels to achieve high growth rates. Regarding cold weather, this species tolerates only light and short frosts (BRISTOW et al., 2005).

Thaman et al. (2000) described it as a multipurpose species suitable for agroforestry systems due to timber quality and the ability to reach up to 35 meters at maturity, allowing normal forage growth beneath its crown, being also suitable as windbreaks. Lamb e Borschmann (1998) reported that the Australian red cedar benefits from planting in intercropping with other forest species, with reduced pest attacks.

Cardoso (2004) also indicates the Australian red cedar as a shading alternative for coffee in agroforestry systems. It is well accepted by farmers due to its easy management, endurance and low competition with coffee for water and nutrients. It presents satisfactory development and plays an important role by adding timber production to the system.

In Central Brazil, Australian red cedars have been planted since 2005 in Campo Grande-MS (Figure 10.10). Development has been satisfactory, with height of five meters and DBH of eight centimeters in the second year. It has also sparse crown and rectilinear growth, providing a volume increase around 15 m^3/ha/year. These data show its potential for SPS, particularly because of reduced competition with forages.

In SPS and ILPF, it should be introduced in lines at least 15 m apart, with double or triple rows. Additionally, thinning is necessary to reduce competition between plants and improve timber quality. Since it demands fertile soils, this condition can accelerate its initial growth. Consequently, farmers may grow crops in the year the system is implemented and introduce pastures between tree lines in the second year. However, trees should be pruned when necessary. The lower the competition between the plants, the more side branches must be removed to increase commercial sawlog length.

Figure 10.10

Australian red cedar plantation in Campo Grande, MS in intercropping with pineapple. *Photo: Alex Marcel Melotto.*

Acacia mangium Willd. (*Acacia mangium*)

Over the past decade, the Australian tree species *Acacia mangium* has been widely cultivated for commercial purposes in several tropical countries such as Thailand, Malaysia, Nepal and the Philippines. In Brazil, the planted area for pulp and energy production is estimated at about 10,000 ha. This species grows fast, reaching up to 3.5 meters and 8 centimeters of DBH in the second year. Additionally, it may reach up to 0.9 m^3 per tree within 10 years, requiring pruning (Figure 10.11) for saw timber.

The calorific value of the species (4,900 kcal/kg) favors its use for energy production. Additionally, its use is four times more efficient than native wood traditionally used in brickyards and furnaces in the Amazon (AZEVEDO et al., 2002).

Its wood is also used for furniture, adhesives, besides being used in urban silviculture, in the recovery of degraded areas and as firebreaks, being also suitable for honey farming. One silvicul-

Figure 10.11

Pruning an *Acacia mangium* tree, with subsequent application of Bordeaux mixture for protection against fungi.
Photo: Alex Marcel Melotto

tural advantage of Acacia is the symbiosis with Rhizobium, fixing nitrogen in the soil (NATIONAL RESEARCH COUNCIL, 1983).

Souza et al. (2004) observed an annual increase of 45 m^3/ha/year for Acacia mangium afforestation in the Amazon. The authors state that this species can be used in reforestation programs, avoiding deforestation of native species.

Its ability to fix nitrogen turns it into an option of high potential for intercropping with both perennial and annual crops, as the nutrient will benefit surrounding plants. Association with crops occurs mainly in the first three years of development, when the tree, in its turn, partially absorbs crop fertilization. Attention should be given to the fact that this species presents foraging potential, with its leaves serving as fodder for ruminants, especially in the dry season. It is also important to remark that when trees are excessively exposed to the wind, damages can be substantial, since its crown is dense with many bifurcations, making it susceptible to cracks and falls (Figura 10.12).

Figure 10.12

Acacia mangium plantation with trees damaged by the wind in Campo Grande, MS. *Photo: Alex Marcel Melotto.*

Azadirachta indica A. Juss (Neem)

Neem is an Asian tree, original from Burma and arid regions of the Indian subcontinent. It presents rapid growth, usually reaching 10-15 m and reaching up to 2.5 m within a year and 8 m high within five years (NEVES et al., 2003). It usually presents straight sawlogs, with average diameter ranging between 25 and 30 centimeters at eight years after planting.

Its root system reaches 15 m deep. It adapts better to tropical climates with 40 to 800 mm annual rainfall, being resistant to long dry periods and flourishing even in dry, nutrient-poor soils. This species is not resistant to frosts nor suitable for wet and saline regions (NEVES et al., 1996).

Neem's timber is hard, relatively heavy (0.56 to 0.85 g/cm^3), being widely used in manufacture of wagons, tools and agricultural equipment, as it is resistant to termites and rot. Its heartwood is rich in tannin and inorganic salts of calcium, potassium and iron. Proper stand management in pure forests can produce high quality wood up to 15 m^3/ha/year until the fourth year and 40 m^3/ha/year at ten years (NEVES et al., 2003). Since it is durable and resistant, it is also used for fence poles, buildings and fine furniture, being particularly important in developing countries (VIETMEYER, 1992; NEVES et al., 2003).

Neem wood presentes calorific value of 4,088 kcal/kg, with charcoal yield of 38.20%, ash content of 2.11% and carbon percentage of 81.82%, which demonstrates the quality of this species also for energy generation (ARAÚJO et al., 2000).

Neem can be strategically used as a windbreak, protecting crops from desiccation in areas of low rainfall and strong winds.

Neem can be strategically used as a windbreak, protecting crops from desiccation in areas of low rainfall and strong winds. According to Benge (1988), in Nigeria, neem is used as windbreaks in cornfields, increasing grain yields by 20%.

In Kenya, it is used as windbreaks in sisal plantations, and can be planted with fruit species or sesame, cotton, peanuts, beans, sorghum etc. However, a possible incompatibility with other crops remains to be investigated (RADWANSKI e WICKENS, 1981).

As for other products, application of neem oil to 0.6% in the soil is a good alternative to control pupae of the flies *Lucilia cuprina, Chrysomya megacephala, Cochliomyia hominivorax* and *Musca domestica* (DELEITO and BORJA, 2008).

The Cerrado climate and soils are suitable for afforestation with this species (Neves et al., 2005), either in pure plantations or in silvipastoral systems. Neem can be planted in crop areas with subsequent pasture introduction, reaching up to 3 m at the end of the first year, depending on technology level adopted. In addition, its is recommended to be planted close to residences, corridors and other facilities, since its dense and oval crown provides quality shade in abundance (Figures 10.13 A and B). Scattered trees on pastures should be avoided, giving preference for rows, also intercalated with other species of similar growth rates, such as *eucalyptus citriodora*.

Figures 10.13 A and B

Neem plantation in the form of a windbrake for feedlot operation in the Brazilian Midwest. *Photos: André Dominghetti Ferreira.*

Tectona grandis L.f. (Teak)

Over the past 40 years the Brazilian forestry sector experienced substantial growth based on exotic species of the genera Pinnus and Eucalyptus. However, *Tectona grandis*, popularly known as teak (Figure 10.14), has also emerged as a species known for its yield and timber quality. The Brazilian market has shown great potential for this species.

Teak is a native species of tropical forests located between 10°N and 25°N in the Indian subcontinent and Southeast Asia. It adapts easily to different environments, with vertical dispersion between 0 and 1,300 m above sea level and growing in areas with annual rainfall of 1,100 to 2,500 mm and extreme temperatures of 2°C to 42°C, though it is not resistant to frosts (LAMPRECHT, 1990).

Considered an easy to grow plant, *T. grandis* is little subject to pests and diseases. Mature trees reach 25 to 35 m and approximately 1 m of DBH, losing leaves during dry season. Teak produces

Figure 10.14
Teak (*Tectona grandis* L.f.) planting in the region of Cuiabá, MT.
Photo: Alex Marcel Melotto.

wood of excellent quality, valued for its beauty, strength and durability. It presents high global demand, with prices sometimes three times higher than mahogany (*Swietenia macrophylla*). It is used for furniture, decor, high standard frames and vessels. In Asia, its rotation cycle varies from 60 to 100 years. Dry periods of over three months and shallow soils of low fertility affect its growth. In Brazil, the species has been planted for more than 15 years, especially in the North, where afforestation has been successful, mainly due to well distributed rainfall, reaching hights above 1,400 mm/year.

Teak is indicated for agrisilvipastoral systems in the North and Southeast of Brazil (Figure 10.15), especially for its moderate growth and high quality wood. In systems integrated with livestock, more spaced plantations (12 m × 2.5 m) did not cause timber yield/quality loss, confirming that the species maintains its strengths when integrated with pastures. In this case, cattle can be introduced around the third year after planting. In these systems, animals may remain in the area until the final cutting of the trees, which, in Brazil, occurs around the fifteenth year after planting.

Figure 10.15

Teak (*Tectona grandis* L.f.) plantation in an agrisilvipastoral system in Mato Grosso. *Photo: Alex Marcel Melotto.*

Figure 10.16

Wood from teak thinning.
Photo: Alex Marcel Melotto.

Recently, the use of SPS with teak benefited from the opening of the market for young teakwood, which is harvested by thinning between 5 and 9 years after planting (Figure 10.16), allowing sunlight into the systems and consequently improving conditions for forage gorwth.

CLOSING REMARKS

Silvipastoral systems have been widely used in Brazil. Several research projects have been conducted and farmers have shown interest in their implementation. Large forest-based companies are also investing in the implementation of SPS, further supporting the activity. However, despite the great potential it presents, farmers should remember that each region and even a single farm has specific characteristics which require an implementation model suitable to their needs. It is important for farm-entrepreneurs to evaluate the characteristics of their sites and region, seeking detailed information, exchanging experiences and making careful planning to reach a sustainable farming model.

Chapter

11

Tree Management and Wood Properties in Integrated Crop-Livestock-Forestry Systems with Eucalyptus

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EUCALYPTUS PRODUCTION IN INTEGRATED SYSTEMS

The wood market's growth has led to a substantial increase in search for technical information on forestry and agrosilvipastoral systems, including characteristics of eucalyptus clones available and the most appropriate tree disposition for these systems. Due to the importance of beef industry in Brazil, there is a strong demand for information on introduction of trees sown pastures used for rearing beef cattle.

It is known that silvipastoral systems when implemented in a typical beef cattle farming Central Brazil, growing 200 trees per hectare for timber, is estimated to increase farm income by an average of BRL 300,00/ha/year within a period of 12 years, the time necessary for harvesting the trees. Profitability of silvipastoral systems has been demonstrated by several studies, including that of Marlats et al. (1995), showing the results of comparing forest monoculture, traditional grazing and silvipastoral system with 250 and 416 trees per hectare. In this study, the silvipastoral system presented the best internal rates of return on investment, exceeding the net income from monocultures. Therefore, the main objective of introducing a forestry component in the production systems is to diversify farmers' income, while offering several other economic and environmental benefits.

Integrated crop-livestock-forestry (ICLF or ILPF) and silvipastoral (SPS) systems require more elaborate planning as well as more frequent and detailed monitoring to maintain balance among components. ILPF also usually demands higher initial investments than monocultures, especially extensive cattle systems.

One of the main points to be considered while planning the implementation of an ILPF system is the end-use of the wood to be produced, what directly affects tree management. Wood quality is influenced by several factors, including tree species, spacing and silvicultural management.

Eucalyptus has emerged as a major option to compose ILPF systems, since it has a vast number of species and several interspecific hybrids, allowing selection of genetic materials according to specific uses of wood and suitability to different climate and soil conditions in Brazil.

Despite the fact there are several potential uses of eucalyptus wood, farmers should prioritize special uses, such as poles, saw timber and veneer for furniture production, in order to obtain greater profitability from the system. On the other hand, it is important to remember that the more sophisticated the use of wood, the longer it must grow and the more complex are the silvicultural management practices to be adopted.

When planning the system, it is important to get acquainted with the target market. This applies especially to timber, which has several use options, though the demands for different specs vary from region to region. For instance, if the purpose is to produce eucalyptus sawlogs that will be chemically treated to increase durability, it is desirable to contact local businesses that buy logs for this purpose. These companies will provide important information about harvesting and transportation, especially regarding industry-farm distance and amounts to be produced, which influences economy of scale and consequently profitability. Moreover, potential lumber buyers could also indicate their preferred species as well as desired or unwanted product's characteristics. For example, if the system is aimed at producing chemically treated fence poles using eucalyptus, contrary to what is true for native wood, trunks with thinner heartwood are more desirable. In other words, trees with a higher proportion of sapwood than heartwood result in higher quality treated poles, due to their better absorption of chemicals used in the treatment, which provides them a greater durability (Figures 11.1 and 11.2).

THE IMPORTANCE OF MANAGEMENT PRACTICES IN INTEGRATED SYSTEMS

In integrated production systems, it is necessary to leave a wider spacing between trees rows in order to allow enough forage or crop growth between rows. Wider spacing increases light incidence on trees, consequently impeding natural pruning, a natural process that occurs in pure

Figure 11.1

Eucalyptus log more suitable for treatment due to thinner heartwood and thicker sapwood. *Photo: Davi J. Bungenstab.*

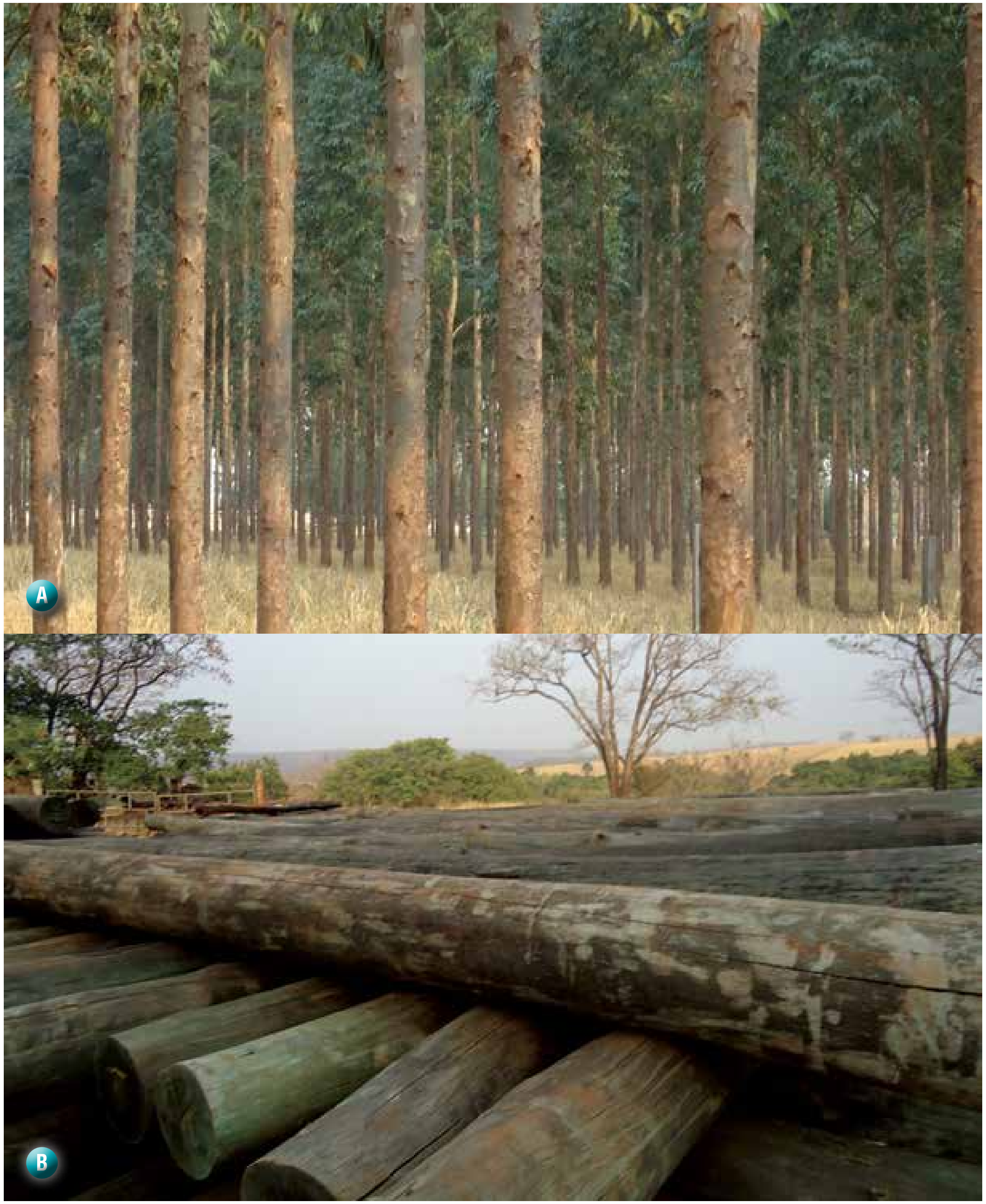
forests with narrower spacing. In this context, artificial pruning is essential to achieve the goals of producing quality wood with high commercial value in integrated production systems.

According to Hawley and Smith (1972), the value and utility of wood from managed forests are more harmed by the knots and distortions in fiber orientation than by any other factor. Especially when there is wider spacing between trees, branches rarely come off after their physiological activity is over. These branches hamper vertical growth and lead to knot formation. Therefore, eucalyptus in ILPF and SPS systems should be artificially pruned until about four to eight meters of their sawlogs are free of branches, ensuring a quality log for timber production. Note that the sawlog considered herein is the part of the trunk between the soil and first branches.

Thinning, that as well as pruning will be discussed in detail in this chapter, is also a very important management practice to improve wood quality in integrated systems. It can be defined as the removal of a proportion of trees in an a plot with the objective of maintaining the quality of one or more system components, and resulting in higher quality logs, with larger diameter sawlogs at the end of the production cycle and a satisfactory yield of the forage and crop components (Figures 11.3 A and B).

Figure 11.2

Eucalyptus log less suitable for treatment due to its thicker heartwood and thinner sapwood. *Photo: Davi J. Bungenstab.*



Figures 11.3 A and B

High quality eucalyptus trees and trunks for wood production.
Photos: Davi J. Bungenstab.

EUCALYPTUS AS FORESTRY COMPONENT IN INTEGRATED SYSTEMS

There are several tree species with potential for ILPF, AFS and SPS systems. In Brazil, especially in the Midwest, eucalyptus has been one of the most commonly used species in these systems. There is substantial information on eucalyptus management, seedlings are easy to purchase at affordable prices, and its wood is widely used for different purposes. Moreover, eucalyptus grows fast and easily adapts to different environments. It is also suitable for integrated systems because it allows a higher incidence of sunlight underneath the trees (RADOMSKI, RIBASKI, 2009).

The *Eucalyptus* genus has about 700 species, of which, the most common in Brazil are *Eucalyptus grandis*, *E. urophylla*, *E. saligna*, *E. camaldulensis*, *E. deglupta*, *E. cloeziana*, *E. pellita*, *E. maculata*, *E. globulus*, *E. tereticornis*, *E. exserta*, *E. paniculata*, *E. dunnii, E. robusta* and *Corymbia citriodora*, in addition of interspecific hybrids. These species and hybrids present variations regarding type of wood produced, growth rates and regional adaptation, among others. Thus, certain aspects should be taken into account when selecting species to be planted, such as wood end-use, soil and environmental conditions as well as market demands (ANGELI, 2005).

Chart 11.1 presents some of the main eucalyptus species grown in the state of Mato Grosso do Sul, their characteristics and uses.

SPATIAL ARRANGEMENT OF EUCALYPTUS IN INTEGRATED SYSTEMS

The difference between a plain forest and a forest in an integrated system is basically the amount of existing trees per unit of area and their spatial arrangement. Especially in ILPF areas, but also in silvipastoral systems, the number of trees per area is lower than in a pure forest. In integrated systems, trees are arranged in a way not to affect agricultural practices and to promote better microclimate conditions for animals. Thus, the most indicated planting disposition are lines of single or multiple rows (Figures 11.4 A, B and C), with wide spacing between each line (PORFÍRIO da SILVA, 2006).

Furthermore, the number of trees and their disposition should not impair other components of the system, since the crop and/or forage species will be cultivated in-between the forestry component (Figures 11.5 A, B and C).

Therefore, when planning the implementation of an integrated production system, it is essential to define the spacing of the forestry component that will enable the highest yield for all components or systems in question, particularly in areas with low fertility soils and water availability (BERNARDO, 1995).

CHART 11.1
Characteristics of the Main Eucalyptus Species with Cultivation Potential Especially in Central Brazil

SPECIES	MAIN CHARACTERISTICS
Eucalyptus grandis	Presents the highest growth rates and volumetric efficiency among the eucalyptus species. It should be planted in areas not affected by severe frosts. Recommended for energy purposes (direct burning or charcoal), hardwood pulp, construction and processing (if produced in long cycles).
Eucalyptus urophylla	Grows at a slower rate than *E. grandis*; however, it has a good regeneration capacity through the growth of strains. Indicated for regions not affected by severe frosts. Produces wood for general use.
Eucalyptus camaldulensis	Species featuring more twisted trees. Recommended for regions with high annual water deficit, but without severe frosts. Its wood is recommended for energy production, railroad ties and fencing.
Eucalyptus cloeziana	Presents excellent stem shape, with good natural durability and high resistance to insects and fungi. Sensitive to severe frosts, its wood is recommended for energy purposes (direct burning or charcoal) and construction, inclusively farm facilities.
Eucalyptus saligna	Species with higher wood density compared to *E. grandis* and less susceptible to boron deficiency. Its wood can be used to produce poles, support props, fencing, veneer, furniture and charcoal.
Eucalyptus dunnii	Presents fast growth and adequate tree shape, despite the difficulty in producing seeds. Species recommended for planting in areas subject to severe and frequent frosts. Its wood is suitable for charcoal and lumber production.
Corymbia citriodora	Species recommended for areas not affected by severe frosts. Good resistance to water deficit. When planted in poor soils, it may present several bifurcations due to nutritional deficiencies (especially boron). Its wood is used as saw timber and for poles, railroad ties, fencing, firewood and charcoal.

Source: Adapted from Silva (2003).

In this context, based on recent studies carried out by Embrapa, it is recommended a distance of at least 14 meters between the eucalyptus lines or rows. When defining the spacing between the rows, it is also crucial to consider the width of machines and equipment to be used in these areas.

According to Porfírio da Silva et al. (2008), in integrated systems where main objective is wood production, it is possible to shorten the distance between tree lines or increase the number of rows in each line. Systems prioritizing crop and/or grazing, in turn, should have larger distances between lines and/or fewer rows in each line (Chart 11.2). It should also be noted that in both cases thinning is necessary if saw logs are desired.

Figure 11.4 A

Integrated crop-livestock-forestry systems with eucalyptus in a single row.

Figure 11.4 B

Integrated crop-livestock-forestry systems with eucalyptus in double row.

Figure 11.4 C

Integrated crop-livestock-forestry systems with eucalyptus in triple row. *Photos: André Dominghetti Ferreira and Alex Marcel Melotto.*

Figures 11.5 A

Green millet between Eucalyptus tree rows for future no-till soybeans seeding.
Photo: Davi José Bungenstab.

Figures 11.5 B

Millet straw ready for no-till soybeans seeding.
Photo: Davi José Bungenstab.

Figures 11.5 A, B and C

Gandule beans planted in-between Eucalyptus rows.
Photo: Davi José Bungenstab.

CHART 11.2
Examples of Plantations with Different Spacing and Number of Trees per Hectare

	END-USE OF WOOD					
	THIN WOOD (CHARCOAL, FIREWOOD, FENCES)			THICK WOOD (TIMBER AND LAMINATES)		
SPACING	SPACING	NO. OF TREES/HA	AREA OCCUPIED BY TREES (%)	SPACING AFTER THINNING	NO. OF TREES/ HA	AREA OCCUPIED BY TREES (%)
Single row	14x2	357	14	14x4 or 28x4	179 or 89	14 or 7
Double row	14x2x3	417	25	18x3	185	11
Triple row	14x3x1.5	1,000	40	20x3	167	10

Source: Adapted from Porfirio da Silva et al. (2009).

In integrated systems aimed at timber production, trees should grow for longer periods, requiring lower densities. However, in order to generate intermediate income until final forest harvest, it is possible to start with higher densities and harvest them partially (thinning) throughout the cycle. This strategy generates cash flow from wood sale of for firewood or charcoal and reduces tree density in the system, favoring larger diameter logs (Chart 11.2). According to Oliveira et al. (2009), form the third year after planting there is a positive direct relationship between the usable area and diameter at breast height (DBH), i.e. the increase in usable area generates larger diameter trees that consequently provide less conic logs with higher market value.

If an ILPF system is aimed timber, it is recommended to plant trees in single rows or three or more rows, avoiding double rows, since this design hampers the upright growth. Also in three-rows stripes, only the central row has potential for use as timber, therefore, it is recommended that the remaining trees are thinned on intermediate harvests, for example, in the third and seventh years and used for other purposes like firewood or charcoal.

In any event, spacing between trees can be easily changed through thinning (Figure 11.6), even at the risk of eliminating trees that could provide high returns. In situations where cattle farming is the main activity, pasture establishment should be prioritized. Moreover, in cases of excessive competition the possibility to remove some plants in a line or even of entire lines is an important strategy for maintaining a tree density that does not jeopardize forage and crop growth.

To produce high quality wood in integrated systems, thinning and pruning are essential.

THINNING EUCALYPTUS IN INTEGRATED SYSTEMS

Eucalyptus trees have great potential for lumber production. However, to produce high quality wood in integrated systems, it is essential to adopt some management techniques, such as thinning and pruning. These practices are key to adjust shading and allow forage and

Figure 11.6

Thinning an eucalyptus plot.
Photo: Ademar Pereira Serra

crop growth, enabling higher sunlight incidence under the canopy height in order to meet grass and crops radiation needs.

While thinning is technically important for high quality timber, it is also an excellent strategy to generate cash flow. Moreover, it can be used to take advantage of eventual market opportunities.

According to Simões (1989), there are several criteria for tree selection for thinning, the most important are:

- Relative position and crown conditions (dominant trees should be retained);
- Health and vigor;
- Log form and quality.

Preference should be given to a thinning scheme that extracts fewer trees in each operation, but is done frequently. At least two or three thinning operations are suggested in a cycle of twelve years. More intensive thinning should be carried out in early phases of the cycle, when growth responses are better, since it expands the usable area per tree left. However, too early and too intensive thinning can affect regular crown formation and stimulate undesirable side sprouts. Additionally, when performed too early, this practice increases chances of breaking slender trees, not allowing gradual adaptation of remaining trees (*REVISTA da MADEIRA*, 2003).

In forests planted in integrated systems, there are two types of thinning that can be used - ***systematic*** and ***selective*** thinning.

Systematic thinning should be carried out in areas where trees have not yet grown into different crown classes or in not previously thinned areas. It removes trees of pre-established positions without prior evaluation. For example, one can remove all trees from outside rows when stripes have triple rows, or remove plants alternately in a single row. In plantations where trees are not uniform, this technique has the disadvantage of removing superior trees, once it is not selective.

Selective thinning removes trees evaluated according to pre-established characteristics important for the end-use of wood. Since forestry in integrated systems often aim saw timber production, this method enables removal of trees that are weaker or have some type of malformation (e.g. twisted and split trunks), improving final yields and log quality for special uses (Figures 11.7 A and B and Figures 11.8 A and B).

In this type of thinning, usually two cuts are made with an approximate intensity of 30% each (in the fifth and tenth year after planting, for example), with around 40% of the trees, which are the most suitable for timber harvested at the end of the cycle (12-14 years).

Figure 11.7 A and B

Twisted Eucalyptus trees recommended for thinning.

Figure 11.8 A and B
Split Eucalyptus trees recommended for thinning.

A practical way to define proper time for thinning is to monitor DBH measurements from a random sample of trees in a certain area. According to Oliveira Neto; Paiva (2010), thinning should begin when there is tree competition, which can be checked through frequent trunks growth monitoring, measuring them at 1.3 m height (DBH). This should be made every six months and the numbers should be recorded. When average growth rate begins to decrease, i.e. growth curve begins to stabilize, it is the proper time for thinning. Number of trees to be measured varies according to the type (whether they are clones or not), the number of trees per hectare and the size of the field. A useful electronic spreadsheet and a file with instructions are available at www.ilpf.cnpgc.embrapa.br as support tools to assist farms in the definition of the sample size and to facilitate recording DBHs as well as to display growth curves graphically.

A practical way to define proper time for thinning is to monitor DBH measurements.

PRUNING EUCALYPTUS TREES IN INTEGRATED SYSTEMS

Another mandatory management practice for timber forestry components in ILPF, ILF and ICF systems is the elimination of tree side branches, known as pruning (Figures 11.9 A and B).

This technique aims to prevent the development of knots in sawlogs, by removing branches during primary tree growth stages. Pruning stems periodically will assure a knot-free sawlog at harvest, improving quality and, therefore, chances for higher timber prices. Figures 11.10 A and B and 11.11 A and B, respectively, show eucalyptus sawlogs with and without knots. Moreover, this practice reduces the number of damaged trees due to animals browsing in lower branches.

Soon after the first pruning, trees should have at least 1.8m of their sawlogs free from branches, avoiding the *browsing* and consequent damages. (Figures 11.12 A and B).

Consecutive pruning should be carried out until sawlogs have four to eight meters free from branches (Figure 11.13), though this is only necessary in trees with potential for sawlog and industrial processing (OLIVEIRA NETO and PAIVA, 2010). It is mandatory, though to prune Eucalyptus trees before introducing cattle into de systems (trees around 12 to 18 months). A practical advice is to prune 2 more meters in the second year and further 2 meters in the third. After that, heights difficult the pruning operation and after that tree growth will provide for branch free sawlogs.

Pruning should be carefully carried out removing only branches of the lower third of the crown, avoiding excessive reduction of leaf area, what would hinder plant growth. First pruning is carried out on average between 15 and 18 months after planting, when their height reaches approximately 10 meters. In this phase, twigs and green branches are removed to a height of 2.5 to 3 meters from the soil. To perform this task, there are specific hand saws and pruning machines. While cutting branches levelled to stem, one must be careful not to harm the bark, preventing contamination by disease-causing agents (SIXEL, 2008; OLIVEIRA NETO and PAIVA, 2010).

Figures 11.9 A and B

Pruning with handsaw (A) and hedge trimmer (B). *Photos: Alex Marcel Melotto and Roberto Giolo de Almeida.*

Figures 11.10 A and B

Defective eucalyptus stems in an ILPF system ("knots"), caused by improper pruning management.
Photo: Davi J. Bungenstab.

Figures 11.11 A and B

Undamaged Eucalyptus stems in an ILPF system, thanks to proper pruning management.
Photo: Davi J. Bungenstab.

Figures 11.12 A and B

Trees pruned after 18 months of planting (A) and young trees before pruning (B). *Photo: Alex Marcel Melotto and Davi J. Bungenstab.*

Figures 11.13

Pruned eucalyptus trees in an ILPF system, with about eight meters of the stem free of branches. *Photo: Davi J. Bungenstab.*

PROPERTIES AND QUALITY OF EUCALYPTUS WOOD IN INTEGRATED SYSTEMS

The idea that eucalyptus trees do not produce quality wood for special uses (Figures 11.14 A and B) has been changing in recent years, thanks to studies on proper management of eucalyptus planted for this purpose as well as its wood properties. These investigations have also been motivated by current and expected scarcity of wood from native species.

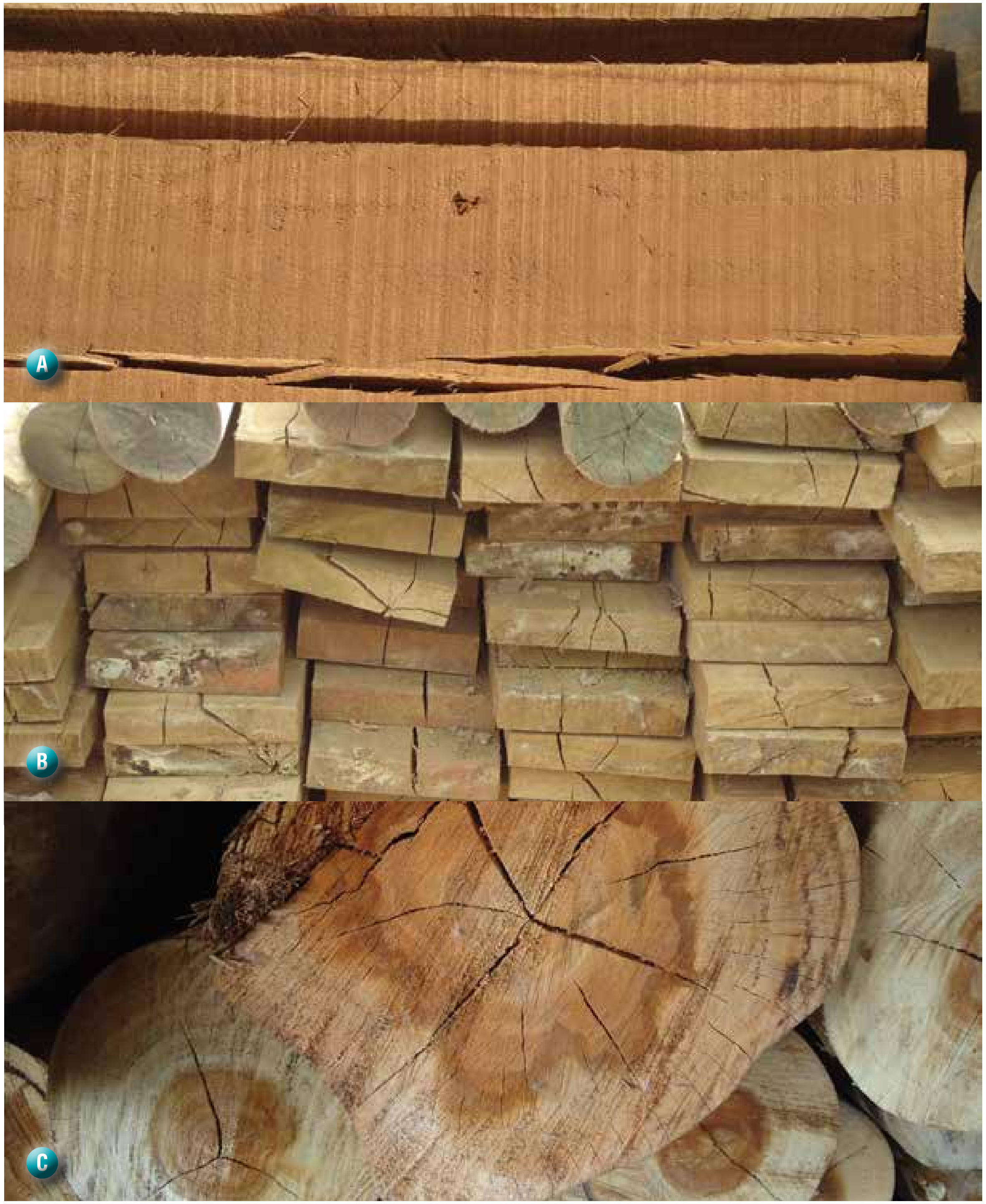
The use of thinning and pruning techniques, coupled with careful sawing and drying, has allowed commercial use of eucalyptus as saw timber. We present below some of the most important properties of wood necessary for a high quality product.

Sawlog Shapes

Sawlog shapes vary according to the species and among individuals of the same species. Climate and soil conditions, tree density, silvicultural management (thinning and pruning), age and tree position in relation to competing individuals are factors that influence development and final shape. In this context, problems during growth may result in lower-diameter, longer saw-

Figures 11.14 A and B

Wall (**A**) and farm barn structure (**B**) built with eucalyptus wood.
Photos: Davi José Bungenstab.



Figures 11.15 A, B and C

Splitting in eucalyptus lumber caused by growth stress and/or inadequate drying processes. *Photos: André Dominghetti Ferreira and Davi J Bungenstab.*

logs, or twisted and split trunks. In order to benefit as much of the sawlog as possible, the used species should present minimum taper, straight stems and low number of split trees. Defective trees should be eliminated through thinning.

Basic density

Basic density is considered one of the best indicators to determine wood quality, as it is directly related to the mechanical properties, which in their turn reflect the processing potential, allowing identification of species with higher viability for saw timber (SANTOS et al., 2004). As final wood quality is defined while trees are still alive, it can be adjusted by environmental variations and specific interventions, hence the importance of choosing proper spatial arrangement and professional management.

Growth stress and log end splitting

Growth stress is a mechanism developed by arboreal plants to remain upright and not to break when subjected to winds or side forces. The radial splitting tendency of logs during processing is a negative consequence of high growth rates that creates tension, depreciating timber value (Figures 11.15 A, B and C). To mitigate problems related to growth stress and to reduce end-splitting in eucalyptus logs, attention should be given to the drying process.

It is important to note that growth stress is not exclusive of eucalyptus. It occurs in all broadleaf trees, though it is more intense in certain species. Therefore, the potential use of each type of wood depends on its intrinsic characteristics, which may be evaluated through systematic sampling (PONCE, 1997).

CLOSING REMARKS

Tree management models should be defined at planning phase. It should be part of a set of activities aimed at delivering a well-defined final product.

There is no unique model for managing forestry components in integrated systems that could be implemented in any farm. Tree management models should be defined at planning system implementation. It should be part of a set of activities aimed at delivering a well-defined final product, which, in turn, should meet market demands, bringing the expected return for farmers-entrepreneurs. With encouragement of the processing sector, the system will also bring regional social and economic benefits.

Thus, the basic management procedures presented in this session should be adjusted to the circumstances and needs of each project. Specific activities and interventions will depend on observation and *in loco* analysis of each system, which is dynamic and requires adaptations over time. Processes and adjustments definition should be guided both by environmental factors, such as climate, and strategic and economic factors, including cash flow and market opportunities. The key point, however, is that farmers should have a good initial planning including risk analysis. Whenever necessary, a qualified professional should be consulted to assist in decisions regarding exact timing and degree of intervention in the system to ensure excellence towards management practices and final products.

Whenever necessary, a qualified professional should be consulted to assist in decisions regarding exact timing and degree of intervention in the system.

Chapter

12

Benefits of Tree Shade for Beef Cattle under Integrated Crop-Livestock-Forestry Systems

Fabiana Villa Alves

INTRODUCTION

Brazil is one of the world's largest beef producers and exporters, with approximately two-thirds of its herd located in the intertropical zone (Figure 12.1) and production systems almost exclusively dependent on pastures (FERRAZ; FELICIO, 2010).

Beef cattle production plays a key role in the Brazilian economy, being the main agricultural activity in several States (GOLONI; MOITA, 2010). For the consumer market, especially the export market, the main qualitative advantage of extensive grazing cattle, i.e. the low risk of contracting Bovine Spongiform Encephalopathy (BSE), known as the mad cow disease, is not sufficient to offset the negative pressing appeal of environmental degradation linked to extensive cattle farming in the country.

A significant proportion of pasture areas, especially in Central Brazil, are under climate conditions that cause medium to severe heat stress from October to March (PORFIRIO DA SILVA, 2003) (Figure 12.2). In this scenario, as thermal comfort is part of the concept of animal welfare, which in turn impacts animal performance, the climate effect is the main factor to be tackled in tropical countries in order to prevent animals from excessive heat transfer from the environment (PIRES et al., 2010). Especially in pasture areas with no shade, changes in grazing and rumination time, excessive dislocation, animals lying down for long periods, grouping in the borders of paddocks and frequent water intake can be signs of heat stress (PIRES et al., 2010).

Thus, production systems in integration with trees can help mitigate impacts on animals, whether beef or dairy cattle. Moreover, its importance for sustainable development is clear, as it combines production (food, timber, firewood, forages, and fibers), conservation of natural resources (soil, water, forested areas, biodiversity) and environmental services (carbon sequestration). Hence, agrosilvipastoral systems promote animal welfare while enabling the effective recovery of degraded areas, with potential to reduce the exploitation of natural areas for agricultural purposes (DUBOC et al., 2007), which are critical issues in traditional extensive farming systems.

Although considered an innovative idea, since ancient times animal husbandry happens in pastures established under trees in different arrangements and geographical regions. Over the years, however, integrated systems became less popular, especially in countries with temperate climate, especially because of logistics and management, prevailing specialized systems (BALBINO et al., 2011). In Brazil, the introduction of integrated crop-livestock-forestry (ICLF or ILPF) systems took place at the beginning of last century, with the arrival of European immigrants (BALBINO et al., 2011). However, use of ILPF systems is still limited, despite evidence that trees are key to improving the ambience, especially in tropical environments (MOTA, 2010).

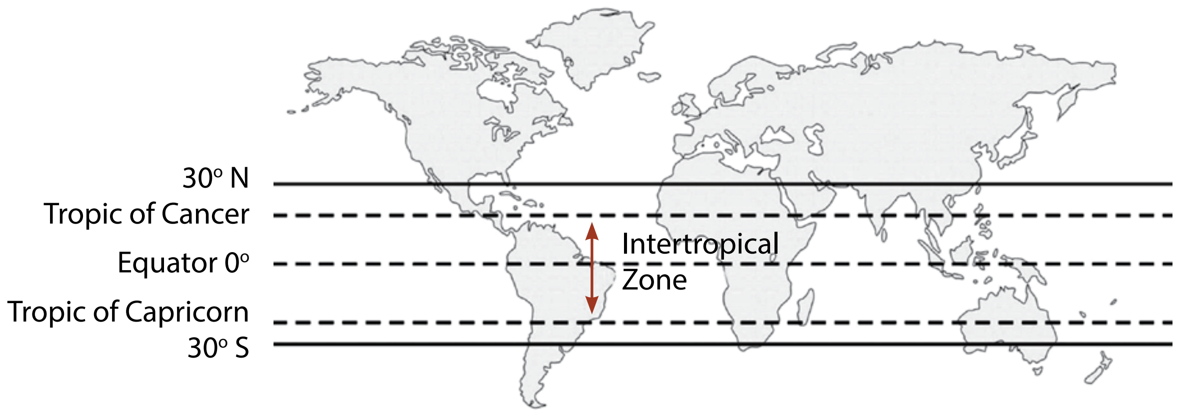


Figure 12.1
Intertropical Climate Zone.

Figure 12.2
Cattle seeking for shade in a traditional extensive cattle ranching system in the Brazilian Midwest. *Photo: Davi J. Bungenstab.*

CATTLE IN INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS

Under proper management, integrated production systems promote direct and/or indirect zootechnical and environmental improvements. Also worth to notice are the improvements in forage quality in some of these systems due to shading and greater availability of nutrients in the soil, which, combined with greater thermal comfort, increases forage consumption and individual weight gain (Figure 12.3).

As trees are the long lasting component of integrated systems and are responsible for setting understory microclimatic conditions, they are often the focus of attention, with other components – including animals – standing aside (SILVA; BARRO, 2005). For animals, the main effect resulting from the presence of trees is undoubtedly the improvement of environmental conditions and consequently their welfare (PORFÍRIO DA SILVA, 2003). This is mainly a reflex of greater shade

Figure 12.3

Cattle grazing in a shaded area in an integrated crop-livestock-forestry system. *Photo: Davi J. Bungenstab.*

availability with temperature and humidity reduction, resulting in higher yields and improved breeding for ruminants in tropical environments (CAMERON et al., 1989).

In fact, the forestry component impacts positively the microclimate of pastures by directly reducing solar radiation incidence, and improving the system's energy balance. In this context, changes in temperature and humidity are directly related to environment quality and animal thermal comfort (BUENO, 1998; SOUZA et al., 2010; BALISCEI, 2011). Consequently, its influence and effects will be greater and more effective in zones closer to the Equator, where solar radiation on Earth's surface reaches maximum and constant values throughout the year (Figure 12.4).

Thus, the intertropical zone, illustrated in Figure 12.1, is the one that presents the highest solar radiation intensity, as the sun stands in the zenith, i.e. perpendicular to the Earth's surface at some time of the year. Despite the different climatic zones and environmental characteristics in Brazil, solar radiation is high and fairly uniform throughout the year. For some Brazilian States, like in the Northern semi-arid region, Northern Minas Gerais, Northeastern Goiás and Southern Tocantins maximum values can reach up to 6.5 kWh/m^2/day, while in coastal regions of southern States(Northern Santa Catarina, Paraná and Southern São Paulo) minimum values are 4.5 kWh/m^2/day (MARTINS et al., 2008).

In Central Brazil, solar radiation is higher in the dry season, particularly from July to September, when rainfall is seldom, with more days of clear skies and few clouds (MARTINS et al., 2007).

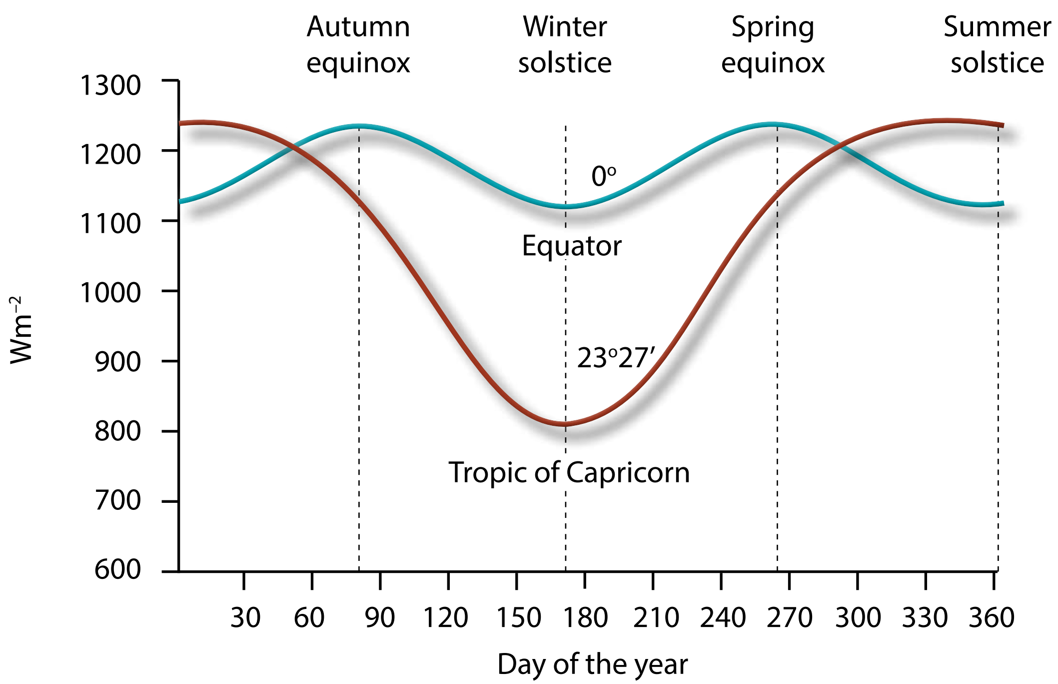


Figure 12.4

Estimated change in intensity of solar radiation reaching Earth's surface in the intertropical band of the Southern Hemisphere at sea level, considering a value m = secΨ for atmospheric mass, absence of clouds and atmospheric turbidity coefficient T = 0.1. Source: Silva (2006).

Higher radiation can be considered an important advantage in terms of tree and pasture growth, though it reduces thermal comfort for animals raised in unshaded areas, requiring shelters to protect them against excessive radiation (SILVA, 2006; GLASER, 2008).

By changing the surface where they are installed, silvipastoral or agroforestry systems alter the transfer of solar radiation through shading (limiting incidence of radiation) and radiation reflection by tree canopy (Figure 12.5) (PORFÍRIO DA SILVA et al., 2004).

In this regard, the tree species and size, the geometric shape of its crown and the angle of sunlight incidence are some of the factors that will determine the quantity and quality of produced shadow, as well as its benefits (Figure 12.6).

Karvatte Junior (unpublished data) evaluated shade formation and microclimate under shade and unshaded areas in integrated systems and concluded that 4-year-old eucalyptus trees can

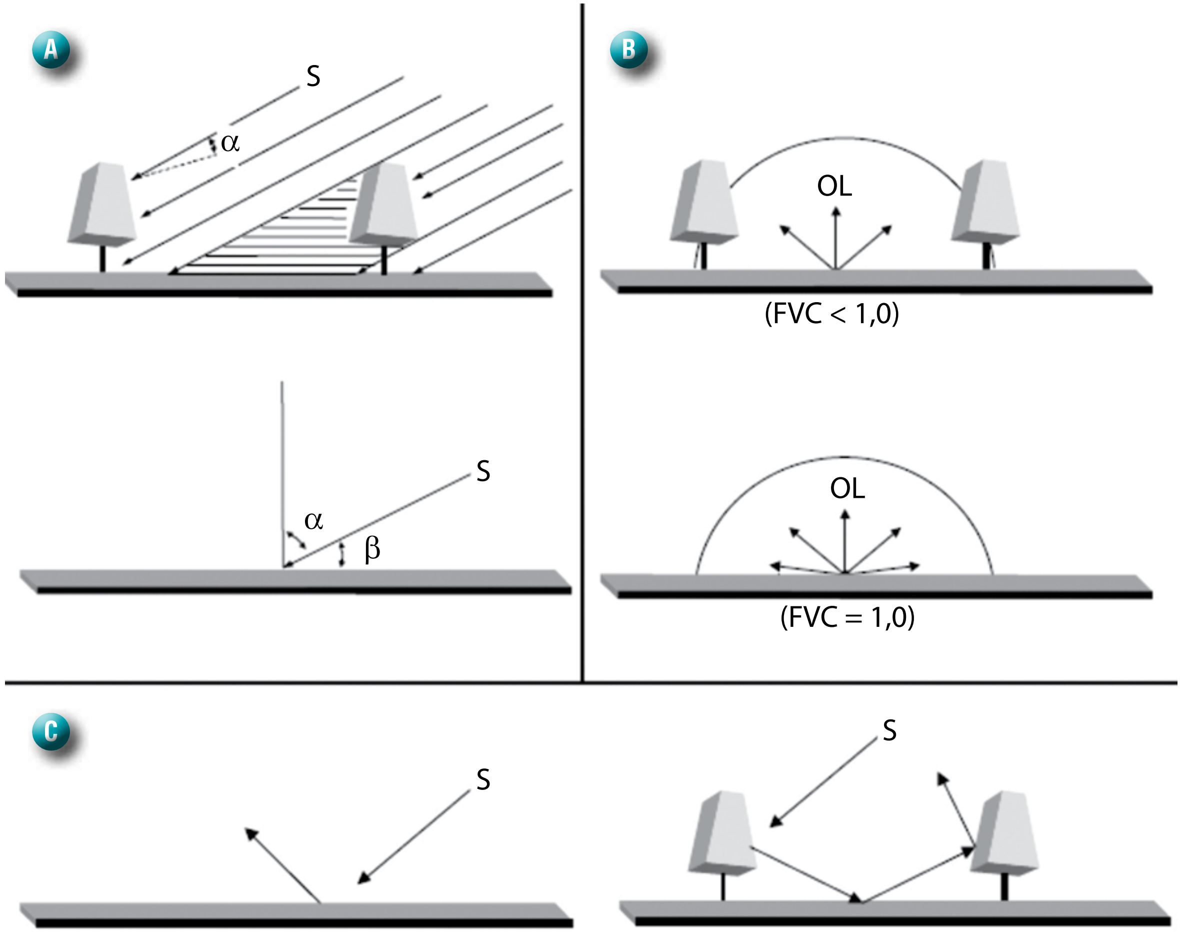


Figure 12.5

Influence of tree rows in radiative transfer. Comparison of the surface with and without parallel rows in terms of a) reception of direct short-wave radiation (S), in which α is the angle between the normal of the surface plane and the direction of the fraction of radiation reaching it and β is the angle the sun rises above the horizon; b) emission of direct long-wave (LW) radiation, considering FVC as the celestial sphere perspective, which varies according to the height and distance between two rows; and c) reflection of S. Source: adapted from Porfírio da Silva et al. (2004).

provide approximately 7 m^2 shadow/tree, decreasing air temperature in 1.5° C. He also noted that adult native Cerrado trees, such as Baru (*Dipteryx alata*), with different sizes and formation, can provide as much as 139 m^2 shadow/tree, reducing temperature by up to 3°C in the shade compared to unshaded areas.

With regard to animal performance in integrated systems with trees, information is still scarce and little is known about the effects of shade on animals. Souza et al. (2010) studied heifers crossbred with Nelore cattle in an ILPF system with eucalyptus trees and observed that the animals remained under tree shade an average of 47% of available time. Ferreira (2010) evaluated physiological and behavioral responses of crossbred dairy cattle in the Brazilian Midwest submitted to different shade offers and noted that animals spent up to 57% of their time in the paddocks under the shade. Leme et al. (2005) observed that crossbred Holstein x Zebu cows grazing *Brachiaria decumbens* pastures in a silvopastoral system remained 68.6% of the time under the shade, in contrast to 31.4% in open areas, in situations where the Temperature and Humidity Index (ITU), an indicator of thermal comfort, achieved average value (76.3) above thermo neutrality limit.

Oliveira (2012c) analyzed the thermal comfort of Nelore heifers through the Globe Temperature and Humidity Index (GTHI) and found out a risky situation (GTHI = 80) in an agropastoral system. Moreover, although trees improve animal thermal comfort, the situation was classified as of alert (GTHI = 77) ($p<0.05$) in an agroforestry system with eucalyptus trees, according to the classification quoted by Baêta (1985).

Figure 12.7 shows the variation in GTHI values throughout the day in systems with different shading conditions.

Though more evident in *Bos taurus taurus* than in *Bos taurus indicus*, both benefit from the shade (Figures 12.8 A and B).

Navarini et al. (2009) evaluated thermal comfort of Nelore cattle in tropical conditions and concluded that grazing animals suffer from thermal discomfort and the presence of trees forming small woods provide a more comfortable thermal environment. The authors also

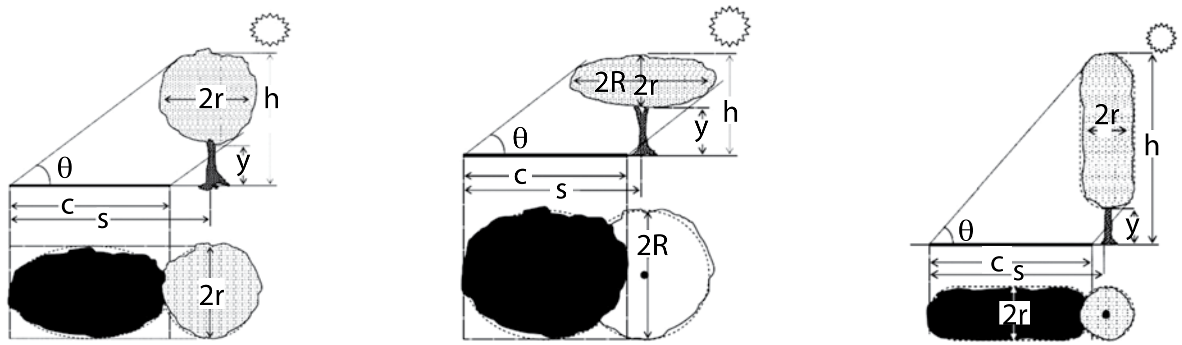


Figure 12.6

Projections shadow of tree species with crowns of different geometric shapes. Source: adapted from Silva (2006).

emphasize that thermal stress probably would not lead to physiological problems in healthy animals, though it could reduce weight gain.

Castro (2005) analyzed production performance of buffaloes reared in a silvopastoral system in Belém, Pará State, and concluded that the presence of shading trees provides better ambience, mitigating heat stress and improving animal performance.

Situations of higher or lower thermal comfort affect animal behavior, especially food intake behavior, as mechanisms to maximize heat dissipation. Ferreira (2010) noticed) that grazing time is negatively associated with temperature and that the grazing period is shorter for animals with no access to shade. Oliveira et al. (2012a) studied beef cattle behavior in three integrated systems (with trees) in Mato Grosso do Sul and concluded that the animals spent more time grazing in the shade.

Nearly four decades ago, Silva (1973) analyzed Canchim cattle and concluded that the increase in rectal temperature during exposure to solar radiation is inversely proportional to weight gain. Animal position (standing or lying) may also indicate greater or lesser thermal discomfort, as it is related to how animals dissipate heat through convection (LEME et al., 2005; SILVA, 2008). Baliscei (2011) observed less standing idle time during winter (9.1%) compared to the summer period (20.1%), in a situation where the maximum air temperature reached almost the upper critical temperature for zebu cattle: 35ºC (SILVA, 2000).

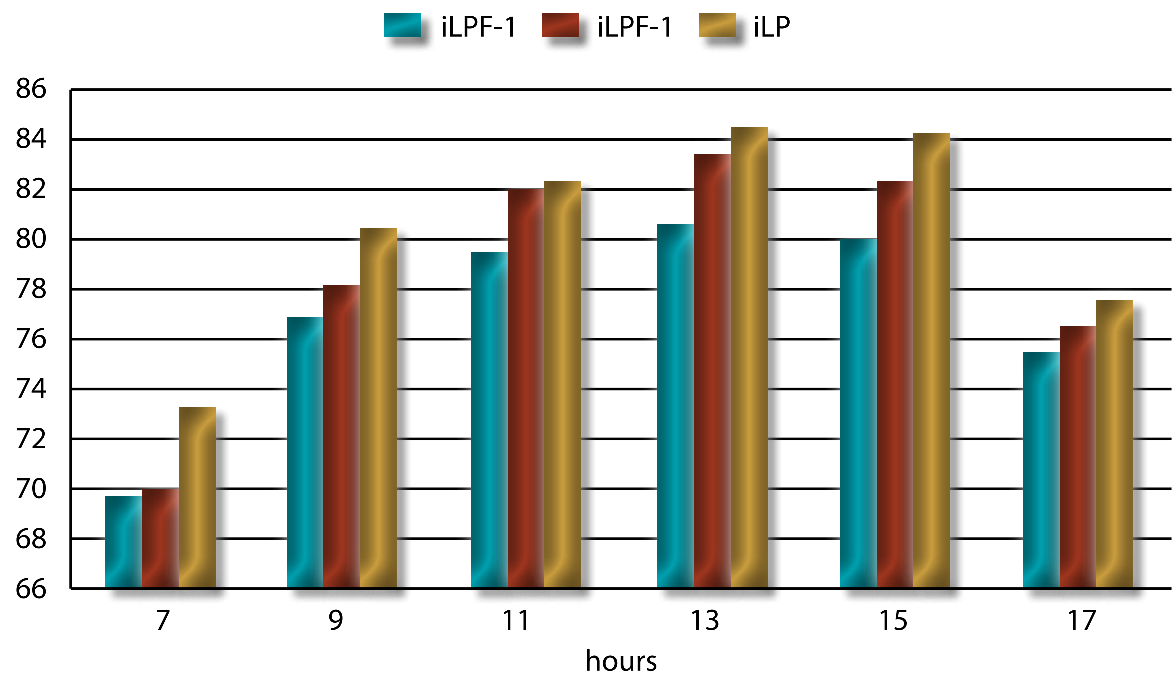


Figure 12.7

Globe Temperature and Humidity Index (GTHI) in an integrated crop-livestock-forestry system 1 (ILPF-1, with 357 eucalyptus trees/ha), integrated crop-livestock-forestry system 2 (ILPF-2, with 227 eucalyptus trees/ha) and integrated crop-livestock system (ILP, with five remaining native trees/ha) from 7:00 a.m. to 5:00 p.m. in Campo Grande (MS). Source: Adapted from Oliveira et al. (2012c).

Figures 12.8 A and B

Crossbred (Brangus) steers on feedyard under Eucalyptus tree shade and Nelore cattle on pasture with scattered native trees. *Photos: André Dominghetti Ferreira and Davi J. Bungenstab.*

As expected, solar radiation interception by trees varies up to 80% depending on species, height, crown conformation, spatial arrangement, plant density and time of the year (HERNANDES et al., 2004; PORFÍRIO DA SILVA et al., 2004; VILLA NOVA et al., 2003), and the corresponding reduction in the radiant heat load (RHL) may exceed 30% (BLACKSHAW; BLACKSHAW, 1994; SILVA, 2006). Karvatte Junior et al. (2013) studied solar radiation in integrated systems in the Cerrado region, under unshaded areas and under shade, and observed that the presence of trees can intercept 70.7% of photosynthetically active radiation in the systems compared to environments under unshaded areas. SILVA et al. (2010) reported a RHL up to 26% lower under the shade of *Acacia holosericea* scattered on a Marandu palisade grass pasture compared to a situation of unshaded area (532.8 and 670.9 W/m^2, respectively). Oliveira et al. (2012b) recorded average reduction of 3.4% ($P<0.05$) in RHL under eucalyptus trees (E. *grandis* x E. *urophylla*) in shaded areas (589 W/m^2) in the Brazilian Midwest compared to full sun exposure (609 W/m^2). Souza et al. (2010) also analyzed RHL under the canopy of eucalyptus trees planted in rows and observed gradual decreases proportional to tree heights, with reductions of 10.2, 12.5 and 20.8%, respectively, in systems with trees 8, 18 and 28m high. Navarini et al. (2009) studying thermal comfort of Nelore cattle in different shading conditions and unshaded areas observed that shading reduced RHL by an average of 11% in small forests with predominance of native Guajuvira trees (*Patagonula americana* L.) compared to the treatment with no shade.

In general, forest areas absorb more radiation than grazing areas, as they reflect a lower amount of solar radiation (13% vs. 18%) due to radiation trapping as a result of multiple reflections in the deep canopy, as illustrated in Figure 12.5 (PORFIRIO DA SILVA et al., 2004). In this context, temperature is also lower in forest areas than in pastures due to the turbulent movements of the air near the surface and consequently reduced emission of thermal radiation.

Despite the increased ventilation, wind speed may be reduced (windbreak effect) to 26% and 61% in winter and summer, respectively, increasing understory humidity, lowering thermal amplitude (oscillation between day and night temperatures) and improving microclimate conditions (NÃÃS, 1989). In silvopastoral systems with tree rows, air temperature may differ by up to 8°C between unshaded and shaded areas (PORFÍRIO DA SILVA et al., 1998). Under the Cerrado conditions, Carvalho et al. (2011) reported that crop-livestock-forestry systems with Eucalyptus trees showed lower temperature and wind speed, as well as higher relative humidity compared to systems with no trees, indicating improved microclimate conditions for cattle grazing. As previously mentioned, the combination of these effects provides a more comfortable environment for cattle, especially during the hottest months.

Integrated systems with Eucalyptus trees showed lower temperature and wind speed, as well as higher relative humidity compared to systems with no trees, indicating improved microclimate conditions for cattle.

There is a wide range of tree species suitable for use in integrated systems in Brazil, but still little is known about the characteristics of crown growth and shape that benefit integration, especially in terms of animal ambience (CASTRO et al., 2008). Despite the lack of detailed technical information, the rapid growth, the vast diversity of species and high adaptability to soil and cli-

Figures 12.9 A and B

Nelore cattle in an integrated crop-livestock-forestry system with eucalyptus trees and Piatã palisade grass in the rainy season (**A**) and dry season (**B**). P*hotos: Davi J. Bungenstab.*

mate conditions in different regions make the genera *Eucalyptus and Corymbia* the most widely used in Brazil (ELDRIDGE et al., 1993).

ANIMAL MANAGEMENT IN INTEGRATED SYSTEMS

Regarding the complex interactions between the components, silvopastoral and agroforestry systems can be classified into: (1) temporary or occasional, in which livestock is included in tree or crop exploration (or vice versa) for a period at some point of the process; and (2) real or permanent, in which the coexistence and association of pasture-livestock-forestry or crop-pasture-livestock-forestry is established since the planning of the system (VEIGA, 1991). In the first case, the focus is usually a system component (wood production, for example) while other components are considered additional income components (such as beef production). In the second case, the intrinsic synergy between forages-animals-trees means that there is no production emphasis on one factor separately, but that they are complementary. As an example, if the tree species are used as a source of animal feed, its performance will be higher compared to systems focused on timber or fruit production, in which the animals are considered just as a secondary income component.

In a broader context, the selection of the animal component for a given system should be based on tradition and suitability of the region and/or farm, and follow nutritional, health and reproductive management practices recommended according to the desired species, breed, animal category, production system, stocking rate and grazing system (Figures 12.9 A and B). The animals are therefore a management product and tool, as they play an important role, from an integrated point of view of the system, in maintaining lower understory and tree competitiveness by consuming the forage. They also accelerate nutrient cycling by returning faeces and urine to the soil in more easily mineralized compounds and anticipate the return on invested capital compared to monoculture forestry, among other benefits (PORFIRIO DA SILVA, 2009; GARCIA et al., 2010).

CLOSING REMARKS

Integrated systems can fulfill two modern livestock concepts – responsible agribusiness and sustainability – combining production and financial efficiency with best production and environmental practices.

Silvipastoral and agroforestry systems can fulfill two modern livestock concepts – responsible agribusiness and sustainability – combining production and financial efficiency with best production and environmental practices. Systems with a tree component improve animal welfare, which translates into greater production and reproduction performance.

The selection of the best combination for crop, animal and forestry components will depend on factors such as location and suitability of the farm, investment capacity, consumer market, technical know-how of farmers and workers, availability of machinery/labor and soil type.

Chapter 13

Supplementary Feeding for Beef Cattle under Integrated Farming Systems

Sergio Raposo de Medeiros
Rodrigo da Costa Gomes

SUPPLEMENTARY FEEDING FOR GRAZING CATTLE

Supplementary feeding has a great impact on the beef cattle production systems' sustainability, especially in Central Brazil. This reflects the significant seasonality in forage production in this region, which expressively reduces plant growth in the dry season. The main limiting factor is certainly water, but a shorter photoperiod and lower temperatures also limit forage growth. Forages also have lower nutritional quality especially due to plant tissues aging, a consequence of reduced cellular content and higher lignification. Even at low stocking rates, the combination of lower supply and lower quality of forages results in animal weight loss or, at best, weight gain at very low rates.

Strategic feed supplementation in the dry season, if carried out properly, reverts weight loss into moderate weight gain or at least animal weight maintenance. When conditions allow it, especially in economic terms, the use of more intensive supplementation to increase weight gain can be valuable for the system, depending on producers' objectives. The main factors affecting this decision are usually cattle prices, grain prices and forage supply (Figures 13.1 A, B and C).

The decision of supplementary feeding for cattle, especially in integrated systems, depends also on local rainfall patterns. Significant rainfall levels in the dry season can boost pasture quality and availability. Therefore, supplementary feeding, especially protein-based feeding, can become unnecessary. Often in these situations supplementary feeding with higher energy content (Figure 13.2), such as fine grind corn, can be a good option. However, low cost is a crucial factor in this case, as the phenomena of substitution rate will probably be caused by supplementary feeding, e.g. the sum of forage and supplement wil be lower than the previous intake of forage alone. Whether deciding not to supplement or to use only small amounts of high energy feed, a careful cost-benefit analysis should be previously carried out.

If economically viable, supplementary feeding can be an excellent tool to boost production efficiency also for more intensive systems, such as integrated crop-livestock (ICL or ILP) and crop-civestock-forestry (ICLF or ILPF) systems. In this context, this chapter aims to present and discuss several options for supplementary beef cattle feeding in integrated production systems.

CONCEPTS AND RECOMMENDATIONS FOR BEEF CATTLE SUPPLEMENTARY FEEDING

Beef cattle supplementary feeding on pastures follows some basic principles to avoid problems and improve efficiency of its use:

1. It may be used all year round, although the best result is achieved with strategic supplementation during the dry season, as it compensates forage primary protein limitation

Figures 13.1 A, B and C

Cattle supplementary feeding in the dry season in pastures with high forage supply. *Photos: Davi J. Bungenstab.*

and allows higher intake of low-quality forage. Higher consumption and better use of forage nutrients increase several production indices, especially weight gain and pregnancy rates.

2. High forage availability is essential for supplementary feeding having the desired positive effect during the dry season. Therefore, pasture deferment is recommended before the dry season to maximize forage accumulation. Deferment means the removal of animals from a paddock to allow free grass growth and accumulation. In general, in Brazil, it is recommended between 4-6 tons dry matter per hectare at the beginning of the dry season and a stocking rate of around one animal unit per hectare (450 kg live weight per hectare – AU/ha). In Central Brazil, where the dry season lasts from May through September, an option is the deferment of one third of the area in February and two thirds in March, for use between June-July and August-September, respectively, enabling sufficient forage availability to support supplementary feeding throughout the dry period.

Figure 13.2

Supplementary animal feeding with high energy content feed in a high quality pasture. *Photo: Josimar Lima.*

3. Animal comfort is extremely important. In the case of supplementary feeding, space available in troughs, i.e. the number of linear centimeters available per head, is extremely important. In addition to avoiding competition stress, easy access to the trough has a positive effect on feed consumption and particularly on homogeneous feed intake improving final performance of the whole feeding lot.
4. Weight gain is expected to increase at each stage of animal's life (first rain season < the dry season < second rain season < second dry season and so on).
5. Feeding levels (supplement amount offered daily per head) may vary and formulations should be based on supplements and ingredients costs as well as farmer goals with the strategic feeding.
6. Comparing the protein-mineral mix supplement and dry feed supplement on pastures, the first strategy results in weight gains around 200 to 400 g/head/day and the latter, 700 to 1,200 g/head/day. However, supplement intake is much lower with protein-mineral mix supplement, approximately 0.1 to 0.2% of live weight (LW), i.e. from 0.45 to 0.9 kg/AU/day, while intake of dry feed supplement on pastures is around 1% of the LW (4.5 kg/AU/day). Therefore, protein-mineral mix supplement is often more cost-effective than other alternatives..
7. Considering the above mentioned, providing supplements at intermediate consumption levels, such as 0.6% of LW, or 2.7 kg/AU/day) may be not economically appealing. This strategy is not recommended because it neither promotes the performance of higher feeding levels nor achieves the cost-effectiveness of protein-mineral mix supplements.
8. Supplements become less efficient as the feeding levels increase. This means that the second kg of supplements that is consumed by the animal will not result in the same weight gain as the first does. For example, if 1 kg supplement increased weight gain by 300 g/day, supplementing 2 kg will most likely not result in 600 g/day weight gain. Whatever strategy is adopted, it is important to acknowledge this information and to consider the cost-effectiveness of supplementary feeding.

In the case of supplementary feeding, space available in troughs is extremely important.

MAIN SUPPLEMENTARY FEEDING STRATEGIES IN THE DRY SEASON

Here the basic parameters adopted for cattle supplementary feeding strategies in the dry season in Brazil will be introduced. The most used supplements are: *minerals mixture with urea*, protein supplements and concentrates. All of them can be used in ICLF systems, and in all cases a stocking rate of 1 AU/ha is recommended. Higher stocking rates are recommended only under special conditions, that is, high forage supply on pastures.

Mineral Mixture with Urea

Mineral mixture with urea is a supplementary feeding alternative that requires lower investment in the dry season. The goal is to maintain animal weight through the period. It is important to ensure a high forage supply, even with poor nutritional quality (Figure 13.3). Recommended daily rates are about 100 g/AU, of which, 30% is urea. The recommended trough space is at least six linear centimeters per animal.

Improper use of urea causes poisoning, which can lead to animal death. Therefore, urea should not be fed to fasting animals i.e. under previous restriction to feed and/or to very lean animals.

It is essential to adapt cattle to urea consumption. A quite safe and practical suggestion is shown in Chart 13.1.

For better use, urea should be associated with a source of sulfur at a ratio of approximately 10 to 15 parts of nitrogen for 1 part sulfur. In a practical way, 4 kg of sulfur powder and 15 kg of ammonium sulfate should be added to 100 kg urea. Chart 13.2 presents two formulations for mineral mixture with urea, one with ammonium sulfate and the other with sulfur powder.

Figure 13.3

Inadequate provision of minerals with urea due to the low forage supply. *Photo: Davi J. Bungenstab.*

CHART 13.1
Practical Strategy for Mixing Minerals with Urea to Adapt Cattle to Supplementary Feeding Considering Commercial Ingredient Bags

PERIOD	MINERAL MIXTURE W/O UREA	MINERAL MIXTURE W/ UREA
First week	2 bags	1 bag
Second week	1 bag	1 bag
Third week onwards	Minerals mixed with urea	

CHART 13.2
Examples of Minerals Formulations with Urea, Based on Usual Minerals for Brazil

INGREDIENT	FORMULATION 1	FORMULATION 2
Ammonium sulfate (%)	3	–
Sulfur powder (%)	–	1
Urea (%)	30	30
Minerals (%)	67	69
Total	**100**	100

The main points in urea feeding, apart from animal adaptation, include:

1. Not to be used in pastures with low forage availability, prioritizing those with high supply but low nutritional value, such as deferred pastures;
2. Thoroughly mix with minerals, and keep feeding continuous;
3. Feed the mixture preferably in sheltered troughs;
4. Place troughs unevenly and be sure it is perforated to drain rain water. This avoids water accumulation and the risk of poisoning due to excessive intake of solubilized urea.

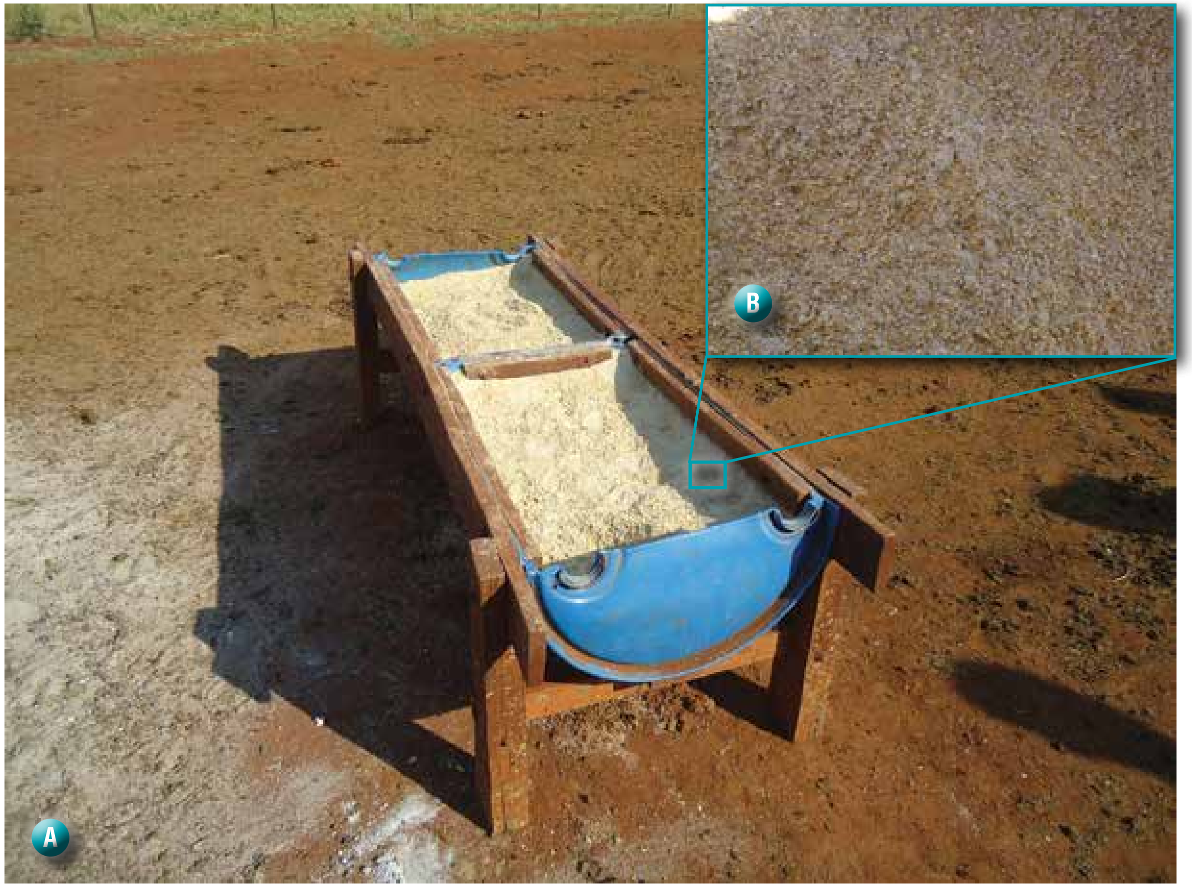
In case of urea poisoning, treatment is effective when the problem is diagnosed in time. The most common antidote is vinegar or a 5% acetic acid solution. Once this is a therapeutic procedure, it should be performed by a qualified professional. However, treatment is only effective if applied when the first symptoms appear and they are usually difficult to notice. Due to the operational constraints and very short time span for saving the animal, it is essential to focus on the effective above listed preventive measures.

Protein Supplements

Protein supplements are basically a mix of mineral sources, urea and true protein sources, mostly protein meals. This kind of supplement is often an alternative with the best cost-effectiveness (Figures 13.4 A and B). Pastures with high forage availability and potential stocking rates of 1 AU/ha, can allow weight gains of around 200 to 400 g/head/day.

Protein supplements have higher costs than mineral mixtures with urea. However, since they are also fed at low rates (1-2 g/kg LW), they can be very cost effective as well. Linear trough space of 12 to 15 cm per animal is recommended for this kind of supplement.

Troughs should be periodically replenished with the supplement. The ideal frequency is determined by local conditions, such as cost and availability of labor, pasture access and intake patterns. However, intervals longer than a week are not recommended. In fact, one of the biggest challenges when using protein supplements is to ensure consumption at pre-established



Figures 13.4 A and B

Trough to supply protein-mineral mix supplement on pastures in the Brazilian Midwest. *Photos: Davi J. Bungenstab.*

levels. Sometimes the same supplement fed in the same farm, in similar pastures for similar categories presents variations in consumption among lots. Therefore, monitoring consumption is highly recommended, both, to determine the frequency to refill the troughs and to control supplementation costs.

Monitoring consumption is highly recommended, both, to determine the frequency to refill the troughs and to control supplementation costs.

When supplement consumption is low, the best option is to reduce inclusion of sodium chloride (plain salt) in the mixture. If this is not possible, as in the case of commercial feed, one alternative is to increase trough space per animal or blend the mixture with ground corn or other palatable concentrate. However, this last option may lead to significant intake variations. Therefore, the extra concentrate should be added gradually, in small amounts (2% to 3% of the mixture, for example), with careful intake and animal behavior monitoring.

In the other hand, in cases when consumption is higher than planned, one can increase sodium chloride content in the mixture. When it is unpractical or proves ineffective, an alternative is to feed for a certain period the amount that reach intended rates per animal (g/head.day), even if the entire feed is consumed before the end of the intended period. For example, the expected feed amount that should be consumed by a given group in three days is consumed in only two days. In this case, troughs would be refilled only in the fourth day as programmed. There are indications that not consuming supplements for one day will not substantially affect the benefit of supplementary feeding in cattle. Obviously this is an extreme-case strategy and should be used only when other measures fail. In any case, it is vital to ensure a trough linear space with more than 12 cm per animal. Another very important remark is that cattle should not be kept from supplements for longer than one day, especially when feed additives are used.

Chart 13.3 shows two examples of protein supplements formulation for minimum consumption of 1 g/kg LW and 2 g/kg LW. Due to consumption variation, a target consumption rate from 1 to 2 g/kg LW for the former and 2 to 3 g/kg LW for the latter is recommended.

Concentrate

Concetrate is basically a mix of energy sources (grains and byproducts), protein meals, minerals sources and urea, very similar to concentrates used for feeding feedlot cattle. It is mostly used for finishing cattle in grazing systems in order to increase energy consumption. Among the options for supplementation of grazing cattle this is the alternative with the highest economic risk, as high consumption and weight gain at satisfactory levels are less certain than other supplementation alternatives. However, concetrates on pasture systems may be an interesting option to anticipate finishing of grazing animals, without requiring a feedlot structure and roughage (silage, cut-and-carry, etc.) production (Figures 13.5 A and B).

Maintaining well defined feeding time schedules is important because routine brings comfort to the animals.

CHART 13.3

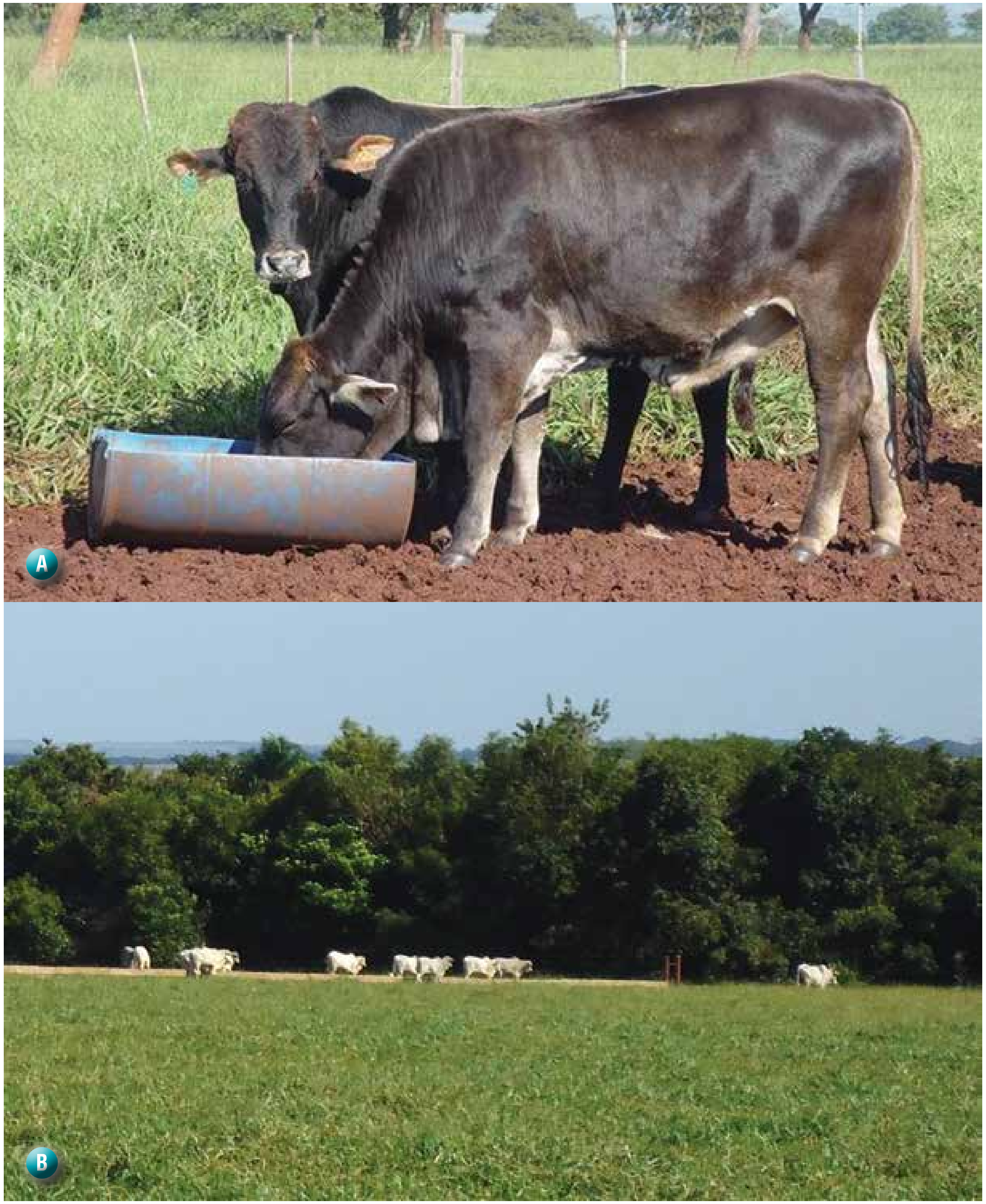
Examples of Simple Formulations for Multiple Mixtures (Protein-Mineral Mix Supplements) that Can Be Mixed on Farm

INGREDIENT (%)	CONSUMPTION OF 1-2 g/kg LW/ANIMAL	CONSUMPTION OF 2-3 g/kg LW/ANIMAL
Corn, ground	20	30
Soybean meal	30	25
Mineral mix	20	20
Plain salt (NaCl)	17	20
Urea	12	4
Ammonium sulfate	1	1
Total	**100**	100

LW: Live Weight

Cattle weight gains under this type of supplementation varies from 700 to 1,000 g/head/day considering a consumption of dry feed equivalent to 1% of live weight in dry matter basis. The minimal linear trough space recommended is 50-60 cm per animal, which is much larger if compared to other supplements, in order to provide access to the concentrate for all animals at the same time. For this supplementation method, the following should also be considered:

- Concentrate supply should be divided into two feedings, one in the morning and another in the afternoon. Maintaining well defined feeding time schedules is important because routine brings comfort to the animals, conditioning them to be close to troughs at the moment of feeding. It is important to remember that cattle have group behavior, i.e. an animal will attend the trough only when the group is close to it. If the group leaves, all animals will follow it by instinct, even if some would be willing to consume more supplements. This reinforces the need to provide enough trough space for simultaneous access to the whole group.
- There are dominance relationships among cattle. Considering that their flight distance (minimum distance from which it feels threatened by another animal) is equal to the length of their body, a distance of around two bodies is recommended between troughs scattered on pasture and/or trough lines. This allows a more submissive animal to choose a trough where there is no threat from competitor, and even if the dominant animal is in the next trough, the submissive animal will not feel threatened and will peacefully consume



Figures 13.5 A and B

Cattle finishing with dry feed supplement on pasture with high forage availability.
Photos: Davi J. Bungenstab.

In the dry season, animal stocking rates should be adjusted towards prioritizing individual performance instead of beef production per area.

the supplement. Placing the troughs at reasonable distances therefore allows more uniform consumption.

- The finishing period upon this supplementation strategy should not be longer than 60 days during the dry period of the year when forage growth declines. Without forage foliar growth and with selective leaf consumption by cattle, the stem:leaf ratio becomes too high over time, substantially reducing weight gain. This situation is aggravated by increasing nutritional demands as the finishing phase advances. Therefore, when the finishing period is expected to exceed 60 days, it is recommended to have two or more deferred pastures available for use in sequence.
- The previous paragraph assumes a typical situation, using a stocking rate of 1 AU/ha and minimum initial forage supply of 4,000 kg DM/ha. In most cases, the crop-livestock integration allows greater accumulation of forage and hence higher stocking rates. However, just as in traditional pastures, extending the period of supplementation is not recommended, once it reduces forage quality due to aging plants and stems accumulation. It is important to note that in the dry season, animal stocking rates should be adjusted towards prioritizing individual performance instead of beef production per area. Undergrazing the area, i.e. using less than optimal stocking rates, is preferable, as it improves individual performance and consequently produces heavier animals in shorter periods of time. The reverse situation, i.e. overgrazing the area using higher than optimal stocking rates, reduces individual performance and undermines pasture longevity, therefore, it is not advisable.
- The most suitable animals for finishing under these conditions are those that require only about 40 to 50 kg to achieve the minimum slaughter weight. Therefore, for typical beef cattle in Brazil, males weighting more than 400 kg and females weighting more than 300 kg are considered suitable for this strategy, provided that cost effectiveness is favorable. The BCSS spreadsheet, developed by Embrapa Beef Cattle, is helpful in this evaluation. It can be accessed and downloaded at www.ilpf.cnpgc.embrapa.br.

Chart 13.4 presents two formulation options for dry feed supplement on pasture. It is important to remember that in these systems it is possible and even recommended to develop a specific formulation for each situation. As it is possible to better adjust feeding to specific grazing conditions and the use of local ingredients, a specific formulation should be prepared by professionals.

Finally, it is important to remember that the suggestions herein presented for different types of supplements are minimum reference values and can be altered if not considered optimal for a specific situation. In addition, daily deliveries of supplements in the pastures can be a challenging task which requires more labor, machinery and equipment. This aspect should be seriously taken into account when deciding to use high consumption supplements.

CHART 13.4

Examples of Formulations for Dry Feed Supplement that Can Be Mixed on Farm

INGREDIENTS (%)	FORMULATION 1	FORMULATION 2
Corn, ground	69.80	18.40
Soybean hulls	–	68.00
Soybean meal	28.00	–
cottonseed meal	–	11.00
Urea	1.00	1.50
Ammonium sulfate	0.10	0.15
Plain salt (NaCl)	0.40	0.20
Mineral mix	0.70	0.70
Total	100.00	100.00

WHAT CHANGES IN BEEF CATTLE SUPPLEMENTARY FEEDING UNDER INTEGRATED SYSTEMS?

The same concepts presented and successfully used in traditional systems, which do not have the tree component or crops are valid for supplementary feeding in pastures under integrated systems. The main difference in integrated systems is that, in the case of ICL, pastures usually have at least two characteristics overlapping those of conventional systems: higher yields per hectare and better forage quality. In the case of cattle feeding on pastures, the prevailing factor is increased forage availability, because of better soil fertility from crop fertilization residues.

In this case, when comparing pastures with greater or lower forage availability using similar supplementing levels and the same stocking rates, grazing pressure is naturally lower on pastures with higher forage supply. This condition allows a better animal selection of the most nutritious plant parts and, consequently, improved performance. Therefore, in the case of the usual performance range obtained with protein-mineral supplements, pastures from integrated systems are more likely to provide higher gains. On the other hand, as pastures have better quality; differences in weight gain between supplement-fed and non-fed animals are smaller.

Moreover, as integrated systems usually present higher forage availability, if the stocking rate increases in a way that the grazing pressure between the two systems (ICL vs. conventional cattle raising) is the same, animal performance on both pastures is expected to be similar. Therefore, the result of integrated system would be better due to the increased stocking rates with consequent higher beef yields per area.

In the case of cattle feeding on pastures under integrated systems, the prevailing factor is increased forage availability, because of better soil fertility from crop fertilization residues.

Grasses under tree rows shade present 15% to 40% higher crude protein content compared to pastures from open areas.

Another relevant point is that the ICL systems may allow high stocking rates for short periods, increasing the number of animals to be fed in the farm, favoring economies of scale. There are ICL cases of supplementary feeding 700 to 1,000 animals in 100 ha modules. In these more intensive feeding situations through space availability for animals is essential to assure satisfactory feed intake by all animals.

In the case of supplementary feeding in integrated systems with a tree component, two characteristics are relevant: the first is the forage lower growth rate but better nutritional value. Paciullo et al. (2011) reported differences of approximately 15% in the number of tillers and green forage mass in *Urochloa decumbens* compared to areas of higher and lower shading between tree rows, especially *Acacia mangium* and *Eucalyptus grandis*. In turn, Behling Neto et al. (2012) observed reductions of around 50% in the annual average supply in the dry matter content of fresh Piatã grass in ICLF systems compared to ICL systems (1,156 kg/ha and 2,307 kg/ha respectively). These results indicate that carrying capacity is lower in integrated systems with the forestry component.

Grasses under tree rows shade present 15% to 40% higher crude protein content compared to pastures from open areas while presenting lower mass production (SOUSA et al., 2007, MOREIRA et al., 2009; BEHLING NETO et al., 2012). In this context, dietary protein requirements in this type of system can be more easily met by the pastures, demanding lower protein supplementation and therefore reducing costs. Welfare from shade in these systems can have a synergistic effect on performance of supplement-fed cattle.

SUPPLEMENTARY-FEEDING OPPORTUNITIES IN INTEGRATED SYSTEMS

Use of Grain Processing Residues

Especially the integrated crop-livestock systems present good opportunities to use byproducts and residues of grain processing, usually being an attractive alternative. However, there are also some challenges, in particular the high variation in nutritional values. Chart 13.5 presents the nutritional values of some soybean residues analyzed in commercial laboratories.

These data show significant variation in protein, fat and mineral matter content. In fact, a significant share of mineral residue (ashes) is observed in Soybean Residue 2 (about 50% of weight). The energy value of this residue is clearly very low, and no matter how low its price can be, its cost per energy unit is extremely high. In this context, it is essential to carry out a proximate analysis before purchasing residues.

Sometimes the analyzes to be made depend on the type of residue, but in general, it is important to assess energy content, including Total Digestible Nutrients (TDN), using the formula

CHART 13.5
Nutritional Values of Soybean Processing Residues Analyzed in Commercial Laboratories

TYPE OF RESIDUE	DRY MATTER (DM) (g/kg)	CRUDE PROTEIN (g/kg MS)	FAT (g/kg MS)	ASHES (g/kg MS)
Soybean Residue 1	900	302	78	97
Soybean Residue 2	968	193	66	470
Soybean Residue 3	921	300	109	11
Soybean Residue 4	994	183	62	64
Maximum variation	10%	65%	76%	4,173%

suggested by Weiss et al. (1992). To apply this formula, usually referred to as the "Weiss formula", it is necessary to assess crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), neutral detergent insoluble protein (NDIP), acid detergent insoluble protein (ADIP) and sulfuric acid lignin (SAL) content. When sending the sample to a lab, it is important to request the specifications above. An electronic spreadsheet that automates the calculation and storage of the result can be accessed at www.ilpf.cnpgc.embrapa.br. This model is quite simple and its results have proved suitable for diets and supplements formulation.

Also regarding the nutritional value of residues, attention should be given to variations due to their origin. Although there are default values expected for a residue identified by a given name, their names, or the way they are called, may also vary. Different products may have the same name and vice versa. For example, when sent to the laboratory the residues listed in Chart 13.5 were labelled as: "soybean residue", "soybean broken grains" and "soybean *hulls*."

Another problematic issue with regard to residues is that, just as there is no standard for granulometry. This limits drying, because if the dryer setting is suitable for larger grains, the smaller parts may get burned, loosing nutritional value. On the other hand, if the dryer is adjusted not to burn finer grains, larger residue particles will keep moisture content above levels suitable for storage. For this reason and also due to their low commercial value, residues are usually not dried. However, moisture above 15% facilitates microorganism development. In the case of fungi, mycotoxins may be produced and some can cause great harm, even in small amounts. The main effects of mycotoxins are reduced performance, reproductive problems, reduced immune resistance and pathological damage to the liver and other organs. Often, the damage caused by mycotoxins on feed may go unnoticed in the absence of clinical signs and result in disruption in weight gain rates, which is not always properly identified or related to the presence of mycotoxins in the feed.

Damage caused by mycotoxins on feed may go unnoticed in the absence of clinical signs and result in disruption in weight gain rates.

There are commercial kits for mycotoxins diagnosis. However, as they occur in concentrated form, even with careful sampling, a poor residue party may be approved while a good one might be rejected, depending on where samples were taken. Therefore prevention is the best option.

Storing ingredients with low moisture content (<10%) in areas protected from insects and mites favors their preservation. In addition to increasing the risk of contamination, higher moisture content and pest attacks reduces nutritional value. The use of organic acids, especially acetic and propionic acids can help maintain nutritional quality, as they inhibit microorganism growth. The amount of organic acids to be used depends on product's moisture and expected storage time. For contaminated materials, decontamination measures are usually impractical. But if residues are in good condition and nutritional value is known, they can be used as any other ingredient, usually reducing costs.

Grazing Crop Residues

Positive results have been obtained with grazing over crop areas immediately after harvest, especially with maize, sorghum and millet.

Crop residue grazing is another type of supplementary cattle feeding in integrated systems. Positive results have been obtained with grazing over crop areas immediately after harvest, especially with maize, sorghum and millet.

Crop residue grazing requires no investments in haying equipment and reduces costs related to storage and distribution. Additionally, a large part of the crop remains in the area, allowing nutrient recycling and no-tillage cultivation over left straw. Another favorable aspect is animal manure, despite its uneven distribution in the soil, especially because of usual low stocking rates.

There are certain limitations for using this strategy. First, there is high variation in crop residues nutritional value. Variations occur due to the crop type, proportions of plant parts, and stage of maturity at harvest for example. Crop management also affects the nutritional quality of crop residues. Typically, plant diseases and irrigation reduce straw quality, while the early grain harvest improves it.

The nutritional value of crop residues is low, similar to that of poor pastures and their use can be enhanced with strategic supplementation, being particularly important to correct deficiencies in crude protein. Grazing crop residues requires also some infrastructure, such as fences and water supply. To reduce these costs, electric fences and centralized or mobile water and feed troughs can be used.

Grazing Maize Crop Residues

In the case of maize, Figure 13.6 presents the average proportions of the main plant parts. Note that 50% of the total weight corresponds to the stem, which has low nutritional value.

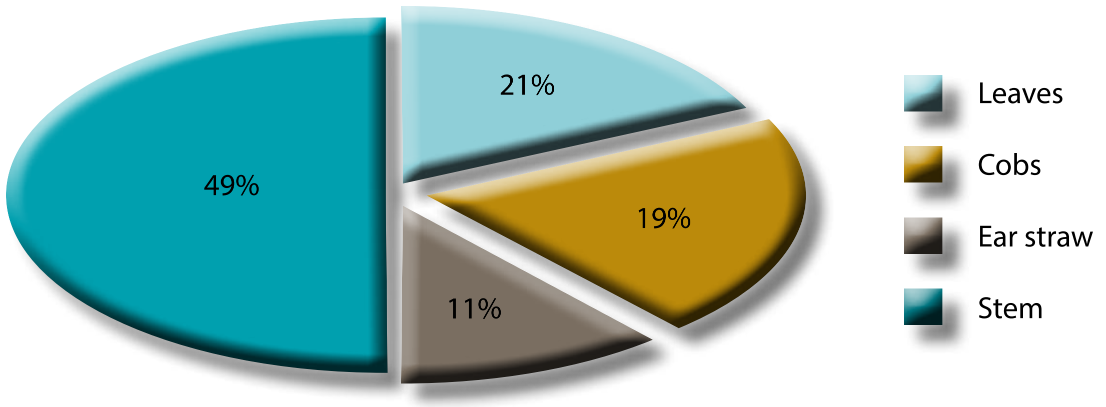


Figure 13.6

Maize crop residues composition, with their average component share. Source: Bose; Martins Filho, 1984.

Also in the case of maize, in terms of dry matter, there is a ratio of nearly 1:1 between grain and straw yields (RUSSEL et al. 1993). In this context, a grain crop yield of 5 t/ha will produce around 5 t/ha straw. Under ideal conditions, this amount would be able to support 3 AU for one month (Figures 13.7 A, B, C and D).

Chart 13.6 presents crude protein content and digestibility of maize crop residues components.

However, according to Gutierrez-Ornelas; Klopfenstein (1991), the residual grains on the cobs after harvesting are the main source of nutrients in maize crop residues. About 2 to 8 g of maize grain is estimated to be produced per 100 g of crop residues. In certain situations they are totally consumed in the first 21 days of grazing (RUSSEL et al., 1993), with no supplementation needed in the period.

As for grazing habits, the animals showed preference for maize crop residue parts in the following order: 1) Grains; 2) Ear straw; 3) Stem; 4) Cob; 5) Leaves.

Therefore, it is clear that there is no preference by protein content and energy value, but probably by a combination of nutritional value and ease of access.

CHART 13.6

Crude Protein Content and Digestibility of Maize Residues in Percent of Dry Matter

NUTRITIONAL VALUE	TOTAL RESIDUES ON FIELD	STEM	LEAVES	COB
Crude protein (% of DM)	4.6	3.7	7.0	2.4
Digestibility (% of DM)	50.0	48.2	49.8	52.6

Source: Cruz (1992).

Figures 13.7 A, B, C and D

Crossbred beef cattle grazing maize crop residues, with details of plant parts. *Photos: Davi J. Bungenstab e Rodrigo da Costa Gomes.*

The degree of maize crop residues utilization efficiency increases with stocking rates. Fernandez-Rivera and Klopfenstein (1989), for example, observed an increase of almost 30% in the use of after-harvest maize residues grazed by steers for 50 days, changing the stocking rate from 1.54 to 2.47 head/ha. However, this increased utilization efficiency reduces animal weight gains, as confirmed by Russell et al. (1993), who showed pregnant beef cows kept on after-harvest maize residues for 55 days and supplemented with soybeans grains at 0.91 kg/head/day rates. The experiment compared stocking rates of 3.4 AU/ha, 1.7 AU/ha and 0.9 AU/ha, resulting in weight gains of -0.060 kg/head/day, -0.010 kg/head/day and 0.410 kg/head/day, respectively. The improved performance with lower stocking rates reflects feeding behavior with better residues selection. Residue digestibility at the highest and lowest stocking rates were 53% and 62%, respectively.

Improved performance with lower stocking rates reflects feeding behavior with better residues selection.

Grazing sorghum crop residues

As for sorghum, each hectare usually produces 3 to 8 tons of crop residues, which usually corresponds to 500% of total grain produced. An important feature of sorghum is that there is no death of plant tissues at maturity, resulting in better quality residues after harvesting compared to crops (Figure 13.8).

Figure 13.8

Finishing beef cattle grazing sorghum crop residues. *Photo: Davi J. Bungenstab.*

The BCSS model is available at www.ilpf.cnpgc.embrapa.br for comparing supplementary feeding options in terms of economic returns.

CHART 13.7
Nutritional Value of Sorghum Residues According to Different Authors

NUTRITIONAL VALUE	FEEDSTUFFS (1992)	BOSE (1991)	WARD (1978)
Crude protein (% of DM)	5.3	2.5	6.6
Energy – TDN (%of DM)	54.0	47.0	46.0

Source: Henrique; Bose (1997).

Chart 13.7 presents some references on nutritional values of sorghum residues, which also vary considerably. Note that crude protein content is usually low, indicating need to supply concentrate supplements for cattle grazing sorghum crop residues.

Ward (1978) recorded weight gains of 230 g/head/day in an experiment with supplementary feeding of pregnant cows grazing after-harvest sorghum residues supplemented with 0.5 kg/head/day soybeans meal for 90 days, showing that the combination of both supplements can lead to satisfactory results and may even release strategic grazing areas for recovery.

COMPARING SUPPLEMENTARY FEEDING OPTIONS FOR THE DRY SEASON

The BCSS model is available at www.ilpf.cnpgc.embrapa.br for comparing supplementary feeding options in terms of economic returns. This free and easy to use electronic spreadsheet helps decision making for various production systems in different situations. The file can be downloaded from the above listed link and fill in the yellow entries with local data. To begin, follow the "Step-by-Step Help Tutorial", which helps users get acquainted with all features available and adequately fill in the data as well as interpret the results automatically obtained in the calculations.

Examples of valuable results include the return on investment and the exact weight gains necessary for reaching supplementation break-even point, i.e. weight gains needed to cover all supplementation expenses.

CLOSING REMARKS

There are several opportunities to increase production efficiency through supplementary cattle feeding in integrated systems, particularly using grain crop residues and grazing straw residues after harvesting. A few simple, practical and effective suggestions to better use these opportunities are listed below:

- Graze grain crop residues for very short periods to improve utilization of left grain residues;

- Put animals on feedlot after a period of grazing on crop residues with supplementary grain feeding to maximize compensatory gains at feedlot and take advantage of previous adaptation to concentrate feeding;
- Use electric fences to keep animals in small defined areas progressing through the field and increasing momentary stocking rates. This increases residue usage efficiency and allows a more uniform manure distribution.

It is important once more to mention that feed supplements should always be fed along with high forage availability, since they must be complementary. Therefore, stocking rates must be properly adjusted to assure adequate forage availability.

The ultimate goal is to reach the highest possible performance with supplementary feeding in ICLF systems and to make the best use of crop residues and other agricultural residues for animal feeding, reducing need for external inputs, lowering costs, avoiding unnecessary environmental impacts, and contributing to sustainable agricultural production.

Feed supplements should always be fed along with high forage availability, since they must be complementary.

Chapter

14

Parasite Control for Beef Cattle under Integrated Farming Systems

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INTRODUCTION

The increasing use of integrated crop-livestock (ICL or ILP) and integrated crop-livestock-forestry (ICLF or ILPF) systems for beef cattle farming demands adaptation of know-how and technologies already established for animal husbandry. In this sense, integration with crops and/or forests introduces components that can affect parasites' epidemiology of beef cattle raised in these systems. The "crop" component breaks the parasite cycle, in theory, growing pastures free of them after a crop cycle. On the other hand, the tree component protects ILPF systems against solar radiation, which may favor parasites survival. Despite these new components, it is possible to adapt existing technologies for integrated systems. This chapter will discuss recognized effective parasite control mechanisms and ways to adapt them to these systems.

RELEVANCE OF BEEF CATTLE PARASITE CONTROL IN INTEGRATED SYSTEMS

A number of diseases affect cattle production, reducing yields and profitability. Several problems, especially those caused by viruses and bacteria, can be avoided or controlled with vaccines and other preventive measures. In the case of parasites, herd immunization is difficult and ends up being the main health issue in beef cattle production around the globe, particularly in the tropics.

The damage parasites cause to beef cattle can reduce weight gain by 20%, not to mention those considered indirect damages, such as increase in production costs due to the acquisition of antiparasitic drugs.

In traditional production systems, both, animal contamination mechanisms and the most efficient parasite control techniques are well known. Studies on the life cycle of parasites in traditional cattle systems, as well as infection/infestation mechanisms, led to the development of effective techniques for parasite control. Therefore, based on the awareness of parasites incidence in extensive systems, combined with complex crop management techniques in integrated crop-livestock and integrated crop-livestock-forestry systems, it is possible to implement sanitary measures to mitigate their incidence in integrated farming systems.

MOST COMMON CATTLE PARASITES

In a simple definition, parasites are organisms that feed on other living beings (cattle in this case) to survive and/or reproduce. As a result, they eventually hinder animal development, causing losses to farmers.

Each parasite species (group or type) has its own morphological (physical), feeding and life cycle characteristics that are essential for efficient control. Understanding these characteristics is the key to develop efficient management programs.

Understanding characteristics of parasites is the key to develop efficient management programs.

An important feature of the parasites' life cycle is that most of them spend part of their lives in the host (parasitic phase) and in the environment (non-parasitic phase). It is therefore possible to use control techniques specific for each of these phases.

In a simplified manner, we can divide the parasites into two major groups:

- ***Ectoparasites***: those who live on the surface or cavities of the host (animal) during their parasite phase. Examples: ticks and flies.
- ***Endoparasites***: those who live inside the host, in their blood, gastrointestinal tract or other body tissues during the parasitic phase. Examples: helminths (worms) and protozoa.

Chart 14.1 shows the most common cattle parasites in Brazil and some of their biological characteristics, as well as important measures for their management and control in ILP and ILPF systems.

Ectoparasites

Flies

The flies that infest cattle can be hematophagous (which feed blood) or myiasis-causing (bot flies/screw-worm flies). **Hematophagous** flies are parasites in the adult phase, while screw-worm flies infests when a larvae. Figure 14.1 shows the life cycle of basic hematophagous flies and how they relate to cattle and the environment.

Damages caused by Hematophagous flies are due to blood loss, skin damages, productivity loss due to stress consequent to the bites, as well as the diseases they can transmit. The main hematophagous flies that parasite cattle are *Haematobia irritans* and *Stomoxys calcitrans*.

Haematobia irritans spends virtually all the time feeding or resting on cattle, leaving only to lay their eggs, which are deposited in fresh cattle manure pats. Unlike *Haematobia irritans*, *Stomoxys calcitrans* spends most of the time outside the host. It only approaches the animals to feed, stays for a few minutes and then looks for a safe place to rest. This species uses preferably organic matter in a fermentation state to reproduce (Chart 14.1).

In the case of **myiasis-causing** flies, the main species found in Brazil lay their eggs directly on injured animal skin, such as those caused by scratches, surgery, and unhealed umbilical cord stump, among others. Hatched larvae feed on animal tissue, skin and others. An important feature is that these flies do not have preference for cattle. In other words, they can feed and repro-

CHART 14.1
Biological Characteristics and Control of Most Common Beef Cattle Parasites in Integrated Systems.

GROUP	PARASITES	BIOLOGIC CHARACTERISTICS	CONTROL IN ILP AND ILPF SYSTEMS
Ectoparasite	Horn fly	• Hematophagous • Vectors of pathogen organisms • Long periods over host • Lay eggs on fresh cattle feaces	• Strategic treatment along with tick treatment • Use of drugs in September and October in Brazil
Ectoparasite	Stable fly	• Hematophagous • Vectors of pathogen organisms • Short periods over host • Lay eggs on decaying materials	• Preventive treatment through keeping clean handling facilities, troughs and other farm edifications and equipment.
Ectoparasite	Cattle tick	• Hematophagous • Biological cycle over a single animal • Larvae feed and grow in the host until maturity	• Strategic treatment from July to September • A series of 5 or 6 treatment with 21 days intervals • Choose the most eficiente drug, possibly specificly tested for the farm
Endoparasite	Helminths	• Gastric tract worms • Simple (direct) or complex biologic cycles	• Tactical treatment; to treat animals showing high EPG before entering renewed pastures. • Strategic treatment; to treat animals in May, July, September and/or November.
Endoparasite	Coccidea	• Microscopic organisms • Multiply within intestinal cells • Limit nutrient absorption	• Preventive treatment through keeping clean handling facilities, troughs and other farm edifications and equipment. • To avoid moisture accumulation
Endoparasite	TFA (protozoan and rickettsia)	• Protozoan destroy red blood cells • Cause fever and anemia • Transmitted by cattle ticks	• Tick control • Calf Pre-immunization or vaccination in areas without ticks

duce in any hot blooded animal, including wildlife. Bot fly is the larva of a fly called *Dermatobia homminis*. Its biological cycle is more complex than that of the other flies above mentioned. The bot fly does not lay its eggs directly on animals – it captures another fly to lay its eggs on it, which in turn takes the eggs to the host.

These flies depend on animals to survive, yet they spend much of their lives in the environment, where they are influenced by environmental factors, which can sometimes be modified to stop the cycle.

Ticks

Rhipicephalus (*Boophilus*) *microplus* is one of the parasites that cause more financial losses to famers, especially if there are *Bos taurus* breeds in the herd. *These* cattle are less resistant to ticks and the diseases they transmit. This tick species have a monoxenous life cycle, i.e. it parasites only one animal during their cycle. Another feature is that the larvae attach to cattle, feed and develop to adult within 21 days (Figure 14.2). After being fed, the engorged females (swollen with blood) fall into the pasture, where they lay their eggs. After finished the hatching process, the new larvae remains in the pastures waiting for a new host. The average period the tick larvae remains in the environment may vary from 45 to 120 days, depending on environmen-

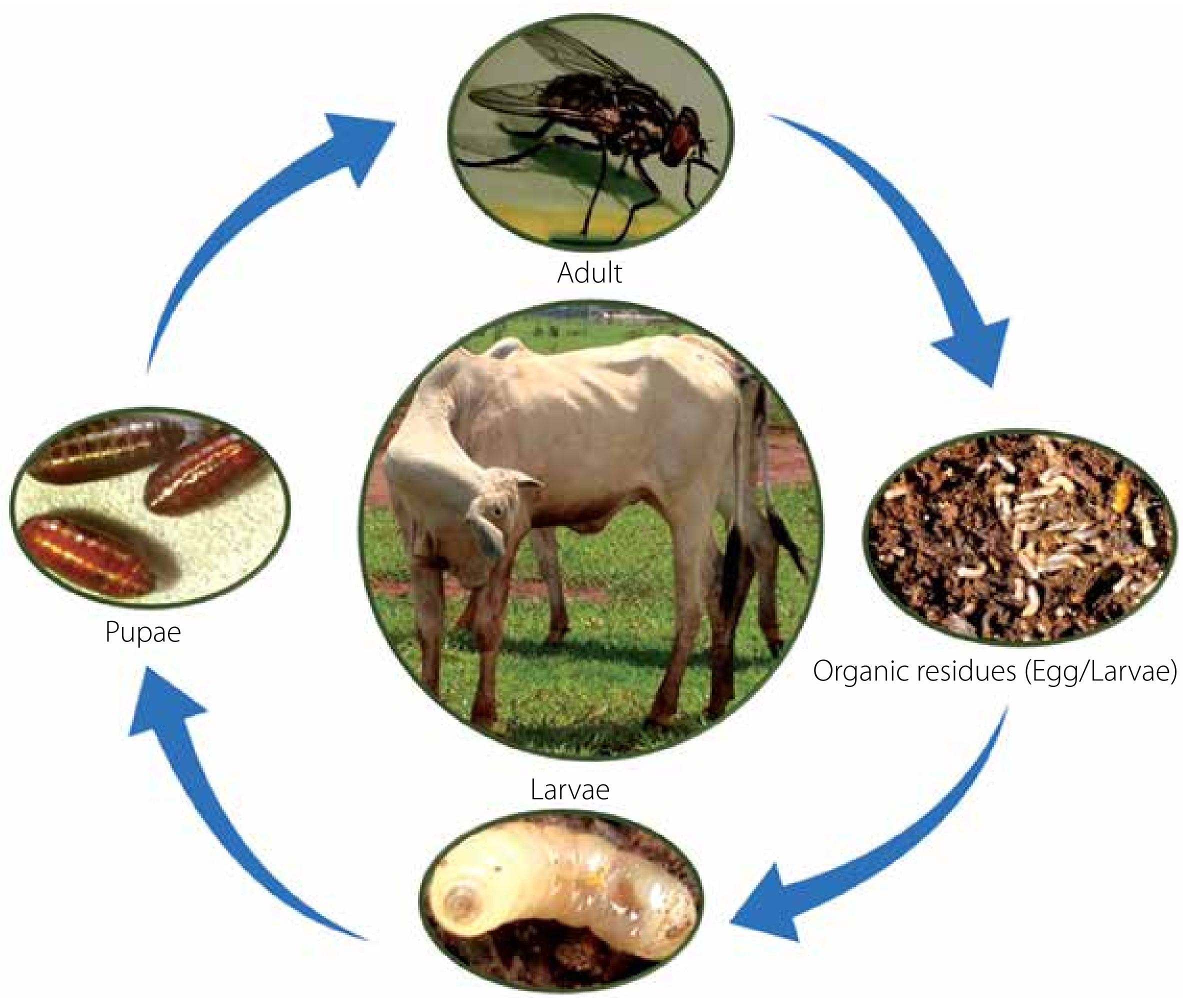

Figure 14.1
Basic life cycle of hematophagous flies.

tal conditions. Temperature and relative humidity conditions in the microenvironment may increase or decrease survival of ticks on pastures.

Endoparasites

Helminths (Worms)

Intestinal helminths, also called worms, present variable life cycles, depending on the species, which can be simple or complex. Simple biological cycles (direct cycles) involve cattle and the environment (Figure 14.3). Complex life cycles involve the environment, animals and

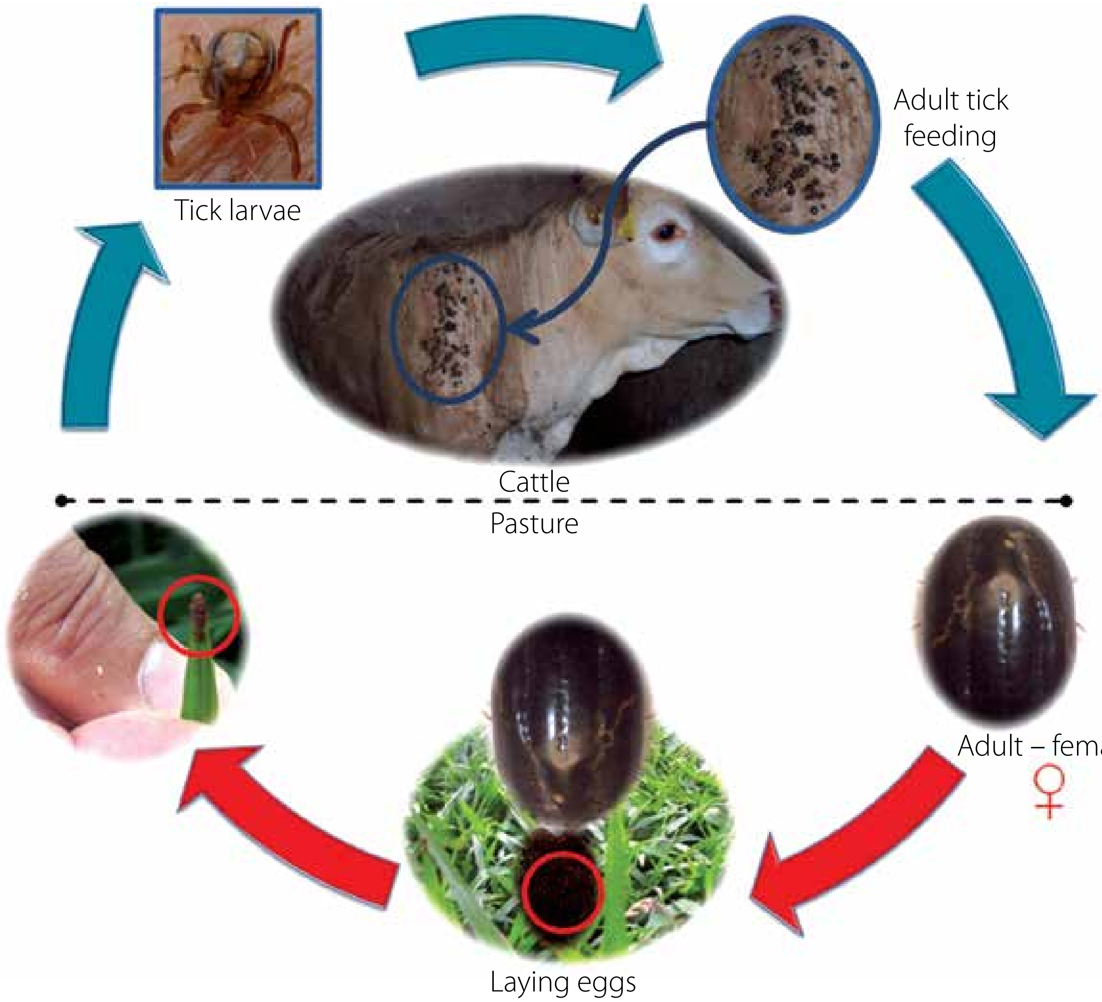

Figure 14.2

Life cycle of cattle tick *Rhipicephalus (Boophilus) microplus*.

other living beings that are used as intermediate hosts. Intermediate hosts can be insects, mites, worms, snails and even vertebrates. Like ticks, cattle helminths can lead to significant affect herd performance due reduction in weight gains and consequently increasing slaughtering age.

In ILP and ILPF systems, integration of livestock with annual crops considerably affects the micro-environment and consequently the intermediate host populations, reducing helminths population on pasture.

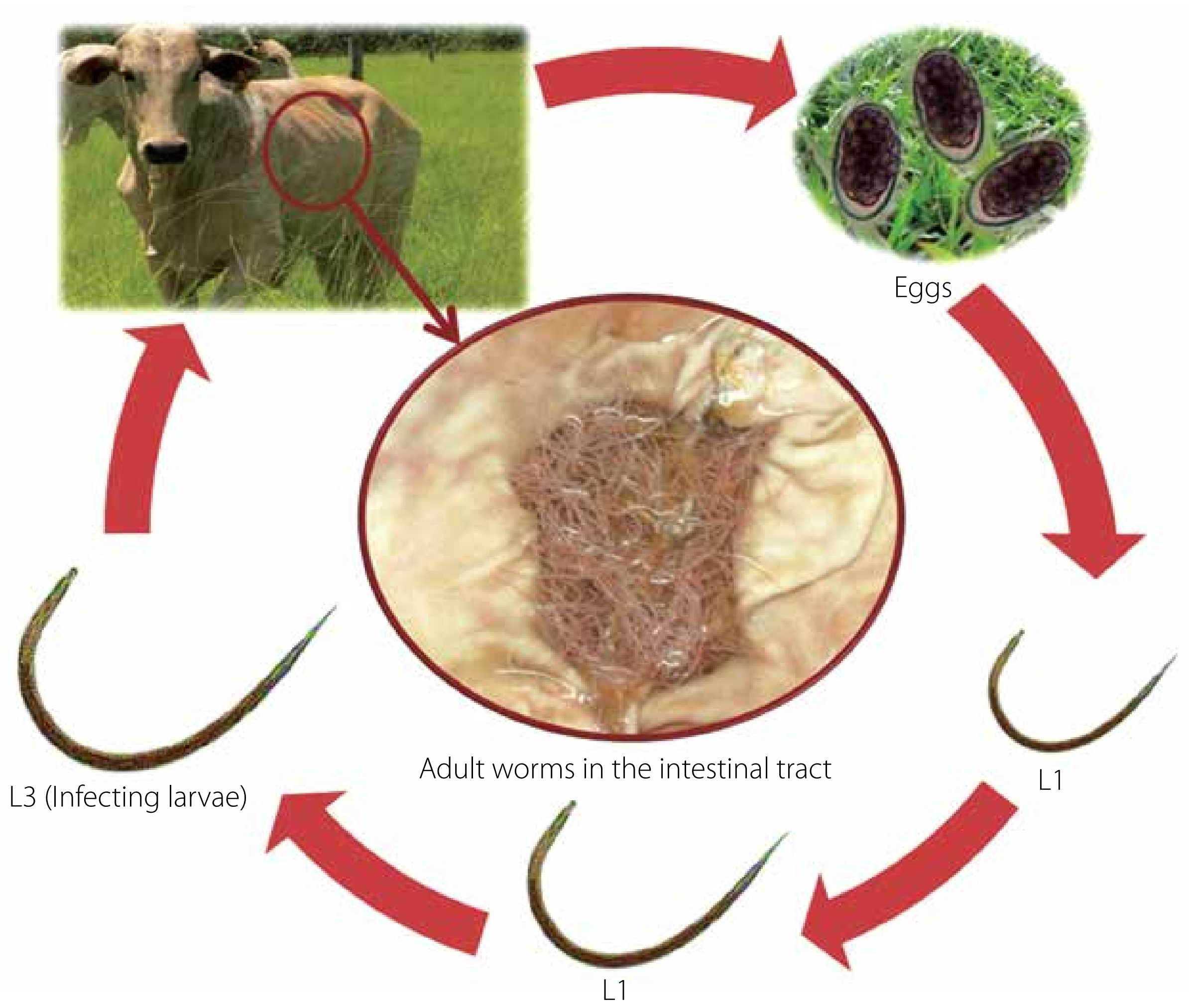

Figure 14.3

Simple life cycle of intestinal helminths – direct cycle.
Photos: João Batista Catto, Josimar Lima

Coccidia (coccidiosis)

The main parasite of cattle belonging to this group is *Eimeria bovis*. Coccidia are microscopic parasites that multiply within the intestinal cells of animals and usually destroy them. The reduction in the number of cells impairs nutrient absorption, reducing weight gain. In severe cases, they can cause calves death. These parasites live outside the animals in certain phases of their life cycle. Therefore, as for helminths, changes in the environment due to integration with crops and management techniques used in ILP and ILPF systems will strongly influence the development of Coccidia.

Tick Fever Agents

Tick fever in Brazil is caused by blood parasites, *Babesia bovis*, *Babesia bigemina* and *Anaplasma marginale*. It is transmitted by ticks and it is one of the diseases responsible for the major losses in cattle husbandry in the tropics. These three parasites cause essentially fever and hemolytic anemia, i.e. destruction of red blood cells, which are responsible for transporting oxygen and CO_2 in the blood. This stage of the disease is especially severe in animals with no prior immunity, such as cattle imported from regions with no history of tick infestation or calves that did not receive colostrum and were not vaccinated or pre-immunized.

Since these parasites are transmitted by the cattle-tick [*Rhipicephalus* (*Boophilus*) *microplus*], control techniques applied to ticks end up controlling tick fever.

PARASITE CONTROL IN INTEGRATED SYSTEMS

Established control techniques applied in other cattle husbandry systems can usually be used in and/or adapted to ILP/ILPF systems.

As ILPF systems are relatively recent, there are yet no scientific studies in Brazil on the positive or negative influence of this new environment on cattle endo and ectoparasites life cycle. However, established control techniques applied in other cattle husbandry systems can usually be used in and/or adapted to ILP/ILPF systems. It is important to be aware of the peculiarities of each system, especially with regard to the tree component.

Changes in the microenvironment caused by the presence of trees, which provide shade, will not only interfere with the development of forages - shading of pastures also decreases soil temperature, influence the incidence of ultraviolet rays (UV) and increase humidity. This increase in shading is evident in systems with a tree component, especially those with higher tree density. But, there are also differences on parasites' environments under ILP systems, mainly because recovered pastures become denser and have higher plant cover. These features, which are often positive and favorable for forage and cattle, also benefit breeding and the survival of parasites in the environment. In this context, farmers who want to introduce an ILP and/or ILPF system must also be aware of possible problems with parasites.

Parasite Control

The main benefit of ILP and ILPF systems in parasite control is breaking parasites' life cycle. When intercalating crop with livestock, animal parasites usually die when the grain crop is growing, in the same way parasites from annual crops tend to die when areas are planted with forage grasses for several years. Therefore, the use of integrated systems is desirable. Interrupting the life cycle has been since long considered the best way to control parasites. Thus, after crop harvest, the "new" pasture area is virtually free of parasites.

With the pasture ready and clean, the main concern should be on how to keep the area with low parasites infestation. Consequently, it is very important to treat young animals, i.e. weaned calves of up to 18 months (yearlings), before introducing them to these areas (tactical treatment). The anthelmintic and anti-tick treatment of only the most affected animals over 18 months will ensure a healthier environment for the herd and prevent selection of resistant parasites.

The anthelmintic treatment should follow a program of tactical and strategic treatments developed by Embrapa Beef Cattle (document available at www.ilpf.cnpgc.embrapa.br). However, it is important to synchronize the crop, forest and livestock components. One example of a system is presented in Table 14.2. Under Brazilian conditions, the aim is to make cattle enter the "new" pasture in May and June, after harvesting, which usually occurs between February and March. Thus, the treatment will be done within the strategic program that will be a preventive treatment for animals, with no need of tactical treatments. Wherever possible, an endectocide should be used in this case, as it serves both to combat helminths and ticks.

In order to control ticks it is important to follow some guidelines developed by Embrapa (document available at www.ilpf.cnpgc.embrapa.br). Note that the same guidelines for preventive treatment of intestinal parasites apply to ticks. Cattle should have few ticks (low infestation) when introduced in new grazing areas. Especially in Central Brazil, even if animals enter the system in May, when tick infestation is not as intense as in the rainy months, they can still be treated to prevent pasture contamination, enabling a favorable cost-benefit ratio.

Preventive treatments for ticks and helminths are aimed at mitigating environmental infestation, as they do not eradicate the parasites from the environment. Therefore, tactical treatments carried out before the introduction of animals on pastures do not eliminate the need for other strategic treatments in the following months, following the treatment schedule presented in Table 14.2. The goal is to expand the strategic effect of crop-livestock integration, extending the beneficial effect of eliminating parasites and keeping pastures with low contamination rates for longer. The final result will be cost reduction with parasite control and better herd performance.

Although simple, preventive parasite treatment must be accompanied by veterinarians, who will help choose the best drugs and adequate dosages to be applied. Choosing the right drug is one of the key points for success in parasite control. Improper use of chemicals can make para-

Preventive treatments for ticks and helminths are aimed at mitigating environmental infestation, as they do not eradicate the parasites from the environment.

sites resistant, causing great losses for farmers and eventually for an entire region. It is therefore crucial to choose the right drug and apply it as recommended by manufacturers.

Treatment of Tick Infestation in Cattle

With regard to tick control, it is important to stress that each farm has specific characteristics and, therefore, frequently a drug that works well for some does not work so well for others. Embrapa Beef Cattle provides tests to check the resistance of ticks to drugs/active ingredients in Brazil, helping choose the most suitable drug for each farm. For more information, visit http://carrapatos.cnpgc.embrapa.br/.

Tick control treatments should be carried out in the period of the year when ticks are most vulnerable, like in the dry season.

Tick control treatments should be carried out in the period of the year when ticks are most vulnerable, having a more efficient control. In Central Brazil, the best time to treat cattle is from July to September, when the relative humidity is lower (dry period), helping to control ticks. During this period, 5 to 6 treatments are recommended, with intervals of 21 days. This is called "Strategic Treatment" (ST) and consists of the right drug application as recommended, at the most appropriate season for farmers and at the most unfavorable season for ticks.

Treatment of Helminth Infection in Cattle

Helminthic infections should also be treated following recommendations of Embrapa Beef Cattle (www.ilpf.cnpgc.embrapa.br). According to the Strategic Control plan, treatments are recommended in May, July and September in Central Brazil, with one more possible treatment in November. In addition to this strategic calendar, it is recommended to treat calves (weaning age up to 18 months), as explained earlier, before introducing them to the "new" pasture (Tactical Treatment - TT), which is free of parasites after the crop period. As for tick infections, the objective of this tactical treatment is to prevent pasture contamination. The chemical base to be used should prevent parasitic resistance. Chemical base rotation is known to be an important mechanism in preventing resistance. At this point, it is worth noting that there are several drugs with different names in the market, though they use the same chemical base, i.e. they have the same composition, changing only trade names. Therefore, professionals can help farmers choose the most cost-effective drug, always bearing in mind resistance prevention.

Fly Control in Cattle

Fly control is recommended in the period preceding the rain season. In the suggested schedule (Chart 14.2), strategic fly control should be implemented along with the acaricide treatment in September and October.

CHART 14.2

Example of a Schedule for Tactical (T) / Strategic (E) Control of Parasites in Beef Cattle in Integrated Systems. Cattle Are Introduced in the Pastures 15-18 Months after Introducing Eucalyptus (A) or 1-2 Months after Harvesting the Grain Crop (B)

MONTHS AFTER PLANTING TREES	15	16	17	18	19	20	21	22	23	24	25	26
MONTHS / ACTION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OUC	NOV	DEC
Introducing cattle		A			B							
Tick control		T			T		E	E	E			
Helminth control		T			E		E		E			
Fly control									E	E		

Most acaricide drugs also control flies. However, it is important to be alert to the used dosages, which may be different for each parasite species. More information on fly control, updated by Embrapa Beef Cattle, is available at www.ilpf.cnpgc.embrapa.br. Again, we emphasize the importance of professional assistance of a veterinarian for proper selection and orientation on drug use.

OTHER BENEFITS OF INTEGRATED SYSTEMS IN PARASITE CONTROL

Effective parasite control requires integrated actions, and the main and most obvious benefit of ILP and ILPF systems is crop rotation, which provides a "clean" pasture following grain crops cultivation.

However, despite some potentially negative effects, the benefits of a tree component in an ILPF system should also be taken into account. Crop diversification increases biological diversity within the system, including birds, insects and other animals, consequently increasing the number of natural enemies for parasites.

This diversity helps to control parasites, such as birds that feed on ticks. These mechanisms should be considered within system's broader approach. The variety of species improves the entire system's balance - insects compete for food, the number of beetles that feed on faeces (coprophages) increases, consequently reducing chances of more intense parasite infestation.

Giving adequate attention to each system component and to the available strategies for its specific management, society as a whole will benefit from integrated systems, both due to environmental preservation and increase on higher quality beef supply. Farmers, consequently, will raise healthier animals, reduce costs related to parasite control and boost profitability.

Crop diversification increases biological diversity within the system, including birds, insects and other animals, consequently increasing the number of natural enemies for parasites.

Chapter

15

Sheep Farming for Mutton Production under Integrated Systems

José Alexandre Agiova da Costa
Carmen Iara Mazzoni Gonzalez

SHEEP FARMING IN BRAZIL

Brazil is among the seventeen countries with the largest sheep flock in the world, totaling 17.4 million head. It accounts for 1.4% of world production, with China (134 million), India (74 million), Australia (68 million), Iran (54 million) and Sudan (52 million) being the world's largest producers, representing 35.4% of the global flock (FAO, 2012).

International trade of sheep products is estimated at 11 billion dollars a year, mainly comprising mutton and wool, although the share of the latter has gradually decreased over the years, while mutton sales has increased (MDIC, 2010). Mutton sales totaled US$2 billion in 1990 and exceeded US$4 billion in 2008. Other products, including hides, milk, cheese, offal and livestock, although less representative, should see a growth in sales in the coming years (SORIO et al., 2010).

In Brazil, sheep farming for mutton production has also been expanding continuously, having reached a growth rate of 3.86% per year between 2007 and 2010 (IBGE, 2012), led by the South region (Paraná State), Southeast (São Paulo State) and Midwest (Mato Grosso, Mato Grosso do Sul States and the Federal District) regions. Rio Grande do Sul State has the largest sheep flock, with 3.98 million head, which is mainly managed for mutton production (IBGE, 2012). The Northeast region, however, recorded the largest increase in the flock, representing 53% of the Brazilian flock, concentrated in Bahia and Ceará States, which together exceed 5 million head. The Midwest region accounts for about 6.7% of the flock, with 1.26 million head. (IBGE, 2012; ANUALPEC, 2011).

The Southeast region concentrates a significant share of the mutton consumers market, while the Midwest has a solid potential to supply this demand (SORIO, 2009), given its suitable soil and climate conditions for sheep farming. The advantages of grazing systems, the possibility of scaling up production during the year and easy sanitary control due to the dry period favor the expansion of local sheep farming. However, the main competitive advantage of sheep farming in the region is the possibility of integration with beef and dairy cattle farming.

Sheep farming can encompass the full production cycle or farms can have specific purposes, such as finishing for slaughtering, ewe rearing to replace breeding ewes, and genetic selection and breeding for flock improvement.

SHEEP PRODUCTION SYSTEMS

Farmers-entrepreneurs who wish to invest in the sheep industry should adopt the technological and management alternatives that enable greater technical and financial feasibility for each situation in order to produce high quality mutton. Herd yields will depend on prolificacy (number of lambs born per ewe), mating season and consequently lamb delivery, adjustments in feeding, reproductive and health management to be adopted in each production system.

Thus, choosing production models that promote higher weight gains, reduced breeding periods and shorter lambing intervals is a basic pillar for the development and expansion of commercial sheep farming as a successful agribusiness activity (CUNHA et al., 2005). The use of polyestrous breeds, i.e. breeds that present various estrous during the year, further increases production, as it is possible to obtain up to three deliveries in two years. The selection of sheep with two or three deliveries is a goal to be pursued, provided that they have good weaning ability.

In a Brachiaria pasture with proper management but low nutrient replacement, the average annual cattle load is 450 kg live weight (LW) per hectare (1 AU/ha), while sheep stocking rate is 300 kg/ha. However, the stocking rate is one animal per hectare for cattle and five animals per hectare for sheep, with an average weight of 60 kg.

Cow productivity in a year, measured by calf weaning and growth in the same period, is 180 kg LW/ha. In the case of sheep, lamb yield is 222 kg LW/ha (prolificacy of 1.2, totaling six weaned lambs) in less than six months, while a steer cannot be finished under these conditions, lambs are ready for slaughter.

With a finishing cycle of around five months on pasture using supplementary feeding, the system increases farm turnover, as it eliminates the lack of finished animals on interseason.

INTEGRATED SHEEP AND CATTLE GRAZING WITH A FOCUS ON SUSTAINABILITY

Sheep and cattle integrated grazing optimizes pasture use. This is possible by different grazing behavior of herbivores on the same forage, which results in a more efficient use of forage available (CARVALHO, 2010). Mixed grazing can be done simultaneously or in a rotational system, depending on the objectives and forage species used (SILVA SOBRINHO, 2007) (Figures 15.1 A and B).

Thus, two basic principles guide integrated sheep and cattle grazing: their complementary grazing habits and lower pasture contamination with worms. Sheep are more selective in terms of leaves they eat, while cattle grazing are more homogeneous as they eat forages as a whole (leaves and culms).

Two basic principles guide integrated sheep and cattle grazing: their complementary grazing habits and lower pasture contamination with worms.

In relation to pasture management, preference of cattle for the upper stratum and of sheep for the lower stratum increases grazing efficiency (ARAÚJO FILHO; CRISPIM, 2002) and makes pasture more homogeneous. This is particularly important when using tall species, such as *Panicum* forages. The cattle-sheep ratio of 5:1 (AU = 450 kg of live weight) makes forage use more efficient (CARVALHO et al., 2005).

It is important to remark that plant growth structures should not be damaged and the remaining pasture must be sufficient to maintain animal productivity. Integrated grazing has

Figures 15.1 A and B

Silvopastoral systems with integrated sheep and cattle grazing on a *Brachiaria decumbens* pasture with eucalyptus forest. *Photos: Fernando Alvarenga Reis.*

increased meat production by 24% compared to exclusive cattle grazing and by 9% compared to exclusive sheep grazing (REIS, 2009).

However, there are certain limitations on integrated sheep and cattle grazing:

- Specialized labor is required, with additional skills, especially in terms of health management of small ruminants;
- Higher costs with fences and other necessary structures;
- Potential logistics issues in the allocation of duties among those directly involved in cattle and/or sheep management;
- More complex product sale.

CONTROL OF SHEEP INTERNAL PARASITE INFESTATIONS IN INTEGRATED PRODUCTION SYSTEMS

Although internal parasite infestations have no major impact on direct production costs related to the purchase of drugs, if not properly managed, it becomes a limiting factor in sheep management in tropical conditions and may substantially limit pasture-based mutton production. The degree of infection in sheep varies according to the management conditions and intensity of pastures contamination (AMARANTE, 2010).

Illnesses caused by gastrointestinal nematode infestation are closely related to the following factors:

- Birth and weaning seasons;
- Age and nutritional conditions, which affect immune defense;
- Management of grazing animals.

Endoparasite proliferation requires strict sanitary control of grazing sheep. It is essential to adopt management techniques that mitigate pasture infestation, as well as routine prophylactic measures, such as frequent water troughs cleaning and careful pen cleaning in feedlot operations.

Usually, until reaching puberty animals are more susceptible to increased helminths infestations. Other important factors for nematode infestations are the physiological conditions and breed. In the periparturient period, comprising the period from late pregnancy until early lactation, ewes become more susceptible to endoparasitic diseases and eliminate more eggs through the faeces, consequently increasing pasture contamination. In this period, adult helminth fertility increases, besides hypobiotic larvae and new infective larvae development. The intensity of these occurrences depends also on animal breed, being lighter in sheep breeds that are resistant to nematodes (KATIKI et al., 2008; ROCHA et al., 2004; BUENO et al., 2002).

It is essential to adopt management techniques that mitigate pasture infestation.

Rotational grazing systems interspersed with adult cattle grazing significantly helps to control internal parasite infections in sheep (FERNANDES et al., 2004). These authors observed a reduction in the number of anthelmintic treatments in sheep throughout the year, whereas from a total of 115 treatments, 77 were applied in sheep under rotational grazing without integrating with cattle while only 38 treatments were necessary for sheep under integrated grazing with cattle. This result shows that integrated grazing systems are an important tool to prevent gastrointestinal helminthes in sheep.

Pasture decontamination or reduction of endoparasite infestation in sheep and cattle occurs because the most common gastrointestinal nematodes are species-specific (BIANCHIN; CATTO, 2008) and due to the lower presence of infective larvae (L3) in the lower pasture profile (POLI et al., 2008). It is worth noting that improper use of anthelmintics promotes parasite resistance to active ingredients available in the market.

Climate conditions, such as temperature and relative humidity, influence pasture contamination by helminths. The optimum temperature for maximum development of larvae within the shortest period possible is in the range of 18º to 26º C and humidity of 60% or more. At higher temperatures, development is faster, but larvae death rates are higher, with a consequent reduced number of larvae reaching the infective stage (L3). The same occurs during prolonged droughts. In addition, heavy rains often cause the release of large numbers of larvae from the fecal matter, increasing chances of major infections in animals within a short period (PINHEIRO et al., 2005).

One way of favorably using rotational grazing is forming different lots of sheep and cattle that sequentially graze the area, with a minimum rest period of 60 days for the animal species and 30 days for the forage fallow. This results in forages with higher nutritional value, as they grow back within 30 days, while sheep benefits from its return only after 60 days, mitigating specific gastrointestinal parasitic infestation. Amarante (2010) states that pasture used in rotational grazing systems that rest for 20 to 40 days are not decontaminated, while Souza et al. (2005) concluded that a 60 day rest period in temperate climate conditions were sufficient to at least reduce pasture contamination.

The lowest parasite load was observed on pastures with integrated sheep and cattle grazing.

In the *Cerrado* region of the Federal District, an experiment was carried out during the rainy season related to L3 larvae recovery in sheep grazing a *Panicum maximum* cv. Tanzania pasture and subjected to three grazing systems: (1) combined sheep and cattle grazing on the same pasture; (2) alternate grazing, first with cattle and subsequently sheep; (3) sheep grazing. Five areas were used, which were grazed for seven days each with a 21 days rest period. Cattle remained on pasture all the time and the sheep were kept in closed shelters overnight. The largest L3 recovery was for *Haemonchus* sp., with the following averages: integrated grazing: 40; pasture alternating: 89; exclusive sheep grazing: 82. Therefore, the lowest parasite load was observed on pastures with integrated sheep and cattle grazing. It is important to remember that this endoparasite is one of the main causes of anemia in ruminants in the region.

Sheep farming in integrated production systems particularly combined with cattle farming, along with selection of more endoparasite-resistant sheep are relevant research subjects in the parasitology field, as these systems have presented positive results in the control of sheep gastrointestinal parasites and improved forage quality.

SHEEP FARMING IN INTEGRATED SYSTEMS

In the case of sheep on pastures with a tree component, animals can benefit from the thermal comfort due to the natural shade provided by trees. In given situations, animal grazing in a silvipastoral system (Figures 15.2 A and B) helps to reduce costs related to the regular afforestation, with revenue return anticipated by animal production in a shorter period than revenue from forest products.

Lamb finishing in integrated crop-livestock systems has been tested at the Mid-Western Regional Sheep and Goats Center, in Campo Grande-MS. Tests followed the steps listed below:

1. Young lambs supplemented through creep-feeding are weaned at 70 to 80 days and finished in grazing systems or feedlot with *ad libitum* diets;
2. Pastures are implemented intercropped with maize or sorghum, and animals are introduced after grain or silage harvest.
3. Grazing lambs are supplemented with a balanced energy-protein concentrate (TDN 80% and CP 16%);

These systems have been showing satisfactory results, presenting no difference on finishing parameters for lambs kept in feedlot or pastures. Average daily gains were 200g/day and 70% of animals reached slaughter endpoint at 152 days (Costa et al., 2012 – unpublished data). Lambs received deworming treatment before entering the fresh implemented pastures and no other dose was administered until slaughter because of ILP breaking parasites cycle.

Integrated crop-livestock systems have been showing satisfactory results, presenting no difference on finishing parameters for lambs kept in feedlot or pastures.

Forages produced in integrated crop-livestock (ILP) systems usually have higher nutritional value due to better soil fertility, which helps to improve sheep nutrition, a high demanding category in terms of feeding. The system also eliminates infective helminth larvae on pasture, due to the crop period with no animal grazing.

In ILP areas with rotation of grasses and legumes, such as summer and winter crops (soybeans, maize, sorghum and oats) and continuous single crop or intercropped with forages, a number of sheep finishing systems are possible. Pastures established after soybeans harvest contribute to proper sheep nutrition which are at the last third of pregnancy and during lactation. In ILP systems, ewes mated in October/November (non-seasonal sheep breeds) giving birth in March/April will have favorable nutritional conditions. Areas cultivated with interseasonal crops (safrinha) as

Figures 15.2 A and B

Sheep farming in an integrated crop-livestock-forestry system (ILPF).
Photos: Fernando Alvarenga Reis.

intercropping maize/Brachiaria or sorghum/Brachiaria seeded after soybean harvest can be used in sheep weaning in July and August, after harvesting maize for silage or grain. These lambs are finished by the end of September in areas with no animal grazing for about 8 months. Therefore this area will be free for a new crop or to receive ewes in the new breeding season. However, supplementary feeding is necessary to ensure higher weight gains, (POLI et al., 2008), though the entire cycle is held on pasture, reducing production costs and demand for labor.

Stocking rates can be high in pastures under ILP, thanks to better soil fertility and conditioning. Proper pasture management enables high animal gain while forage residues left on the field are sufficient for subsequent no-tillage seeding. Experiences reported by farmers in Mato Grosso do Sul State indicate that, farm's beef herd does not have to be reduced when incorporating new pasture areas into ILP systems because higher forage yields from cropping areas returned to grazing provide higher stocking rates. For instance, in a farm in Mato Grosso do Sul, originally used only for beef cattle farming, the ILP system was initially implemented in ¼ of the area, being expanded to ¾ of it over time, with constant animal production while now it is using most of the area to grow grain crops in spring and summer.

CLOSING REMARKS

Sheep farming for mutton production is expanding in Brazil thanks to the different possibilities of integrating it into existing production systems. Cattle farming is still the main animal production activity in large-scale integrated systems in Brazil, though sheep farming, supported by cattle farming know-how, tends to rapidly overcome some technological barriers that limit its development as a local agribusiness option.

Integrated systems substantially reduce use of deworming products in sheep farming, due to annual crops and integrated grazing with cattle. Moreover, these systems promote animal welfare by improving ambience through tree shading and increased forage nutritional value.

Compared to traditional cattle farming, sheep farming results in higher meat yields in short production cycles, which, coupled with a promising market would increase and diversify farmers' income, optimizing inputs and natural resources efficiency.

Integrated systems substantially reduce use of deworming products in sheep farming, due to annual crops and integrated grazing with cattle.

Chapter

16

Geospatial Monitoring for Integrated Crop-Livestock-Forestry Systems

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Célia Regina Grego
Daniel de Castro Victoria

INTEGRATED PRODUCTION SYSTEM

In Brazil there are incentives for the application of techniques that favor sustainable agriculture and animal husbandry, such as the Low Carbon Agriculture Program – ABC, which addresses the Brazilian Crop-Livestock-Forest Integration (ICLF or ILPF), as a system that will promote rehabilitation of degraded pasture areas. For example, Bolfe and Batistella (2011) have analyzed integrated Crop-Forestry systems in northern Brazil and emphasized that this integration originates differentiated production systems in the Amazon's agriculture and cattle husbandry context, considering the region's structure and diversified production potential. In order to effectively implement sustainable production systems, it is necessary to develop methodologies for low-cost monitoring and evaluation of such areas after implementation. Therefore, geospatial monitoring and geotechnologies as a whole, which comprise satellite imagery, aerial photography, geographic information systems and satellite global navigation satellite systems (GNSS), play a major role for identifying, monitoring, consolidating and expanding integrated production systems on a local, regional or national scale.

REMOTE SENSING

Remote sensing is defined as the science of obtaining information about an object, area or phenomenon by analysis of data recorded through a device which is not in contact with the object, area or phenomenon under investigation (LILLESAND et al., 2004). Objects of interest on the surface include natural vegetation, agricultural crops, pasture, planted forest, soil, rock formations, and waterbodies, among others, technically denominated as targets (Figure 16.1). The use of remote sensing with several spectral, temporal and spatial resolutions allows one to characterize different targets in ILPF systems.

Knowledge of the spectral, temporal and spatial variability of land cover and land use can make a significant contribution to understanding changes in the agricultural and environmental systems, such as biomass production, soil vulnerability and degradation levels, carbon retention, plant health among others. This is an important need, given the highly diversified land use characteristics in ILPF systems, which involves targets with spatially different biophysical and phenological aspects.

OUTLOOK

Qualitative detection (target identification) has been studied since the 1960s through remote sensing. However, only recently the quantitative estimate (determination of the abundance and relative presence) of land surface targets has been applied to economic and environmental management decision making. That is why functional relations are developed between the biophysical characteristics of the targets and the remotely collected data.

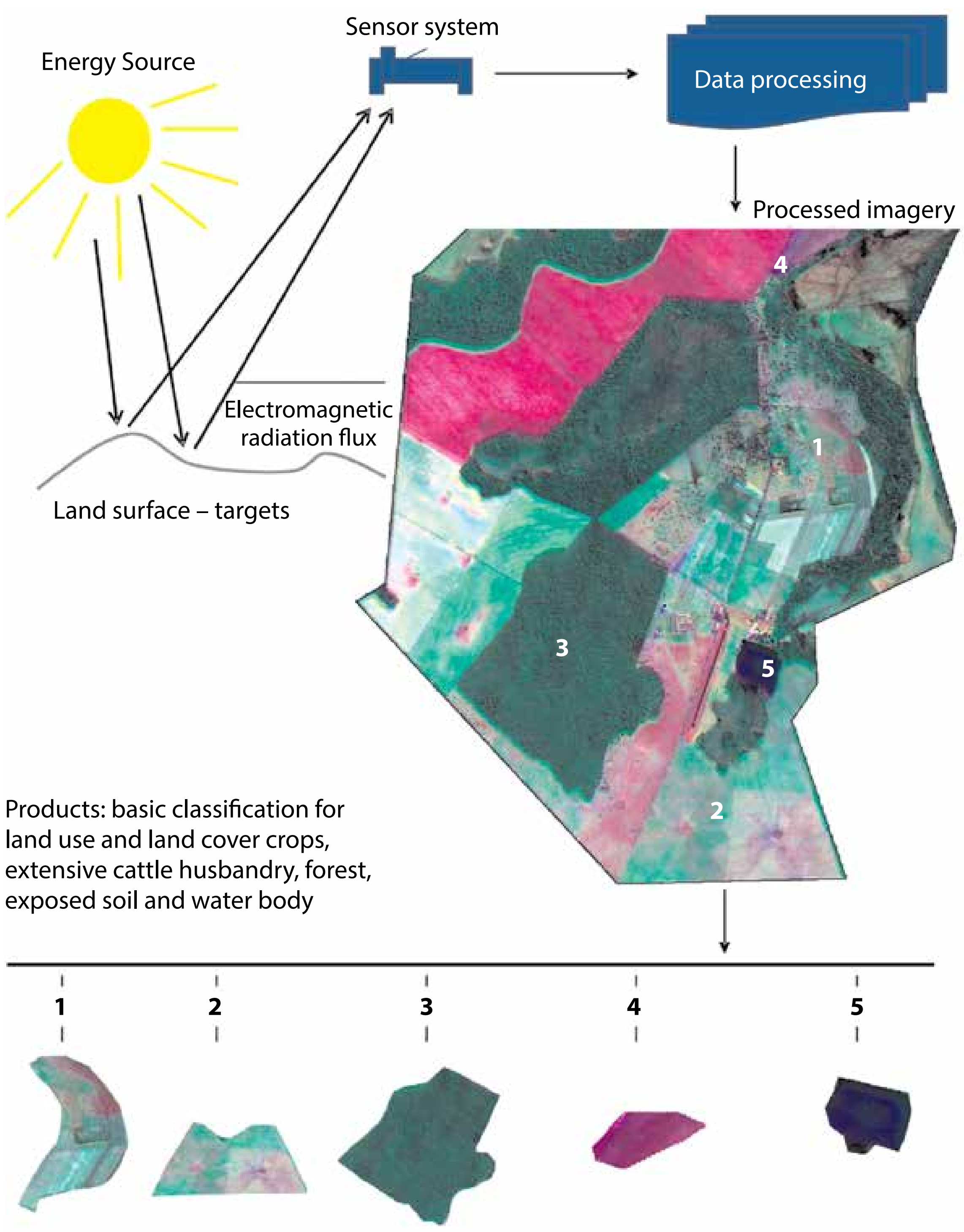


Figure 16.1

Schematic illustration of the registration, processing and basic classification of land use and land cover from optical images (pansharpened image from satellites CBERS 2B high spatial resolution sensor and Landsat 5 TM, bands 543 color composition). The following targets are highlighted: 1 – crops, 2 – extensive cattle husbandry, 3 – forest, 4 – exposed soil and 5 – water body.

Generation of temporal series of images and data for a region enables to understand processes related to land cover and land use dynamics.

Examples of these advances include the use of experimental sensors, such as ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) and EO1-Hyperion, which allow semi-detailed identification of mineral soil components (VICENTE; SOUZA FILHO, 2011) and plant characteristics (RAMSEY et al., 2005) which were impossible to be mapped by traditional sensors/methods so far. This means that the higher the number of spectral bands available and the greater their coverage of strategic sections of the electromagnetic spectrum, higher are the chances of obtaining information for environmental and agricultural systems. This current tendency is for more and better quality remote data availability, especially regarding increase of spectral bands on orbital sensors, costs reduction and image collection through airborne sensors, especially via unmanned aerial vehicles (UAV's).

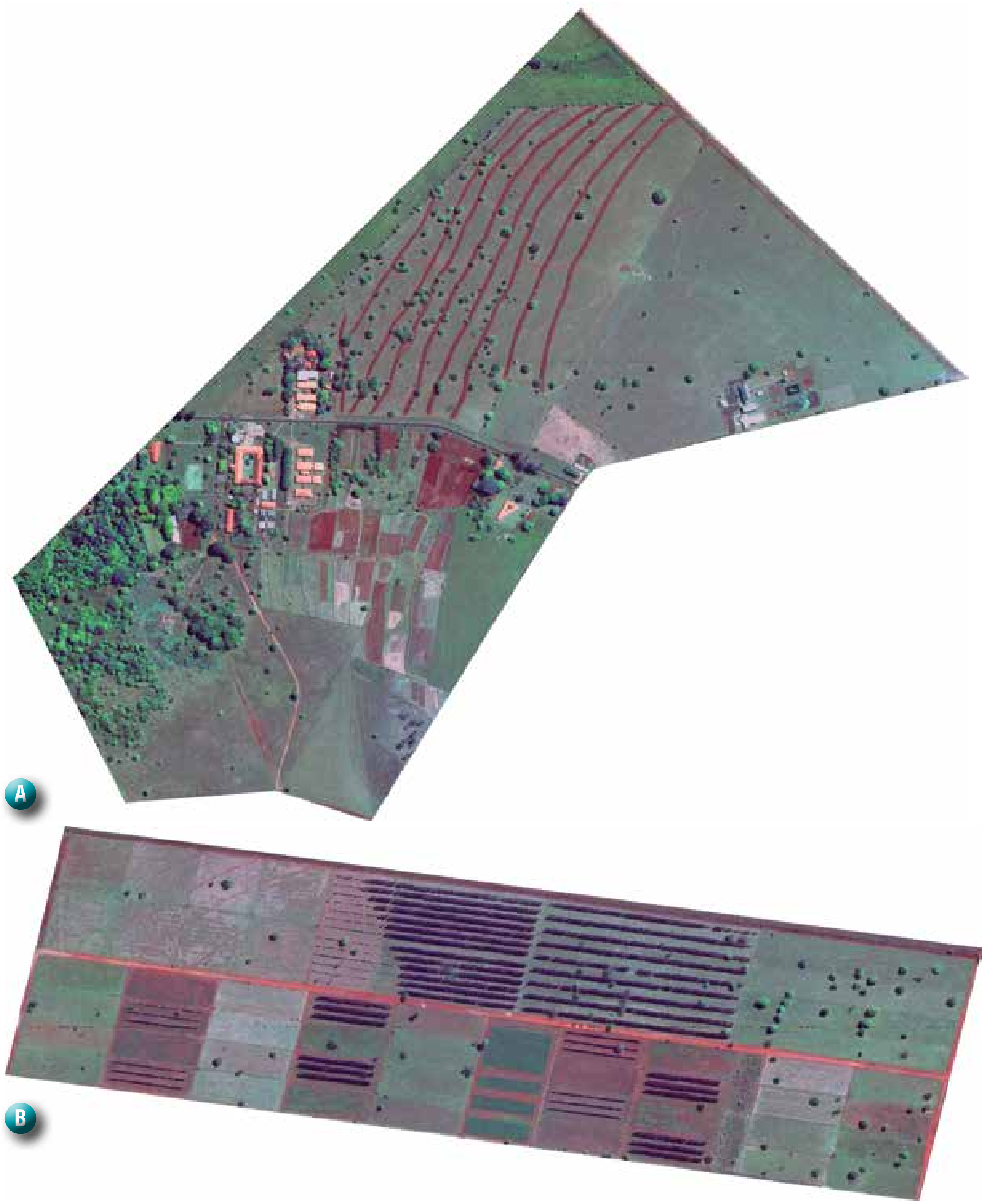
In another relevant field of geotechnologies, high temporal resolution images, remote sensing techniques allows information acquisition in a degree that allows generation of temporal series of the region under study, enabling to understand processes related to land cover and land use dynamics. Figures 16.2 A and B show spatial high resolution images of Embrapa Beef Cattle Experimental Station in Campo Grande, MS. In this sector, use of remote sensing allows monitoring agricultural areas through planted area and yield estimates, which are very useful for logistics, industrial and farm planning. It can also support decision making, pricing, policy making and implementation of regional development programs (CONAB, 2011).

In the cattle ranching sector, identification, quantification and monitoring pasture yields are currently very important issues. Based on these priorities, it is possible to assess and map pasture degradation problems by analyzing spectral behavior of selected targets. This is a very important aspect of sustainability, especially in regard to livestock systems in Central Brazil, because rehabilitation of degraded sown pastures has been difficult to foster due to the lack of updated and detailed information on its spatial distribution (SANO et al., 2000).

Remote sensing is an excellent tool to help decision making in order to improve local production systems, once it is cheaper than ground monitoring. Embrapa has been playing an important role with research and development projects related to the application of geotechnologies aimed at the sustainability of Brazilian cattle farming sector. Additional information on projects is available at Embrapa's satellite monitoring website: www.cnpm.embrapa.br/projetos/projetos.php.

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

According to Câmara et al. (2004), the term Geographic Information Systems (GIS) is applicable to systems that provide computerized treatment of geographic data, store the geometry and attributes of georeferenced data, i.e. located on the land surface and represented in a cartographic projection. According to the authors, from a broad point of view, a GIS has



Figures 16.2 A and B

GeoEye-1 images of October 9, 2010 of integrated crop-livestock-forestry system plots at Embrapa Beef Cattle Experimental Station in Campo Grande, MS.

the necessary components for user interface, data input and integration, image and graphic processing functions, visualization and plotting, data storage and data recovery (organized as a geographic database).

GISs have several applications in agriculture, whether on a global, national, regional or local scale, especially when combined with the use of remote sensing data. GIS are indispensable for evaluating land use and vegetation, as well as changes in land cover over time, resulting in vegetation monitoring studies.

GIS are also used in agricultural and agroclimatic zoning in order to identify the most appropriate crops and cultivation seasons for each region. These applications are already used in current production systems and are also being increasingly used for ILPF systems monitoring. Other studies assess soils capacity and use aptitude on a national or regional scale. In the case of integrated production systems, aptitude mapping and zoning can be carried out to identify the most appropriate practices and production systems for different areas. GIS also have enormous potential towards data spatialization and analysis, as shown by Batistella et al. (2011), which addresses aspects of regional land management for sustainable cattle farming in Brazil with the use of census databases and data from remote sensing.

GEOSTATISTICAL ANALYSIS TOOLS

The main advantages of using geostatistics in ILPF systems are the possibilities to identify spatial variability, and to elucidate correlations and spatial dependence of biophysical parameters involved in these mixed systems (BERNARDI et al., 2004). The use of geostatistics is well known, mainly in soil science, because it assumes that the spatial distribution of observation points is correlated, i.e. there is spatial dependence (GREGO et al., 2011).

Geostatistics starts from the hypothesis that closer samples, within the same patch, are more similar than more distant ones. This assumption is not shared by classical statistics, which assumes independence, which in most cases does not occur in studies involving natural sciences. Geostatistics is therefore an exceptionally important tool for geotechnologies. In ILPF systems, it allows the interpretation of data spatial distribution with strong impact over results and decision-making.

Geostatistical techniques can be used in the analysis of ILPF systems using variables with rather different degrees of complexity for sample collection and sampling density which show spatial dependence and are strongly correlated. In integrated systems, several involved factors allow the occurrence of spatial variability and the final objective of identifying this variability is to establish homogeneous management zones.

In integrated systems, several factors allow the occurrence of spatial variability. The final objective of identifying this variability is to establish homogeneous management zones.

CASE STUDY

In order to show some possible applications of geotechnologies in the analysis of production systems involving integrated systems, a summarized case study of integrated crop-livestock (ILP) system in Campo Grande (MS) is presented. In this study, the biophysical parameters were estimated by a Landsat 5 – TM image from March 5th, 2008, jointly with the SEBAL algorithm (Surface Energy Balance Algorithm for Land), following the methodology detailed in Waters et al. (2002). The goal was to analyze the variability of certain biophysical parameters in ILP systems, providing applicable information for surveying and monitoring existing conditions in this system. Figure 16.3 shows a Landsat 5 – TM color composite image (bands 5, 4, 3) with the Embrapa Beef Cattle Experimental Station experimental plots overlayed on top. The blow-up shows the area where the ILP system is implemented. Figures 16.4 A and B show the normalized difference vegetation index (NDVI) and the leaf area index (LAI, in $m^2\ m^{-2}$); figures 16.5 A and B show surface temperature estimates (Ts in Kelvin), and daily actual evapotranspiration (ET, in mm day^{-1}). For the ILP plot, the NDVI and LAI ranged from 0.41 to 0.80 and from 1.01 to 5.00 $m^2\ m^{-2}$, respectively. Regarding Ts and ET, estimated values oscillated from 293 to 298 K and 0 and 3.0 mm day^{-1}. As for the practical application of these results, it is possible, for example, to assess spatial and temporal water demand, energy and biomass variability, as well as to associate this information

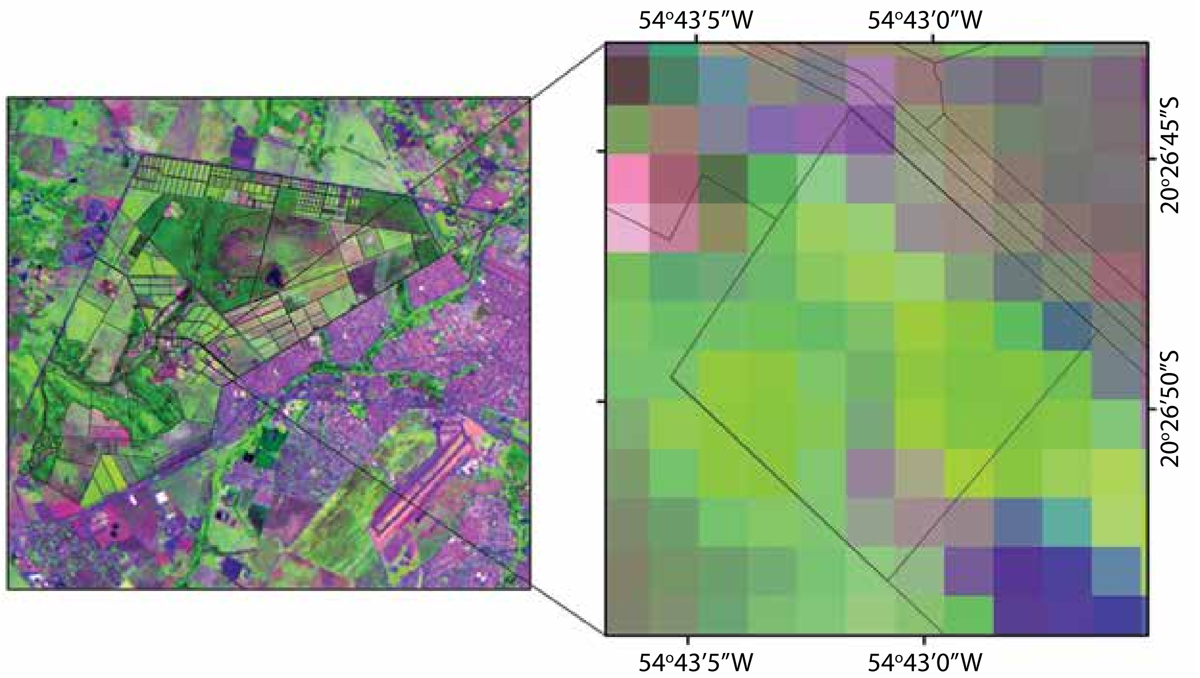


Figure 16.3

Landsat 5 – TM color composite image (bands 5, 4, 3) from March 5th, 2008, overlaied by the experimental field plots from Embrapa Beef Cattle Experimental Station in Campo Grande, MS. The blow-up shows the area were integrated crop-livestock system is located.

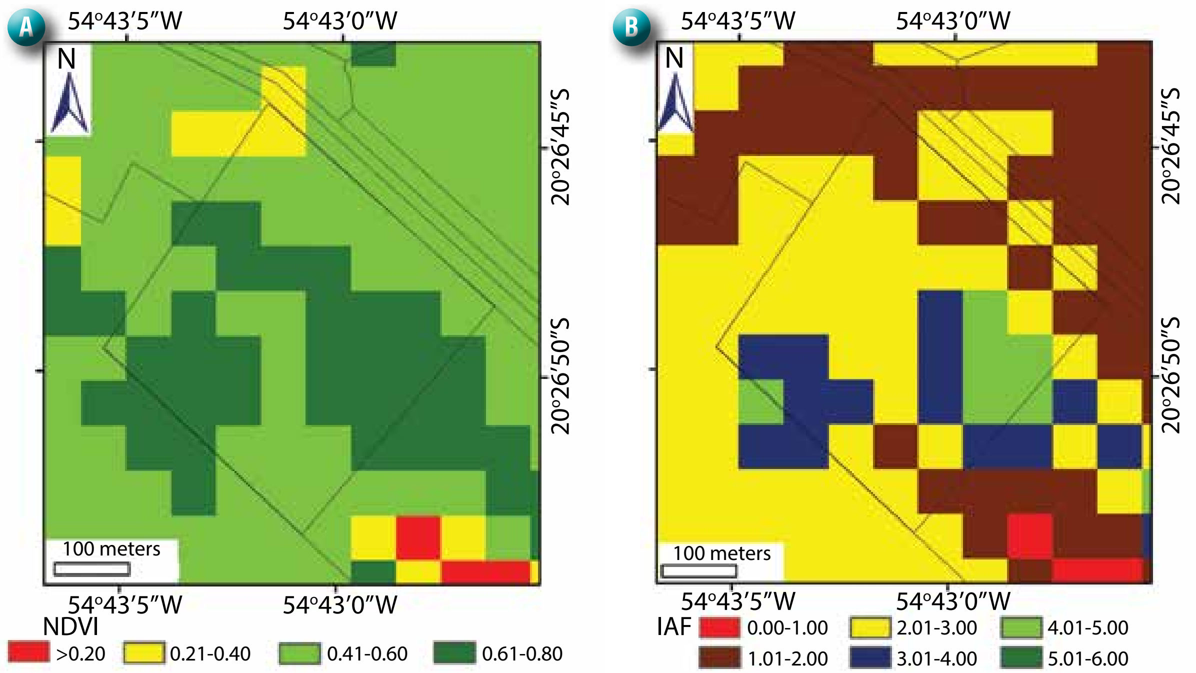


Figure 16.4

(A) normalized difference vegetation index (NDVI); leaf area index (LAI, in $m^2\ m^{-2}$) for a plot with an integrated crop-livestock system at Embrapa Beef Cattle Experimental Station in Campo Grande, MS.

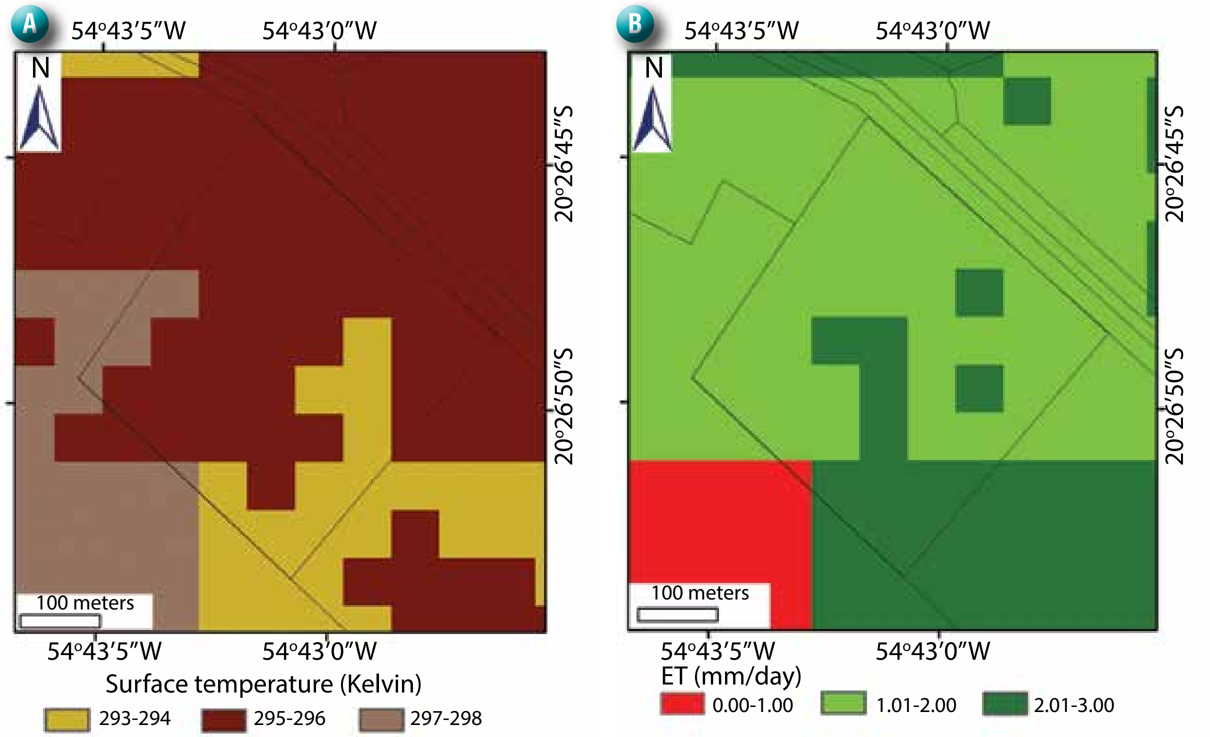


Figure 16.5

(A) Surface temperature (K); (B) daily actual evapotranspiration rate (ET, in mm day^{-1}) for a plot with an integrated crop-livestock system at Embrapa Beef Cattle Experimental Station in Campo Grande, MS.

with soil fertility and compaction patterns, weather and relief, among others. All this aiming to improve understanding of biophysical processes involved in the ILP an ILPF system.

CLOSING REMARKS

Geospatial monitoring and geotechnologies are basically a product of the union among remote sensing, geographic information systems, global navigation satellite systems, computer programming and geostatistics. The orbital images from several remote sensors, through several spectral, temporal and spatial resolutions, have been proved relevant sources of information. These images assure application possibilities to characterize areas of integrated production system, monitoring land cover and land use changes in space and time and, especially, helping to correlate biophysical parameters such as biomass, carbon and leaf area indices.

Applications of geographic information systems feature high operational capacity and the low cost to collect, process, integrate and analyze spatial data to produce high quality information, especially regarding:

- Data and knowledge on existing natural resources in a given geographic area;
- Specific geographic zoning based on integrated analysis capacity from data previously available via database;
- Developing dynamic models of future scenarios to support planning and implementation of integrated production systems.

The applicability of geotechnologies is very promising in the scope of research, development and technology transfer actions for land cover and land use monitoring. By overcoming existing technological obstacles through research, the use of geotechnologies and the insertion of spatial analyses mechanisms are expected to establish low-cost technologies and processes which will optimize production and improve the environmental quality encompass ILPF systems.

On the other hand, geotechnologies should not be understood as a sole and miraculous solution. Despite the several initiatives in Brazil and the extensive applicability of these technologies, geospatial information is still underused in the agricultural sector, especially due to insufficient promotion by institutions and professionals. In this sense, this chapter was dedicated to present a summary of concepts and examples regarding remote sensing and geographic information systems, highlighting its potential for application in ILPF systems.

Applications of geographic information systems feature high operational capacity and the low cost to collect, process, integrate and analyze spatial data to produce high quality information.

Chapter

17

Cost-Effectiveness of Integrated Production Systems

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ADOPTION OF INTEGRATED PRODUCTION SYSTEMS

According to Medrado (2000), an agroforestry system is "a system of sustainable land management that increases land productivity, deliberately combining forestry with crops and/or animal production in the same land unit simultaneously or consecutively, using management practices compatible with local native traditions."

Integrated crop-livestock (CL), livestock-forest (LF) and crop-livestock-forest (ICLF or ILPF) systems present a number of advantages, many of which have a social appeal that goes beyond farm gate, while others are restricted to the farm. The main direct economic benefits for farmers include:

- Increase in total yield;
- More efficient use of labor;
- Reducing unitary costs of outputs;
- Increased profit as a result of higher yields and lower cost;
- Better distribution and diversification of revenue throughout the year, generating a more balanced cash flow;
- Risk mitigation in production and prices due to activity diversification.

Added value has also been mentioned as one of the benefits of integrated systems, though this is not actually true in most cases, as to some extent, the systems would also need to involve the processing of the primary harvested products , as well as their certification.

Given all the economic advantages presented above and the countless agronomic, zootechnical and environmental benefits cited in other sections of this publication, one could expect integrated systems to be widely adopted, especially because they have existed for several decades. In this context, why have monocultures become dominant in the Brazilian agricultural scenario?

In a speculative manner, some possible reasons are listed:

- Farmers short-term vision, prioritizing monoculture and its immediate gains;
- Influence of equipment and inputs manufacturers, which are usually specialized and therefor are also interested in having specialized customers;
- Economies of scale enabled by specialization;
- Specific investments required in items that are unusual in the traditional system;
- Need of investment in cattle also by ranchers in order to take advantage of increased carrying capacity resulting from improved pastures;

- Lower need for management skills and information technology in not diversified systems, since exploring (producing and selling) a sole product is much simpler than dealing with several production factors from quite different activities.
- Secondary importance attributed to social and environmental issues, possibly due to the lack of a direct compensation by them;
- Lack of initiative and entrepreneurial skills among traditional and new farmers entering the sector.

Despite these opposing forces, in recent years integrated systems have gained importance in an expedited manner. In this trend, some crop farmers are including livestock activities and production of timber or other forest products. The reverse situation is also true, i.e. some cattle farmers are introducing activities related to agriculture and forestry. Several studies point out difficulties faced by cattle farmers who want to implement integration, with an emphasis on cultural reasons, deficiencies in management and lack of proper machinery, among other factors (COSTA; MACEDO, 2001; YOKOYAMA; STONE, 2003). However, certain references (PIMENTEL, 2004 e PIMENTEL, 2005) have stated otherwise, pointing out the major difficulties faced by crop farmers, including lack of credit to build handling facilities, water supply and fences, and even to buy cattle, in addition to the complexity of animal production systems and the need for larger areas to implement pasture-based production.

For regional and national development, it is essential to offer suitable alternatives that may boost sustainability of production systems, requiring them to be economically feasible. Determining feasibility and presenting results of such analyses clearly and accurately, preferably following a widely accepted standard, is crucial for disseminating integrated systems.

For regional and national development, it is essential to offer suitable alternatives that may boost sustainability of production systems, requiring them to be economically feasible.

ECONOMIC CHARACTERISTICS OF CROP-LIVESTOCK-FOREST INTEGRATION

Definition of appropriate evaluation criteria requires full understanding of the economic nature of integrated systems. We present below the main characteristics of this type of exploration:

- Large number of production alternatives available, allowing several combinations of activities. It is worth noting the complexity of this choice, given the dynamics of succession systems, in which space and time variables are fundamental;
- Numerous possible combinations of production factors (land, capital and labor as well as their unfolding variations). This characteristic is even more evident in cattle farming, where production systems are extremely flexible in terms of technology adoption and level of inputs used;

Benefits of integrated systems include several outputs with limited monetary valuation due to the lack of market value.

- Demands a changing process from an existing system, whether crop or animal production, emphasizing difficulties in defining plant species, especially the tree component ideal for each condition;
- Production plans involving investments whose effects extend over long time horizons;
- Lagged effects of certain inputs. For example, crop fertilization can benefit subsequent pasture for several years;
- In line with the pursuit for sustainability, farmers goals tend to be multiple rather than being restricted to profit maximization;
- Benefits of integrated systems include several outputs with limited monetary valuation due to the lack of market value, such as the positive effects on soil microflora and microfauna, erosion reduction, microclimate and animal welfare.

GUIDELINES FOR ECONOMIC EVALUATION OF INTEGRATED SYSTEMS

For the sake of clarity, in first place, it is worth mentioning that the ILPF systems can be evaluated in terms of macro and microeconomic aspects. In the first form, their aggregate impacts are considered at regional level, as carried out by Yokoyama and Stone (2003) in ICL systems. The second form is restricted to the farm, considering private costs and benefits.

A second division refers to the source of data to be analyzed, which can be a real case or an experiment. The main limitation in case studies is lack of data. Experiments, in their turn, provide the necessary information, as long as they were well planned. Special attention should be given to the extrapolation of results. An economic analysis of experimental data requires statistical analysis, since treatments that do not differ in terms of physical responses do not differ in terms of economic results associated with them either.

It is also worth noting that economic evaluations can be classified into two types: ex-ante evaluations, based on expected outcomes and aimed at providing input to decision-making; ex-post evaluations, targeted at real cases, producing results about past events and aimed at evaluating the success of the venture. Analyses focused on planning fall into the first group, and technical coefficients and prices used in this case are presented in the literature that disseminates research results, in the experience of qualified informants and other secondary sources. Ex-post evaluations require specific data that must be collected, recorded and tabulated from the routine of real production system under analysis.

The guidelines presented below are intended to provide greater uniformity in the economic evaluation process of integrated systems. The first points are directly associated with each of the characteristics mentioned in the previous section and are followed by general recommendations.

The large number of production alternatives available makes planning and control of production systems very complex, consequently turning decision-making more difficult. In the planning phase, instruments such as linear programming could be used to assist selection of activities combination. Control, in the other hand, requires systematic recording of events that constitute the production process of all activities implemented. This systematic record must include the amounts of each resource used, their values and dates of use.

The large number of production alternatives available makes planning and control very complex, consequently turning decision-making more difficult.

The wide range of possible combinations of production factors, as well as the previous point, contributes to the complexity of integrated systems. The same considerations apply for the need of an adequate data recording system, whose absence can totally impair evaluations of actual cases. To cope with this characteristic, optimization tools, such as linear programming, could be explored. Associated with these tools or used separately, electronic spreadsheets are a simple and essential tool to store, organize and analyze data from such systems.

As it represents a process of change, ILPFS must be evaluated in comparison to the pre-existing system, as if this was the control treatment of an experiment. If investments achieve larger sums, one must verify the possibility of making them in stages. For example, it is worth comparing the expected results from the recovery of 30% of degraded pasture in one year with a three-stage recovery of 10% of that degraded pasture.

The "improved" and "traditional" systems can be compared by confronting already stabilized situations or taking into account the transition process inherent to the implementation of the integrated system. The first case corresponds to a static, less informative evaluation, insufficient to support decisions such as the adoption or not of ILPF by a given farmer. When the transition is taken into account, the analysis becomes much more realistic, once all events that compose the project are considered and properly distributed over time. On the other hand, the long time horizon associated with ILPFS in contrast to the short cycle of annual crops requires special attention. Regardless of the inflation process, i.e. even if real prices are used, it is necessary to take into account the change in the value of money over time.

When comparing two integrated systems, the one that presents higher gains at the beginning of the planning horizon will obviously be chosen if the other factors remain unchanged. This time preference is expressed by indicators such as net present value (NPV) and internal rate of return (IRR), among others. These two parameters lead to the same conclusion regarding project attractiveness, though NPV is simpler to calculate and less subject to misinterpretation and misuse. To calculate these indicators, it is necessary to use a cash flow that, depending on the complexity of the system and the relevance of each production event in particular, one may consider a month, a season or even a whole year as the time unit.

When calculating NPV and even IRR, it is recommended to take as reference an additional cash flow, i.e. the cash flow that represents the process of change proposed or accomplished by the

In the formulation of projects for change into integrated systems, the intended goals, which can go further beyond simply maximizing profit, must be clearly stated.

ILPFS which is obtained as the difference between benefits and additional costs (in relation to traditional system), following the same principles of partial budgeting.

It is also important to notice that when evaluating the attractiveness of a given system, one must also look at the cash flow profiles, since the option with the highest NPV, despite higher profitability can endanger the financial stability of the farm. In this case, simulating options (credit availability, distribution of investments over longer periods etc.) are necessary to prevent periods of negative balance. When considering financing, resources released by the bank, as well as installments for capital pay back and interest, should be included in the cash flow. Additionally, cash flow for the last year must include variations in assets values, such as cattle herd, facilities and equipment, as well as eventual depreciation to date. This should be done because the lifetime of many investments does not necessarily coincide with the time horizon considered in the evaluation.

Attention should be given to extended effects of certain practices or inputs in order to avoid underestimating the benefits of interactions between activities. For instance, when the last period of the time horizon analyzed includes crop fertilization followed by pasture, it includes a cost to the crop without taking into account the full corresponding benefits. In this case, such benefits could be estimated and added to the last year's cash flow. An example of this type of problem is presented in Costa and Macedo (2001).

In the formulation of projects for change into integrated systems, the intended goals, which can go further beyond simply maximizing profit, must be clearly stated. This is a difficult task that requires deep analysis and skills. The result, however, will certainly have a significant impact on the composition and format of the integration project to be implemented.

The complexity of integrated systems also implies certain monetary benefits that are difficult to quantify. This is the case, for example, of crop residues (straw) used for no-till systems and weight gain in rearing cattle. The first case is more complex, but it does not prevent creating assumptions to support an estimate. As for weight gain in beef cattle, the usual procedure is to transform live weight on carcass weight using a low yield, such as 50%.

Despite being a common practice, it is important to remind the relevance of calculating the percentage share of each cost item in the total cost and intermediary cost groups. In complex systems, such as ILPF, this simple calculation is particularly very informative. Also simple and informative is the presentation of performance indicators for the evaluated systems (traditional system and ILPF) in the form of indices, which offers a better view of the changeover impact.

Another important recommendation is to carry out sensitivity analyses for the most important variables, such as crop yields, cattle weight gain as well as grain, meat and wood prices. This procedure is recommended because, with rare exceptions, the variables considered in the evaluation are treated deterministically. These sensitivity analyses broaden the spectrum of expected results, qualifying the decision-making process. More specific risk assessment techniques, such as the Monte Carlo method, can also be used, as long as time series of the most relevant random variables are available. Finally, attention is necessary to two issues in some extent observed on integrated system evaluation reports: first, the lack of a better definition for the economic indicators used, which demand clearness and accuracy. This is necessary because these indicators are usually given several different names. Profit, for example, can be expressed as net profit, normal profit, pure profit etc. To solve this problem, it is necessary to describe how the indicator is calculated (which cost components are included in the calculation). The second point is not allowing a mismatch between costs and benefits attributed to the new system, which can lead to biased interpretations. This problem stems from overestimated benefits due to the inclusion of numbers that had already been generated by the existing system, and the underestimated costs due to the omission of items generated when adopting integrated systems.

CLOSING REMARKS

The increase in the use of integrated systems represents an actual paradigm shift, as the consensual sustainability discourse is put into practice. Example of this trend is the emergence of concepts such as "Sustainomics", created by the International Society for Ecological Economics to label a knowledge base that is also transdisciplinary, integrative, comprehensive, heuristic and practical, aimed at making development more sustainable (MUNASINGHE 2004). Under this new perspective, only the traditional concern with production and financial aspects is no longer enough to ensure growth and continuity of businesses – it is necessary to include sustainability indicators in ordinary controls and formal accounting. Climbing that step is a major challenge, for which Ecological Economics (or Environmental Economics) is an important ally, as it recognizes that while the social and economic system is based and depends on natural systems, it interferes with and transforms natural systems functioning.

The increase in the use of integrated systems represents an actual paradigm shift, as the consensual sustainability discourse is put into practice.

Chapter

18

Economic Sustainability of Silvipastoral Systems Using Eucalyptus for Timber

Omar Daniel
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Flávia Araújo Matos

SUSTAINABILITY CONTEXTUALIZATION IN THE EUCALYPTUS/ LIVESTOCK HUSBANDRY INTEGRATION

The search for sustainable land use alternatives has brought attention to agroforestry systems (AFS) capable of making some farming and animal husbandry activities compatible to meet the expected income, thus keeping local cultural and traditional aspects of agriculture. These systems may contribute towards product diversification, jobs and income generation, through crops cultivation during trees growing stage, besides several environmental benefits (VALE et al., 2004).

Divided into three significant groups, according to the nature of the consortium, the AFS are considered to be sustainable land use systems once they can combine wood components, crop and livestock production, called according to their composition, the silvipastoral, agrosilvipastoral and agrosilvicultural systems. Certain AFS practices have also been considered, respectively, ILF (integrated livestock-forest), ICLF (integrated crop-livestock-forestry) and ICF (crop-forestry).

Although our research routine has taken into consideration the environmental relationships of the AFSs at several economic levels, i.e., both in small holders agriculture (HEID et al., 2010; PEZARICO et al., 2013) and in agribusiness (PEZZONI et al., 2012), in this chapter, sustainability is addressed focusing basically on the economic aspect.

The delimitation of this debate, focusing on economic profitability, has a previous history. In our constant contacts with farmers, we have had the opportunity to discuss the advantages of using agroforestry land use systems (AFS) at all economic levels, i.e., from family farmers to large rural entrepreneurs, two issues are brought to light: a) *which forestry species may be used in these systems combined either with animal or crop production* and; b) *what economic return can be expected considering the long time period for these projects to mature.*

The answer to the first issue is not difficult because although there is enough information on the production systems from several forestry species, such as hevea, teak, pine, and others, it is from eucalyptus that the largest volume of research results comes. In addition, its wood can be used for many different market applications and it adapts to several climatic conditions. From the economic point of view, it has already been proved that an agrosilvipastoral AFS with eucalyptus in the *Cerrados* may reach an internal return rate of over 23% and a benefit/cost ratio of 1.8 (DANIEL, 2010).

As for the second question regarding economic return, below are the necessary calculations that provide answers to some forestry/cattle combinations, emphasizing some of the most common types of AFS, especially in the Brazilian Mid-West.

These calculations depict the great economic potential of agroforestry, with eucalyptus that was primarily used to produce sawlogs and laminates.

Complementing our statement towards addressing this chapter to the economic issue, we emphasize our opinion, based on our experience in research and daily contact with farmers. In general terms, they will hardly bear conservationist and socially fair actions if they cannot financially profit from their activities, even if they are already aware of their role on environmental conservation.

In general terms, farmers will hardly bear conservationist and socially fair actions if they cannot financially profit from their activities, even if they are already aware of their role on environmental conservation.

This financial return enables investments in life quality improvement, and, also in other related agroforestry activities. We believe that wood production in AFS should always be primarily related to sawlog production, due to its added value. However, it is necessary to search markets for other uses, since tree tops and branches usually do not reach lumber and veneer market requirements and therefore could be used for energy generation, paper and cellulose, particle boards, sheets and others.

ECONOMIC ANALYSIS OF SILVIPASTORAL SYSTEMS WITH EUCALYPTUS

Three indicators were used to evaluate these systems, which are simpler to interpret and sufficient to carry out a basic discussion on the economic advantages of production systems analyzed. These criteria consider capital variation over time (SILVA and FONTES, 2005) and must be used simultaneously to support decision making:

a. Net Present Value (NPV) – it is the difference between present value of incomes minus present value of costs, i.e.:

$$NPV = \sum_{j=0}^{n} R_j (1+i)^{-j} - \sum_{j=0}^{n} C_j (1+i)^{-j},$$

where Rj = present value of incomes; Cj = present value of costs; i = interest rate; j =period of incomes or costs occurrence; and n = number of periods or project duration;

b. Internal Rate of Return (IRR) – it is the rate of discount of an investment that turns its NPV null, i.e., which makes the project pay up the initial investment considering the value of the money over time. It may also be interpreted as the expected investment rate of return. It needs to be larger than the capital opportunity cost (borrowing rate, for example);

c. Benefit/Cost Ratio – It is the ratio between the income and the costs and should be ≥ 1 to render the project feasible. It also means how much each capital unit spent may return as income.

The discount rate (i), i.e., the interest rate applied on the criteria was 12%.

Eucalyptus in Homogeneous Cultivation and Beef Cattle Farming

In this chapter all calculations are carried out in the Brazilian official currency, the Brazilian Real (BRL), hereafter abbreviated as R$.

It is questionable to dedicate all land of a certain region for cultivation a single monoculture, regardless of species cultivated, not only due to market and climatic risks, but also due to the social issues involved in this process.

Seven years of rotation were considered, for analyzing investment in eucalyptus plain forestry, aiming at wood for energy generation (firewood or charcoal) or cellulose. Wood yield was 45 m^3 per ha/year, worth R$ 45.00 per m^3 (value of standing trees). Spatial arrangement was 3 × 2 m (1,667 trees per ha). Details on the costs, as well as on the resulting incomes may be found in Charts 18.1 and 18.2.

As for beef cattle, it was considered the purchase of 18 months old steers for finishing and selling them for slaughter every two years paying for replacement purchase. For finished cattle prices it was considered the equivalent to (in local currency) R$ 6.20 per kg carcass-weight for 12 years as average value. When looking for further information, readers should be aware that in most of Brazil, cattle prices are displayed in a local very traditional unit, called arroba, which is equivalent to 15kg carcass-weight.

Although the study was based on extensive cattle system, some technologies such as an electric fence were added, reducing costs. Details on costs incurred may be found in Charts 18.3 e 18.4

For all equipment, livestock, saddlery, housing and cattle handling facilities, the due depreciation has been calculated. The result was R$ 6.20 per ha, which, in this chapter, was used in all beef-cattle related discussions and calculations.

In order to estimate annual cash flow, both for the eucalyptus forestry and livestock, the data in Charts 18.1 to 18.4 were adopted.

For the eucalyptus, estimated income was R$ 14,175.00 and costs amounted to R$ 3,613.28, resulting in an accumulated balance of R$ 10,561.72. Whereas for beef cattle income was R$ 8,370.00 and costs R$ 7,500.74 resulting in R$ 869.26 accumulated balance. The results based on adopted criteria indicate that the extensive cattle ranching loses capital over time, considering the negative value of the NPV for this activity (Chart 18.5). It can be observed that expected investment return rate (4.3%) is even lower than revenues from savings account, one of the lowest yielding investments in Brazil.

On the other hand, the plain eucalyptus plantations exceed by many times the return on investment in livestock, with a IRR (Internal Rate of Return) of 26.8%, a positive NPV and R$ 2.00 of return for each Real invested.

In Brazil, if there is well established local market for wood, planting eucalyptus is, no doubt, a better financial deal than extensive cattle grazing. This fact can be easily seen in areas around paper and cellulose industries, like in the Três Lagoas region, in Mato Grosso do Sul State, where pastures undergoing degradation have been turned into eucalyptus forestry.

However, it is questionable to dedicate all land of a certain region for cultivation a single monoculture, regardless of species cultivated, not only due to market and climatic risks, but also due to the social issues involved in this process, such as rural exodus and professional education for locals.

CHART 18.1

Cost Composition to Implement One Hectare Eucalyptus per Operation, Considering Mechanized and Manual Activities, Inputs Application and Tree Spatial Distribution of 3 × 2 m (1667 Plants per ha)

	MECHANIZED			MANUAL			INPUTS				COST
OPERATION	HM/ HA	R$/ HM	R$/ HA	HH/ HA	R$/ HH	R$/HA	ITEM	QTE/ HA	R$/ UN	R$/HA	R$/HA
Project preparation and topography											20,00
Roads, facilities, fire breaks	0.64	69.00	44.16								44.16
	0.08	170.00	13.60								13.60
Heavy tillage	0.50	44.00	22.00								22.00
1stant control				7.50	4.00	30.00	Insecticide (ants) (kg)	6.00	7.50	45.00	75.00
Rows marking poles				10.80	4.00	43.20					43.20
Fertilizers preparation				1.17	4.00	4.68	Rock fosf. (kg)	400.00	0.70	280.00	284.68
Fertilizers application	0.25	16.80	4.20								4.20
Tillage-bedding	0.25	44.00	11.00								11.00
Seedlings holes preparation				13.00	4.00	52.00					52.00
Seedlings holes fertilization	0.09	16.80	1.51	5.00	4.00	20.00	NPK(6-30-6) (kg)	250.00	0.90	225.00	246.51
							KCl	165.00	1.20	198.00	198.00
Termites control				5.00	4.00	20.00	Termite contr. prod. (kg)	2.50	7.50	18.75	38.75
Termites/fertilizers mixture				1.50	4.00	6.00					6.00
Herbicide application			70.00				Herbicide			200.00	270.00
2ndant control				1.50	4.00	6.00	Insecticide (ants) (kg)	0.50	7.50	3.75	9.75
Fire breaks maintenance	0.08	170.00	13.60								13.60
Seedlings transport	0.15	15.70	2.36	0.60	4.00	2.40					4.76
Seedlings distribution				7.00	4.00	28.00					28.00
Planting				16.00	4.00	64.00	Seedlings	1667.00	0.40	666.80	730.80
3rdant control				0.94	4.00	3.76	Insecticide (ants) (kg)	0.50	7.50	3.75	7.51
Replanting				6.00	4.00	24.00	Seedlings	167.00	0.40	66.80	90.80
Irrigation	0.30	16.80	30.00	5.00	4.00	20.00					50.00
IMPLEMENTATION COST (R$/ha)			**212.43**			**324.04**				**1,707.85**	**2,264.32**

hM – hour machine; hH – man hour.

CHART 18.2

Cost Composition to Maintain One Hectare Eucalyptus, per Operation, Considering the Mechanized and Manual Activities, Inputs Application and Tree Spatial Distribution of 1667 Plants per ha

		MECHANIZED			MANUAL			INPUTS				COST
	OPERATION	HM/HA	R$/HM	R$/HA	HH/HA	R$/HH	R$/HA	ITEM	AMT/HA	R$/UN	R$/HA	R$/HA
1st Maintenance (year 0)	Herbicide application			35.00				Herbicide			24.00	59.00
	Fertilizer 150 g/plant 60 days	0.27	16.80	4.54	1.60	4.00	6.40	NPK(18-00-18) (kg)	250.00	0.90	225.00	235.94
	Fertilizer 150 g/plant 6 months	0.27	16.80	4.54	1.60	4.00	6.40	NPK(18-00-18) (kg)	250.00	0.90	225.00	235.94
	Fertilizer 60 g/plant 12 months	0.27	16.80	4.54	1.60	4.00	6.40	KCl (kg)	100.00	1.20	120.00	130.94
	Roads and fire breaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	8.00	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	23.00
	COST (R$/ha)			**62.21**			**27.20**				**609.00**	**698.41**
2nd Maintenance (year 1)	Herbicide application			35.00				Herbicide			7.00	42.00
	1st pruning (until 4,00 m)				40.00	4.00	160.00					160.00
	Fertilizer 150 g/plant 24 months	0.27	16.80	4.54	1.60	4.00	6.40	NPK(18-00-18) (kg)	250.00	0.90	225.00	235.94
	Roads and fire breaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	8.00	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	23.00
	COST (R$/ha)			**53.14**			**174.40**				**247.00**	**474.54**
3rd Man. (year 2)	Roads and fire breaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	8.00	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	23.00
	COST (R$/ha)			**13.60**			**8.00**				**15.00**	**36.60**
4th Man. (year 3)	Roads and fire breaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	4.51	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	19.51
	COST (R$/ha)			**13.60**			**4.51**				**15.00**	**33.11**
5th Man. (year 4)	Roads and fire breaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	4.51	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	19.51
	COST (R$/ha)			**13.60**			**4.51**				**15.00**	**33.11**
6th Man. (year 5)	Roads and fire breaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	8.00	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	23.00
	COST (R$/ha)			**13.60**			**8.00**				**15.00**	**36.60**
7th Man. (year 6)	Roads and fire breaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	8.00	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	23.00
	COST (R$/ha)			**13.60**			**8.00**				**15.00**	**36.60**
MAINTENANCE COST (R$/ha)				**183.34**			**234.62**				**931.00**	**1,348.96**
IMPLEMENTATION AND MAINTENANCE COST (R$/ha)				**395.77**			**558.66**				**2,638.85**	**3,613.28**

hM – hour machine; hH – man hour

CHART 18.3

Cost Composition for the Implementation, Maintenance and Infrastructure for One Hectare Pasture (*Brachiaria*) per Operation, Considering Mechanized and Manual Activities and Inputs Application

	MECHANIZED			MANUAL			INPUTS				COST
OPERATION	HM/ HA	R$/ HM	R$/ HA	HH/ HA	R$/ HH	R$/ HA	ITEM	AMT/ HA	R$/ UN	R$/HA	R$/HA
Pasture implementation (year 0)											
1stheavy tillage	0.99	53.00	52.47								52.47
2ndheavy tillage	0.83	53.00	43.99								43.99
Levelling tillage	0.50	53.00	26.50								26.50
Seeding and fertilization	0.50	16.80	8.40				Simple Superphospate (kg)	100.00	0.70	70.00	78.40
							Rock phosphat (kg)	400.00	0.69	276.00	276.00
							Seeds (kg)	7.00	20.00	140.00	140.00
Light tillage	0.5	53.00	26.50								26.50
COST (R$/ha)			**157.86**			**0.00**				**486.00**	**643.86**
Pasture maintenance(year 10)											
Fertilizers mixture				1.40	4.00	5.60					5.60
Fertilizers distribution	0.50	16.80	8.40				Limestone (t)	1.00	75.00	75.00	83.40
							Rock phosphat (kg)	300.00	0.69	207.00	207.00
							Simple Superphospate (kg)	200.00	0.70	140.00	140.00
							KCl (kg)	80.00	1.20	96.00	96.00
Combate a cupins				0.83	4.00	3.32	Termite contr. prod. (kg)	2.50	7.50	18.75	22.07
Roçada				7.50	4.00	30.00					30.00
COST (R$/ha)			**8.40**			**38.92**				**536.75**	**584.07**
Infra-estrutura (year 0)											
Fencing (eletric)**				5.33	4.00	21.32	Wires (m)	160.00	0.20	32.00	53.32
							Accesories (m)	160.00	0.13	20.16	20.16
Water troughs installation (10600 L; 50 ha)				2.17	4.00	8.68	Water troughs. (un)		600	0.00	8.68
		36.4	0.00	3.33	4.00	13.32	Piping systems hidráulica (m)		0.83	0.00	13.32
Mineral troughs				1.8	4.00	7.20	Materials - poles	13.00	12.00	156.00	163.20
COST (R$/ha)			**0.00**			**50.52**				**208.16**	**258.68**
COST TOTAL (R$/ha)			**166.26**			**89.44**				**1,230.91**	**1,486.61**

** Calculations based on 25 ha paddoce and two wires fence (4 km); hM – machine hour; hH – man hour.

CHART 18.4

Cost Composition for Inputs, Labor and Animal Purchase for One Hectare Pastures

ITEM	UNIT	R$/UNIT	AMOUNT/ UA	COST (R$/HA)
Inputs				
Vaccine (Foot-Mounth disease (2×/year)	Dose	1.50	2.00	3.00
Vaccineclostridia (1×/year)	Dose	0.25	1.00	0.25
Deworming (2×/year)	ml		12.00	0.00
Minneral supplement (60g/UA/dia)	kg	0.60	21.63	12.98
Parasites control	ml	0.30	6.00	1.80
COST (R$/ha)				**18.03**
Labor				
Worker (1 man/300 head)	H	1,000.00	0.003	3.33
COST (R$/ha)				**3.33**
Cattle				
Purchase 18 months steers **	head	1,040.00	1.00	1,040.00
COST (R$/ha)				**1,040.00**
COST TOTAL (R$/ha)				**1,061.36**

CHART 18.5

Criteria Adopted for Investment Analysis at 12% Interest Rate for Eucalyptus (7-year Time Frame) and Beef Cattle, in a Traditional Production System with Biannual Inflows and Outflows (13-years Time Frame)

PRODUCTION SYSTEM	NPV (R$/HA)	TIR (%)	BC
Eucalyptus	719.26	26.8	2.05
Livestock	-2,806.66	4.3	0.83

Agroforestry has been recommended to overcome these problems. Some of the advantages of these systems are:

- Famers may keep their traditional activity, i.e., continue as foresters or famers/ranchers;
- Reduction of risks related to lower yields due to environmental variations;
- Improvement in cash flow and labor use;
- Support through diversification when market variations happen.

More details on this matter may be found at www.do.ufgd.edu.br/omardaniel and www.do.ufgd.edu.br/gesaf.

One of the advantages of ICLF systems is that famers may keep their traditional activity, i.e., continue as foresters or famers/ranchers.

Silvipastoral Systems with Eucalyptus and Beef Cattle

Two types of silvipastoral systems are presented below, considering variations in eucalyptus tree density and use of rotational grazing system for livestock.

As previously mentioned, and primarily recommended, these systems should be aimed at timber production. Analysis of silvipastoral systems exclusively for other wood purposes are not presented here.

Pasture is sowed in between tree rows, keeping 1 meter stripe at tree side free from grass and weeds. Young Eucalyptus is sensitive to competition, especially from Brachiaria.

The complete tree cycle takes 12 years, while cattle cycle using finishing steers is biannual Animal enter the cycle with around 150 kg Live Weight (LW) (5 arrobas) and finishes with around 450 kg (15 arrobas). The forage considered is Brachiaria. Below are two systems that exemplify and allow analysis on integration viability, there being many different possible combinations which investors should evaluate for entering the business.

Depreciation was calculated for all equipment, livestock, saddlery, housing and animal handling facilities.

Silvipastoral System with Low Tree Density

Calculations for this system considered a tree density of 250 individuals per hectare. The distance between rows is 10 m and between trees is 4 m (Figure 18.1). It is important to consider that this space between tree rows should only be used with tree species of low leaves density, such as *Corymbia citriodora* and those related to *E. camaldulensis*. Other species may require larger distances between tree rows.

Figure 18.1

Low tree density silvipastoral system with Eucalyptus (hybrid urograndis – I 144) and dairy cattle, (distance 10 × 4 m), grass: *Urochloa brizantha* and *U. decumbens*. Four years after implementation in Dourados (Itahum District), Mato Grosso do Sul State. *Photo: Alex Marcel Melotto.*

For the livestock component, calculations included costs for pasture establishment, maintenance and infrastructure for one hectare pasture (Brachiaria), as shown in Chart 18.3. However, regarding cost composition for inputs, labor and animals purchase, the amounts in Chart 18.4 were multiplied by four, considering the use of sufficient technology to maintain an average of 4 animal units per hectare (AU/ha), which therefore results in R$ 4,245.44 per hectare. If calculations with different stocking rates are desired, all it takes is to calculate the proportion based on Chart 18.4.

To create cash flow, considering the system as a whole, i.e., eucalyptus and cattle, these data plus those in Charts 18.6 and 18.7 were computed per year. Expected income, in a 12-years cycle, was R$ 43,200.00 and the costs were R$ 25,592.86, resulting in an accumulated balance of R$ 17,607.14/ha.

The costs in Chart 18.7 show pruning operations. Its purpose is to increase sawlog value, by reducing the presence of knots. If this operation should not be carried out because of system's purpose, this cost can be eliminated from eucalyptus maintenance costs.

CHART 18.6

Cost Composition to Implement One Hectare Eucalyptus per Operation in Silvipastoral System with 250 plants/ha, Considering the Mechanized and Manual Operations and Inputs Application

	MECHANIZED			MANUAL			INPUTS				COST
OPERATION	HM/ HA	R$/ HM	R$/HA	HH/ HA	R$/HH	R$/HA	ITEM	AMT/ HA	R$/UN	R$/HA	R$/HA
Project preparation and topography											18.95
Roads, facilities, fire breaks	0.64	69.00	44.16								44.16
	0.08	170.00	13.60								13.60
Heavy tillage	0.50	44.00	22.00								22.00
1stant control				7.50	4.00	30.00	Insecticide (ants) (kg)	6.00	7.50	45.00	75.00
Rows marking poles				1.78	4.00	7.12					7.12
Fertilizers mixture				1.17	4.00	4.68	Rock fosf. (kg)	400.00	0.70	280.00	284.68
Fertilizers distribution	0.25	16.80	4.20								4.20
Light tillagebedding	0.25	44.00	11.00								11.00
Seedlings holes preparation				2.14	4.00	8.56					8.56
Seedlings holes fertilization	0.09	16.80	1.51	0.83	4.00	3.32	NPK(6-30-6) (kg)	38.00	0.90	34.20	39.03
							KCl	25.00	1.20	30.00	30.00
Termites control				0.83	4.00	3.32	Termite contr. prod. (kg)	2.50	7.50	18.75	22.07
Termites/fertilizers mixture				1.50	4.00	6.00					6.00
Herbicide application			35.00				Goal			66.00	101.00
2ndant control				1.50	4.00	6.00	Insecticide (ants) (kg)	0.50	7.50	3.75	9.75
Fire breaks maintenance	0.08	170.00	13.60								13.60
Seedlings transport	0.15	15.70	2.36	0.60	4.00	2.40					4.76
Seedlings distribution				1.25	4.00	5.00					5.00
Planting				2.76	4.00	11.04	Seedlings	250.00	0.40	100.00	111.04
3rdant control				0.94	4.00	3.76	Insecticide (ants) (kg)	0.50	7.50	3.75	7.51
RePlanting				1.00	4.00	4.00	Seedlings	25.00	0.40	10.00	14.00
Irrigation	0.30	16.80	5.04	0.75	4.00	3.00					8.04
IMPLEMENTATION COST (R$/ha)			**152.47**			**98.20**				**591.45**	**861.06**

CHART 18.7

Cost Composition to Maintain One Hectare Eucalyptus per Operation in Silvipastoral System with 250 plants/ha, Considering the Mechanized and Manual Operations and the Application of Inputs

OPERATION		MECHANIZED			MANUAL			INPUTS				COST
		HM/ HA	R$/ HM	R$/ HA	HH/ HA	R$/ HH	R$/ HA	ITEM	AMT/ HA	R$/ UN	R$/ HA	R$/HA
1st Maintenance (ano 0)	Herbicide application			35.00	0.00	4.00	0.00	Herbicide			7.00	42.00
	Fertilizer 150 g/plant 60 days	0.09	16.80	1.51	0.23	4.00	0.92	NPK(18-00-18) (kg)	38.00	0.90	34.20	42.11
	Fertilizer 150 g/plant 6 months	0.09	16.80	1.51	0.23	4.00	0.92	NPK(18-00-18) (kg)	38.00	0.90	34.20	36.63
	Fertilizer 60 g/plant 12 months	0.09	16.80	1.51	0.23	4.00	0.92	KCl (kg)	15.00	1.20	18.00	20.43
	Roads and fire breaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	8.00	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	23.00
	COST (R$/ha)			**53.14**			**10.76**				**108.40**	**172.30**
2nd Maintenance (year 1)	Herbicide application			35.00	0.00	4.00	0.00	Herbicide			7.00	42.00
	1stpruning (until 4.00 m)				6.00	4.00	24.00					24.00
	Fertilizer 150 g/plant 24 months	0.09	16.80	1.51	0.23	4.00	0.92	NPK(18-00-18) (kg)	38.00	0.90	34.20	36.63
	Roads and fire breaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	8.00	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	23.00
	COST (R$/ha)			**50.11**			**32.92**				**56.20**	**139.23**
3rd Man. (year 2)	Herbicide application			35.00	0.00	4.00	0.00	Herbicide			7.00	42.00
	2ndpruning (until 6.00 m)				29.00	4.00	116.00					116.00
	Roads and fire breaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	8.00	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	23.00
	COST (R$/ha)			**48.60**			**124.00**				**22.00**	**194.60**
4th Man. (year 3)	3rdpruning (until 8.00 m)				29.00	4.00	116.00					116.00
	Roads and fire breaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	8.00	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	23.00
	COST (R$/ha)			**13.60**			**124.00**				**15.00**	**152.60**
5th – 11thMan. (year 4-11)	Roads and fire breaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	8.00	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	23.00
	COSTS ANUAIS (R$/ha)			**13.60**			**8.00**				**15.00**	**36.60**
MAINTENANCECOST(R$/ha)				**274.25**			**355.68**				**321.60**	**951.53**
IMPLEMENTATION AND MAINTENANCE COST (R$/ha)				**426.72**			**453.88**				**913.05**	**1,793.65**

The results considering the adopted criteria indicate that the silvipastoral system used (250 trees/ha in a 12 year time frame and a livestock rotational grazing system) show a financial return higher than that of the conventional cattle grazing, although it does not exceed plain eucalyptus forestry. The NPV for this activity was positive (NPV = R$ 1,831.01), with an expected investment rate of return (IRR = 15.5%) higher than the 12% used as interest rate and three times higher than the 4.3% obtained for the extensive cattle ranching. The benefit/cost ratio (BCR) was also higher, reaching 1.12.

These results are enough to give the silvipastoral system, even with low tree density an advantage compared to the traditional grazing system. It is necessary to bear in mind, however, that investments in this system is also several times higher than in the traditional cattle husbandry.

Situations with differences even more favorable to the silvipastoral system are presented below, when compared to conventional cattle farming and also higher than plain Eucalyptus forestry.

Silvipastoral System with High Tree Density

For this system, a tree density of 755 individuals per hectare was considered. The distance inside the triple alleys was 3 × 2 m, and between alleys was 16 m. Especially the distance between alleys must be chosen carefully, seeking, among other technical criteria, to verify the architecture of the tree crowns. Distances can be decreased with less dense crowns, which let more light passing through, while should be increased in those where crowns are denser (Figures 18.2A and B). The costs are described in Charts 18.8 and 18.9.

Due to the higher density and always focusing on commercial timber production, the distances used require trimming the trees.

These harvests take place approximately in the fourth and eighth year after implementation (periods that must be defined based on a forest inventory). Main purposes or trimming are: a) to remove individuals, giving room for the remaining trees to grow; b) to anticipate income before the final tree harvest; c) to avoid mortality due to competition; d) to allow better forage growth between trees.

In addition, Chart 18.9 shows the cost of pruning, reminding that it has great regional variation.

For the livestock component, the costs composition included pasture establishment, maintenance and infrastructure for one hectare pasture (Brachiaria), as demonstrated in Chart 18.3. However, for cost composition of inputs, labor and animal purchase the values used were from Chart 18.4 multiplied by four, considering optimal resources availability and the use of sufficient technology to keep an average of 4 AU/ha, resulting in R$ 4,245.44/ha. If calculations with different stocking rates are desired, all it takes is to calculate the proportion based on Chart 18.4.

Figures 18.2 A and B

Silvipastoral system with eucalyptus (grancam – I 1277 [**A**]; hybrids: urograndis – I 144 [**B**]) and cattle, high tree density [distance varying from 16 to 27 m (between alleys) × 3 × 1,85 m (between lines and plants)], grass Urochloa brizantha, 2 years after implementation in Ivinhema, Mato Grosso do Sul State, São Paulo Farm. *Photos: Omar Daniel and Igor Murilo Bumbieris Nogueira.*

CHART 18.8

Cost Composition to Implement One Hectare Eucalyptus per Operation in Silvipastoral System with 755 Trees per ha (16 × 3 × 2 m), Considering the Mechanized and Manual Operations, Inputs Application of and Tree Pruning at 4 and 8 Years after System Implementation

	MECHANIZED			MANUAL			INPUTS				COST
OPERATION	HM/HA	R$/HM	R$/HA	HH/HA	R$/HH	R$/HA	ITEM	AMT/HA	R$/UN	R$/HA	R$/HA
Project preparation and topography											30.75
Roads, facilities, fire breaks	0.64	69.00	44.16								44.16
	0.08	170.00	13.60								13.60
Heavy tillage	0.50	44.00	22.00								22.00
1stant control				7.50	4.00	30.00	Insecticide (ants) (kg)	6.00	7.50	45.00	75.00
Rows marking poles				4.90	4.00	19.60					19.60
Fertilizers mixture				1.17	4.00	4.68	Rock fosf. (kg)	400.00	0.70	280.00	284.68
Fertilizers distribution	0.25	16.80	4.20								4.20
Light tillage Bedding	0.25	44.00	11.00								11.00
Seedlings holes preparation				6.50	4.00	26.00					26.00
Seedlings holes fertilization	0.27	16.80	4.54	2.50	4.00	10.00	NPK(6-30-6) (kg)	115.00	0.90	103.50	118.04
							KCl	75.00	1.20	90.00	90.00
Termites control				2.50	4.00	10.00	Termite contr. prod. (kg)	2.50	7.50	18.75	28.75
Termites/fertilizers mixture				1.50	4.00	6.00					6.00
Herbicide application			105.00				Herbicide			66.00	171.00
2ndant control				1.50	4.00	6.00	Insecticide (ants) (kg)	0.50	7.50	3.75	9.75
Fire breaks maintenance	0.08	170.00	13.60								13.60
Seedlings transport	0.15	15.70	2.36	0.60	4.00	2.40					4.76
Seedlings distribution				3.80	4.00	15.20					15.20
Planting				8.30	4.00	33.20	Seedlings	755.00	0.40	302.00	335.20
3rdant control				0.94	4.00	3.76	Insecticide (ants) (kg)	0.50	7.50	3.75	7.51
RePlanting				3.00	4.00	12.00	Seedlings	76.00	0.40	30.40	42.40
Irrigation	0.90	16.80	15.12	2.26	4.00	9.04					24.16
IMPLEMENTATION COST (R$/ha)			**235.57**			**187.88**				**943.15**	**1,397.35**

CHART 18.9

Cost Composition to Maintain One Hectare Eucalyptus per Operation in Silvipastoral System with 755 Trees per ha (16 × 3 × 2 m), Considering the Mechanized and Manual Operations Inputs Application and Tree Pruning at 4 and 8 Years after System Implementation

		MECHANIZED			MANUAL			INPUTS				COST
	OPERATION	HM/ HA	R$/ HM	R$/ HA	HH/ HA	R$/ HH	R$/HA	ITEM	AMT/ HA	R$/ UN	R$/HA	R$/HA
1ª Maintenance (year 0)	Herbicide Application			35.00	0.00	4.00	0.00	Herbicide			7.00	42.00
	Fertilizer 150 g/plant 60 days	0.27	16.80	4.54	0.72	4.00	2.28	NPK(18-00-18) (kg)	113.00	0.90	101.70	109.12
	Fertilizer 150 g/plant 6 months	0.27	16.80	4.54	0.72	4.00	2.28	NPK(18-00-18) (kg)	113.00	0.90	101.70	109.12
	Fertilizer 60 g/plant 12 months	0.27	16.80	4.54	0.72	4.00	2.28	KCl (kg)	45.00	1.20	54.00	61.42
	Roads and firebreaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	8.00	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	23.00
	COST (R$/ha)			**62.21**			**16.64**				**279.40**	**358.25**
2ª Maintenance (year 1)	Herbicide Application			35.00	0.00	4.00	0.00	Herbicide			7.00	42.00
	1st pruning (until 4.00 m)				18.00	4.00	72.00					72.00
	Fertilizer 150 g/plant 24 months	0.27	16.80	4.54	0.72	4.00	2.88	NPK(18-00-18) (kg)	113.00	0.90	101.70	109.12
	Roads and firebreaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	8.00	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	23.00
	COST (R$/ha)			**53.14**			**82.88**				**123.70**	**259.72**
3ª Man. (year 2)	Herbicide Application			35.00	0.00	4.00	0.00	Herbicide			7.00	42.00
	2ndpruning (until 6.00 m)				87.00	4.00	348.00					348.00
	Roads and firebreaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	8.00	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	23.00
	COST (R$/ha)			**48.60**			**356.00**				**22.00**	**426.60**
4ª Man. (year 3)	3rd pruning (until 8.00 m)				87.00	4.00	348.00					348.00
	Roads and firebreaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	8.00	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	23.00
	COST (R$/ha)			**13.60**			**356.00**				**15.00**	**384.60**
5th-11th Man. years 4-11)	Roads and firebreaks maintenance	0.08	170.00	13.60								13.60
	Ant control				2.00	4.00	8.00	Ant contr.prod. gr.(kg)	2.00	7.50	15.00	23.00
	ANNUAL COSTS (R$/ha)			**13.60**			**8.00**				**15.00**	**36.60**
MAINTENANCE COST (R$/ha)				**272.74**			**867.52**				**545.10**	**1685.36**
IMPLEMENTATION AND MAINTENANCE COST (R$/ha)				**508.32**			**1055.40**				**1485.25**	**3,082.71**

To create the cash flow, considering the system as a whole, i.e., eucalyptus and cattle, the above data added to the data from Charts 18.8 and 18.9 were computed annually. The expected income, in a 12-year cycle was R$ 80.746,10, and the costs were R$ 26.268,06, resulting in an accumulated balance of R$ 54,478.04/ha.

Under the criteria used, results indicate that the composition with 755 trees per ha and a rotating system for cattle, in a 12-year time frame, generates a financial return higher than that of the conventional cattle grazing, higher than Eucalyptus forestry and the low-tree-density silvipastoral system with low tree density (250 tree/ha).

The NPV for this activity was positive (NPV = R$ 14,241.58), with an expected rate of return (RR= 29.3%) more than twice higher than the 12% used as interest rate, 6.8 times higher than 4.3% obtained for extensive cattle grazing and twice as high as the RR obtained in the previously analyzed low-density silvipastoral system. The benefit/cost ratio (B/C) was also higher, reaching 1.86.

This silvipastoral system with 755 trees per hectare presents high economic viability, enabling cattle husbandry and include forestry in a combination that increases the profitability per area unit by many times of that from traditional Eucalyptus forestry and extensive cattle production. However, it is important to remark that this possibility demand optimal conditions in all aspects like soil fertility, climatic conditions, farmer's experience etc. This option with high cattle stocking rates was here demonstrated to show the high potential such integrated systems can have. However, they should not be taken as an average for the usual situations in Brazil. Besides, it is necessary to be aware that investments and management abilities will have to correspond to the high expected returns.

The option with high cattle stocking rates in silvipastoral system was here demonstrated to show the high potential such integrated systems can have.

If cattle stocking rates of 2 UA/ha are used in these calculations, which could be considered an average value for integrated crop-livestock-forestry systems in the Brazilian Midwest, the investment on the activity would remain attractive, as demonstrated in the results below:

- Expected income (12-year cycle): R$ 66.796,10
- Total costs: R$ 15.801,46
- Accumulated balance: R$ 50,994.64/ha.
- NPV: R$ 13,848.86
- RR= 31.9%
- B/C=2,34

Silvipastoral systems are a good alternative to increase profitability in regions with poor soils and dry seasons.

FINAL REMARKS

Especially in Central Brazil, extensive cattle farming has been subject to gradual capital reduction, due to low beef prices for farmers, higher production costs and low pasture carrying capacity.

Silvipastoral systems are a good alternative to increase profitability in regions with poor soils and dry seasons. In economic analyzes that were carried out, and considered present net value (NPV), internal rate of return (TIR) and benefit/cost ratio (B/C), silvipastoral systems, both with low (250) and high (755) tree densities have proved to be a good alternative to overcome the sustainability crisis in local beef cattle farming.

If financial resources are available, analysis indicate that conversion from extensive grazing systems into silvipastoral systems becomes a sustainable production alternative, allowing farmers to stabilize capital investment in restoring carrying capacity.

It brings along not only financial returns to farmers, but also benefits like sustaining jobs in rural areas, improving local salaries, decreasing rural exodus (usually caused by monocultures), environmental benefits related to soil and water conservation, the possibility to foster timber consuming industrial hubs, along with many other benefits.

Chapter

19

The Strategic Position of Integrated Farming Systems in the Context of Agriculture and Environment

Davi José Bungenstab

QUALITY IN THE PRODUCTION PROCESS

In the last decades the world has been experiencing an intense technological development in almost all areas of science, and consequently, in the corresponding productive sectors and industrial chains. Simultaneously, volume and speed of information exchanged is increasing at fast pace, accelerating globalization. Therefore, consumer exigency levels regarding variety and quality of goods is increasing, also in the food sector, with emphasis on food safety.

Modern concepts of product quality include demand for environmental protection in the production process, often requiring formal certification. This attitude has already brought many positive effects to the environment, especially in the industrial sector of Western-Europe. In those countries, not only awareness and social debate, but also official regulation and control of natural resources usage and environmental safety in the whole production process are in mature stages of discussion and implementation. Sometimes the same measures are expected to be applied in developing countries. However, such nations, even with a high development potential like Brazil, still have their economies based on internal market and primary goods exports, mainly minerals and non-processed agricultural commodities. This chapter, considering the aforesaid context, addresses the potential of integrated production systems as alternative for sustainable development through high quality agricultural production.

THE ENVIRONMENTAL DEBATE AND THE BRAZILIAN AGRIBUSINESS

For its natural resources endowment and high potential for agricultural production, including bioenergy, Brazil is central in the debate regarding food production and environment. Recent economic and political stability has allowed a relatively constant and more organized growth than in the past. International projection turned Brazil into a strategic country for implementing and demonstrating sustainable development strategies based on fair use of natural resources.

Land appropriation for agriculture, including energy production, is directly related to occupation of the Cerrado and to some extent also the Amazon rainforest, attracting attention from the international community. According to Brown (2002) over half of carbon emissions reduction in tropics could be accomplished by containing deforestation and promoting forest regeneration. Brazil, with its large forest areas, has a huge potential for such, avoiding emissions and keeping a great biodiversity reserve. Therefore, the country has something very valuable to be considered in the global environmental debate, with potential to be very influential on it. The Brazilian beef industry, for its large extensions of land used, plays a major role in this context.

The first step to evaluate environmental performance of an economic activity is to assess efficiency of natural resources usage, looking for weaknesses and strengths related to systems planning and management. In the case of agriculture, the final goal should be to detect technologies and practices that would help attenuate problems and reduce environmental impacts.

Brazilian beef chain has shown increasing production volumes. In the other hand, as seen in previous chapters of this book, sown pastures, which occupy a large portion of agricultural land in Brazil, faces some degree of degradation, demanding urgent intervention to recover potential carrying capacity.

The first direct effect of pasture degradation is decreasing animal performance. Production indices are the first indicators for efficiency on natural resources usage. Land is the main natural resource applied to extensive beef production. Therefore, stocking rates in relation to local potential carrying capacity of each agro environment are the first indicators of environmental efficiency, which, in its turn, is fundamental for meeting sustainability.

LAND USE EFFICIENCY

Within an environmental efficiency analysis for extensive agricultural systems, land use is one of the first parameters to be assessed. In Brazil, because of its large extensions of available arable land, sometimes some stakeholders are confused by the impression that land is an unlimited resource. As a matter of fact, arable land availability in Brazil is much higher than in other countries. However, land prices in some new agricultural zones have increased over twenty times in the last decade, revealing a scarcity that sometimes is not recognized by society.

Within an environmental efficiency analysis for extensive agricultural systems, land use is one of the first parameters to be assessed.

Therefore, land use efficiency has a core position on the agricultural sustainability debate. This kind of analysis is very important because an agricultural system operating below its region´s potential can be classified as inefficient (Figures 19.01 A and B). If several neighboring farms are in this situation, sustainability of a given region might be compromised. This would demand action especially from local governments to support initiatives for change, what many times can come in the form of suitable infrastructure, minimum prices guarantee, crop insurances, technology transfer and education.

Considering the importance of land use for environmental efficiency, sown pastures degradation could be named as one of the main problems regarding sustainability of the whole Brazilian beef chain. Low yields from these areas represent a waste of natural resources, since it does not optimize production in already cleared land. This also substantially increases greenhouse gases (GHG) emissions per unit beef produced per hectare in such areas. Therefore, improved production systems would provide a double solution through increasing food production and becoming a carbon sink.

Figures 19.1 A and B

Area with good soils used for extensive cattle grazing with pastures showing evidence of degradation and consequent low yields, neighboring a commercial high yielding maize crop.
Photos: Davi J. Bungenstab.

GREENHOUSE GASES EMISSIONS AND MITIGATION ALTERNATIVES

Besides land use change, animal related emissions from natural digestive processes have substantial impact on the total Brazilian greenhouse gases inventory. Considering the outlook of Brazilian beef cattle farming and its potential to reduce GHG emissions, compared to other sectors, like road freight, which has GHG emissions volume similar to beef cattle in Brazil, it becomes evident that cattle has a much larger potential to reduce emissions, especially because of the technology adoption potential from the sector.

Adoption of available farming technologies can substantially reduce GHG emissions, also positively reflecting on beef yields. Farmers, inputs industries, government, research and extension institutions have been concentrating efforts to make the Brazilian beef sector a major player on global warming reduction.

Adoption of available farming technologies can substantially reduce GHG emissions, also positively reflecting on beef yields.

This can be achieved, for example, adopting the following strategies:

- ***Reducing deforestation*** – although deforestation causes are not always directly related to cattle ranching itself, cattle husbandry is often the main activity carried out in new cleared areas. Therefore, turning cattle systems more profitable in traditional areas would help to avoid new clearings and consequently emissions from deforestation. Also, avoiding deforestation is one of the quickest and most effective ways to reduce emissions in tropical countries. In this case, carbon credits for avoided emissions should play a major role. This alternative would have an excellent potential in Brazil. However, estimating, accounting and remunerating such credits is not an easy task. Developing international mechanisms should be a priority.

- ***Sown pastures rehabilitation*** – it is well known that degraded pastures are GHG emissions sources while stabilized productive areas can become carbon sinks. Although demanding a rather complex system, carbon credits to help financing pasture recovery should have a huge impact in tackling the problem.

- ***Emissions avoided through reducing cattle slaughtering age*** – it is estimated that in Brazil, one cow or steer is responsible for about 1.5 metric ton emissions of CO_2 equivalent per year. In the case of slaughtering steers, the less they stay in the system to produce the same amount beef, the lower are the emissions per unit beef per area. Improved systems, with good forage and strategic feeding, especially for finishing animals, have potential to reduce at least one year slaughter age, with direct effect on GHG emissions reduction and the bonus of improving carcass quality.

The cattle sector is much more flexible, agile and prone to adopt technologies than other sectors.

- ***Carbon sequestration by integrated farming systems*** – this alternative is enhanced in systems that include a forestry component like crop-livestock-forestry integration and silvipastoral systems. Its adoption directly affects other strategies above discussed. Accounting and financial compensation for carbon fixation in agrosilvipastoral systems is not yet available in formal carbon credit markets. However, this is also a mechanism with great potential for voluntary markets, since it merges needs from the industrial sector, farmers and government. Research on assessing and certifying carbon sequestration in these systems is in early stages. Support to improve techniques and processes is necessary.

Regarding public policies to foster mitigation of GHG emissions in Brazil, it is important to emphasize that compared to other sectors, as the above mentioned road transport, the cattle sector is much more flexible, agile and prone to adopt technologies, which in turn can be effective to the point of potentially turning the sector from source to sink as the case of using no-tillage and integrated production systems.

Such policies will be effective when succeeding to have farmers adopting technologies which are promptly available in most parts of the country. As examples of public efforts in this regard is the National Program for Low Carbon Emissions Agriculture, the ABC Program, or local public initiatives that directly reward systems' improvements and efficiency, like the "Programa de Avanços na Pecuária (PROAPE)" also locally called "Programa do Novilho Precoce" in Mato Grosso do Sul State. Also private initiatives from local farmers associations and groups negotiating niche markets with supermarket chains for prime beef from improved systems can also be found throughout the country. In the near future they will include quality of farming processes in their product labels.

INTEGRATED PRODUCTION SYSTEMS AS IMPROVEMENT STRATEGY

When promoting environmental quality throughout the production process to build a product´s sustainability, the search for technical and scientific information about local and regional applicable practices is crucial for decision making.

Integrated farming systems, although expanding, still represent a relatively small share of the agricultural areas in Brazil. For farmers, a critical point upholding them from adopting integrated systems is the need to screen many alternatives and to plan all details involved in these rather complex systems compared to traditional monocultures. This planning goes beyond selecting tree, forage and crop species. It demands a careful analysis of all surrounding resources and infrastructure availability and, many times, farmers own willingness to face a much more time-and-efforts demanding undertaking.

After decision is made, and the planning phase begins, there are several different options for cultivation techniques, machines and processes. But there is no single technological package that fits all systems, also because every farm is somehow unique. Systems' goals, resources availability and cost-benefit of alternatives should always guide decision making. Partnerships, contracting or procurement can be beneficial for farmers who are not specialized in the other components of the systems, like a cattle rancher who is not familiar with soybeans farming or Eucalyptus afforestation. Sometimes the best alternative is to procure services or whole operations for specialized individuals or companies. Depending on local availability, partnerships with crop farmers or hiring afforestation companies to implement the forestry component can be rather cost-effective.

Sometimes the cost of making mistakes in such complex systems are very high and this "brought-in" experience would reduce risks and increase chances of success.

CLOSING REMARKS

Integrated farming systems offer several direct benefits for farmers, surrounding environment and communities and indirectly benefits to society as a whole. The different components of integrated systems have a synergetic effect among them and also stimulate farmers to adopt better management practices. Besides these advantages, farmers should also consider the benefits of being pioneers in an economic activity. Despite difficulties caused by lack of experience, farmers who introduce even small scale integrated systems in part of their farm benefit from creating internal know-how that will allow them to grow and exponentially improve their systems in the future.

Voluntary environmental services market, either specific or incorporated in certified goods prices, shows a tendency to become a reality in the near future. More efficient, process safe, real time monitored food production will become the standard in the future. Pioneer, more experienced farmers, independently of location and operation scale, will benefit from the intrinsic knowledge of their own production systems and their potential to truly contribute for a more sustainable agriculture.

Besides other advantages, farmers should also consider the benefits of being pioneers in an economic activity like using integrated systems.

Chapter

20

Potential of Integrated Production Systems in Semi-arid and Arid Zones of Africa

Horst-Jürgen Schwartz

INTRODUCTION

In recent decades the incorporation of trees and other woody plants into agricultural production systems has found more and more scientific attention but also increasing interest in development agencies operating in rural Africa. Agroforestry, silvo-pastoralism, and agro-silvo-pastoralism are seen and promoted as means to increase food production while simultaneously providing valuable ecosystem services. It is claimed that such systems halt and even revert widespread land degradation, improve and diversify the range of farm products, and safeguard local and regional biodiversity.

Trees are reputed to improve water availability to adjacent crops through rainfall interception, through benign effects on evapotranspiration, increased water infiltration, and, if occurring in higher densities, also through rainfall induction. In the sub-humid and semi-arid regions plant nutrient availability is often higher under tree canopies then in neighbouring open land. Three processes can be cause of this. The first is redistribution within the through far reaching lateral root systems common in woody plants of the drier environment, through nutrient transport by surface run-off, and dung deposition of shade seeking animals. The second is through reduction of losses by slowing erosion, through recapture of leached nutrients by deep rooting woody plants, and through recycling in form of seasonal leaf shedding. The third and most important is enrichment through N-fixation by leguminous species and improved P-absorption by root associated mycorrhiza and fungi. The realisation of these potential benefits depends on complex sets of abiotic and biotic conditions. Rainfall amount and distribution, various soil properties, as well as past and present land use are the major factors determining whether woody species can stabilise African agricultural environments and can contribute to the desired development goals.

The previous chapters have demonstrated in great detail the current status and the advances of integrated crop-livestock-forestry systems in Brazil. This last one is meant to give a summary of the respective situation in Sub-Saharan Africa. Brazil and SSA have much in common in terms of natural potential for agricultural production, however much they may differ in economic, social and political terms. It is therefore hoped that lessons learned in Brazil may also become beneficial in the African context.

THE NATURAL POTENTIAL FOR ICLF IN SUB-SAHARAN AFRICA

Figure 20.1 shows an approximate map of the major eco-climatic zones in Sub-Saharan Africa. The equatorial humid zone receives from 1500 to over 3500 mm annual rainfall and the length of the growing period is between ten and twelve months. On the western half of the continent there is a strictly latitudinal climatic gradient of declining rainfall and increasing seasonality. In the eastern half this pattern is less clear due to the disturbing effects of the Great African Rift with its north-south chain of highlands, deep valleys and large lakes. East of the Great Rift there is no equatorial humid zone, instead one finds a mosaic of lower ecological potentials more determined by altitude then by latitude.

The sub-humid to semi-arid zone which covers the largest portion of SSA receives rainfall between 1500 mm and 350 mm. In the western half of the continent monomodal rainfall is prevalent whereas in the eastern half it is predominantly bimodal. The length of the growing period ranges from eight months at 1500 mm to three months and less at 350 mm.

The semi-arid to arid regions receive between 350 and 100 mm annual rainfall, with very high inter-annual variability. Total annual precipitation occurs frequently in a few high rainfall events. The length of the growing period is often below two months.

The natural vegetation in the humid zone is the evergreen tropical rainforest. Here the potential for ICLF systems is limited, mainly due to the high challenge of parasites and endemic diseases for ruminant livestock. On the fringe of this eco-zone, cattle, sheep, goats and poultry are associated to fruit tree plantations like oil palm, mango, guava, cocoa, as well as banana and plantain.

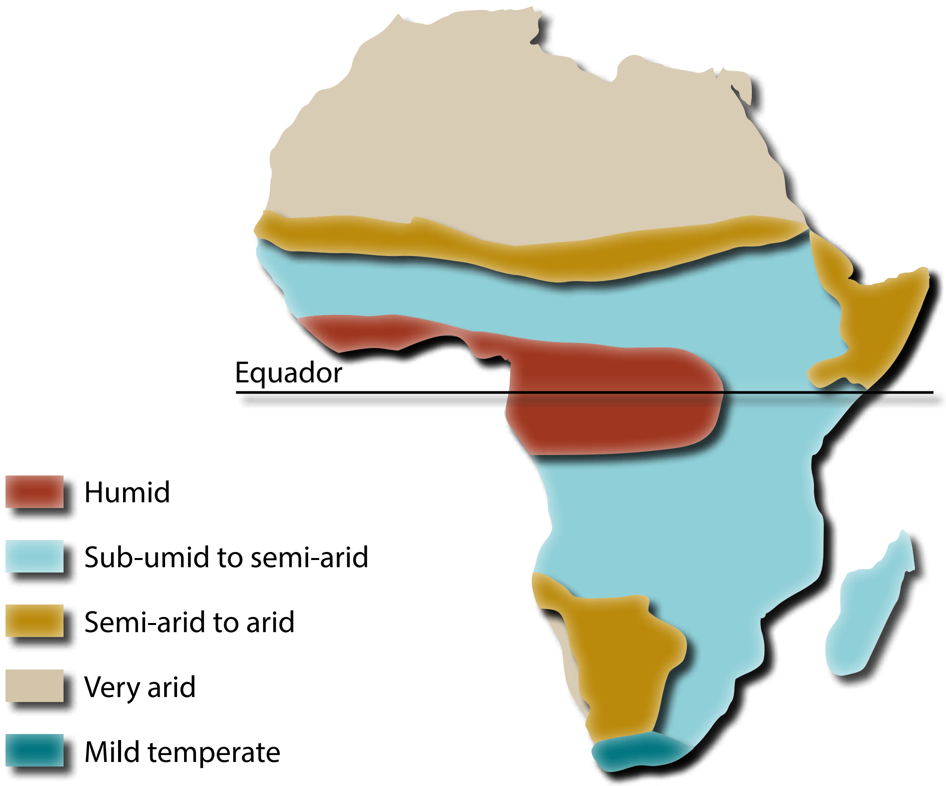

Figure 20.1

Schematic drawing to show the approximate extent of the major eco-climatic zones in Sub-Saharan Africa.

Following the climatic gradient outwards from the inner tropics into the sub-humid to semi-arid zone, the rainforest gives way to semi-deciduous forest, tree savannah, grass savannah, and semi-arid dwarf-shrub/annual grassland in that order. Interspersed are highland areas of varying size, which may reach from glaciers through high altitude tundra, broad leafed mountain forest, bamboo belts and the various savannah types down into desert lowlands. The most prominent are the highlands of Ethiopia, Kenya, Uganda, Ruanda and Burundi. A multitude of ICLF systems is possible and is practised in this eco-zone some of which will be described later in this chapter.

The semi-arid to arid zone with its' low and erratic rainfall is mainly utilised by nomadic pastoralists who have their specific ways of incorporating tree and other woody vegetation into their production system.

A TYPOLOGY OF ICLF SYSTEMS IN SUB-SAHARAN AFRICA

System Categories

Agroforestry is a wide spread land use form in SSA, combining utilisation of naturally occurring or planted trees and shrubs with crop and/or fodder production and pastures. Chart 20.1 shows common agroforestry systems in different agro-ecological zones in Africa. The agro-silvo-pastoral one is probably the most important one, as the largest proportion of agricultural land is in smallholder hands, who, for various reasons, almost always keep some herbivorous livestock.

Trees and shrubs fulfil a variety of functions on farms.

Trees and shrubs fulfil a variety of functions on farms. They are used to demarcate boundaries or to form living fences around farm compounds and fields. At the same time, they can produce

CHART 20.1

The Strategic Position of Integrated Farming Systems in the Context of Agriculture and Environment

HUMID LOWLANDS	SEMI-ARID LOWLANDS	HIGHLANDS
Shifting cultivation	Silvopastoral systems	Silvopastoral systems
Shamba systems	Windbreaks/Shelterbelts	Soil conservation plantings
Compound farming	Fodder/fuel trees	Plantation/crop farming
Multi storey tree gardens	Multipurpose trees	Boundary plantings
Plantation/crop farming	Soil conservation plantings	
Intercropping systems	Boundary plantings	

(Modified after Kang, 1993)

fruits, forage in cut and carry systems, they provide shade, and, if planted properly, serve as windbreaks and reduce soil erosion.

If shrubs and trees are interplanted with crops they can be arranged in alternating rows, in the form of alley cropping, or as randomly dispersed individuals in the fields or pastures.

In the so called shamba (taungya) system, farmers are allowed to plant crops on recently cleared forest land under the condition that they also plant trees, usually prescribed species. Cropping can be continued for some years until the trees have reached a development stage when they start hindering crop growth or when, in turn, the cropping activities impair further development of the trees. Farmers are then forced to move to other plots. This system is perceived as a cost effective way of reforestation but does little to stabilise the livelihood of the respective farming communities.

In the so called shamba (taungya) system, farmers are allowed to plant crops on recently cleared forest land under the condition that they also plant trees, usually prescribed species.

In the high rainfall areas of the humid to sub-humid zones, intensive, multi storey compound farming, also called home gardens, is common. It is a traditional, rather stable agro-forestry system which combines tree crops with herbaceous food crops for subsistence, sometimes cash crops like tea, coffee, or cocoa and livestock (goats and poultry) on very small plots around the homestead. It allows reasonable livelihoods in areas with very high population densities like in large proportion of the SSA highlands.

Contour planting is a means for erosion control which is widely practiced not only on steep slopes. In the drier areas of the continent, rainfall events tend to be short but high yielding with corresponding erosive power, which can lead to soil surface compaction and increased runoff. Therefore, bunding and contour planting are advisable in the rainfed farming areas in West Africa at slope angles as low as 3 %. With a proper mix of woody vegetation, perennial grasses, and leguminous herbaceous plants, major improvements in soil retention, soil fertility, fodder production, and food security can be achieved.

Dispersed trees in fields and pastures, either natural or cultivated, also known as parkland systems are, depending on the species, producing fruits, food, fodder, various non-food products, they give shade to crops and livestock, are known to improve soil fertility, and be used for timber and/or fuel wood.

Types and Species of Forages, Crop and Tree Components

The most common grasses and crops in integrated systems are the ones already used in traditional systems, like the Guinea, Napier and Bracharia grasses, while for crops maize, sorghum, millet and different sorts of vegetables are used. These species have satisfactory yields, varying according to the intensity of use of the other competing components, especially trees in the systems. This intensity, in its turn, is determined by the importance of the output for the farmer. As integrated systems evolve in the region, research regarding selection and adaptation of species and varieties for them will also evolve, improving their potential.

Regarding the tree component, the multitude of indigenous and exotic agro-forestry tree species in Africa can be classified into trees for timber, fuel, fodder, fruit and non-food products generation. The special group of the leguminous species with over 80 indigenous and almost as many exotic ones are considered fertiliser trees. In most cases trees fulfil more than one function and have therefore almost all multipurpose characteristics. Chart 20.2 lists some of the most important species, their function and the integrative value within ICLF systems.

The livestock species within ICLF systems are the domestic ruminants cattle, goats, and sheep, and, in the dry areas also camels.

Livestock Species

The livestock species within ICLF systems are the domestic ruminants cattle, goats, and sheep, and, in the dry areas also camels (*Camelus dromedarius*). Donkeys are regionally of great importance but are usually left to find their feed on roadsides and other fallow land. Poultry are found virtually everywhere, but like donkeys they mainly support themselves as scavengers on the farm.

Three types of feed are available through the inclusion of woody species into the farming system:

1. Parts of bushes and trees, leaves, flowers, fruits, bark, shoots and roots which can be harvested by man and fed to the animals (cut and carry), or can be harvested by the animals directly;
2. By products, which are mainly fruit pulps or peels (dried or fresh), occasionally also oil cakes if there is on-farm processing of any oil seeds; in addition there can be residues of crops grown under woody vegetation and stubble grazing after harvest;
3. Undergrowth consisting of grasses, forbs or smaller woody perennials which can also be harvested by man or fed on directly by the animals.

Chart 20.3 summarises the possible combinations of cropping systems with woody perennials and the feeding systems which may be associated with those.

One can generally differentiate between the "cut and carry" systems and direct feeding (grazing/browsing) systems. Advantages and disadvantages can be claimed for the direct feeding systems (Chart 20.4). "Cut and carry" systems are less controversial but are generally more labour intensive. Chart 20.4 also indicates major factors in the domestic herbivore biology which can positively or negatively affect the integration of livestock and tree cropping systems. These factors can be differentiated as arising from animal behaviour [feed preference and selectivity], from

CHART 20.2
Tree Species Commonly Used in ICLF Systems in Sub-Saharan Africa

SPECIES	FUNCTION	INTEGRATIVE ASPECT
Acacia ssp. (various)	soil fertility fodder	N-fixation, green mulch foliage, seed pods
Faidherbia albida	soil fertility fodder	N-fixation, leaf fall seed pods
Prosopis ssp. (various)	soil fertility fodder fuel	N-fixation, green mulch seed pods wood, charcoal
Balanites aegyptiaca	food feed	edible oil oil cakes
Adansonia digitata (Baobab)	food	vegetable (leaves) juice from fruits
Tamarindus indica	food	fruits
Tectona grandis (Teak)	timber	ground cover grazing
Grevillea robusta	timber, fuel, fodder	ground cover grazing
Coconut, Oil Palm, Date Palm	food industrial raw materials	ground cover grazing cut and carry
Hevea	rubber	ground cover grazing cut and carry
Leucaena leucocephala *Gliricidia sepium*	fodder demarcation, fencing soil fertility	direct feeding cut and carry N-fixation, green mulch
African Locust Bean *Parkia* ssp. (various)	food soil fertility	condiments, fermented food product N-fixation
Eucalyptus ssp. (various)	timber fuel	

the anatomy/morphology of the animal [reach and harvesting capacity], and the digestive physiology [metabolisation of various plant substances]. In the context of this chapter the subject cannot be discussed exhaustively but rather by the way of one or two examples for each of the most important aspects. The examples given refer to Africa and to the utilisation of natural woody vegetation. However, parallels can easily be drawn to cultivated systems.

CHART 20.3
Cropping Systems for Cultivated Woody Vegetation and Associated Feeding Systems for Domestic Ruminants

UTILISATION PRIORITY		FEEDING SYSTEM
Plant Product	Timber	Undergrowth Pasture
Terminal Use	Paper Firewood Charcoal	Forage Crop Crop residues
Plant Product	Fruits	[By-Products]
Continuous Use	Sap & Resin Leaves Bark	[Residues] Direct Feeding Undergrowth-Pasture
Plant Function	Erosion Protection Windbreaks Demarcation & Fencing Shade Abiotic/Physical Functions	Cut & Carry Undergrowth-Pasture
Animal Product	Forage	Direct Feeding Cut & Carry Undergrowth-Pasture

Animal Dietary Preferences

Dietary preferences of domestic herbivores have been measured using various experimental approaches in Africa.

Dietary preferences of domestic herbivores have been measured using various experimental approaches in Africa (Schwartz and Dioli, 1992; Schwartz and Schultka, 1995). Accordingly, cattle and donkeys can be classified as non-selective grazers; sheep as non selective, intermediate feeders with a preference for grasses; goats as selective, intermediate feeders with a preference for browse; and camels [*Camelus dromedarius*] as selective browsers. The use of a calculated selectivity index allows evaluating animal preferences relative to the forage on offer which is illustrated in Figure 20.2 comparing selectivity indices for cattle and camel on a semi-arid bushed grassland during a growing season.

The strong preference of cattle for grass is obvious although grasses are of much lower quality during the dry season than the foliage and fruits of the available and accessible woody vegetation which in turn is strongly preferred by camels.

CHART 20.4
Advantages and Disadvantages of Direct Feeding Systems in Natural or Cultivated Stands of Woody Vegetation in Africa (Schwartz and Schafft 1988)

ADVANTAGES	DISADVANTAGES
For the Animal	
high quality forage available	forage may not be accessible
seasonal fluctuations of feed quality less pronounced	forage preferences of animals may not be met
seasonal use of undergrowth prolonged	anti-nutritive substances in woody plants may have negative effects if intake is not controlled
shade reduces heat stress	herd supervision may be difficult increased risk of ectoparasites [ticks, biting flies. mosquitoes]
For the Vegetation	
unwanted undergrowth reduced	potential damage to the trees or bushes [overutilization, trampling, debarking]
increased soil fertility through manure	natural rejuvenation of woody plants impeded

Animal Reach and Harvesting Capacity

Acacia ssp. are widely spread leguminous trees in SSA which are also valuable feed sources for domestic herbivores. Flowers, fruits and leaves are consumed to varying degree by all animals. Cattle, sheep and donkeys feed mainly on plants parts dropped to the ground whereas goats with their greater agility and their ability to climb trees, and camels, because of their body size and superior reach, mainly harvest young, green fruits and foliage directly from the trees. This allows them to select a much better quality diet from the same source.

In general, a wide variety of forage qualities can be found on African savannah type pastures, whereby a significant relation exists between forage quality [dry matter digestibility] and height above ground of the respective vegetation stratum. Flowers, fruits and young leaves of leguminous trees and tall bushes are rapidly fermented in the forestomach and thus form a readily available energy source. Animals like camels and goats which have a sufficient harvesting capacity for small leafed forages [selective feeders] and an adequate reach to harvest higher vegetation strata, have distinct advantages during the dry seasons when high-quality forages are absent from the herblayer.

In general, a wide variety of forage qualities can be found on African savannah type pastures.

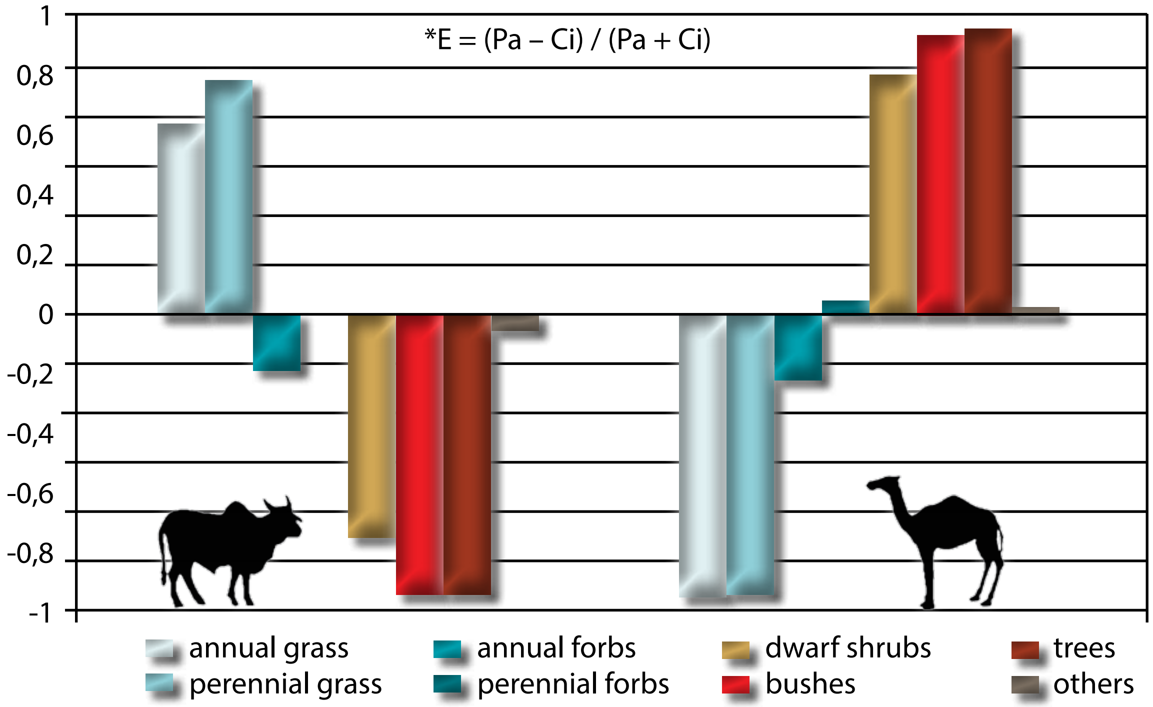

Figure 20.2

Selectivity index E for cattle and camels calculated for a semi-arid wooded savannah in Kenya during the dry season.

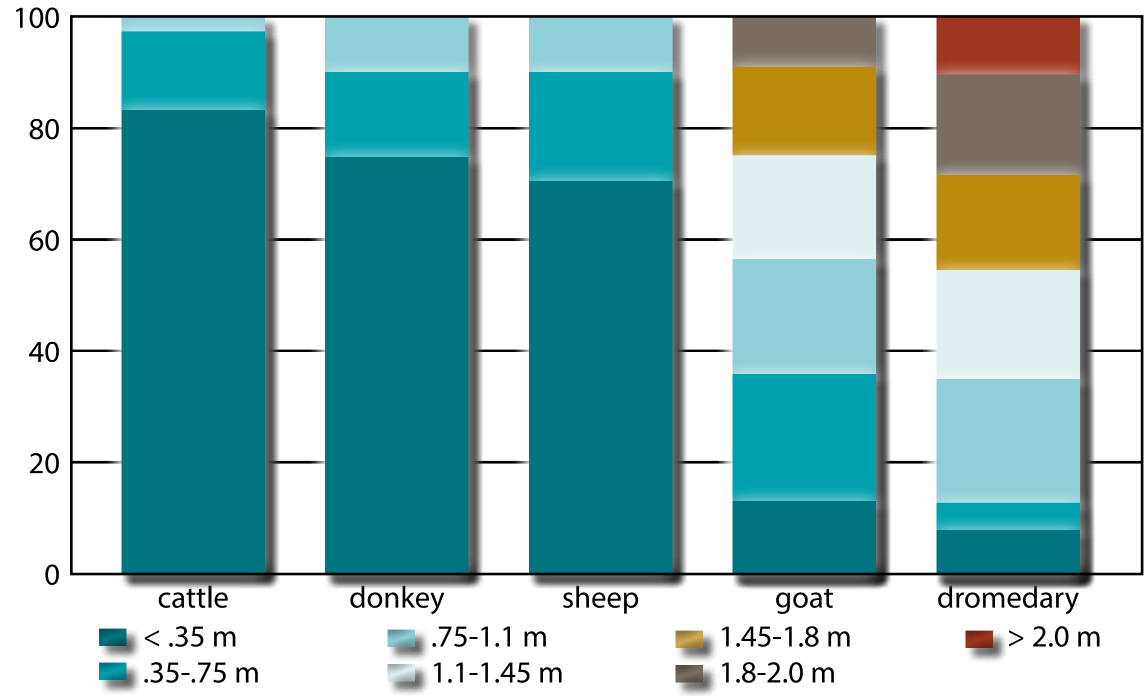

Figure 20.3

Proportion of total feeding time spent in vegetation strata at various heights above ground by free ranging domestic herbivores.

Accessibility

As mentioned above, accessibility is a function of reach, but also of plant height and crown diameter for any given combination of animal and forage plant species. A schematic representation of this relation is shown in Figure 20.4 which delineates penetration depths by browsing animals in dense bushes and trees.

Long-term experiments with Small East African goats on a dwarf shrub pasture [dominant species: *Duosperma eremophilum*] showed that availability of foliage biomass to browsing goats was not primarily a function of total foliage biomass but rather a function of plant density and crown diameter. High plant densities combined with medium crown diameters gave highest availability levels at stocking levels which allowed sustained forage yields. This will certainly have parallels to other combinations of animal and plant species and will affect management of cultivated woody forage species.

Anti-nutritive Substances in Forages from Woody Vegetation

Tannins are one of the most frequently occurring groups of phenolic substances in plants. They are not a uniform chemical group but exhibit quite differential molecular structures. Tannins are able to react with certain macromolecules, e.g. feed proteins, microbial and other proteins in the digestive tract as well as with polymerised components of the fibre fraction of feeds, and may precipitate these substances. Tannins can negatively affect protein digestibility in the rumen which may considerably reduce the nutritive value of tropical fodder trees and bushes. Under extreme circumstances, they may be toxic, i.e. when large quantities of tannin-rich feedstuffs are consumed by animals.

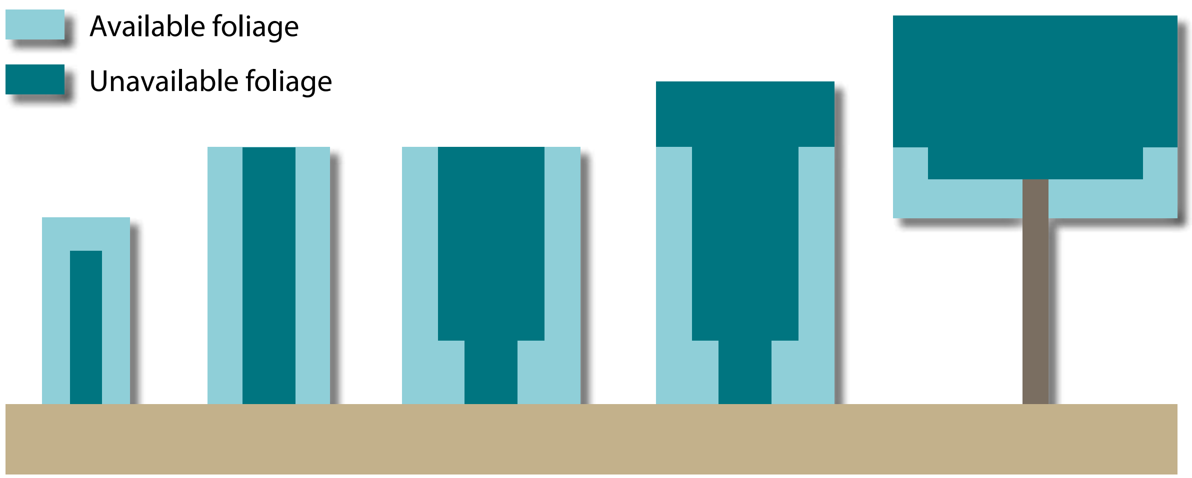

Figure 20.4

Schematic presentation of foliage availability to browsing animals in relation to and crown diameter of woody plants.

The toxic amino acid mimosine is found in varying concentration in all parts of *Leucaena leucocephala* and other leguminous woody plants. The mimosine content is affected further by various external factors such as soils, climate, processing and storage of the harvested material, but also varies in different subspecies and cultivars. Mimosine is an L-neutral amino acid, i.e. an alkaloid. If fed to animals in high amounts it may cause various toxic effects such as: growth depressions, reduced fertility, partial paralysis, loss of hair and damage to the eye, haemorrhagic cystitis and hypertrophic development of the thyroid in ruminants. There appear to be some species and/or breeds which are tolerant to mimosine.

SOME EXAMPLES OF WIDELY PRACTICED INTEGRATED SYSTEMS IN AFRICA

As SSA exhibits worldwide the highest yield gaps for most field crops, incorporation of woody plants is seen as one means to improve that.

There are various traditional and long established integrated crop-livestock-forestry systems in SSA. It is difficult to ascertain their present importance due to the lack of specific data, but most of the systems seem to be in gradual decline as population density and land use intensity are increasing. On the other hand, there is active promotion of integrated systems by international development agencies, non-governmental organizations (NGOs) as well as by national governmental institutions. As SSA exhibits worldwide the highest yield gaps for most field crops, incorporation of woody plants is seen as one means to improve that. Yet there is also frequently disinterest among farmers, if not outright rejection, as integrated systems are not always well understood by farmers and are considered cumbersome and labour intensive. The need for improved extension programmes in this field is obvious in many areas.

Below a few ICLF systems are described to document the wide range of systems which are practiced.

Shifting Cultivation

Shifting cultivation is most likely the oldest integrated system which has been practiced for many centuries. It is found in the higher potential regions of the humid and sub-humid lowlands and also in higher altitudes where the potential natural vegetation is forest. Farmers clear moderately sized areas in virgin or secondary forest by slash and burn, usually sparing big trees and woody plants which have some direct use. Livestock, which are often poultry and/or goats, seek forage in the surrounding forest and are supplemented with crop residues and stubble grazing. The cleared area is cultivated for a number of years until soil fertility declines and is then abandoned for the forest to reclaim the land by natural succession. These fallow periods have been as long as 40 years or more in the past. Increasing population density is now forcing a reduction of the fallow periods to less than 10 years in many areas, sometimes turning into continuous cultivation.

Figure 20.5

Integrated production system in the Gambia River valley.

Figure 20.5 shows an example from the Gambia River valley. The plot in the foreground was cleared 8 years before the picture was taken. The main crops are maize, manioc and groundnuts. There are also some Papaya (*Carica papaya*) plants. Two local cows (N'Dama), several goats, and some chicken constitute the farm herd. The adjacent forest is secondary as the area had been cleared at least twice before. The large trees in the background are residual from the original primary forest. The big Baobab is used for food, the leaves as vegetables, the fruits for juice and a fermented drink. Fruits and non-food products are collected from the forest. The farmer had already started to clear a new plot as yields on this one were declining.

Smallholder Dairy Systems

Smallholder dairy farms are probably the most common farm type in SSA and their number is growing. For the past 30 to 40 years a massive gene transfer from exotic high yielding breeds

Figure 20.6

Smallholder dairy farm in the coastal hinterland of Tanzania.

(Friesian, Jersey, and Ayrshire) into the local African cattle populations has taken place. This necessitated an increase in feed supplies and particularly in feed quality to realise the improved genetic potential. As the concentrate industry is still not well developed and small farmers can ill afford purchased inputs, a solution was found in forage crops. Herbaceous legumes and increasingly woody legumes are used to upgrade the quality of the tropical grasses like Napier (*Penisetum purpureum*), Guinea (*Panicum maximum*), or Signal grass (*Brachiaria ssp.*). Among the woody legumes *Leucaena leucocephala* and *Gliricidia sepium* are the most popular aside from indigenous tree legumes like *Acacia* ssp.

Figure 20.6 shows some of the most important aspects of a smallholder dairy farm in the coastal hinterland of Tanzania. In the foreground is the milking crush, to the right the open-walled cattle shed. The unit is shaded by an old Mango tree (*Mangifera indica*). Just behind the crush and the shed is a 2000 m^2 plot with Lucerne (*Medicago sativa*) and a little further out are 30 hedgerows of *Leucaena* with 20 plants each. This is sufficient for two cross-bred dairy cows to

Figure 20.7

Communal forage and fruit trees nursery in the Gambia.

supplement a base diet of Napier grass with protein. The expected lactation yield is about 2500 litres of milk a year. The feed supply functions as exclusive "cut and carry" system as long as the cows are lactating. Dry cows are tethered along roadsides or on communal land. *Gliricidia* can be found under similar circumstances but is usually allowed to grow into taller trees which are frequently coppiced to the leaves as feed and the wood for fuel or timber. A number of farmers in that village are running a communal nursery for Napier grass, Leucaena and various fruit trees (Figure 20.7).

Plantation Systems

Plantation systems can offer interesting potential for the integration of livestock. Sisal, oil palm, date palm, coconut palm, *Hevea*, various fruit trees, and timber tree plantations can offer interesting integration possibilities for livestock in SSA. Natural or planted herbaceous undergrowth can be used as feed for livestock as well as livestock manure can recycle some nutrients into the tree

Figure 20.8

Cattle grazing under mature Hevea plantation in Ghana.

crop. With the exception of sisal, all plantations systems have in common that they are available for direct feeding only for certain periods in the production cycle, that they can be used for "cut and carry" during other periods, and that they don't yield any herbaceous biomass due to light competition after canopy closure. These cycles are different for each specific type. Grazing between sisal rows does not have any such restrictions.

Most trees need an initial period after planting of two or more years to establish and grow out of the feeding reach of the grazing livestock, it can then be used for grazing until the canopy closes and ground cover biomass becomes negligible. This is the case in Hevea plantations, where grazing can start about 3 to 4 years after planting and can go on for about 6 to 8 years until canopy closure. When the trees mature and the canopy thins out there is again a limited grazing potential. Figure 20.8 shows cattle grazing under a mature stand of Hevea which has reached the end of its productive lifespan. There is increased herbaceous ground cover, although of poor quality. As the trees are old, there is no concern anymore that the animals might damage the bark which would make harvesting less efficient.

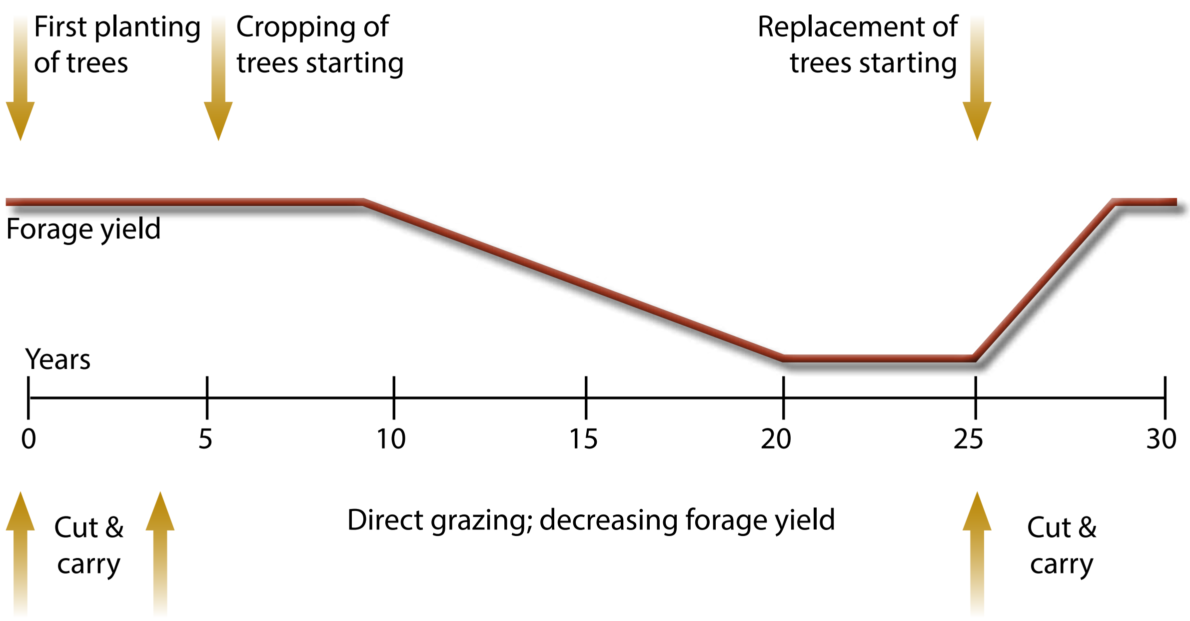

Figure 20.9
Time pattern of an oil palm-livestock integrated system.

In coconut plantations canopy closure does not occur, consequently about one year after planting the plots can be grazed until the end of the trees productive lifespan. Grazing under coconut has the added benefit that the undergrowth is kept short which facilitates the collection of fallen Nuts. Figure 20.9 shows the time pattern for an oil palm-livestock integrated system.

For the first three years after planting of the trees undergrowth can only be utilised in a cut and carry approach. After three years the trees are high enough to allow direct grazing by cattle or small ruminants. At five years the harvesting of the oil fruit starts. For the first eight years after planting the herbaceous groundcover gives maximum yield. After that yields decline to a minimum at around twenty years after planting and stay on that minimum level due to shading by the now closed canopy. Between twenty-five and thirty years trees will be replaced by new seedlings, forage yields go up, and grazing can no longer be allowed until three years after planting. Balancing of forage supply and animal numbers needs constant adjustment.

Agropastoral Parkland Systems

Parkland systems are characterised by scattered trees, either naturally occurring or cultivated in fields or on pastures. This system is well adapted to dry sub-humid and semi-arid areas. The most common trees are Mango, Baobab, *Faidherbia albida*, African Locust Bean (*Parkia ssp.*), *Balanites aegyptiaca*, and various indigenous acacias. The trees are protected and managed, and, even when they are naturally occurring on communal land, there are usually specific property rights

Figure 20.10

Mixed farming set-up with parkland character near Ouahiguya, Burkina Faso.

attached to them. All of them contribute to forage supply to livestock in form of leaves, flowers, and fruits. Some of them like Mango, Baobab, and Locust Bean produce food for humans, most of them are also used for fuel and timber. The leguminous species contribute to soil fertility by N-fixation and leaf fall. Outstanding among those is *Faidherbia albida,* also called Winter Thorn, which retains green leaves throughout the dry season, shedding them at the beginning of the rains, allows high light penetration to field crops and pastures under its crown. It is therefore frequently associated with rainfed cultivation in dry areas.

Figure 20.10 shows a mixed farming situation with a parkland component near Ouahiguya, Burkina Faso. It is rainfed cultivation of millet with scattered trees most of which are old fruit trees like the Mango in the picture. In the foreground is a harvested millet field with plenty of cattle droppings. The tree serves as shady resting place for the animals during midday hours. The bottom of the crown forms a straight browseline caused by browsing cattle. In this case the farmer does not own cattle himself, but allows Fulani herders to come in during the dry season for stub-

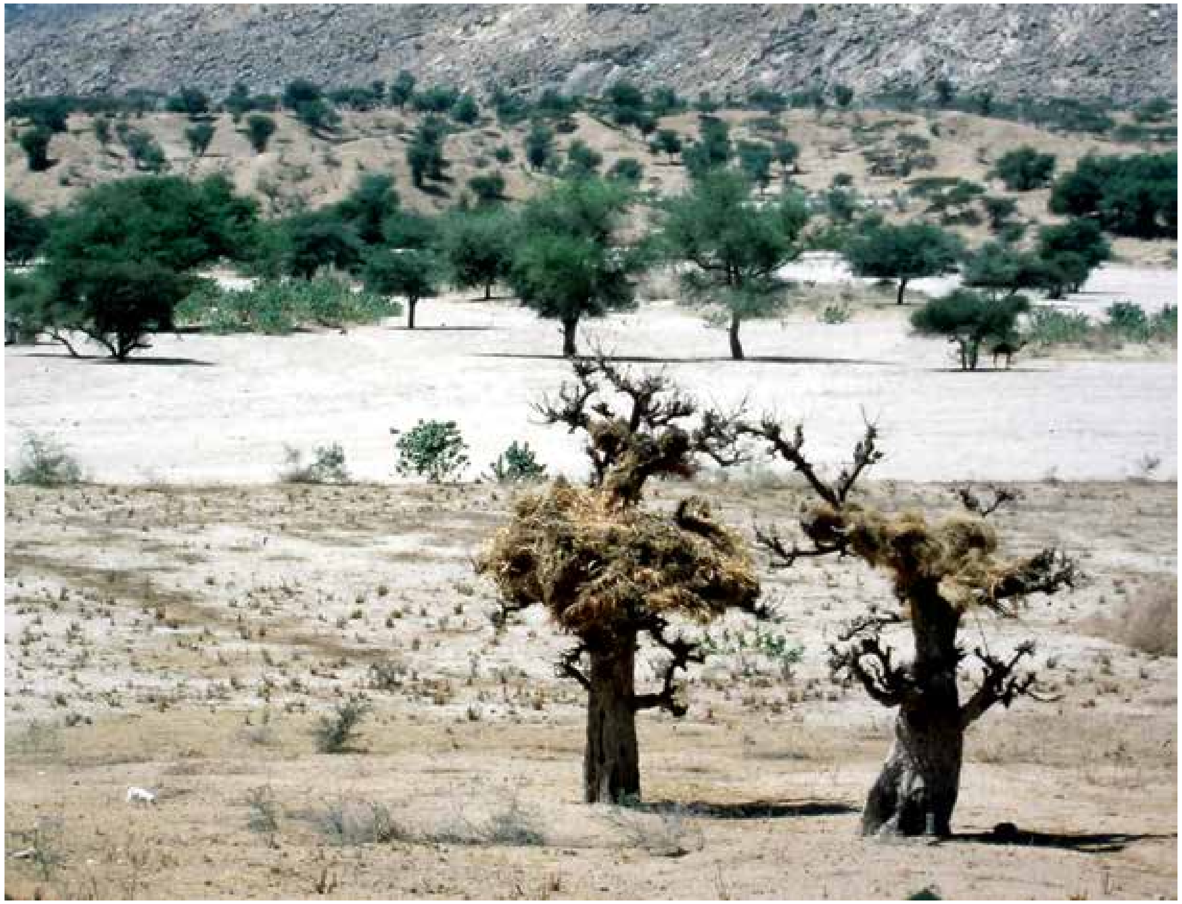

Figure 20.11

Agro-pastoral parkland system in Gash-Setit Province, Eritrea.

ble grazing. He is compensated for this by the manure dropped and is usually given a male calf or two in addition. The herds leave the area going north when the rainy season approaches. As the farmers belong to the Mossi ethnic group this is a good example of inter-ethnic cooperation.

Figure 20.11 depicts a different situation. Here farmers practice flood retreat cultivation of millet on the river bank in the foreground. As the river does not flood every year this is an opportunistic activity, probably carried out in three out of five years. The main livestock in the system are camels (*C. dromedarius*) and goats. Both species can persist on the foliage of the scattered Acacia inside the riverbed and on the opposite river bank due to their dietary preferences and their harvesting capacity. As the ground water table is high, the deep rooting trees carry green foliage through most of the year. This includes years when the rain and consequently the millet crops fail. The Baobab trees in front serve as storage facilities for millet stalks kept as a dry season feed reserve.

Soil Degradation Control Systems

Many soil conserving measures are using trees and bushes as stabilising elements, i.e. terraces, micro water catchments, or contour bunds. Figure 20.12 gives schematic presentation of a rather sophisticated terrace fixation by woody plants. The main elements are trees (1), often easily coppicing fuel wood trees. Upslope of the trees is a row of perennial grasses (2) like Napier, followed again upslope by a creeping legume (3) which may be perennial, and last a row of leguminous forage shrubs (4). Below and above this contour belt annual field crops (5) are planted.

Such design is quite complex and it takes a considerable proportion out of the available cropping area depending on the slope angle. This may be 10 % on mild slopes, where distances between bunds are large, and go up to 30 % on steep slopes, where inter-bund distances need to be shorter. However, with the choice of the right species there are palpable advantages, such as the supply of food, timber and fodder, top soil and water retention, and improved soil fertility. This form of bunding can also be used to rehabilitate badly eroded land as the Figures 20.13 and 20.14 show.

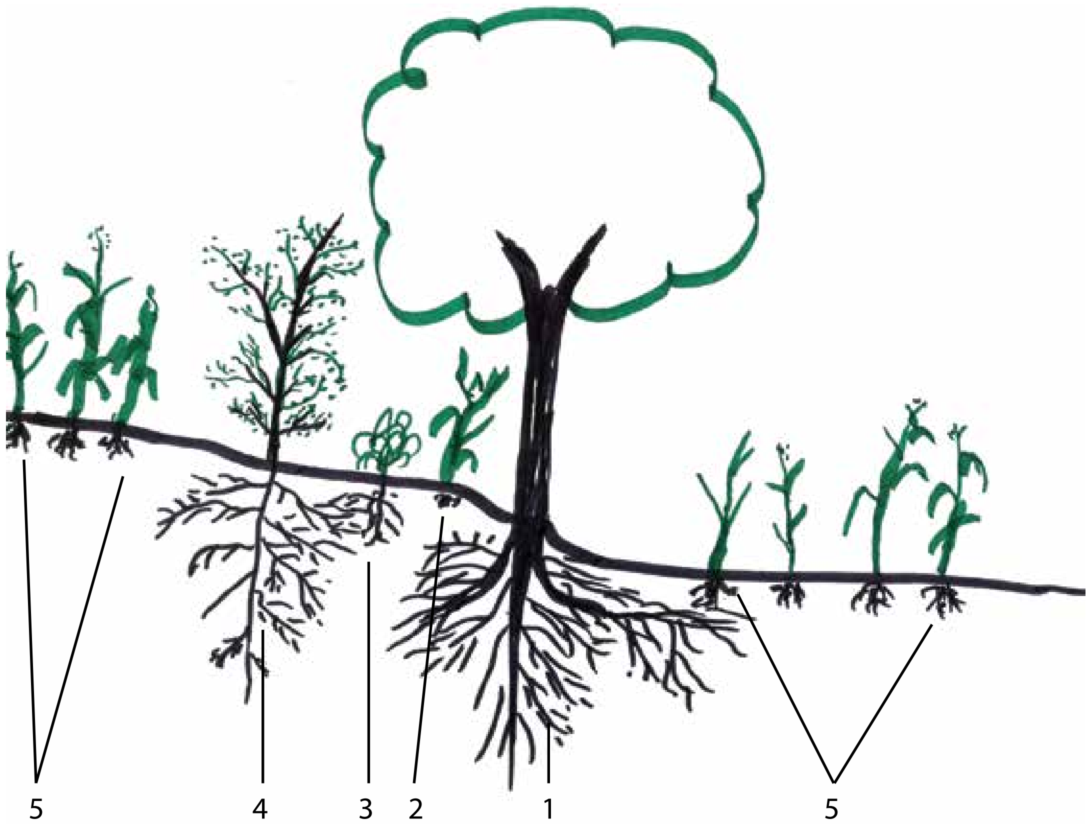

Figure 20.12

Schematic presentation of a contour bund fixation by tiered planting of different plant species.

Figure 20.13

Wide erosion gully with freshly established water and soil retention bund planted with Aloe ssp. and small Acacia seedlings, Nyanza Province, Western Kenya.

Figure 20.14

The same area above four years later, grazing with sheep and cattle, will commence again at controlled stocking rates in the next rainy season.

Woodlots

Woodlots are a system with little integration potential but should be mentioned here as they appear to be in the increase even in smallholder systems. They are a relatively recent introduction featuring *Eucalyptus ssp*., other exotic species and also a few indigenous African trees for timber production on hilltops and steep slopes which would otherwise present an erosion risk. There are also some developments where *Eucalyptus* woodlots are established on high potential farmland as gross income per unit area can exceed income from maize by 200% if the trees are grown for pulp (Oballa et al 2010). Although woodlots can considerably increase on-farm income they are a separate enterprise entity that can progressively become integrated systems.

PROMISES OF AND CONSTRAINTS TO DEVELOPMENT OF TRADITIONAL AND NEWLY INTRODUCED INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS

Promises

The introductions of new integrated crop-livestock-forestry systems in SSA, as well as the improvement of traditional ones are driven by the perspective to combat malnutrition and poverty, to halt and reverse natural resource degradation, to prepare farming communities for the expected climate change, and to increase agricultural production to keep pace with growing populations.

Closing the Yield Gap

Soil nutrient limitations can be alleviated by combining field crops with fertiliser trees in alley farming systems, in parkland systems and in boundary and contour plantings.

It is estimated that there is not a single food crop in SSA which achieves 75% of the attainable yields. This is due to widespread soil nutrient limitations, to limitations of plant available water, or to combinations of both. Nutrient limitations can be alleviated by combining field crops with fertiliser trees in alley farming systems, in parkland systems and in boundary and contour plantings. In particular, leguminous trees have proved precious in this context through N-fixation and leaf drop. Various *Acacia* species, *Faidherbia albida* and *Parkia* species belong to this group. In addition, they produce animal fodder and can be used for timber and fuel. One disadvantage is that their products do not have a very high market value.

Other trees with high market value products as *Mangifera indica*, *Persea americana*, *Anacardium occidentale*, and *Eucalyptus* on the other hand, appear to reduce crop yields in their vicinity.

Sorghum crop with *Acacia saligna* systems were found to have better total water use efficiency than each of the two if cultivated alone (Droppelmann and Berliner 2003). It is most likely that other crop-tree combinations can be found which exhibit similar characteristics.

Rehabilitating Degraded Lands, Soil and Water Conservation

Parkland systems, either cultivated fields or pastures, in SSA have seen a steady decline in tree cover over the past thirty years. As the existing trees are usually protected by the community, the decline is caused by their very low regeneration rate, which in turn is due to high grazing pressure in most areas. The young shoots are invariably eaten by goats and sheep. In many regions of the western Sahel one can see plenty of magnificent mature Baobabs scattered through the landscape but not a single young one. In the past twenty years farmers in Niger started to protect tree seedlings and young shoots and achieved a remarkable success. This was obviously a spontaneous development in the communities as it was observed that yields in "neglected" fields, i.e. fields which had not been carefully weeded and cleared of tree seedlings, were higher than in properly prepared fields. A recent study by the International Fund for Agricultural Development (IFAD) reported by the International Center for Research in Agroforestry (ICRAF), showed that tree cover in the provinces Zinder and Mapadi had dramatically increased yields (Pye-Smith C. 2013). The spontaneous development became formalised as "farmer-managed natural regeneration" system and has led among other benefits, also to increased millet yields from approximately 150 kg/ha to more than 500 kg/ha due to the trees positive effect on soil fertility.

A recent study showed that tree cover in the provinces Zinder and Mapadi had dramatically increased yields.

Other measures include more active rehabilitation as the example shown in Figures 20.13 and 20.14. Of similar importance are water retention measures operating with micro catchments or bunds which are usually stabilised with shrubs or bushes.

Improving Food Security and Farm Income

Food security and farm income can vastly benefit from the inclusion of trees into the farming system. Tree species like *Mangifera indica*, *Persea americana*, and *Carica papaya* not only produce edible fruit, but also high value market products, thus safeguarding regular farm income. Other species like *Eucalyptus* ssp. and *Grevillea robusta* secure high but sporadic income from timber sales. Also the numerous parkland species, either natural or cultivated, deliver many subsistence foods and marketable products to stabilise pastoral and agro-pastoral household economies.

Carbon Trading for Smallholders

One way to motivate small holder farmers to engage in integrated crop-livestock-forestry systems is the promise of carbon trading, i.e. to sell VERs (Verified Emission Reductions) on the carbon market for efforts to sequester carbon in form of woody vegetation on their farms and increased carbon content in the soil. At present this is still in a trial and error phase, but there are numerous projects on-going trying to establish methods and standards which will allow trading with VERs a widely applicable means to remunerate smallholder farmers for environmental services. This chapter is not a platform to discuss the topic exhaustively. A quote from Cullen and Durschinger (2012) must suffice here: "The AFOLU (Agriculture, Forestry and Other Land Use) carbon market is growing at a rapid rate. The demand for land-based offset credits will undoubtedly increase further with changes in the regulatory systems of developed countries, and because there is no other single source that could potentially meet this growing demand. The measurement, permanence, additionality, and risk issues of AFOLU projects will be better understood and managed, and as the market matures numbers of buyers and early investors will increase. Such maturation will occur as quality projects are brought to market, transparent and rigorous standards are applied, ample technical expertise to measure carbon is developed, and adequate financing to initiate projects is efficiently sourced."

Constraints

Land Tenure Issues

According to Dixon et al. (2001) 3% of the total agricultural lands in SSA are tree crop systems, 11% are forest based systems (shifting cultivation), 8% are agro-pastoral (parkland) systems, and 14% are pastoral (partially parkland) systems. Here the integrated systems approach is common by tradition but is frequently not as efficient as it could be. In the remaining approximately two thirds of the agricultural lands inclusion of woody plants into farming systems is less common, often restricted to boundary demarcation in form of hedgerows or trees as live fence posts. Only about 5 to 6% of all lands are under large scale commercial management. The remainder comprehends smallholdings, ranging from 0.5 ha in the high potential western highlands in Kenya to about 20 ha in the semi-arid to arid lowlands in the western Sahel.

Investments into the establishment of woody vegetation components on small farms constitute a barrier for widespread implementation. The legal status of land tenure has a great effect.

Investments into the establishment of woody vegetation components on small farms constitute a barrier for widespread implementation. The legal status of land tenure has a great effect. Norton-Griffiths and Herr (2013) reported an overall decline of tree cover in Western Kenya, with a strong decline of natural tree cover and a gradual increase of managed tree cover. This increase was restricted to adjudicated, i.e. freehold and leasehold land, whereas unadjudicated land accounted for the overall decline. Between 1983 and 2013 the cover declined from 14% to less than 4%. This is explained through reluctance of farmers to make longer term investments in the face of land tenure insecurity. As land grabbing by local and foreign investors is on the increase in most of SSA a reversal of this tendency will be difficult. The ratio of adjudicated to unadjudicated land in SSA differs strongly between countries and regions within countries. However, as a trend, one will find higher proportions of unadjucicated land with declining productive potential.

Farmers' Competence and Extension Services

Land degradation, low soil fertility and lack of quality livestock feed are key problems for farmers throughout sub-Saharan Africa. Agroforestry initiatives can counteract all three very effectively. However, agroforestry and in particular integrated crop-livestock-forestry practices are more complex than many agricultural practices. Farmers' awareness of the possibilities, their skill and knowledge and the availability of extension services are major components in the adoption of such measures. Franzel and Scherr (2002) and Kabwe et al (2009) have reported various studies of factors influencing agroforestry adoption among African smallholder farmers. They confirmed that knowledge of the technology and having the appropriate skills was essential to higher adoption rate. The most obvious deficiencies are skills, establishing tree and shrub nurseries, pre-treatment of seeds, and tree pruning. Furthermore availability of seeds and planting material, as well as a number of household characteristics were strongly linked to the incidence of adoption.

Since, as a rule, several years are required before agroforestry measures generate economic returns, wealthier households are more apt adopting such measures. Female led households are less reluctant to apply soil fertility enhancing agroforestry techniques, whereas male led households show a tendency to rely more on purchased fertilisers. Animal management, especially community based regulation of free grazing to avoid feeding on or trampling of newly planted trees is another crucial point for acceptance.

As a rule, several years are required before agroforestry measures generate economic returns, wealthier households are more apt adopting such measures.

Acceptability of Innovations and Past Experiences

Past experiences with introduced exotic species have created a widely spread aversion against such undertakings. Exotic species have often shown invasive characteristics. Well known and documented are *Prosopis juliiflora* and other *Prosopis* species, *Lantana camara*, and *Opuntia ficus indica*. There are also others like *Leucaena leucocephala* which has turned invasive under certain circumstances despite its' overall usefulness. *P. juliiflora* can be used for animal fodder, human food, fuel, and for environmental services like windbreaks, carbon sequestration, and soil fertility enhancement. In the whole of East Africa it has turned out to be a runaway invasive plant which has colonised large tracts of land in semi-arid and arid regions with relatively high groundwater tables. It outgrows all native species, forming impenetrable thickets, rendering these formerly productive lands completely useless. One of the main reasons was that the varieties introduced into Eastern Africa are unpalatable to livestock and could therefore multiply without any regular off-take (Admasu, D. 2008). It is reported that *P. juliiflora* has infested more than one million hectares of semi-arid grazing lands in Ethiopia rendering them useless as pastures for ruminant livestock.

Another case of contention is Eucalyptus. It was introduced more than 100 years ago into South Africa and was cultivated there in timber plantations. In the past 50 years it was introduced to many other African countries. Eucalyptus species are among the fastest growing woody plants in the world. Eucalypts produce high value timber for pulping and construction. In SSA they are not only planted in large scale commercial plantations but have also been promoted for use in small woodlots, boundary plantings and as scattered single trees on farm. Only 10 to 15 years ago such plantings experienced great expansion. In the meanwhile this expansion has shown that, due to the fast growth, they are using water to such an extent that many water scarce African countries consider a ban for Eucalypt planting and the eradicating of existing trees. Already in 1993 Davidson states that Eucalypts appear to use less water per unit weight of biomass produced than other kinds of trees and many agricultural crops, but their potentially high biomass production under low rainfall conditions may reduce stream flow more than slower growing kinds of trees. In view of the high market value of Eucalyptus products such warnings had been overlooked. Presently the controversy between promoters and adversaries of the fast growing evergreen species has taken an almost ideological twist and Eucalyptus are called colonialists' trees.

SUMMARY AND OUTLOOK

Crop-Livestock-Forestry Integration is a set of agricultural practices combining trees, livestock and agricultural crops. It is an ancient practice but was neglected for many decades during the last century in favour of intensification, mechanisation, and large scale monocultures. Tropical deforestation, land degradation, and growing food insecurity revived the interest in this practice since the 1970s. There are many benefits to be gained from agroforestry and integrated crop-livestock-forestry systems, such as fodder for livestock, timber and fuelwood, environmental services like windbreaks, improved soil fertility, erosion protection, increased biodiversity and lately also carbon sequestration.

Despite these obvious advantages adoption has not been as fast as expected by researchers and development organisations. The reasons for this are manifold:

1. The systems are much more complex than other agricultural undertakings as they have to optimise the management of trees, crops, and livestock simultaneously. This takes more skills than traditional farmers in SSA usually have. Acquiring these skills takes awareness on the side of the farmers and it takes extension services which are prepared for that task.
2. Investing into integrated systems takes a longer time horizon as benefits only accrue after three to five years. This needs more cash and/or resource reserves within the farm household than are available to most African smallholders.
3. Past experiences with introduced exotic species have not always been encouraging. National and international research organisations have failed in the past to generate sufficiently accurate information on appropriate systems applicable to specific circumstances. Applied research with farmers' participation has only recently been recognised as instrumental for the successful adaptation and introduction of sustainable production systems.

However, much has been learned recently about crop-livestock-forestry integration, both through successes and through failures. The potential benefits are clear. They can substitute purchased products, enhance production diversity, and can thus reduce production risk for resource poor farmers. In SSA it needs to become a major approach within the smallholder farming sector for closing the yield gap and improving food security. Large scale commercial enterprises, which presently form only a minor proportion of the land use in SSA, are less prone to embrace this approach, as they lack the commitment to the land.

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Embrapa
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Brazil has pioneered some important agricultural technologies in the world, as the no-tillage system, which allows two harvests a year in many parts of the country. Likewise, Brazilian integrated crop-livestock-forestry systems are somehow unique in the way they operate, especially regarding component's rotation time, investments payback capability for soils recuperation/improvement and revenues diversification, thus helping to stabilize farmer's finances. These systems present several particularities in comparison to other integrated crop-livestock-forestry systems in the world and its local abbreviation – ILPF – which stands for "Integração Lavoura-Pecuária-Floresta" should remind its individuality and innovative features. For this reason, this Brazilian abbreviation will be used many times in this book instead of ICLF. The Brazilian model can run a full cycle in periods as short as four years, including the forestry component. Besides soil improvement, annual crops and cattle sales provide constant cash flow to the farm, while timber brings high financial returns at the end of the cycle, i.e. allowing future investments with farmer's own funds. The Brazilian integrated systems are still under development in several aspects. However, they can be considered mature enough to be presented and tested as an alternative for sustainable farming.

SEVENTH FRAMEWORK PROGRAMME

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