

HANDBOOK ON BIOFUELS

HANDBOOK ON BIOFUELS

AUTHORS

Federico Ganduglia – IICA

ARPEL Biofuels Project Team: José Guillermo León (ECOPETROL); Raúl Gasparini and María Elena Rodríguez (YPF (Repsol YPF Group)); Guillermo José Huarte (ExxonMobil); José Estrada (PETROPERU); Ernani Filgueiras (IBP)

October, 2009

Handbook on Biofuels
ARPEL AFR#6-2009

Interamerican Institute for Agricultural Cooperation
(IICA for Spanish acronyms)
Vázquez de Coronado, San Isidro POB 55-2000
11101 San José, COSTA RICA
Tel.: (506) 216-0222
Fax: (506) 216-0296
E-mail: iicahq@iica.int
Website: www.iica.int

Regional Association of Oil and Natural Gas Companies of
Latin America and the Caribbean (ARPEL)
Javier de Viana 2345
CP 11200 Montevideo, URUGUAY
Tel.: (598-2) 410-6993
Fax: (598-2) 410-9207
E-mail: arpel@arpel.org.uy
Website: www.arpel.org

Authors The present handbook was developed upon request of ARPEL's Refining Committee, by:

Section 1: DOWNSTREAM:

José Guillermo León – ECOPETROL – BPT Leader
Raúl Gasparini and María Elena Rodríguez – YPF (Repsol YPF Group)
Guillermo José Huarte – ExxonMobil
José Estrada – PETROPERU
Ermani Filgueiras – IBP
With the collaboration of:
Carolina Chiozza – YPF (Repsol YPF Group)
Maura Moreira, Mauro Silva – PETROBRAS
Irene Alfaro - ARPEL

Section 2: UPSTREAM: *Developed based on a technical cooperation agreement between ARPEL and IICA, by:*

Federico Ganduglia – IICA
With the collaboration of:
Paula Nieto Alemán – IICA

Acknowledgements Frederico Kremer, Sergio Fontes, Geraldo Diniz - PETROBRAS
Cecília Cascardo – YPF (Repsol YPF Group)
Marcos Benzecry and Luiz Filipe Veiga - ILOS
Emilio Ruz – Regional Specialist in Technology and Innovation IICA and Executive Secretary PROCISUR
Frederique Rosa e Abreu (IICA)
IICA Offices in Argentina, Brazil, Chile, Colombia, Paraguay, Peru and Uruguay.

Copyright The present document's copyright, in its printed version as well as electronic (CD or diskette) or other; belong to the Inter-American Institute of Agricultural Cooperation (IICA) and to the Regional Association of Oil and Natural Gas Companies of Latin America and the Caribbean (ARPEL). Any copy of this document must include this copyright notification. When utilizing this document in future events, the user will grant IICA and ARPEL all credits as source of information.

Disclaimer Although all efforts were made in order to assure the accuracy of the information contained in this publication, nor IICA or ARPEL or any of their members assume the responsibility for any use of the same.

International Number ISBN13: 978-92-9248-120-9

Index

EXECUTIVE SUMMARY	i
1 Reasons for promoting or not biofuels	ii

Section 1: Downstream

2 Biodiesel's technical aspects	1
2.1 General Aspects	1
2.1.1 Process for obtaining biodiesel	1
2.1.2 Raw materials for biodiesel's production	2
2.1.2.1 Conversion of the raw material in vegetable oil	3
2.1.2.2 Chemical transformation of oils into esters	4
2.1.3 Factors that have an influence on the production process	6
2.1.4 Biodiesel's specification	8
2.1.5 Quality assurance by suppliers	11
2.1.6 Possible mixtures guaranteed by engine and automobile manufacturers.	11
2.1.7 Biodiesel performance (B100 and other mixtures)	12
2.1.7.1 Energy content of B100	13
2.1.7.2 Cold properties of B100	13
2.1.7.3 B100 Cetane Number	14
2.1.7.4 Stability of B100	15
2.1.7.5 Iodine Index	16
2.1.7.6 Effects on diesel properties in the mixture of soy biodiesel (Bx)	16
2.1.8 Performance in engines of pure biodiesel and its mixtures with diesel	20
2.1.9 Additives	21
2.1.9.1 Antioxidants	21
2.1.9.2 Flow conditioners	21
2.1.10 Energy and environmental impact analysis of biodiesel's life cycle	21
2.1.10.1 Life cycle's energy balance.	22
2.1.10.2 CO ₂ emissions	23
2.1.10.3 Emissions of particulate matter and CO	24
2.1.10.4 NO _x emissions	24
2.1.10.5 Waste waters and solids.	24
2.1.10.6 Water consumption.	24
2.2 Specific Aspects	24
2.2.1 Disposal of glycerine – alternative uses	24
2.2.2 Bio-Refining: co-processing of vegetable oils or fats in existing refining units	27
2.2.2.1 HBIO in Brazil	27
2.2.2.2 Biocetane in Colombia	28
2.2.3 Second-generation biofuels	29
2.2.4 Biomass	30
2.2.5 Biogas, BTL, GTL	31
3 Logistical aspects of biodiesel's production chain	3
3.1 Introduction	3
3.2 Reception	4
3.3 Storage	5
3.4 Transportation	7
3.4.1 Inconveniences in transportation	8

3.5	Mixture of B100 and diesel	8
3.5.1	Mixture in refineries or terminals	9
3.6	Necessary installations.....	10
4	Environmental, health and safety aspects of biodiesel handling	11
5	Biodiesel's economic aspects	12
6	Regulatory aspects of biofuels	14
6.1	Argentina	14
6.2	Brazil.....	14
6.3	Colombia.....	16
6.4	Peru	17
7	Experiences with biofuels in the region	18
7.1	AGROPALMA Project	18
7.2	Lengthy tests of diesel-biodiesel mixtures	19
7.2.1	Performance of the fuel storage and mixture station	19
7.2.1.1	Design and construction.....	19
7.2.1.2	Optimization of the blender's operation	21
7.2.1.3	Plan for the fuels' quality assurance.....	21
7.2.2	Conclusions	22
7.2.2.1	Design and operation of the fuels storage and mixture pilot plant.....	22
7.2.2.2	Quality control of raw materials and mixtures	23
7.2.2.3	Follow-up to the performance of the buses with diesel – palm biodiesel mixtures	23
7.2.2.4	Revision to the injection system of the buses using diesel – palm biodiesel mixtures	23
7.2.2.5	General results of the oils' tribology analyses.....	23
8	Bibliographical references.....	24

Section 2: Upstream

9	Agricultural activity.....	26
9.1	Overview.....	26
9.1.1	A quick glance towards the concepts of bioenergy and biofuels	26
9.1.2	The configuration process of the biofuels' global chain and agriculture	27
9.1.3	Global tendencies in the use of agricultural feedstocks for biofuels	28
9.1.3.1	Use of feedstocks of immediate availability	28
9.1.3.2	Next biofuels' generations and their raw materials	33
9.2	Characterization and potential of the South American agro-business for the development of biofuels	35
9.2.1	The agriculture and food sector in South America	35
9.2.2	Feedstocks for bioethanol's production	37
9.2.2.1	Immediately available feedstocks.....	39
9.2.2.2	Alternative feedstocks.....	55
9.2.2.3	Lignocellulosic feedstocks.....	67
9.2.3	Feedstocks for biodiesel's production	73
9.2.3.1	Immediately available feedstocks.....	76
9.2.3.2	Alternative feedstocks.....	90
9.2.3.3	Other crops and feedstocks for the production of biodiesel	108
9.2.4	General considerations	113
9.3	Economic, environmental and social aspects of the development of biofuels	115

9.3.1	The biofuels vs. food dilemma.....	115
9.3.2	Biofuels and environmental sustainability	121
9.3.2.1	Agriculture and environment	121
9.3.2.2	Energy and emissions balances of biofuels.....	133
9.3.2.3	Sustainability criteria, certification and initiatives in the production of feedstocks for biofuels	140
9.3.3	Biofuels and social inclusion	145
10	Bibliographical references.....	149

List of Figures

Figure 2.1.1.1:	Outline of the transesterification reaction with methanol	1
Figure 2.1.2.2:	Outline of the productive process of refined oil	4
Figure 2.1.2.3:	Mass balance of the transesterification reaction	4
Figure 2.1.2.4:	Outline of the transesterification process. Reagents and products	5
Figure 2.1.2.5:	Outline of biodiesel's separation and purification processes	5
Figure 2.1.2.6:	Outline of the conditioning process of glycerine phase	6
Figure 2.1.3.1:	Biodiesel production process	6
Figure 2.1.7.5:	Rancimat's Test Scheme	16
Figure 2.2.1.2:	Current applications of glycerine and future proposals	26
Figure 2.2.2.1:	Co-processing of vegetable oils or fats and diesel oil in hydro-treatment units: process scheme	27
Figure 2.2.2.2:	HBIO process scheme	28
Figure 2.2.2.3:	FCCU process scheme	28
Figure 2.2.3.1:	Production cycle of second generation biodiesel	30
Figure 2.2.3.2:	Second generation biofuels from algae	30
Figure 3.1.1.1:	Stages of the study on biodiesel in Brazil (IBP/UFRJ)	3
Figure 3.1.2.1:	Biodiesel production chain	4
Figure 3.2.1.1:	Scheme for the reception of B100	5
Figure 4.1.1.1:	Warning signals for the transportation of B100	11
Figure 7.2.1.1:	External and internal view of the fuels storage tanks and their containers	20
Figure 9.2.3.24:	Potential zone for the cultivation of <i>Jatropha curcas</i>	106
Figure 9.3.2.8:	Agricultural water withdrawals as a percentage of total renewable water resources (1998)	132
Figure 9.3.2.9:	Area equipped for irrigation as a percentage of cultivated land (1988)	132
Figure 9.3.3.1:	Conceptual linkages between the expansion of biofuels and land access	146

List of Tables

Table 2.1.2.1:	Forecast of the main oils used in biodiesel's production	3
Table 2.1.3.2:	Advantages and disadvantages of the main biodiesel transesterification methods	7
Table 2.1.4.1:	Specification limits in biodiesel: purpose, importance and effects of its deviation	9
Table 2.1.6.1:	Recommendations on the use of biodiesel from automobile and engine manufacturers	11
Table 2.1.7.3:	Data of cold flow for different biodiesel	14
Table 2.1.8.1:	Comparison of the emission levels between biodiesel (B100) and diesel	20
Table 2.1.10.1:	Requirement of fossil energy for the diesel oil's life cycle	22
Table 2.1.10.3:	Requirement of fossil energy for the soy's biodiesel's life cycle	23
Table A1.1:	Biodiesel specifications – limit values	1

Table A1.2:	Specifications of biodiesel – test methods	2
Table A2.1:	Quality of diesel 1, mixtures and biodiesel 1	1
Table A2.2:	Cetane Number	1
Table A2.3:	Cold flow	1
Table A2.4:	Quality of the used diesel	2
Table A2.5:	Quality of the used biodiesel	2
Table 3.3.1:	Compatibility of elastomers with biodiesel	6
Table 9.1.1.1:	Criteria to classify biofuels	27
Table 9.1.3.1:	Global consumption of feedstocks for biofuels in 2007 (Thousands of tons)	29
Table 9.2.1.1:	Agricultural Production Index	36
Table 9.2.1.2:	Availability and distribution of the land resource in South America	37
Table 9.2.1.3:	Potentially cultivable land in South America - All crops	37
Table 9.2.2.1:	Feedstocks for bioethanol's production. 2007	38
Table 9.2.2.4:	Sugar cane in South America – Productive and commercial statistics	40
Table 9.2.2.7:	Sugar cane's expansion potential in the region	43
Table 9.2.2.8:	Total production of cereals in South America. 2007	47
Table 9.2.2.11:	Corn in South America – Productive and commercial statistics	48
Table 9.2.2.13:	Grain sorghum in South America – Productive and commercial statistics	53
Table 9.2.2.15:	Cassava in South America – Productive and commercial statistics	56
Table 9.2.2.17:	Composition of some lignocellulosic feedstocks	67
Table 9.2.2.18:	Forest cover in South America	69
Table 9.2.3.1:	Classification of biodiesel production	74
Table 9.2.3.2:	Production of oleaginous seeds and fruits in South America. 2007 (figures in tons)	74
Table 9.2.3.4:	Production of vegetable oils in South America. 2007 (figures in tons)	75
Table 9.2.3.8:	Soybean in South America – Productive and commercial statistics	77
Table 9.2.3.12:	Composition and products of African Palm racemes	84
Table 9.2.3.13:	Oil palm in South America – Productive and commercial statistics	84
Table 9.2.3.16:	Evolution of the production of African Palm in the Andean Region	86
Table 9.2.3.17:	Rapeseed in South America – Productive and commercial statistics	91
Table 9.2.3.20:	Castor in South America – Productive and commercial statistics	97
Table 9.2.3.22:	Composition in dry matter of the components of <i>Jatropha curcas</i>	102
Table 9.2.3.23:	Exploitation of the components of <i>Jatropha curcas</i> L.	104
Table 9.2.3.27:	Tropical oilseeds	111
Table 9.3.2.1:	Common practices in conventional agriculture and its consequences	121
Table 9.3.2.3:	Basic concepts and principles of Conservation Agriculture	126
Table 9.3.2.4:	Conservation agriculture in the world	128
Table 9.3.2.5:	Global availability and utilization of renewable water resources	131
Table 9.3.2.6:	Renewable water resources and agriculture in South America	131
Table 9.3.2.10:	Fossil energy balance of selected fuels	133
Table 9.3.2.11:	Energy balance of the production of biodiesel according to different studies	134
Table 9.3.2.12:	Biofuels' GHG emissions balances (without land use change)	137
Table 9.3.2.13:	Estimated typical and default values for future biofuels that are not or in negligible quantities on the market in January 2008, if produced with no net carbon emissions from land use change	138
Table 9.3.2.14:	RSB, global principles and criteria for the sustainable production of biofuels – “Version Zero”	141

List of Graphs

Graph 2.1.7.1:	Composition of raw materials for biodiesel	12
Graph 2.1.7.2:	Energy content of diesel and different biodiesel	13
Graph 2.1.7.4:	FAME's cetane number of different fatty acids.	14
Graph 2.1.7.6:	Distillation curve of the different mixtures	16
Graph 2.1.7.7:	Density (ASTM D 4052) of the different mixtures	17
Graph 2.1.7.8:	Cetane index and number	18
Graph 2.1.7.9:	Cetane Number	18
Graph 2.1.7.10:	Cetane Number	19
Graph 2.1.7.11:	Cold flow (CFPP)	19
Graph 2.1.7.12:	Cold flow (CFPP)	20
Graph 2.1.9.1:	Oxidation stability vs. additive concentration	21
Graph 2.1.10.2:	Ranking of the demand of fossil energy for diesel oil's production stages	22
Graph 2.1.10.4:	Requirement of fossil energy versus energy in the product for soy's biodiesel's life cycle	23
Graph 2.2.1.1:	Glycerine's price evolution	25
Graph 7.2.1.2:	Follow up of diesel and palm biodiesel temperatures at the moment of fuel-feeding the buses	22
Graph 9.1.3.2:	Feedstocks' consumption for bioethanol production per regional blocks. 2007	30
Graph 9.1.3.3:	Regional blocks share in the consumption of feedstocks for the production of bioethanol. 2007	30
Graph 9.1.3.4:	Feedstocks share in the global production of bioethanol. 2007	31
Graph 9.1.3.5:	Consumption of feedstock for the production of biodiesel per regional blocks	31
Graph 9.2.2.2:	Composition of the South American production of feedstocks usable for the production of bioethanol	38
Graph 9.2.2.3:	Countries share in the production of feedstocks usable for the production of bioethanol	39
Graph 9.2.2.5:	Sugar cane – production share by countries	41
Graph 9.2.2.6:	Evolution of the cultivated area and the production of sugar cane in Brazil	41
Graph 9.2.2.9:	Composition of the South American production of cereals. 2007.	47
Graph 9.2.2.10:	Cereals: production share per countries	47
Graph 9.2.2.12:	Corn: production share per country	48
Graph 9.2.2.14:	Grain sorghum - production share per country	53
Graph 9.2.2.16:	Cassava - production share per countries	56
Graph 9.2.2.19:	Total area of planted forests and annual planting rate in South America	70
Graph 9.2.3.3:	Composition of the South American production of oleaginous seeds and fruits	74
Graph 9.2.3.5:	Composition of the South American production of vegetable oils	75
Graph 9.2.3.6:	Countries' share in the production of oilseeds. 2007	76
Graph 9.2.3.7:	Countries' share in the production of vegetable oils. 2007	76
Graph 9.2.3.9:	Soybean - share in the production per countries	78
Graph 9.2.3.10:	Soybean oil - share in the production per countries	78
Graph 9.2.3.11:	Soybean, sown area and production in Brazil and Argentina 1990 - 2007	79
Graph 9.2.3.14:	Palm - Production share per countries	85
Graph 9.2.3.15:	Palm oil - production share per countries	85
Graph 9.2.3.18:	Rapeseed - production share per countries	91
Graph 9.2.3.19:	Rapeseed oil - production share per countries	92
Graph 9.2.3.21:	Castor - production share per countries	97

Graph 9.2.3.25:	Sunflower production share per countries 2007	108
Graph 9.2.3.26:	Sunflower oil – production share per countries 2007	109
Graph 9.3.2.2:	Wild protected areas in South American countries (Categories I-IV according to IUCN classification) in proportion to national surface areas. 2003	123
Graph 9.3.2.7:	Renewable water resources and projected water withdrawal to 2030	132

EXECUTIVE SUMMARY

The present handbook was developed jointly by ARPEL and IICA with the objective of documenting the best practices of production programs implementation and use of biofuels based on experience, the difficulties and achievements accomplished by the different countries of the region and others. It includes all aspects that make up a sustainable biodiesel production, as well as many issues related to alcohol biofuel, considering all the production chain, from the agricultural stage to the distribution to the final consumer, inclusively. The handbook is divided in two sections: Section 1 – developed by ARPEL – comprises all the productive chain after the agricultural stage; and section 2 – developed by IICA – comprises the agricultural stage exclusively.

Section 1, firstly and objectively establishes the arguments for a country or company to make the decision to undertake biofuels projects or decide to enter this market, from the different points of view or approaches of the oil industry.

Subsequently, it describes various production-specific aspects and biodiesel handling. Based on the specifications, raw materials and available technologies for its production, the condition of the vehicles' fleet and weather conditions of the region, several technical aspects of biodiesel production are analyzed. Subsequently, it describes the precautions, necessary infrastructure and all logistic aspects involved in its handling, pure or mixed, and it provides some general guidelines for the clean and safe handling of biodiesel, its raw materials and by-products. The economic aspects of biodiesel production are also considered since, even though costs and necessary investments are mainly dependent on the local environment and the specific level of the industry's participation in the biodiesel business, it's possible to estimate such costs' and investments' magnitude level, and there are certain general conceptual guidelines that must be taken into account when entering such business. The same aspects developed specifically for biodiesel will also be specifically developed for ethanol in a later stage, and will be attached as annexes to this handbook.

Following, in force laws on biofuels in Latin America and the Caribbean are referred to and analyzed, as a guideline for those countries and companies willing to enter this market. At the end of section 1, the handbook also presents two specific experiences related to biofuels, and intends to be the initial trigger for a future virtual exchange through ARPEL's Portal on learned lessons, case studies, vehicle performance testing, unsuccessful events and causes of the same.

Section 2 "Upstream" concentrates on the agricultural stage of the biofuels chain, from a global and regional perspective, the latter comprising the Southern Cone countries (Argentina, Bolivia, Brazil, Chile, Paraguay and Uruguay) and the Andean Region (Colombia, Ecuador, Peru and Venezuela). This section presents an overview of the biofuels international chain configuration process and a detailed analysis of a selected group of raw materials, considering the particularities and potentialities of their production in the different countries of the region, as well as the advantages, opportunities and limitations of their utilization in the production of biodiesel and bio-ethanol. This section also approaches three critical topics related to the sustainable development of biofuels and its particularities in the region: the alternative between food and biofuel production; the environmental sustainability of agriculture and biofuels; and biofuels consideration from a social perspective.

1 Reasons for promoting or not biofuels

In the last few years, more than in any other moment in history, the world is facing situations that require global solutions and that will somehow mark their future. Due to globalization, any decision in a world's region will impact on the rest. A series of issues like: non-resolved poverty, food, agriculture and food security, climate change, etc. with the current financial crisis in USA and its global effects will surely have delayed solutions.

Biofuels became a solution for many of these problems, especially for reducing greenhouse gases, developing regional agricultural economies and for the independence of the economy based on fossil fuels. Countries and organizations started to regulate their mandatory use in certain percentages and granting subsidies for their production. However, many concerns have arisen globally about the real sustainability of their production when their complete life cycle is analyzed, especially when land use change is considered. A series of studies are being developed in the scientific world, that are yielding different results based on the fact that different bases and calculation proceedings are being used, and also, biofuels' sustainability is being monitored. As a consequence, many organizations are trying to standardize the criteria and mechanisms to calculate the correspondent emissions that would confirm or not these presumptions and would define a sustainable production requirement that is already being generated in European countries. ARPEL supports these standardization efforts.

In this context, even though biofuels production is still reduced considering the total energy demand, the possible environmental and social impacts of their continuous growth must be acknowledged. Agricultural production usually generates certain unexpected negative effects on the earth, water and biodiversity that are especially alarming in relation to biofuels. The increase of agricultural production, if supported on non sustainable processes of the agricultural border expansion – based on deforestation and/or the advance of large scale monoculture – or on intensification processes using conventional agriculture practices, would in general cause negative effects on the earth, air, water and biodiversity. All this, enhances the importance and need of the development and improvement of instruments as territorial ordering or economic-ecologic zoning, as well as of the deployment of good agricultural practices (conservation agriculture), essential elements to mitigate the negative externalities of biofuels production. The following chapters of this handbook examine the repercussions of biofuels on the environment.

Based in the information available on literature, it is not inferred that biofuels themselves may be a total alternative for the energy crisis that the world will face with the expected fall of oil, but that humanity has rediscovered a renewable energetic alternative that can partially respond for part of the energy requirements that must be gradually substituted.

The available scientific information does neither say unequivocally that the energetic balance of biofuels is neutral or positive, but it does show the big or small advantages that the different energetic cultivations and the best production techniques have in this respect in order to increase such energetic balance.

In the field of food security, in spite of the continuous manifestations that associate biofuels with the current relative scarcity and shortage of certain basic agricultural goods, it is not totally conclusive that the same is a main consequence of the recent commercial rise of biofuels, or that the inevitable tendency is to oppose biofuels to world food security. Additionally, the expected production of second-generation biofuels based on cellulose, would end up at least partially in its beginning, with the risk of competence between food and biofuels.



What is evident is that in all previous fields, and in other associated ones, science, academy, industry and those responsible for public policies, must go on advancing in the investigations and studies, preferably in a joint, inter-institutional and interdisciplinary manner, because the last word on technical as well as economic and environmental sustainability topics has not been said yet.

In the face of this situation it will be necessary for the oil industry in Latin America and the Caribbean to focus the attention on all these changes during the biofuels business planning.



SECTION 1: DOWNSTREAM

2 Biodiesel's technical aspects

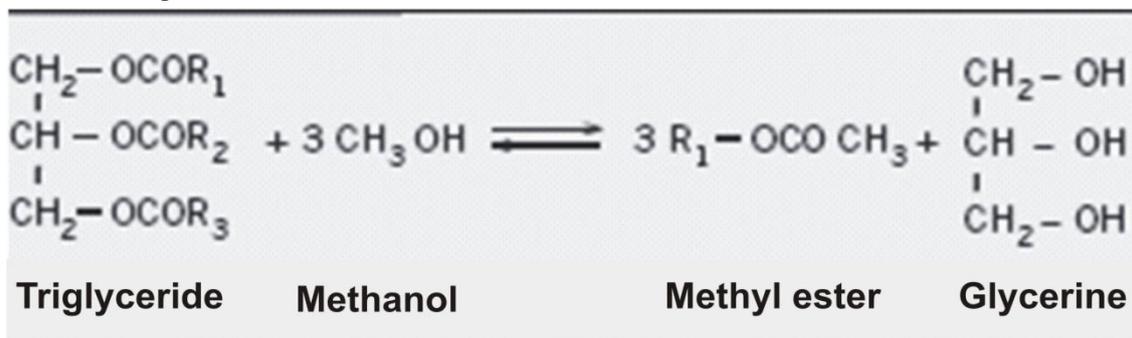
2.1 General Aspects

2.1.1 Process for obtaining biodiesel

The raw material used in the biodiesel's production process is quite varied (different types of vegetable oils and animal fats, reprocessed oils, etc.), making the result of the correspondent chemical reaction a multiplicity of esters of different fatty acids, in varied proportions, all them called biodiesel.

The chemical reaction that has demonstrated to have the best results in obtaining biodiesel is transesterification. It consists on the reaction between a triglyceride (composed by an esterified glycerol molecule by three fatty acid molecules), contained in the vegetable oil or animal fat and a light alcohol (methanol or ethanol), obtaining as products glycerine and esters derived from the three original fatty acids, this is, biodiesel. Methanol is generally used as a substitute alcohol, in which case biodiesel will be composed of methyl esters.

Figure 2.1.1.1: Outline of the transesterification reaction with methanol



Source: ISF 2 Reports. Biodiesel Production. Application to developing countries. 2007

Although methanol has, compared with ethanol, more environmental and manipulation restrictions, there is a tendency to its use due to the following reasons:

1. It is more economical
2. Available and mature technology
3. Less complexity in the process
4. Easier separation of the alcohol/water mixture
5. Smaller volume of recirculating alcohol

Although ethanol has the advantage of being a raw material from a renewable source, its possible utilization in the future, replacing methanol, would necessarily require the development of new technology in order to obtain an efficient and cost-effective process.



2.1.2 Raw materials for biodiesel's production

Even though biodiesel can be obtained from animal fat and used frying oil, the most abundant raw material is vegetable oil. The two necessary stages to obtain biodiesel from vegetable oils are:

1. Conversion of the raw material in vegetable oil
2. Its chemical transformation in ester.

Among the main vegetable oils used are: colza oil, palm oil, soy oil, sunflower oil, jatropha oil, cotton seed oil, canola oil, animal fats and used oils.

The investigation on raw materials is leded mainly by USA, China, Japan, India, Germany and Turkey, who are working especially on soy, colza, sunflower and palm. There is a close relation between the raw material's availability and the publication of scientific articles, since each country is mainly doing researching on the raw material it possesses. Animal fats and cooking oils are also considered important raw materials, and may be the most promissory one is jatropha Curcas.

Since vegetable oils account for 60 to 75% of biodiesel's final cost, permanent research is done in search for lower cost raw materials, such as animal fats and used cooking oil. Another essential factor is the requirement for farmland, the source of each type of raw material. In this sense, jatropha Curcas would have an advantage to some extent, since it is adaptable to unproductive marginal soil, so it would not displace food cultivation.

The United Soybean Board, 2005 carried out a study where prices, incentives, demands and regulations regarding the main oils used to produce biodiesel were evaluated, using as reference four main regions: USA, the EU, Brazil and Others; this last group composed by Malaysia, India, Taiwan, Colombia, the Philippines, Ecuador and considered investigations in Indonesia, Australia and South Africa. As a consequence of this study, the table below shows the production forecast of the three main raw materials (soy, palm and colza).

Table 2.1.2.1: Forecast of the main oils used in biodiesel's production

(in 1,000 metric tons)

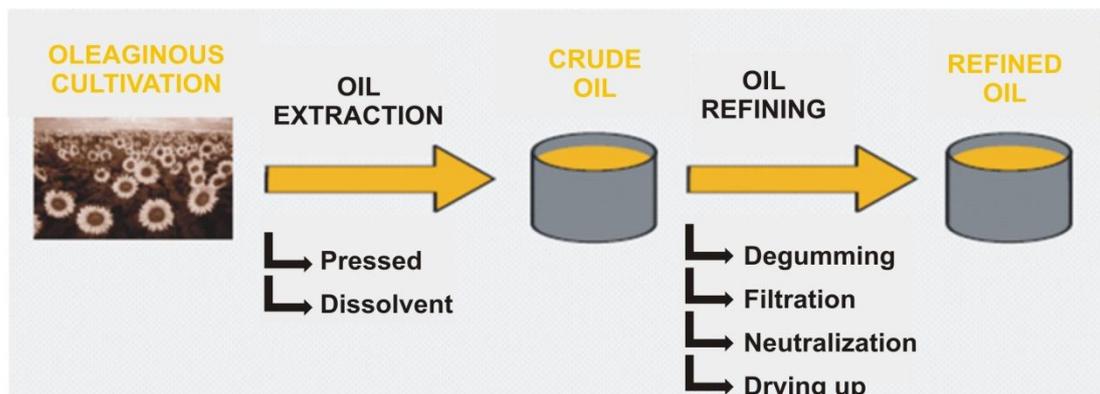
REGIONS	2000	2001	2002	2003	2004	2005	2007	2008	2009	2010	2011	2012
European Union	375	475	875	1375	2000	3200	4860	5440	5970	6500	6750	7000
Colza	350	450	800	1200	1700	2500	3200	3350	3600	3850	3850	3850
Palm			50	100	200	500	1000	1200	1300	1400	1500	1600
Soy				25	50	100	500	700	850	1000	1150	1300
Others	25	25	25	50	50	100	160	190	220	250	250	250
USA	10	20	40	85	125	250	1155	1400	1700	2000	2300	2600
Colza							250	300	300	300	300	300
Palm							75	100	150	200	250	300
Soy	5	15	35	75	115	225	750	900	1100	1300	1500	1700
Others	5	5	5	10	10	25	80	100	150	200	250	300
Brazil				10	15	45	400	550	650	750	825	900
Palm							50	75	100	135	150	165
Soy				5	5	25	300	400	450	500	550	600
Others				5	10	20	50	75	100	115	125	135
Other Countries				25	50	100	425	600	775	900	1000	1100
Colza							25	50	75	100	100	100
Palm				10	20	50	300	400	500	550	600	650
Soy				5	10	20	50	75	100	125	150	175
Others				10	20	30	50	75	100	125	150	175
Total	385	495	915	1495	2190	3485	6690	7840	8895	9950	10875	11600
Colza	350	450	800	1200	1700	2500	3475	3700	3975	4250	4250	4250
Palm	0	0	50	110	220	550	1425	1775	2050	2285	2500	2715
Soy	5	15	35	110	180	260	1450	1925	2300	2725	3350	3775
Others	30	30	30	75	90	175	340	440	570	690	775	860

Source: World Soy Foundation (2005)

2.1.2.1 Conversion of the raw material in vegetable oil

The oil used in the production of biodiesel by transesterification, shall present certain characteristics for the final biofuel to comply with the desired specifications. Thus, raw oil is usually exposed to degumming, filtration, neutralization and drying out. Such procedures depend on the raw oil's nature, obtaining refined oil without suspended solids and with minimal acidity (<1%) and humidity (<0.5%) suitable for its transesterification to biodiesel.

Figure 2.1.2.2: Outline of the productive process of refined oil



Source: ISF 2 Reports. Biodiesel Production. Application to developing countries. 2007

2.1.2.2 Chemical transformation of oils into esters

Once refined oil is obtained, it is usually made to react with a monovalent alcohol as methanol, in presence of a basic catalyst (less demanding pressure and temperature conditions).

Stoichiometrically, the mass yield of the reaction is approximately equal to one; therefore the same mass of biodiesel as initial vegetable oil is obtained. Moreover, the stoichiometry between alcohol and glycerine is similar in mass terms, in principle requiring a quantity of alcohol equal to 10% of oil (in mass).

Figure 2.1.2.3: Mass balance of the transesterification reaction



Source: ISF 2 Reports. Biodiesel Production. Application to developing countries. 2007

The necessary stages for the production of biodiesel from already refined vegetable oils are the following ones: Transesterification reaction per se; and separation and purification of the obtained esters.

The transesterification reaction is made between the oil's triglycerides and a methanol excess, generally in presence of a basic catalyst (usually sodium hydroxide or sodium methylate) at a temperature that often varies between 40 °C and 110 °C. During the transesterification reaction some secondary reactions appear, which generate undesirable products that pollute the esters. These undesirable products, soaps, diminish the reaction's conversion and yield and will cause subsequent purification stages to be necessary.

Figure 2.1.2.4: Outline of the transesterification process. Reagents and products

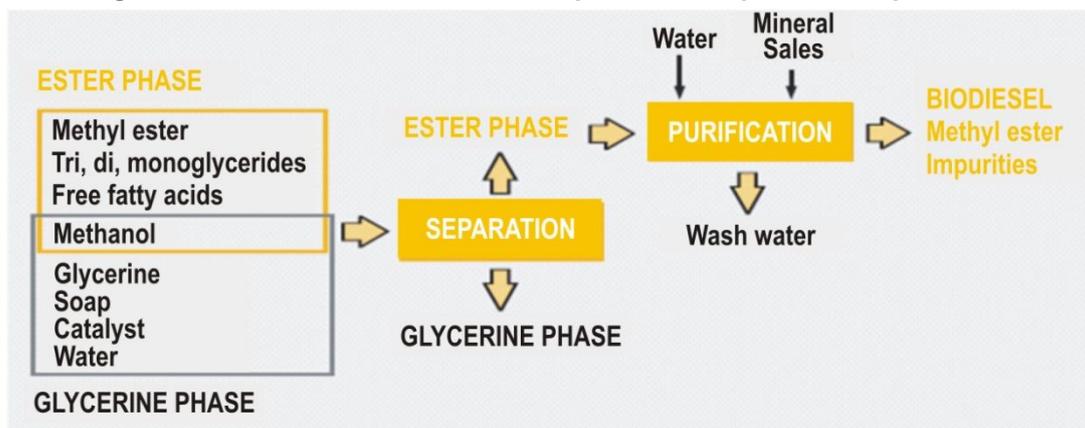


Source: ISF 2 Reports. Biodiesel Production. Application to developing countries. 2007

The following fundamental stage in the process of biodiesel production is the separation of ester and glycerine phases and their subsequent purification.

At the end of the transesterification reaction, various products are found in the reactor. They will have to be separated from the methyl esters or biodiesel. Besides the oil's components that did not react (tri, di, monoglycerides and free fatty acids), there can be found in the medium, the excess of methanol, the rests of the basic catalyst and the secondary reactions' products (soap and water).

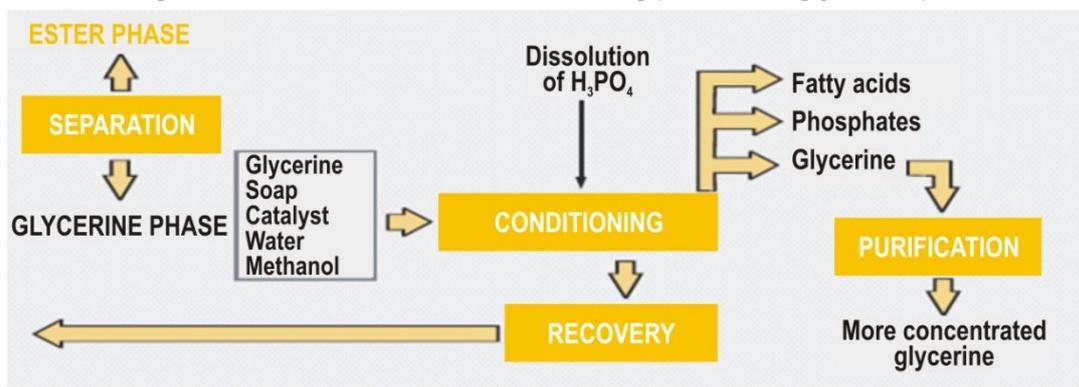
Figure 2.1.2.5: Outline of biodiesel's separation and purification processes



Source: ISF 2 Reports. Biodiesel Production. Application to developing countries. 2007

The last process to obtain biodiesel is esters' purification. In this stage, the excess of alcohol introduced to improve the yield is separated and recovered, and free fatty acids and mono, bi and triglycerides that were not esterified, are cleaned. The glycerine phase will also be purified to obtain a product that may be commercialized.

Figure 2.1.2.6: Outline of the conditioning process of glycerine phase

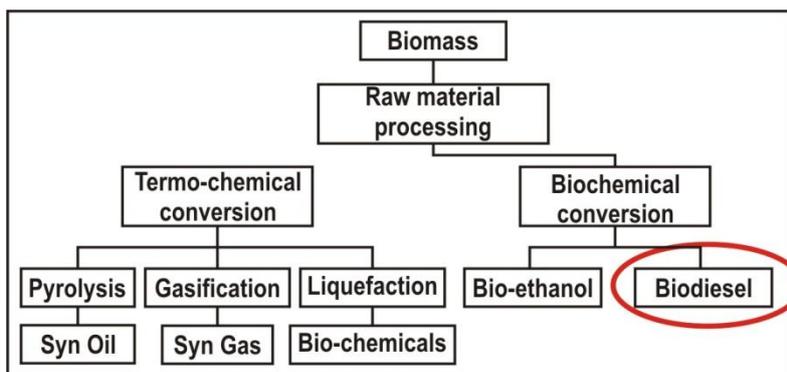


Source: ISF 2 Reports. Biodiesel Production. Application to developing countries. 2007

2.1.3 Factors that have an influence on the production process

The previous section only refers to obtaining biodiesel through transesterification with basic catalysis, the most common way of obtaining it. However, the production process of biodiesel may be framed within the general sequence of biomass' treatment, which is performed by utilizing two types of generic conversion processes: thermochemical and biochemical, which are outlined in a simplified manner, in the diagram below.

Figure 2.1.3.1: Biodiesel production process



Source: "Technological Surveillance Report" COLCIENCIAS Colombia.

As previously stated, biodiesel is mainly produced through the transesterification process, which is considered as a biochemical conversion process, and its raw material is essentially composed of vegetable oils, represented as biomass in the previous diagram.

Transesterification can be produced by alkaline catalysis, acid catalysis, and lipase and alcohol catalysis in supercritical conditions. The mostly used methods are alkaline and acid catalysis. The following table summarizes the advantages and disadvantages of the main processes of biodiesel production by transesterification.

Table 2.1.3.2: Advantages and disadvantages of the main biodiesel transesterification methods

	Advantages	Disadvantages	Characteristics of the transesterification
Alkaline catalysis	<ul style="list-style-type: none"> • Technology most used commercially • Moderate pressure and temperature conditions • Conversions obtained in a reaction time of aprox. 60 minutes. 	<ul style="list-style-type: none"> • It requires the oil and alcohol to be anhydrous and to limit the amount of free fatty acids in the input in order to avoid the creation of soaps. 	<ul style="list-style-type: none"> • Marked quantity of unitary operations for products' separation. • Reaction under atmospheric conditions • Requires alkaline catalyst.
Acid catalysis	<ul style="list-style-type: none"> • Used in oil's adequacy (esterification of free fatty acids with methanol). • It can process raw materials with high content of free fatty acids (animal fats and used oils). 	<ul style="list-style-type: none"> • Reaction times are much slower in comparison with alkaline catalysis. 	<ul style="list-style-type: none"> • Used as a pre-esterification process before carrying out such process through alkaline catalysis. • Requires the usage of acid catalyst.
Lipases catalysis	<ul style="list-style-type: none"> • The reaction is neither affected by the presence of water in the raw materials nor by the content of free acids. 	<ul style="list-style-type: none"> • Reaction times are high, so they cannot be continuous processes. 	<ul style="list-style-type: none"> • Organic solvents are used as reaction mediums, because they improve reactivity and provide the possibility of reutilization. Alcohol is added per stages, to avoid inhibition.
Supercritical alcohols	<ul style="list-style-type: none"> • Low reaction times. • Raw materials with large amounts of free fatty acids and water can be processed • The usage of a catalyst is not necessary. 	<ul style="list-style-type: none"> • High costs due to the conditions of the reaction at high temperatures and pressures. 	<ul style="list-style-type: none"> • High temperatures and pressures are used.

Source: *Technological Surveillance Report- COLCIENCIAS- Colombia*

Additionally and significantly, there are already processes in the market that use the heterogeneous catalysis. Even though these catalysts require more severe pressure and temperature conditions compared with homogeneous catalysis, they offer other advantages, mainly: greater conversion, better quality glycerine, simple separation and purification stages, without the consumption of chemical products and the production of other phases. Pyrolysis has been under development not long since, as an interesting alternative and its massive use will evolve according to the lowest processing costs.

From the table it can be deduced that there is certain relation between the available raw material and the method to use for the transesterification process; thus, authors *Marchetti* and *Demirbas* indicate that, even though animal fats and used cooking oils are more economical raw materials, they present the inconvenient of a high content of fatty acids that cannot be converted into biodiesel through an alkaline catalyst. According to these authors, in order to use the **alkaline catalysis** method, the used oils could come from any vegetable, such as corn, canola, peanut, sunflower, olive or palm. For **acid catalysis**, the type of alcohol and oils are the same as for alkaline catalysis; **lipase catalysis** is applicable to vegetable and animal oils, whereas for the **supercritical alcohol** method they do not define a specific raw material.

There are two important factors that influence the process of biodiesel production: the type of catalyst and the type of process (discontinuous, semi-continuous and continuous). The types of catalysts were shown in the previous table. Regarding the type of process, there are the discontinuous, the semi-continuous and

continuous processes. Evidently, the discontinuous process (per batches) is the most appropriate one for small productions, it is also more flexible to process multi-oleaginous raw material. On the contrary, for large productions, (>50,000 tons/year) the continuous process is generally used because it is more economical, even though it has greater technical difficulties of operation and start-up. Another determining element, besides the production's size, is the availability and quality of the raw material; therefore, the continuous operation is more convenient for feedings of a raw material with a certain assured quality.

2.1.4 Biodiesel's specification

Biodiesel's specifications have been implemented in many countries around the World; USA has adopted the ASTM D 6751 regulation, Europe regulation EN 14214 and Brazil regulation ANP N° 7/08. These standards have arisen from the consensus of relevant groups that have participated in their creation, such as: vehicle, engine and injection equipment manufacturers, refining companies, biofuels' producers, government's representatives and biofuels' consumers.

Not all regulations specify values for the same properties. Annex 1 shows biodiesel specifications according to the aforementioned regulations, and other referential regulations at regional level.

The ASTM specification defines biodiesel as a fuel composed of mono-alkyl esters of long chain fatty acids, derived from vegetable oils or animal fats. Unprocessed vegetable oils and animal fats do not comply with biodiesel specifications. Moreover, the ASTM specification is for the biodiesel that will be mixed with diesel of fossil origin in a 20% proportion or less, and it should not be considered as a pure biodiesel (B100) specification, that could be commercialized as a fuel itself. In USA, any biodiesel used for a mixture shall comply with ASTM D 6751 previously to the mixture.

The European regulation EN 14214, establishes the specification of fatty acid methyl esters (FAME) for diesel engines. In contrast with ASTM D 6751, the B100 that complies with this standard could be purely used in a diesel engine (if the engine has been adapted to operate with B100) or mixed with diesel, to produce a mixture that complies with EN 590, the European specification for diesel. Mixtures of up to 5% of FAME (B5) are allowed and the resulting mixture is considered as a normal diesel defined by EN 590 without requiring special clarifications in the service station's pumps. EN 14214 is more restrictive and only applies to biodiesel produced with methanol. It also demands a minimum esters content of 96.5% and it does not allow adding other components different from fatty acid methyl esters, except for additives.

The European regulation EN 14214, presents a greater level of demand in biodiesel's quality than the US regulation ASTM D 6751, which is manifested mainly in the control levels established for acidity, oxidation stability, cetane number and content of certain by-products of the transesterification reaction, such as methyl-esters and glycerides. Likewise, it includes the control of residuary methanol from the production process and a narrower viscosity range.

Probably, this greater demand of the European regulation is associated mainly with the concept of using pure Biodiesel B100 in certain engines conditioned for such aim, while the US regulation considers its usage only to be mixed with diesel oil.

The following table describes the purpose and importance of biodiesel's properties, as well as the effects caused by deviations regarding the specified limits.

Table 2.1.4.1: Specification limits in biodiesel: purpose, importance and effects of its deviation

Property	Purpose / importance / possible effects of deviation from specification
Ester (min.)	Values inferior to the specification indicate incomplete reaction/ oil presence. It will cause high viscosity, reduction of the spray effect, increase of slack, deficient combustion.
Density (15°C)	It depends on the oil line and transesterification process. A low value indicates a remanent alcohol excess.
Viscosity (40°C)	Satisfactory fuel's combustion. The viscosity's value must be at the same level as conventional diesel. Greater viscosity values than diesel shall be avoided; however, a viscosity tending to the specification range's lowest value could result being advantageous for engines requiring less power in the injection pump and in the injectors exit. Low values indicate a methanol excess. High values indicate thermal and oxidative degradation, presence of non-reacting oil and they can cause problems in the injectors and pump system. It shortens the engine's life cycle.
Flash point (min.)	Safety against fires. It is used as a mechanism to limit the level of non reacting alcohol that remains in the terminated biodiesel. Normally, biodiesel's flash point is greater than that of diesel. A low value may cause manipulation, transportation and storage problems.
Sulphur	To protect the catalytic system of the exhaust. Biodiesel generally contains less than 15 ppm of sulphur. It is recommended to use the test method ASTM D 5453 with biodiesel. Using other test methods may provide wrong results when analyzing B100 with extremely low sulphur levels (less than 5 mg/kg.). A high value would indicate the biodiesel's pollution and would cause greater emissions of SO ₂
Cetane Number (min.)	Good engine's performance, it is a measure of the quality of the fuel's ignition and of the combustion process. The requirements of cetane number depend on the engine's size and design, the nature of the speed and load variations and the atmospheric conditions. It depends on the biodiesel's raw material and oxidation level. A low value indicates little tendency to self-ignition and would cause a greater amount of depositions in the engine and greater pistons wear.
Water	An excess of water in biodiesel may cause hydrolysis problems (appearance of free fatty acids).
Water and sediments	Prevent corrosion and proliferation of organisms. Established at the same level of conventional diesel. An excess of water may cause corrosion and provide a propitious environment for the proliferation of micro-organisms. Oxidation may increase the level of sediments: Therefore this analysis shall be used together with that of the acid number and viscosity in order to determine to which extent the fuel oxidized during its storage. An excess of water may cause hydrolysis problems (appearance of free fatty acids). The presence of sediments/pollution depends on unsaponifiables in the raw material and the production process. A high value indicates the presence of unsaponifiables, soaps and mechanical impurities. The first leave residues in the engine because they have a greater evaporation point, soaps cause sulphated ashes, and mechanical impurities obstruct filters.
Copper corrosion strip	Indicates difficulties with the vehicles' bronze, tin or copper components. The presence of acids or compounds with sulphur may deteriorate the copper strip, thus indicating the possibility of a corrosive attack. High values would cause corrosion problems during the storage and to the engine.
Methanol	Depends exclusively on the production process. Methanol remanent cause low ignition temperature, viscosity and density, and corrosion to aluminum and zinc pieces.
Free glycerine	Good performance at low temperatures. The total glycerine comprises free glycerine and the portion of glycerine from oil or fat without reacting or partially reacting. Low levels of total glycerine assure a high conversion of the oil or fat towards its mono-alkyl-esters. The free glycerine amount depends on the production process. A high value indicates bad biodiesel's decantation and washing, and causes an increase in the emissions of aldehydes and acrolein. High levels of mono-, di- and triglycerides and of free glycerine may cause depositions in the injectors and adversely impact on the operation in cold climates causing filters' plugging.
Total glycerine	

Property	Purpose / importance / possible effects of deviation from specification
Iodine index / number	Depends exclusively on raw material and quantifies the unsaturation level. High values indicate a great presence of double bonds that favor the polymerization and hydrolysis processes.
Acidity index	Protects the engine. Used to determine the level of free fatty acids or process acids that may be present in biodiesel. A large number of acids may cause an increase in biodiesel's degradation, an increase in the formation of depositions in the injection systems and the probability of corrosion.
Alkaline (Na+K) and Group II (Ca+Mg) metals	Their presence depends on the production process. Metals cause depositions and catalyze polymerization reactions. High values of (Na + K) indicate catalyst's remanents. High values of (Ca + Mg) indicate presence of insoluble soaps.
Cold soak filterability	To determine, by means of the filtration time after a low temperature treatment, the adequate operability of B100 to be mixed with diesel in cold conditions, as a minimum in the cloud point. Some substances that are soluble or apparently soluble in biodiesel at room temperature, separate from the solution under cooling or when remaining at room temperature for a long time. These substances may cause filter plugging. This trial method provides a fast means to measure the tendency of these substances to plug filters. The higher the values of filtration time, the greater the possibility of filter plugging and the greater the operability problems at low temperatures.
Total pollution	Idem sediments in "Water and Sediments"
Carbon residue	Protects the engine. Measures the tendency to form carbon deposits generated by an oil distillate; although it does not have a strict direct correlation with engine depositions, this property is considered simply as an approach in this respect. Depends exclusively on the transesterification process. A high value indicates a high content of glycerides, presence of metals (soaps, catalyst remanents) or other impurities.
Sulphated ashes	Satisfactory fuel's combustion. The materials that form ashes may be present in biodiesel in three ways: (1) abrasive solids, (2) soluble metallic soaps and (3) non removed catalysts. Abrasive solids and non removed catalysts may damage the injectors, filters and injection pump, outwear the pistons and rings and leave depositions in the engine. Soluble metallic soaps have little effect on the wastage but may damage the packing, contribute to plugging the filters and generate depositions in the engine.
Oxidation stability (at 110°C)	Its value depends on the raw material and the production process. It enables the use of additives in order to improve this parameter. A low value indicates degraded original oil, or biodiesel's degradation in the process. A time inferior to the specified would not assure the biodiesel's stability during its storage and distribution.
Methyl ester linolenic acid	Depends on the raw material (content of C18:3). High values cause low Cold Filter Plugging Point (CFPP) value, low cetane number and high iodine index.
Monoglyceride and diglyceride	Depends on the process. Indicates incomplete reaction since they are oil remanents that have not finished reacting. High values cause depositions (injectors, cylinders) and crystallization (they have a greater melting point and low solubility in biodiesel).
Triglyceride	Depends on the process. A high value indicates presence of non-reacting oil or fat. It will cause high biodiesel viscosity and deposition in cylinders and valves.
Poly-unsaturated methyl ester (≥4 double bonds)	Depends on the raw material (methyl-ester content with 4 or more double bonds). High values favor the polymerization processes that cause depositions and deteriorate the lubricating oil.
Phosphorus	Prevents damages on the catalytic converter. Phosphorus may deteriorate the emissions control systems and the treatment of exhaust gases, reason why its content must be low. High contents would indicate a bad blanketing of the original oil and presence of unsaponifiables.
Eq. atmospheric temp. (90% R)	In order to assure that the biodiesel has not been polluted with high boiling point materials, such as worn out lubricating oils.
Cloud point	Good performance at low temperatures. Defines the temperature at which a cloud or cloudy crystals appear in the fuel, under expected test conditions. Operation problems in cold climates.

Property	Purpose / importance / possible effects of deviation from specification
CFPP	CFPP value is an indicator of the operability limits. This value depends on the raw material and the production process (mechanical impurities).

2.1.5 Quality assurance by suppliers

In order to assure the correct functioning of the fuel in the vehicles, it must comply with the correspondent specifications that must be certified by the supplier. When the fuel is obtained as from the mixture of two different fuels, as in the case of the diesel-biodiesel mixture, there would be quality specifications for the mixture and for the fuels that compose it. Oil companies acquiring biodiesel to mix it with the diesel they produce, shall demand the biodiesel's producer to comply with the correspondent quality specifications.

Large biodiesel producers generally may access to a quality certification through some internationally-recognized entity (for example: ISO) and through a contract may assure the produced biodiesel's quality. However, it may also happen that the government demands oil companies to acquire biodiesel from small non-certified producers. In this case, the buyers should assure the biodiesel's quality by performing themselves quality controls in plant and sealing the controlled product that will after be delivered to them. It is recommendable for the oil company to create a plan for the development of reliable suppliers, which will support the continuous improvement of the same and assure the biodiesel's quality in a simple and sustainable way in the long term.

2.1.6 Possible mixtures guaranteed by engine and automobile manufacturers.

In Europe, some producers allow the use, in some vehicles, of B100 or B30 fuels, but most vehicles are approved only to use a diesel that complies with EN 590, which by definition can contain up to a maximum of 5% of FAME in the mixture. Producers have expressed their concern about the possibility of increasing the percentage of FAME mixture up to 10% due to compatibility problems of that fuel with the existent fleet of vehicles and the potential increase of emissions. In USA, the position of most automobile manufacturers is that biodiesel's mixture up to a 5% (and in some cases up to 20%) is acceptable as long as they comply with D 6751. Moreover, the *American Trucking Association* has also approved the use of B5. Many are the concerns about quality and stability of mixtures of more than 5%. Table 2.1.6.1 summarizes the position of engine and vehicle manufacturers regarding biodiesel's use.

Table 2.1.6.1: Recommendations on the use of biodiesel from automobile and engine manufacturers

Manufacturer	Position
Engine Manufacturers Association (EMA)	B5 is acceptable if it complies with ASTM D 6751
Caterpillar	Many engines approved for B100; for others only B5 is acceptable. It shall comply with ASTM D 6751
Cummins	All engines approved for B5. It shall comply with ASTM D 6751
DaimlerChrysler	B5 is acceptable for all vehicles but it must comply with ASTM D 6751
Detroit Diesel	B20 is approved for all engines/vehicles but it shall comply with diesel specifications.
Ford	B5 is acceptable for all vehicles but it must comply with ASTM D 6751 and EN 14214
General Motors	B5 is acceptable for all vehicles but it must comply with ASTM D 6751
International Truck and Engine	B20 is acceptable for all engines but it must comply with ASTM D 6751

John Deere	B20 is acceptable for all engines but it must comply with ASTM D 6751
Volkswagen	B5 is acceptable for all engines, but the fuel shall have a quality standard (ASTM D 6751 or EN 14214)
Manufacturers of fuel injection equipments	Position
Bosch	B5 is acceptable for all vehicles but it must comply with EN 14214
Delphi	B5 is acceptable for all vehicles but it must comply with ASTM D 6751
Stanadyne	B20 is acceptable for all vehicles but it shall comply with ASTM D 6751

Source: IFQC Biofuels Center. See also NBB fact sheet “Standards and Guarantees” available in http://77biodiesel.org/resources/fuelfactsheet/standards_and_warranties.shtm

2.1.7 Biodiesel performance (B100 and other mixtures)

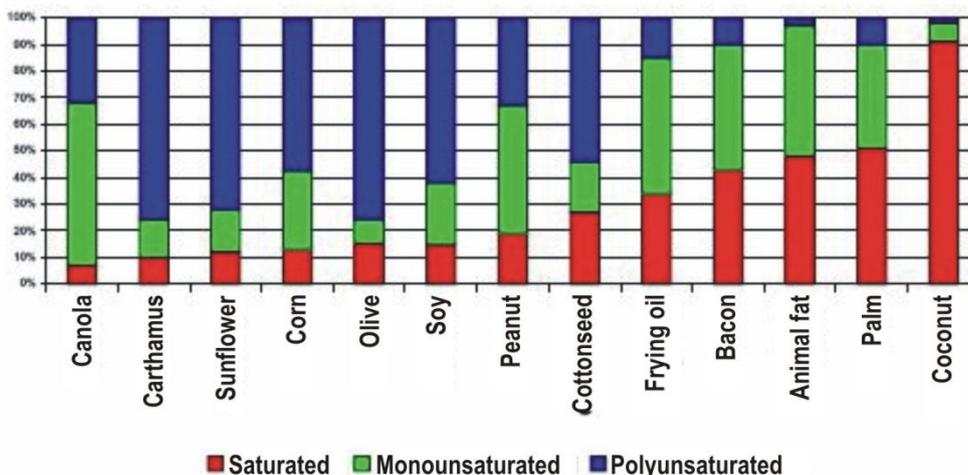
Biodiesel may be produced commercially as from a wide range of fats and vegetable oils:

- Vegetable oils: soy, sunflower, palm, castor, colza, jatropha curcas, corn, etc.
- Animal fats: cow tallow, buffalo tallow
- Recycled frying oil.
- Micro-algae oils

Animal fats and vegetable oils listed above are composed by the 10 most common fatty acids, which have between 12 and 22 carbon atoms, with 90% of them of about 16 and 18 carbons. Some of these fatty acid chains are saturated, while others are monounsaturated and others polyunsaturated. Within the specifications’ limits, the different levels of saturation may impact on some of biodiesel’s properties.

What makes each available raw material different from the other is that in their composition they have different proportions of saturated, monounsaturated and polyunsaturated fatty acids (Graph 2.1.7.1). A “perfect” biodiesel should be formed only by monounsaturated fatty acids.

Graph 2.1.7.1: Composition of raw materials for biodiesel



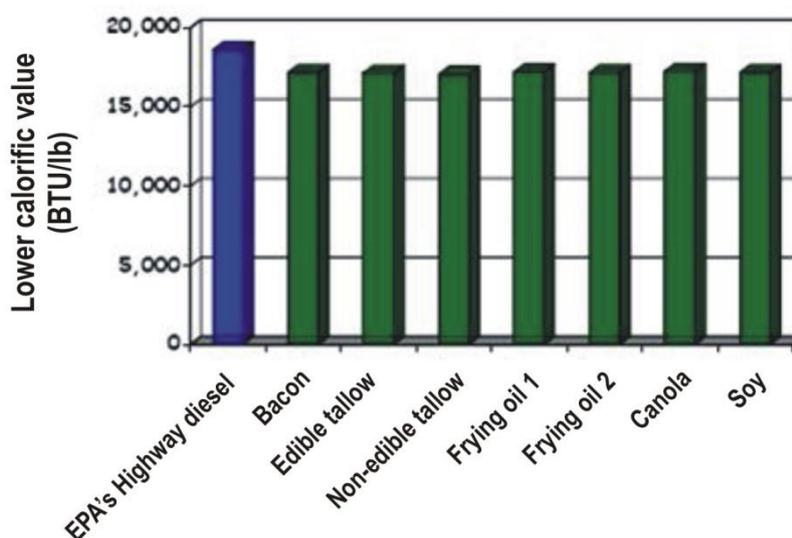
Source: United States Department of Energy. Energy Efficiency and Renewable Energy. Biodiesel – Handling and usage guideline 2004.

Oils with a greater proportion of unsaturated fatty acids in their composition (sunflower, soy, olive) result in a biodiesel with a lower number of cetane, less stability (higher Iodine Index) and less freezing temperature (better cold properties). Likewise, oils with a greater proportion of saturated and monounsaturated fatty acids (palm, coconut, animal fat) result in a biodiesel with a large number of cetane, good stability and higher freezing temperatures (worse cold properties).

2.1.7.1 Energy content of B100

Biodiesel's or B100's energy content does not vary significantly as regards fossil diesel (Graph 2.1.7.2). This is caused by the fact that the energy content of the fats and oils used in the production of biodiesel does not vary substantially regarding the components used to produce fossil diesel. Therefore, the B100 obtained as from most of the available raw materials will have the same impact on fuel economy, power and torque than a conventional diesel.

Graph 2.1.7.2: Energy content of diesel and different biodiesel



Source: United States Department of Energy. Energy Efficiency and Renewable Energy. Biodiesel – Handling and usage guideline 2004.

2.1.7.2 Cold properties of B100

Cold properties of biodiesel and conventional diesel are extremely important. In contrast with gasoline, both fossil diesel and biodiesel may start to freeze as the temperature of the environment decreases. If this happens, fuel filters may be obstructed, maybe reaching a total plugging and making the fuel normal supply for the engine's functioning to stop. There are three tests used to assess the cold properties of fuels for diesel engines: Cloud point, CFPP and pouring point or flow point.

Cloud Point: Temperature at which the first small paraffin crystals are observed, as the fuel is cooled.

Cold Filter Plugging Point (CFPP): Temperature at which enough quantity of crystals have agglomerated so as to produce a plugging in the fuel filter. It is a less conservative test than the cloud point and for many it is the best indicator of operability at low temperatures.

Pouring Point: Temperature at which the fuel has so many agglomerated crystals that the fuel’s normal flow is no longer possible.

Biodiesel’s cold properties will depend on the origin of the raw material used to produce it. The higher the saturation level of the fatty acids present in its composition, the worse its performance at low temperatures (greater unsaturation, better performance).

Table 2.1.7.3 shows some examples of cloud points, pouring points and CFPP of B100 obtained from different raw materials.

Table 2.1.7.3: Data of cold flow for different biodiesel

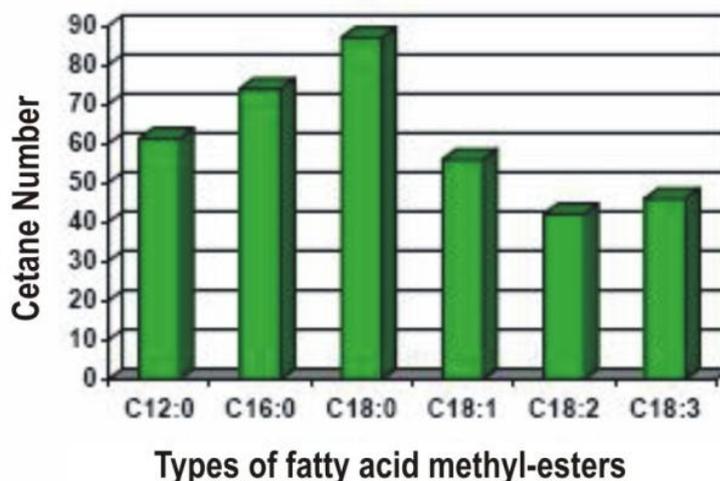
Test method	Cloud Point ASTM D 2500		Pouring Point ASTM D 97		Cold Filter Plugging Point IP 309	
	°F	°C	°F	°C	°F	°C
B100 fuel						
Soy methyl-ester	38	3	25	-4	28	-2
Canola methyl-ester	26	-3	25	-4	24	-4
Bacon methyl-ester	56	13	55	13	52	11
Edible tallow’s methyl-ester	66	19	60	16	58	14
Non-edible tallow’s methyl-ester	61	16	59	15	50	10
Frying oil 1 methyl-ester	--	--	48	9	52	11
Frying oil 2 methyl-ester	46	8	43	6	34	1

Source: United States Department of Energy. Energy Efficiency and Renewable Energy. Biodiesel – Handling and usage guideline 2004.

2.1.7.3 B100 Cetane Number

Biodiesel has a greater number of cetane than most fossil diesels. Highly saturated biodiesel, as that coming from animal fat and recycled frying oil processing, may have a cetane number of 70 or more. On the other hand, biodiesel of unsaturated base, containing high levels of C18:2 and C18:3 fatty acids, where soy, sunflower and colza are included, will have a much lower cetane number – about 47 or slightly more. Graph 2.1.7.4 shows biodiesel’s cetane numbers of different types of fatty acids.

Graph 2.1.7.4: FAME’s cetane number of different fatty acids.



Source: United States Department of Energy. Energy Efficiency and Renewable Energy. Biodiesel – Handling and usage guideline. 2004

2.1.7.4 Stability of B100

Stability has to do with two very important issues related with the fuel: aging (or stability loss) during long terms of storage of the same; and stability at high temperatures and/or pressure during its usage on the engine. The former is normally called “oxidation stability” and the latter “thermal stability”.

Thermal stability is an indicator of the fuel’s degradation when the same is subject to high temperatures for a short period of time, the same it would experience in a fuel’s injection system of a modern diesel engine. The available data indicate that B100 has a good thermal stability. Field-test data have demonstrated that biodiesel produces less coke residues in the engines’ injectors than conventional biodiesel.

The US Regulation (ASTM D 6751) does not directly specify stability, not for fossil diesel or for biodiesel. The European Regulation (EN 14214) does specify it as such. However, biodiesel’s aging or oxidation may lead to high acidity degrees, high viscosity and formation of gums and sediments that plug filters. If these properties exceed the limits permitted by ASTM D 6751, B100 is considered out of specification and should not be used as fuel.

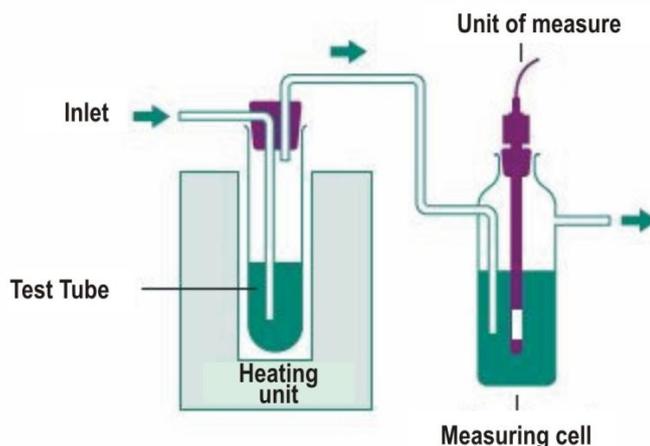
Some features that may help to identify conditions that may derive in the fuel’s stability problems are listed below:

1. The higher the saturations level of the original raw material, the higher the probability of the fuel’s oxidation. As a general rule, saturated fatty acids (such as 16:0 or 18:0) are stable. As the unsaturation level increases (for instance from 18:1 to 18:2 and 18:3) the fuel’s stability is noticeably reduced. Solar heat and light accelerate this process.
2. Certain metals or alloys such as copper, tin, bronze, lead, pewter and zinc, accelerate the degradation process and form high levels of sediments. B100 should not be stored for long periods in recipients made of these metals.
3. Maintaining biodiesel out of contact with oxygen reduces or eliminates the fuel’s oxidation and increases the storage period. This is achieved by using nitrogen seals in storing tanks (Blanketing).
4. The usage of additives may help to increase the stability of B100.

There is not much experience in the storage of B100 for periods of more than six months; therefore should it be necessary to store it for periods of more than six months, antioxidants should be used in order to avoid the product’s quality failure. The antioxidant’s addition should be made in the moment of the production; the minimum time possible should pass up in order to optimize its effect.

The Rancimat test is the most commonly used method to measure biodiesel’s oxidation stability. This test consists on bubbling air through heated biodiesel at 100 °C (figure 2.1.7.5).

Figure 2.1.7.5: Rancimat's Test Scheme



2.1.7.5 Iodine Index

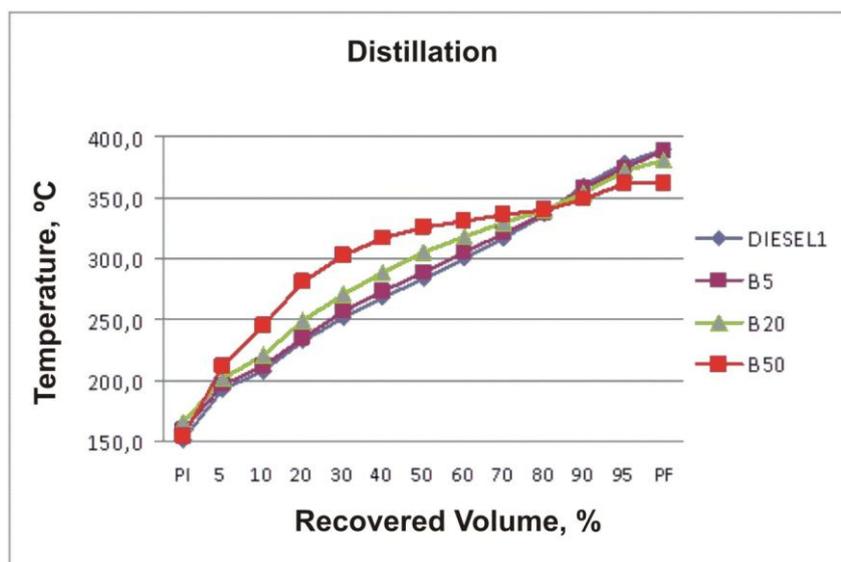
Iodine index is an indicator of the number of double bonds present in biodiesel, but without distinguishing its location (the fuel's oxidation stability depends not only on the amount of double bonds, but also on their location). Even though high values of Iodine Index show a greater tendency of biodiesel to oxidation, this indicator is a weak predictor of biodiesel's oxidation stability and does not reliably show its tendency to form depositions in the engine. Different biodiesel may have the same iodine index, but different behaviors regarding stability.

2.1.7.6 Effects on diesel properties in the mixture of soy biodiesel (Bx)

According to the results obtained in tests carried out on different mixtures, the following tendencies were observed:

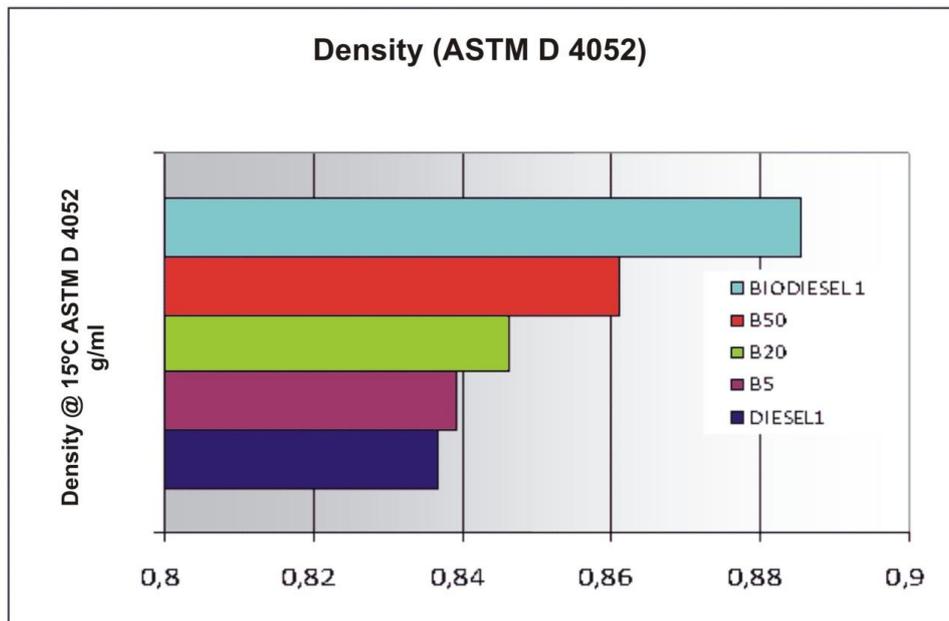
- *Distillation Curve (ASTM D 86)*: In mixtures of up to 5 % of biodiesel, differences are slightly significant; on the contrary, in B20 or superior, important curve variations are registered in the middle zone and in the final stretch.

Graph 2.1.7.6: Distillation curve of the different mixtures



- *Density (ASTM D 4052)*: Since biodiesel's density is significantly greater than that of assessed diesel, and as long as this property is additive, density increases are observed, as the biodiesel's percentage increases in the mixture.

Graph 2.1.7.7: Density (ASTM D 4052) of the different mixtures

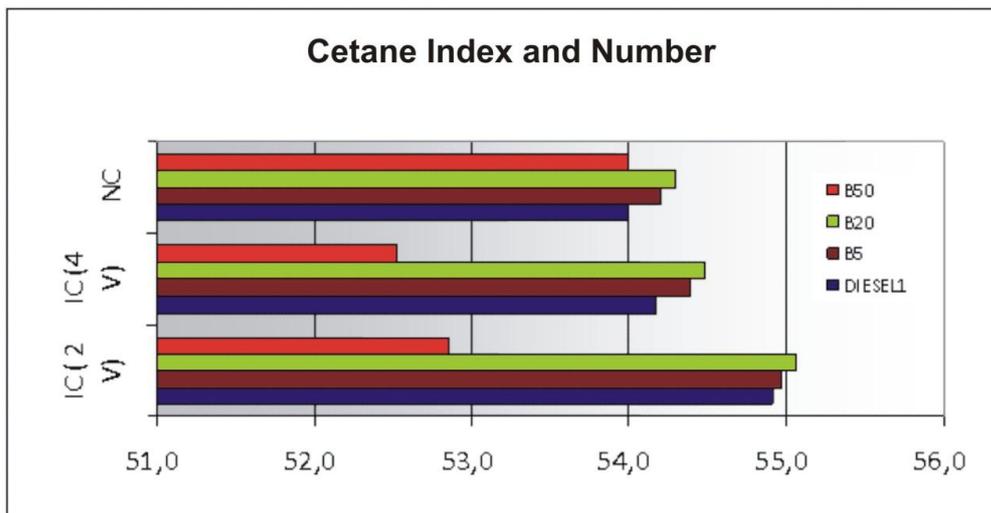


- *Flash Point (ASTM D 93)*: due to the high flash point of biodiesel compared with diesel, the greater the amount of biodiesel in the mixture, the greater the flash point of BX (see Table A2.1, Annex 2).
- *Cetane Index*:

-Calculated Cetane Index (2 variables, ASTM D 976): this method uses a formula or equation (or its abacus or nomogram) to determine the calculated cetane index (CI), a direct way of estimating the Cetane Number. The index is calculated as from the density data at 15°C and temperature of 50% of the Distillation Curve (T50). The higher the density of the mixtures: the less the CI; and the greater T50: the greater the CI. In the Table A2.1 (Annex 2) a slight increase of the CI can be observed, up to the B20 mixture. In B50 there is an important decrease (2 units compared with base diesel) due to density's increase. See Graph 2.1.7.8 below.

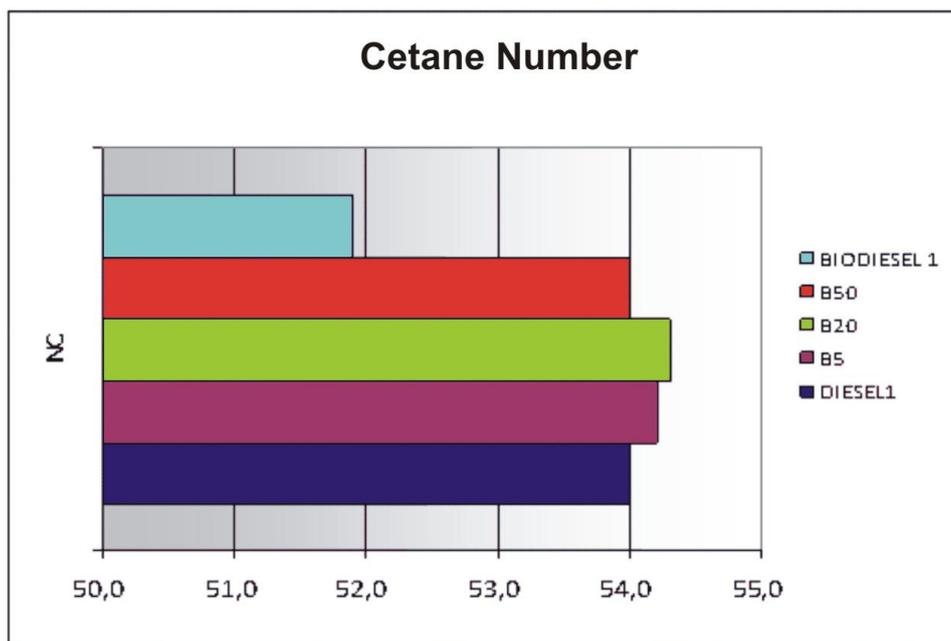
-Cetane Index calculated per equation of four variables (ASTM D 4737): in this calculation, besides density and T50, the distillation points, T10 and T90 intervene. According to the results obtained in the mixtures, this parameter has no significant variation up to B20 (Table A2.1, Annex 2). As in the CI (2V), the impact of biodiesel can be noticed only in B50 (see Graph 2.1.7.8). The values obtained get closer to the Cetane Number determined with engine (ASTM D 613).

Graph 2.1.7.8: Cetane index and number

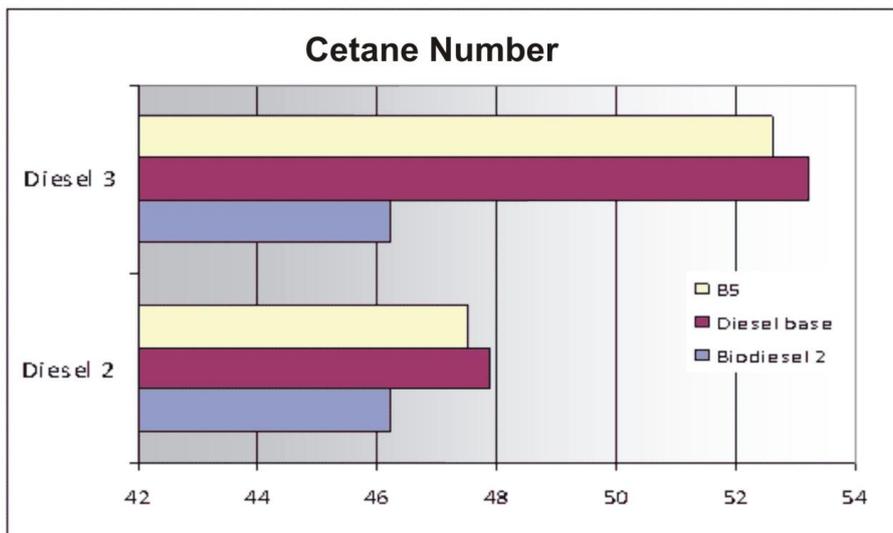


- Cetane Number (ASTM D 613):** the impact of biodiesel on this property depends on the cetane number (CN) of the diesel and biodiesel being mixed. In a diesel with a high CN as those of Table A2.1 (Annex 2) and similar CN values of biodiesel (diesel N° 1 with CN 54 and biodiesel N° 1 with CN 51.9) no significant impact can be observed (see Graph 2.1.7.9 below). In cases of B5 with biodiesel of low CN value a slight decrease in the mixture's CN value can be observed, according to Table A2.2 (Annex 2) and in Graph 2.1.7.10 (below) of 0.3 to 0.6 units in diesel with a CN of 47.9 and 53.2.

Graph 2.1.7.9: Cetane Number

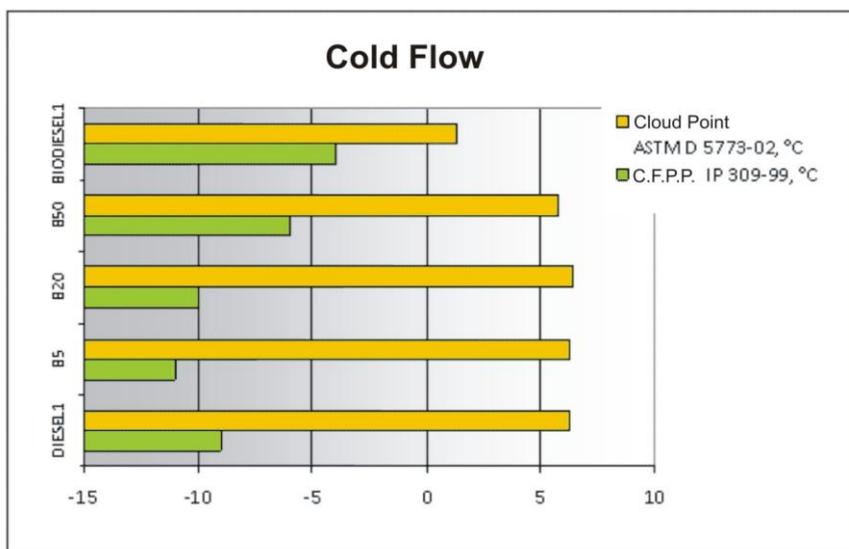


Graph 2.1.7.10: Cetane Number

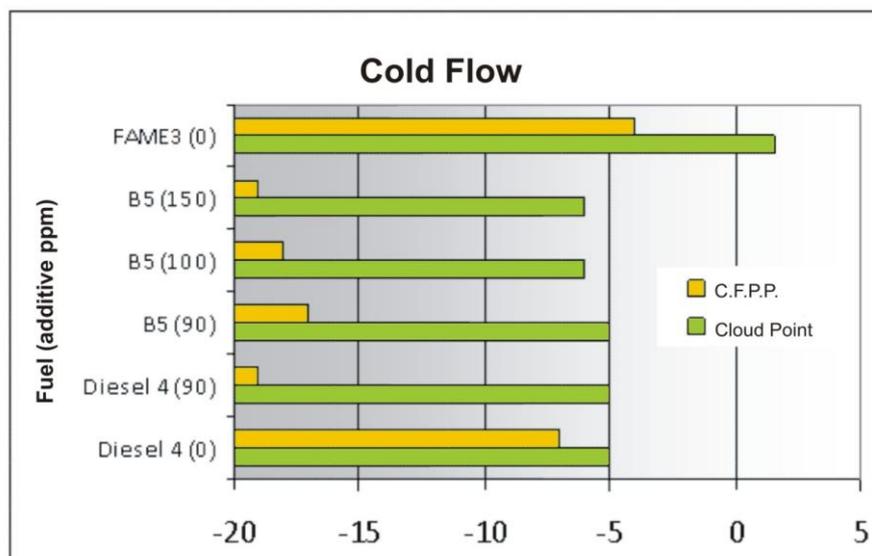


- Cold flow properties:* in the performed studies, an unequal behavior of the effects of higher concentrations of biodiesel in the mixture was observed. As in the Cetane Number, the behavior seemed to depend on the values of the cloud point (ASTM D 2500) and CFPP (Cold Flow Plugging Point, IP 309) of both components, as well as on the chemical composition of diesel. In the case of Table A2.1 (Annex 2) and Graph 2.1.7.10 (below) it can be observed that the addition of biodiesel with a much lower cloud point than diesel (1°C vs. 6.3°C) produces a slight improvement in the CFPP value. Deterioration in the values of CFPP is verified only in B50. In other evaluations performed with winter diesel (Table A2.3 in Annex 2 and Graph 2.1.7.11 below) a slight negative impact on the CFPP value can be observed, which may be corrected with specific additives that improve this property. In B5 with 90 ppm of additive, a greater value of CFPP is verified. With greater concentrations, the initial diesel's values are regained (-18°C). In this case, the diesel's additive is used to correct the variation, but there also are additives that improve CFPP for biodiesel.

Graph 2.1.7.11: Cold flow (CFPP)



Graph 2.1.7.12: Cold flow (CFPP)



Tables A2.1, A2.4 and A2.5 of Annex 2, show the main characteristics of the evaluated diesels and biodiesels.

2.1.8 Performance in engines of pure biodiesel and its mixtures with diesel

From some tests carried out in engines of on-duty vehicles with commercial diesel (reference), pure biodiesel (B100) and different diesel mixtures – biodiesel (B5, B15 and B30) some conclusions may be inferred:

1. Maximum torque: No significant differences were detected among the values of the following mixtures: B5, B15 and B30
2. Maximum power: The mixtures' values are of the same magnitude level (than the reference diesel) but with a decrease ($\approx 4\%$) in B100.
3. Opacity: B5 mixture increases the maximum opacity. With the other mixtures, the opacity progressively decreases according to the mixture's biodiesel content.
4. Exhaust gases' temperature: no significant differences are registered for the mixtures.
5. Consumption at total load: the hour consumptions of all mixtures are greater than those of the reference diesel. The specific consumptions also increase.

Table 2.1.8.1: Comparison of the emission levels between biodiesel (B100) and diesel

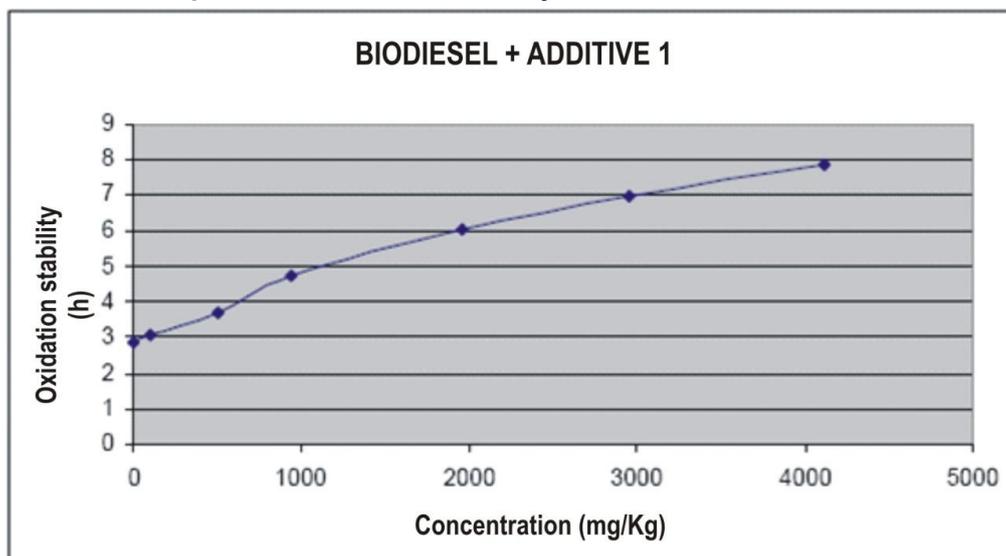
Biodiesel average emissions compared with those of traditional diesel according to EPA (USA)	
Type of emission	100% biodiesel
Total non burned HC	-67%
Carbon Monoxide	-48%
Particulate matter	-47%
NOx	+/-2%

2.1.9 Additives

2.1.9.1 Antioxidants

It is possible to increase the biodiesel’s natural stability, by adding an appropriate antioxidant to it. Graph 2.1.9.1 shows a biodiesel with low oxidation stability (3hs), which with an addition rate of 2000 ppm, achieves to comply with the specification of a minimum of six hours according to the Rancimat test.

Graph 2.1.9.1: Oxidation stability vs. additive concentration



There is a wide variety of effective antioxidant products in the market.

2.1.9.2 Flow conditioners

The additives that improve flow enable the biodiesel and its mixtures with diesels to have a better performance at low temperatures. Additives for biodiesel shall be designed for each specific base, as those used for conventional diesel. A specific product could work very well with colza’s methyl-ester, but not so well with those of soy or vice versa. It is very important to take precautions when trying to use a specific flow conditioner for diesel in mixtures of it with biodiesel, since the results could be really negative. Also, some lab tests have shown that best results are obtained when diesel and biodiesel are added with specific additives.

2.1.10 Energy and environmental impact analysis of biodiesel’s life cycle

The Life Cycle Analysis (LCA) is an environmental management tool that systematically evaluates the environmental aspects and impacts of a biofuel through its life cycle analysis, from the acquisition of the raw material (biomass), its production (agricultural production, industrial process), use (combustion), treatment, recycling and final disposal. Generally, this analysis is known as the “well to wheel” analysis. It is noteworthy that this tool is based on the interpretation of mass and energy balances and therefore more useful to evaluate emissions and energy consumption than to estimate other impacts. Biodiversity loss, eutrophication, acidification and the effects on human health, are impacts that require a systematic vision that is not explained through an input – output analysis. Therefore, other complementary tools have to be used.

Particularly for biodiesel, its life cycle analysis – sequence of the steps involved in the production and use of the fuel from the attainment of the raw material from nature, up to the final use as fuel in a bus for instance – enables to know better the net energy balance involved in all the process, the effects on the emission of greenhouse gases and the generation of residues that may pollute air, water and soil. This is to say, the life cycle analysis is a tool that provides a better comprehension of the associated benefits of biodiesel as a fuel, regarding diesel oil. *Section 9.3.2.2 “Energy and biofuels’ emissions’ balances”* describes some other important general aspects on this topic.

2.1.10.1 Life cycle’s energy balance

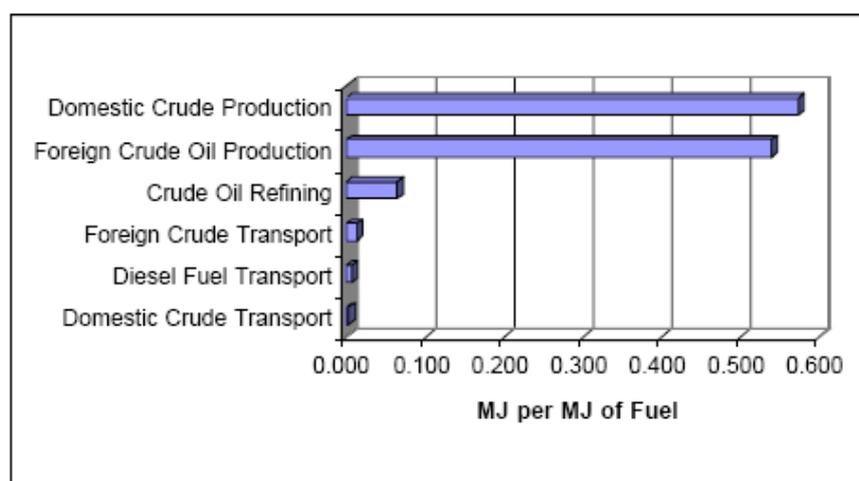
Table 2.1.10.1 and Graph 2.1.10.2 summarize the requirement of fossil energy, regarding output energy in diesel oil, according to calculations of the US Department of Agriculture and Energy. For diesel, 1.1995 MJ of fossil energy is used to produce 1 MJ of energy in the final product. This corresponds to a relation of fossil energy of 0.8337 (Relation of fossil energy = energy in the fuel/input of fossil energy).

Table 2.1.10.1: Requirement of fossil energy for the diesel oil’s life cycle

Stage	Fossil Energy (MJ / fuel’s MJ)	Percentage
National oil production	0.572809	47.75%
Foreign oil production	0.539784	45.00%
National oil transportation	0.003235	0.27%
Foreign oil transportation	0.013021	1.09%
Oil refining	0.064499	5.38%
Diesel transportation	0.006174	0.51%
Total	1.199522	100.00%

Source: US Department of Agriculture and Energy. *Inventory of the life cycle of biodiesel and diesels to be used in public transport buses 1998*

Graph 2.1.10.2: Ranking of the demand of fossil energy for diesel oil’s production stages



Source: US Department of Agriculture and Energy. *Inventory of the life cycle of biodiesel and diesels to be used in public transport buses 1998*

Table 2.1.10.3 and Graph 2.1.10.4 summarize the requirement of fossil energy for soy’s biodiesel’s life cycle, also according to calculations of the US Department of Agriculture and Energy. Soy’s biodiesel uses 0.311 MJ of fossil energy to produce 1 MJ in the fuel, which implies a relation of fossil energy consumption of 3.215. In

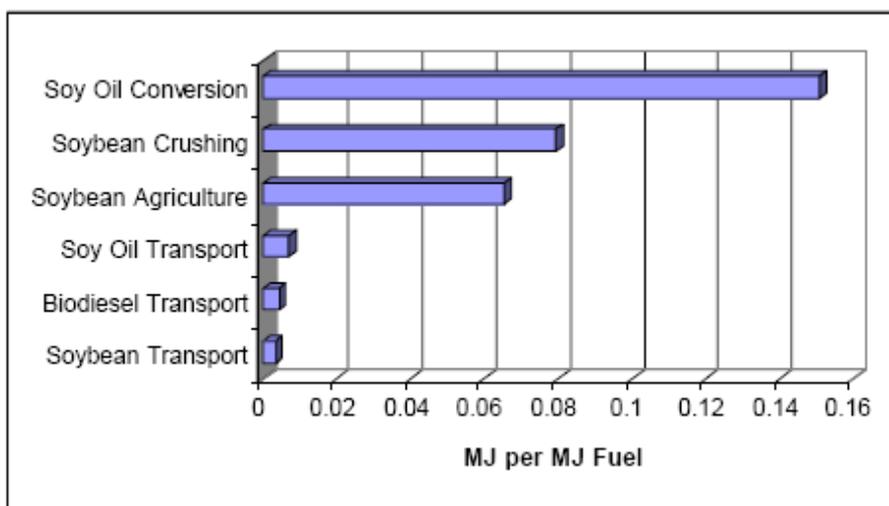
other words, soy's biodiesel's life cycle produces a little bit more than thrice the energy in the final product, compared to the fossil energy used to produce it.

Table 2.1.10.3: Requirement of fossil energy for the soy's biodiesel's life cycle

Stage	Fossil Energy (MJ / fuel's MJ)	Percentage
Soy's agriculture	0.0656	21.08%
Soy's transportation	0.0034	1.09%
Soy's grinding	0.0796	25.61%
Soy's oil transportation	0.0072	2.31%
Soy's oil conversion	0.1508	48.49%
Biodiesel's transportation	0.0044	1.41%
Total	0.3110	100.00%

Source: US Department of Agriculture and Energy. Inventory of the life cycle of biodiesel and diesels to be used in public transport buses 1998

Graph 2.1.10.4: Requirement of fossil energy versus energy in the product for soy's biodiesel's life cycle



Source: US Department of Agriculture and Energy. Inventory of the life cycle of biodiesel and diesels to be used in public transport buses 1998

To sum up it can be said that in terms of the effectiveness of the fossil's energy usage, soy's biodiesel yields approximately 3.2 energy units in the fuel product per unit of consumed fossil energy. In contrast, diesel oil yields only 0.83 energy units in the product per unit of consumed fossil energy. This confirms the "renewable" nature of biodiesel. The life cycle of B20 has proportionally a lower fossil energy relation (0.98 energy units in the product per unit of consumed fossil energy). The relation of fossil energy of B20 reflects the impact of adding diesel oil to the mixture.

2.1.10.2 CO₂ emissions

Given the low demand of fossil energy associated with biodiesel, it is not surprising that the CO₂ emissions of its life cycle are substantially lower. Per work unit developed by a bus engine, B100 reduces the net emissions by 78.45% compared with diesel oil. B20 emissions are 15.66% lower than those of diesel. Therefore, the use of biodiesel to displace diesel in urban buses is a very effective strategy to reduce CO₂ emissions.

2.1.10.3 Emissions of particulate matter and CO

The life cycle of B100 produces fewer emissions of particulate matter and CO (reductions of 32% and 35% respectively) than the equivalent to that of the diesel oil's life cycle. Most of these reductions occur due to lower emissions from the vehicles' exhaust pipe. PM10 emissions of an urban biodiesel-powered bus are 63% lower than the emissions of the same bus powered with diesel oil. Biodiesel reduces 46% the CO emissions from the vehicles' exhaust pipe.

2.1.10.4 NOx emissions

NOx emissions of the life cycle of B100 are 13% greater compared with those of the diesel oil's life cycle. For the life cycle of B20, NOx emissions are 2.67% greater. This increase is due to greater emissions from the vehicles' exhaust pipe. An urban B100-powered bus has NOx emissions 8.89% greater than those of a bus powered by diesel oil.

2.1.10.5 Waste waters and solids

The generation of disposal waste waters in biodiesel's life cycle is lower in 80% than that of the diesel oil. The generation of hazardous waters is also lower for biodiesel.

2.1.10.6 Water consumption

In the life cycle of B100 water consumption is three times greater than the equivalent in diesel oil. For more information, see *section 9.3.2.1 Agriculture and environment*.

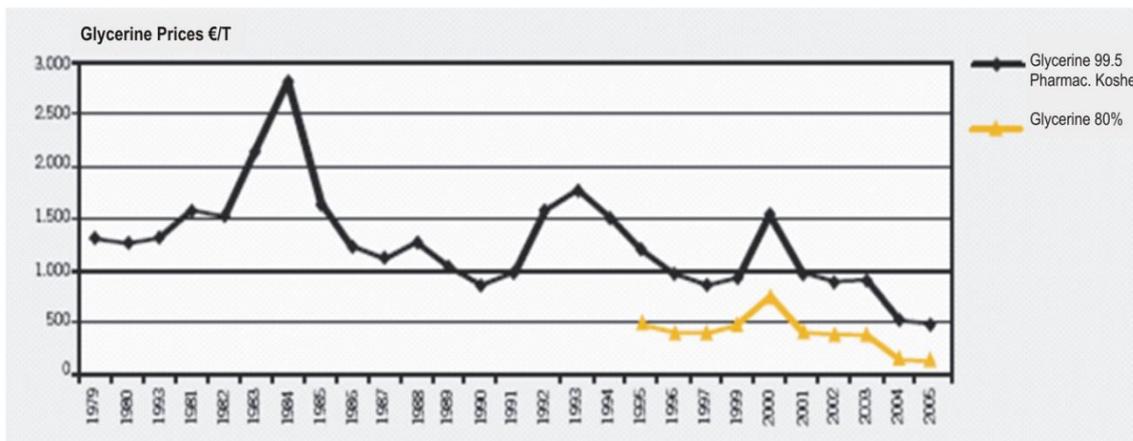
2.2 Specific Aspects

2.2.1 Disposal of glycerine – alternative uses

Glycerine is a by-product of the production of biodiesel ($\approx 10\%$ of the input) that once purified has a large number of applications. Most current applications assume contributing an added value to the final product. The appearance of large quantities of glycerine in the market due to the growing usage of biodiesel as a fuel, not existing new developed application fields, has caused the decrease of its price to limits where it can compete with other raw materials in applications with lower prices. Its applications of larger volume are: Chemical intermediate (polyols, resins and others), personal care, pharmacy and food.

The increase of the offer in the last years has made its quotation to be below other commodities with which it has physico-chemical similarities: lubricant bases and glycols; and given the tendency, an increase in the difference of prices should be expected, making of glycerine a strong competitor of these families of products. Graph 2.2.1.1 shows the evolution of glycerine's price in the last years.

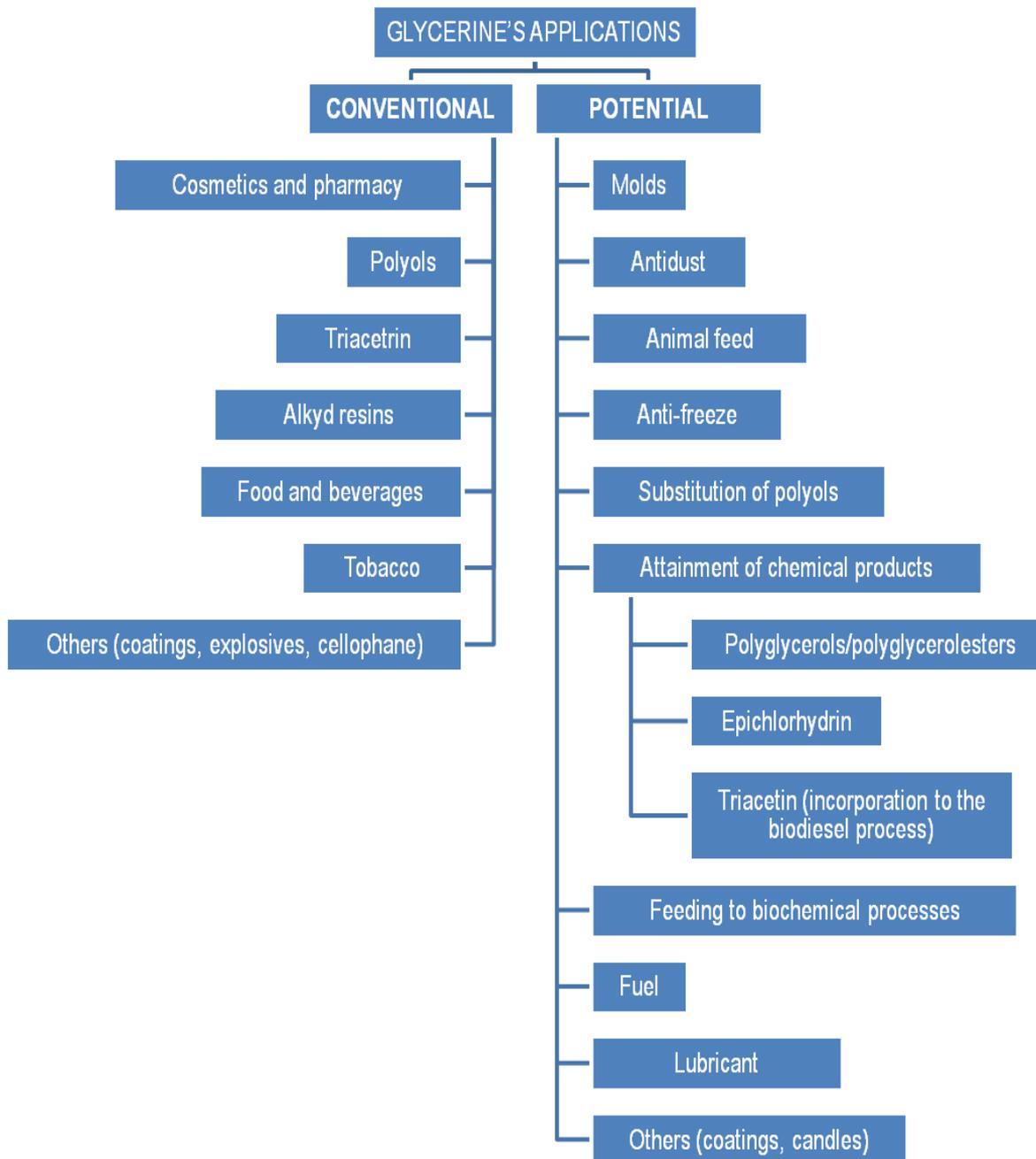
Graph 2.2.1.1: Glycerine's price evolution



Source: ISF 2 Reports. Biodiesel Production. Application to developing countries. 2007

The following scheme shows in a simplified manner, the current applications of glycerine and future possible applications.

Figure 2.2.1.2: Current applications of glycerine and future proposals

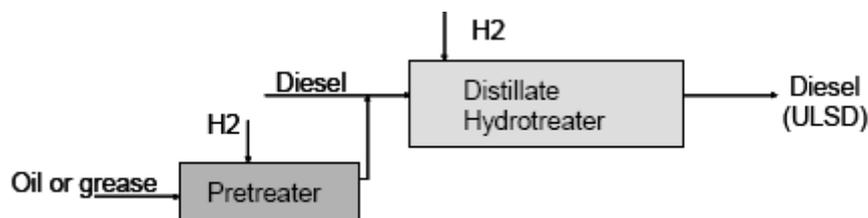


After more than seven years of research, a new second-generation fuel (IUCT-S50) was introduced at the end of year 2007 in Spain, which is obtained as from using as raw material the glycerine produced in the biodiesel production process. This new technology will enable increasing the global profitability of a traditional biodiesel plant, since it has made possible to transform all the incoming biomass (oil) in biofuel (part of it biodiesel and another IUCT-S50).

2.2.2 Bio-Refining: co-processing of vegetable oils or fats in existing refining units

It is possible to co-process biomass with typical loads of existing refining units (hydrotreaters, fluid catalytic cracking units) and obtain good performances and products' quality. This alternative of processing vegetable oils or fats in refining units is a business opportunity that can be seized in moments of low prices of the vegetable oil and if there is idle capacity in the facilities.

Figure 2.2.2.1: Co-processing of vegetable oils or fats and diesel oil in hydro-treatment units: process scheme



Advantages:

- ✓ Oils of different origins may be used. Little influence of the vegetable oil's quality and origin in the process.
- ✓ Some properties of the diesel are improved: density, viscosity, cetane number; and sulphur content is reduced.
- ✓ No residues are generated
- ✓ No vehicular tests are needed
- ✓ No additional care is required in transport and stock

Disadvantages

- ✓ Diminishing of lubricity and detriment of cold properties
- ✓ CO and particulate matter emissions are not reduced
- ✓ Great consumption of hydrogen, mainly in highly unsaturated loads
- ✓ Hydrogen's high price
- ✓ The high TAN (*Total Acid Number*) of vegetable oils and fats (2-200) may force to incur in additional costs in order to improve the metallurgy of the section of reaction if the processed percentage of these flows is important. Other capital costs may include a pre-treatment in the load to remove pollutants (metals).
- ✓ Given the high cost of the hydro-treatment units, the construction of units exclusively for oils or fats processing is not attractive.

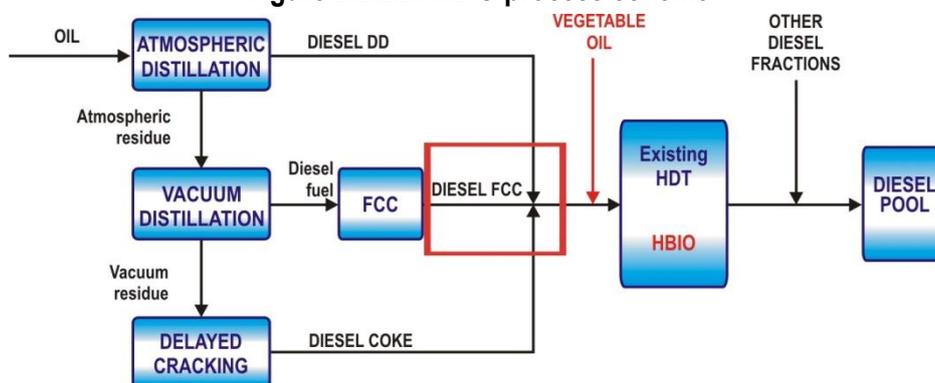
2.2.2.1 HBIO in Brazil

Aligned with the scheme of co-processing of diesel oil and vegetable oil in existing hydro-treatment units, PETROBRAS has been working in the development of HBIO project. The proportion of vegetable oil in the total feeding flow to the hydro-treater is about 5%, although PETROBRAS has operational licence to work with 10%.

HBIO potential in Brazil:

1. Short term – 2009-2010: Implementation in six refineries. The maximum vegetable oil volume expected to be processed is 425,000 m³/year.
2. Long - Term – 2011-2014: Implement the process in 11 refineries. Processing of up to 1,300,000 m³/year of vegetable oil.

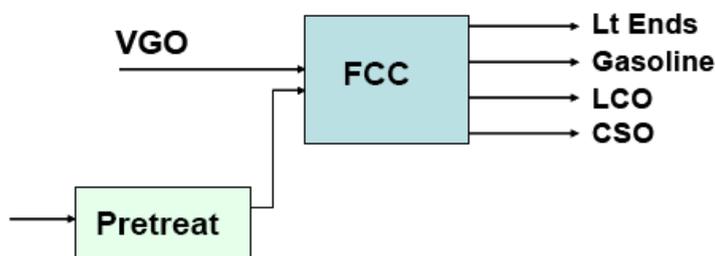
Figure 2.2.2.2: HBIO process scheme



Process' performance: 100 liters of soy oil yield 90 liters of diesel and 2.2 m³ of propane and about 27 Kg. of H₂ are consumed.

Co-processing of vegetable oils or fats with typical feedings to a catalytic cracking unit (FCCU): Vegetable oils or fats may be co-processed in a fluid catalytic cracking unit, with typical flows feeding this unit. In order to process vegetable oils and fats, a separated feeding system with pre-treatment will be required to remove metals (Ca, K) that could poison the FCC catalyst and also avoid metallurgical problems in the load feeding system when mainly fats are being processed.

Figure 2.2.2.3: FCCU process scheme



2.2.2.2 Biocetane in Colombia

Colombia, through the Colombian Oil Institute (*Instituto Colombiano del Petróleo*) of ECOPETROL, during two years of research in the labs, pilot plants and an hydro-treatment plant of the refinery of Barrancabermeja, achieved to produce a fuel from palm oil, with no sulphur and a cetane number close to 100. This product was called "biocetane".

The great advantage of using biocetane as a component of diesel is that, besides mixing it with diesel in a larger proportion than biodiesel, it does not have the restrictions established by the automotive sector to diesel

and FAME mixtures. Another advantage in the production of biocetane is that no glycerine is generated; instead of it, LPG is produced, which in certain circumstances is more useful than glycerine.

Some preliminary results of an engine's performance with biocetane, in order to measure the relation of gallon per travelled kilometer, revealed a 10% reduction in the consumption, which would be ideal for the environment. However, tests in other engines and operation conditions will still be performed in order to validate these results.

2.2.3 Second-generation biofuels

The current biofuels generate more and more doubts about their viability, their impact on the environment and their long-term sustainability. Therefore, several technological researches and projects around the world are working on the development of a second generation to counteract these inconveniences. The possibilities regarding raw materials and technologies are diverse, and experts believe that in the next few years they could already be in our vehicle's deposits.

The main difference of new second-generation (2G) fuels regarding the current ones is that they will be produced from better technological processes and raw materials, which are not meant to be food and are grown in non-farm land or marginal land. This way, the controversy generated by the current biofuels about substituting food for fuel would be resolved. That is why 2G biofuels appear with the objective of overcoming expansion limitations and the serious conflicts that the current agro-fuels can generate.

The main countries that are betting for these new 2G biofuels are almost the same as in the case of first generation biofuels. In this regard, the countries especially making researches for their implementation at large scale are Germany, USA and Sweden. In Sweden for instance, there is a Government's plan to completely substitute oil in transport, for fuels of vegetable origin by 2020.

According to EFE Agency, Germany inaugurated the first commercial plant of 2G biofuels in Freiberg on the 16th. April, 2008, with the presence of Angela Merkel, Germany's Prime Minister. The plant will use waste wood and plants as raw materials. The manufacturer, *Choren Industries*¹, would have announced that the projection for the plant was to produce about 18 million liters of 2G biofuels per year. Regarding the products that will be developed out of this second generation, they will mainly be used in highway transportation, substituting gasoline and diesel fuels. At medium term, they also will be able to substitute the kerosene used in aviation.

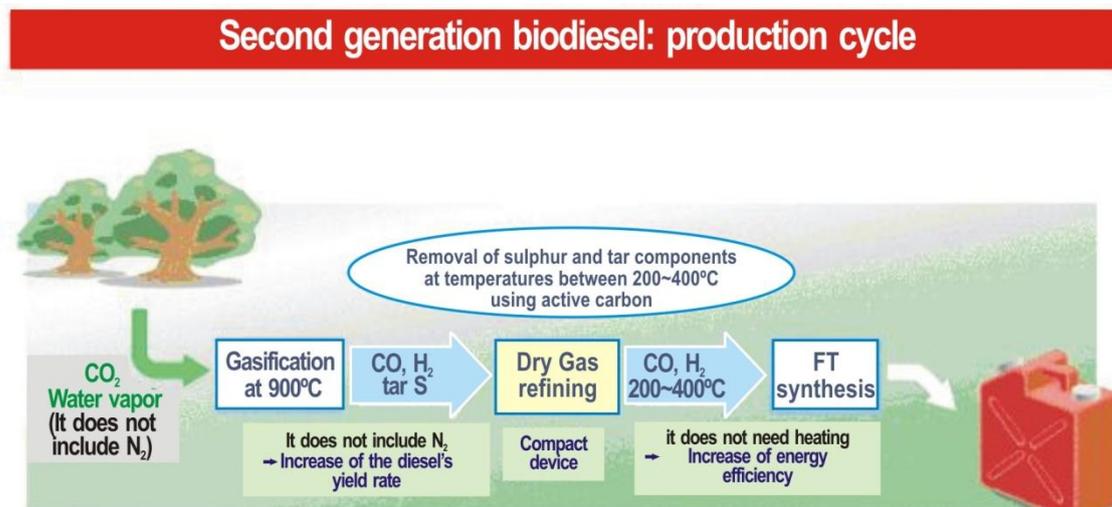
Nevertheless, 2G biofuels are still in laboratory phase or pilot project. Estimations indicate that they will be significantly used in a period of three to five years, even though some countries are about to start using them.

Second generation biodiesel presents the following features:

1. It is a mixture of vegetable origin
2. The habitual process is performed in two phases:
 - a. Biomass gasification and syngas attainment
 - b. Fischer-Tropsch (FT) reaction and attainment of an hydrocarbon
3. There are several technologies, currently at lab and/or pilot phase.

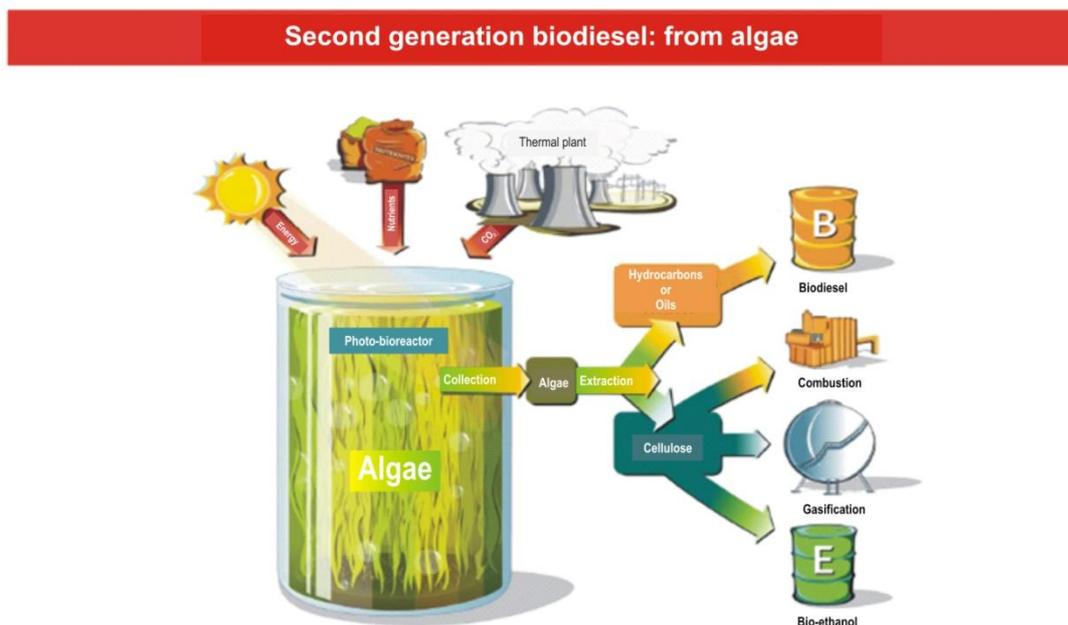
¹ www.choren.com

Figure 2.2.3.1: Production cycle of second generation biodiesel



Source: Second-generation biofuels. Point of view of Acciona. Acciona Biofuels. 2008

Figure 2.2.3.2: Second generation biofuels from algae



Source: Second-generation biofuels. Point of view of Acciona. Acciona Biofuels. 2008

2.2.4 Biomass

Biomass is the name given to any organic matter of recent origin, derived from animals or vegetables as a result of the photosynthetic conversion process. Biomass' energy is derived from vegetable and animal matter, such as timber forest, residues from agricultural and forestry processes and from industrial, human or animal waste.

The energy value of vegetable matter biomass originally comes from solar energy, through the process known as photosynthesis. The chemical energy stored in plants and animals (that feed on plants or other animals), or in the wastes they produce, is called bio-energy. During conversion processes such as combustion, biomass releases its energy, usually as heat, and carbon is once again oxidized to carbon dioxide to replace the one that was absorbed during the plant's growth.

Producing energy from biomass means accessing to different alternatives for its conversion into energetically usable products. In general a bio-energetic system is constituted by the following elements:

- ✓ Biomass produced in dedicated crops (forests, pastures, etc.), litter, forests' residues, or biomass from waste (industrial wastes, domestic and industrial organic wastes)
- ✓ Biomass must be harvested, gathered, transported and finally stored in the processing place.
- ✓ Biomass may be transformed through different selected processes, according to the type and amount of available biomass, the final use, the environmental demands and economic conditions, among others.

Most conversion processes use routes known as thermo-chemical or biochemical. The thermo-chemical route uses three different methods: combustion, gasification and pyrolysis. The biochemical route may use the digestion and fermentation processes used to produce alcohols.

Unlike energies extracted from carbon or oil, the energy derived from biomass is indefinitely renewable. Unlike wind and solar energy, biomass energy is easy to store. Instead, it operates with large fuel volumes that make its transportation expensive and constitute an argument in favor of a local and especially rural utilization.

Lignocellulosic biomass of bagasse, wood or pastures is subject to acid or enzymatic hydrolysis processes to produce sugars that ferment into ethanol. Nowadays the objective is to develop cost-efficient technologies for the exploitation of this abundant raw material.

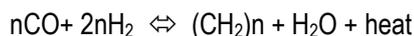
2.2.5 Biogas, BTL, GTL

Biogas is the mixture of methane and other gases that is released during the anaerobic degradation of the organic matter due to the action of microorganisms. It is obtained by means of a digester or by canalizing it directly into a controlled landfill site. In the first case, the digester's temperature is maintained at about 50°C; this way the pH can be between 6.2 and 8, which favors the microorganisms' activity. The chemical degradation, of great complexity and lasting between 10 and 25 days, develops in three main phases: hydrolysis and acidogenesis, acetogenesis and methanogenesis. The type of organic substrate, the conditions of the process and the degree it reaches, make the proportions of the biogas' components (54%-70% for methane, 27%-45% for CO₂, etc.) to vary a lot. Biogas is used for the generation of heat by means of combustion as well as for the generation of mechanical energy and electricity, mainly in the same plants where it is obtained.

GTL means "Gas to Liquid" and is a process that converts natural gas into ultra clean liquid fuels. The GTL process has three markedly differentiated stages, which are as follows:

1. Generation of syngas. Where the mixture of hydrogen and carbon monoxide from natural gas, is produced. There are diverse processes for this stage, as steam reforming, partial oxidation, CO₂ reforming, auto-thermal reforming and plasma. The difference between them lies mainly on the H₂/CO relation obtained, type of catalysts and logically operations conditions.

2. Fischer-Tropsch synthesis, where syngas is converted to liquid by means of an exothermic reaction and in presence of a cobalt or iron catalyst:



The obtained products depend mainly on syngas, the catalyst and the operation conditions; if these are more severe (temperature of 300 – 350°C) more gasoline is obtained and if they are less severe (temperature of 220 to 240°C) diesel yield prevails. Operation pressures fluctuate between 145 and 580 psia.

3. Product's rectification, performed through a hydro-cracking process less severe than the conventional operation of a refinery, due to the better crackability of the load, which is mainly composed of long hydrocarbon chains. The main final products obtained are gasoline, diesel and lubricants.

Diesel is the main product of the GTL process: it represents up to 70% of the total, which has as main advantages its low sulphur content which may be even lower than 5 ppm, less than 1% aromatics and a cetane number greater than 70.

Gasoline is the second product in yield, which varies between 15 and 25% of the total production. It is highly paraffinic, but with the disadvantage of a low octane; therefore it is not used in vehicles' gasoline engines, but it is ideal to feed petrochemical plants.

In general, the fuels produced in a GTL plant present certain environmental advantages in comparison with their equals obtained in conventional oil refineries, such as a greater hydrogen/carbon relation, which derives in a lower emission of particulates and nitrogen oxides (NO_x), and a lower concentration of sulphur and aromatics, which influences in a lower emission of sulphur oxides and particulate matter.

Moreover, a GTL plant can produce certain specialties as normal paraffins, waxes, lubricant oils and small quantities of oxygenated products like ethanol, methane, n-propanol, n-butanol and acetone. South Africa is the leader in the production of liquid fuels from gas, both natural gas and the one obtained from carbon. After it come Qatar and Malaysia. Likewise, there are projects in execution in many other countries.

Until recently, GTL plants were considered expensive, because they require an investment of about 25,000 to 30,000 USD per barrel of fluid produced; however, with the accelerated increase of oil's price and environmental demands, these investments have become more and more attractive for countries that have appreciable volumes of gas. It is known that, per each thousand barrels of fluid produced per day, approximately 9 to 11 million cubic feet of natural gas are required per day.



ANNEX 1

Global referential biodiesel specifications

Table A1.1: Biodiesel specifications – limit values

Characteristics	Units	Europe	USA	Brazil	Argentina	Colombia
		EN 14214/07	ASTM D-6751-08	ANP N°7/08	Resolution SE 1283/06	NTC 5444
Ester content	%m/m, min.	96.5		96.5	96.5	96.5
Density at 15%	g/cm ³	0.860-0.900		(at 20°C) 0.850-0.900	0.875-0.900	0.86-0.900
Viscosity at 40%	cSt	3.5-5.0	1.9 – 6.0 (1)	3.5-6.0	3.5-5.0	1.9-6.0
Flash point	°C, min	120	93	100	100	120
Sulphur	%m/m, max.	0.001	0.0015 (2)	0.005	0.001	
Cetane Number	min.	51	47	Report	45	47
Water content	Mg/Kg., max.	500		500		500
Water and sediments	%v/v., max.		0.05		0.05	
Copper corrosion strip	max.	1	n°3	1	1	1
Methanol	%m/m., max.	0.2	0.2 (or P.I. 130°C min.)	0.2 (3)		0.2 (3)
Free glycerine	%m/m., max.	0.02	0.02	0.02	0.02	0.02
Total glycerine	%m/m., max.	0.25	0.24	0.24	0.24	0.25
Iodine Index / N°	max.	120		Report	135	120
Acidity index	mg KOH/g., max.	0.5	0,5	0.5	0.5	0.5
Cold soak filterability	Seconds, max.		360			
Alkaline Met. (Na+K)	Mg/Kg., max.	5	5	5		5
Metals Group II (Ca+Mg)	Mg/Kg., max.	5	5	5		5
Total Pollution	Mg/Kg., max.	24		24		24
Carbon residue	%m/m., max	0.3 (s/10 % dist.)	0.05	0.05		0.3
Sulphated Ashes	%m/m., max.	0.02	0.02	0.02		0.02
Oxidation stability 110°C	Hours, min.	6	3	6	6	6
ME linolenic acid	%m/m., max.	12				12
Monoglyceride content	%m/m., max.	0.8		Report		0.8
Diglyceride content	%m/m., max.	0.2		Report		0.2
Triglyceride content	%m/m., max.	0.2		Report		0.2
ME Content polyunsaturated (≥ 4 double bonds)	%m/m., max.	1				
Phosphorus	Mg/Kg., max.	10	10	10	10	10
Equivalent atm. temperature (90%R)	°C, max.		360			360
Cloud Point	°C		Report (4)			Report
CFPP	Limits			Specified by region		Report
Grade A	°C, max.	5		5		
Grade B	°C, max.	0		0		
Grade C	°C, max.	-5		-5		
Grade D	°C, max.	-10		-10		
Grade E	°C, max.	-15		-15		
Grade F	°C, max.	-20		-20		

(1) Limit superior to diesel. It must be considered when mixing it.

(2) For different limits of Sulphur of the commercialized diesel

(3) It corresponds to methanol or ethanol

(4) Limit generally superior to that of diesel. It must be considered when mixed.

Table A1.2: Specifications of biodiesel – test methods

Characteristics	Europe	USA	Brazil	Argentina	Colombia
	EN 14214/07	ASTM 6751-08	ANP N°7/08	Resolution 1283/06	NTC 5444
Ester content	EN 14103		EN 14103	EN 14103	EN 14103
Density at 15%	EN ISO 3675 EN ISO 12185		ASTM D-1298 /4052 EN ISO 3675 / 12185	ASTM D-1298	ASTM D-4052 ISO 3675
Viscosity at 40%	EN ISO 3104	ASTM D-445	ASTM D-445 EN ISO 3104	IRAM IAPG A 6597 ASTM D-445	ISO 3104 ASTM D-445
Flash point	EN ISO 3679	ASTM D-93	ASTM D-93 EN ISO 3679	ASTM D-93 IRAM IAP 6539	ASTM D-93 ISO 2719
Sulphur	EN ISO 20846 EN ISO 20884	ASTM D-5453 ASTM D-7039 (op)	ASTM D-5453 EN ISO 20846/20884	ASTM D-4294	
Cetane Number	EN ISO 5165	ASTM D-613 ASTM D-6890 (op)	ASTM D-613/6890 (op) EN ISO 5165	ASTM D-613	ASTM D-613 ISO 5165
Water content	EN ISO 12937		ASTM D-6304 EN ISO 12937		ASTM E-203 ISO 12937
Water and sediments		ASTM D-2709		ASTM D-1796	
Copper corrosion strip	EN ISO 2160	ASTM D-130	ASTM D-130 EN ISO 2160	ASTM D-130 ISO 2160	ASTM D-130 ISO 2160
Methanol / alcohol	EN 14110		EN 14110		EN 14110
Free glycerine	EN 14105 EN 14106	ASTM D-6584	ASTM D 6584 (1) EN 14105 (1) EN 14106 (1)	ASTM D-6584 NFT 60-704	ASTM D 6584 EN 14105 EN 14106
Total glycerine	EN 14105	ASTM D-6584	ASTM D 6584 EN 14105 (1)	ASTM D-6584 NFT 60-704	ASTM D-6584 ISO 14105
Iodine Index	EN 14111		EN 14111	EN 14111	EN 14111
Acidity index	EN 14104	ASTM D-664	ASTM D-664 EN 14104 (1)	ASTM D-664	
Cold soak filterability		ASTM D 6751 Annex A1			
Alkaline Metals (Na+K)	EN 14108 / 14109/14538	EN 14538	EN 14108 /14109/ 14538		EN 14108 / 14109 ASTM D5864
Metals Group II (Ca+Mg)			EN 14538		EN 14108 / 14109
Total Pollution	EN 12662		EN 12662		EN 12662
Carbon residue	EN ISO 10370	ASTM D-4530	ASTM D-4530		ASTM D-4530
Sulphated ashes	ISO 3987	ASTM D-874	ASTM D-874 ISO 3987		ASTM D-874 ISO 3987
Oxidation stability 110°C	EN 14112		EN 14112 (1)	EN 14112	EN 14112
ME linolenic acid	EN 14103				EN 14103
Monoglyceride content	EN 14105		EN 14105 ASTM D 6584 (1)		EN 14105 ASTM D 6584
Diglyceride content	EN 14105		EN 14105 ASTM D 6584 (1)		EN 14105 ASTM D 6585
Triglyceride content	EN 14105		EN 14105 ASTM D 6584 (1)		EN 14105 ASTM D 6586
Polyunsaturated ME content (≥ 4 double bonds)	Under development				
Phosphorus	EN 14107	ASTM D-4951	ASTM D-4951 EN 14107	EN 14107 ASTM D-4951	ASTM D-4951 EN 14107
Equivalent atm. temperature (90%R)		ASTM D-1160			ISO 3405
Cloud point		ASTM D-2500			ASTM D-2500
CFPP	EN 116	ASTM D-6371	ASTM D-6371 EN 116		ASTM D-6371 EN 116

⁽¹⁾ It shall be validated for the raw material that was not projected in the method and route of ethyl production.



ANNEX 2

Test of the properties of diesel mixtures with soy biodiesel – data tables

Table A2.1: Quality of diesel 1, mixtures and biodiesel 1

REFERENCE	DIESEL 1	BX			BIODIESEL 1
		B5	B20	B50	
Density @ 15°C ASTM D 4052 g/ml	0.8368	0.8393	0.8464	0.8611	0.8855
Sulphur ASTM D 2622-04, % w/w	0.154				
Viscosity @ 40°C ASTM D 445-03, cSt	3.0998	3.2232	3.2706	3.5720	4.1422
Cetane Index ASTM D 976 (2 V)	54.9	55.0	55.1	52.9	
Cetane Index ASTM D 4737 (4 V)	54.2	54.4	54.5	52.5	
Cetane Number ASTM D 613	54.0	54.2	54.3	54.0	51.9
Flash Point ASTM D 93 °C	52.4	53.1	56.6	65.1	168.0
Transparency and brightness	C&B ⁽³⁾	C&B ⁽³⁾	C&B ⁽³⁾	C&B ⁽³⁾	
ASTM color by spectrophotometer DP-02-114	1	1.1	0.8	0.7	
Flash Point ASTM D 5773-02, °C	6.3	6.3	6.4	5.8	1,3
CFPP IP 309-99, °C	-9	-11	-10	-6	-4
% recovered volume (°C):					
<i>Initial Point</i>	150.9	159.5	164.8	154.1	
<i>T5</i>	191.8	196.0	201.7	211.9	
<i>T10</i>	207.1	211.1	219.9	245.0	
<i>T20</i>	232.6	235.2	248.5	280.4	
<i>T30</i>	251.0	255.9	270.0	302.7	
<i>T40</i>	267.7	272.8	288.5	316.7	
<i>T50</i>	283.4	288.6	304.6	325.3	
<i>T60</i>	300.0	304.9	317.8	331.1	
<i>T70</i>	317.1	320.9	329.5	335.5	
<i>T80</i>	336.2	337.3	339.8	340.2	
<i>T90</i>	360.4	357.1	353.5	348.1	
<i>T95</i>	378.5	374.7	372.1	360.9	
<i>Final Point</i>	389.9	388.8	381.4	361.4	
<i>Yield, % vol.</i>	98.5	99.1	98.6	98.8	
<i>Residue, % vol.</i>	1.0	0.7	1.0	1.0	
<i>Losses, % vol.</i>	0.5	0.2	0.4	0.2	

Table A2.2: Cetane Number

	Diesel 2 ⁽¹⁾			Diesel 3 ⁽²⁾		
	Test 1	Test 2	Average	Test 1	Test 2	Average
FAME 2	46	46.4	46.2	46	46.4	46.2
Base diesel	48.1	47.6	47.9	53.1	53.3	53.2
B5	47.6	47.3	47.5	52.6	52.6	52.6

⁽¹⁾ Contains additive to condition the cetane number.

⁽²⁾ It does not contain additive to condition the cetane number.

⁽³⁾ Clear and bright.

Table A2.3: Cold flow

	Diesel 4		B5	B5	B5	FAME 3
	0	90	90	100	150	0
Concentration of the additive to condition the diesel's cold flow, ppm	0	90	90	100	150	0
Cloud point (°C)	-5	-5	-5	-6	-6	1,6
CFPP (°C)	-7	-19	-17	-18	-19	-4

Table A2.4: Quality of the used diesel

Sample	DIESEL 2	DIESEL 3	DIESEL 4
Density @ 15°C, ASTM D 4052, g/ml	0.8536	0.8354	0.8392
Cetane Index ASTM D 976 (2 V)	49.1	53.0	48.8
Transparency and brightness	C&B (1)	C&B (1)	C&B (1)
Distillation, ASTM-D-86, °C			
10% recovered volume	202.0	191.0	191.5
50% recovered volume	283.0	271.0	258.0
90% recovered volume	358.0	353.0	357.1

(1) Clear and bright.

Table A2.5: Quality of the used biodiesel

REFERENCE	FAME 1	FAME 2	FAME 3
Origin	Soy oil		
<i>Date</i>	<i>June 2007</i>	<i>January 2009</i>	<i>January 2009</i>
Density @ 20°C, ASTM D 4052, mg/ml	0.8855	0.8817	0.887
Acid Number, ASTM D 664, mg KOH/g	0.313	0.149	0.298
Iodine Number, prEN 14111, g iodine/100 g	128.1	130.5	
Viscosity @ 40°C ASTM D 445, cSt	4.1422	4.136	
Water, ASTM D 4928-96, mg/Kg.	281.45	321	
Flash Point, ASTM D -93 °C	>160	169	
Corrosion to the copper strip 3 hs.@ 50°C, ASTM D 130	1A	1A	
Cetane Number ASTM D 613	51.9	46.8	46.2
Sulphur ASTM D 2622-03, % w/w	<0.0003	< 0.001	
Oxidation stability @ 110°C, EN 14112, hs	6.5	8.25	6
Cloud Point ASTM D 5773-05, °C	1.3	1.6	
CFPP IP 309-99, °C	-4	-4	-5
Methyl esters, capillary gas chromatography w/FID & MSD, %w/w	97.15	95.65	98.77
<i>Methyl ester C12:0</i>	0.01		0.01
<i>Methyl ester C14:0</i>	0.07	0.08	0.07
<i>Methyl ester C16:0</i>	10.22	10.84	10.73
<i>Methyl ester C16:1</i>	0.1	0.11	0.13
<i>Methyl ester C18:0</i>	4.19	4.57	4.42
<i>Methyl ester C18:1</i>	21.87	20.88	20.92
<i>Methyl ester C18:2</i>	51.38	50.3	52.73
<i>Methyl ester C18:3</i>	7.37	7.17	7.93
<i>Methyl ester C20:0</i>	0.34	0.34	0.36
<i>Methyl ester C20:1</i>	0.06	0.21	0.2
<i>Methyl ester C22:0</i>	0.39	0.3	0.36
<i>Non identified</i>	1.16	0.76	0.8
Methyl ester of linolenic acid, EN 14103, %w/w	7.37		
Methanol, EN 14110, %w/w	<0.01		
Monoglycerides, EN 14105, %w/w	0.63	0.62	
Diglycerides, EN 14105, %w/w	0.14	0.26	
Triglycerides, EN 14105, %w/w	<0.03	0.04	
Free glycerol, EN 14105, %w/w	<0.001	0.06	
Total glycerol	0.18	0.2	
Metals of group I (Na + K), EN 14538, mg/Kg.			
<i>Sodium</i>	<0.5	< 0.1	
<i>Potassium</i>	0.9	< 0.1	
Metals of group II (Ca + Mg), EN 14538, mg/Kg.			
<i>Calcium</i>	<0.5	< 0.1	-
<i>Magnesium</i>	<0.5	< 0.1	-
Phosphorus, UNE-EN 14107, mg/Kg.	<1.0	< 0.1	-

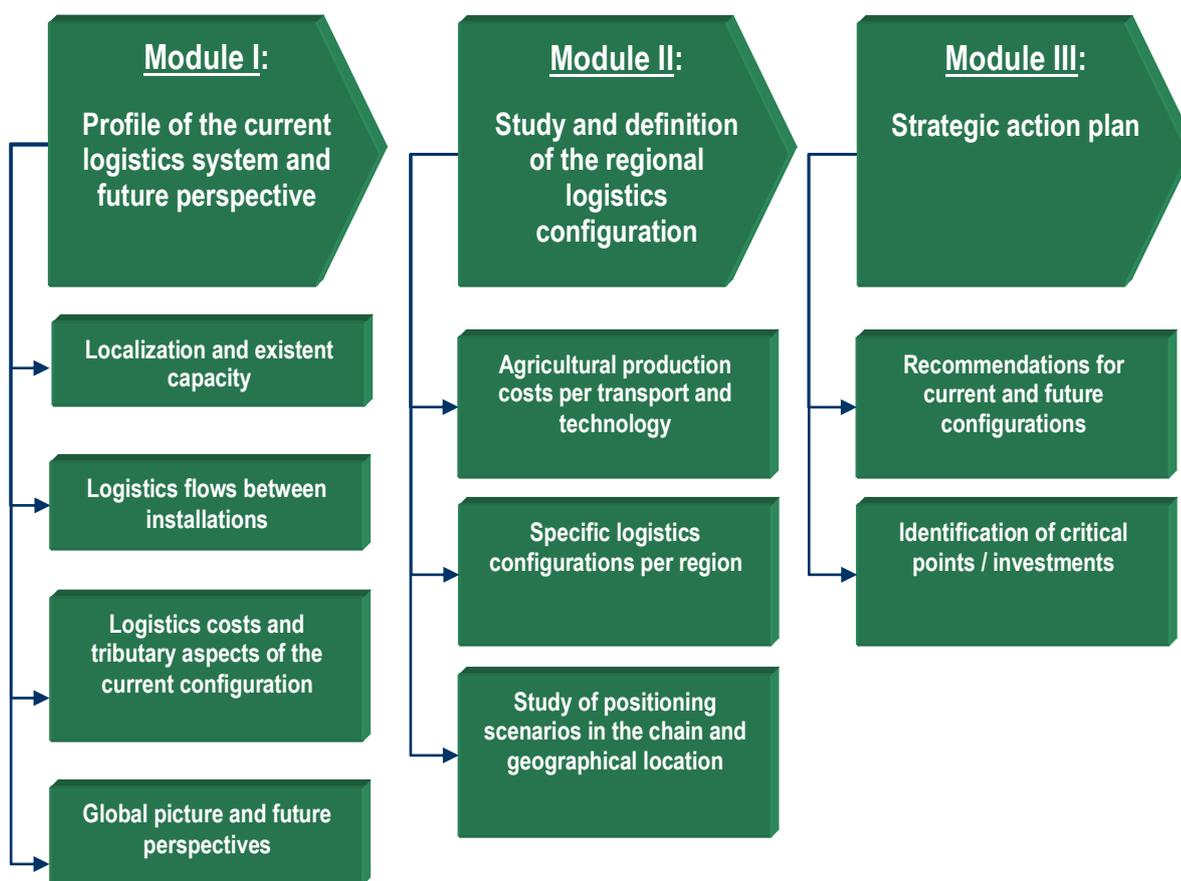
3 Logistical aspects of biodiesel’s production chain

3.1 Introduction

The definition of logistical aspects and their requirements will need a strategic study of each country’s conditions, including its motivations, crops, locations, distribution of demand and production, etc. that will then enable to identify for each country and its conditions, the best strategy of biofuels production and transport.

An example of a successful strategy to attain this purpose is the second in biodiesel’s study in Brazil, carried out by IBP, together with Universidad Federal do Río de Janeiro (UFRJ), whose preparation included the following stages:

Figure 3.1.1.1: Stages of the study on biodiesel in Brazil (IBP/UFRJ)



The objective of module I was to map and underpin the profile of the current operations, through the understanding of the actors and their roles in the supply chain, the existent production infrastructure, the cultivation regions and load flows. This stage also included the quantification of this system’s logistics costs, in terms of transport, stocks and storage.

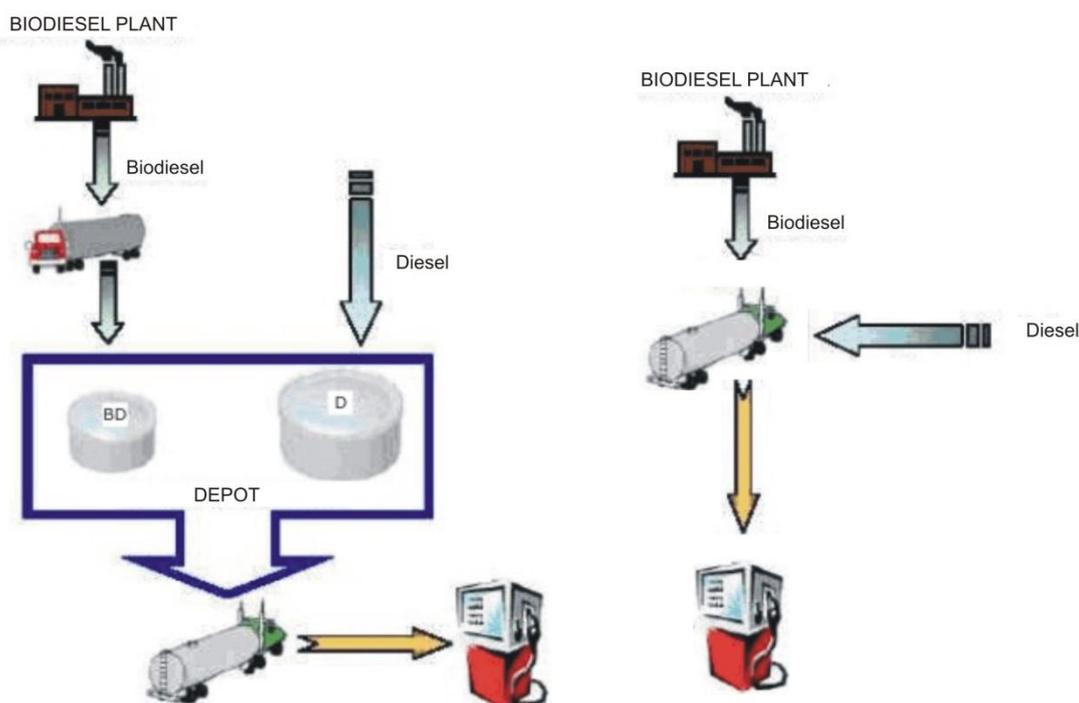
Module II defined the best logistics configurations for the current system of biodiesel supply for each country’s region, considering technological restrictions, their position in the chain and the opportunities for reducing

logistics costs. Also the necessary investments for the optimization of the current supply chains were identified.

Module III consisted on the preparation of recommendations on the best logistics configurations, considering the supply chain configurations, the agricultural development initiatives and the new industrial projects (pressers and biodiesel plants). This stage also included a survey of the needs for investments in specific logistics resources that assist in the optimization of the logistics flows and the indication of actions for the sector.

In general, for the oil business, biodiesel's logistics chain begins with the availability of B100. Following, the two possibilities for such scheme are presented:

Figure 3.1.2.1: Biodiesel production chain

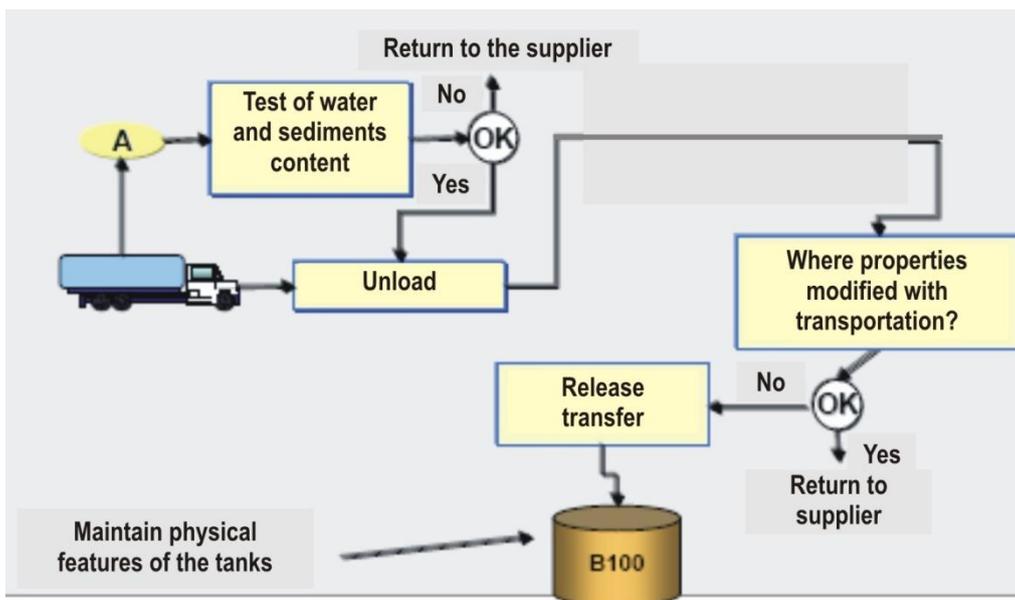


Source CNE (Comisión Nacional de Energía de España) - National Energy Commission of Spain.

3.2 Reception

The producer of B100 must seal the storage tank in its plant with certified quality and attach the correspondent certificate (density, flash point, ester content, etc.) when delivering the product. Nevertheless, it is recommendable that the recipient (in this case, the oil company) carries out fast additional controls when receiving the truck tank. Density, water and sediments, color, aspect, or other test of properties the company considers that could have been affected during its transportation.

Figure 3.2.1.1: Scheme for the reception of B100



Source: IBP/UFRJ Study

3.3 Storage

The stability of diesel and its mixtures with biodiesel is related with its long-term storage stability (usually called “oxidative stability”) and with its stability at high temperatures in the fuel system (usually called “thermal stability”). Vegetable oils and fats contain natural antioxidants; however, certain processing methods may eliminate these natural antioxidants and therefore reduce their stability. Some examples of this type of procedures are: blanketing, deodorization, or fats and oils distillation. In such cases the usage of antioxidant additives is advisable. Below there is a listing of some important considerations to assure an adequate storage of biodiesel:

1. **Avoid the exposition of the fuel to heat, light and oxygen:** Oxidative stability of biodiesel is closely related with the level of unsaturation of the fatty acids that compose it. The greater the saturation of such acids, the more stable is the fuel. The unsaturations may react with oxygen and form peroxides that in turn are transformed into acids, sediments and gums, and solar heat and light accelerate this process.
2. **Store diesel-biodiesel mixtures instead of B100:** B100 is less stable than its mixtures with diesel, and there is less concerns in cold climates towards the cloud point with these mixtures than with B100. Biodiesel could solidify much easily at low temperatures than diesel; however, mixtures with less than 20% maintain the same cold flow properties than diesel, and below 5% are practically the same as diesel.
3. **Monitoring of acid number and viscosity of B100 when receiving it and after that, for a period of time, may indicate if it is oxidizing:** The loss of oxidative stability (aging) of biodiesel may increase its acid number, viscosity and form gums and sediments that plug the filters and reduce the pumps’ life cycle. However, in some cases, the formation of depositions as a consequence of B100 cleaning or dissolution may be misread with the formation of gums or sediments originated in the fuel’s aging. In both cases the filter may be plugged, but precaution should be taken by knowing how to correctly differentiate the cause. For instance, if the acid number of the fuel complies with the specification, then the formation of sediments is probably caused by the cleaning and not by the aging or oxidation of the fuel.
4. **Store B100 in carbon steel tanks:** Certain metals such as copper, lead, pewter and zinc and their alloys accelerate the oxidative degradation process of B100, so they should not be stored in systems containing these metals for long periods. Chelant additives may be added in order to deactivate such metals reducing

or eliminating their impact; however, it is recommended to store B100 in carbon steel tanks in order to avoid these inconveniences. Other materials as aluminum, steel, Teflon, viton, fluorinated plastics, nylon and most fibreglasses are also compatible with B100. It is recommendable to establish a monitoring program to perform monthly visual inspections of the exposed materials for more than a year, since there is still little experience in the usage of B100. For instance, it is known that B100 may be weared out, softened or filtered through hoses or seals produced with elastomers, rubbers and plastics with prolonged exposition. Materials like rubbers of nitrile, polypropylene, polyvinyl and tygon® are particularly vulnerable to B100 (see table below). Viton, Teflon and elaflex are compatible with B100 and can be used in hoses. For mixtures of 20% or less there are no great compatibility differences with materials.

Table 3.3.1: Compatibility of elastomers with biodiesel

Material	Compatibility
Buna-N	Not recommended
Butadiene	Not recommended
Butyl	Slight effect
Chemraz	Satisfactory
Ethylene Propylene EPDM	Moderate effect
Fluorocarbon	Satisfactory
Fluoro silicon	Soft effect; increases swelling
Fluoro silicone	Soft effect
Hifluor	Satisfactory
Hypalon	Not recommended
Natural rubber	Not recommended
Neoprene	Not recommended
Neoprene / Chloroprene	Not recommended
Nitrile	Not recommended
Nitrile, acetonitrile	Soft effect with B20, affects swelling and resistance to breaking
Hydrogenated nitrile	Not recommended
Nitrile cured with peroxide	Soft effect with B20, affects swelling and resistance to breaking
Nordel	Moderate to severe effect
Nylon	Satisfactory
Perfluoro-elastomer	Satisfactory
Polypropylene	Moderate effect; increases swelling, reduces hardness
Polyurethane	Slight effect; increases swelling
Styrene - butadiene	Not recommended
Teflon	Satisfactory
Viton	Satisfactory; type of cure affects compatibility with oxidized biodiesel. See specific types of viton below:
Viton A-401C	Satisfactory with fresh colza methyl-esters; not recommended for oxidized B20 mixtures or superior.
Viton F-605C	Satisfactory with fresh colza methyl-esters; not recommended for oxidized B20 mixtures or superior.
Viton GBL-S	Satisfactory with fresh colza methyl-esters and with any oxidized mixture.
Viton GF-S	Satisfactory with fresh colza methyl-esters and with any oxidized mixture.
Wil-Flex	Moderate to severe effect

Source: *Guideline of Biodiesel Handling and Usage (4th Edition, 2008)*, National Committee of Biodiesel, USA.



- 5. Store B100 for no more than 6 months unless additives are used to stabilize it:** Biodiesel (B100 and its mixtures) has a higher flash point than diesel. Regulation ASTM D 4625 suggests that the least stable B100 could be stored for up to 8 months, while the most stable could be stored for a year or more. However, there is not much experience in storing B100 for periods longer than 6 months.
- 6. Avoid pollution with water:** Biological pollution may happen in diesel as well as in biodiesel and in this case the pollution with water must be monitored, since the microorganisms that consume hydrocarbons – either fungi, bacteria, aerobic yeast – (usually called HUM BUGS) generally grow in the water-fuel interface. Anaerobic colonies, which generally reduce sulphur, usually grow in the sediments deposited on tanks' surfaces and corrode them. In order to avoid water pollution, the suggestion is to maximize the height / diameter relation of the storage tanks, use secant filters in the relief valve and use small volume tanks. Additionally, tanks of inverted conical bottom could be used to facilitate water drainage, or biocides (indistinctively for diesel or biodiesel because they act in water).
- 7. Store at a temperature higher than its pouring point:** B100 may be stored underground without taking specific measures in almost any climate condition; however, onshore it may need isolation, agitation, heating or other measures if air temperature descends below its pouring point. These requirements apply to pipes, tanks, pumping system and vehicles. Should the biodiesel's temperature descend below its pouring point, the crystals that start to form should liquify again if the biodiesel's temperature increases. However, this process may be slow if the fuel is very slowly heated or not heated enough. These crystals can decant to the tank's bottom and form a gel layer. The slow agitation may avoid the accumulation of crystals in the tank's bottom, and also help to dissolve them. If B100 has completely turned into gel and must be quickly used, it may be useful to increase its temperature to approximately 40°C to melt the most saturated components of biodiesel. If there is more time, inferior temperatures may be used and time given to the mixture in order to reach its equilibrium cloud point. The effectiveness of additives for cold flow depends on the type of biodiesel and it also may vary for the same type of biodiesel, if the oil where it came from was pre-treated or not. For these reasons, it is convenient to perform laboratory tests to measure the cold performance using the most unfavorable real conditions to which the fuel will be subject to in each case (lower temperatures, specific winter fuel if applicable, specific additive to use).

3.4 Transportation

It is recommendable to observe the following guidelines when transporting biodiesel:

1. Use exclusive means to avoid incompatible loads and materials, clean them periodically and drain and inspect them in each load change.
2. Assure that the previous load and the residual are diesel or another acceptable substance (residues of food products, vegetable crude oil, gasoline or lubricants are only acceptable if a previous washing was made).
3. Assure there is no residual water left in the tank.
4. In case of transporting tallow or palm biodiesel it is also recommendable to avoid low temperatures (according to the biodiesel's flow point). In these cases it may be necessary to isolate or heat the means of transport of B100, or either transport it already mixed with diesel.
5. In cold climates it should be seen that the filters in the fuel load pumps are not obstructed due to FAMES crystallization. Therefore, the mixture of biodiesel with diesel can be filtered before delivering it to the client's tank. In this case it is recommendable to use a filter that is, at least, as thin as vehicles' filters.

3.4.1 Inconveniences in transportation

Biodiesel's transportation in pipelines is not recommendable when jet fuel is also being transported in the same pipeline. The same happens in case of transporting biodiesel and Jet A1 in the same tanker. This is due to the fact that FAME can be absorbed through the walls of the pipeline or tank when in contact, and then desorbed when transporting another fuel and pollute it. IATA² recommends not exceeding 5ppm of FAME in Jet A1 until the studies being carried out to evaluate superior pollution (of up to 100ppm) are not finished.

In case of transporting biodiesel in the same pipeline or tanker together with Jet A1, it is recommended to take certain precautions:

- Minimize the sizes of Jet batches
- Modified interface cut
- Control the sequence of products in the pipeline
- Use buffers (anterior and posterior) not containing FAME
- After transporting B5 in a tanker, wash it with hot water and transport another product without FAME before transporting Jet. In case of transporting B100, 3 previous loads plus washing with hot water will be required so that the tank is in conditions of transporting Jet.

3.5 Mixture of B100 and diesel

In general, the mixture of biodiesel and diesel is simple if it is taken into account that the more it is mixed the better, and that biodiesel is slightly denser than diesel (specific weight 0.88 compared to 0.85 of diesel). Before mixing them up, it is always recommendable to keep a sample of the original fuels, in order to perform tests should some inconvenient arise due to the mixture's performance. It is worth clarifying that biodiesel is a fuel designed to be mixed with diesel and not with gasoline. There are three different ways of mixing biodiesel with diesel.

1. Splash mixture: diesel and biodiesel are separately loaded in a recipient with relatively little mixture during the loading. The recipient is usually a tank truck or fuel truck, or also a barrel. Once the fuels are in the recipient, road travelling is considered enough agitation. Generally a good mixture is obtained through this procedure; however, if biodiesel is loaded in the recipient before diesel and the temperature is low, it is probable that no good mixture will be attained.
2. Mixture in the tank: diesel and biodiesel are separately or jointly loaded at such a speed that will enable the mixture without the need of recirculation or additional agitation. In some cases this type of mixture is similar to the previous one, with the proviso that this one does not need road travelling; however, in other cases, the tank may need recirculation or additional mixture. Due to the fact that diesel and biodiesel are easily mixed, depending on the way the fuels are loaded and the tank's geometry, among other things, in many cases the mixture in the tank is usually enough to obtain an homogeneous mixture.
3. Mixture on line: in this case biodiesel is added to a diesel flow in a pipeline or hose in such a way that both fuels are mixed with the turbulent movement along the line, or with the mixture caused when loading the biodiesel. Biodiesel is slowly and continuously loaded to the diesel flow through an input line or a "Y", or in small quantities, way down in time, in a similar way as additives are added to diesel.

² International Air Transportation Association

The best option to mix biodiesel with diesel depends on the fuel's volume, the investment and the needs. Small volumes, as barrels, are generally mixed by splash or by dispersing B100 in a homogeneous way on the diesel's surface in the storage tank. If it cannot be dispersed in a homogeneous way or simply adding diesel is not enough to mix it completely, some additional agitation may be required. B20 is usually mixed in tank trucks with bottom load. Biodiesel is firstly loaded and diesel is secondly loaded. The mixture continues during the truck's travel up to the delivery point and when pumping the fuel from the truck to the storage tank in the point of consumption. These mixture instances are usually enough, except in very cold climate conditions (when air temperature is below the gel point of B100) where it is recommendable to load the tank truck first with half the diesel, then with the biodiesel and finally with the rest of the diesel. This way, the conversion of B100 into gel when contacting the cold walls of the truck tank is prevented. The mixture on line requires two pumps and a dual injection system. It is the most accurate and reliable mixture procedure to guarantee a specific mixture percentage. These systems are dimensioned for a single mixture percentage, so, if two different levels are required they must be mixed in different instances.

There are two simple tests to confirm that biodiesel and diesel have been sufficiently mixed inside the tank. Three samples are taken: one from the superior zone, another from the medium zone and a third one from the inferior tank's zone, and then:

1. The mixture percentage is analyzed in each sample by means of infrared spectroscopy (EN 14078) or by density's measure or specific weight. If the variation of the results of the specific weight is less than or equal to 0.006 the mixture is probably sufficient.
2. The samples are placed in a freezer with a thermometer and controlled each 5 minutes until any of the samples start to crystallize. Such temperature is registered and the samples are now controlled each 2 minutes until they have all started to crystallize. The three samples' crystallization temperatures are compared and they must all be within a range of 3°C, otherwise the fuel will require more agitation.

3.5.1 Mixture in refineries or terminals

The most frequent distribution scheme (due to the fact that biodiesel production centers and refineries usually have different locations) consists of transporting biodiesel and diesel separately to an intermediate terminal where the tank trucks are loaded for the subsequent capillary distribution, instead of transporting biodiesel to the refinery for its mixture with diesel. However, there are no negative impacts for the refinery's operation if the mixture is made there, except for the need of having a specific tank for B100. Moreover, in the following there is a listing of certain advantages of the mixture in refinery versus the mixture in terminal:

- Hydro-treatment of diesel to reduce its sulphur content diminishes its lubricity, but the biodiesel with which it is mixed improves it, avoiding the usage of additives to improve the lubricity in the refinery and complying with the regulation when exiting the refinery, if so required.
- Usually, a refinery's lab is more complete than a terminal's lab; therefore biodiesel's quality can be better controlled in a refinery than in a terminal.
- In case of detecting out-of-specification biodiesel, it will be more difficult to correct such deviation in a refinery than in a terminal.
- Depending on the type of raw material used to produce biodiesel, the same could reduce the cetane number of the mixture with regard to diesel, thus requiring the addition of additives in the refinery to increase it.



3.6 Necessary installations

Following is a listing of the installation requirements for the reception of B100, its mixture with diesel and distribution:

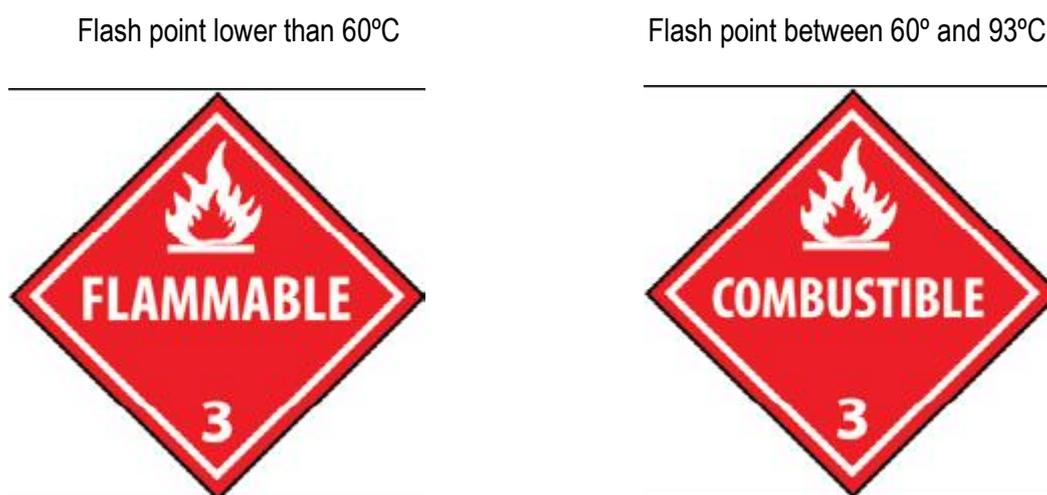
- System of reception of the tank truck with B100: Loading and unloading platform.
- Specific tank for B100
- Circulation/mixture system in the tank.
- Heating system in case it is required to maintain the biodiesel fluid.
- Mixture in truck: Dosage and measuring system.
- Specific lab equipments necessary to control B100 and its mixtures with diesel.

4 Environmental, health and safety aspects of biodiesel handling

B100 is a fuel and as such, the usual precautions must be taken for the safe handling of this type of substances; however its flash point is higher than 100°C, therefore it is considered of low risk in comparison with its mixtures with diesel and/or kerosene. The latter ones are highly flammable (flash point of 52° to 96°C for diesel and of 38° to 72°C for kerosene), thus, the mixture with biodiesel has an intermediate flash point.

As a reference, in USA, no warning signal is demanded for the transportation of B100, but for the transportation of its mixtures if their flash point is lower than 93°C according to the figure below:

Figure 4.1.1.1: Warning signals for the transportation of B100



Source: *Guideline of Biodiesel Handling and Usage (4^o Edition, 2008), National Board of Biodiesel, USA.*

Should B100 catch fire, it could be extinguished with dry chemicals, foam, halon, CO₂ or water; however, the water jet could disperse B100 and the fire with it.

Methyl-esters are excellent solvents of sediments and have been used as cleaners with a low content of volatile organic compounds for decades. Any biodiesel spill must be cleaned immediately, since it may dissolve certain materials, paints, and even labels that may be in contact with or near the fuel.

The precaution of cleaning with water and soap and drying in a ventilated environment, the rags that were soaked up in B100, must be taken before they are thrown away, otherwise they could spontaneously catch fire.

5 Biodiesel's economic aspects

The irruption of biofuels in the oil companies' business, as a consequence of legal regulations that have forced them or will force them to mix a percentage of the same with fossil fuel, have compelled them to position in this new scenery.

In each one of these countries in which regulations on the usage of biofuels are implemented, especially biodiesel, the refineries will have the possibility to integrate in all the biofuels' value chain, or simply participate on only its last stage.

The investments needed to undertake these projects depend on the strategic decision taken. If the decision was to integrate in all the biodiesel's value chain, it could imply the involvement in activities such as: a) exchange of grains for oil products (sale of diesel and lubricants to farmers who pay these products with grains), b) grinding of these grains to obtain oil (shareholding in mills or payment of a rate to third parties in order to delegate them this task) c) processing of the company's own oil by third parties in order to obtain biodiesel or processing in a company-owned or associated plant and d) mixture of the company's own biodiesel with diesel in handling refineries or terminals.

In this integration scheme, the investment will be associated with setting up a new plant for biodiesel production or with shareholdings in grain grinding and/or biodiesel production and with the necessary for the reception, storage and mixture of biodiesel with diesel in handling refineries or terminals.

Regarding the investments to set up a new biodiesel production plant, the plant's scale is a very important issue. Small scales (<100,000 tons/year) would not be profitable. Larger scales (200,000 tons/year) would require investments of about US\$ 40 million. The economy of scale and a good market price for the process' byproducts increase these projects' profitability.

The investments and costs associated with the strategy of participating in the last stage in the biodiesel chain, this is its mixture with the fossil product, may be about 100 US\$/m³ of biodiesel. This value includes the logistics costs to transport biodiesel from the producer to the mixture installations, costs of capital for reception, storage and mixture of biodiesel with diesel, working capital and costs to control the quality of reception and handling.

Biodiesel's production costs and sale prices may vary considerably depending on the local environment in consideration. In Brazil, IBP together with the Universidad Federal de Rio de Janeiro (Federal University of Rio de Janeiro) carried out an in-depth study on biodiesel in Brazil in 2007, in which biodiesel production costs were calculated for different types of oilseeds, resulting in approximately 700 US\$/m³ for soy. The average price of biodiesel is about 1,000 US\$/m³ (established by ANP³).

In Colombia there is a pricing structure regulated by production, distribution and sale of the mixture of diesel with biodiesel (see Resolution 18 1780 of 12/29/2005). Such structure fixes the maximum income of the producer based on the parity price of the import of diesel (factor of efficient production of diesel in turn settled based on "the quotation of the 2 US Golf Coast Waterborne index") and the market's representative rate. The minimum income of the producer is settled based on the parity price of the export of palm oil, the factor of efficient production of biodiesel (US\$ 151/Ton, which corresponds to the local average cost of biodiesel

³ Agencia Nacional de Petróleo, Gas Natural, y Biocombustibles, www.anp.gov.br (National Agency of Oil, Natural Gas and Biofuels)



production from palm) and the market's representative rate. It also establishes the maximum sale price to the wholesaler distributor and the sale price at the wholesale plant supply.

In general, all countries that have sought to increase the participation of biofuels in their energy matrix have done it by leveraging the investments and costs to be taken on by the involved companies, through fiscal and tax benefits. From the point of view of diesel's production-demand balance, for those countries with a deficit in their production regarding the country demand, introducing an additional volume of biodiesel to the pool of diesel will enable the refineries (especially the small ones) to postpone or avoid investments to increase diesel's production and, at country level, substitute imports, and therefore, improve the system's economy.

6 Regulatory aspects of biofuels

Each country is autonomous when establishing the specific policies and regulations to foster the development of biofuels. Through a compilation and analysis of the most relevant aspects of biofuels laws (quality, taxes/control, adulteration, etc.) in force in the region, the intention is to make of this chapter a guideline for those countries and companies who want to enter the biofuels market.

In April 2007, OLADE published the report “*Análisis de legislación sobre biocombustibles en América Latina*” (“*Analysis of biofuels laws in Latin America*”). The same does not reflect the position of ARPEL or of any of its members, but since it significantly contributes to the objectives of this chapter, the same will be limited to complement part of the information there contained.

6.1 Argentina

The legal framework in Argentina is ruled by Law 26093/2006 “*Biocombustibles: Régimen de regulación y promoción para la producción y uso sustentables*” (“*Biofuels: Regulation and promotion regime for its sustainable production and use*”, that comprises aspects such as: regulation and promotion regime for biofuels’ sustainable production and use, application authority, functions, national advisory committee, qualification of production plants, mixture of biofuels with fossil fuels, subjects beneficiaries of the promotional regime and breaches. This law was regulated by Decree 109/2007 (Biocombustibles: Ley N° 26093 – Alcances) (Biofuels: Law N° 26093 – Scope) that details the activities involved by the terms of Law 26.093, the application authority, functions, national advisory committee, qualification of production plants and promotional regime. Law 26334 was promulgated on the 2nd. January, 2008. It establishes the promotion regime of bioethanol production (under the dispositions of Law 26093). Complementing Law 26093, the mechanism of selection, approval and priority order of bioethanol production projects is established through Resolution 1293/2008 of 13th. November 2008. The promotional benefits of the Regulation and Promotion Regime for Biofuels’ Sustainable Production and Use will be granted by means of this mechanism. Similarly, on the same date, the Secretary of Energy, through Resolution 1294/2008, determined the procedure to establish the acquisition price of ethanol destined to the mixture for the Biofuels’ Sustainable Production and Use created by Law N° 26.093. The Quality Specifications that biofuels must comply with are determined in Resolution SE 1283/2006 for biodiesel and Resolution 1295/2008 for bioethanol, in accordance with Decree 109.

6.2 Brazil

The PNPB - *Programa Nacional de Producción y Uso de Biodiesel (National Program of Production and Use of Biodiesel)* - is ruled by Law 11.097, dated on 13th January 2005, which establishes minimum percentages of the mixture of biodiesel with diesel, as shown below:



Since July 1st. 2009, through Resolution CNPE n°2, the minimum percentage increased to 4%. Law 11,116, published on 18th May 2005 is also noteworthy. It disposes the special registration of the producer or importer of biodiesel and the incidence of the contribution for the PIS/Pasep (Programs of Social Integration and Formation of the Government Employee’s Patrimony) and Cofins (Contribution for social security financing) on

the incomes derived from the sales of that product. Following, are the other regulations and laws of biodiesel's regulatory framework in Brazil.

Decrees

- [Decree Nº 6,458, May 14, 2008](#)
It extended the options of raw materials of family farming for the northern and northeast and semiarid regions and modified the PIS/CONFINS for those regions.
- [Decree Nº 5,457, June 6, 2005](#)
It reduced the contribution aliquots for the PIS/PASEP and the COFINS incidents on the import and commercialization of biodiesel.
- [Decree Nº 5,448, May 20, 2005](#)
It regulates the § 1 of article 2 of Law Nº 11,097, of 13th. January 2005. It disposes the introduction of biodiesel in Brazil's energy matrix and grants other measures.
- [Decree Nº 5,298, December 6, 2004](#)
It modified the aliquot on industrialized products incident on the product mentioned.
- [Decree Nº 5,297, December 6, 2004](#)
It disposed the reduction coefficients of the contribution aliquots for PIS/PASEP and COFINS, incidents in production and commercialization of biodiesel, the terms and conditions for using the differentiated aliquots and grants other measures.
- [Decree, December 23, 2003](#)
It created the Inter-ministerial Executive Commission in charge of implementing the actions directed to the production and use of vegetable oil – biodiesel as an alternative source of energy.
- [Decree, July 2, 2003](#)
It created the Inter-ministerial Work team in charge of presenting studies on the viability of using vegetable oil – biodiesel as an alternative source of energy, proposing, if necessary, the necessary actions for the use of biodiesel.

Disposition

- [Disposition MME 483, October 3, 2005](#)
It established the guidelines for the execution of biodiesel acquisition biddings by the ANP.
- [Disposition ANP 240, August 25, 2003](#)
It established the regulations for the usage of solid, liquid or gaseous fuels not specified in the country.

Resolutions

- [Resolution CNPE nº 02, May 18, 2009](#)
It increased the compulsory minimum percentage of the mixture of biodiesel with diesel from 3% to 4%.
- [Resolution ANP nº 07, March 19, 2008](#)
It modified the specification to commercialize biodiesel.
- [Resolution CNPE n ° 3, September 23, 2005](#)
It reduced the terms for the compliance with the minimum mandatory percentage of the biodiesel added to diesel, it determines the acquisition of the biodiesel produced by manufacturers with the label "Social Fuel", through biddings.
- [Resolution ANP nº 42, November 24, 2004](#)
It established the specification for the commercialization of biodiesel which may be added to diesel in a proportion of 2% in volume.

- [Resolution ANP n° 41, November 24, 2004](#)
It established the regulation and obligatoriness of the authorization of the ANP for the exercise of the activity of biodiesel production.
- [Resolution BNDES N° 1,135 / 2004](#)
Subject: Program of Financial Support to Investments in Biodiesel within the Program of Production and Use of Biodiesel as an Alternative Source of Energy.

Normative Instruction

- [Normative instruction n° 02, September 30, 2005](#)
It set out the criteria and procedures relative to framing biodiesel production projects in the label “social fuel”.
- [Normative instruction n° 01, July 5, 2005](#)
It set out the criteria and procedures relative to the concession of the usage of the social fuel label.
- [Normative instruction SRF n° 628, March 2, 2006](#)
It approved the option applicable by the Special Regime of Calculation and Payment of the Contribution for the PIS/Pasep and Cofins incidences on Fuels and Beverages (Recob)
- [Normative instruction SRF n° 516 February 22, 2005](#)
It set out the Special Registration to which all biodiesel producers and importers are subject to and grants other measures.

Ethanol was adopted in Brazil as part of the fuel mixture in 1931, when its usage was regulated with decree-law n° 19,717 of 20th February, 1931. In that moment, the established limit for the fuel mixture of anhydrous alcohol was from 0 to 5%. In 1976, during the oil crisis, the percentage of fuel mixture varied between 10% and 15% and later between 20% and 25%, limits adopted nowadays and determined by law n° 10,464, article 16 of 25th May, 2002. Other items of the ethanol legislation may be consulted in the website of ANP (National Agency of Oil, Natural Gas and Biofuels), regulating body of the activities integrating the mentioned industry in Brazil, or CIMA (Consejo Interministerial del Azúcar y del Alcohol – Inter-ministerial Council of Sugar and Alcohol), body responsible for the approval of the programs of production and use of fuel ethanol in the country, establishing the respective unitary financial values and maximum costs.

6.3 Colombia

Decree 4299 of 2005 has the aim of establishing the requirements, obligations and the punitory regime, applicable to the agents of the distribution chain of liquid fuels derived from oil and mixtures with biofuels. It also establishes definitions such as: fuel alcohol, storage, certification, certificate of conformity, basic fuels, industrial marketer, wholesaler distributor, retailer distributor, service station, evaluation of conformity, among others. The Decree 2629 of 2007, establishes dispositions to promote the usage of biofuels in the country, as well as measures applicable to vehicles and other engine artifacts that utilize fuels to work. This Decree defines that as from 1st January, 2012 the new vehicles' fleet and other new engine artifacts requiring gasoline to operate, which are produced, imported, distributed and commercialized in the country, must be conditioned with flex-fuel engines for at least 20% (E-20), this is to say, they shall normally operate at least using indistinctly basic gasoline or mixtures composed by 80% of basic fossil gasoline and 20% of fuel alcohol (flex-fuel engines by 20%, E-20). As from 1st January, 2012 the new vehicles' fleet and other new engine artifacts requiring diesel to operate, which are produced, imported, distributed and commercialized in the country, must be conditioned so that their engines use at least B-20, this is to say, they shall normally operate at least using indistinctly fossil diesel or mixtures composed by 80% of fossil diesel and 20% of biofuels for diesel engines.



Finally it regulates that when exceptional situations of social, public and/or national interest occur, according to the National Government's judgment, it may authorize the simultaneous use of another type of fuel and/or vehicles or engines. Decree 2328 of 2008 creates the Cross-sectorial Commission for Biofuels' Handling, which is constituted by the Ministries of Agriculture, Mines and Energy, Environment, Transport, Commerce and the National Director of Planning. Among its functions are the following: coordinating the process of formulating and implementing policies regarding biofuels, to be adopted, formulated and executed by the different bodies and entities of the Government, and organizing actions to promote the development and innovation in the production and handling of biofuels.

6.4 Peru

The legal framework in Peru is specified with Law N° 28,054 "*Ley de Promoción del mercado de Biocombustibles*" ("*Law of Promotion of the Biofuels' Market*") published on the 7th. August, 2003, which comprises aspects to promote the biofuels' market, with the objective of promoting the agricultural and agro business development, reducing environmental pollution and searching for renewable energy sources. The Regulation of such Law, D.S. N° 013-2005-EM, published on 13th. March, 2005, establishes parameters for the production and commercialization of biofuels: the percentage, the application schedule and usage of fuel alcohol (7.8% in gasoline) and of biodiesel (from 2 to 5% for Diesel N° 01 and N° 02). Both applications would be executed as from 30th. June, 2006 by sectors in the country and would end up on 1st. January, 2010 with the commercialization in all the country. The regulation for the commercialization of biofuels D.S. N° 02-2007-EM, published on 20th April, 2007, establishes the percentage of mixture, commercialization schedule of biodiesel B100, diesel B2 and B5, the obligatoriness of the usage of diesel B2 as from 1st. January, 2009 and of fuel alcohol as from 1st January, 2010. By means of Ministerial Resolution N° 165-2008-MEM-DM, dispositions regarding the quality and trial methods for diesel B2, B5 and B20 were established. On 27th December, 2008, by means of Decree N° 064-2008-EM the regulation of biofuels regarding control, wholesale commercialization and mixture locations was modified.

7 Experiences with biofuels in the region

The objective of this chapter is to present learned lessons, case studies, vehicle performance testing, unsuccessful events and their causes, all related to biofuels in Latin America and the Caribbean. Following we present two experiences, and hope that the members of ARPEL go on exchanging additional experiences of this sort, through ARPEL Portal and especially through ARPEL's Virtual Forum on Biofuels⁴.

7.1 AGROPALMA Project

A different example of biodiesel production is the process developed by Professor Donato Aranda, of the Chemistry School at the Federal University of Rio de Janeiro – UFRJ, which consists in the esterification of the fatty acids present in palm, according to the details below.

This invention is related to the catalytic process and presents the ranges of optimal conditions of reaction in terms of temperature, pressure, reaction time and concentration of reagents, for the efficient transformation of the fatty acids present in palm grains in methyl or ethyl esters. Moreover, it refers to the use of solid catalysts with acid sites for the esterification with alcohol of the free fatty acids coming from palm grains.

In this project, solid acid catalysts are used for the esterification of mixtures of palm fatty acids, defined as carboxylic acids of chains of 16 to 18 carbon atoms with or without double bonds between the carbons. These fatty acids may be esterified with methyl or ethyl alcohols. The usage of solid acid catalysts in this esterification process of fatty acid mixtures, assumes the existence of acid sites capable of promoting the reaction. Moreover, this project demonstrates the vital importance of adding alcohol in a larger proportion than the stoichiometric.

In the face of the current situation of biodiesel's international homologation, methanol and ethanol are the mainly used alcohols. However, other products may be used, both for the formation of biodiesel and for the formation of additives in order to improve the lubricity, the cetane index even as surfactants for mixtures of polar and not polar fuels (for example, alcohol - diesel mixtures). Therefore, the formed esters may be used also as solvents, surfactants or intermediaries of surfactants or detergents.

In order to obtain high conversions and high selectivity to ester, alcohol-acid molar relations of 3 to 15 and preferably between 6 and 12, must be utilized. In this reactive medium, it is required to have a catalyst that fosters the esterification reaction of fatty acids at the lowest temperature possible, in such a way that the reaction is economically viable and that there is no thermal decomposition of the reagents. The process involves temperatures between 6° and 200°C. The preferred range is between 120° and 170°C.

High pressure favors the reaction but is not indispensable. For more volatile alcohols, as methanol and ethanol, the range of reactive temperature previously described, causes the process' pressure to be usually over atmospheric pressure. Reactions involve components in liquid phase and active sites located among the solid catalyst's particles, and in consequence, subject to the limits of mass transfer. A sufficient agitation must be assured in order to minimize this problem. Agitation speeds between 400 and 1,500 rpm are adequate for this aim.

⁴ To participate in the Forum please contact ARPEL Portal Administrator, administrador@arpel.org.uy

Any solid and thermally stable catalyst with Bronsted and/or Lewis acidity under the reaction conditions may be used. The preferred catalysts are the following: zirconium sulphate (sulphur content between 3% and 6%) with a surface between 30 and 200 m²/g pre-calcined at a temperature between 300° and 800°C; zeolites with hydrogen as compensation cations with a molar relation silica – aluminum of between 4 and 75 and a surface of 200 to 800 m²/g; or super anhydrous aluminum chloride or chemically supported.

The esterification process of fatty acids in heterogeneous catalysts can be carried out in batches, in a continuous reactor of perfect mixture, or in a fixed bed reactor. In case of using continuous systems, the reaction time related to the fatty acid is 1 to 20 min. The recommendable term is 3 to 15 min.

7.2 Lengthy tests of diesel-biodiesel mixtures

The development of biofuels in Colombia, especially biodiesel, has involved several sectors such as the agro business, transport and fuels distribution sectors. Thus, a technical cooperation agreement was signed between ECOPEL – ICP and Cenipalma in June 2005, whose objective was to “Jointly develop efforts to define the physicochemical characterization of the mixtures of palm oil and biodiesel with diesel; the evaluation of the mixtures in test engines and vehicles; and the performance of lengthy tests with vehicles’ fleets”.

The results of the first stage, conducted in laboratory, demonstrated that palm biodiesel pure or mixed with diesel fuel has a good performance in the engine and that the emissions of particulate matter, nitrogen oxides and carbon dioxide are significantly reduced when it is used. The second stage of this project was designed to validate the results obtained in stage 1, performing lengthy tests (100,000 km.) with mixtures of diesel and biodiesel of palm oil, which would also enable evaluating both the engine’s performance and the effect the usage of palm biodiesel has over time on the injection system’s components that are in contact with the fuel.

Carrying out these tests in the city of Bogotá, at 2,600 meters above sea level, additionally enables to evaluate the effect of altitude in the performance and in the emissions of diesel engines when diesel – palm biodiesel mixtures are used, from 5 to 50%. Thus, 12 buses from the capital’s public transport system were used to evaluate two buses with each one of the following mixtures: 0, 5, 10, 20, 30 and 50%.

7.2.1 Performance of the fuel storage and mixture station

7.2.1.1 Design and construction

With the objective of facilitating fuel supply to test buses, it was necessary to build a fuel storage station that enabled supplying the defined mixture of diesel-palm diesel in proportions of 5, 10, 20, 30 and 50% to the selected vehicles.

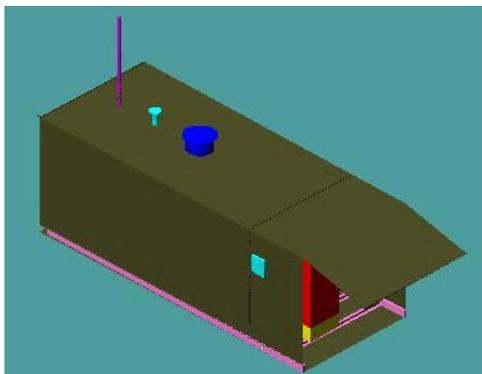
The design of the mixture and storage station had two tanks of 3,000 gallons of capacity, one of them destined to store biodiesel and the other to store diesel. The design also had four tanks of 1,000 gallons of capacity to store diesel - palm biodiesel mixtures at 5, 10, 20 and 30% and a tank of 3,000 gallons to handle the non-conforming product.

The functional units of the storage and mixture station are described below:

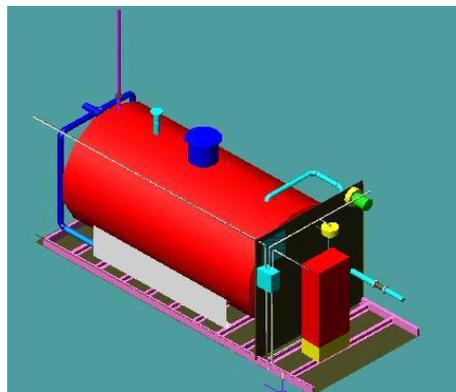
7.2.1.1.1 Fuels storage

The design of the plant has two storage tanks and they in turn have an external container (see Figure 7.2.1.1). The external container operates as a dike should there be a fuel spill, with a holding capacity of 137% with regards to the tank's nominal capacity.

Figure 7.2.1.1: External and internal view of the fuels storage tanks and their containers.



External view of an EDS



Internal view of an EDS

Fuels storage tanks are built according to regulation API 650. Each tank has a nominal capacity of 5,873 US gallons, of which it is allowed to work only with a payload of approximately 4,200 gallons. Each tank is conditioned in such a way that different activities may be carried out, such as: (corrective and preventive) inspection and maintenance tasks, inventories control and detection of leaks. They also have: a loading alarm system, steam output and fuel input – output pipelines. As palm biodiesel can solidify at temperatures lower than 14°C, the container of the palm biodiesel tank was conditioned with an indoor air heating system, in order to maintain the container's temperature between 20°C and 25°C, which guarantees that the product will remain liquid during the storage.

7.2.1.1.2 System of fuels reception and transportation.

In order to avoid pollution between products, the system of fuels' reception and transportation was designed in a way to enable an independent handling of each product. In the fuels' reception point, there are flange elements and quick couplings that guarantee the joint's tightness and reduce to the utmost the product's spill risks. Moreover, as a prevention measure, should there be a failure in any of the bombs; the design enables the plant to operate with only one bomb. The line destined for palm biodiesel has fiber glass insulation and a system of electric heating, which enables heating the pipeline if necessary.

7.2.1.1.3 System of diesel – palm Biodiesel mixture and fuels dispatch

The mixture of diesel and palm biodiesel fuels is carried out on line by means of a blender type fuel pump. The same has two input lines, one coming from the diesel tank and the other from the biodiesel tank; after that, two flow proportional electronic valves dose the required quantity of each fuel for the selected mixture.

The used blender was standardized and programmed to perform 5 diesel-palm biodiesel mixtures: B5, B10, B20, B30 and B50. Besides guaranteeing that each vehicle uses the same mixture during all the process, the blender has an electronic system that enables identifying the vehicle and type of fuel it uses.

7.2.1.1.4 Legal and industrial safety aspects.

This plant of biodiesel storage and mixture had the required permits for this type of fuel handling units, issued by the respective environmental authority. The plant has a license granted by the Environmental Secretary and the authorization to the transportation company for its construction.

Before the plant went into operation, the operational risks analysis or Hazop was made, which enabled to identify the possible environmental and safety risks which could arise during the plant's operation. Based on this Hazop, some modifications were implemented to the plant's design which enabled mitigating the risks.

7.2.1.2 Optimization of the blender's operation

Once the construction process of the storage and mixture station was concluded, it was necessary to carry out a verification of the accuracy of the fuel mixing system, which was performed at two levels:

- Verification of the fuel's volume dispensed by each of the mixer's lines.
- Quantification of the amount of biodiesel present in each mixture.

The quantification of the content of biodiesel in the mixture was performed by means of infrared analysis. Thus, a model with a Petrospec® equipment was developed, which enables quantifying the content of fatty acid methyl esters (FAMEs) present in the mixtures through the near infrared spectroscopy analysis. The analyses were performed in the Spectroscopy Laboratory of ECOPETROL –ICP, which has the computational equipment and model at disposal for the analysis of these samples.

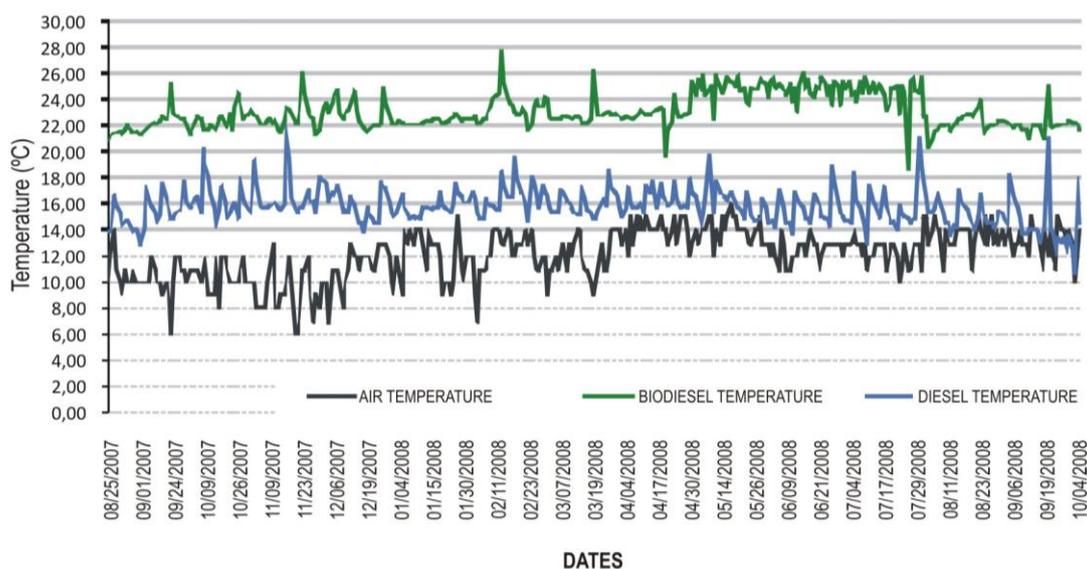
Additionally, tests were carried out to identify the most representative sample (blender or bus tank). Also, the procedure to obtain a representative sample of the mixture was performed, enabling a more accurate measurement of biodiesel's content. The results indicated that the sample must be obtained from each vehicle's fuel tank.

The results of the analysis for each sample, enabled to confirm that the established mixture was appropriately delivered by the mixture system and that it worked correctly. It is worth to mention that the model presents a greater variation in the results of FAMEs content when the mixture contains values between 5% and 10%. For mixtures containing concentrations of more than 10%, the method's reproducibility is greater.

7.2.1.3 Plan for the fuels' quality assurance

Considering that palm biodiesel has a cloud point of 14°C and that the environmental conditions of the plant's location include average temperatures of 9°C, the project implemented a continuous follow-up of the air temperature and the storage tanks' temperature. As previously mentioned, the tank where palm biodiesel is stored has a temperature control system that enables to keep the product at 20°C, 6°C over its cloud point. A temperature sensor was installed in each tank; this enabled the daily monitoring of this variable (Graph 7.2.1.2).

Graph 7.2.1.2: Follow up of diesel and palm biodiesel temperatures at the moment of fuel-feeding the buses.



Although fossil diesel fuel does not have cold flow problems at the plant's location's air temperature, it is necessary to know the temperature of this fuel at the moment of mixing it with biodiesel, in order to determine if under the station's operational conditions, there is any "thermal shock" issue between the two flows. "Thermal shock" is the formation of crystals when two fuels that have different cloud points and are at different temperatures are mixed. During the plant's operation, palm biodiesel's average temperature is 23°C, and diesel's is about 14°C; the operational programming of the test buses has implied that most fuel supplies have to be made at dawn, at an average air temperature of 9°C. Under these conditions, no formation of crystals in the mixtures used in the project has been evidenced.

Likewise, in order to control the humidity entering the storage tanks, filters with silica-gel have been installed in the tank's air valves. In addition, and with the objective of guaranteeing the quality of the fuels delivered at the station, a quality control scheme was deployed, enabling the monitoring to the established quality parameters for pure fuels and for each mixture.

7.2.2 Conclusions

7.2.2.1 Design and operation of the fuels storage and mixture pilot plant

- The deployed blender or fuel mixing system worked normally, thus enabling the assurance of the specified mixtures' supply for each one of the test's buses.
- In spite of identifying sediments at the bottom of the biodiesel tank, a program of adequate maintenance for the storage tank enabled to control the quality of the fuel supplied to the buses.
- The fuel loading and inventory management program prepared for the test was fulfilled, demonstrating that if the adequate precautions are taken, it is possible to safely store palm biodiesel under cold climate conditions, maintaining its quality.

7.2.2.2 Quality control of raw materials and mixtures

- The quality control scheme implemented enabled to perform an in-depth follow-up to the quality of the biodiesel used in the test. As a result of this follow-up, it was achieved to identify and determine the nature of the formation of sediments in pure biodiesel (B100).
- The follow-up performed to biodiesel loadings in the storage station, enabled to establish as quality critical parameters, the water content control, total pollution, content of Monoglycerides, Diglycerides, Triglycerides and total glycerine, as fundamental and indicative parameters of the risk of appearance of sediments in B100.
- Since palm biodiesel is a hygroscopic product, it is necessary to carry out a strict control on this product's storage and transportation conditions, from the supplier's plant to the mixture point.
- It was possible to determine that the formation of sediments at temperatures higher than 20°C is not an exclusive phenomenon of palm biodiesel; there are international reports stating that this phenomenon was present in biodiesel derived from other oils, like soy and colza.
- Monitoring the quality of diesel – biodiesel (B5, B10, B20, B30 and B50) mixtures enabled to establish that they comply with all the quality properties contained in the Colombian regulations.

7.2.2.3 Follow-up to the performance of the buses with diesel – palm biodiesel mixtures

- 1,200,000 kilometers of test were travelled, during which the 10 buses using diesel – palm biodiesel mixtures operated satisfactorily, just like the other buses of the operator's fleet.
- The consumption of fuel of the buses using mixtures of diesel – palm biodiesel is within the range of consumption of the buses exclusively using extra diesel fuel (less than 500 ppm of sulphur).
- The average opacity of the buses that used the diesel – palm biodiesel mixtures, was lower than the opacity registered by the buses operating with diesel fuel and the history of the same buses before starting this project.

7.2.2.4 Revision to the injection system of the buses using diesel – palm biodiesel mixtures

- The analysis performed to the lubrication oil indicated that there is no materials wear due to the presence of palm biodiesel in the diesel fuel, nor is the oil's quality negatively affected.
- It was not evidenced that the palm biodiesel impacted on the injection system's packing.
- The wastage generated in each one of the injection system's pieces (Pump and Injectors) is normal and consistent with the mileage travelled by each. Maxdiésel and Turbos Experts conclude *"the parts that were in contact with biodiesel generated a normal wastage due to the mileage and not to their contact with this type of fuel"*.
- The results of the test were satisfactory because no inconveniences were found in the performance of any of the buses operating with diesel – palm biodiesel mixtures.
- The results presented for the mechanical revisions at 50,000 km and 100,000 km. of test, enable to confirm that palm biodiesel may be safely used in conventional engines without the need of modifying the water.

7.2.2.5 General results of the oils' tribology analyses

- The content of metals due to wastage is found in normal concentrations according to the travelled mileage.
- The physico-chemical properties of the lubricant: kinematic viscosity and TBN are within the normal parameters of the lubricant oil's use.
- With the use of diesel – palm biodiesel mixtures, a substantial decrease of soot was obtained.
- TBN decrease was slower in the buses that used palm biodiesel.

8 Bibliographical references

The following documents were taken as reference to develop section 1 of this handbook:

1. "Guideline for biodiesel's handling and use". National Laboratory of Renewable Energy, Department of Energy USA. NREL/TP-540-43672, 4th Edition. USA. January 2009. 52 pages. <http://www.osti.gov/bridge>.
2. "El estado mundial de la agricultura y la alimentación. Biocombustibles: perspectivas, riesgos y oportunidades". Food and Agriculture Organization of the United Nations (FAO). ISBN 978-92-5-305980-5. ISSN 0251-1371. Rome, Italy. 2008. 146 pages.
3. "Life cycle inventory of biodiesel and petroleum diesel for use in an urban bus". Department of Agriculture and Energy, USA. NREL/SR-580-24089 UC 1503 Category. May, 1998 www.biodiesel.org/resources/reportsdatabase/reports/gen/19980501_gen-339.pdf
4. "Informe de Vigilancia Tecnológica: Tecnologías de producción de biodiesel". Programa Nacional de Energía y Minería, Instituto Colombiano para el Desarrollo de la Ciencia y la Tecnología "Francisco José de Caldas" (COLCIENCIAS) – National Program of Energy and Minery, Colombian Institute for the Development of Science and Technology "Francisco José Caldas" (COLCIENCIAS). ISBN 978-958-8290-27-0. Bogotá, Colombia. December, 2007. 122 pages.
5. "Aspectos técnicos relevantes en la estructura de cadenas de abastecimiento para la adopción de biodiesel como combustible para el transporte en Brasil". Technological Strategic Planning of the National Program of Biodiesel Production and Use. COPPETEC/PET/IBP. PET-9478. Rio de Janeiro, Brazil. November, 2007. 55 pages.
6. "Planeamiento estratégico logístico del Programa Nacional de Producción y Uso de Biodiesel – Módulos I, II, y III". COPPEAD/IBP. Rio de Janeiro, Brazil. November, 2007. 55 pages.
7. "Análisis de Legislación sobre Biocombustibles en América Latina". OLADE. April, 2007. 26 pages.
8. "Guideline for biodiesel's handling and use". Energy Efficiency and Renewable Energy. Department of Energy USA. DOE/GO-102006-2358, 3^o Edition. USA. September, 2006. 61 pages. <http://www.osti.gov/bridge>.



SECTION 2: UPSTREAM

9 Agricultural activity⁵

The present chapter analyses the agricultural stage in the biofuels chain, considered from a global and regional perspective.

Section 9.1 presents an overview, considering some basic concepts, the context defined by the configuration process of the biofuels global chain, and the global tendencies in the use of agricultural raw materials for biofuels.

Section 9.2 presents a general characterization of the agriculture and food sector in South America and an in-depth analysis of a selected group of feedstocks (of immediate availability and alternative ones) for the production of bioethanol and biodiesel, considering the particularities and potentialities of their productions in the different countries of the region, as well as the advantages, opportunities and limitations of using such crops in biofuels production.

Finally, section 9.3 approaches three critical topics related to the sustainable development of biofuels and its particularities in the region: a) the biofuels vs. food dilemma; b) agriculture's and biofuels' environmental sustainability; c) biofuels and social inclusion.

9.1 Overview

9.1.1 A quick glance towards the concepts of bioenergy and biofuels

The multiplicity of concepts referring to bioenergy and therefore to biofuels tend to complicate their conceptualization. Broadly, the different approaches tend to conclude that biofuels constitute a source of bioenergy derived from biomass.

The UWET (2001) classifies biofuels in three groups: wood fuels, agro fuels, and municipal-type by-products. Wood fuels refer to “[...] biofuels directly or indirectly derived from trees and bushes growing in forest and non forest lands.” (FAO, 2001a). On the other hand, agro-fuels are those mainly coming from biomass resulting “[...] from crops to be used as fuels and agricultural, agro industrial and animal by-products” (FAO, 2001a). Finally, municipal-type by-products refer to the “biomass wastes produced by urban population, which may be of two types: solid by-products of municipal origin and gaseous/liquid by-products of municipal origin produced in cities and towns” (FAO, 2001a).

Likewise, there are criteria to classify biofuels. Table 9.1.1.1 attempts at unifying the approaches towards the conceptualization that the different institutions make about biofuels (CLAES, 2008).

⁵ Author: Federico Ganduglia (IICA's office in Argentina). Technical assistance: Paula Nieto (IICA's office in Argentina). The present chapter was prepared by IICA's office in Argentina, with the collaboration of IICA's Regional Specialist in Technology and Innovation, Emilio Ruz, and of IICA's offices in Brazil, Chile, Colombia, Paraguay, Peru and Uruguay, which provided statistical and qualitative information about agriculture and biofuels in their respective countries.

Table 9.1.1.1: Criteria to classify biofuels

According to the physical status	Solid biofuels: wood, forest wastes.
	Liquid biofuels: bioethanol, biodiesel, vegetable oils, MTBE and ETBE.
	Gaseous biofuels: biogas and gasogene.
According to the origin	Agro fuels: bioethanol and biodiesel of annual or multiannual crops like sugar cane, beetroot, soybean and corn, rapeseed, sunflower, palm, respectively.
	Wood fuels: wood.
According to the final use	Biofuels to produce heat energy: wood, biogas.
	Biofuels to produce electricity: rice husks, biogas, cane bagasse, biodiesel for power units.
	Biofuels for transportation: biodiesel and bioethanol.
According to the conversion process	Chemical processes: biodiesel for transesterification.
	Thermal processes: forests wastes for direct combustion, pyrolysis gas.
	Biochemical processes: biogas for anaerobic fermentation, ethanol.

Source: CLAES Workshop, 2008.

This way, a much broader perspective of the connotation of the word “*biofuels*” is obtained. Within this framework, the present document will mainly concentrate on liquid biofuels originated from agricultural and agro industrial feedstocks (“agro fuels”) with final use in transportation (biodiesel and bioethanol).

9.1.2 The configuration process of the biofuels’ global chain and agriculture

The start of the millennium speaks to an important paradigm change. The world is witnessing the first steps towards the transformation of the global energy model as a consequence of the end of the “abundant and economical” oil era. An inexorable phenomenon in which the supply of this non-renewable resource stays relatively stable and is getting near its peak, at the same time that the global energy demand, in a context strongly influenced by tensions linked to “oil’s geopolitics”.

At the same time, the more and more evident and concrete impact of environmental pollution and climate change arouses increasing concern in many countries, causing the adoption of policies tending to reduce the greenhouse gases emissions and promote renewable energies. In this context, agro-energy and biofuels are conceptualized as part of the solution to these problems, causing USA, the EU, Latin America and several countries to adopt policies tending to their introduction into the energy matrix by establishing mandatory regulations and different types of incentives (subsidies, tax exemptions, etc.)

In response to that, the rise of biofuels’ chain in the world is produced, whose configuration is being determined by the confluence of a wide diversity of players coming from different sectors (oleaginous, cereal, sugar, livestock and forest, etc. complexes) and links (from the seeds and biotechnological sectors to the food industry) of the agro business chain, of the energy sector in general and of renewable energies in particular, of the public sector, of the automotive sector, of specialized areas of the machinery and equipment industry, as well as of large investment groups that are part of the international financial sector.

The rise and configuration of the global chain of agro energy and biofuels means not only a new market for agriculture, but also the possibility to be protagonists of a new paradigm with multiple opportunities and challenges. For South American countries, as well as for other current and potential producer countries, the development of agro energy and biofuels represents opportunities in economic, environmental, social and strategic terms (Ganduglia, 2008):

- Reduction of the dependency on non-renewable energies and more security in energy supply.
- Environmental improvements from the reduction of polluting emissions.
- Generation of investments and direct and indirect, regional and rural employment.
- Productive diversification of the agricultural sector.
- Value added to the agro business chain.
- Rural and postponed regional economies' development, through the development of energy crops in marginal areas.
- New value chains insertion possibilities for agricultural SMEs and family agriculture.

Beyond these opportunities, the incipient agro energy and biofuels global and domestic chains constitute extreme complexity systems where the influence of multiple interconnected factors coexists; factors so diverse as the own *fundamentals* of domestic and global markets of agriculture and energy *commodities*, the impact of conjuncture factors as the “climate market”, geopolitical issues and energy, agricultural, environmental and trade policy decisions, among others. This complexity is also maximized with the chain's rise own high levels of dynamisms and uncertainty (multiple technological developments, continuous learning, strong intervention and change to the ground rules of the global market's big players, etc.) and of conflicts, latent tensions and risks, where the “food vs. energy” dilemma and the potential negative externalities on the environment and biodiversity stand out, which could be generated by an un-coordinated expansion of the sector at global level. (Ganduglia, 2008).

9.1.3 Global tendencies in the use of agricultural feedstocks for biofuels

9.1.3.1 Use of feedstocks of immediate availability

According to statistics of the specialized consultant F.O Licht (2008), in 2007, 72.5 million tons of cereals, 263.8 million tons of sugar cane, 14.4 million tons of molasses and 3.3 million tons of sugar beet were destined to the production of ethanol, whereas the production of biodiesel required 7.8 million tons of vegetable oils (Table 9.1.3.1).

Table 9.1.3.1: Global consumption of feedstocks for biofuels in 2007 (thousands of tons)

2007	Feedstocks for ethanol						Feedstocks for biodiesel	
	Cereals	Cassava	Sugar beet	Cane and beet molasses	Sugar cane	Wine alcohol	Vegetable oils	Other feedstocks for biodiesel
EU-27	3555	0	3300	813	0	149	4690	285
Argentina	0	0	0	82	0	0	384	0
Brazil	0	0	0	9750	259854	0	339	11
Canada	2010	0	0	0	0	0	30	60
Colombia	0	0	0	80	3785	0	75	0
USA	62583	0	0	0	0	0	1635	70
Paraguay	14	0	0	88	0	0	0	3
Peru	0	0	0	0	0	0	10	0
Central America and others	0	0	0	615	0	0	74	2
Américas	64606	0	0	10615	263889	0	2473	76
Australia	104	0	0	160	0	0	75	25
China	4016	0	0	0	0	0	0	100
India	0	0	0	1640	0	0	10	0
Pakistan	0	0	0	144	0	0	0	0
Indonesia	0	0	0	0	0	0	100	0
Malaysia	0	0	0	0	0	0	100	0
Philippines	0	0	0	0	0	0	80	0
Singapore	0	0	0	0	0	0	20	0
South Korea	0	0	0	0	0	0	80	0
Thailand	0	245	0	1046	0	0	130	0
Total Asia/Rest of the world	4120	245	0	2989	0	0	595	125
World	72479	245	3300	14416	263889	149	7841	486

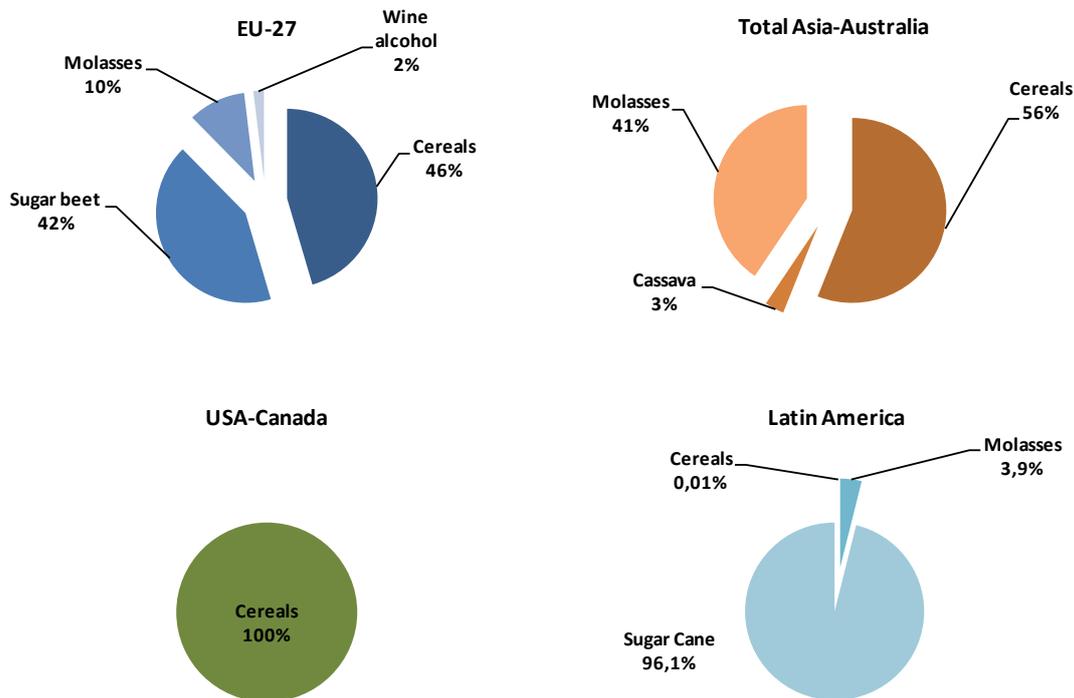
Source: F.O. Licht

As yet, each country or region has generally based on the utilization of feedstocks which have more immediate availability. Thus, for example, in the case of ethanol, USA produces it from corn, Brazil from sugar cane and the EU mainly from sugar beet and wheat. In the case of biodiesel, the EU is using mainly colza, USA, Brazil and Argentina produce biodiesel mainly from soybean oil and Southeast Asian countries are based on the utilization of palm oil⁶.

In graphs 9.1.3.2 and 9.1.3.3 it may be observed, per regional blocks, the diversity of feedstocks currently used for the production of bioethanol. USA (62.6 million tons) and Canada (2 million tons) as yet, consume only cereals, whereas Asia, Australia and the EU (EU-27) present a much more diversified feedstock portfolio. In the case of Latin America, sugar cane represents 96.1% of the total consumption of raw materials for the production of bioethanol, followed by molasses with 3.9% and cereals with just 0.01%.

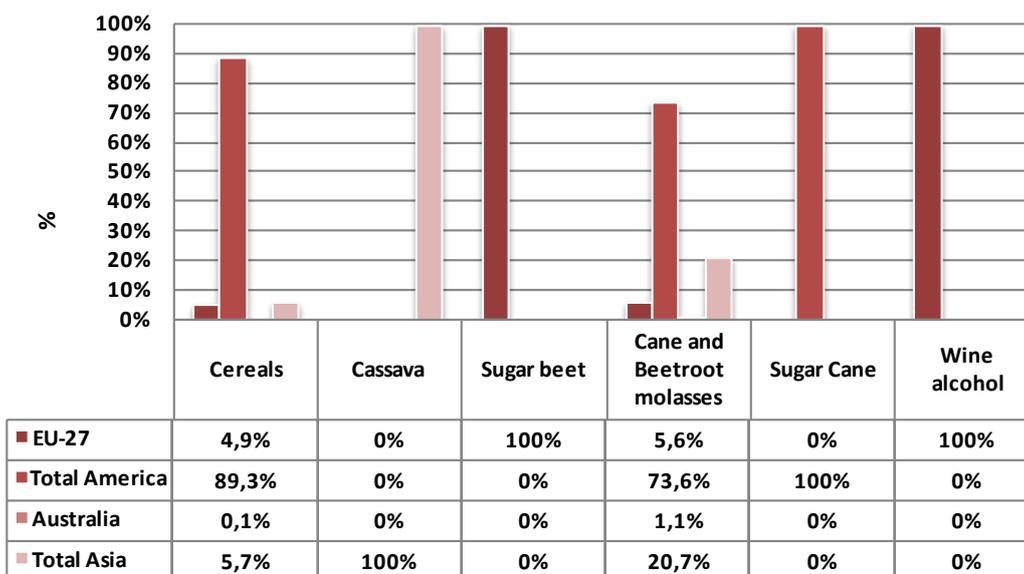
⁶ Soy, palm and colza represent about two thirds of the world production of oils and fats.

Graph 9.1.3.2: Feedstocks' consumption for bioethanol production per regional blocks. 2007



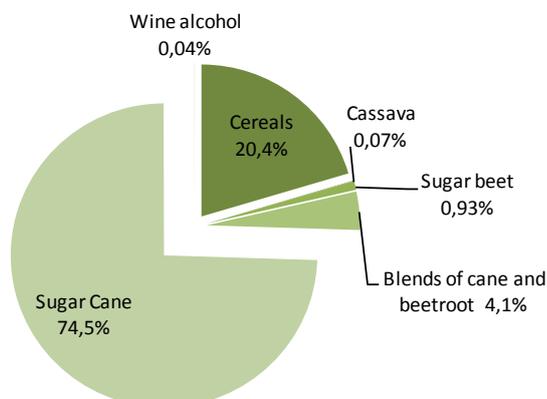
Source: Created by IICA-Argentina with data from F.O.Licht

Graph 9.1.3.3: Regional blocks share in the consumption of feedstocks for the production of bioethanol. 2007



Source: Created by IICA-Argentina with data from F.O.Licht

Graph 9.1.3.4: Feedstocks share in the global production of bioethanol. 2007

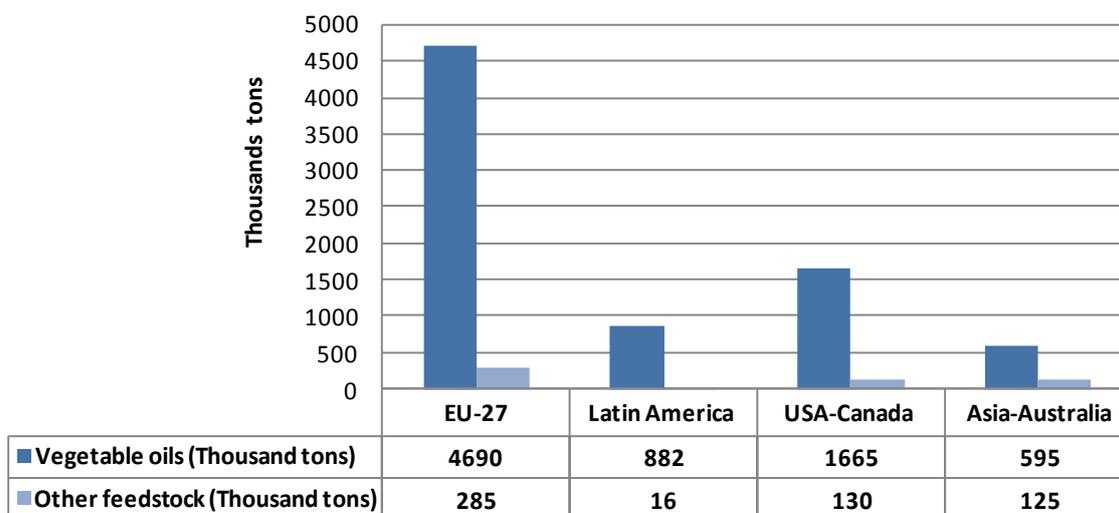


Source: Created by IICA-Argentina with data from F.O.Licht

Sugar cane destined to bioethanol production accounted for 17% of the global production in 2007 (16% in 2006). F.O. Licht (2008) estimates for the specific case of cereals, that the consumption destined to the production of bioethanol represented 4.5% of the global supply of cereals in 2007 (3% if co-products of ethanol's production are considered, as dry distilled grains) and 3.3% in 2006 (2.2% considering co-products). The greatest impact of ethanol in grains' supply was registered in USA, where ethanol's demand absorbed 17% of the production of cereals.

According to the mentioned institution, the influence of biodiesel's production in the vegetable oils' market is more significant than ethanol's in the grain market. In 2007, 5.9% of the global supply of vegetable oils was used to produce biodiesel (3.7% in 2006). If only colza, soybean and palm oils are considered, the mentioned participation increases to 7.6% (4.9% in 2006). The greatest impact on the supply of vegetable oils was registered in the EU, where 39.7% of the production was destined to processing biodiesel.

Graph 9.1.3.5: Consumption of feedstock for the production of biodiesel per regional blocks



Created by IICA-Argentina with data of F.O.Licht

According to estimations of the Economic Research Service (ERS) of USDA, in 2007, about 8.5 million hectares were used globally for the production of feedstocks for biofuels. These figures represent about 1.3% of all cropland used in the production of cereals, oilseeds and cotton. According to the ERS, at the margin, the increase in the area of biofuels feedstocks harvested between 2004 and 2007 (4.5 million hectares) represented 24% of the increase in total harvested area during the same period.

It is worth to mention that the usage of agricultural feedstocks to produce biofuels will significantly increase in the next few years, considering the goals of increasing usage of biofuels imposed in the main world consumers, and the fact that many countries with high productive potential are just starting to enter into the production at commercial scale. Some relevant examples:

- In USA, the main global producer and consumer of bioethanol, according to USDA estimations, in cycle 2006-07, 20% of the corn harvest (54.6 million tons) was destined to be processed in ethanol plants, whereas for cycle 2007-08 it is estimated that the participation in the use destined to ethanol will reach 26% of the production (86.4% million tons) and for 2008-09 33% (about 100 million tons). Even though *Energy Independence and Security Act* has been a key factor to impose limits to the participation and expansion of corn-based ethanol⁷, the demand for this cereal to satisfy the *Renewable Fuel Standard* (RFS) of 2015 will be substantially superior to the current one, if it is considered that the conventional ethanol goal, which will be fixed as from the year mentioned, exceeds in 67% the one stipulated for 2008. In the case of biodiesel, RFS will be valid as from 2009 with 1.67 million tons (1,900 million liters) and is extended up to 3.35 million tons (3,800 million liters) in 2012, figure considered as a minimum to be used from 2013 and on. That would require duplicating the current use of vegetable oils for biofuels in such country.
- In the case of the EU, main global consumer of biodiesel, the quota for the use of biofuels will increase from 4.25% of the consumption of fossil fuels valid in 2008 to 5.75% in 2010 and, if the Renewable Energy Directive proposed by the Commission was approved without changes, to 10% in 2020. Considering its internal consumption of gasoil, it is estimated that in 2010, the potential demand for biodiesel to reach the 5.75% target would reach about 13.2 million tons (15,000 million liters). According to estimations of the *European Biodiesel Board* (EBB), in order to satisfy the 10% blend in 2020, between 25 and 28 million tons (between 28,400 and 31,800 million liters) of biodiesel will be required. The installed capacity in the EU was already in 16 million tons by July 2008 (EBB). All these figures imply requirements of vegetable oils substantially superior to 4.7 million tons destined to biodiesel production in 2007⁸.
- In Brazil, second producer of bioethanol in the world, a significant growth in the utilization of sugar cane for the production of bioethanol is expected, fostered by the projected growth of the flex-fuel vehicles' fleet, the significant increase of the installed capacity that involves the current wave of investments in the sugar-alcohol sector and the increase of the external demand. According to projections of the Ministry of Agriculture of Brazil, bioethanol's production will increase from 18,900 million liters in 2007 to more than 31,800 million liters in 2013 (with exports of 7,000 million liters) and by 2018 it would reach 41,600 million liters with an internal consumption of 30,300 million liters (exports of 11,300 million liters). Brazil and Argentina would be among the main world's producers and exporters of biodiesel, based mainly on soybean. The growing installed capacity of its developing industries, which already accounts for more

⁷ The goal imposed by such legal instrument is increasing over time, until reaching a level of use of 36,000 million gallons (136,000 million liters) of biofuels in 2011, composed by 15,000 million gallons (56,800 million liters) of conventional ethanol (from corn), 16,001 million gallons of cellulosic ethanol (60,600 million liters) and 5,000 million gallons (18,900 million liters) of other biofuels (biodiesel, biogas, butanol, etc.).

⁸ The conversion of vegetable oil into biodiesel is equal to 1 and usually a decrease of between 3 and 4% is calculated.

than 5,600 million liters between approved and under construction or regularization plants, implies a significant growth in the use of oilseeds and vegetable oils during the next years. To them it should be added the growth of the installed capacity for ethanol and biodiesel production in the rest of the countries of Latin America and the Caribbean, with the consequential demand for sugar cane, palm, soybean and other feedstocks.

- In Malaysia and Indonesia, the main world's producers and exporters of palm oil⁹, an important expansion in the utilization of this feedstock for the production and export of biodiesel is expected. In 2007 biodiesel's production reached 340 million liters in Malaysia and 185 million liters in Indonesia, but the installed capacity already sums up 1,400 million liters in Indonesia and 1,150 million liters in Malaysia¹⁰. Other countries of Southeast Asia, as Thailand - first world's producer and exporter of cassava – and the Philippines – first world's producer and exporter of coconut oil – also have important incentives to expand the utilization of these feedstocks for the production of biodiesel, according to their comparative advantages.

According to the IEA's (2006) projections, the projected growth in the global production of biofuels will require in the long term (2030) between 35 and 53 million hectares (2.5% to 3.8% of the world's available arable land), according to referential and alternative policies scenario respectively.

9.1.3.2 Next biofuels' generations and their raw materials

The process of emergency and configuration of the global biofuels chain is characterized by a great dynamism in matters of research, technological development and innovation. The research, development and innovation play a key role in the attainment of new generations of biofuels with a potential of contribution to the energy matrix substantially superior than that of the current generation and, more importantly, to increase the production possibility frontier without generating competence in the use of the land destined to the production of food and/or conflicts with the environment (Ganduglia, 2008).

The main players of the global market, with USA, the EU and Brazil as leaders, are investing significant budgets in RDI, both at public and private levels, in the framework of large multidisciplinary and integrated investigation and development platforms, where botany, agricultural R&D, genetic engineering, biotechnology, synthetic biology and industrial science and technology converge.

This dynamic technological R&D process and its consequential biofuels generations, has direct implications in terms of the type of feedstock to be used.

Considering both the feedstock used and the conversion technology, biofuels may be classified in the following generations¹¹:

- *First-generation biofuels*: they constitute the current generation of biofuels, based on the utilization of raw materials that are also used as food (corn, sugar cane, sugar beet, soybean, palm, etc.) and simple fermentation technologies (bioethanol) and transesterification (biodiesel).

⁹ In 2007 they jointly produced 33 million tons (84% of the world's production) of which they exported 24 million (90% of the world's exports).

¹⁰ F.O. Licht, 2008. Op.Cit.

¹¹ The described classification, except for the reference to generation 1.5 biofuels, is based on: Biopact (2007). "A quick look at fourth generation biofuels".

- *Biofuels of 1.5 generation:* includes biofuels produced with conventional technologies and feedstocks alternative to those immediate available and less sensitive to competition with the production of food. Among these feedstocks there are different perennial shrubby and arboreal species and other alternatives with potential to grow in arid or semiarid zones and on marginal, degraded or abandoned lands, such as castor, jatropha, artichoke thistle, sweet sorghum, topinambur, among others. Among these alternative crops, castor is the most advanced alternative in terms of agricultural development, given the active experience in the production of its oil, whereas the rest is in advanced R&D phases for their production at commercial scale.
- *Second-generation biofuels:* they represent a change in the conversion technology that enables replacing sugars, starch and oils of the feedstocks used by the first generation, by different forms of lignocellulosic biomass (primary and secondary agricultural and forest residues, perennial grasses, fast growing trees, etc.). The conversion of lignocellulosic biomass into biofuels leads to the attainment of cellulosic bioethanol, synthetic biofuels and bio-oil. Second generation biofuels, besides representing a larger potential participation in the energy matrix¹² and a significant advance in terms of carbon balance, would avoid the dilemma biofuels vs. food. These technologies have not yet reached their point of maturity for production at large scale and according to the current scientific consensus, the first lignocellulosic biofuels plants will not be available before 2012 (OECD, 2008).
- *Third-generation biofuels:* this generation is based on the utilization of especially designed or adapted energy crops (through advanced techniques of molecular genetics, genomics and the traditional design of transgenic crops, etc.), for the purpose of obtaining more efficient raw materials for the conversion into biofuels and by-products. Several recent R&D lines as the design of eucalyptus and alamos with low lignin content, of first generation crops with high sugars or oil content and/or tolerant to drought (corn, cotton, rapeseed, among other crops) or more arid conditions, or developments tending to increase the energy crops biomass yield, constitute some examples of the wide range of possibilities presented by the third generation of biofuels¹³. Biotechnology and the emergent field of synthetic biology will be essential for the development of third generation biofuels, which would represent highly positive energy and environmental balances and a feasible coexistence with food production, considering that this type of developments is also being replicated for the case of food crops.
- *Fourth-generation biofuels:* they would represent a revolutionary advance in the mitigation of climate change by incorporating the concept of “bioenergy with negative carbon balance”¹⁴. In this case, the production of agro-energy and biofuels is combined with carbon capture and storage technologies at feedstock and process' technology levels. These developments imply an incremental evolution of the third generation, from the attainment of feedstocks especially designed for the capture of large amounts of CO₂. Some first advances in the area were made known recently: eucalyptus trees with greater capacity of CO₂ storage (3 times greater than the usual) developed by a team of researchers

¹² According to the World Energy Council, appointed by Biopact, these biofuels could replace approximately 40% of fossil fuels used in transport by 2050.

¹³ Other examples include sorghum with low lignin content, corn with incorporated enzymes for the conversion of biomass into biofuels, sorghum with the capacity of growing in acidic soils, and the investigations to sequence the genome of species of oil palm or cassava, which will enable these crops to be more appropriate for the production of biofuels (Biopact, 2007a).

¹⁴ The negative carbon balance means that the carbon dioxide released during the biofuel's production and utilization is less than the one captured or consumed during the cultivation of the raw material and the biofuel's production (IBERCIB). In this case the performance of other renewable energies, like solar and wind energy, that generate energy neutral in carbon, would be outperformed.

of USA and Taiwan, and hybrid larches that capture even 30% more CO₂, developed by Japanese scientists¹⁵.

9.2 Characterization and potential of the South American agro-business¹⁶ for the development of biofuels

9.2.1 The agriculture and food sector in South America

Even though the countries that integrate the South American continent are highly heterogeneous in their size and productive and social structures, they all have in common the significant economic and social importance of their agriculture and food sector¹⁷. That is reflected in the important participation of the sector in the GDP, in exports and employment of these countries.

The countries of the Southern Region have an extraordinary endowment of natural resources for the agricultural production and a low population density in relation to the available agricultural land, comparative advantages that have been recently complemented with an important process of technology innovation that has deepened its historical international competitiveness. The productive tendencies in these countries show a considerable growth in the production and export of almost all products of economic importance in the last fifteen years.

Most of the countries of the Andean Region are located in the tropics, where most of the agro-ecological environments providing the resources exist. These countries have a great biodiversity, land qualities, water resources and all types of microclimates. The importance of agriculture in the economies of the Andean Region represents 27% for Ecuador, 23% for Bolivia, 18% for Colombia, 16% for Peru and 2% for Venezuela; whereas the participation of agricultural exports in relation to total exports is: 45% Ecuador, 30% Bolivia, 23% Colombia, 21% Peru and 1% Venezuela, with an average value for the Region of 24%. (IICA – Andean Region Annual Report, 2008).

Agricultural production in South American countries is in continuous growth and its exportable balances are increasing. In this sense, according to FAO (2008), the agricultural production index for South American countries from 2000 to 2006 has improved significantly and reflects the good moment the agricultural activity is going through in these countries. As a whole, South America contributes significantly and increasingly to the global production and export of several agricultural products such as: wheat, corn, soybean, soybean oil, sunflower oil, soybean meal, sunflower meal, beef, poultry meat, sugar, coffee, tropical, citrus and pome fruits, among others.

¹⁵ To learn more about fourth generation biofuels and their advances, beside the aforementioned article of Biopact, see: Biopact "The strange world of carbon-negative bioenergy: the more you drive your car, the more you tackle climate change". October, 2007. Available on: <http://biopact.com/2007/10/strange-world-of-carbon-negative.html>; Biopact. "New study shows way to fourth-generation biofuels: scientists uncover mechanism that regulates carbon dioxide fixation in plants". March, 2008. Available on: <http://biopact.com/2008/03/new-study-shows-way-to-fourth.html>

¹⁶ South American countries considered in the present study comprise those of the Southern Region of the continent (Argentina, Bolivia, Brazil, Paraguay and Uruguay) and those of the Andean Region (Colombia, Ecuador, Venezuela and Peru). Both in statistics and in the subsequent analyses, Guiana, French Guiana and Suriname are not included.

¹⁷ The following activities are considered as part of the agriculture and food sector: agriculture, livestock, agri-food industry, forest production, fishing and vegetable fibers cultivation.

Table 9.2.1.1: Agricultural Production Index

Country	Year						
	2000	2001	2002	2003	2004	2005	2006
Argentina	100.03	99.50	97.69	103.20	105.24	113.98	114.86
Bolivia	103.01	101.48	108.87	113.87	113.99	119.25	117.71
Brazil	99.19	104.73	111.23	119.51	126.05	125.78	129.28
Chile	98.81	105.98	106.53	108.71	113.04	119.37	122.83
Colombia	101.09	102.73	105.13	105.27	110.09	113.80	112.36
Ecuador	98.48	104.15	100.84	106.65	111.43	111.37	110.47
Paraguay	93.68	104.43	101.91	114.81	121.78	116.79	117.24
Peru	100.11	101.64	108.84	115.57	115.48	125.77	125.19
Uruguay	101.64	89.31	93.29	97.54	114.65	116.69	118.56
Venezuela	100.70	105.04	102.04	96.84	96.50	105.01	104.13

The indexes are based on the total production; this is, without deducting the quantities destined to animal feed and seed production. Base period: 1999-2001.

Source: FAO

The technological innovation and expansion of the region’s agricultural production have not been accompanied in the same order of magnitude by an agro-industrialization process and increase of the added value of exports of agricultural origin. This is reflected in the low average value and low differentiation level of exports of agricultural origin, in comparison with those registered by other agro-exporting countries like Australia, Holland or New Zealand (IICA, 2008). In this sense, biofuels are presented as a new variant for adding value and diversification.

South America envisions important opportunities to turn into a major biofuels global pole, from its soil and climate conditions, optimal for the production of a wide variety of feedstocks, the comparative advantages of its agricultural sector, based on its current and potential production factors endowments – the region has the greatest availability of renewable water resources of the planet and a potentially cultivable land of 746.5 million hectares, suitable to a certain extent for rainfed cropping, of which currently only about 16% is being used under temporary and permanent crops (tables 9.2.1.2 and 9.2.1.3) - its increasing exportable balances and the competitive advantages of key -agribusiness chains like the one of sugar-alcohol in Brazil, soybean oil in Argentina or palm oil in Colombia, to mention the most representative ones. Both for its natural resources' endowment and for its exportable balances, South America is in conditions to produce biofuels without putting its food security at risk.

It is worth to mention that a significant part of the potentially suitable land for rainfed agriculture is not available in practice, since it is destined to valuable uses like forests, protected areas or human infrastructures and settlements, or because it presents characteristics that hinder agricultural activity, as low fertility soils, high toxicity in soil, rugged terrain or difficult for other reasons, etc. (Cotula *et al*, 2008). Considering the aforementioned and the fact that the expansion processes of the agricultural frontier or of production’s intensification imply eventual environmental risks, such as deforestation and biodiversity loss, pollution or adverse effects in the soil, it is essential that the configuration and emergency process of the biofuels’ chain in the region’s countries is mainly based on yield increase (for which RDI is essential) and on sustainability criteria (good agricultural, forest and natural resources management practices, territorial planning, agro-ecological – economic zoning, etc.).

Table 9.2.1.2: Availability and distribution of the land resource in South America

Product/Countries	Figures in thousands of hectares										Total
	Southern Region					Andean Region					
	Argentina	Brazil	Paraguay	Uruguay	Bolivia	Chile	Venezuela	Colombia	Ecuador	Perú	
Land area	273.669	845.942	39.730	17.502	108.438	74.880	88.205	110.950	27.684	128.000	1.715.000
Agricultural area	129.355	263.600	24.258	14.955	37.768	15.245	21.690	42.557	7552	21.310	578.290
Arable land and permanent crops	29.505	66.600	4.298	1.412	3.256	2.315	3.450	3.613	2.562	4.310	121.321
Arable land	28.500	59.000	4.200	1.370	3.050	1.950	2.650	2.004	1.348	3.700	107.772
Permanent crops	1.005	7.600	98	42	206	365	800	1.609	1.214	610	13.549
Permanent meadows and pastures	99.850	197.000	19.960	13.543	34.512	12.930	18.240	38.944	4.990	17.000	456.969
Forest area	33.021	477.698	18.475	1.506	58.740	16.121	47.713	60.728	10.853	68.742	793.597
Other land	111.293	104.644	n.d.	1.041	11.930	43.514	18.802	7.665	9.279	37.948	346.116

Source: FAOSTAT - FAO Statistics Division 2008 – Access 16th. September, 2008. Data correspond to year 2005

Table 9.2.1.3: Potentially cultivable land in South America - All crops

	Figures in thousands of hectares										Total	
	Southern Region					Andean Region						
	Argentina	Brazil	Paraguay	Uruguay	Bolivia	Chile	Venezuela	Colombia	Ecuador	Perú		
Total land	277.685	853.637	39.905	17.907	108.903	75.202	92.388	113.184	25.263	128.922	1.732.996	
Very suitable, suitable, moderately suitable, and marginally suitable land	93.675	438.221	18.300	14.272	63.023	6.658	48.449	34.500	6.425	23.017	746.540	
Cultivable land in use in proportion to very suitable, suitable, moderately suitable, and marginally suitable potentially cultivable land	31%	15%	23%	10%	5%	35%	7%	10%	40%	19%	16%	
Very suitable, suitable and moderately suitable land	85.067	376.459	13.369	14.265	60.259	4.130	45.228	27.529	4.910	14.264	645.480	
Very suitable and suitable land	69.630	309.950	7.884	13.924	51.152	1.293	39.414	21.582	3.263	8.448	526.540	
High inputs	Very suitable land	29.136	122.800	2.144	9.220	22.434	0	21.128	8.748	1.136	389	217.135
	Suitable land	34.395	172.442	4.993	3.979	25.871	502	17.099	11.892	1.266	6.256	278.695
Intermediate inputs	Very suitable land	601	103	213	0	75	174	36	20	26	146	1.394
	Suitable land	5.457	14.605	534	725	2.707	617	1.151	922	835	1.462	29.015
	Slightly suitable land	11.936	62.660	4.509	341	7.533	2.138	5.436	5.812	1.476	4.516	106.357
Low inputs	Very suitable land	0	0	0	0	0	0	0	0	0	15	15
	Suitable land	41	0	0	0	65	0	0	0	0	180	286
	Moderately suitable land	3.501	3.849	976	0	1.574	699	378	135	171	1.300	12.583
	Slightly suitable land	8.609	61.762	4.931	8	2.763	2.523	3.221	6.972	1.513	8.752	101.054
Not suitable land	184.010	415.417	21.606	3.635	45.881	68.548	43.940	78.683	18.839	105.906	986.465	

*Gross extents of land with rain-fed cultivation potential - maximizing technology mix. Figures in thousands hectares.

Source: IIASA – FAO.

9.2.2 Feedstocks for bioethanol's production

Bioethanol may be obtained from three types of feedstocks:

- Crops and materials with high saccharose content, as sugar cane, sugar beet, sweet sorghum and molasses, among others.
- Amylaceous crops with high starch content such as cereals (corn, grain sorghum, wheat and barley) or roots and tubers (cassava, potato, sweet potato, etc.) or inulin (topinambur, agave, yam, etc.).
- Feedstocks and crops with a high cellulosic content (lignocellulosic), whose carbohydrates are in more complex forms (wood, agriculture and forest residues, lignocellulosic crops, herbaceous materials, etc.).

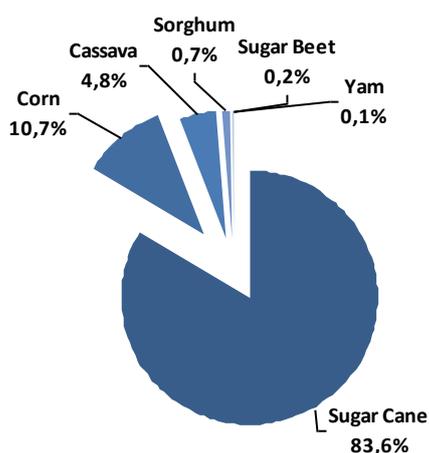
In the case of the South American countries, the production of the most relevant feedstocks for bioethanol production summed up almost 760 million tons in 2007. Sugar cane, whose production extends to all countries except for Chile, is the main immediately available crop in the region. Brazil, main world's producer of sugar cane, exerts a significant predominance in the regional production of this feedstock. Following this crop is corn, whose production is concentrated in Argentina and Brazil, cassava, grain sorghum, sugar beet and yam (Table 9.2.2.1 and Graph 9.2.2.2). Brazil, Argentina and Colombia are in this order, the main South American producers of feedstocks usable for the production of bioethanol (Graph 9.2.2.3).

Table 9.2.2.1: Feedstocks for bioethanol's production. 2007
(figures in tons)

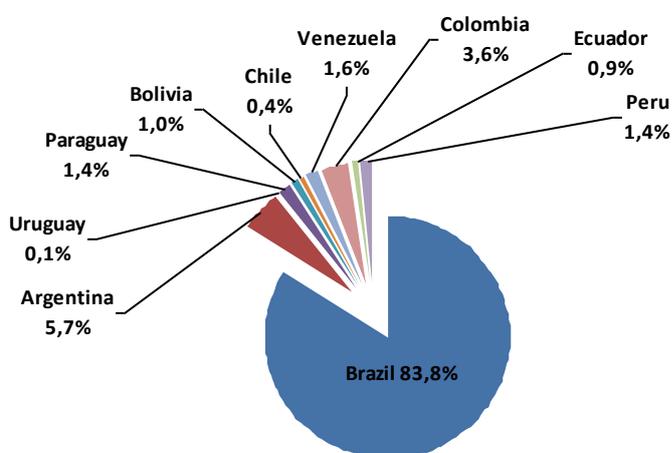
Feedstocks	Total Production South America
Sugar Cane	635,530,273
Corn	80,016,184
Cassava	36,495,443
Sorghum	5,361,594
Yam	619,242
Sugar Beet	1,833,150
TOTAL	759,855,886

Source: IICA, based on official countries' statistics and FAOSTAT

Graph 9.2.2.2: Composition of the South American production of feedstocks usable for the production of bioethanol



Graph 9.2.2.3: Countries share in the production of feedstocks usable for the production of bioethanol



Following, a detail of the feedstocks usable to produce bioethanol and the correspondent characterization and analysis for the Southern Cone countries is presented. The analysis is segmented between feedstocks considered of immediate availability and relevant alternative feedstocks of less development in the region.

9.2.2.1 Immediately available feedstocks

The immediately available feedstocks in the region, for the production of bioethanol are essentially sugar cane, where Brazil is the main producer and cereals like corn and grain sorghum, where Argentina is highlighted with significant exportable balances.

Caña de Azúcar / Cana-de-Açúcar / Sugar Cane

Crop	<i>Sugar Cane (Saccharum officinarum)</i>
Characteristics	Perennial herbaceous plant native of the Southeast of Asia. Cane is a tropical species that can be exploited also in subtropical zones. It requires a warm and humid climate and temperatures between 16 and 30°C for its adequate growth. It does not require any specific type of soil and it may be cultivated in different types of soils, from sandy soils to clay-loam and clayey soils. The soil should preferably be well aerated and have a total water content available of 15% or more. It has great needs of nitrogen and potassium and relatively low requirements of phosphate. It is a crop that is moderately sensitive to salinity. An efficient cultivation may produce 100 to 150 tons of cane per hectare per year. Sugar, alcohol, molasses, fibers, fertilizers and other byproducts may be obtained from sugar cane.
Water requirement	1.500-2.500 mm/year
Fermentable sugars content	15%
Efficiency of the conversion to biofuels (lts/tn)*	75
By-products / co-products of its utilization for biofuels	Cane bagasse: derived from squeezed cane (about 260 kg. of bagasse per ton of cane), it may be used to produce electricity and heat by cogeneration, as livestock forage and as fertilizer. Vinasse, derived from the production of alcohol (10-15 lt. of vinasse per lt. of alcohol) may be used (treated) as fertilizer, or for the production of biogas, from an anaerobic treatment.
Agricultural yield (tn/ha)	70.88 (global average)
Regional average (weighted)	79.37
Countries with higher yield	Colombia (125), Peru (122), Brazil (79) and Ecuador (78)

Potential	110-150 (in dry tropics and subtropics with irrigation)
Ethanol yield per ha (lts/ha)*	5.300
With average regional agricultural yield	5.926
In countries with higher agricultural yield	5.850-9.375
Potential	8.250-11.250

* Considering alcohol production from cane's juice

Source: Own elaboration; information obtained by IICA's regional offices; FAO Water Development and Management Unit and several sources.

Table 9.2.2.4: Sugar cane in South America – Productive and commercial statistics

2006-2007		Southern Region						Andean Region				Total	
Crop	Variable/Country	Brazil (1)	Argentina (2)	Uruguay (3)	Paraguay (4)	Bolivia (5)	Chile (6)	Venezuela (7)	Colombia (8)	Ecuador (9)	Peru (10)		
Sugar Cane	Cultivated area (hectares)	7.080.300	296.760	3.000	84.000	115.862	-	123.470	214.569	78.000	66.122	8.062.083	
	Agricultural production (tons)	559.431.900	18.799.055	144.500	4.100.000	6.201.125	-	9.322.937	23.356.350	5.928.000	8.246.406	635.530.273	
	Agricultural yield (tons/ha)	79,01	66,05	48,82	50,00	53,52	-	75,51	125,13	78,00	121,70	79,37	
	Sugar foreign trade* (tons)	Exports	12.443.221	138.007	-	75.369	12.276	-	-	208.198	14.573	48.894	12.940.538
		Imports	27	1.539	54.487	502	-	610	233.319	588	215	23.247	314.532
	Cane molasses foreign trade* (tons)	Exports	1.052	13.677	-	2.762	-	-	-	220	-	1.822	19.533
		Imports	-	6	980	-	37	13.289	1	-	1.872	-	16.185
	Cane bagasse production (kbp)**		7.306	290.982	167	1.086	2.186	0	0	13.940	2.439	2.692	320.798

(1) Source: Conab, Season 2007

(2) Source: SAGPyA, Season 2005 (Last available data)

(3) Source: MGAP-DIEA. Data on area corresponds in this case to harvested area.

(4) Source: DGP/MAG

(5) Source: National Institute of Statistics – Bolivia – Preliminary 2006

(7) Source: MAT. Preliminary 2006. Data on area corresponds in this case to harvested area.

(8) Source: Ministry of Agriculture and Rural Development (MADR). Directorate of Sectorial Politics. GS. Preliminary 2007

(9) Source: Fenazucar. SDEA/DPD/AVC Years correspond to agricultural year from June to July.

(10) Source: Regional Directorates of Agriculture – Directorate of Agricultural information. Preliminary 2007

*Source: UN Comtrade. Hs 2002. Data 2007

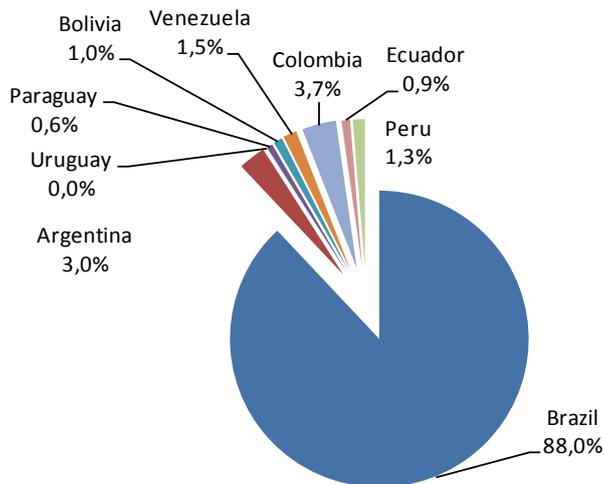
**Source: OLADE, Energy Statistics Report 2007

Sugar cane is the main feedstock for the production of bioethanol in South America. The area cultivated with cane in the region exceeds 8 million hectares, with a production of about 635 million tons (41% of the world's production). The agricultural yield of the region is 79.4 tn/ha, above the world's average and with countries like Colombia and Peru, that have very high yields, among the highest in the world.

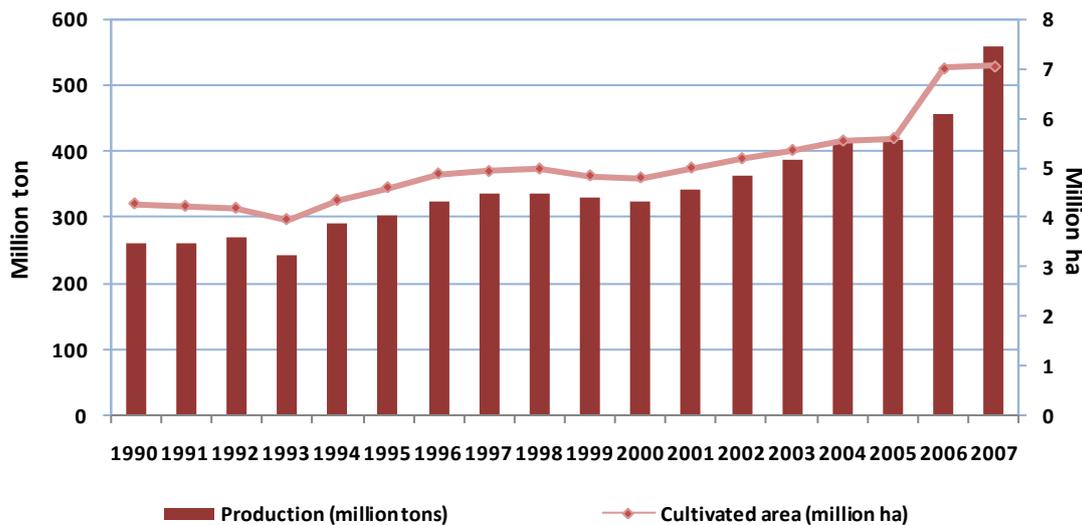
Brazil, first sugar cane world's producer (31% of the world's production), has a decisive contribution to the crop availability in the region, representing 88% of the regional cultivated area and of the regional production. Well below the Brazilian production level, in order of importance are Colombia, Argentina, Venezuela and Peru (Graph 9.2.2.5).

Brazil is currently a consolidated power in matters of agroenergy and biofuels, precisely from its vast experience in the production and use of cane bioethanol.

Graph 9.2.2.5: Sugar cane –production share by countries



Graph 9.2.2.6: Evolution of the cultivated area and the production of sugar cane in Brazil



Source: CONAB

Brazil produces bioethanol directly from the cane’s juice, which assures a high yield in lts/ha (about 6,000 lts/ha) and a high efficiency in costs and land’s use. In 2007, 53% of the Brazilian production of cane was destined to the production of alcohol. These figures represent 3.9 million hectares (just 1% of Brazil’s cultivable land and 6% of Brazil’s cultivated area).

Brazil’s high efficiency also comes from its high technology for the production of sugar cane and ethanol. The long history and experience in the production of sugar cane and cane ethanol have led to an increasing efficiency and decreasing costs, result of learning the increase in the agricultural yields and the technological progress in all the links of the sugar-alcohol chain. Brazilian cane ethanol is the most competitive ethanol in the world in terms of costs, even though its production does not get any direct subsidy, in contrast with USA and the EU.

In general, the rest of the region's countries have a cane tradition and consolidated regional sugar cane industries, with a high coordination of their chains and high levels of technological R&D, both at crops and industrial level (varieties, biotechnology, agronomic management, processes' technology, etc.). Among them, Colombia and Argentina stand out for production volume and Peru that, together with Colombia has the region's highest yields. Except for Chile, where sugar cane is not produced, all considered countries have investment projects that aim at the construction and/or enlargement of distilleries for the production of ethanol from this feedstock.

In contrast with the Brazilian case, alcohol in these countries is mainly produced from molasses; thus, its production represents technologically, a by-product of sugar's production. Under this productive model, yields in liters per hectare are substantially lower: 820 lts/ha¹⁸. For example, in Argentina, obtaining alcohol from molasses represents a yield of 660.5 lts/ha (considering the average agricultural yield at national level) to 935 lts/ha (considering the agricultural yield obtained by the most productive refineries, with vertical integration).

Due to the establishment of mandatory mixtures of gasoline with bioethanol in cases like Colombia or Argentina, investment projects of the sugar-alcohol industries have arisen, aiming at the direct production from cane's juice.

The expansion of the cane production frontier is feasible, considering the potential area for the cultivation of cane (Table 9.2.2.7) and the potential to increase the crop productivity from technological improvements (improvements in varieties and in agricultural management, mechanization, expansion of the irrigated area, etc.). From the point of view of the industrial capacity it is also feasible to expand cane bioethanol's production, given the existent installed crushing capacity and the growth of the distillation industry.

The largest expansion potential of cane's production's frontier is in Brazil, country that will be in conditions to face the projected increasing demand of bioethanol (both domestic and external) without difficulties. In the rest of the countries, the potential of productive expansion is more limited from the point of view of the potentially cultivable land. Nevertheless, except for Chile, such potential would enable to cover, for example, a hypothetical domestic market of E5.

¹⁸ Considering the region's agricultural average, excluding Brazil and that from a ton of cane, 4% of molasses is obtained and that from a ton of molasses 240 to 260 liters of alcohol are obtained.

Table 9.2.2.7: Sugar cane’s expansion potential in the region

(Figures in hectares)

Country	Current cultivated area	Potential cultivable area*	Potential expansion
Brazil	7.080.300	17.800.000	10.719.700
Argentina	296.760	435.000	138.240
Uruguay	3.000	n.d	n.d.
Paraguay	84.000	450.000	366.000
Bolivia	115.862	n.d	n.d.
Venezuela	123.470	276.000	152.530
Colombia	214.569	414.569	200.000
Ecuador	78.000	675.932	597.932
Peru	66.122	n.d	n.d.
TOTAL	8.062.083	20.051.501	12.174.402

*Source: Based on IICA – Agroenergy and biofuels Atlas of the Americas: I.ethanol

Some additional considerations on the potentially sugar cane’s expansion potential in the region’s countries:

- Brazil: there still are feasible areas to be cultivated with cane at the west of Sao Paulo State (where there is expansion currently). In the limits of such region, there is also potential for the production's expansion in the "Triângulo Mineiro", at the South of Goiás and East of Mato Grosso do Sul. Considering that the areas of the Cerrado are also suitable for the expansion of the cultivation of cane, other regions could also be productive, as the Mid-North, comprising the north of Tocantins and the south of Maranhão and Piauí (IICA-Brazil).
- Colombia: estimations indicate that sugar cane’s frontier may be extended 200,000 hectares. According to ASOCAÑA, the expansion potential of the production of ethanol in the geographical valley of the Cauca River, is limited both for the need of maintaining an important production of sugar to supply the domestic market and for the limitation in the availability of land. According to the Colombian Sugarcane Research Center, appointed by ASOCAÑA, new potential areas for the development of sugar cane have been identified. These regions are located along the Colombian geography, from the Atlantic Coast, Suarez River Hoya and the Eastern Plains to the Tolima.
- Argentina: one of the main restrictions for a significant expansion in the production of cane ethanol is the availability of suitable land. In the case of Tucuman, main productive province of the country, 100,000 potentially cultivable hectares additional to the 205,000 under exploitation would be available, even though it would imply displacing other crops. In this province, the land occupied by other crops that could potentially be replaced by cane, are in zones with less rainfall that require complementary irrigation and are more exposed to frost. They could be feasible only in contexts of favorable prices. For their part, in the provinces of Salta and Jujuy, the capacity of extending their sugar cane plantations is more limited, since the most suitable areas and nearer to the mills are already under exploitation. In this case, the restrictions to the expansion have to do mainly with the lower water schemes of marginal areas. The potentially cultivable land in Salta and Jujuy would be about 120,000 hectares. The greatest expansion potentiality would be at the north of Salta, in the Tabacal zone. In the case of Jujuy, the greatest possibilities would be in the north, even though it would imply the substitution of crops or clearance, in some cases of degraded land. One of the keys for the future expansion will be in the advances in genetic improvement that will enable a greatest adaptation for the



marginal areas. Hopefully, according to the most important project of cane bioethanol existent in the country, in the Northwest region the utilization of sugar cane will be complemented by the utilization of cereals, thus, extending the operations beyond the period of sugar cane harvest, partially evading the restrictions to the cane's area expansion.

- ⇒ Peru: counts with two areas that are the most suitable ones for the cultivation of sugar cane: the coast that has large available land extensions for sowing sugar cane, but limitations related to the hydric resource, and the jungle that has large extensions of land that may be utilized to sow sugar cane, marked seasonal rains, suitable soils and sufficient water coming from the rivers, but where there is no tradition of sowing this product and off-season rains may cause the saccharose content of cane to be low. This way, in order to enter in areas with potential for growing sugar cane, both for human consumption and for the production of ethanol, the agricultural frontier ought to be expanded into unimproved land or substitute some crops for others, in this case for sugar cane.
- ⇒ Ecuador: of the analyzed countries of which there is available data, Ecuador is the one that would have the greatest agricultural expansion potential of sugar cane, after Brazil. According to data of the Ministry of Agriculture, Livestock, Aquaculture and Fishing, the country has 675,900 hectares of land with potential for cane cultivation.
- ⇒ Paraguay: it has a potentially cultivable area of about 450,000 hectares in all its territory. Its expansion and strengthening depend on the fact that the main promotion conditions are given. These are: financing, assistance, organization and promotion.
- ⇒ Uruguay: the most suitable conditions for the development of sugar cane are given in the North region, in the Department of Artigas and in the Northern zone of Salto¹⁹. However, other varieties of cane more suitable for more temperate climates for their higher yield are being incorporated. The objective is re-seeding with these new varieties.
- ⇒ Venezuela: PDVSA financially collaborated to carry out feasibility studies in future cane cultivation areas, which indicate that even 276,000 hectares of this crop could be grown. Currently, ethanol is imported from Brazil to be mixed with gasoline in proportions of up to 8%.

By and large, sugar cane as feedstock for the production of biofuels has several advantages:

- Agronomically it stands out for its adaptability in almost all types of soils and its high exploitation of solar radiation, it possesses several productive cycles, and it admits intercalations and responds with efficiency to fertilization and irrigation.
- Its high potential yield of alcohol per hectare in comparison with cereals and other alternatives, implies a lower requirement of land and, consequently, greater efficiency in the distribution of this resource between food and agro-energy production.
- Its immediate availability in most of the region's countries implies a supply guarantee for the production of bioethanol.
- The vast experience and knowledge in this cultivation existent in the region.

¹⁹ "Alternative Energies". Chapter 6 of the publication "Sector energético en Uruguay, diagnóstico y perspectivas" of the National Directorate of Energy and Nuclear Technology/MIEM.



- The existence of a well established agro-industry in almost all the region's countries and in particular, the know-how of the sugar industry in fermentation and distillation processes and alcohol management (Sustaita, 2007).
- Technologically, the production process of sugar cane's ethanol is simpler than that of cereal's ethanol.
- Sugar cane's bioethanol presents lower production costs with regard to the one made from cereals²⁰.
- Favorable impact on regional economies, due to the great economic and social incidence of sugar cane agroindustry in several regions of the considered countries, such as Brazil's South-central region, the valleys and towns of the Peruvian Northern coast, the Argentine Northeastern region or the Cauca valley in Colombia, to mention some representative examples.
- From the point of view of the energy and environmental efficiency, given the great capacity of cane to accumulate solar power, the energy and environmental balance of cane's ethanol is much higher than that of ethanol produced from cereals.
- Almost all the plant can be exploited to generate bioenergy: the stem contains mainly juice (with sugar contents that can be transformed into ethanol by direct fermentation), minerals and starch, among its main components; it contains fiber that, when the juice is extracted can be used as fuel to generate vapor in suitable boilers and electricity (bagasse); the plant's leaves and tipping may also be used to generate vapor if they are burnt in bagasse boilers (Cárdenas, 2007)
- For the medium-long term, cane's bagasse represents extremely favorable possibilities to be used as feedstock in the production of cellulosic ethanol. That would enable the regional bioethanol's chain to count with the possibility of a balanced transition from first generation biofuels to second generation ones, based on the transfer of distinctive abilities developed endogenously.

Among the possible restrictions and limitations of the use of sugar cane as feedstock for the production of bioethanol, the following can be mentioned:

- In comparison with Brazil, in the rest of the region's countries sugar industry has not been historically oriented to the production of bioethanol for its utilization as fuel. That requires certain technological conversions and investments, as for example, adding distilleries to move from the production of hydrous bioethanol to anhydrous ethanol and/or, according to its economic feasibility, move from the model of alcohol production from molasses to the model of production from cane juice, much more efficient in terms of yield in liters per hectare. In the production of ethanol from molasses, alcohol is a by-product of the production of sugar, whereas ethanol production from cane juice implies choosing for sugar or bioethanol production. In this case, the "biofuels vs. food" dilemma would influence Venezuela, Chile and Uruguay, since they are net importers of sugar and its availability would be affected. The rest of the considered countries have exportable balances of cane and/or sugar, therefore, they would not be affected by this dilemma.

²⁰ Even in Argentina, the region's most competitive country in cereals production, the production of cane's bioethanol is more economical than the production of corn ethanol, yet considering the value of the by-products of grinding the latter. According to a recent study (Medina, J., *Insumos para la Producción de Biocombustibles Estudio Exploratorio*. INTEA – IES – INTA, March 2008), with a yield of 85 liters of ethanol per ton of processed cane and a price of US\$ 12.46/tn of cane, the cost of the raw material is 146.6 US\$/m³ of produced ethanol; whereas in the case of the cost of corn, considering 2.5 tons of cereal per each m³ of ethanol and an internal price of 126 US\$/ton, the cost of the raw material is 341 US\$/m³. According to such study, the value of the by-products from grinding corn can not cover this difference in costs.



- Sugar cane presents some restrictions regarding its seasonality and perishability. The latter has to do with the fact that sugar cane has a short storage life. Sugar industry has traditionally extended its processing cycle through the extraction and storage of sugars in the form of molasses. In other cases, like Peru and Colombia, harvest is made throughout the year. In some countries, alcohol's industry is evaluating the possibility of using other crops to extend the operations beyond the sugar harvest period (grain sorghum and corn in the North of Argentina, sweet sorghum in Brazil).
- Sugar cane is very demanding in terms of water requirement, thus, under certain circumstances, a significant expansion could cause a competence for the use of the resource in some locations. This restriction can be reduced by means of research on hydric requirements of sugar cane and rational use of water²¹.
- Certain environmental aspects associated with certain productive models of the cultivation of sugar cane, as pre-harvest sugarcane burning and post-harvest residues burning, with high negative impact on the environment (especially soil and atmosphere). This restriction can be overcome by means of the utilization of clean technologies ("green harvesting", mechanization, exploitation of post-harvest residues, etc.).
- Regarding the aforementioned, even though sugar cane is a crop with more intensity in the use of manpower in relation to other alternatives (like cereals), the spread of the mechanized harvest – necessary to eliminate the need of burning cane fields before being harvested - implies a negative impact on the levels of direct employment.
- At industrial level, the production of bioethanol from sugar cane generates flows of effluents with polluting potential, as mud (*cachaza*) and vinasse from the distillation of alcohol. The latter is among the organic residues of greatest polluting effect on the environment. As in the case of the burning, this restriction can be overcome by means of adequate treatments and uses, as the utilization of vinasse (treated) in fertilization and irrigation or in the production of biogas, or the utilization of mud as fertilizer in sugar cane plantations.

Cereals

The region's countries sowed 36.2 million hectares and produced 132 million tons of cereals in 2007 (6% of the global production). The main cereals produced in South America are corn (61% of the total production of cereals), wheat (16%), rice (16%) and grain sorghum (4%). The South American production of cereals is mainly concentrated in the Southern Cone countries, specifically Brazil (50% of the production) and Argentina (31%).

Within the group of cereals, the most valued ones for the production of bioethanol in some countries of the region are corn and grain sorghum, due to their immediate availability and lower relative costs.

²¹ For example, in Colombia, this type of researches and the rational administration of water have contributed to reduce up to 50% the number of irrigations per cycle of cultivation, thus reducing the consumption of water and cane production costs.

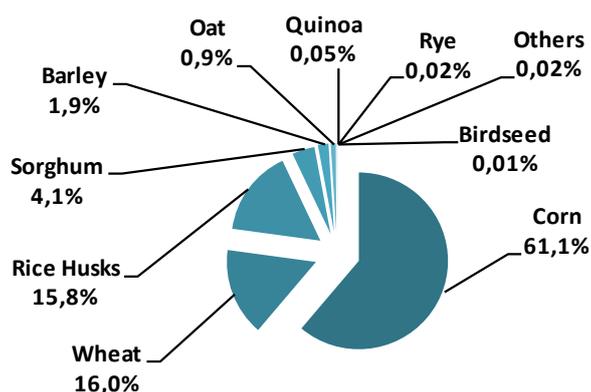
Table 9.2.2.8: Total production of cereals in South America. 2007.

(Figures in tons)

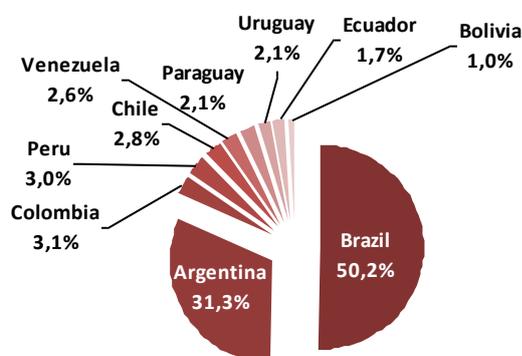
Crop	Total South America
Corn	80,016,184
Wheat	20,956,889
Rice	20,708,528
Sorghum	5,361,594
Barley	2,499,270
Oat	1,192,411
Quinoa	61,490
Rye	24,752
Canary seed	11,490
Others	23,680
TOTAL	130,856,288

Source: Created by IICA – Argentina based on the countries' official statistics and FAOSTAT

Graph 9.2.2.9: Composition of the South American production of cereals. 2007.



Graph 9.2.2.10: Cereals: production share per countries



Corn / Maíz / Milho

Crop	<i>Corn (Zea Mays)</i>
Characteristics	Herbaceous plant of annual cycle, native from the Andean region of Central America, from the family of grass. Corn is cultivated in temperate to tropical climates, during periods when average daily temperatures are above 15° and free from frost. The adaptability of its varieties in different climates can vary widely. It adapts well to all types of soils, except for very sandy soils or dense and heavy clayey soils. The soil should preferably be well aerated and drained, since the cultivation is susceptible to waterlogging. Corn is moderately sensitive to salinity. Its fertility demand is relatively high. Corn's grain has a high content of starch and other sugars (of up to 70%). A wide range of food and industrial products can be obtained from corn, as well as forage for animal feed.
Water requirement	500-800 mm/year
Content of fermentable biomass	70%
Efficiency of the conversion to biofuels (lts/tn)	399
By-products / co-products of its utilization for biofuels	By dry grinding: Humid or dry distilled grains (DDGS, for animal feed) and carbon dioxide (usable to gasify drinks or freeze meat). By humid grinding: corn oil, gluten feed and gluten meal (animal feed).
Agricultural yield (tn/ha)	4.97 (global average)
Regional average (weighted)	4.33
Countries with higher yield	Chile (11.61), Argentina (7.66), Uruguay (5.76) and Paraguay (5).
Potential	A good commercial yield of the grain, under irrigation is 6 to 9 tn/ha. In direct sowing (no-till), with high technology in Argentina: 12 tn/ha
Ethanol yield per ha (lts/ha)	1983
With average regional agricultural yield	1728
In countries with higher agricultural yield	1995-4628
Potential	3591-4788

Source: Own elaboration; information obtained by IICA's regional offices; FAO Water Development and Management Unit and several sources.

Table 9.2.2.11: Corn in South America – Productive and commercial statistics

2006-2007		Southern Region						Andean Region				Total	
Crop	Variable/Country	Brazil (1)	Argentina (2)	Uruguay (3)	Paraguay (4)	Bolivia (5)	Chile (6)	Venezuela (7)	Colombia (8)	Ecuador (9)	Peru (10)		
Corn	Cultivated area (hectares)	13.177.000	3.578.235	58.700	400.000	306.000	134.140	630.000	581.452	440.000	217.144	19.522.671	
	Agricultural production (tons)	47.924.000	21.755.364	338.200	2.000.000	686.000	1.557.087	2.104.000	1.655.074	880.000	1.116.459	80.016.184	
	Agricultural yield (tons/ha)	3,63	7,66	5,76	5,00	2,24	11,61	2,10	2,86	2,00	3,96	4,33	
	Foreign trade* (tons)	Exports	10.933.454	14.990.341	99.003	2.109.144	24.177	74.622	11	2.140	17.656	7.506	28.258.055
		Imports	1.095.539	4.209	46.807	12.638	14.404	1.763.606	528.252	3.322.831	562.341	1.570.865	8.921.492

(1) Source: MAPA - CONAB: *Strengthening and Accompaniment of the Harvest 2006/2007, 5th Harvest*

(2) Source: Sagpya

(3) Source: MGAP-DIEA 2007

(4) Source: DGP/MAG 2007

(5) Source: FAO 2007. The data on sowed area corresponds in this case to harvested area.

(6) Source: Office of Agricultural Studies and Policies (ODEPA). Ministry of Agriculture -Government of Chile- 2007.

(7) Source: FAO 2007. The data of sowed area corresponds in this case to harvested area.

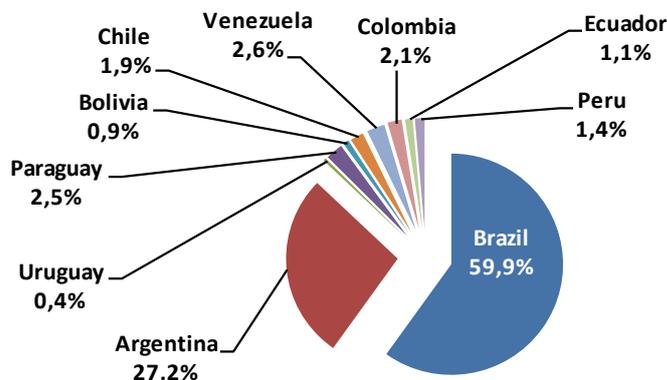
(8) Source: Ministry of Agriculture and Rural Development (MADR). Directorate of Sectorial Policy. GSI. Preliminary 2007

(9) Source: FAO 2007. The data on sowed area corresponds in this case to harvested area.

(10) Source: Regional Directorates of Agriculture - Directorate of Agricultural Information. Preliminary 2007.

*Source: UN Comtrade. Hs 2002. 2007 Statistics.

Graph 9.2.2.12: Corn: production share per country



Corn is the main cereal produced in South America. In 2007, the area cultivated with corn was 19.5 million hectares, with a production of 80 million tons (10% of the global production). The agricultural yield achieved by the region in that year was 4.33 tn/ha, below the global average. Nevertheless, some countries have high relative yields, where Chile (with artificial irrigation), Argentina and Uruguay stand out.

The region's countries reflect a marked contrast regarding the availability of corn. While the Southern region's countries concentrate 93% of the production and, except for Chile, have a net exporter position of the cereal, the Andean region's countries are net importers.

The region's main producers of corn are Brazil and Argentina, who have very high exportable balances (10.9 and 15 million tons, respectively in 2007). Beyond the highlighted productive and exporter position of Brazil, the use of corn (and of cereals in general) for the production of ethanol is null in this country and has lacked economic interest, given the solid competitive advantages of producing cane bioethanol.

Argentina (second world's exporter of corn) and Paraguay also have very high export coefficients, much superior to those registered by other big corn producers of the world. In this sense, bioethanol would represent an opportunity for the value added to the corn chains in these countries. Both countries could comfortably cover their goals of domestic use of ethanol with just a part of their exportable balances. For example, Argentina could cover its domestic requirement of E5²² with just 4% of its exportable balance in 2007, whereas Paraguay would need 7% of its corn exports in 2007 to cover its domestic E24 requirement.

Even though there are no corn bioethanol plants in the region, this alternative is highly valued by the rural sector in Argentina, due to the opportunity it represents for the development of organizational models similar to those in USA, based on the establishment of medium scale plants, property of societies and cooperatives of agricultural producers, whose format is perfectly adjusted to the foreseen priorities for the allocation of the fiscal share established in the promotional framework for biofuels in force in this country.

The use of corn as feedstock for bioethanol in countries like Argentina and Paraguay also represents an opportunity from the social point of view, considering that in these countries, respectively 70% and 83% of the agricultural exploitations that cultivate it, belong to family agriculture.

Argentina is the region's country with greatest possibilities for the use of corn for the production of bioethanol. Besides the high exportable balances, the country has a very high level of experience and knowledge of the

²² Biofuels law 26,093 establishes the mandatory utilization of E5 as from 2010.

crop, the corn chain is highly organized and, during the last two decades, corn's production has stood out for a very high level of dynamism in terms of technological development. Agricultural yields were duplicated during such period, from the use of new hybrids with greater yield potential and better performance towards plague and diseases, the gradual adoption of no-till system, the use of complementary irrigation, the increase of the fertilized area and, more recently, the increased use of transgenic materials that have provided resistance to insects and herbicides.

Considering a domestic consumption of bioethanol projected in 315 million liters for 2010 and the average agricultural yield of 2007, Argentina would require 785,000 tons of corn and 102,000 hectares (501,000 tons and 65,000 hectares if corn is produced under no-till with high technology). These figures represent just between 2% and 4% of the production of corn of the season 2006/07, between 2% and 3% of the area cultivated with corn and between 0.2% and 0.4% of the area cultivated with cereals and oilseeds in such season. Part of this expansion could also be covered with an increase of the yields, due to the still real wide growth margin in this respect, especially from the increasing utilization of transgenic events (in 2007 and 2008 the first stacked GM maize events were approved in the country).

At industrial level, even though there are no operative corn bioethanol plants in Argentina, both the fermentation technology of its starch and the production yield from dry or humid grinding methods are currently mature (Patrouilleau, 2008).

The use of corn as feedstock for the production of bioethanol in the region, presents several restrictions:

- As noted above, the Andean region's countries are net importers of corn. In this sense, importing the feedstock means higher costs, while deviating its current domestic production to the production of ethanol implies risks on food security, in terms of less availability and access to corn. Among the countries of the Southern region, the greatest restrictions are in Chile. In contrast with the Andean countries, Chile does not produce sugar cane and corn has been identified among the most viable crops currently on production which could be used to produce ethanol. However, this country is also a net importer (with 1.8 million tons in 2007 is the largest corn importer in South America, importing even more than it produces). Bolivia on its part, has a low coefficient of corn net exports and much reduced exportable balances (with the corn exports of 2007 it would barely cover a 0.5% of its domestic gasoline consumption). On the other hand, Uruguay would need a high proportion of its corn exports to cover its domestic requirement of E5 (67% of the amount exported in 2007).
- Its lower yield in liters per hectare in comparison with cane bioethanol turns it into a less efficient crop in terms of the use of the land resource.
- Its high requirement of nitrogen in comparison with other feedstocks potentially usable for the production of ethanol.
- In comparison with the production of cane ethanol, the technology of corn ethanol production is more complex, since it requires of more processes to degrade the starch molecules to transform it into soluble sugars for its fermentation (in the case of cane's juice and molasses, saccharose may be fermented directly). This process represents additional costs in terms of equipment, manpower and use of the energy.
- Related with the aforementioned, one of the main limitations of corn (and of cereals in general) as a feedstock for ethanol is its disadvantage in costs in comparison with sugar cane. Likewise, if the possibility of exporting is considered, corn bioethanol should compete with the Brazilian cane bioethanol (the cheapest in the world) and with the highly subsidized corn bioethanol of USA.



- From the point of view of energy and environmental efficiency, corn bioethanol presents substantially lower energy and environmental balances than those of sugar cane bioethanol. In the case of its eventual production oriented towards exports, this aspect also locates it in a risky situation in the world's markets, according to the required level of GHG emission savings which achieve the imminent criteria and sustainability certification systems.
- Other relevant vulnerability factors have to do with its wide use as feedstock of diverse sectors of the agro-food industry and since it is a basic component in human and animal food, aspect that has positioned it in the middle of the food vs. biofuels debate's controversy and that would cause future restrictions in the global market. Moreover, the fact that it is the feedstock used by USA, first world's producer of ethanol and with high growth perspectives in its demand, it represents projections of future high prices, which would put in risk the economic sustainability of the projects of bioethanol based exclusively on corn. It is worth to mention that in the specific case of Argentina, the use of corn to satisfy a domestic market of E5 would have no impact on the internal food security (due to its exportable balances) or global food security (corn's requirement would barely represent 4% of Argentina's corn exports, 0.7% of the world's exports and 0.1% of the world's production). The same argument is also applicable to Paraguay's case.

One of the main attractions that corn bioethanol presents is the possibility of developing models integrated with livestock activities, considering that in the dry grinding process, dry distillers' grains with soluble are obtained as co-product (DDGS), highly valued and nutritious for animal feed²³. It comes down to models that demonstrate that corn bioethanol and food production can be perfectly complementary. In cases like the Argentine, that has the imperative need of reinforcing its cattle productions, corn seems to be a suitable crop for the vertical integration, combining the agricultural activity for the production of bioethanol with the use of its co-products for the production of animal protein (Patrouilleau, 2008)²⁴. Likewise, corn silage may be used to produce biogas, and the leaves and the stem of corn represent a possibility for the production of cellulosic ethanol.

²³ In USA, main world's producer of corn ethanol, in 2007 ethanol plants produced 14.6 million tons of distiller's grains. 84% of this production was destined to feed ruminants (42% dairy cattle and 42% beef cattle respectively), while the rest was distributed to pigs (11%) and poultry (5%).

²⁴ One of the main projects of ethanol foreseen in Argentina, announced by Adecoagro, will integrate the production of dairy products, corn bioethanol and biogas. It is a large-scale project (it will include the annual process of 500,000 tons of corn) with an investment of US\$ 390 million; one of the main challenges is to promote the feasibility of this type of models for the case of projects of medium scale plants that horizontally integrate small and medium corn producers.

Grain Sorghum/ Sorgho / Sorgo

Crop	Grain Sorghum (<i>Sorghum Vulgare</i>)
Characteristics	Herbaceous plant of the family of grass. It is an annual or perennial plant, herbaceous, of erect and thin stems and elongated leaves. Native of Africa's and Asia's tropics, it possesses a wide geographical adaptation and it has been spread in the five continents. It stands out for its great resistance to drought and high temperatures. Its resistance to drought is due to the fact that this crop has few leaves and its stems are protected by a vegetable wax. The optimal temperature for high yield varieties is about 25° but there are varieties adaptable to lower temperatures that generate acceptable yields. Grain sorghum develops well in almost all types of soils, both in sandy soils and in clayey soils, but it develops better in soils with light to medium texture. The soil should preferably be well aerated and drained. Grain sorghum is moderately sensitive to salinity. Its fertility requirements are lower to those of corn, relatively low in phosphate and potassium and high in nitrogen. Grain sorghum is used for human consumption (mainly in Southern Asia, Africa and Central America), for animal forage, to prepare balanced food for bovines and porcine and for industrial use in humid grinding (amylase, alcoholic drinks, etc.) and dry grinding (flour).
Water requirement	450 - 650 mm
Content of fermentable biomass	70%
By-products / co-products of its utilization for biofuels	When starch is extracted from the sorghum grain, the by-products of this process, sorghum gluten or sorghum gluten's flour, may be used as feed. Humid and dry distilled grains and carbon dioxide are obtained from the process of ethanol production.
Efficiency of the conversion to biofuels (lts/tn)	380
Agricultural yield (tn/ha)	1.47 (global average)
Regional average (weighted)	3.24
Countries with higher yield	Argentina (4.70), Uruguay (3.80) and Colombia (3.70)
Potential	A good yield under irrigation is of 3.5 to 5 tn/ha. There are hybrids that can yield between 8 and 12 tn/ha.
Ethanol yield per ha (lts/ha)	559
With average regional agricultural yield	1231
In countries of higher agricultural yield	1406-1786
Potential	3040-4560

Source: Own elaboration; information obtained by IICA's regional offices; FAO Water Development and Management Unit and several sources

Table 9.2.2.13: Grain sorghum in South America – Productive and commercial statistics

2006-2007		Southern Region						Andean Region				Total	
Crop	Variable/Country	Brazil (1)	Argentina (2)	Uruguay (3)	Paraguay (4)	Bolivia (5)	Chile (6)	Venezuela (7)	Colombia (8)	Ecuador (9)	Peru (10)		
Sorghum	Cultivated area (hectares)	722.000	700.000	42.900	11.120	55.000	-	232.000	31.970	5.000	24	1.800.014	
	Agricultural production (tons)	1.601.000	2.794.967	163.200	25.085	150.000	-	498.000	118.289	11.000	53	5.361.594	
	Agricultural yield (ton/ha)	2,21	4,70	3,80	2,26	2,72	-	2,14	3,70	2,20	2,41	3,24	
	Foreign trade* (tons)	Exports	225.430	1.071.717	38	6.238	10.867	51	2	0	0	35	1.314.378
		Imports	2.513	1.697	2.311	553	1.789	128.213	485	67.280	40	21.761	226.643

(1) Source: MAPA – CONAB: Consolidation and Accompaniment of the Harvest 2006/2007, 5° Survey

(2) Source: Sagpya

(3) Source: MGAP-DIEA

(4) Source: DGP/MAG 2007

(5) Source: FAO 2007. Data on area corresponds in this case to harvested area.

(7) Source: FAO 2007. Data on area corresponds in this case to harvested area.

(8) Source: Ministry of Agriculture and Rural Development (MADR). Directorate of Sectorial Politics. GS. Preliminary 2007

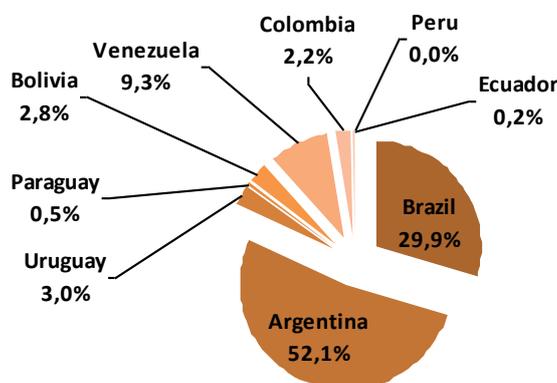
(9) Source: FAO 2007. Data on area corresponds in this case to harvested area.

(10) Source: Regional Directorates of Agriculture – Directorate of Agricultural information. Preliminary 2006/2007

*Source: UN Comtrade. Hs 2002. Data 2007.

Grain sorghum is the fourth cereal of greatest importance in the world and in South America. In 2007, the cultivated area was 1.8 million hectares, with a production of 5.36 million tons (8% of the global production). The average agricultural yield achieved by the region in that year was 3.24 tn/ha, more than doubling the global average. The higher yields are obtained in Argentina, Uruguay and Colombia.

Graph 9.2.2.14: Grain sorghum - production share per country



Argentina concentrates more than half the sorghum’s regional production, following in order of importance, Brazil and Venezuela. As in the case of corn, there is a marked contrast between the Southern Cone countries and those of the Andean region regarding the availability of grain sorghum. The Southern Cone concentrates 86% of the production and is a net exporter of grain sorghum, whereas the Andean region is a net importer. Likewise, among the Southern Cone countries there is heterogeneity also. Chile does not produce grain sorghum, Paraguay registers an almost null exportable balance and Uruguay registers a net importer position, while Argentina, Brazil and Bolivia are net exporters of the cereal. Even though the whole region exports 25% of its production, 82% of exports are concentrated in only one country, Argentina, which stands out as the second world’s exporter of grain sorghum.



As in the case of corn, the use of grain sorghum as feedstock for the production of bioethanol is not spread to the region's countries. It is worth indicating the Argentine case, where there are two plants for the production of alcohol from cereals that use almost exclusively grain sorghum to obtain alcohol, though the production is not destined to be used as fuel, but to drinks and cosmetics.

The use of sorghum as feedstock for the production of bioethanol presents some advantages, in comparison with corn. Agronomically, it stands out for its greater resistance to drought, to high temperatures and for its reduced need of water. In this sense, it has the potential to develop in semiarid locations, where it would be impossible to grow corn or more demanding crops. Its yields are more stable in marginal zones; moreover, the crop's genetic variability grants it a great flexibility to adapt and increase its yield potential, in different environments and types of utilization (INTA). Besides, grain sorghum is a very efficient crop in capturing carbon. From the economic point of view, grain sorghum is relatively cheaper than corn, even though their prices are strongly correlated. On the other hand, it is worth indicating that the yield in liters of grain sorghum ethanol per hectare is lower than that of corn.

The current availability of sorghum in the region is much lower than that of cane and corn, even in Argentina, which, as it was previously mentioned, has exportable balances. In order to cover the domestic consumption of ethanol foreseen for 2010 in this country, 824,000 tons of grain sorghum and 175,000 hectares would be required. These figures account for 29% of the production, 25% of the area cultivated with grain sorghum in the season 2006/2007 and 77% of its exports. Any how, these requirements imply the utilization of just 0.7% of the area planted with cereals and oilseeds and the expansion of the area with grain sorghum is highly feasible due to the reasons aforementioned.

9.2.2.2 Alternative feedstocks

Cassava / Mandioca / Mandioca

Crop	<i>Cassava (Manihot esculenta)</i>
Characteristics	Also known as manioc or tapioca, cassava is a perennial ligneous bush from the Euphorbiaceae family. It is one of the greatest producers of starch from the tropics. Probably native from Tropical America and Northeastern Brazil, today it is grown in the tropical and subtropical regions of Latin America, Africa and Asia. It can be grown in altitudes that vary from near sea level up to a thousand meters, with vegetative periods that vary from 8 to 12 and in some cases from 18 to 24 months. The ideal average temperature for its development varies between 18-35°C (optimal 25-30°C), and 10°C is the minimum temperature it can tolerate. Short days, with less than 12 hours of light favor the root's enlargement. It tolerates drought well and possesses a wide adaptation to the most varied climate conditions and soils. It adapts well to acid and low fertility soils. The most recommendable soils are deep ones, with medium texture and good drainage; its cultivation on sandy soils and those with a permanent excess of water is not recommendable. It is a nutritionally demanding crop, especially in potassium (its lack highly reduces the yield and starch content) and great extractor of nutrients from the soil, therefore, maintaining the soil's fertility requires the application of the amount of nutrients the crop absorbed. Beyond its adaptability to low fertility soils, the maximum potential of production of cassava is attained with adequate fertilizers. Commercially, the most important part of the plant is the root, which has a high content of starch, which makes it a good source of energy. Cassava is the base for many products. In Africa and Latin America it is mainly used for human consumption (cassava's root and flour), whereas in Asia and parts of Latin America it is also used as animal feed (roots and aerial part or silage of the aerial part) and products based on its starch (inputs for food, textile, cosmetics, paper and biofuels industries). (CLAYUCA, IICA, CEPLAC, EMBRAPA, CENIAP, IITA).
Water requirement	It needs a good deal of humidity during the period of establishment. After the germination and establishment, water demand is minimal (500 mm/year as minimal rainfall to obtain production).
Starch content	74%-85% of its total dry weight in roots
By-products / co-products of its utilization for biofuels	Cassava's aerial part may be used as silage for animal feed. Cassava's pomace, the residue from the extraction of the starch from the roots, has less value than the root's meal, but may be included in bovine ration (in Asia it is also employed to feed pigs) and it has been used in rations for poultry in up to 10% (FAO: Animal Feed Resources Information System). Vinasse may be used as bio-fertilizer.
Efficiency of the conversion to biofuels (lts/tn)	180
Agricultural yield (tn/ha)	12.16 (global average)
Regional average (weighted)	13.82
Countries with higher yield	Paraguay (17), Brazil (14)
Potential	> 35 tn/ha with improved varieties, good handling, annual temperature 22-28°C, 1000 mm/year of well distributed rainfall, soil's high fertility and use of fertilizers only to conserve the soil's fertility (maintenance) and stakes treatment (with fungicides and insecticides) (Cock, 1989). Yields superior to 60tn/ha have been obtained under experimental conditions.
Ethanol yield per ha (lts/ha)	2189
With average regional agricultural yield	2488
In countries with higher agricultural yield	2520-3060
Potential	> 6300

Source: Own elaboration; information obtained by IICA's regional offices; and several sources.

Table 9.2.2.15: Cassava in South America – Productive and commercial statistics

2006-2007		Southern Region						Andean Region				Total	
Crop	Variable/Country	Brazil (1)	Argentina (2)	Uruguay (3)	Paraguay (4)	Bolivia (5)	Chile (6)	Venezuela (7)	Colombia (8)	Ecuador (9)	Peru (10)		
Cassava	Cultivated area (hectares)	1.941.000	17.500	n.d.	300.000	36.366	n.d.	41.651	199.667	31.257	55.504	2.622.945	
	Agricultural production (tons)	27.222.000	175.000	n.d.	4.800.000	371.280	n.d.	489.177	2.111.005	172.027	1.154.954	36.495.443	
	Agricultural yield (ton/ha)	14,0	10,0	n.d.	17,0	10,2	n.d.	11,7	10,6	5,5	11,2	13,8	
	Foreign trade* (tons)	Exports	433	0	0	7.050	0	0	29	118	22.362	0	29.992
		Imports	5.737	0	14	0	0	58	0	20.955	0	42	26.805
	Production of by-products		n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

(1) Source: IBGE – Municipal agricultural production and systematic survey of agricultural production. Data on area corresponds in this case to harvested area. Preliminary 2007

(2) Source: FAOSTAT. Data on area corresponds in this case to harvested area.

(4) Source: DGP/MAG

(5) Source National Institute of Statistics – Bolivia – Preliminary 2006

(7) Source: MAT. Preliminary 2006

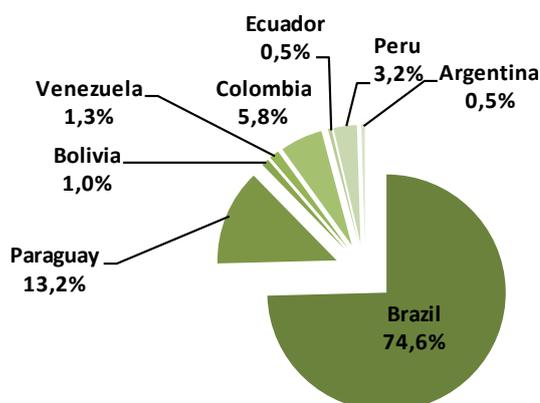
(8) Source: Ministry of Agriculture and Rural Development (MADR). Directorate of Sectorial Politics. GS. Preliminary 2007. Statistics on traditional and industrial cassava. Weighted yield.

(9) Source: MAG /SAGRO. Provisional data 2007

(10) Source: Regional Directorates of Agriculture – Directorate of Agricultural information. Preliminary 2006/2007

*Source: Un Comtrade. Hs 2002. Data 2007, except for Venezuela whose last available data corresponds to 2006.

Graph 9.2.2.16: Cassava - production share per countries



Cassava constitutes the staple food of million low-income farmers of Africa, Asia and Latin America. Likewise it is considered as a potential source of ethanol, taking into account the high content of starch of its roots and the fact that 10% of starch's world's production is produced from this crop (FAO).

South America possesses a significant production of cassava, of about 36.5 million tons in 2007 (16% of the world's production). Brazil concentrates 75% of the region's production, followed in order of importance by Paraguay and Colombia.

There are experiences of production of ethanol from cassava, both in the world (Thailand, China and Indonesia) and in the region (Brazil and Colombia).

Brazil is the second world's producer of cassava, with more than 27 million tons produced in 2007. Cassava is grown in all the country, though about 50% of the production is concentrated in the states of Pará, Bahia and Paraná. Between the mid 70s and 80s, 6 factories of cassava ethanol were installed, in the framework of the National Program of Alcohol (PROALCOOL), which were finally non-viable because they were built in non-

traditional regions for the production of cassava and due to the performance of the production of sugar cane ethanol (Felipe & Alves, 2007). The interest in this feedstock was revived in the last years, since it is considered as an alternative to obtain income for the family agriculture, especially in the North and Northeast regions of the country. In the latter there already are some units in implementation phase, while EMBRAPA has intensified the works of genetic improvement of cassava for the production of ethanol (CEPEA, 2007). The crop's technological development attained especially in the states of Paraná, Sao Paulo (where yields of about 26 tn/ha are obtained) and Mato Grosso do Sul, is also worth mentioning. An important industrial complex has been formed in the frontier area of these three states, as well as an industry of specialized inputs for its cultivation. This complex produces and processes approximately 6 million tons of cassava roots for flour and starch, which led to turn this region into a global reference point (Ereno, 2008). In 2007, a legislative bill that foresees tax cut for agents commercializing cassava ethanol came into consideration.

In Paraguay, second region's producer of cassava, cassava's starch is a traditional product, used as basic food of the rural and urban population. Cassava's production is concentrated in the departments of San Pedro, Caaguazú, Canindeyú, Alto Paraná and Itapúa, which join more than the 75% of the total cultivated area. According to the MAG, Paraguay has a good diversity of varieties of cassava, though the production system employed by producers is based on traditional practices, without incorporating the new technologies required by the crop. The objective is to train cassava producers in the modern techniques of the crop's production, in order to satisfy the fresh consumption demand, the processing industries demand, and the development of new products, for which the National Cassava Program 2003/08 was implemented (IICA/REDPA/CAS, 2008). Even though the production of cassava ethanol does not have a long tradition in Paraguay, there are several experiments and projects that consider this feedstock.

In Colombia, third region's producer, cassava is a typical crop of the peasant economy, with an average sown area per farm of 1 to 5 hectares and old production systems. In this country, some projects have been announced which aim at producing cassava ethanol (in the departments of Cesar, Meta and Sucre), as well as a functioning pilot plant, built in the University of Antioquía, co-financed by the Ministry of Agriculture and Rural Development, in the framework of the *Program to Strengthen the Bioethanol Chain from Cassava, its Evaluation and Co-product*.

The use of cassava for the production of ethanol presents, among others, the following advantages and opportunities:

- From the agricultural point of view, cassava has several advantages, such as its high potential yield per hectare, high flexibility for sowing and harvesting, tolerance to drought and to degraded soils, high resistance to insects and minimal requirements of cultural care (FAO, 2006, CENIAP).
- In line with the above, it could be grown in poor soils or in marginal lands where the production of other crops presents high risks or are not feasible. Cassava could present, for example, a more viable alternative in regions with unfavorable climates for sugar cane, where higher yields of the former are obtained, due to its great adaptation capacity.
- As a source of starch, cassava is very competitive, since its root has a very high content of starch per dry weight and the same is easy to obtain with simple technologies (FAO, 2006). Its one of the cheapest starch sources, used in more than 300 industrial products.



- Beyond its low levels of current yield, cassava has a high potential yield, with varieties that have exceeded 60 tn/ha²⁵. These figures would represent a potential of more than 10,800 liters of ethanol per hectare.
- It is a social and labor intensive crop, traditionally developed by low-income small farmers, thus, the conversion of this feedstock in high value starch could strengthen the rural economy, increase the producers' income in many developing countries (FAO, 2006) or provide a new market to the peasant communities producing cassava, for the channeling of their surplus.
- Cassava is one of the most cultivated species in association with other crops. For example, in Brazil it is grown simultaneously with corn, beans and peanut, enabling the attainment of greater income to the farmer.
- In contrast with sugar cane, it does not present seasonality problems, since it can be produced all year long; leading to a better utilization of the installed production capacity and a lower requirement of storage capacity for the periods between harvests (FAO-ECLAC-BNDES). Moreover, as cassava's roots can be stored in the soil for up to 24 months (some varieties for up to 36 months) without losing and even increasing their productivity, the harvests may be delayed until market, processing or other conditions are favorable (IITA).

Likewise, cassava presents limitations of different sorts when being assessed as an alternative for the production of ethanol, among them, the following can be mentioned:

- At agricultural level, the current yield levels are very low, since it is usually produced using very little technology by family farmers. That leads to a low yield in liters of ethanol per hectare in comparison with that obtained from cane.
- In line with the above, cassava is considered an "orphan crop". Cultivated by small farmers, usually far from the distribution channels and from the agro-processing industries, mainly in locations that have a reduced or null access to improved varieties, fertilizers and other production inputs (FAO, 2008). Regarding that, FAO highlights that governments have not yet made the necessary investments to boost its added value, which would turn cassava's starch products into competitive ones at international level, nor has the investment in the improvement of this crop been significant, but much inferior to that destined to other basic crops for food (leading to a lower increase in cassava's productivity through the last three decades: less than 1% annual).
- Other disadvantages of cassava are its high perishability (roots suffer a fast postharvest physiological damage so they have to be consumed in the first days of harvest), and the fact that it is a voluminous product for its high water content, which would represent higher transportation costs to the plant, in comparison with other crops.
- Regarding the processing, as in the case of other amylaceous feedstocks as corn, the technology of production of ethanol from cassava is more complex than in the case of sugar cane, since it requires more processes and the utilization of enzymes (whose costs are still high) to degrade the molecules of starch in order to transform it in soluble sugars for its fermentation²⁶.

²⁵ According to the International Center of Tropical Agriculture (CIAT), Colombia has the record yield of 84 tn/ha in a large area (9.5 hectares), with an industrial variety developed by the mentioned institution.

²⁶ Varieties of cassava may be developed by genetic engineering which, instead of starch, would accumulate a larger quantity of saccharose in its roots (sweet cassava), but in this case the disadvantage would be that the root would require a much greater volume of water in order to maintain saccharose in its soluble form (Buckeridge, 2007). At the end of 2008, EMBRAPA announced



- Linked to the above and with the current low agricultural productivity, one of the main limitations of cassava ethanol is its disadvantage in costs, in comparison with sugar cane ethanol.
- Cassava represents risks from the point of view of soils depletion (its harvest loosens the soil and if it remains bare, rainfall and wind accelerate the erosion and degradation processes), though there are sowing and harvest methods, as well as soil postharvest practices that can avoid these issues. Likewise, cassava is one of the tropical crops that absorb more nutrients from the soil. Since it is a high extractor of nutrients from the soil, its successive cultivation gradually diminishes its yields. In order to maintain the soil's fertility it is required to replace and maintain the adequate level of nutrients by means of fertilization and/or crop rotation.
- Apart from vinasse, there are no co-products of significant value in the production process of cassava ethanol (FAO-ECLAC-BNDES). Cassavas' pomace (flour resulting from the extraction of the roots' starch) has less value than cassava's root's meal (FAO, Animal Feed Resources Information System).
- Cassava represents a staple food for poor people in tropical zones. In this sense, its utilization for the production of ethanol should carefully consider its effects on production and food security (FAO). A massive use and at large scale of cassava for ethanol could have negative effects for poor urban homes whose basic diet rests on this food.

the development of a variety of cassava with a high content of sugar instead of starch, avoiding the hydrolysis process and thus reducing the energy cost for the production of ethanol.

Sugar beet / Remolacha azucarera / Beterraba

Crop	<i>Sugar Beet (Beta vulgaris Var. Saccharifera)</i>
Characteristics	<p>Sugar beet is a round root vegetable that belongs to the <i>chenopodiaceae</i> family, probably native of Asia. The crop grows in different climates. The seed's germination is possible at 5°, but the effective minimum should be from 7-10°C. During the vegetative growth higher temperatures are desirable, but high yields in sugar are obtained when night temperature is at 15°C and 20°C and daily temperature is between 20-25°C during the last part of the growing period. During this period, temperatures above 30°C reduce its yield. It requires a lot of insolation; in shaded areas yields are considerably reduced. Sugar beet has traditionally been grown in countries or regions of temperate climates, though the recent development of tropical varieties of sugar beet facilitates its expansion to tropics and subtropics. The crop adapts to a wide variety of soils, though those of medium or slightly heavy texture are preferred, well drained and deep. Limited productions in root's weight are obtained in clayey soils, though its saccharose richness is higher. pH values in soil lower than 5.5 are unfavorable for beetroot growth. It has a good tolerance to the soil's salinity, except for the initial growth phase during the crop's establishment. It requires an adequate quantity of nitrogen to assure the maximum early vegetative growth, though in excessive quantity or late applications during the growth phase, generates a reduction in sugar content. The applications of fertilizers should be the following: N: up to 150 Kg./ha, P: 50-70 Kg./ha when sowing it, K: 100-160 Kg./ha. Sugar beet requires a careful handling of the crop and the postharvest to achieve reasonable yields. Even though it is a biannual crop, it is harvested on the first year for the production of sugar. The main commercial component of beetroot is its tuberous root, from where sugar is obtained, usually used as sweetener, or consumed as a vegetable (FAO, PFAF, CENIAP, Lopez Bellido, 2003).</p>
Water requirement	<p>550-750 mm. Sugar beet is particularly sensitive to lack of water when the crop is emerging and about a month after the emergence. Mild and frequent irrigations are preferable during this period; irrigation could also be required to reduce the formation of crusts on the soil and to reduce the salinity of the soil's surface (FAO).</p>
Content of fermentable biomass	15%
By-products / co-products of its utilization for biofuels	<p>Sugar beet leaves and tops may be harvested and ensilaged for forage or added to the soil to improve its fertility. Beetroot's tops and pulp (residue left after the extraction of the root's juice) are used for cattle feed, especially dairy cattle, bovine fattening cattle and pets (pulp). Sugar beet pulp could also be used for human feed, as a source of pectin (of lower quality than citrics' and potatoes') or for the production of dietary fibers (it requires previous treatment due to high ash content). Molasses's vinasses (obtained after the molasses's fermentation) may be used for animal feed and as fertilizer. Sugar refineries' foams can also be reused as fertilizers. (López Bellido, 2006). The leaves, tops and residues of the alcoholic fermentation are usable for biogas production.</p>
Efficiency of the conversion to biofuels (lts/tn)	110
Agricultural yield (tn/ha)	46.8 (global average)
South American yield	74.4
Countries with higher yield	Chile (81.4)
Potential	<p>A good commercial yield (for sugar beet of 160-200 days) is 40 - 60 tn/ha and under certain circumstances between 70 and 80 tn/ha are obtained (FAO). In Chile, in term 2007-08, yields fluctuated, according to the region, between 80 and 124 tn/ha (ODEPA). For the variety of tropical sugar beet, Syngenta reports that experimented farmers may achieve yields of more than 100 tons per hectare if they deploy good fertilization, soil preparation, sowing and irrigation practices, as well as an efficient and integrated control of scrubs, plagues and diseases. In Colombia, yields of 120 tn/ha in experimental crops have been obtained with such variety.</p>

Ethanol yield per ha (lts/ha)	5148
With regional agricultural yield	8184
In countries with higher agricultural yield	8954
Potential	8800-13200

Source: Own elaboration; information obtained by IICA's regional offices; FAO Water Development and Management Unit and several sources.

Sugar beet provides about 16% of the world's sugar production and is usually considered as one of the feedstocks with more potential for the production of ethanol, especially in the regions of temperate climate, along with sugar cane and sweet sorghum.

Despite its importance in the global production of sugar, sugar beet is not an extended crop in South America. About 99% of the South American production of sugar beet is concentrated in Chile, which produced 1.8 million tons in 2006-07 (0.7% of the world's production), followed in order of importance by Venezuela (22,700 tons).

In Chile, sugar beet, grown mainly in the regions of Bío Bío and Maule, is one of the alternatives with greatest possibilities for the production of ethanol. Both the agricultural yield and sugar content of the sugar beet obtained in this country are the highest in the world (ODEPA, 2007). The level of technology of the cultivation of Chilean sugar beet is high; they use monogerm seeds in all the sown area (some of these seeds are tolerant to fungal diseases typical of this crop), with high root and industrial yield, of fast coverage between rows (natural control for scrubs' emergence) and with less secondary roots (ODEPA, 2009). 60% of the area uses tech irrigation (center pivot or side roll), installed by means of credits granted by the only beetroot processor of the country and public bonuses. Likewise, a more intensive technological transfer program is being developed for farmers who obtained lower yields, in order to reduce the productivity gap.

Colombia does not have relevant antecedents in the production of traditional varieties of sugar beet, but has been selected as pilot location for the development of especial varieties for America's tropical zone, by its developing company, the multinational Syngenta. Test sows have been taking place since 2004 in Boyacá, Cundimarca and the Colombian Atlantic Coast. This initiative has derived in a private project of ethanol production from sugar beet, which probably would be the only existing one in South America up to now. Besides the intensive sow of beetroot, the project foresees the set up of two plants in Boyacá and Cundinamarca, for the product's processing, its conversion into sugar and subsequent conversion into alcohol. According to the stages previously foreseen by this project, the plant at Boyacá (with a daily capacity of 300,000 liters) should be in operation by the first semester of 2009, whereas the plant at Cundinamarca would be in operation in 2010. The estimations are that from this project, about 10,000 hectares of beetroot would be grown in Bogotá's Savanna and the high plains of Cundinamarca and Boyacá. From the public sector, CORPOICA develops evaluation of genetic materials of sugar beet and evaluation of integrated crop management conditions in the irrigation district of Alto Chicamocha and river Ranchería.

In Argentina there are some antecedents of growing sugar beet. Currently, its potential is being studied by INTA. It initiated a crop trials network in four departments of the province of San Juan, with different varieties of European and Chilean origin, with the purpose of evaluating the yields in feedstock, percentage of saccharose and production of biofuels, determining the quality of bioethanol obtained and the technical and economic feasibility of producing it in such region from such crop. INTA is also carrying out tests in the Lower



Valley of the Negro river and the Valley of the Colorado river in Buenos Aires province, obtaining satisfactory yields, superior to 80tn/ha in most of the varieties used, even reaching 160 tn/ha in one of them.

In Uruguay, sugar beet is not produced since sugar year 1990/91, though in principle it can be grown in all the agricultural area of the country. Since 2005, private technicians have been evaluating European and Chilean alcoholigenous sugar beet materials in the Department of Canelones. Such tests have reflected promissory results and they would be practiced also in the littoral and North (IICA-Uruguay).

The use of sugar beet for the production of ethanol presents, among others, the following advantages and opportunities:

- The current agricultural yield leads to a high yield in liters of ethanol per hectare, superior to that of corn and other cereals, whereas the potential agricultural yields (or those obtained currently in the case of Chile) would generate a yield in biofuels per hectare potentially superior to that of sugar cane. In this sense, sugar beet's ethanol is highly efficient in the utilization of the land resource.
- From the agricultural point of view, it has advantages regarding its capacity to adapt to a wide variety of soils, like saline and alkaline soils, and its low water requirement (about a third of that of sugar cane). These characteristics would make its cultivation viable in less productive land, under certain conditions.
- The tropical varieties, besides facilitating the introduction of a new crop in countries like Colombia or Venezuela, and having high potential yields, provide the possibility of obtaining two harvests per year. In most tropical countries it can be sowed in seasons when there is no feedstock for cane plants, thus improving the use of the assets and increasing its productive capacity, both of sugar and ethanol (Syngenta).
- Sugar beet also represents opportunities in terms of regional economies development in different South American countries, productive diversification, employment generation and less competition for the use of land for food.
- The production process of ethanol from beetroot generates co-products with high potential positioning in the market, especially in the case of beetroot's pulp, that has an important value for cattle and pet nutrition. Given its high carbohydrates content, beet pulp could also turn into additional feedstock to produce ethanol if there was an efficient enzymatic process capable of extracting the complex sugars and degrade them in simple sugars to be used to transform into bioethanol, an alternative that is starting to be researched²⁷.
- As in the case of sugar cane, since they are saccharide crops, the technological route for the production of ethanol is less complex than in the case of amylaceous crops.

Among the restrictions or disadvantages of sugar beet as feedstock for the production of ethanol, the following can be mentioned:

- As in the case of other alternative feedstocks, and in comparison with those of immediate availability, in the region's countries there are limitations to be overcome for the development of sugar beet,

²⁷ For more information on the research project of bioethanol production from sugar beet pulp: http://www.dyadic.com/wt/dyad/pr_1168958752



related to less experience, spread and knowledge about the crop and its handling (considering it requires a very careful handling of the crop and postharvest in order to obtain reasonable yields), its diseases and plagues, technological restrictions to be overcome, both at agricultural and industrial levels (for example, the design and/or technological adequacy of distilleries for the processing from sugar beet), low or null development of the chain and/or the market, etc.

- Sugar beet ethanol has registered higher production costs than sugar cane ethanol²⁸, mainly due to higher production costs of the feedstock (it should be clarified that these registrations correspond to comparisons between sugar beet ethanol in the EU and Brazilian cane ethanol).
- From the point of view of energy efficiency, sugar beet ethanol has a significantly lower energy balance than that obtained with sugar cane (though superior to that of corn). From the point of view of environmental efficiency, sugar beet bioethanol would enable high savings of GHG emissions (lower than that obtained with sugar cane bioethanol and higher than corn bioethanol).
- Other restrictions of sugar beet have to do with its size, that causes its transportation to be relatively expensive and with its high perishability which leads to a shorter potential storage life and to the need of processing it quickly, before the sucrose deteriorates. Thus, plants have to be located in the feedstock's production zone. The potential storage life and, consequently, the processing season, may be extended through the extraction and storage of sugar in the form of molasses (The Mother Earth News, 1980).
- It's a very extractive crop and without the suitable conservation practices, leads to the soil's degradation in the medium and long term. For example, in Uruguay, the experience in the crop left lots of interrogations regarding the effects of erosion and degradation of the used soils (IICA-Uruguay). Likewise, the repetition of sugar beet cultivation on the same soil or the rotation with other crops in a short time interval frequently causes serious problems of plagues and diseases that affect the yield (López Bellido, 2003). These aspects require sugar beet to be sequentially rotated with other crops, in order to return to the same soil each 3 to 8 years (with sugar beet cultivation each four years as a general rule).

²⁸ In comparison with corn ethanol, according to information from FAO and OECD (FAO, 2008c), sugar beet ethanol produced in the EU registered higher production costs in 2004 and lower costs in 2007 (result of the high increase of the price of corn in the global market).

Sorgo dulce / sorgo sacarino / sweet sorghum

Crop	<i>Sweet sorghum (Sorghum bicolor Moench)</i>
Characteristics	Sweet sorghum is a species that belongs to the sorghum genre, family of grass. It is an annual plant native of Africa and extended to all continents. It grows in temperate-warm zones and humid subtropical zones. Its optimal temperature is between 25 - 31°C and its growth is little below 16°C. It stands out for its great resistance to drought, high temperatures and strong winds. Sweet sorghum may be grown in a wide variety of types of soils, but yields are typically higher in deep, well drained and fertile soils. Its growth in shallow or low in organic matter soils may be more susceptible to drought stress. It tolerates salinity and different levels of acidity in the soil. Even though it is more tolerant to drought than many other crops, abundant humidity during the growing period is important in order to obtain good yields in stem and juice. In contrast with grain sorghum, whose greatest content of fermentable material is in the grain's starch, sweet sorghum is characterized for its high content of fermentable sugars in the stem. According to the different positions of the sugar contained in the stalks, sweet sorghum may be divided into those of the "saccharin" type, that mainly contain sucrose (saccharose), and those of the "syrup" type, that mainly contain glucose. The following can be produced with sweet sorghum: syrup (its main historical use), molasses, sugar crystals, forage and silage for animal feed and ethanol (Universidad Pública de Navarra, Vermerris (2007), Duke (1983), PROTA Database, Dajue (1997)).
Water requirement	450 - 650 mm
Fermentable biomass content (% of sugars in the juice extracted from stems)	16%-23% Brix
By-products / co-products of its utilization for biofuels	Sweet sorghum bagasse (crushed stalks) is the residue obtained after removing the juices and may be used for the generation of electricity or vapor as a part of a cogeneration scheme or may be compacted in nutritious blocks for cattle feed. Sweet sorghum grain may be harvested, cured and used to feed cattle and poultry.
Efficiency of the conversion to biofuels (lts/tn)	70
Agricultural yield (tn/ha)	The yields of sweet sorghum vary considerably depending on the varieties/hybrids used, location (soil, water, climate, plagues and diseases), inputs and production practices (Vermerris, 2007). In general it can produce between 45 and 75 tn/ha of stalk (Dajue, 1997).
Ethanol yield per ha (lts/ha)	3742-5612

Sweet sorghum (*Sorghum bicolor Moench*) is considered as one of the most promissory alternative feedstocks for the production of ethanol. Currently it presents a slightly significant production at global level, and the main experiences are registered in USA (where it has been traditionally grown for the production of syrups and animal feed), India, some African countries and China.

In contrast with grain sorghum, whose greatest content of fermentable material is in the grain's starch, sweet sorghum is characterized for its high content of fermentable sugars in the stalks. This way, sweet sorghum ethanol is obtained from grinding the stalks and the subsequent distillation of the obtained sweet juices. Hybrids, which are a cross between grain sorghum and sweet sorghum that combine both species' characteristics, have also been developed. There is research that aims at developing sweet sorghum varieties and hybrids with high yield in high quality grain, which retains the characteristics of the juicy stems, rich in sugar (NARI).

Experiences with the cultivation of sweet sorghum in South America are still very limited, though due to the advantages and opportunities detailed below, great interest has arisen in various countries of the region, reason why it is being researched.

In Brazil, EMBRAPA already has four Brazilian varieties of sweet sorghum with advanced technological domain. In Uruguay, technicians of INIA and the Faculty of Agronomy are carrying out several experimental tests in different departments of the country and evaluating the performance of diverse genetic materials of sweet sorghum, since 2005. Some recent experiences have also been performed by private ventures, regarding the growth of new varieties of sweet sorghum (IICA-Uruguay). Yields of between 57 and 82 tn/ha have been obtained. In Argentina, sweet sorghum is considered as a high potential crop in the North of the country, due to its resistance to drought and high temperatures. In Bolivia, according to a recent study²⁹, all the departments seem to be suitable for its growth.

Among the Andean region's countries, the research actions developed in Colombia stand out. CORPOICA, under the framework of the National Convocation for the co-financing of research projects (2007), carries out the projects "Integrated handling of the cultivation of sweet sorghum for the production of fuel alcohol under the environmental conditions of the Caribbean, Interandean Valleys and Piedemonte Plain" and "Attainment of sweet sorghum for the competitive and sustainable production of fuel alcohol in Colombia", whose objectives aim at obtaining and implementing types of hybrids of sweet sorghum for the production of ethanol nationwide with high efficiency, sustainability and competitiveness standards. Therefore, it has introduced 20 advanced sorghum lines for yield tests, together with efficiency and evaluation tests of sweet sorghum lines in Cereté, Tolima and Villavicencio, as well as in the Piedemonte Plain, Interandean Valleys and the Caribbean. The introduced lines had passed various selection cycles in the framework of an agreement between CORPOICA and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), where after selecting the best materials of sweet sorghum; they will be implemented in the integrated handling of the crop for the production of biofuels by the farmers of such regions (IICA-Colombia). In Peru, ethanol from sweet sorghum could be produced, due to the favorable soil and climate conditions, both in the North coast and in the country's high jungle (IICA-Peru).

The main advantages and attractions of sweet sorghum as a feedstock for the production of ethanol are the following:

- Agronomically it stands out for its high tolerance to a wide variety of climate and soil conditions (high temperatures, drought, floods, soil's salinity and toxicity due to acidity), which would enable to grow it in less productive land than for other crops like sugar cane or corn (saline-alkaline and low fertility soils).
- Sweet sorghum, has various favorable characteristics that resemble it to sugar cane: sugar contents are located in the stalks and are directly fermentable, which grants it an advantage over the amylaceous crops; total reducing sugars' contents in the stalks are not significantly different from those found in sugar cane, previously cut; from its production for ethanol also a sufficient quantity of bagasse can be obtained for the generation of vapor for industrial activity (Teixeira et al, 1997); while it also has some advantages over this crop: lower water requirements, short productive cycle (from 120 to 130 days) which would enable more than one harvest per year and a joint production with sorghum grains and silage from the plant's residue, that can be used for animal feed.
- It has a relatively high yield of ethanol per hectare, superior to that obtained from cereals and some alternative crops like cassava.

²⁹ CAINCO-IBCE. *Productive Departmental Vocations for the Production of Biofuels and Food Security*, 2008.

- In line with the aforementioned, the production of ethanol with sweet sorghum has a high potential of generation of high value co-products. a) bagasse: besides being usable to provide energy for the distilleries, the same may be used to produce cellulosic ethanol when feasible at commercial scale, while according to the International Livestock Research Institute (ILRI), bagasse's value could be duplicated if it is compacted in nutritious blocks for cattle feed (ICRISAT); b) sorghum grains: sweet sorghum is the only crop that can jointly produce stalks usable for the production of ethanol and grains for human and/or animal feed that are not implied in the biofuels' production process. The latter makes of sorghum a very good option for integrated systems of rural exploitation that jointly aim at self-sufficiency in biofuels and at agricultural production (Teixeira et al, 2007).
- It has the possibility to be produced in the inter-harvest period of sugar cane, complementing with this product and reducing the period of idleness of the sugar-alcohol industry, and also enabling that sugar cane stalks reach a complete maturation, which represents greater sugar contents (Teixeira et al, 2007).
- From the environmental point of view, in comparison with many other crops, sweet sorghum has a high efficiency level in the use of water and nutrients (Vermerris, 2007) and an energy balance³⁰ superior to that of cereals, beetroot and cassava and potentially similar to that of sugar cane (Da Silva et al, 1978).
- Since it is a low demand product in the regional and global food markets, its use for the production of ethanol would not have a significant impact on the prices of food and on food security.

Regarding the limitations of the use of sweet sorghum for the production of ethanol, the following can be mentioned:

- The main limitation of sweet sorghum lies in its reduced resistance to degradation once harvested, therefore, it can not be stored for long periods of time. Moreover, sweet sorghum juice can not be stored easily leading to a serious seasonality problem. In this sense, the installations for processing should be large enough as to handle the entire harvest in just a few weeks, fermentation should be made immediately, and plants would only be operative during a few months a year, hindering its economic feasibility (Duke, 1983; Vermerris, 2007; OSU, 2006). The seasonality problem could be solved by means of the development of integrated systems such as: a) integration of the cultivation of sweet sorghum with the cultivation of sugar cane or corn, depending on the region; b) processing and integrated conversion of sweet stems and sorghum grains or of other crops; c) ethanol production using both sorghum's simple carbohydrates and its lignocellulose (when the latter is commercially feasible) (Dike, 1983). In USA, several research groups have designed harvesters' prototypes that extract the juice and leave the bagasse in the fields, but the fact that this technology turns out to be commercially feasible is still uncertain (Vermerris, 2007). Moreover, the feasibility that the fermentation may be carried out in large containers in the field is also being researched (OSU, 2006).
- In line with the aforementioned, the costs of transportation and nearness with the ethanol processing and/or production plants play a determining role to identify the profitability of the production of sweet sorghum (Vermerris, 2007).
- Other restrictions have to do with the limited base of germplasm and of varieties for which the seed is entirely available. In a context of wide and fast adoption of this feedstock, the seeds would be difficult

³⁰ Approximately a fossil energy ratio equal to 4 (Woods, 2000, by simulation).

to obtain (Vermerris, 2007). Its resistance to plagues and diseases is also low (FAO-ECLAC-CGE-BNDES, 2008).

- The fact that temperatures below 16°C affect its growth, limits its possibilities in certain regions and locations of the Southern Region’s countries.

9.2.2.3 Lignocellulosic feedstocks

The use of feedstocks and crops with high cellulose content (lignocellulosic) constitutes one of the most promissory variants for the production of biofuels.

The carbohydrates of lignocellulosic feedstocks are found in more complex forms than in crops with high saccharose and amylaceous content. Lignocellulosic materials are composed of cellulose, hemicellulose and lignin (Table 9.2.2.17). Of those, the two first ones are a potential source of fermentable sugars.

There is a wide variety of lignocellulosic feedstocks, which can be grouped in the following categories:

- Agricultural and agroindustrial residues and wastes.
- Primary and industrial forest residues.
- Dedicated energy crops, such as perennial grasses and short rotation or fast growing trees.
- Organic parts of urban wastes.

Table 9.2.2.17: Composition of some lignocellulosic feedstocks

	<u>% Cellulose</u>	<u>% Hemicellulose</u>	<u>% Lignin</u>
Corn stover	30-38	19-25	17-21
Sugarcane bagasse	32-43	19-25	23-28
Hardwood	45	30	20
Softwood	42	21	26
Hybrid poplar	39-46	17-23	21-28
Bamboo	41-49	24-28	24-26
Switchgrass	31-34	24-29	17-22
Miscanthus	44	24	17
Giant Reed	31	30	21

Source: Oak Ridge National Laboratory, Bioenergy Feedstock Development Program (compiled by J. Scurlock in 2002, updated by L. Wright in 2008).

The conversion of lignocellulosic biomass in biofuels presents two big technological routes: biochemical and thermochemical. The first one leads to the attainment of cellulosic ethanol, based on the utilization of enzymes and microorganisms; the second is based on processes as gasification and fast pyrolysis to obtain synthetic biofuels and bio-oil, respectively.

Due to the technological reasons exposed below, the production at commercial scale of ethanol based on lignocellulosic feedstocks is almost null in the world (0.1% of the total production of ethanol in 2007 according to IEA/OECD), though significant R&D efforts are registered, especially in USA and the EU, where significant budgets are being invested for its development. Regarding the availability of these feedstocks, there are two types: those with a significant potential supply in the short term (agricultural residues, forest biomass and

urban wastes), that could perform an early role in the development of the industry of cellulosic ethanol, and those potentially available in the long term (dedicated energy crops).

- **Primary agricultural and agroindustrial residues and wastes.**

Primary agricultural residues and wastes are composed of biomass that remains on the field after harvesting, which is currently the lignocellulosic feedstock available in greater quantity.

Among the most relevant agricultural residues and wastes in the region are, wheat, rice and other cereal's straw, leaves, corn stover (stalks, leaves and/or cobs), sugar cane leaves, cotton stalks and residues of the oil palm production (empty fruit bunches, shells and fibre). Among the secondary or agroindustrial residues and wastes, sugar cane bagasse stands out.

The region's countries with greatest availability of primary agricultural residues and wastes, considering the production of cereals and sugar cane, are Brazil, Argentina and Colombia. These countries also lead the production of sugar cane bagasse, where Brazil stands out, concentrating about 90% of the South American production.

The main advantages of these feedstocks are given by their very high immediate availability. Probably, agricultural residues are among the cheapest feedstocks for the production of liquid biofuels (FAO, 2008f). Likewise, the same could represent an additional source of revenues for farmers. Cane bagasse and corn stover stand out particularly for being easily integrable to the current industry of ethanol. Energy and GHG emission savings balances of agricultural residues' ethanol are positive and much superior to those of cereals' ethanol, according to the life cycle's analysis, but the increase of some gases' emission, like nitrous oxides, remains a concern (BR&Di 2008a). From the environmental point of view, the utilization of agricultural residues for the production of cellulosic ethanol also represents an opportunity to avoid crops' stubble burning that still persists in certain zones of the region's countries and constitutes an important source of emissions of GHG by agriculture.

The main restriction of primary agricultural residues is related to sustainability and conservation issues. Agricultural residues play a very important role in the recycling of the soil's nutrients and maintenance of their fertility and productivity in the long term. In this sense, a significant removal of the same would harass the soil's erosion and wear down the soil's essential nutrients and organic matter (BR& Di, 2008a) or impact on the availability of the natural fertilizers and micronutrients that should be replaced by chemical ones (ECLAC, 2007). According to research done in USA, under certain conditions and within certain limits, the removal of residues from the soil may be sustainable. The quantity to be removed without increasing the soil's erosion and without reducing fertility will vary according to tillage practices, the type of soil and region (BR&Di, 2008a). Some estimations propose that only about 15% of the total residues production should be used for the generation of energy, after satisfying the demands related to the soil's conservation, production of cattle feed and other factors as seasonal variations (Bowyer and Stockmann, 2001, cited by FAO).

The valid technological restrictions for its collection and handling also present limits in terms of the potentially available quantity of primary agricultural residues. In cases of extensive agricultural exploitations, the collection of the residues would be too expensive, reducing their economic value (Patrouilleau et al, 2007). The need to build the infrastructure and logistics required for the transportation of large quantities of agricultural residues to the plants of cellulosic ethanol and other bioenergies is added to these restrictions. In the case of agroindustrial residues or wastes as cane bagasse, these difficulties would not arise since they are already concentrated in the processing plants.

- **Primary and industrial forest residues**

Primary forest residues are constituted by the products derived from forest activities (pruning, harvest, forest extraction or chopping down) or from the sustainable handling of native forests, and include woody residues like bark, branches, leaves, pruning branches, pollard rests, dead trees, damaged or discarded stalks, etc. A great quantity of these residues are usually separated and left on the surface during chopping down and pruning activities. Woody residues coming from wood's industrialization process, such as bark, pieces, boards, splinters, wood chips, sawdust, etc. are added to them.

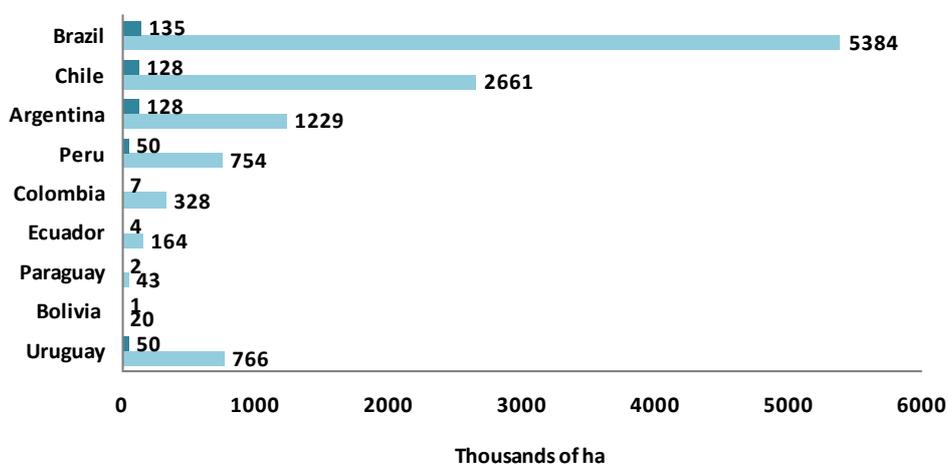
Forest residues represent another significant source of feedstock for the production of second-generation liquid biofuels. The region has a wide forest cover³¹, where Brazil, Peru, Colombia and Bolivia stand out for their natural forest area and Brazil, Chile, Argentina and Uruguay for their area of planted forests (Table 9.2.2.18). According to ECLAC (2007), total biomass found on the soil is about 420,000 million tons in the world, of which 40% is in South America and 27% only in Brazil.

Table 9.2.2.18: Forest cover in South America

Forest Cover 2000					
Country	Country area (thousands ha)	Natural forest (thousand ha)	Natural forest as a percentage of country area (%)	Forest plantation (thousand ha)	Natural forest area per capita (ha)
Argentina	278,040	31,792	11.4	1,229	0.8
Bolivia	109,858	58,720	53.5	20	6.5
Brazil	851,488	472,314	55.5	5,384	2.6
Chile	75,663	13,460	17.8	2,661	0.8
Colombia	113,891	60,399	53.0	328	1.3
Ecuador	28,356	10,689	37.7	164	0.8
Paraguay	40,675	18,432	45.3	43	3.2
Peru	128,522	67,988	52.9	754	2.5
Uruguay	17,622	740	4.2	766	0.2
Venezuela	91,205	-	-	-	-
South America	1,783,770	772,468	43.3	11,357	2.1

Source: FAO based on FRA 2005

³¹According to FAO's statistics, forest cover is constituted by natural forest areas plus planted forests. Natural forest is the primary forest plus modified and semi-natural natural forest. Planted forest is the addition of planted forests with productive purposes and planted forests with protection/conservation purposes.

Graph 9.2.2.19: Total area of planted forests and annual planting rate in South America


Source: FAO based on FRA 2005 and National Studies

Forest residues present similar advantages to the agricultural residues, in terms of high immediate availability and high energy and GHG emissions savings balances. Moreover, from the environmental point of view, the utilization of forest residues for the production of cellulosic ethanol also represents an opportunity to prevent threats to forest's health related to fires, plagues and invasive species, factors whose occurrence may be caused by the excessive accumulation of woody biomass (BR&Di, 2008b).

Beyond its high potential in terms of availability, primary forest residues present important restrictions related to technology and collection and handling costs, as well as accessibility to forest zones, whose distances from consumption centers may be long and cause high transportation costs. In the case of forest-industrial residues, restrictions related to the collection would not exist since they would be already concentrated in the processing plants. From the environmental sustainability point of view, as in the case of primary agricultural residues, the significant removal of forest residues would cause the soil's erosion and nutrients' and organic matter's depletion. In the case of wood industry residues, the possibility of competition for feedstock with other industrial activities depending on them shall also be considered (for example, sawmill residues are used in the production of cellulose pulp and particle or fiber boards) (Patrouilleau et al, 2007).

- **Dedicated energy crops**

Among the lignocellulosic feedstocks that are potentially available in the long term, the following are highlighted: perennial herbaceous crops such as switchgrass (*Panicum virgatum*), miscanthus (*Miscanthus giganteus*), elephant grass (*Pennisetum purpureum*), reed canary grass (*Phalaris arundinace*) and cynara thistle among others, and short rotation or fast growing trees (eucalyptus, poplar, pine, etc.) which may be specifically dedicated to biofuels production.

Herbaceous perennial crops are usually grown for the production of forage, but some varieties with high yield potential of biomass per hectare could be used for the production of cellulosic ethanol. In many of these cases, they are new crops that practically do not have market experience.

Among the more researched grasses in the countries with more experience in cellulosic ethanol R&D, switchgrass (*Panicum virgatum*) and miscanthus (*Miscanthus giganteus*) stand out. Switchgrass is a perennial grass native of North America, with several important advantages. Among them its high dry matter yield (from 10 to 25 tn/ha, according to different authors), its tolerance to drought and wide range of adaptation to low

fertility conditions, which makes it suitable for marginal land, low humidity land and land with lower opportunity costs, such as pastures (BR&DI, 2008a). *Mischantus* is a tall grass, native of some parts of Asia, Polynesia and Africa, highlighted for its high dry matter yields per hectare (12 to 37 tn/ha according to studies in non irrigated areas, mentioned by IFAS – University of Florida) and for its adaptability to a wide range of soil and environmental conditions, including a very high tolerance to cold. Perennial grasses present some benefits from the environmental point of view, related to lower erosion, carbon sequestration in the soils and nutrients' recycling by its rhizome systems (BR&DI, 2008b). Likewise, these crops' fertilization and pesticides requirements are usually low.

Broadly, perennial herbaceous crops present high potentiality in terms of biofuels yield per hectare and of energy and emissions savings' balances, which could significantly exceed that of first generation feedstocks. Among their limitations and eventual risks, the following can be mentioned: many of these species are considered invasive or potentially invasive and could have negative effects on water resources, biodiversity and agriculture (FAO 2008c). The latter would happen in the case of using land previously destined to food production. Other restrictions to overcome have to do with risk aversion of producers in order to produce new crops, due to the lack of information, skills and know how, with the need to count with more research and knowledge about their yields and handling and with environmental aspects as the impossibility to develop crop rotation in perennial biomass crop systems³², which is crucial for plague and disease control (BR&DI, 2008a).

Fast growing trees constitute another important category of specialized energy crops with potential of being used in the future. They are trees developed in high density plantations at relatively close spacing (up to 33,000 trees per hectare) and harvested under shorter rotation periods than conventional forests (Dickman, 2006, mentioned by BR&DI, 2008b). Among the more researched species in advanced countries in RDI of lignocellulosic feedstocks are, hybrid poplar and willow, due to their high potential biomass yields per hectare (12 to 17 tn/ha and 27 to 30 tn/ha, respectively³³). Other relevant short rotation species are eucalyptus, bamboo, sycamore and pine.

Fast growing trees offer multiple environmental benefits: they provide the possibility of storing carbon, reducing the soil's erosion and promoting a stable nutrients' and organic matters' cycle in the soil, at the same time that, in contrast with agriculture, they provide habitat to a wide range of birds and may enhance the landscape's diversity (BR&DI, 2008b).

As the other categories of lignocellulosic feedstocks, fast growing trees still face a series of significant limitations, many of which are related with its handling: high establishment costs due to the many cuttings or seedlings required per hectare, low wood-bark ratio, and lack of efficient mechanical harvest of dense plantations (Dickman, 2006, mentioned by BR&DI, 2008b). From the economic point of view, with the current status of market prices, harvest yields and technologies, fast growing trees are not yet competitive to be used for bioenergy, and face competition in price by pulp, paper, wood and fossil fuels of lower costs (carbon and natural gas) industries (BR&DI, 2008b).

According to the Biomass Research and Development Initiative of USA, since they are essentially scarce or slightly improved feedstocks, both perennial grasses and fast growing trees have potential to obtain large improvements in terms of increase of yields and development of other desirable characteristics (optimal growth

³² Regarding the latter, according to BR&DI (2008a), from the long term (environmental and economic) sustainability perspective, the ecology of perennial herbaceous crops requires the multiplicity of crops or even a mixture of species within the same area. A mixture of various herbaceous crops in the same region would contribute to reduce plague and disease spread risk (consequence of monoculture), as well as to optimize the offer of biomass to ethanol plants, since different herbaceous materials could be harvested in different moments.

³³ ECLAC (2007).

in specific microclimates, better resistance to plagues, efficient use of nutrients and greater tolerance to humidity deficit and other stress sources). Therefore, a much complete knowledge of its biological systems and the application of the last biotechnological advances will be fundamental.

By and large, biofuels made of lignocellulosic feedstocks have significant advantages and opportunities:

- Cellulosic biomass constitutes the most abundant biological material on earth (FAO, 2008c), thus second-generation biofuels represent a potential contribution to the energy matrix that is substantially superior to that of first-generation biofuels. According to the World Energy Council, these biofuels could replace approximately 40% of fossil fuels used in transport by 2050 (Biopact, 2008).
- Given its potentiality to be used entirely in the production process, lignocellulosic feedstocks represent very high potential yields of biofuels per hectare.
- They have energy and GHG emissions savings balances potentially superior than those obtained by biofuels based on first-generation feedstocks. That is due to higher potential yields of energy per hectare, as well as to the possibility of using energy coming from the same plants' wastes for its production (FAO, 2008c).
- They would enable avoiding the biofuels vs. food dilemma, considering that they are agroindustrial or forest-industrial residues and non-food crops. In the last case, some perennial grasses and short rotation trees may sometimes grow on poor and degraded soils, where food crops' production is not optimal. Nevertheless, in contrast with first generation biofuels, no co-products such as food for animal production are generated from cellulosic ethanol production processes, which should also be taken into account in a comparison (IEA/OECD, 2008):

Despite its multiple potentialities and significant investments in pilot plants and demonstration projects, biofuels for transportation produced from lignocellulosic feedstocks do not register production at commercial scale in the world yet. That is explained by a series of significant barriers for their development that still persist:

- The main challenge faced by cellulosic ethanol is of technological nature and has to do with the conversion of the feedstock into biofuels. The complexity of the lignocellulosic feedstocks' structure causes the conversion to fermentable carbohydrates to be difficult and expensive³⁴. Technological routes have not yet reached their point of maturity and are not yet economically viable for production at large scale. The projections on the moment when second generation biofuels will be available at commercial scale vary widely, though it is commonly considered as unlikely that it occurs before year 2015.
- In the current state of the art, their production costs are high in comparison with first generation biofuels and fossil fuels. The improvement of second generation biofuels' competitiveness will require reductions in the costs of biomass feedstocks, transport logistics and conversion processes. (IEA/OECD, 2008).
- Collection and handling systems of feedstocks, as well as infrastructure and logistics aspects of transportation and storage systems also represent challenges to overcome. The current systems are

³⁴ Lignocellulosic materials are composed of cellulose (35-50%), hemicellulose (15-25%) and lignin (20-25%). Of them, the two first ones are a potential source of fermentable sugars. The main challenges faced by the technological development of cellulosic ethanol are the extraction and dissolution of cellulose and hemicellulose (their encapsulation in lignin hinders the extraction process and the hydrolysis to sugars) and the hydrolysis process of cellulose (Romano S. et al, 2005).

still inadequate for the processing and distribution of biomass at the necessary scale for the production of large volumes and require expensive expansions in infrastructure (IEA/OECD, 2008).

- From the environmental sustainability point of view, beyond the multiple benefits described above, there are limitations, challenges and the need of greater research and knowledge, as in the mentioned cases of removal of primary agricultural and forest residues or the potential environmental effects of a large scale expansion of energy crops (perennial grasses and short rotation trees).

So far, the global investment in R&D in lignocellulosic feedstocks and pilot and demonstration plants has been concentrated on USA and Europe. In the region's countries the research and knowledge levels linked to the topic is still limited, therefore it is crucial to advance in the (economic, environmental and social) study, research and evaluation of the different alternatives that represent lignocellulosic feedstocks.

For the region's countries, all these alternatives require strict and opportune R&D actions, not only for their potentialities but also for the fact that the big players of the global market are already aiming at them, with wide programs and significant budgets. In the particular case of second-generation biofuels, this dynamism in the skills development in the potential competitors and markets could restrict a balanced transition from first generation biofuels to second generation biofuels, especially in the South region countries with high potential for the export of biofuels (Ganduglia, 2008). In this sense, it is vital for the sustainability of the South American agro-energy chain that the irruption of new generations of biofuels does not operate as a disruptive technology dramatically displacing the original actors. On the contrary, they should be in conditions to generate and have at their disposal, the necessary knowledge and tools, which facilitate a gradual concentric diversification towards new technologies.

9.2.3 Feedstocks for biodiesel's production

Biodiesel is obtained from the transesterification of vegetable oils or animal fats. Vegetable oils can be produced from a wide variety of oleaginous seeds and fruits and other alternative feedstocks, as algae. Used frying oils are also usable.

South American countries produced more than 130 million tons of oleaginous seeds and fruits and about 17.3 million tons of vegetable oils in 2007. The production of oilseeds in the region is highly concentrated in soybean (87%), the feedstock of greatest immediate availability; followed by African palm, cotton seed and sunflower (Table 9.2.3.2 and Graph 9.2.3.3). Soybean oil concentrates almost 80% of the production of vegetable oils in the region, followed in order of importance by sunflower oil, palm oil and cotton oil (Table 9.2.3.4 and Graph 9.2.3.5).

Table 9.2.3.1: Classification of biodiesel production

Categories			
Animal Oils and Fats	Vegetable Oils and Fats	Used Frying Oils	Sewage Oils and Fats
Origins			
Slaughterhouses – Meat packing depots – Tanneries	Temporary and Permanent Agriculture	Commercial and Industrial Burning	Waste Water from Cities and Certain Companies
Attainment			
Extraction with water and vapor	Mechanical Extraction – Solvent Extraction – Mixed extraction	Accumulations and Recollections	Processes in Research and Development phase

Source: IICA – Brazil 2007

Table 9.2.3.2: Production of oleaginous seeds and fruits in South America. 2007 (figures in tons)

Oilseeds	Total
Soybean	112,472,935
African Palm	7,353,058
Cottonseed	4,749,269
Sunflower	4,043,463
Coconut	3,100,003
Peanut	908,093
Rapeseed	194,787
Castor	162,750
Sesame	114,896
Safflower	58,000
Linseed	51,298
Tung	49,759
TOTAL	133,258,311

Source: IICA – Argentina based on countries' official statistics and FAOSTAT

Graph 9.2.3.3: Composition of the South American production of oleaginous seeds and fruits

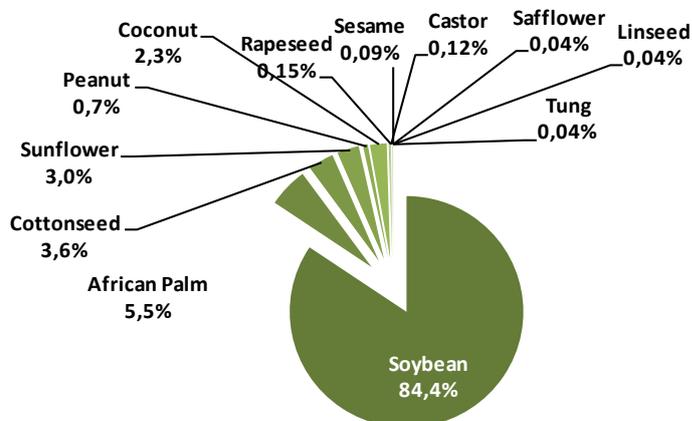
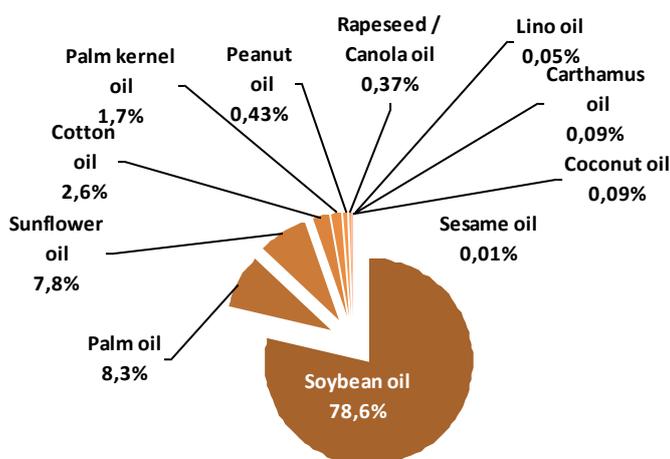


Table 9.2.3.4: Production of vegetable oils in South America. 2007 (figures in tons)

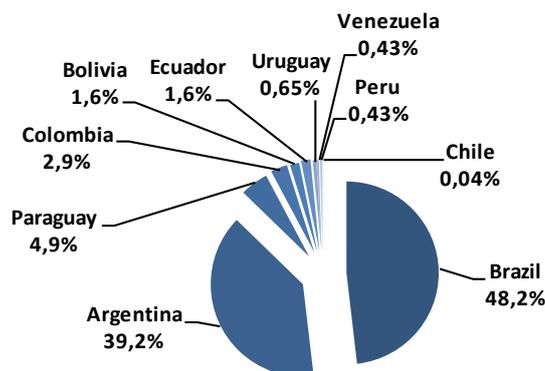
Oils	Total
Soybean oil	13,589,896
Palm oil	1,442,631
Sunflower oil	1,342,023
Cottonseed oil	446,041
Palm kernel oil	288,428
Peanut oil	74,867
Rapeseed / Canola oil	64,091
Coconut oil	15,220
Safflower oil	14,820
Linseed oil	8,980
Sesame oil	1,600
Castor oil	s/d
Tung oil	s/d
TOTAL	17,288,597

Graph 9.2.3.5: Composition of the South American production of vegetable oils

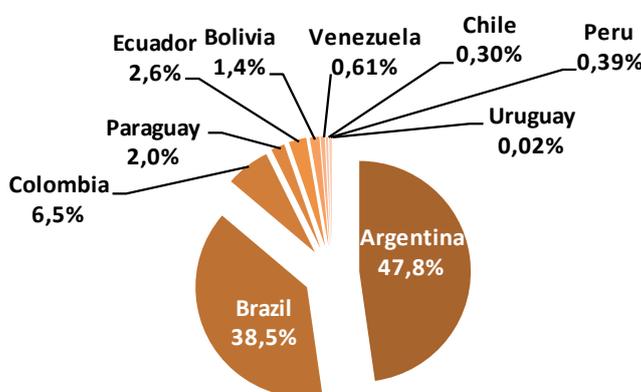


Brazil and Argentina concentrate more than 85% of the region’s production of oilseeds and vegetable oils (Graphs 9.2.3.6 and 9.2.3.7). While Brazil is the main producer of oleaginous seeds and fruits, Argentina is the main producer of vegetable oils. Other highlighted countries are Colombia and Paraguay, for their palm and soybean complexes, respectively.

Graph 9.2.3.6: Countries' share in the production of oilseeds. 2007



Graph 9.2.3.7: Countries' share in the production of vegetable oils. 2007



9.2.3.1 Immediately available feedstocks

Feedstocks of greatest immediate availability for the production of biodiesel in the region are mainly soybean oil, with Brazil and Argentina as main producers and exporters, and palm oil, where Colombia and Ecuador stand out.

Soybean / Soja / Soja

Crop	<i>Soybean (Glycine max)</i>
Characteristics	Leguminous plant of annual cycle native of Eastern Asia. It is cultivated under warm conditions in tropics, subtropics and temperate climates. It is a relatively resistant crop to low and very low temperatures, though growth rates diminish above 35°C and below 18°C. Soybean may grow in a wide range of soils, except for very sandy soils. It is not very demanding in soils rich in nutrients, thus, it is usually a crop used as an alternative for those soils with little fertilization that are not suitable for other crops. Its fertilization requirements are 15 to 30 kg./ha of phosphorus and 25 to 60 kg./ha of potassium. Soybean fixes the atmospheric nitrogen, which enables it to partially cover its requirements for high yields. The plant is sensible to waterlogging, but moderately tolerant to the soil's salinity. Its seeds contain a high percentage of proteins which make it one of the richest and cheapest protein sources in existence. Soybean is a basic legume in human nutrition in many Eastern Asian countries (China, Japan, Korea, etc.) and used for the production of oil and other human consumption products, and protein meal for animal feed.
Water requirement	For maximum production: 450-700 mm per season depending on the climate and the duration of the growing period.
Oil content	18%-20%

Efficiency of the conversion to biofuels (lts/tn)	205
By-products / co-products of its utilization for biofuels	Soybean meal (animal feed) and glycerine
Agricultural yield (tn/ha)	2.27 (global average)
Regional average (weighted)	2.78
Countries with higher yield	Argentina (2.97), Brazil (2.73), Paraguay (2.41) and Uruguay (2.13).
Potential	7-8 (with addition of nutrients, irrigation or contribution of water through layers in the South of Santa Fe, Argentina)
Biodiesel yield per ha (lts/ha)	465
With average regional agricultural yield	570
In countries with higher agricultural yield	437-609
Potential	1435 – 1640

Source: Own elaboration; information obtained by IICA's regional offices; FAO Water Development and Management Unit and several sources.

Table 9.2.3.8: Soybean in South America – Productive and commercial statistics

Crop	Variable/Country	Southern Region						Andean Region				Total
		Brazil (1)	Argentina (2)	Uruguay (3)	Paraguay (4)	Bolivia (5)	Chile (6)	Venezuela (7)	Colombia (8)	Ecuador (9)	Peru (10)	
Soybean	Sowed area (hectares)	20.581.000	16.141.337	365.700	2.429.794	960.000	0	13.000	26.450	31.000	712	40.548.993
	Agricultural production (tons)	56.316.000	47.482.784	778.000	5.855.804	1.900.000	0	23.800	52.900	61.000	2.647	112.472.935
	Agricultural yield (tons/ha)	2,73	2,97	2,13	2,41	1,97	0	1,83	2,00	1,96	1,56	2,78
	Soybean foreign trade* Exports (tons)	23.733.775	11.842.536	773.142	2.380.344	66.057	9.711	0	111	4.673	78	38.810.427
		Imports	97.928	2.245.391	26.749	15.322	244.490	188.579	1.926	332.064	354	48.962
	Soybean oil production (tons)** Exports	6.046.000	6.962.675	2.600	252.904	204.200	30.000	17.000	59.887	14.000	630	13.589.896
		Imports	2.342.541	6.403.549	0	206.202	198.534	0	0	6.689	n.d.	0
	Soybean oil foreign trade* Exports (tons)	44.049	309	14.795	2.714	275	2.629	256.748	163.844	97.016	300.544	882.923
		Imports	101.215	2.477	50.068	-	502	702.665	643.655	810.604	523.784	776.895
	Soybean meal production Exports	24.109.000	28.085.817	n.d.	1.047.096	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	53.241.913
		Imports	12.474.182	25.991.012	0	914.172	1.022.265	0	0	0	0	40.401.631
	Soybean meal foreign trade* Exports (tons)	101.215	2.477	50.068	-	502	702.665	643.655	810.604	523.784	776.895	3.611.865
		Imports	101.215	2.477	50.068	-	502	702.665	643.655	810.604	523.784	776.895

(1) Source: MAPA - Conab

(2) Source: SAGPyA

(3) Source: MGAP-DIEA.

(4) Source: CAPECO

(5) Source: FAOSTAT. Data on area corresponds in this case to harvested area.

(6) Source: FAOSTAT

(7) Source: FAOSTAT. Data on area corresponds in this case to harvested area.

(8) Source: Ministry of Agriculture and Rural Development (MADR). Directorate of Sectorial Politics. GS.Preliminary 2007

(9) Source: FAOSTAT. The data on area corresponds in this case to harvested area

(10) Source: Regional Directorates of Agriculture – Directorate of Agricultural information. Preliminary 2006/07.

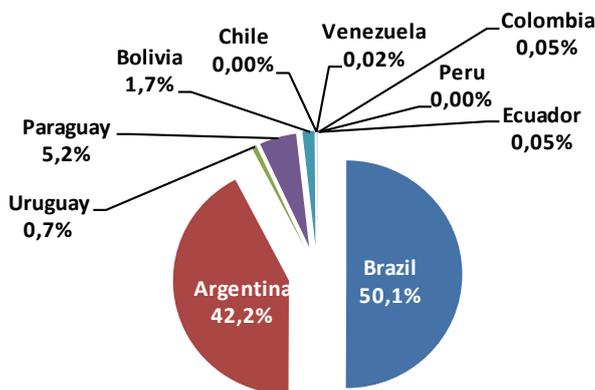
*Source: UN Comtrade. Hs 2002. Data 2007

**Source: (1) ABIOVE. (2) Sagpya (4) IICA – Paraguay. (8) IICA—Colombia. FAOSTAT

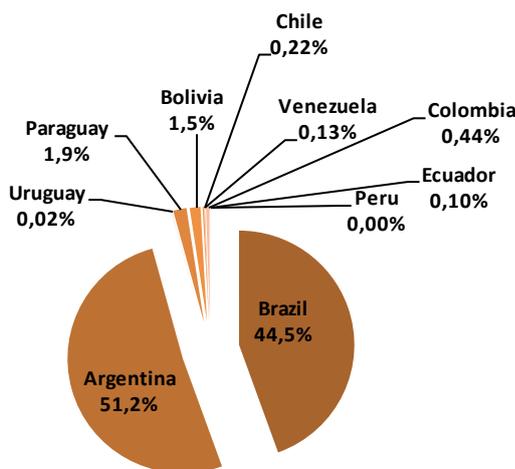
Soybean is the main oilseed produced in South America. In 2007, 40.5 million hectares were sown with soybean, with a production of 112 million tons (52% of the global production). The agricultural yield achieved

by the region in that year was 2.78 tn/ha, 22% above the global average. The best yields are obtained in Argentina, Brazil and Paraguay, exactly the main producers of soybean in the region. Soybean oil's production summed up 13.6 million tons in 2007, (37% of the global production).

Graph 9.2.3.9: Soybean - share in the production per countries



Graph 9.2.3.10: Soybean oil - share in the production per countries



The production of the soybean complex is concentrated almost 100% in the Southern Region's countries, which in turn constitute the largest global block of production of the oilseed. Argentina, Brazil and Paraguay are particularly highlighted. Argentina is the second global producer and the first global exporter of soybean oil, while Brazil occupies the fourth global place as producer and the second as exporter. Brazil and Argentina are second and third global producer and exporter of the grain respectively, and Paraguay occupies the sixth place in the world's production and fourth in global exports. Bolivia and Uruguay, with substantially lower production levels register, over the last ten years, a significant expansion of the cultivated area and soybean's production. Bolivia is a net exporter of soybean grain and oil, while Uruguay is a net exporter of soybean grain and registers net positive imports of soybean oil. Chile does not register soybean production, and is a net importer of soybean grain and oil.

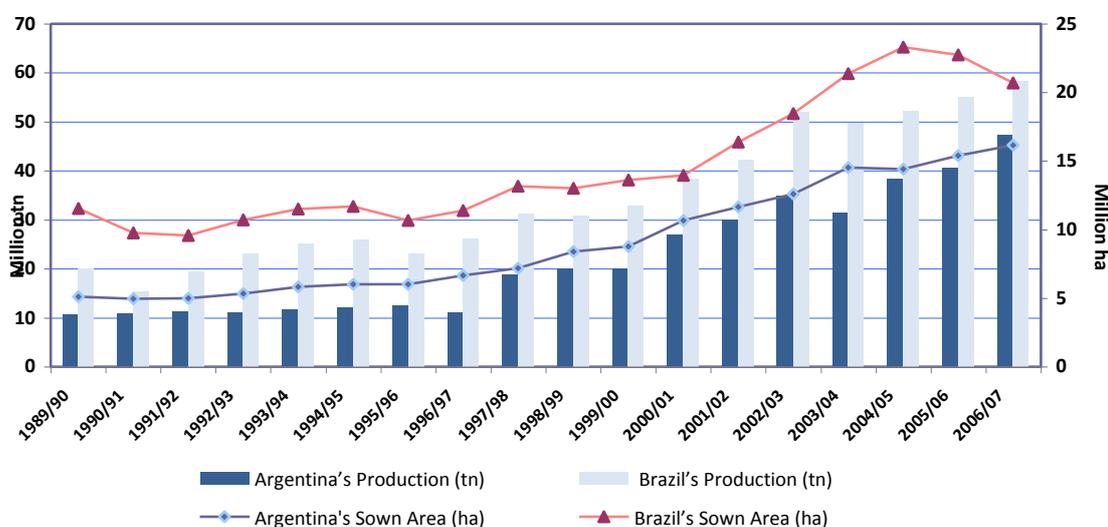
The production of the Andean Region's countries summed up only 140,000 tons of soybean grain and 91,500 tons of soybean oil in 2007. The main Andean producer of soybean grain is Ecuador, while Colombia leads the

soybean oil production. All the region’s countries are net importers of soybean oil and grain, with the exception, in the last case, of Ecuador which registered an exportable balance of 8% of the production of soybean grain in 2007.

The fact that Argentina and Brazil are in conditions of consolidating among the main global producers and exporters of biodiesel is due to the high level of competitiveness of their oilseed chains, which in both cases are highly centralized in soybean. Until now, soybean oil has been the main feedstock used for the production of biodiesel in both countries.

In the case of Argentina, its oilseed complex is probably the most efficient in the world, from its lowest relative costs of oilseed implantation, the privileged location of its vegetable oil industry – in the port of exit and very close to the core zone of the production of soybean (within a radius of less than 300 km.) -, the high technologic development and plants' scale, and a high level of organization and development throughout the chain. Since 2004, an investment boom in the oil industry has occurred in this country, estimated in US\$ 770 million, destined to increase the processing and refining capacities and the port and shipment logistics, among other aspects. Between 2003 and 2007, the processing capacity was increased 37% to be currently positioned in about 45 million tons annually. The area and production of soybean in Argentina have experienced an explosive growth since 1996 onwards, from the conjunction between the no-till system and the massive utilization of genetically modified seeds.

Graph 9.2.3.11: Soybean, sown area and production in Brazil and Argentina 1990 - 2007



Source: IICA - Argentina based on SAGPyA and MAPA statistics

All reasons have led Argentina to consolidate as the first world's exporter of soybean oil.

The Brazilian soybean complex also has notable competitive advantages that have enabled it to position as the second world’s exporter of soybean’s grain and oil. As in Argentina, soybean’s area and production have had a substantial expansion. Its soybean oil industry’s growth has also been significant over the present decade. According to ABIOVE statistics, the processing capacity has increased from 108,000 daily tons in 2001 to 149,500 daily tons in 2007 (45 million tn/year).

The perspectives of expanding the Brazilian's soybean production are favorable considering its significant potential of agricultural expansion

Both countries have very high exportable balances of soybean oil (8.7 million tons in 2007) and grain (35.6 million tons). Argentina exported 92% of its soybean oil production and 25% of its grain production in 2007, while Brazil exported 39% of its soybean oil production and 42% of its grain production in the same year. In this sense, biodiesel is a great opportunity for value adding at domestic level. Both the Argentinean and Brazilian soybean complexes can comfortably satisfy the requirements of the biodiesel's domestic market arisen from their laws.

In the Argentinean case, according to the National Program of Biofuels of SAGPyA, the market projected for the first year of implementation of the Biofuels Law will be positioned in 645 thousand tons of biodiesel in 2010, which will arise from the mandatory blend of diesel with 5% biodiesel. According to estimations of such institution, supplying the domestic market in 2010 will require 670,000 tons of soybean oil (10% of its production and exports of 2007), 3.5 million tons of soybean (7% of the production and 30% of the exports of 2007) and 1.3 million hectares of soybean (8% of the area sown with soybean or 4% of the area sown with grains in 2006-07). According to INTA, assuming a greater growth rate in the consumption of diesel, the domestic market of biodiesel would be positioned in 886 million liters in 2010 (780,000 tons). According to its calculations, the domestic demand of biodiesel would require 4.9 million tons of soybean and an agricultural area of 1.09 million hectares (early-season soybean with high technology in no-till farming), 1.76 million hectares (early-season soybean under no-till or conventional farming) or 2.23 million hectares (late-season soybean under no-till farming).

In the case of Brazil, satisfying its current requirement of B3³⁵ represents about 1.35 million tons of soybean oil (22% of its production and 58% of exports of 2007), 6.8 million tons of grain (12% of production and 29% of exports of 2007) and 2.5 million hectares of soybean (12% of the area sown with soybean and 5.5% of the area sown with grains in 2007). In order to comply with the requirement of utilization of B5 in 2013, Brazil should allocate 2.3 million tons of soybean oil, 12.1 million tons of grain and 4.4 million hectares of soybean to the production of biodiesel.

Except for Chile, the rest of the Southern Region's countries also have sufficient availability of soybean as to comfortably cover the domestic requirements of biodiesel that arise from their current laws (or eventual, as in the case of Bolivia). Paraguay exported 41% of its grain production and 82% of its oil production in 2007, while Bolivia exported 97% of its oil production and Uruguay 99% of its grain production.

The utilization of soybean as feedstock for biodiesel presents some significant advantages that position it as the most probable option for the short/medium term, especially in the main producers of the continent. Among them, the following can be mentioned:

- Agronomically it stands out for its environmental flexibility, which enables it to grow in different agro-ecologic environments. The existence of cultivars with different requirements of light, temperature and different growing habits, enable adapting the crop to different regions.
- In the case of the Southern Region's countries, the very high immediate availability of soybean, expressed in high exportable balances of grain and soy oil, guarantees the supply for the domestic industry and biodiesel exports, providing also an elevated response capacity to eventual increases in the demand.

³⁵ B4 since July 2009



- The high level of experience and knowledge in the crop and its cultivation, as well as the high level of technological development achieved at agricultural level, from the incorporation and growing utilization of conservationist tillage systems, biotechnology and improvements in the implantation, nutrition, protection and harvest systems and techniques.
- The high level of technological development in the rest of the stages of the chain and the high efficiency and scale of the region's (Argentina and Brazil) vegetable oil industry.
- The high level of development, organization and institutionality of all the productive chain.
- The lower production costs of soybean, its low requirements of capital investment and, generally, its larger profitability margins, in comparison with other oleaginous crops.
- The traditionally lower prices of soybean oil regarding various vegetable oils (sunflower, rapeseed, cotton, castor or peanut oil, among others).
- It is not a critical product for the food's security of the region's countries. The human domestic consumption of soybean is insignificant, while as it was mentioned previously, in the case of soy oil, the countries have high export coefficients.
- Regarding other oilseeds, soybean is the main producer of vegetable proteins per hectare. Its grain contains between 38% and 42% of protein content, highly valued and consumed in animal and human feed. In this sense, the production of soybean meal resulting from the extraction of the grain's oil decisively contributes to the biodiesel projects' profitability. Moreover, since biodiesel is a co-product of the production of soybean meal, it does not affect the region's food chain (unless they significantly substitute land intended for the production of food crops or livestock). A greater domestic processing of the currently exported grain would generate a significant additional offer of soybean meal in the region's countries. That would have a favorable effect on the agroindustrial chains of intensive production of animals (bovine, poultry and pigs) that demand soybean meal for their diets in different proportions. In countries importing soybean meal like Uruguay and the Andean region's countries, a larger domestic processing of the grain could generate nearer levels to self-sufficiency of meal, lower prices of this product and competitiveness gains in the demanding chains.
- The high spread of no-till technology applied to the soybean crop in the region's countries, system that favorably contributes to the environmental sustainability and biodiesel's emissions balance.
- In the case of the Andean Region's countries, soybean represents an opportunity for the productive diversification of the agroindustrial sector. For example, in Colombia, soybean seems to be a suitable crop for the rotation within the regional production systems: corn – soybean in the Cauca Valley, rice – soybean in the Eastern Plains or sorghum – soybean in Tolima and the Cauca Valley; while in Ecuador it is a suitable alternative as summer crop for small farmers without irrigation infrastructure (the winter season humidity's remanent is utilized) and for rotation with corn (SICA). In Peru, soybean may be adapted to the climate zones of the North Coast, Central Coast and Jungle.

The main disadvantages of the utilization of soybean as feedstock for biodiesel have to do with the following aspects:

- Its low oil content and potential yield in liters of biodiesel per hectare, make it a less efficient alternative, in comparison with most oilseeds, from the point of view of the agricultural area it would

require to supply the biofuels' domestic or international demand³⁶. It is worth mentioning that such restriction could be overcome through the spread of double crops systems, for example, rapeseed – late-season soybean in Argentina, which would significantly increase the potential yield of biodiesel per hectare.

- Exclusively using soybean to satisfy the domestic market's requirements and the exports demand could increase the tendency to concentrate the Southern region's agricultural production, especially in the cases of Argentina and Paraguay, where the area dedicated to this crop represents more than 50% of the land under grain production. If the expansion of the production is made by increasing the area, the risk of displacing or substituting other food crops and cattle activities, or of advance of the agricultural frontier on the natural ecosystems and reduction of biodiversity, could come up. This scenario could also have negative effects from the point of view of the damages a monoculture could generate in terms of soil degradation and loss of their productive capacity, greater plague, scrubs and diseases pressure or greater pollution risk due to insecticides, among others. These pressures can be reduced by means of an ordered growth, without risking the sustainability of the region's natural and agricultural ecosystems (territorial planning / ecological-economic zoning), crop rotation and integrated production systems' adding some kind of diversification, such as inter-cropping (association of two crops in the same soil and cycle), among others.
- From the social point of view, its lower relative impact on the generation of direct employment, element shared with the rest of the oleaginous crops of extensive nature. It is worth mentioning, in contrast, the importance of soybean for family agriculture in some relevant countries like Argentina, where family exploitations represent 54% of the exploitations dedicated to this crop's production.
- The chemical quality of soybean oil – characterized by a low proportion of monounsaturated fatty acids (23.5%) and a high proportion of polyunsaturated fatty acids (60.5%) – leads to an acceptable but not optimal diesel, in comparison with that obtained from other feedstocks (rapeseed, sunflower high oleic and safflower high-oleic oils)
- Even though soybean oil usually quotes below other vegetable oils, the increasing and significant use for biodiesel by its three main world's producers (Argentina, USA and Brazil)³⁷, together with the structurally increasing trend of human consumption of soybean oil by China and other Southeastern Asian countries, configure – *ceteris paribus* – a scenario of high prices and opportunity costs in the short – medium term.
- In the Andean region soybean is not a traditional crop, thus it faces certain restrictions to overcome, typical of these cases, related to less experience and accumulated knowledge of this crop and its handling, the need for development of the infrastructure and high technologies adoption, the lack of a sufficient number of cultivated varieties for all the agro-ecologically suitable zones, less development and articulation of the chain, insufficient installed capacity for processing short cycle oilseeds, etc. Likewise, soybean biodiesel should compete with palm biodiesel, which seems to be more competitive in these countries. Among the Southern Region's countries, it is worth mentioning the low installed capacity and supply of vegetable oils in Uruguay. Nevertheless, the incorporation of biodiesel to the energy matrix in this country can be interpreted as an opportunity for the expansion of the vegetable oils' industry in general and soybean agroindustry in particular.

³⁶ This disadvantage is relevant in the case where the industry's requirements result in an expansion of the agricultural frontier. In the case of biodiesel made from currently produced but not processed soy, the former would represent a co-product of the protein meals' production and the efficiency criterion in the use of land would lose relevance.

³⁷ According to Oil World's projections the production of biodiesel could account for up to 25% of the total consumption of soybean oil in Argentina, Brazil, USA and the EU during period 2008/09.

Palma aceitera / Dendê/ Oil Palm
Crop

Oil Palm (*Elaeis guineensis*)

Characteristics	Oil palm is a monocotyledoneous plant, included in the Palm order, Palmaceae family, native of Africa. It is a perennial crop typical of humid tropical regions, characterized by high temperatures, abundant insolation and sufficient humidity. The best adaption of the crop is given in altitudes of up to 500 m above sea level and in the Equatorial Strip between 15° North Latitude and 15° South Latitude, where environmental properties are stable. Monthly temperatures of 25°C and 28°C in average are favorable for the crop, if minimal average temperature is not below 21°C. Oil palm adapts to a wide variety of soils, though it develops better in deep, well drained, fertile and abundant in organic matter soils. It resists low levels of acidity, up to pH 4. Its demand of nutrients is low in the first year of growth, but it increases significantly as from 3, 4 and 5 years, becoming stable as from then. Oil palm is the perennial oilseed of greatest productivity and yield of oil per hectare, exceeding in 5 to 7 times to short cycle oilseeds. Commercially it has an average life of 24 to 28 years, depending on the cultivated germplasm. Palm's yield is gradual: it produces compact fruit's bunches, whose weight varies according to the age of the plantation, obtaining a maximum production between the eighth and tenth year of life, producing 500 to 1500 fruits in its adulthood. Two different types of oils are produced from the palm's fruit: palm's oil itself (palmitic acid oils from the fleshy part of the fruit, pulp or mesocarp) and the palm kernel oil (kernel's lauric acid oils). Both the palm oil and palm kernel oil are used in food and industry (production of margarine, butter, table and cooking oil, soaps, enamel, paint, etc.). (ANCUPA /ACUPALMA/FEDEPALMA/CORPODIB/IICA-Peru)
Water requirement	The optimal quantity per month is 150 to 180 mm and 1800 to 2200 mm per year, if it is well distributed throughout all months. Rainfall of 1500 mm annually is also adequate.
Oil content	20%-25%
Efficiency of the conversion to biofuels (lts/tn)	240
By-products / co-products of its utilization for biofuels	The milling of the fresh fruits' bunches produces crude palm oil and a cake as a by-product. From this cake, palm kernel oil and palm kernel meal or protein cake are obtained. Of the economically useful by-products of the palm's fruit, a little more than 90% in weight is oil and 10% palm kernel meal. Palm kernel meal or cake is used as animal feed, directly or integrating the balanced rations for poultry, pigs and bovine cattle. Other by-products of the processing of palm oil are empty bunches and the effluents of the extraction process, which are recyclable in the plantation as organic fertilizers (effluents require previous treatment). Glycerine is obtained from biodiesel's production process. (CORPODIB/SNV)
Agricultural yield (tn/ha)	13.86 (global average)
Regional average (weighted)	14.63
Countries with higher yield	Colombia (19) and Peru (18.9)
Potential	28-32 (5 to 6 years old plant, with high technology level and optimal conditions for its development) (CORPODIB/FEDEPALMA)
Biodiesel yield per ha (lts/ha)	3325
With average regional agricultural yield	3511
In countries with higher agricultural yield	4543-4560
Potential	7200

Source: Own elaboration; information obtained by IICA's regional offices; FAO Water Development and Management Unit and several sources.

Table 9.2.3.12: Composition and products of African Palm racemes

Branch	Fruit 65%	Pulp or mesocarp 62%	Crude palm oil 45%	Refined palm oil 94%	Olein Stearin	
				Residues 6%		
			Fiber 55%			
		Nut 38%	Palm kernel 30%	Cob or rachis 35%	Crude palm kernel oil 43%	Refined palm kernel oil 85%
						Residues 15%
					Palm kernel cake 50%	
					Residues 7%	
Husk 70%						

Source: CORPODIB

Table 9.2.3.13: Oil palm in South America – Productive and commercial statistics

2007		Southern Region						Andean Region				Total	
Crop	Variable/Country	Brazil (1)	Argentina (2)	Uruguay (3)	Paraguay (4)	Bolivia (5)	Chile (6)	Venezuela (7)	Colombia (8)	Ecuador (9)	Peru (10)		
Oil Palm	Planted area (hectares)	88.000	0	0	13.500	0	0	52.384	329.450	223.999	26.000	733.333	
	Agricultural production (tons)	904.000	0	0	130.000	0	0	334.262	3.674.842	1.981.506	328.448	7.353.058	
	Agricultural yield (tons/ha)	10,28	0	0	9,63	0	0	12,33	19,00	8,85	18,93	14,63	
	Foreign trade* (tons)	Exports	0	0	0	0	0	0	0	0	12	0	12
		Imports	0	0	0	0	0	0	7	0	6	6	19
	Palm oil production (tons)	190.000	0	0	3.000	0	0	70.362	734.968	396.301	48.000	1.442.631	
	Palm oil foreign trade** (tons)	Exports	2.402	10	162	0	0	0	0	315.575	171.638	745	490.532
		Imports	98.607	1.267	4.883	214	420	9.103	38.257	14.616	76	24.030	191.473
	Palm kernel oil production (tons)	75.000	0	0	6.000	0	0	3.834	169.894	30.000	3.700	288.428	
	Palm kernel oil foreign trade*** (tons)	Exports	920	0	0	1.736	0	0	0	29.822	4.411	1	36.890
		Imports	87.815	6.131	679	0	0	167	90	0	0	637	95.519
	Palm kernel meal production (tn)	n.d.	0	0	n.d.	0	0	7.159	92.114	n.d.	n.d.	99.273	

(1) Source: MAPA - / IBGE – Municipal agricultural production and systematic survey of agricultural production. Data corresponds to year 2005 (last available). Data on area corresponds to harvested area. FAOSTAT: Data on palm oil and palm kernel oil production 2007

(4) Source: FAOSTAT. Data on area corresponds in this case to harvested area.

(7) Source: Companies Associated with Acupalma 2007.

(8) Source: MADR. Directorate of Sectorial Politics. GSI. Preliminary 2007 Data on production of palm and palm kernel oils and kernel meal.

(9) Source: Ancupa - Fedapal

(10) Source: DGIA - MINAG. Planted area statistics correspond to year 2006 (harvested area in 2007: 12,594 ha) FAOSTAT: Data on production of kernel oil 2007

*Source: UN Comtrade. Hs 2002. Data 2007

**Source: UN Comtrade. Hs 2002 Data 2007

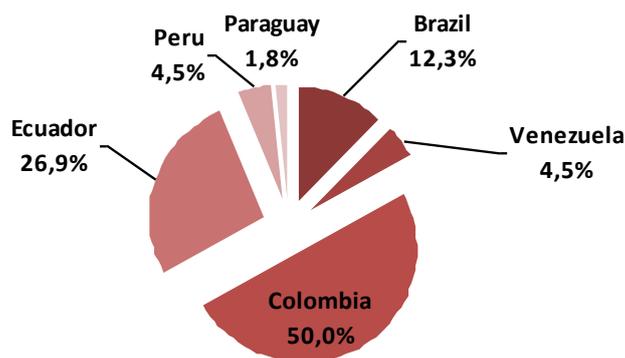
**Source: UN Comtrade. Hs 2002 Data 2007. Tariff items 151321 (palm kernel oil and crude babassu) and 151329 (palm kernel oil and refined babassu).

Even though it is complex to aggregate palm's productive statistics of the considered countries³⁸, it can be confirmed that there are at least 733,000 hectares cultivated with this crop in the region, with a production of about 7.35 million tons (3.8% of the global production). In 2007 the region produced about 1.4 million tons of palm oil (3.4% of the global production) and about 288,000 tons of palm kernel oil.

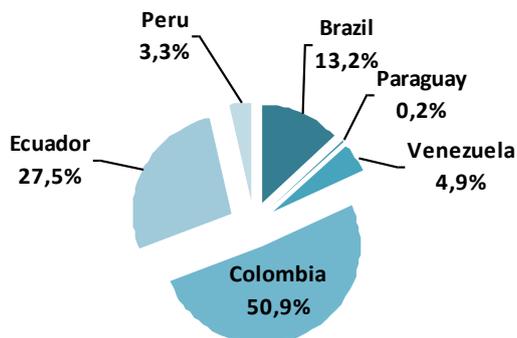
³⁸ This is due to the fact that some countries have statistical registrations of the harvested area, instead of the sown area and that, at the closure of this research; some countries did not have agricultural production statistics of palm correspondent to year 2007.

The sown area and the production of the palm growing complex are mainly concentrated in the Andean region's countries (about 86% of the South American production), where oil palm is highlighted as the most important oleaginous crop and is in an expansion process. Colombia and Ecuador (5th and 7th main global producers of palm) are the principal producers of the region. In the Southern Region's countries, Brazil is the only country that has relatively significant plantation and production levels.

Graph 9.2.3.14: Palm - Production share per countries



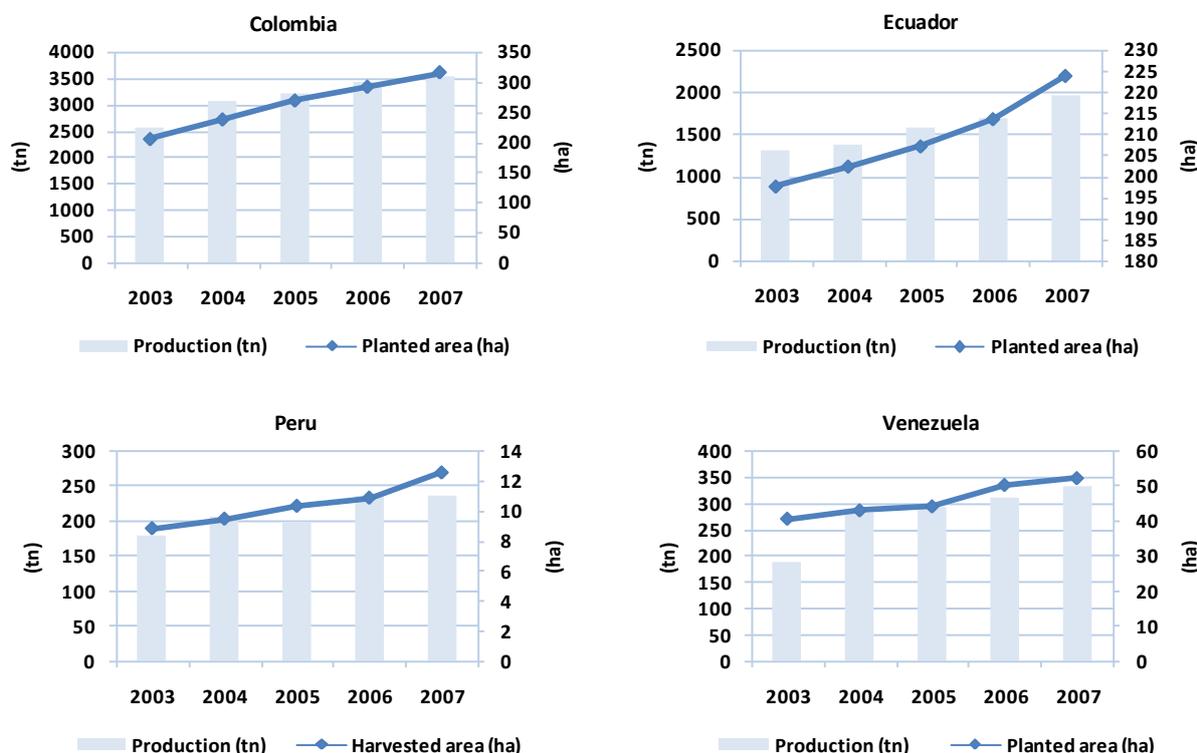
Graph 9.2.3.15: Palm oil - production share per countries



The region's average agricultural yield is positioned above the global average, though below those obtained by Malaysia and Indonesia³⁹, the two main global producers of oil palm. Colombia and Peru are the countries with highest yields in the region, positioned in similar levels to those achieved by the Southeastern Asian countries.

³⁹ In 2007, palm production yield in these countries was positioned in 20.5 and 17 tn/ha, respectively.

Table 9.2.3.16: Evolution of the production of African Palm in the Andean Region



Source: Colombia: FEDEPALMA; Ecuador: ANCUPA-PEDAPAL; Peru: DGIA – MINAG and Venezuela: Acupalma. In the case of Peru the data for the area is expressed in harvested area and in the case of Colombia, Ecuador and Venezuela sowed area.

Colombia is the region’s country with the best position for biodiesel production from oil palm. Palm is grown in more than 70 municipalities distributed in four productive zones: North (Magdalena, North of Cesar, Atlantic, Guajira), Central (Santander, North of Santander, South of Cesar, Bolívar) and East (Meta, Cundinamarca, Casanare, Caquetá). Besides having favorable agro-ecological conditions and a vast experience in the growth of palm (its production at commercial scale started in the forties, consolidating in the sixties of last century), Colombian palm cultivation is in expansion, and has a consolidated agroindustry, with a high institutional development and technological advances and innovations according to the market’s requirements (CORPODIB). Palm and palm kernel oils represent about 90% of the Colombian production of oils and fats. According to statistics of FEDEPALMA, 53 palm oil mills were operating in Colombia in 2007, with an installed processing capacity of 1,037 tons/hour of fresh fruit bunches (FFB). In first half of 2009, 4 biodiesel plants based on palm were already operating, while other 2 will be in operation during this year. According to private projections, palm oil’s production will get near 900,000 tons in 2009 (it exceeded 800,000 tons in 2008). Colombia has high and increasing exportable balances of palm oil, with which it is in conditions to cover its domestic biodiesel market (B5) and have a remanent to export or increase the mandatory blend with diesel up to a level of 15% (FEDEPALMA). Considering the diesel consumption of 2008, in order to supply the domestic B5 market, 55,600 hectares of palm would be required (17% of the current sowed area).

The expansion possibilities of the Colombian palm growing complex are high, considering that, according to CORPODIB, Colombia has more than 3.5 million hectares without soil and climate restrictions for the cultivation of oil palm and a little more than 6 million hectares with moderate restrictions, of which a 35% are short of rainfall, which can be replaced by optimal irrigation systems.

Ecuador is the second producer of palm and palm oil of the region. Palm is cultivated in 11 of its 23 provinces. 70% of the production is concentrated in the provinces of Pichincha, Esmeraldas and Los Ríos. The production zones are mainly located in Santo Domingo de los Colorados, Quevedo, Quinindé and Francisco de Orellana. As in the case of Colombia, Ecuador has optimal climate conditions for the cultivation of oil palm, the sown area, production and processing capacity are in expansion and it has a growing exportable surplus (43% of the oil production in 2007). Ecuador's palm chain also has experience (it is commercially grown since the sixties) and a high level of organization and its institutions promote the crop's training, technological transfer, research and promotion throughout the chain. The cultivation of palm in Ecuador stands out for its social importance. According to the last census of Palm Producers (2005) there are about 5,500 palm producers in the country, of which most are small palm producers with an extension not larger than 50 hectares and only 9 producers have more than 1,000 hectares. Ecuador is in conditions of covering with its exportable palm oil surplus an eventual B5 domestic market. It is estimated that in this country there are about 1.5 million hectares with potentialities for growing palm.

Venezuela and Peru also have soil and climate conditions and experience in the production of oil palm (mainly oleaginous crops in both cases), though they have substantially lower productive levels than those of Colombia and Ecuador. In these countries the sowed area and the production of the palm growing complex register a sustained growth over the current decade, though they still are net importers of palm oil.

In Venezuela, the sowed area, concentrated mainly in the Western region was duplicated between 2001 and 2008. The yields are still below those obtained by Colombia due to the lack of maintenance and renewal of plantations. An increase of the production is expected for the next years, since some of the main country's producers have expansion projects of new areas and renewal projects of the existing ones, and these new plantations would generate higher yields, since they are being sown with novel irrigation systems (ACUPALMA). The total installed capacity of the palm oil extraction plants was positioned in 174.6 tons of FFB per hour in 2007. In that year, palm oil represented 26% of the consumption of vegetable oils in Venezuela and high levels of its imports are still maintained (45% of the palm oil available for consumption in 2007). The Sowing Plan 2007-2011 of the Venezuelan Association of Oil Palm Producers (ACUPALMA) has the goals of incorporating 60,000 hectares to the production, with yields of 20 tn/ha, expanding and installing crude oil extraction capacity in 583 tons of FFB per hour, incorporating 264,000 tons of palm oil to its current production. Should such goals be fulfilled, Venezuela would have exportable surplus by 2011 for the production of biodiesel from palm.

In Peru (Amazonian region), palm is the main oleaginous crop and has a wide growing potential. The areas intended for oil palm production are located mainly in San Martín, Ucayali, Loreto and Huánuco. According to INRENA, mentioned by IICA-Peru, there are 4.86 million hectares with capacity for the production of this crop. The department of Loreto is the one with the greatest availability of land, followed by Ucayali and Huánuco. It is estimated that there are 32,000 palm producers in Peru, and at this research's closure, 5 palm oil extracting plants were operating in the country, with a total installed capacity of 88 tons of FFB per hour, which is under-utilized. There are also four palm biodiesel pilot plants operating and three palm biodiesel projects which totalize a production capacity of 205,000 annual tons.

In the case of the Southern region's countries, only Brazil stands out, third palm producer of South America. Brazilian palm production is mostly concentrated in the Northern region of the country, specifically the humid tropical Amazonia, followed by the Southeast of Bahia and some specific areas. Palm is an option to supply the biodiesel domestic consumption in the Northern and Northeastern regions and is highly valued by the

Government, due to its social impact⁴⁰. Even though Brazil is currently a net importer of palm oil, it has a high potential to expand its sowed area. According to EMBRAPA, mentioned by IICA-Brazil, there is an area of 69.9 million hectares with high/medium suitability for the cultivation of palm in areas of degraded Amazonian forest. Considering the current yields, covering the domestic demand of B3 exclusively with palm biodiesel would require about 560,000 hectares, while in the specific case of the Northern and Northeastern regions, about 135,000 hectares would be required.

In Bolivia, according to IBCE, oil palm could be produced in the departments of Beni, Pando, Cochabamba, Santa Cruz and the North of La Paz. The rest of the Southern region's countries, do not have favorable soil and climate conditions for the production of palm.

Oil palm as feedstock for the production of biodiesel has several advantages. Among the usually cited by bibliography, the following can be mentioned:

- It is the perennial oilseed of greatest productivity and yield of oil per unit of area, exceeding in 5 to 7 times to short cycle oilseeds. Together with coconut palm, oil palm is the most efficient crop potentially, in terms of the utilization of the land resource for the production of biodiesel.
- In certain countries of the Andean region, especially Colombia, there is agricultural and economic experience that guarantees high yields and continuity for the production of oils as feedstocks for biodiesel.
- From the technological point of view, both the agricultural handling and the industrialization of oil palm's products are technically simple (CORPODIB). As a perennial tropical crop, oil palm produces continually throughout the year. (Mutert, 2006).
- At international level, palm oil has the cheapest price in the market of vegetable oils, which reflects the low production costs of palm (according to CORPODIB, 40% less than the unitary production cost of other oilseeds).
- In line with the above, the research conducted in the crop has been directed to the production and efficient handling of nutrients, which has consistently increased the oil's yields, reducing significantly the production costs (Mutert, 2006).
- It is a labor-intensive crop, with high impact on the generation of direct employment and social inclusion potential. According to EMBRAPA, the production of palm generates a direct employment each 6 hectares, while other documents (Corredor Ríos, 2005 cited by SNV) establish a labor requirement of between 6 (first year of activity) to 27 man/days (seventh year of activity). In countries like Colombia, the cultivation of palm by means of the adoption of strategic alliances has enabled a greater social cohesion and a greater intercultural dynamism between big, medium and small producers (IICA - Colombia).
- From the point of view of energy efficiency, as in the case of other perennial crops, the energy balance of palm biodiesel is significantly superior to that of annual oilseeds (see corresponding table in section 9.3.2).
- From the environmental point of view, beyond the negative aspects mentioned below, palm is considered beforehand as an ecological crop, taking into account that it is about protecting forests

⁴⁰ Together with castor, palm is one of the two feedstocks whose utilization for the production of biodiesel is subject to tax benefits, in the framework of the National Program of Production and Use of Biodiesel in Brazil.

(ACUPALMA) that prevent erosion (CORPODIB), where different flora and fauna species cohabit (FEDEPALMA) and that, due to its great potential to absorb carbonic gas, the crop may contribute to reduce carbon emissions by fixing this element in biomass (CEPLAC).

Among the limitations and disadvantages of palm as feedstock for biodiesel, the following can be mentioned:

- The low content of proteins in the fruit and palm's kernel causes the protein content of the co-product of the oil production (palm kernel's cake) to be lower in quantity and quality, compared with the obtained by the most relevant oilseeds for the production of biodiesel (S&T - IDB, 2006). In this sense, palm is more inefficient than other crops like soybean in terms of joint production of food and energy.
- From the agricultural point of view, oil palm has high nutrient requirements, thus requiring a high investment in fertilizers, since without the adequate fertilizer the yields are notably reduced (CORPODIB). Fertilization represents 25 to 30% of the total production costs in the mature stage of the crop (IICA – Colombia).
- It is a crop subject to many plagues and diseases, which reduce the quantity and quality of the harvested fruit and increase the production costs. Since it is a perennial crop, established in cultivated soils with other species, it is affected by many already established microorganisms that are favored by climate conditions. In America, oil palm is affected by a larger number of diseases than in other producer countries as Malaysia and some of Africa, such as bud rot, leaf mottle and lethal wilt (IICA - Colombia).
- The agronomic cycle of palm, with lower yields and lower commercial production in the first years of plantation, as well as its higher levels of investments, implies greater credit demands and a longer payback period of the initial investment in comparison with annual cycle crops.
- From the point of view of its chemical properties, palm biodiesel has advantages related to its high cetane value and high resistance to oxidation, but its high content of saturated fatty acids leads to a high "cloud point" (about 18°C), which affects negatively its performance in cold climates.
- In the specific case of the Southern region's countries, with the exception of Brazil and Bolivia, the rest have very poor or null possibilities of producing palm, due to the lack of soil and climate conditions for its growth. The case of Argentina is an illustrative example: the country is out of the limit of best adaptation of the palm crop (15° North and South latitude), there are no regions free from winter frost, impeding the growth of species very sensible to cold, the annual average of the country's warm climates (20°C) is a little below the minimal temperature required for an optimal development and even though it has a sub-tropical climate zone, in the same prevail soils whose characteristics avoid the possibility of adequately installing palm there (García Penela, 2007)
- Some countries of the Andean region (Venezuela and Peru), together with Brazil, still maintain high coefficients of palm oil imports. That requires as a first step, increases in the production of oil, sufficiently high as not to affect the availability for human nutrition or as to avoid importing it with the subsequent impact on production costs. It is worth mentioning that in the case of Brazil, the main producing company of oil and palm biodiesel obtains biofuels from the residue of oil's refining.
- Beyond being considered as an ecologic crop, palm's monoculture represents risks in terms of pressure on biodiversity and deforestation, since it could promote the loss of tropical forests. In cases of destruction of forest zones, the reduction of emissions would also be questionable, due to the

carbon that is not captured by those forests. However, if the new palm crops are made on degraded or not occupied land, there will be a positive effect on the reduction of emissions (SNV).

- In relation to the aforementioned, palm biodiesel is negatively associated with the case of Indonesia and Malaysia, countries were, according to the increasing complaints made by different NGOs, the expansion of the crop could have caused the deforestation of extended areas of tropical forests⁴¹. In this sense, from the commercial point of view, palm biodiesel presents the risk of suffering restrictions on imports and use in the EU market (main global importer of biodiesel) once the certification mechanisms of production sustainability of feedstocks for biofuels are valid, at least in the case of Southeast Asia.

9.2.3.2 Alternative feedstocks

Rapeseed / Colza / Colza

Crop	Rapeseed / Canola (<i>Brassica napus</i>)
Characteristics	Rapeseed is an annual herbaceous plant that belongs to the cruciferae family, <i>Brassicaceae</i> genus, probably native of Europe and Asia. It is a crop of winter-spring cycle, which adapts to temperate to temperate-cold climates, with good humidity. It is quite resistant to long drought and, once the rosette has grown, it is capable of bearing very low temperatures (-15°C). Early frosts can affect the first stages of the crop since before reaching the rosette phase, the sensitivity to cold is greater and it can not bare temperatures below -2 or -3°C. Rapeseed adapts well to different types of soils with agricultural suitability, but it develops better in good soils, of medium to high fertility and especially permeable, since it is very sensitive to superficial waterlogging. Rapeseed is a great consumer of essential nutritious elements, as nitrogen, phosphorus, potassium and sulphur and needs a balanced fertilization of them. Rapeseed produces a small and round seed, of black, brown or yellow color, with high oil content. There are two types of rapeseed, winter rapeseed and spring rapeseed, which are differentiated by their vernalization requirements. Likewise, they can be distinguished among the oldest varieties of rapeseed, that generate an oil with a high content of erucic acid (50-55%) over the total composition of fatty acids of its fat matter, which is not desirable from the nutritional point of view and the improved varieties (Rapeseed "00" or canola), characterized for having a low content of erucic acid (maximum 2%) and a low content of grain glucosinolates. The oil with low content of erucic acid is used as oil for seasoning and cooking, as well as for making margarine. The oils with high content of erucic acid are used as lubricants and for plastics' synthesis (Chacra Exp. Int. Barrow, INTA, FAUBA).
Water requirement	350-450 mm
Oil content	40% - 50%
Efficiency of the conversion to biofuels (lts/tn)	465
By-products / co-products of its utilization for biofuels	Rapeseed oil cake: It is a residue coming from the extraction of the seed's oil. This extraction meal has high protein content (36-44%) of high nutritional value, used as protein supplement in animals' rations. Glycerine is obtained from biodiesel's production process. Since it is a melliferous, rapeseed also presents the option of producing honey.
Agricultural yield (tn/ha)	1.64 (global average)
Regional average (weighted)	1.57
Countries with higher yield	Chile (3.78), Brazil (1.70)
Potential	4 (yields obtained in Argentina with cultivations of current spread in field experimental smallholdings)

⁴¹ Even the United Nations Development Program (UNDP), in its Human Development Report 2007 – 2008, dedicated to climate change, warned that "the increasing palm crops in Asia-Pacific have linked to the vast deforestation and violation of the human rights of native people".

Biodiesel yield per ha (lts/ha) 732

With average regional agricultural yield 763

In countries with higher agricultural yield 791-1,798

Potential 1,860

Source: Own elaboration; information obtained by IICA's regional offices; FAO Water Development and Management Unit and several sources.

Table 9.2.3.17: Rapeseed in South America – productive and commercial statistics

2007		Southern Region						Andean Region				Total	
Crop	Variable/Country	Brazil (1)	Argentina (2)	Uruguay (3)	Paraguay (4)	Bolivia (5)	Chile (6)	Venezuela (7)	Colombia (8)	Ecuador (9)	Peru (10)		
Rapeseed / canola	Sowed area (hectares)	46.000	10.531	n.d.	57.370	0	11.490	0	0	0	0	125.391	
	Agricultural production (tons)	78.000	11.230	n.d.	62.158	0	43.399	0	0	0	0	194.787	
	Agricultural yield (tons/ha)	1,70	1,25	n.d.	1,08	0	3,78	0	0	0	0	1,57	
	Rapeseed/canola foreign trade* (tons)	Exports	2	11.849	58	26.320	0	1.941	0	0	0	0	40.170
		Imports	17.668	106	0	226	1	45	11	959	1	345	19.362
	Rapeseed/canola oil production** (tons)	30.000	61	n.d.	13.000	0	21.000	n.d.	30	n.d.	n.d.	64.091	
	Rapeseed/canola oil foreign Trade (tons)	Exports	522	4	150	18.459	0	1.261	0	1	0	0	20.396
		Imports	11.659	1.151	54	1	0	137	1.320	3.012	232	361	17.926
	Rapeseed/canola meal production	n.d.	100	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100

(1) Source: FAOSTAT. Data on area corresponds in this case to harvested area.

(2) Source: Sagpya

(4) Source: DGP/MAG

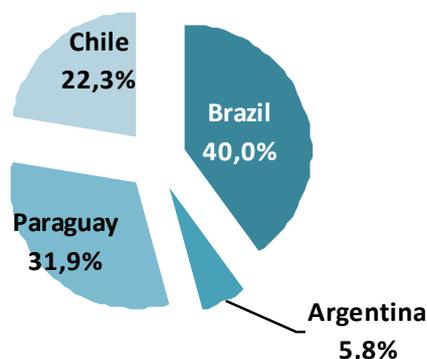
(6) Source: Office of Agricultural Policies and Studies (ODEPA) Ministry of Agriculture - Government of Chile.

*Source: UN Comtrade. Hs 2002 Data 2007

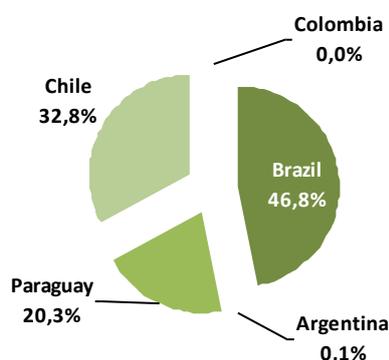
**Source: FAOSTAT (2) Sagpya

Rapeseed – canola is a marginal crop in the current productive structure of grains and oilseeds in South America. The sowed area with rapeseed in cycle 2006/07 represented about 125,000 hectares, with an agricultural production of about 195,000 tons and of oil of about 64,000 tons. The production of rapeseed's grain and oil is concentrated in the Southern Region's countries, with Brazil, Paraguay and Chile as main producers. The region's average agricultural yield is below the global average, though Chile's average yield obtained is worth mentioning, positioned as one of the highest in the world.

Graph 9.2.3.18: Rapeseed - production share per countries



Graph 9.2.3.19: Rapeseed oil - production share per countries



Even though the area sowed with rapeseed-canola in the Southern region is very small in relation to that used at global level, the region has very suitable soil and climate conditions for its growth, even within the rotation system with other crops like wheat. The potential to obtain greater yields is also high, as it is reflected in experiences in the region's countries, where the gradual improvement of the technologies and the familiarity of the farmers with the crop, are decisively contributing to increase the yields.

In Brazil, main producer of the region, rapeseed-canola is grown in the states of Río Grande do Sul, Paraná and Goiás and there is an increasing trend in the cultivated area. Brazil has a great availability of suitable land for the cultivation of canola in the states of the Southern region of the country, as Río Grande do Sul, which would enable a significant expansion in the production of oil, also generating exportable balances that could be used in the production of biodiesel. Likewise, Brazil stands out for being a pioneer in the introduction of canola in low latitudes (17° to 18°, in the Central-Western region), a completely new experience at global level that assumes the "tropicalization" of the crop that has been achieved from genotypes less sensible to photo-period (EMBRAPA)⁴². In this regard, successful experiments and the introduction of the commercial crop in Goiás and Minas Gerais have been developed, demonstrating that canola has a great potential to perfectly fit as a rotation crop in the grain production systems of the Center-West (Tomm, 2007). There is also experience in research on the production and use of the oil as biofuel, started in the eighties, interrupted in the nineties and reinitiated at the end of the nineties.

In Chile, rapeseed-canola is the oilseed of greatest immediate availability for the production of biodiesel. Moreover, the Chilean production of rapeseed-canola has some factors that position it above other crops in terms of competitiveness. Suitable genetic material adapted to the different crop zones, high yields per hectare, farmers' specialization in the crop, agroindustrial operating in the cultivation areas, contractual relation of the companies with the producers and acquisition power of products and by-products, and associated research for years regarding rapeseed-canola as feedstock for biodiesel (IICA-REDPA-CAS, 2008). According to ODEPA, Chile has a maximum land area for the production of rapeseed-canola of 235,000 hectares that would generate a production of biodiesel sufficient to comply with an eventual requirement of substitution of 5% of diesel per biodiesel in 2010. By means of this crop it would be possible to dynamize the agriculture of regions VIII, IX and X.

In Paraguay, currently the third producer of the region, rapeseed-canola also registers an increasing trend in the sowed area, which was duplicated between 2004 and 2007. All the Paraguayan production is destined to

⁴² In addition to this advance, Brazil developed the strategy of partially compensating the low latitude by selecting regions with altitudes preferably above 600 meters, so that temperatures, especially night temperatures, are more suitable for the crop (Tomm, 2007).

the overseas market in grain, meal or oil. In fact, Paraguay was the only region's country net exporter of rapeseed-canola oil in 2007.

In Argentina, rapeseed-canola came to occupy up to about 50,000 hectares at the beginning of the nineties. Over the present decade, the cultivated area has had ups and downs, though it has never exceeded 20,000 hectares. Currently it is mainly grown in the South of the Province of Buenos Aires. Nevertheless, Argentina has a great availability of areas potentially suitable for the crop, both of winter rapeseeds and spring rapeseeds. Currently, tests are being developed in the provinces of Mendoza, Santiago del Estero, Río Negro, San Luis, Buenos Aires and Entre Ríos. According to SAGPyA, rapeseed-canola is a diversification alternative to enrich the rotation scheme of the Argentinean wheat region, especially in the Center-south, Southeast and Southwest of Buenos Aires and East of La Pampa, zones where, during the winter, only wheat and barley are grown and, besides, due to its rusticity, it can provide good yields in less suitable soils for these cereals and in early or intermediate sowings, enabling the performance of second-cycle crops and introducing a variant to the current rotation, limited to wheat-sunflower. Likewise, there is an increasing interest of processing and exporting companies of rapeseed-canola that offer to the producers sowing contracts with assured price and delivery. Currently there is also a larger group of varieties than in previous cycles, from winter materials (with long cycle and important cold requirements) to spring varieties of very short cycle. In 2007, the Argentinean Agricultural Federation (FAA) inaugurated a biodiesel plant from rapeseed in the province of Santa Fe. This plant is part of the BIOFAA project, an initiative of the FAA that aims at helping small and medium agricultural producers to achieve self-consumption, producing their own fuel and their own protein meal⁴³.

In Uruguay, since 2004, the cultivation of rapeseed is slowly gaining space in the rotation systems with the winter grass crops. Even though there are no official data, according to private estimations the cultivated area with rapeseed is about 3,000 hectares. As in the rest of the region's countries, the interest in the crop is important. Given the potentialities described below, a project of scientific research and technological development ("Liquid biofuels from non traditional crops in Uruguay"), is in operation. This project intends to study the agronomic aspects of the rapeseed/canola production (also of castor) for the development of biodiesel in different regions of the country depending on agro-ecological conditions⁴⁴.

In Bolivia, even though there are no significant experiences of rapeseed production at commercial scale, the departments of Chuquisaca, La Paz, Oruro, Potosí, Tarija and Santa Cruz have potentialities for its growth.

Despite the development of rapeseed varieties that may be grown easily in tropical climates, in the Andean region's countries like Colombia, Ecuador and Venezuela there are no relevant antecedents registered of the agricultural production and exploitation of the crop for industrial use. In Peru, the promotional program "Sierra Exportadora" developed by the Government, has the goal of developing 300,000 hectares of rapeseed in 5 years. 200,000 potential hectares have already been identified (in Puno, Junín, Cajamarca, Piura and Arequipa) for its development under rain-fed conditions and on 2,800 meters above sea level (ECLAC, 2008).

Among the alternative feedstocks for the production of biodiesel, rapeseed-canola is one of the most valued and promissory options, at least in the Southern Region's countries, with advantages such as:

⁴³ The producers that participate in the project would destine 10% of their land, unoccupied during the winter, to the cultivation of rapeseed (in counter-season with regard to soy) whose production would be derived to the biodiesel plant that would provide them of the biofuels and flour obtained in the process of oil production.

⁴⁴ The following institutions are taking part of this project: the National Institute of Agricultural Investigation (INIA), the Faculty of Agronomy of the Universidad de la República (UDELAR), the Faculty of Chemistry/UDELAR, the Faculty of Engineering/UDELAR and the Faculty of Sciences/UDELAR.

- Its adaptability to a great diversity of soil and climate conditions and the high potential in terms of land endowment with suitability for its growth in various regions' countries.
- Its adaptability and development capacity in temperate and cold climates make it one of the best alternatives for the diversification of winter crops, providing the possibility of the double-crop rapeseed-soybean.
- In line with the aforementioned, the cultivation of rapeseed-canola has a great social-economic value by facilitating the production of vegetable oils in winter, adding to the production of soybean in summer and thus, contributing to optimize the available means of production (land, equipments and manpower) (EMBRAPA TRIGO).
- The crop is resistant to long droughts and attains a very good recovery once the situation reverts. (IICA-Colombia). It has relatively low water requirements; therefore, it provides the possibility to be produced in zones less suitable for the cultivation of other cereals and oilseeds.
- Since it is a rotation crop, it is an alternative that contributes to the environmental sustainability of the agricultural production. Its introduction in the crop rotation system would enable a better control of diseases in winter cereals, environment's protection, reduction of use of agrochemicals and increase of the soils' organic richness, among other benefits⁴⁵.
- It stands out for its high content of oil in grain (40% to 50%) and potential yield of biodiesel per hectare, superior to that of other oilseeds of annual cycle, among them, soybean.
- The high chemical quality of its oil, due to the high content of monounsaturated fatty acids (which produces a biodiesel of optimal quality) and the low content of saturated fatty acids (generates a biodiesel of better performance in cold climates in comparison with soybean's or sunflower's) and polyunsaturated fatty acids (generates a lower tendency to oxidation and polymerization, elements that determine the formation of corrosive acids)⁴⁶.
- Biodiesel produced from rapeseed has a lower commercial risk at overseas level, than that of other feedstocks: in the EU, potentially the greatest global biodiesel importer, the available and used feedstock to produce biodiesel is rapeseed, and the regulation that establishes the European quality standard and the specifications of biodiesel (DIN EN 14214) are designed to favor rapeseed oil and limit soybean and palm oils⁴⁷.
- Rapeseed's meal, resulting from the extraction of the rapeseed seed's oil, has a high nutritional value regarding other protein supplements, constituting a high quality product that can significantly contribute to the profitability of the projects based on this feedstock. Rapeseed's meal is already used as animal feed, complemented with other meals as soybean's in the preparation of rations for the production of meat and milk. The fiber content of rapeseed's meal is superior to that of soybean meal, which makes it suitable to be consumed by ruminants (Canola Council, mentioned by UBA, 2006)

⁴⁵ See Section 9.4.2 for more details of the environmental benefits of crops' rotation.

⁴⁶ This low content of polyunsaturated fatty acids is converted into a Iodine Index (113) that perfectly adjusts to the technical requirements of the European regulation (maximum of 120) in contrast with other feedstocks as soy oil (130) and sunflower oil (131) (UBA 2007). Garcia Penela (2207) raises that rapeseed oil, together with high oleic sunflower, high oleic carthamus and olive oils are the ones that reach the maximum quality for biodiesel.

⁴⁷ The restriction for soy oil arises in the established level for iodine index, which measures the fuel's stability to oxidation and production of solid depositions (soy's biodiesel has an index of 133 and the European regulation admits up to 120); whereas in the case of palm oil the restriction is related to the stability of its biodiesel at low temperatures. It is important to highlight that the technical requirements established by the European regulation may be attained using blends of different oils to produce biodiesel.

- Rapeseed is also a melliferous species, with a great quantity of flowers, good honey production and excellent quality of pollen, with a protein percentage between 20 and 27% (INTA-Ascasubi), thus, its growth presents the option of complementing with apiculture.

By and large, rapeseed has faced some restrictions that limited and/or still limit its development in the region, mainly related to⁴⁸:

- Technological aspects to overcome, among them: little information and knowledge about the crop (especially in no-till systems), performance and fertilization of cultivations; lack of knowledge on aspects as genotype adaptability, response to the different environments and nutritional requirements, plague and disease control; difficulties in handling the grain⁴⁹ during the harvest, transportation, drying out and storage operations; scarcity of local improvement plans. In general, the investment in research with rapeseed-canola in South America has been highly limited, especially in that directed to the development of handling technologies suitable for the soil and climate conditions of each cultivation region.
- Rapeseed has relatively high nutritional requirements, for the case of potassium and sulphur in particular; it requires more nitrogen than sunflower, and considering the capacity of soybean to symbiotically fix nitrogen, rapeseed-canola would have even greater demands of nitrogen per external supply regarding soybean (Gómez et al, 2007).
- The low volumes of production due to the lack of incentives to the producer, in comparison with other more profitable crops.
- Historically, the vegetable oil industry in various countries of the region has demonstrated little interest for the processing of rapeseed and the production of its oil, precisely for the low volumes of the crop's production.
- Commercialization difficulties due to the presence of few reception points of the production of rapeseed.
- Rapeseed-canola oil usually quotes at higher prices than the immediately available oils of the region (soybean, palm and sunflower)⁵⁰, which makes it less competitive for its utilization in the production of biodiesel.

⁴⁸ Iriarte (2002 and 2006), Gómez et al (2007), SAGPyA, Tomm (2007), de la Fuente et al (UBA, 2006).

⁴⁹ Due to the seed's features (round shape and tiny size) and to the scarcity of harvest equipment suitable for that aim.

⁵⁰ Canola oil, together with olive oil, is considered as one of the best for human nutrition, due to its contribution to low formation of cholesterol in blood.

**Castor / Ricino / Mamona
Crop**

Castor – Ricino - Mamona (*Ricinus communis*)

Characteristics	<p>Castor is a bush that belongs to the Euphorbiaceae family, native of Africa or India and currently grown in several countries of the world. Castor is a shortly perennial species (12 years approximately) thus, it can be handled as such or as an annual crop, depending on the environment and the production system. It is characterized for its great adaptability. It is distributed in tropical, subtropical and temperate countries, and exploited commercially from the Ecuador to latitudes 40° North and 40° South. It may be found in altitudes that go from sea level to 2300 meters, but for commercial production altitudes between 300 and 1500 meters above sea level are recommendable. It adapts to arid and semi-arid regions; its resistance to drought is one of its more highlighted features. The ideal temperature for its growth fluctuates between 20°C and 30°C; the plant does not bare frosts and its production is affected by temperatures above 38°C. It is a heliophylum plant thus, it must be sown completely exposed to the sun, (if it is sown in the shade its growth and production are significantly damaged). The plant grows well on soils with the following features: medium to high fertility, deep, loose, permeable, aerated, well drained, and non alkaline or saline, with high to medium quantities of nutrients. The seeds are contained in capsules (3 seeds / capsule) that are disposed on a raceme. Castor is a species of high phenotypic variability, manifested in many features, among them, the plant's size (arboreal individuals of up to 12 m high and dwarf genotypes of 1.2m) and seeds' characteristics (seeds' color, size and oil concentration). Castor seed, as other parts of the plant, has substances of different nature that are poisonous and/or allergic for humans and animals. The main product of castor is the oil extracted from its seeds, which has chemical characteristics that identify it as the only of its nature. It is almost exclusively composed of (87% to 91%) a single fatty acid (ricinoleic acid) that contains a hydroxyl radical that makes it soluble in alcohol at low temperatures, is very viscous and has especial physical properties. Castor oil is used in industry in more than 180 technological applications; the following stand out: production of high quality lubricants for aeronautics and heavy plant, cosmetic soaps, paints and varnish, secants, textile dyes, polyester type fibers, lighting, leather preservation, among others, and in medicine as purgative (CENIAT, EMBRAPA, SNV, Wassner 2007, Lobato et al 2007).</p>
Water requirement	<p>Even though the crop is resistant to drought during long periods, they affect the weight and content of oil in the seeds. A minimum rainfall of 500 mm to 600 mm is considered desirable. A greater rainfall or the use of irrigation increase productivity.</p>
Oil content	<p>35%-55%. The percentage of oil depends on the variety of the seeds and the crop's conditions (water, fertilizers, etc.) (SNV)</p>
Efficiency of the conversion to biofuels (lts/tn)	<p>485</p>
By-products / co-products of its utilization for biofuels	<p>By-products of castor oil are key ingredients for the synthesis of hydraulic fluids, fats and lubricants of mechanical equipment. The seeds' cake obtained from the process of oil extraction (0.42 to 0.95 tn/ha) cannot be employed as animal feed, unless the toxic component is extracted, thus, its main use is as fertilizer. The cake contains about 20.5% of protein, 6.6% of nitrogen, and it can also be used for generating biogas. The husk can be used as fuel for the generation of heat in boilers, production of pellets or others. Glycerine is obtained from biodiesel's production process (SNV, CENIAP).</p>
Agricultural yield (tn/ha)	<p>0.94 (global average)</p>
Regional average (weighted)	<p>0.74</p>
Countries with higher yield	<p>Ecuador (1.6), Paraguay (1.0)</p>
Potential	<p>A good yield of the crop is 1.5 to 1.8 tn/ha, with irrigation or rainfall superior to 600 mm. Yields of 5 tn/ha have been obtained under experimental conditions.</p>
Biodiesel yield per ha (lts/ha)	<p>456</p>
With average regional agricultural yield	<p>361</p>
In countries with higher agricultural yield	<p>485-776</p>
Potential	<p>873-2,425</p>

Source: Own development; information obtained by IICA's regional offices; and several sources.

Table 9.2.3.20: Castor in South America – Productive and commercial statistics

2007		Southern Region						Andean Region				Total	
Crop	Variable/Country	Brazil (1)	Argentina (2)	Uruguay (3)	Paraguay (4)	Bolivia (5)	Chile (6)	Venezuela (7)	Colombia (8)	Ecuador (9)	Peru (10)		
Castor	Sowed area (hectares)	209.000	n.d.	n.d.	8.500	n.d.	n.d.	n.d.	n.d.	1.400	n.d.	218.900	
	Agricultural production (tons)	152.000	n.d.	n.d.	8.500	n.d.	n.d.	n.d.	n.d.	2.250	n.d.	162.750	
	Agricultural yield (tons/ha)	0,73	n.d.	n.d.	1	n.d.	n.d.	n.d.	n.d.	1,60	n.d.	0,74	
	Castor seed foreign trade* (tons)	Exports	27	0	0	6.284	0	0	0	0	0	0	6.311
		Imports	6.416	n.d.	n.d.	0	125	0	0	0	700	0	7.241
	Oil production** (tons)		52.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	Castor oil foreign trade** (tons)	Exports	146	11	0	231	97	0	0	7	314	0	806
		Imports	3.738	403	25	400	6	86	18	529	242	62	5.508

(1) Source: MAPA. Data on area corresponds in this case to harvested area. Oil World: Castor oil production (Last available data: 2006)

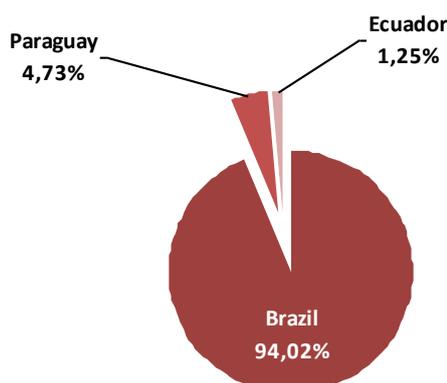
(4) Source: DGP/MAG

(9) Source: FAO 2007. Data on area corresponds in this case to harvested area.

*Source: UN Comtrade. Hs 2002 Data 2006

**Source: UN Comtrade. Hs 2002. Data 2007

Graph 9.2.3.21: Castor - production share per countries



Castor and castor oil production have a marginal participation in the production of the oilseed complexes, both at global level and in South America. In both cases, in general, the crop has been handled with low technology systems and in marginal agro-ecological zones, with productivity levels that are far below its productive potential.

Brazil is the region’s main producer of castor, standing out also for being the third global producer, after India and China. At regional level, Brazil is followed in order of importance by Paraguay and Ecuador, the latter with the highest yields. In the rest of the countries castor production is marginal and there are no official statistics. All the countries of the region have potentiality for the production of this oilseed.

Regarding Brazil, its current production is far below the 400,000 tons produced in the mid eighties, period in which it achieved to be the main global producer of castor and castor oil. Castor has been identified as one of the few agricultural profitable options for the arid and semi-arid zones of the Northeastern region, the poorest



of the country which concentrates about 90% of the Brazilian production⁵¹. Considering this aspect and its high impact on the generation of employment, castor is, together with palm, the most promoted feedstock by the National Program of Production and Use of Biodiesel. According to an agro-ecological zoning made by EMBRAPA, 458 municipalities of the Northeast are suitable for sowing castor, thus, about 4.5 million hectares would be available for its growth under rain-fed conditions. Agricultural yields have historically been below 0.6 tn/ha, though since the beginning of this decade an increasing trend has been registered, reaching a record of almost 1 tn/ha in 2004/05. Despite the concentration in the Northeastern Region, the highest yields are observed in the Central-Southern states (about 1.5 tn/ha), though in these cases the production is insignificant. EMBRAPA has developed in the last years, varieties with oil content of 48% - 49% and yield potential of 1.5 tn/ha (under normal conditions, with medium soil fertility, altitude above 300 m., adequate cultural treatment and at least 500 mm of rainfall), some of which are adapted to the Northeast's family agriculture. In cycle 2005-06, Brazil had an installed processing capacity of about 160,000 annual tons.

In Paraguay, second region's producer, the production is concentrated mainly in the Easter Region, were the departments of Concepción and San Pedro stand out as the main producers. The crop obtains good yields in locations like Canindeyú, where registers of 1.5 tn/ha have been attained, Amambay and Cordillera, among others. In all the country's regions, castor is grown by small farmers that use their own seed. The crops do not have a genetic identity due to the continuous crossing between the numerous existent and grown varieties (MAG, 2007). There already are some biodiesel projects that plan using castor oil among its feedstocks, as well as public-private initiatives that promote this crop⁵².

In Argentina its production has been historically marginal, and its cultivation stopped as from 1989, turning the country into a net importer of its oil (Wassner, 2007). More recently, since the mid nineties, different attempts at developing the castor business have been made, which have not been successful, in general due to the lack of a coordinated action to resolve all the components of the production chain (Wassner, 2007)⁵³. Tests of the cultivation of castor have been made in the provinces of Misiones, Chaco and Salta aiming at determining the culture that better adapts to the local environmental conditions and after that, producing castor oil. In Chile, castor has antecedents of national studies, though it is only maintained as a spontaneous, natural and marginal crop in several regions of the country (REDPA, 2008). In Uruguay, no practices of castor's commercial cultivation have been reported, though isolated experiences made by innovative agricultural producers, individually and with the objective of demonstrating the crop's feasibility, are known (Lobato, 2007). In Bolivia, the departments of Chuquisaca, Tarija and Santa Cruz have potentialities for its growth.

In Venezuela, a small quantity of castor is produced, not reported in the official statistics. In Curarigua, state of Lara, there is a community of producers that sows it associated with other crops and processes the product in a handicraft nature for the attainment of oil, which they commercialize for medicinal use; small sown fields in the states of Cojedes and Guárico are also known. Producers of Curarigua have sown two local varieties for more than 40 years, characterized for being low production materials native of the region (Mazani, 2007). The INIA-CENIAP is testing these varieties by a purification, selection and self-fertilization process of the promissory types, with the objective of standardizing and improving their agronomic and yield characteristics.

⁵¹ In the provinces of the Northeast, inhabited by small low-income farmers with high poverty levels, castor is mostly obtained in small exploitations of up to 15 hectares.

⁵² For example, the National Oil Company PETROPAR is experimentally producing biodiesel based on castor, to be used in its vehicle fleet, and the Government of Paraguari launched a project which guarantees its cultivation on the zone, freely distributing seeds to the farmers, at the same time that an oil entity commits itself to acquire all the products generated on this part of the country at market price.

⁵³ There are no official statistics about the production of castor in Argentina. According to the Government of Chaco, such province leads the Argentinean production, with 4500 grown hectares at the beginning of 2009. According to Wassner (2007), the province of Misiones, from a promotion program of the crop launched in 2004, reached a cultivated area of 4000 hectares in 2006.

Likewise, these materials were added in crosses of a genetic improvement program of the crop, in execution process (Mazzani, 2007).

In Peru there are also antecedents of production of castor, which is not suitable for the Central mountain range, but it is an alternative for the jungle and zones with less altitude. INIA, DEVIDA and other research institutes, with the technical assistance of EMBRAPA, are developing experimental plots, in the framework of a promotion project of castor in the Peruvian Amazonia for the production of biodiesel. In Colombia, castor grows in semi-wild conditions, spontaneously, from sea level up to 2,600 meters. In this country, there is a project in progress of evaluation of foreign cultivations and generation of Colombian varieties for the production of biodiesel and other industrial uses. There is also an agreement with EMBRAPA for the concession of genetically improved materials in Brazil for their testing in different locations of Colombia. In Ecuador, castor has been a traditional crop of small farmers, grown in Manabí, Esmeraldas, Guayas and El Oro.

The interest existent in the region and other countries of the world in the development and utilization of castor as feedstock for biodiesel is related to different positive aspects, among them:

- Its adaptability to different environments, result of its great rusticity and resistance to drought, grants it suitability to grow in conditions of sub-humid and semi-arid climates. Thus, it is an alternative to add marginal land not suitable for more demanding crops, so it would not compete with the production of food crops and/or could foster the local development in postponed regional economies.
- It is simple to handle and has low requirements of inputs and cultural care.
- It is considered a “social crop”, due to the fact that it is labor intense, with potentiality to be developed by family agriculture and generally produced by small farmers in the region’s countries, by enabling a smaller production scale.
- Some favorable aspects for the agricultural stage of the chain are related to the fact that castor is a high value and multi-purpose crop (with more than 180 technological applications at industrial level). The latter would suppose less commercial and/or positioning risks for the product in case of volatility in the biodiesel’s market.
- Due to its toxicity, the resulting oil is non-edible. In this sense, its price is not influenced by the competition with food use.
- It can be developed by integrating it with other crops and diversifying the production. For example, in the Northeastern semi-arid of Brazil, small farmers grow castor frequently alternated with food crops such as bean, while in Venezuela, most sowings are made in association with auyama, quinchoncho and other edible leguminous plants.
- It has a high percentage of oil in its seed and, should the wide gap between its current agricultural yield and potential yield be reduced, it would generate a high yield of biodiesel per hectare.
- The biodiesel obtained from castor oil has some highly positive properties: low iodine index, one of the highest cetane values among vegetable oils and a solidification point between -12 and -18°C (which grants it an advantage of positive performance in cold climates, in comparison with other alternatives as tallow or palm biodiesel). However, castor oil generates a high viscosity biodiesel, which limits its utilization as biofuel (see below).

Beyond the advantages and potentialities mentioned, castor has historically been a marginal crop and, despite the public efforts made in some countries like Brazil, its utilization as feedstock for biodiesel has been relatively poor up to now. This has to do with several restrictions, among them:

- The limited experience in the crop and its low level of technological development, characterized for the reduced supply and/or absence of improved genotypes in the region's countries (fundamental aspect to incorporate new areas to the crop and increase the yields), lack of adapted harvesters, herbicides and models of response to fertilization, utilization of unsuitable seeds (of low average yield and quality and highly vulnerable to diseases and plagues) and scarce general knowledge about the eco-physiological bases implied in the generation of the yield (Ferreira dos Santos and Lemos Barros, 2003, cited by SAGPyA-IICA, 2005, Wassner, 2007).
- In relation to the aforementioned, the agricultural yields obtained in the region are generally low, substantially lower than what is considered a good yield (1.5-1.8 tn/ha), leading to a very low yield of castor biodiesel per hectare, under the current conditions, in comparison with its potential and with that of other feedstocks, including soybean.
- The high opportunity and production costs that the high quotation of castor oil represents, (usually above 1000 US\$/tn), which in the global market has historically been above those of palm, soybean, sunflower and rapeseed oils and other traditional vegetable oils, also exceeding biodiesel's price in many markets. In order to counteract the high relative costs implied in the production of castor oil biodiesel, it should be produced in regions distant from ports.
- Castor production chains in the region's countries have been characterized for low development and institutionality levels, with a high level of disarticulation, disorganization of the domestic market, product's commercialization and positioning difficulties and, in some cases, low prices to the agricultural producer, in many cases leading to abandonment and replacement for other crops, theoretically riskier for the producers.
- Castor's seed, as other parts of the plant, has poisonous and/or allergen substances for humans and animals, among them, ricin, considered as the most poisonous protein known by man (CENIAT). Ricin, which is mainly in the seed, is toxic for humans, animals and insects and is the first responsible for the cake's toxicity, by-product of the oil's extraction. The plant's and seed's toxicity makes their handling risky, while the toxicity of the cake substantially limits or conditions the profitability of oil or biodiesel projects based on castor⁵⁴.
- Castor oil "in natura" is one of the vegetable oils with more viscosity (100 times more viscous than diesel). Even though this characteristic is considerably reduced in the transesterification process, castor biodiesel is still very viscous due to the presence of ricinoleic acid. This limits its use as biofuel and its level of blend with diesel, thus, requiring the blend with other oils in order to comply with the technical specifications of biodiesel demanded by the countries' regulations.

⁵⁴ In Brazil, castor's cake is used as fertilizer for its capacity of restoration of exhausted land; PETROBRAS is investing in research to discover new uses. In the framework of the Brazilian Network of Biodiesel Technology, a project destined to eliminate its toxicity is being developed, in order to facilitate its utilization in animal feed, due to its high protein content. According to TECBIO, mentioned by Lobato, the detoxification process would only make sense if it is applied to the flour, resulting from the oil extraction process by solvents (the cake with an oil content lower than 1%); the cake obtained from the process of mechanical extraction of oil, even undergoing detoxification, can not be used as ration due to its high content of the same (5%-8%).

Jatropha / Jatropha / Pinhao Manso

Crop	<i>Jatropha (Jatropha Curcas L.)</i>
Characteristics	<p>Also known as physic nut, the name “jatropha” is usually used to refer to the jatropha curcas species, though there are about 170 species known of this plant. Jatropha is a bushy perennial oleaginous crop, belonging to the euphorbiaceae family. Native of Mexico and Central America, it has spread all over the world, though it is still a wild plant, with much reduced experiences as a commercial crop. There are three varieties of jatropha curcas: Nicaraguan, Mexican (distinguished by its seed with low or innocuous toxicity) and Cape Verdean. It grows from tropical very dry zones to rainy forests and in most subtropics. According to diverse studies, the suitable temperature for its cultivation is between 18° and 28.5°C and it can resist mild frosts. It can develop in low altitudes (0 - 500 m). Its productive cycle extends from 35 to 50 years; it is a fast growing plant with a normal height of 2 to 3 meters and in especial conditions it may reach 5m. The most suitable soils for jatropha are good sandy soils or light clayey—sandy, ventilated and well drained soils; it does not tolerate liable to flooding or heavy soils. Even though it has been reported that the plant has low nutrient requirements, the limitations in the soil’s fertility (especially through the limited availability of N, P and K in the radical zone) hinder the crop’s growth and production. The harvested part of Jatropha is the fruit, which generally contains three seeds. The seeds constitute about 70% of the fruit’s total weight (the other 30% is pulp). The oil is stored inside the seed, in the kernel (that represents about 65% of the seed’s total mass). Jatropha starts to produce 6 months after sowing and reaches its optimal production level at 4-6 years. The plant is toxic due to the fact that the seed has curcine and alkaloids known as phorbol esters that cause a purgative effect. Due to the seeds’ toxicity, jatropha curcas oil is non edible and is used traditionally for medicinal applications and to produce soap, insecticides and lubricants. (SNV,2008 / Jongschaap et al, 2007, Falasca and Ulberich, 2008 / FAO, 2008)</p>
Water requirement	<p>It can grow with an annual rainfall of between 250 mm and 2000 mm. However, a minimum of 500-600 mm is considered necessary for the production of fruits and a minimal range of 800-1000 mm and a maximum of 1200-1500 mm, well distributed throughout the year, for the production in ideal conditions. In conditions of little rainfall, irrigation may be used (SNV, 2008/ Jongschaap et al, 2007)</p>
Content of oil in the seed	<p>28% - 39%</p>
By-products/co-products of its use for biodiesel	<p>The fruit’s pulp, the seed’s husk and the cake resulting from the extraction of oil (that contains 56% of proteins) can be used for organic fertilization or for the production of more energy. The seeds’ husks can be burnt and together with the fruit’s pulp, they can be used as fuel for use in boilers, in processes that employ heat as the same production of biodiesel. The cake and the fruit’s pulp can be used for the production of biogas by anaerobic fermentation. Due to its toxicity, the cake can not be used as animal feed. Latex is extracted from the stem of the jatropha and other different substances for medicinal applications, use as insecticide, etc. can be extracted from its leaves and bark. Glycerine is obtained from biodiesel’s production process (SNV, 2008/ Jongschaap et al, 2007).</p>
Agricultural yield (tn dry seed/ha)	<p>Due to the variability of the crop’s yield in time and in different environments, and to the fact that there still are no standardized cultivation methods in the world, the estimations of yields are very diverse. Based on results obtained by different authors, the production of seeds of a mature plant would be between 1.5 - 7.8 tn/ha (Jongschaap et al, 2007). At least 2 to 3 tons of seed per hectare could be obtained in semi-arid areas (Heller, J., 1996) or probably less than 1 ton of seed per hectare in case of growth and production with minimal water availability. According to the Centre for Jatropha and Biodiesel of India, the following yields can be obtained from the fifth year (in tons of dry seed/ha): a) without irrigation: low: 1.1; medium: 2; high: 2.75; b) with irrigation: low: 5.25; medium: 8; high: 12.5.</p>
Potential	<p>2.75 (without irrigation) – 12.5 (with irrigation), from the fifth year (Centre for Jatropha and Biodiesel of India)</p>
Biodiesel yield per ha (lts/ha)	<p>450-2290 (assuming an agricultural yield range of 1.5-7.8 tn/ha, 35% of oil content in seed, 75% extraction efficiency, oil density of 0.93 Kg./lt and reduction of 4% in conversion to biodiesel)</p>
Potential	<p>2890 (assuming an agricultural yield with irrigation of 8 tn/ha, 35% of oil in seed, oil extraction by solvents (efficiency: 100%), oil density of 0.93 Kg. /lt and reduction of 4% in conversion to biodiesel).</p>

Source: Own development; information obtained by IICA’s regional offices; and several sources.

Table 9.2.3.22: Composition in dry matter of the components of *Jatropha curcas*

	Moisture (%)	Dry matter (%)	Relative composition (%)	Oil content (%)	Source
Wood	15	85	25		Openshaw, 2000
Leaves			25		Openshaw, 2000
Fruit	8	92	50		Openshaw, 2000
		23	77		Sirisomboom et al., 2007
Coat	85	15	30		Openshaw, 2000
		89	11		Sirisomboom et al., 2007
			26		Mattana Satunino et al., 2005
Seed	3-7	93-97			Jones & Miller, 1992
				37.4	Kandpal & Mandan, 1995
	5	95	70		Openshaw, 2000
				33.0-39.1	Ginwal et al., 2004
			74		Mattana Satunino et al., 2005
Shell			34.7-41.6		Ginwal et al., 2004
			34.3-46.1		Makkar et al., 1997
	11	89			Vyas & Singh, 2007
	10	90	34.3		Openshaw, 2000
	10	90			Trabi, 1998
			37.6		Mattana Satunino et al., 2005
			29.9-31.9		Martinez Herrera et al, 2006
Kernel			58.4-65.3	46.2-58.1	Ginwal et al., 2004
			53.9-65.7		Makkar et al., 1997
			65.7		Openshaw, 2000
				46.0-48.6	Kandpal & Mandan, 1995
	3	97		48.5	Banerji et al., 1985
	3.1-5.8	94.2-96.9			Trabi, 1998
	2.2-11.3	88.7-97.8	68.1-70.0		Martínez Herrera et al, 2006
			62.4		Mattana Satunino et al., 2005
				21.0-74.0	Shah et al., 2005

Source: R.E.E. Jongschaap, W.J. Corré, P.S. Brindraban and W.A. Brandenburg (2007)

Jatropha is an oleaginous bushy perennial crop that, despite its scarce antecedents of production at commercial scale, has awakened great interest in the region and the world.

The bush grows wildly in almost all the region's countries. Its spread area in South America includes Bolivia, Brazil, Colombia, Ecuador, Paraguay, Peru, Venezuela and Argentina (Heller, 1996, mentioned by Falasca and Ulberich, 2008). Likewise, in the last years it started to be cultivated incipiently in some countries in the framework of public research and experimentation projects, private projects with commercial objectives and



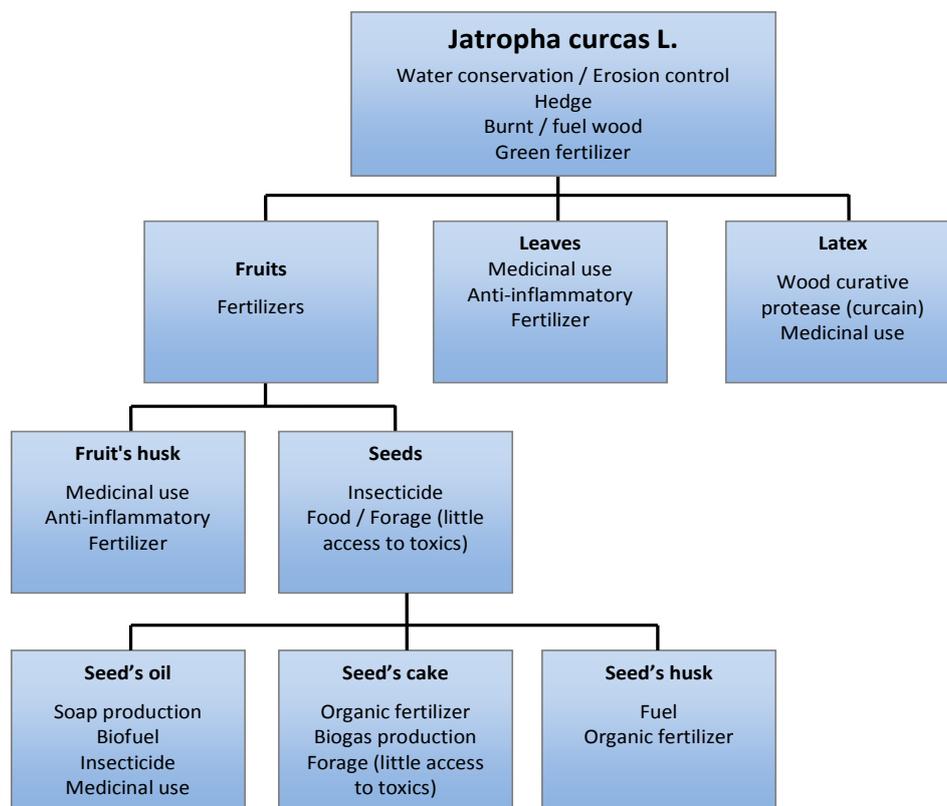
mixed projects. For the moment, according to a global market study about jatropha, more than 90% of the area destined to these projects in South America is concentrated in Brazil (15,800 hectares).

The great interest in jatropha as feedstock for the production of biodiesel is related to the multiple advantages that many authors have granted it.

- It is a crop with low demand regarding the type of soil (it is adapted to grow on saline, sandy and rocky soils) and resistant to water scarcity, which makes it adaptable to semi-arid and warm regions. When produced on marginal land and low fertility or eroded soils, it would not compete with land for the production of food or with forests and could be developed in postponed regional economies.
- Due to the fact that its seeds are toxic, the resulting oil is non-edible, thus, its price is not influenced by competition with food use.
- Theoretically it has a high content of oil in seed and a very high potential yield of biodiesel per hectare, greater than that of other oilseeds like soybean, rapeseed, sunflower or castor.
- It is considered a species recuperative of soils, which makes it an alternative for the reforestation of eroded zones or with risk of desertification and to recover lands that are not longer suitable for agricultural activity since they are exhausted.
- It is considered a “social crop” because it is labor intensive, thus, it could be a source of employment in rural zones and could be developed in smallholdings by family agriculture⁵⁵.
- The chemical quality of its oil, even though it is not optimal, exceeds that of other oilseeds like soybean, cotton, peanut, sunflower and safflower (it has 40% of mono-unsaturated fatty acids).
- It has various favorable characteristics that could increase its profitability potential: Implementation easiness; since it is a perennial culture it does not require annual renewal; its productive cycle extends from 35 to 50 years; all the plant can be utilized (its leaves and roots can have medicinal applications, latex can be obtained from its stem, and from its wood, vegetable carbon, Table 9.2.3.23); it is a crop suitable for inter cropping (especially during its first years, when trees are small); its seeds do not have to be processed immediately (as in the case of palm); its oil is easy to extract and the residual cake can be used as biofertilizer, since it is rich in nitrogen, potassium and phosphorus.

⁵⁵ According to SNV, based on business plans and manpower projections in Central America, a conservative value of manpower requirement would be 105 days - man per hectare during the beginning of the plantation (plantation: 50, maintenance: 50, harvest: 5) and 96 days - man per hectare in year 6, when the crop is in the plenitude of production (maintenance: 45, harvest: 51).

Table 9.2.3.23: Exploitation of the components of *Jatropha curcas* L.



Source: Jongschaap et al (2007)

Despite the multiple potentialities of jatropha, this alternative presents significant limitations for its development at commercial scale in the short term. Among them, the bibliography and specialized sources⁵⁶ mention the following:

- The limited technical knowledge and existent scientific research and the lack of reliable scientific data about its agronomy, together with the fact that its requirements vary significantly with the environment, make it necessary to have more information about its genetic diversity and its potential yields (in seeds and oil content) in different environments and regions.
- In particular, considering the advantages attributed by different authors, the lack of knowledge on its potential requirements under sub-optimal and marginal conditions and the non-existence of scientific data confirming the attribution of a high yield of oil simultaneously with few nutrient needs, a lower use of water, lack of competition with the production of food and resistance to plagues and diseases, acquire especial relevance.
- In line with the aforementioned, the lack of improved varieties and available seeds and the lack of knowledge on its genetic diversity are among its most important lacks. *Jatropha* has still not been domesticated and there are no well established genetic improvement programs in the world that guarantee a suitable yield.

⁵⁶ Jongschaap et al (2007), SNV (2008), FAO (2008c.), EMBRAPA (2007), INTA.



- Jatropha's performance at low temperatures is not deeply known yet, though it is proved that long temperatures near freezing point can kill the plant. That would represent a significant restriction for its development in the Southern region.
- The lack of experience on its cultivation at commercial scale (there are no consolidated projects in the world yet) to confirm its productivity and profitability. The predictions on the crop's productivity and profitability seem to ignore in many cases the results of plantations started in the nineties, many of which were recently abandoned due to low productivity and/or higher labor costs than the expected. Having accurate and reliable predictions on jatropha's yields is essential to make decisions in investment and crop's promotion policies matters.
- Jatropha does not have yet a production system minimally validated that enables recommending its way of propagation (seeds, cutting, seedlings), plantation density, fertilization, harvest systems, specific machinery, etc.
- According to preliminary studies made in Brazil and other countries, the plant is susceptible to many diseases and plagues, some of which do not exist in several countries of the region and could be introduced with the crop. There still are no phytosanitary packages for Jatropha.
- The non-uniform maturation of its fruits and the fact that its harvest is manual increases its production costs. Even though globally there is experimentation for the partial mechanization of the harvest, the plant's fragility, the reduced size of the seeds and the continuous blooming hinder the mechanization processes⁵⁷.
- The current non-existence of an established market for jatropha (domestic and overseas), could lead to a situation of few buyers and low prices for the producer, aggravated by the fact of being a perennial crop.
- Since its seeds are very poisonous, the cake obtained as a by-product from the extraction of oil is toxic, which limits the possibility of being used as animal feed (it requires an activation process)⁵⁸ and affects the profitability of the projects in relation to other alternatives. Since the toxicity of jatropha curcas is based on different components (phorbol esters, curcines, protease inhibitors, among others), the complete detoxification represents a complicated process, not suitable and inconvenient for small scale and domestic use and too expensive for large scale.
- The urgency to extend the cultivation of jatropha⁵⁹, in a framework still characterized by uncertainty and insufficient experience and scientific and technological knowledge, implies serious risks of economic losses and lack of confidence by the local communities who could benefit with the crop (family agriculture, postponed regional economies, etc.).

Considering the versatility and adaptability of jatropha, beyond its mentioned limitations, South America has a high potential for its cultivation, in terms of land suitability (Figure 9.2.3.24).

In the region's countries, despite the great pressure of national and overseas investors for the plantation of large areas of jatropha and the rise of some private ventures with different levels of formality, the advance is

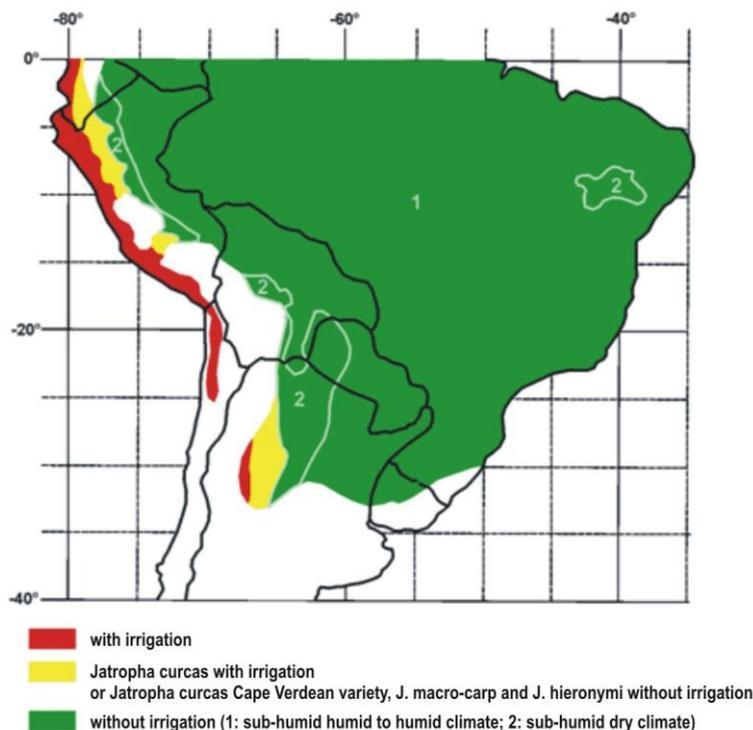
⁵⁷ There are preliminary tests in the world, with olive and coffee harvesters, though without concluding results.

⁵⁸ There is experimentation currently on the detoxification of the cake for its use as animal feed, but until now it has only been done at laboratory scale. Regarding that, the SNV reports that in lab test with rats, made in Nicaragua, carcinogenic effects were discovered up to the 5th generation, even eliminating curcine and other three toxic elements.

⁵⁹ In many countries, the most enthusiastic opinions that foster its cultivation are the same ones that sell seeds and seedlings at very high costs and of unknown genetic potential (Benge, 2006, cited by INTA).

being made with caution: the national governments are not promoting the crop yet and the emphasis is put on research and experimentation for the purposes of gathering the cumulative knowledge, indispensable for the economic, social and environmental feasibility of the crop. To that respect, following are some of the relevant initiatives in the region:

Figure 9.2.3.24: Potential zone for the cultivation of *Jatropha curcas*



Source: Falasca & Ulberich (2008)

In Argentina, in the North of the country, some species of *Jatropha* grow wild, among them those of the *curcas*, *macrocarpa* and *hieronymi* sub-genres. The Bioenergy Program of INTA is coordinating the *Jatropha* Project, which includes performance studies and agronomic conduction in the temperate Valleys (Cerrillos), semi-arid Chaco and in the Umbral Chaco with sub-humid tropical climate; recollection, classification and study of the genetic material of native species, study of diseases and plagues, improvement of molecular genetics, development of micro-propagation technologies, extraction and study of oils' quality, etc. General studies about the production's feasibility are also being developed. Research projects are in their first stages, from 1 to two years (Hilbert, 2008).

In Bolivia, the departments of Chuquisaca, La Paz, Tarija, Santa Cruz, Beni and Pando have potentialities for the production of *Jatropha* (CAINCO-IBCE). The Center of Tropical Agricultural Research (CIAT) is in the phases of research and plantation of nurseries with 4 varieties of *Jatropha* recollected from different countries for their comparison with the variety that grows locally in Santa Cruz, while in the lab, the correspondent analysis are executed to determine the quantity and quality of the oil, both of the local and overseas varieties. At the same time, they are being analyzed for their selection according to the quantity and quality of the oil for the production of biodiesel. At the beginning of 2009, the community of El Pantanal, with the back-up of the Prefecture and oilseed producers started the plantation of *Jatropha* for the tests on soil of the varieties of local and overseas seeds, through CIAT.

In Brazil, EMBRAPA develops an RDI plan in jatropha, which is concentrated in three components: genetics (Active Germplasm Bank and genetic improvement program), handling (nutrition, blooming's seasonality and mechanical harvest) and processing (detoxification of the cake, post-harvest treatment and oil's quality). There also are advances in terms of the coordination of the production, from the foundation of the Brazilian Association of Jatropha Producers (ABPPM, for its Portuguese acronym).

In Chile, jatropha is also in research and experimentation phase. To that regard, 3 projects linked to research institutions and/or universities and public funds' contributions are being developed. INIA is developing the agronomic evaluation of jatropha as a feedstock to produce biodiesel in semi-arid zones in marginal soils, with residual and saline waters; the University of Tarapacá, is developing the cultivation of 1,500 hectares in marginal lands of the province of Arica; and the University of Chile and private companies are studying the performance and rooting of the plant in different zones (Traub R., 2008). This last project called "Development and validation of Jatropha's crop in the North of Chile for the production of biodiesel" consists in the introduction and adaptation of the species; selection and propagation of notable genotypes; defining the productive potential and integral handling model and determine the crop's technical-economic viability (FIA – MINAGRI).

In Paraguay, despite being a native plant, its cultivation is not very known. Some private ventures to produce jatropha in the country have been announced recently.

In Colombia, after carrying out a thorough study of the potential crops and zones for the development of energy crops, CORPOICA found that in most parts of the Colombian geography there are genetic varieties of Jatropha Curcas L. That led this Corporation to take the initiative of applying the project "Determination of the zones with biophysical potential and identification of genetic materials for the agroindustrial establishment and development of *Piñon* (Jatropha Curcas L.) in Colombia", with the aim of gathering, characterizing, documenting and maintaining this information (IICA-Colombia). This project is being developed in La Guajira, Meta, Vichada, Antioquia and Tolima (CORPOICA).

In Ecuador, even though jatropha is not produced commercially, this crop is known since it is used as part of hedges of paddocks and land divisions. The more suitable zones for jatropha are Manabí, Guayas and the frontier cantons of Loja. INIAP develops the project "Development of technologies for the utilization of *piñón* (Jatropha Curcas L.) as a source for biofuels in marginal dry lands of the Ecuadorean littoral", which aims at identifying and validating technologies for the production of jatropha, validating and adjusting technologies for the attainment and use of its oil and its biodiesel and the utilization of its by-products, and at carrying out a financial and market analysis of jatropha's oil and biodiesel (INIAP). In Manabí, the plant has been identified in 7000 kilometers. The same is being investigated in the framework of the mentioned project and the objective is to generate, after 2 years, crop's handling technologies and identify early and productive varieties with high oil yield rates.

In Peru, jatropha develops naturally in the natural mountain and jungle regions located in Piura, Chiclayo, Huaraz, Lima, Ica, Cajamarca, Huanuco, Cerro de Pasco, Huancayo, Huancavelica, Ayacucho, Chachapoyas and Moyabamba (IICA-Peru). INIA is developing analysis of varieties and development of the technological package of Jatropha curcas for the High Jungle and North Coast (with the support of SNV). Prefeasibility studies are also being carried out for the development of the cultivation of jatropha with the approach of Inclusive Businesses (IB); the German Cooperation (GTZ) has been carrying out projects in Piura with different varieties to determine their yield and test their energy supply. According to GTZ, for a commercial use of jatropha in the country, some problems must be solved, such as improving the genetic base, having improved seeds, developing the propagation by cuttings, having grafted plants and attaining a detoxification of residues (GTZ, mentioned by ECLAC, 2008c).

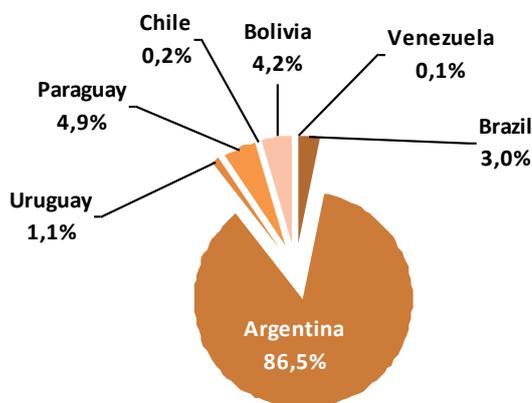
Around the middle of 2008, the constitution in Chile of the Latin-American Research Network on *Jatropha* (AGROENERGETICOS) was announced. The same is a consortium of educational and research centers, companies and international cooperation organizations, with the intention of collaborating in the development and spread of the scientific and applied knowledge of *Jatropha*'s cultivation and other initiatives related to agro-energy.

9.2.3.3 Other crops and feedstocks for the production of biodiesel

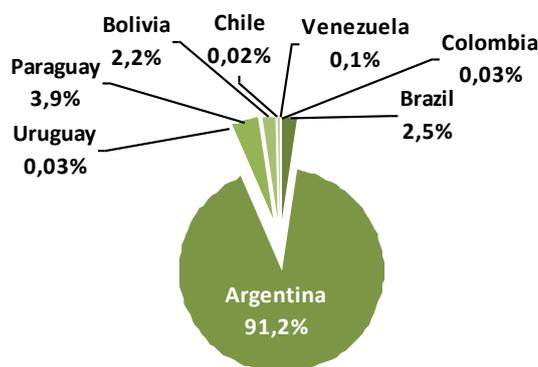
Besides the described crops, there is a wide diversity of feedstocks usable for the production of biodiesel. A thorough analysis of each one of these alternatives is beyond the possibilities of this document. Following there is a synthesis for some cases considered relevant.

Among these feedstocks, **sunflower** (*Heliantus annus*) stands out for its level of availability. With a production of 4 million tons of seed and of 1.34 million tons of oil, sunflower is the third most important oleaginous complex in South America. Nevertheless, the production of this oilseed and its oil is highly concentrated in Argentina (Graphs 9.2.3.25 and 9.2.3.26). Argentina is the third world's producer of sunflower's seed (3.5 million tons in cycle 2006-07) and stands out as the first global exporter of sunflower oil (1.2 million tons in 2007). In this country, sunflower is the second oilseed of importance after soybean. As soybean's chain, Argentina's sunflower's chain is also consolidated and its availability for the production of biodiesel is high, considering that in the last 5 years 75% of oil's production was exported. Sunflower has some features that make it an attractive alternative, such as its relative tolerance to drought and its adaptability to diverse climates (temperate, tropical, and mediterranean), factors that enable it to develop in environments unfavorable for other crops. As in the case of soybean, the joint production of sunflower biodiesel and protein meal (very rich in protein content: 40% to 50%) may result in a relevant advantage for the profitability of the projects. Even though sunflower has a greater content of oil in seed (35% to 54%) and yield in liters of oil per hectare (550 to 850 lt/ha) regarding soybean, the opportunity cost of destining its oil to the production of biodiesel is higher, considering the history prices' differential existent between both oils. The opportunity cost also represents a limitation for the specific case of high oleic sunflower, whose oil would enable obtaining an optimal quality biodiesel, but it quotes with a premium on the conventional sunflower oil. These restrictions explain the reasons why the production of sunflower biodiesel has been practically null in the region.

Graph 9.2.3.25: Sunflower production share per countries 2007



Graph 9.2.3.26: Sunflower oil – production share per countries 2007



The region also has relevant experiences in the production of **cotton** (*Gossypium hirsutum*) and **peanut** (*Arachis hypogaea*) oils. In both cases, the South American production is led by Brazil (first producer of cotton seed and oil) and Argentina (first producer of peanut and peanut oil of the region, second world exporter of such oil). According to monthly statistics of the ANP, cotton oil is currently the third feedstock used in Brazil to produce biodiesel (5% of the quantity of feedstocks used in February 2009). Peanut stands out for its high content of oil in seed (36% to 56%), which could lead to yields of more than 1000 liters of biodiesel per hectare.

These feedstocks have significant limitations related with their high opportunity costs, since the prices of their oils historically quote above those of soybean, rapeseed and palm. Among the edible oils, peanut oil has the highest international quotation after olive oil, reason why it is not being used by biodiesel industry. In the case of cotton, nevertheless, it is worth mentioning that according to a study of the University of San Pablo (ESALQ, 2005), in a scheme that considers the seed as a by-product of the production of fiber, cotton oil biodiesel would have the lowest production cost in Brazil, in comparison with soybean, sunflower, castor, peanut and palm biodiesel. In this case, however, the study establishes, in the face of this economic advantage, limitations related with scale, which would impede attending a national program. Nevertheless, it could be a viable option for self-consumption or supply in small locations far away from ports. Another limitation for these feedstocks is related with the chemical quality of the oil for biodiesel, especially in the case of cotton⁶⁰. The potential yield of cotton biodiesel per hectare (less than 400 lt/ha) is substantially lower than that of the rest of considered oilseeds, due to its low agricultural yield and oil content in seed (15% - 22%).

Safflower (*Carthamus tinctorius*) is a feedstock valued due to arguments such as: a) its rusticity and excellent adaptation to aridity conditions, which would avoid the competition with lands destined to the production of food; b) its feature of regional crop, with potential to be produced in arid and semi-arid zones; c) it is a winter cycle oilseed, therefore it would not compete with summer crops; d) in the specific case of the varieties of improved seeds - high oleic - the high content of monounsaturated fatty acids of its oil generates an optimal quality biodiesel. The South American production of safflower is totally concentrated in Argentina, which in 2007 produced 58,000 tons of seeds and 15,000 tons of oil.

Despite its attractions, safflower has important restrictions, related to: a) technological aspects, such as incipient technological development, lack of R&D in handling, structure and development features of the plants (low initial growth, its has thorns that hinder the harvest); b) its productivity: even though its seed has a

⁶⁰ In both cases, the oil is composed of a larger proportion of saturated and polyunsaturated fatty acids, with respect to monounsaturated fatty acids (whose participation is 19.8% in cotton oil and 38.7% in peanut).



relatively high content of oil (25% - 40%) its low agricultural yield leads to a low potential yield of biodiesel per hectare (210 to 335 lt/ha); b) in the case of traditional seeds, their oil contains a low proportion of monounsaturated fatty acids (14%) and a very high proportion of polyunsaturated fatty acids (75%), which affects negatively to the quality of biodiesel; c) the opportunity cost of the safflower oil, especially the high oleic, in comparison with soybean oil, palm oil and other alternatives (it is a specialty of high value in the food market, since it is one of the oils with better nutritional quality for human consumption).

Among other non traditional oilseeds the following can be mentioned **artichoke thistle** (*Cynara cardunculus* L.), **lesquerella** (*Brassicaceae*), **jojoba** (*Simmondsia chinensis*) and **lupine**. They are alternatives that, theoretically, could represent possibilities for regional economies, for their possibility of being developed in arid or cold climate zones, which in turn would imply not competing with the utilization of land for the production of food. Nevertheless, these alternatives face many of the restrictions mentioned for the case of jatropha, in terms of lack of scientific and technical knowledge, lack of experience and technological development, practically inexistent markets, etc., to which other additional limitations are added, which, according to each crop, are related with the low potential yield of biodiesel per hectare (lesquerella and lupine), the chemical quality of the oil (lesquerella and lupine) or the cost of opportunity that the high quotation of its oil represents (jojoba)⁶¹.

A wide variety of **tropical oilseeds** is added to these alternatives, mainly Amazonian, of native growth (Table 9.2.3.27). Within this group, the most significant in terms of existent commercial experience, is the **coconut** (*Cocos nucifera*). The region's countries summed up a production of 3 million tons of fruit and 15,200 tons of copra oil in 2007, with Brazil leading the production of fruit (89% of the production) and Venezuela leading the oil production (76%). According to EMBRAPA, the growth of coconut has a wide adaptability, it may be grown in areas where other traditional crops would not establish in a sustainable way, it has a great potential for the production of oil (65 to 72%, in giant coconuts and 65 to 66% in hybrid coconuts, being able to attain 4 tn/ha), it has great social and economic importance and it contributes to the sustainability of fragile ecosystems.

In the rest of the tropical oilseeds, the existent experience is null at commercial scale and incipient in matters of research, characterization and knowledge. Among those that have arisen more interest, especially in Brazil, is **babasu palm** (*Orbignia phalerata*). It is an alternative with important social implications, considering that in the North of Brazil, the extraction of oil and other usable products is made by thousands of persons, mainly women, who live in subsistence conditions. It is estimated that in this country the native forests of babasu palm cover about 17 million hectares, though according to some authors, the area with sufficient concentration of explorable palms is smaller than 100,000 hectares (IICA/SAGPyA, 2005). There is practically no systematic cultivation of babasu and the extractive production comes from spontaneous palms. They have a productivity of 2.5 tons of fruits per hectare, seeds that weight 7% of the total fruit and contain 65% to 68% of oil similar to palm oil. Considering the area of explorable palms of 100,000 hectares, the potential production of biodiesel from babasu in Brazil would be of 120 million liters (IICA/SAGPyA, 2005).

⁶¹ For more information see García Penela (2007) (jojoba, lesquerella and lupine); Falasca, S. and Ulberich, A. (2007) (artichoke thistle).

Table 9.2.3.27: Tropical oilseeds

Common Name	Scientific Name	Oleaginous part	Estimated Oil Yield in Plantations (kg/ha/year)	Fruit or Seed Oil Content
Aguaje	<i>Mauritia Flexuosa</i>	Pulp	2,400	21.1
Almond tree	<i>Caryocar Villosum</i>	Pulp and seed	270	
Red Almond tree	<i>Caryocar Glabrumm</i>	Seed		37
Babasú	<i>Orbignia Phalerata</i>	Seed	90 - 150	72
Bacuri	<i>Platonia Insignis</i>	Seed		46
Chest nut	<i>Bertholletia Excelsa</i>	Seed	1575	69.3
Chopé	<i>Gustavia Longifolia</i>	Pulp		30
Coconut	<i>Cocos Nucifera</i>	Endocarp	610 - 732	66
Copoasu	<i>Theobroma Grandiflorum</i>	Seed	482 - 808	
Hamaca Huayo	<i>Couepia Dolycopoda</i>	Seed	70 - 80	
Huasaí	<i>Euterpe Precatoria</i>	Pulp and seed		
Inchi	<i>Caryodendron Orinocense</i>			41 - 59
Cashew	<i>Anacardium Occidentale</i>	Nut		46.3
Olla de Mono	<i>Lecythis Pisonis</i>	Kernel		
Pijuayo	<i>Bactris Gasipaes</i>	Pulp and seed	2.000	23
Poloponta	<i>Elaeis Oleifera</i>	Pulp and seed	1.800	16.2
Sacha Inchi	<i>Plukenetia Volubilis</i>	Kernel	51.4	
Sacha Mangua	<i>Grias Neuberthii</i>	Pulp	165	
Sinamillo	<i>Oenocarpus Mapora</i>	Pulp		
Totai	<i>Acricomia Totai</i>	Pulp and seed	12-15 (pulp)	60 (kernel)
Tucuma	<i>Astrocaryum Vulgare</i>	Pulp and seed		43.7
Umari	<i>Poraqueiba Sericea</i>	Pulp	530	21.2
Ungurahui	<i>Oenocarpus Bataua</i>	Pulp	240 - 525	19 (mesocarp) 14.5 (epicarp)
Uxi	<i>Dickesia Verrucosa</i>	Pulp	20.2	

Source: Castro, Paula et al. (2007)

In Peru, La Molina National Agricultural University (UNALM) has been researching for years, about 50 oilseed plants and seeds that grow in the Peruvian jungle with the purpose of producing biodiesel, such as **moriche palm** (*Mauritia flexuosa*), **umari** (*Poraqueiba sericea*), **ungurahui** (*Oenocarpus bataua*), **Brazil nut** (*Bertholletia excelsa*), **sacha inchi** (*Plukenetia volubilis*) and **poloponta** or American oil palm (*Elaeis oleifera*), among others. These studies have identified some interesting native species that should be studied in more detail, as poloponta, which, even though has lower yields than the spread African oil palm (*Elaeis guineensis*), it could be more recommendable for the specific conditions of the Peruvian Amazonia (Castro P, et al, 2007). In other cases, as Brazil nut and sacha inchi oils, it was determined that they have more profitable uses than biodiesel production, due to their very high quality⁶².

⁶² According to carried out studies, it is believed that sacha inchi's seeds can exceed in quality all oilseeds used for the production of oils, since it has the highest content of omega unsaturated oils (92%) which reduce cholesterol (IICA-Peru, 2008)

Apart from the vegetable oils, it is worth mentioning the possibility of producing biodiesel from **animal fats** which is an interesting option for the meat packing industries, by increasing the value and usefulness of marginal by-products like tallow. Tallow is the gross fat resulting from the extraction and cleaning of the bowels, obtained mainly from the recycled animal tissue. The same implies a defined production process where tallows of different qualities are extracted. The qualities are determined by their percentage of proteins and color. Their use for biodiesel would enable the utilization of this by-product in the form of "melted" tallow.

The potential of production of biodiesel from animal fats in the region is significant, considering that, if only bovine cattle is taken into account, 64 million animals were slaughtered in 2007 in South America, where Brazil, Argentina and Uruguay are particularly highlighted. In Brazil the utilization of bovine fats is registering an increasing participation as feedstock for the production of biodiesel. According to statistics of the ANP, in February 2009, bovine fats represented 19% of the total quantity of feedstocks used in the production of biodiesel, positioning in the second place, after soybean oil. In Uruguay, many of the established biodiesel plants are planning the utilization of bovine tallow. In this country, in the period 2000 – 2005 an average volume of almost 45,000 tons a year without any added value were exported. The same quantity is sufficient to cover the needs of feedstocks required by the goals of blends of biodiesel proposed by the legal framework (IICA-Uruguay). In Argentina no antecedents of biodiesel production from this feedstock are yet registered, though according to estimations of the National Program of Biofuels of the SAGPyA, the potential production of biodiesel that could be obtained from bovine fat should be about 250,800 annual tons⁶³. In Paraguay the production of biodiesel from animal fat was made initially as experimentation, since there was no regulation for its use in a commercial nature or the quality regulations of the same. The regulation of the mandatory blend of diesel with biodiesel has fostered the production of the same for commercial purposes. According to estimations of IICA-Paraguay (Souto, 2008), if 50% of the production of bovine tallow from slaughtering is used for energy aims, there would be a volume of about 9.5 million liters of biodiesel annually, enough quantity to complete the 1% established blend.

Among the relative advantages of bovine tallow biodiesel, its low production and opportunity costs are highlighted, in comparison with vegetable oils. Its main restrictions are related with its chemical properties characterized by a high proportion of saturated fatty acids, which negatively affect the performance of biodiesel at low temperatures⁶⁴.

Other alternatives linked to animal production, with which there are certain antecedents in the world (at least in terms of R&D or certain projects) are chicken and pork fats and fish oil.

Finally, it is important to consider **algae and microalgae**, as an alternative of great potential in the long term. This possibility is already advanced in some countries of the region, like Argentina, where a private project is being developed in the Patagonia, with the support of the Government of the Province of Chubut. The main advantages of the use of algae as feedstock for biodiesel are related with⁶⁵: a) the high oil content of some species (about 50%) and their high potential biodiesel yield per hectare ⁶⁶, highly superior to that of oilseeds;

⁶³ The calculation is obtained by considering the amount of slaughtered animals in 2005 (14.25 million animals), an average weight of 220 kg per animal and 10% of average fat per animal.

⁶⁴ It tends to crystallize in a solid mass that cannot be filtered or pumped. In the case of tallow biodiesel, the cloud point (the temperature at which crystals start to appear) is estimated at 12°C, in contrast to rapeseed (0°C) or sunflower (-18°C). The cloud point can be reduced by mixing it with diesel or a biodiesel produced with other feedstocks and also by the use of additives, which increase costs.

⁶⁵ Dela Vega Lozano (2007); National Renewable Energy Laboratory (1998); Briggs (2004).

⁶⁶ 20.000 liters of biodiesel/ha according to the Hemispheric Program of Agro-energy and Biofuels of IICA, 50.000 liters according to the average of different sources performed by Dela Vega Lozano (2007).

b) they can grow extremely fast under optimal conditions⁶⁷; c) they do not compete with the production of food, since they do not require agricultural land (they can be produced in ponds or in photo-bio-reactors), leading to the possibility of developing projects in desert regions or in coasts; d) a by-product that contains different nutritious compounds that could be used in food and pharmaceutical industries is obtained from the extraction of its oil; e) they have a great capacity to use high volumes of carbon dioxide, therefore, their projects could reduce the emissions of Greenhouse Gases (GHG) near industrial complexes of great generation of CO₂.

Despite its great potential, biodiesel from algae has significant restrictions to overcome, among them⁶⁸: a) the technology is not available yet at industrial scale, despite decades of development in USA, Japan and some countries of the EU; b) maintaining the optimal conditions for the fast growth of algae and their survival implies costs substantially higher than those required by terrestrial crops⁶⁹; c) algae crops tend to be unstable and to be regularly colonized by other stronger algae (that are not necessarily biologically suitable for the production of biodiesel) and, in contrast with land crops, the techniques to deal with it may result extremely difficult; d) harvest difficulties in comparison with land crops, by proved technologies (membranes and flocculation); e) lack of flexibility of the production systems, in comparison with terrestrial agriculture that, in the face of changes in the conjuncture or in the economic environment, may re-orient the utilization of its assets (land and machinery) towards a wide variety of crops.

9.2.4 General considerations

From the analysis presented in the previous sub-sections it follows that the region has a significant potential, in terms of availability of natural resources and soil and climate conditions, for the production of a wide variety of feedstocks. In the case of immediately available feedstocks, in most countries there are exportable balances sufficient to satisfy the blend of biofuels with fossil fuels established in their laws and, in some cases, achieve a relevant insertion in the international market.

Considering both the immediately available feedstocks and the alternative ones, it is important to consider that the possibilities and valuation of each feedstock in each country are related with a wide range of parameters, among them (Ganduglia, 2008):

- The potential of conversion to biofuels (yield in alcohol or vegetable oil per hectare) (mainly sugar cane, sugar beet, sweet sorghum, lignocellulosic feedstocks, oil palm, jatropha, algae).
- The current availability level and supply guarantee (sugar cane, corn, soybean, oil palm and sunflower).
- The production and opportunity costs (sugar cane, oil palm, soybean and bovine tallow).
- The quality and properties of the oil to be used for fuel purposes, in the case of biodiesel (mainly rapeseed, high oleic safflower and high oleic sunflower).
- The potential of utilization of the specific by-products and their impact on the profitability of the producing plants (mainly sugar cane, corn, soybean, rapeseed and sunflower).

⁶⁷ According to Dela Vega Lozano (2007), between 50 and 150 grams of dry matter per cubic meter daily, under favorable conditions inside photo-bio-reactors.

⁶⁸ BIOPACT (2007b and 2007c); National Renewable Energy Laboratory (1998).

⁶⁹ According to a study (Dimitrov, 2007), for the case of the photo-bio-reactors, while it could be theoretically possible to reach growth rates 10 times higher than the best land growth rates (in the tropics), the expenses associated with the cultivation of microalgae in the same are extremely higher than those of land crops.



- ❑ The potential for the joint production of food feedstocks (like protein meals for example) and biofuels (mainly sweet sorghum, sugar beet, agricultural residues, soybean, rapeseed and sunflower).
- ❑ The level of experience and knowledge in the crop and its handling (sugar cane, corn, grain sorghum, oil palm, soybean and sunflower).
- ❑ The level of development and organization of its productive chain (availability of seeds and improved genotypes, of specific inputs, of manpower, of specialists in the crop, of specific machinery and equipment, of infrastructure, etc.). (Sugar cane, corn, grain sorghum, oil palm, soybean and sunflower).
- ❑ Aspects of socio-economic politics, as the labor intensity of the crop and impact on employment, its potentiality to foster the development of postponed rural and regional economies, or to provide insertion possibilities to family agriculture or to small to medium rural producers (mainly cassava, sugar beet, sweet sorghum, castor, jatropha, safflower and tropical oilseeds).
- ❑ Sustainability aspects, such as the growth possibilities in marginal, degraded or arid or semi-arid lands, less suitable for the production of food crops (mainly certain perennial grasses as switchgrass, grain sorghum and sweet sorghum, cassava, sugar beet, jatropha, castor and safflower) or the energy and GHG emissions balance that the biofuels chain specific of the crop generates (perennial crops in general, annual oilseeds under conservation agricultural systems and practices), among others (see section 9.3.2).

Also aspects related to the products' seasonality must be considered, with the logistics and the essential importance of having close markets. In the cases of high opportunity costs, like for example castor oil, the economic feasibility for its utilization as feedstock could only be possible in regions far away from ports.

Considering that each crop or feedstock has relative advantages and disadvantages, or restrictions for its insertion in the biofuels chain, the generation of an optimal portfolio that jointly fulfills competitiveness, environmental sustainability and social inclusion (or at least non exclusion) criteria, results fundamental. That does not imply a priori the rejection of feedstocks, but guaranteeing the compliance with these premises in each considered alternative.

Moreover, the diversification of the agricultural production constitutes one of the greatest possibilities that the development of the biofuels chain provides. Due to the wide range of crops and feedstocks viable to produce biofuels and the great diversity of soil and climate conditions present in the region's countries, the development of the chain also represents great opportunities for the development of rural, regional and local economies.

The utilization of a wide group of feedstocks would enable in turn, to reduce risks in terms of prices and supply stability, fundamental aspect when considering the high participation of the feedstock in the production cost of biofuels.

As it arises from the analysis of the different feedstocks in the previous section, many restrictions to the incorporation or development of socially desirable crops, or with more efficiency of conversion into biofuels per hectare can be overcome through politics that consider suitable programs and instruments, such as R&D, technical assistance and extension, articulation and networking management, promotion of agricultural insurance for non traditional crops, etc. Many of the risks on the environment that some extended crops would represent are more related with the production systems and agricultural practices used than with the crops

itself. In this sense, the adoption of the conservation practices described in the following section may result determinant to minimize negative externalities associated with certain crops.

As a first step to an efficient diversification and regionalization of crops oriented to agro-energy, it will be essential that the countries go on advancing in the design and development of knowledge networks, determination of research lines, creation of networks of introduction and tests of crops in different agro-ecological areas and constitution of a reference atlas for the crops with potential for the production of biofuels.

Likewise, the research on the possibilities of placement and new uses of the by-products associated with each one of these alternatives is fundamental to increase their profitability and feasibility. It would also be extremely fruitful to explore and deepen the study of the possibilities that these crops have for the development of double crops (for example, soybean – rapeseed), poly-cultures (for example rapeseed and safflower are compatible with apiculture, since they are melliferous; castor is produced jointly with beans in the Northeast of Brazil, etc.) or systems integrated with livestock production as those mentioned for the case of corn.

9.3 Economic, environmental and social aspects of the development of biofuels

As it was mentioned in section 9.1.2 the emergence of the global biofuels chain represents relevant opportunities in terms of energy security, mitigation of the climate change and rural, agricultural and economic development, but it also implies risks and potential negative externalities related with: a) the impact on the price of food that would involve an increasing competition for the use of feedstocks currently used to produce biofuels; b) the impact on the environment that the expansion of the agricultural production could have; c) certain not desirable social impacts.

9.3.1 The biofuels vs. food dilemma

One of the main debates around biofuels is its possible competition with the production of food and the subsequent impact on the food security of the world's population. In the framework of this debate, the existence of the usually called “biofuels vs. food dilemma” comes up, arguing that the greater demand of biofuels will generate competition for agricultural land between the crops destined to the production of food and those destined to the production of biofuels, which would lead to negative impacts on food security, in terms of less availability (food scarcity) and access (higher prices to consumers).

At global level, the “biofuels vs. food” debate was deepened in 2007 and, especially in 2008, from the increase on the global prices of the agricultural commodities and food. The performance of these prices – which starting from a trend of a slow but continuous increase as from 2001, rose substantially in 2006 and were drastically accelerated as from the last quarter of 2007 – generated a deep global concern during 2008, from their impact on food security, especially at the level of low income countries net importers of food and at the level of family units net consumers of food, urban and in some cases rural.

Behind the acute increase of prices occurred between 2001 and the second quarter of 2008 there was a wide diversity of explanatory, structural and conjunctural factors, some typical of the specific fundamentals of the

agricultural markets and others of exogenous nature. According to the *Economic Research Service* (ERS) of the USDA these factors are⁷⁰:

- The strong global economic growth, especially in the developing countries and particularly in China and India and other countries of Eastern Asia, with its impact on food demand.
- The diversification in the consumption of food in these countries, where a greater consumption of meat, dairy products and vegetable oils is added to the increase in the consumption per capita of basic food, with the subsequent impact on the demand of cereals and oilseeds.
- The increase of the world's population (about 75 million people every year).
- The global increase of oil's price and its impact on the agricultural production costs (fossil fuels, fertilizers, pesticides, and transport).
- The global depreciation of the dollar and its positive impact on global imports of agricultural *commodities*.
- The increasing demand for feedstocks destined to the production of biofuels.
- The increasing participation of investment funds (index, hedge and sovereign wealth funds) in the agricultural *commodities'* markets.
- The adverse climate conditions occurred in different producing countries and regions in 2006 (Australia, Russia, Ukraine and South Africa) and 2007 (North and Southeast of Europe, Ukraine, Russia, USA, Canada, Northwest of Africa, Australia and Argentina), that caused 2 consecutive droops in the global average yield of cereals and oilseeds⁷¹.
- Since 2007, the increase of the imports by some countries importers of cereals and oilseeds, despite record prices, in order to cover from future increases⁷².
- The policies of different countries exporters of certain agricultural *commodities* (China, Argentina, Russia, Kazakhstan, Ukraine, India, Malaysia and Indonesia, among others) that since 2007 tended to limit the domestic increases in food prices by means of: the elimination of exports subsidies, establishment or increases of exports taxes, quantitative restrictions to exports and exports bannings.
- The decisions adopted since 2007 by different countries importers of certain agricultural *commodities*, which in some cases adopted reductions in imports tariffs (EU, India, South Korea and Indonesia, among others) and in other subsidies to the consumption of foods (Venezuela and Morocco), elements that stimulated the demand despite record prices.

Besides these factors, the ERS mentions other longer term trends, as the impact of the climate change on the agricultural production, which considers is not yet clear; reduced agricultural R&D by governmental and international institutions, which could have contributed to the slow growth in crop yields during the last 20 years; the greater gradual difficulty in the ability to obtain water for agriculture.

There is a high level of dissent with respect to the level of contribution that each of these factors had in the increase of food prices, mainly in the case of speculative funds, to which several experts assigned the greatest responsibility, especially since the end of 2007⁷³, and in the impact of the demand of feedstocks for biofuels.

⁷⁰ The order of the factors follows the chronological explanation of the ERS study (2008), which adds it according to the course of the current decade.

⁷¹ According to the ERS, this situation of two consecutive droops in the global yield of grains was registered only 4 times in the last 27 years.

⁷² According to the ERS, some of these countries that usually imported enough quantities of grain as to cover their needs for the following 3-4 months, started to import quantities to cover their needs for the following 5-10 months. They are countries with high levels of reserve stocks of foreign currencies (oil exporters, China, Japan and other Asian countries).

⁷³ For a detailed description of the impact of speculative funds in the commodities' markets, see: Masters, M. "Testimony before the Committee on Homeland Security and Governmental Affairs United States Senate". May, 2008. Available in: <http://www.bcr.com.ar/Publicaciones/serie%20de%20lecturas/Michael%20Masters%20ante%20el%20comit%C3%A9%20de%20seguridad.pdf>



As follows from the statistics cited in section 9.2, the consumption of *commodities* for the production of biofuels represented in 2007 a low participation in the global supply of cereals (4.5% or 3% considering the distilled grains obtained from the production of ethanol) and vegetable oils (5.9%) as well as in the global area used to produce cereals, annual oilseeds and cotton (1.3%). At the same time, the abrupt drop of global prices of *commodities*, including agricultural, from the accentuation and outbreak of the global economic crisis, it provides strong indications that the performance of prices between 2007 and 2008 was significantly dominated by the actions of a speculative bubble in the market⁷⁴. In this regard, it is worth mentioning as an example, the case of rice, which without being demanded for the production of biofuels and without being displaced by other feedstocks for such aim, registered a duplication of its international price in few months during the first semester of 2008.

Nevertheless, the impact of the demand for ethanol has been considerable in the U.S. corn market (26% of the corn production in 2007-08; 33% projected for 2008-09), main world's exporter of the cereal and price establisher in the global market. According to the mentioned study of the ERS, the increase in the production of ethanol and the significant change in the structure of this country's corn market had a deeper impact on the global supply and demand balance for total coarse grains, and part of the highest prices resulting from the increase of the US demand were spilled over onto the global markets during the growth phase of prices in 2007 and 2008.

The impact on the EU vegetable oils supply has also been relevant, considering that 39.7% of the production was destined to processing biodiesel. Nevertheless, in this case the impact on the global prices of vegetable oil would have been less significant than that of the US corn ethanol, considering that the participation of the EU is 9% in the global consumption and imports of soybean oil, 10% and 15% respectively in the global consumption and imports of palm oil, and that the global consumption of rapeseed oil - of which the EU accounts for 42%, at the same time that it uses this feedstock mainly to produce biodiesel – represents less than 15% of the global consumption of the main 17 oils and fats.

In the case of the impact of cane ethanol in the global market of sugar, the explosive growth of the installed capacity of the Brazilian sugar-alcohol sector (where 67% of the plants are mixed) would have generated a bearish trend, leading to a decrease in sugar's price during the analysis period, even though Brazil destines more than 50% of cane to produce ethanol. Other arguments establish that the influence of sugar cane bioethanol as a cause for prices imbalances and movements is marginal, since the area that would be required to substitute 10% of the global consumption of diesel with sugar cane bioethanol, would be about 23 million hectares, equivalent to 1.5% of the cultivated area or 0.2% of the agro-cultivable area of the planet (BNDES-CGE, 2008).

Beyond the discussion about the impact of the current demand for biofuels feedstocks on the global prices of agricultural *commodities*, the fact that the consumption of biofuels in USA and the EU is still below the expected goals for the medium term foresees, *ceteris paribus*, an increasing impact on the next years, especially in the case of US corn, where the Renewable Fuels Standard (RFS) of conventional ethanol will continue growing in the next years, until positioning in a level 67% higher than the current RFS in 2015.

⁷⁴ A recent article on the international economic crisis and its impact on agricultural commodities, published by the Cereals Stock Market of Rosario, clearly summarizes the dynamics on which such hypothesis lies: "Speculative funds were the first to find in agricultural feedstocks a voucher for their investments in a market in which the dollar was losing value in comparison with the other currencies and interest rates were decreasing. The participation of these funds started to grow and the market left fundamental elements behind in order to create a bubble from a greater flow of resources, which moved from the financial markets to agricultural markets. The changes in the international context motivated corrections in prices, with important droops in agricultural commodities due to the exit of the funds and the uncertainty of the future perspectives".

The bullish trend on the prices of the cereals and oilseeds of greater use in the production of biofuels will also extend to other crops that could be displaced by those, as well as to land prices.

In the analysis of the impact of biofuels on the prices of agricultural and basic food products, it results relevant to distinguish between the short term and the medium-long term. According to FAO, in the short term the increase of the prices of agricultural *commodities* will determine negative effects on food security in net food-importing developing countries, in poor urban homes and poor net food buyers in rural areas (which determines the strong need to establish adequate security networks in order to assure the access of the poor people to food). In the medium to long term, the growing demand for biofuels and the increase in agricultural basic commodities prices offer the possibility of a response from the supplies and of strengthening and revitalizing agriculture's role as a growing engine in the developing countries (FAO, 2008c).

Likewise, there are different factors capable of significantly reducing the specific impact of biofuels on agricultural commodities and food prices. Some of them are part of the markets' logic of operation, while others depend on politics decisions in the main global producers. Among these factors, the following are highlighted (Ganduglia, 2008):

- Increase of the supply of co-products and by-products of the production of biofuels: a factor not frequently mentioned in the most critical positions towards biofuels is the impact of the co-products and by-products of ethanol's production (distillers grains, gluten feed, cane bagasse) and biodiesel's (protein meals), whose production will substantially increase as the production of these biofuels and/or the installed capacity to produce alcohol and vegetable oils grow. In the case of corn ethanol, 290 kilograms of distillers grains are obtained per each used ton of grain in its production; the same return to the animal feeding circuit⁷⁵. In the case of biodiesel, the expected increase in the production of vegetable oils implies a significant growth in the supply of protein meals and a subsequent bearish trend in their prices that would reduce the tensions generated in cattle production, due to the eventual higher prices of coarse grains.
- The potential of agricultural expansion in certain countries and regions: According to FAO (2002) there are few proofs that suggest a future land scarcity at global level. Currently there are about 1560 million hectares in agricultural use in the world (cropland and permanent crops) and it is estimated that there are about 2000 million additional hectares potentially suitable for rainfed cropping in the world (FAO-IIASA). Excluding forests, protected areas and the necessary land to satisfy the growing demand for cattle and food crops, the approximate figures of the potentially available land to increase the production of crops would be about 250 and 800 million hectares, most of which are in the tropics of Latinamerica and Africa (Fischer cited by Cotula et al, 2008). With Brazil in the forefront, some Latin American (see section 9.2.1) and African countries have possibilities of expanding their agricultural frontier, with which part of the agricultural production deviated to the production of biofuels could be offset with these expansions.
- The level and degree of flexibility of the goals for substituting fossil fuels for biofuels: biofuels represent a complement within a wide variety of alternative sources of renewable energies. Totally displacing the global consumption of fossil fuels for the first generation biofuels would be absolutely unviable. Even a substitution of 20% or 25% would also be impossible under the current technological

⁷⁵ According to statistics published by the Renewable Fuels Association, U.S. ethanol plants produced 14.6 million tons of distillers' grains in 2007. 84% of this production was destined to feed ruminants (42% dairy cattle and 42% beef cattle, respectively), while the rest was distributed in pigs (11%) and poultry (5%). It is important to indicate that the possibilities of incorporation of the distillers' grains to the animals' diet are greater in the case of bovine cattle. In the case of pigs and poultry, since they are mono-gastric animals, the incorporation of distillers' grains to their diet is more limited due to the high variability of their composition.



conditions. The valid goals established in the different countries, obviously including the most ambitious ones, in USA and the EU, they were established without any type of global coordination. The future evolution in the commodities' and food's prices could require a revision of such goals and a greater gradualism and global coordination in the definition of their levels.

- The necessary changes in the markets' interventions: the opening of the main biofuels' markets results essential to decompress the tensions on the feedstocks prices. The high import tariffs on ethanol applied in USA and the EU limit the possibilities of a greater efficiency in the global utilization of the land resource. In the case of USA, for example, under free trade conditions, corn ethanol (that yields 3800 lts/ha) would be partially replaced by Brazilian sugar cane ethanol (with a yield of 7000 lts/ha). In this case, free trade in ethanol would reduce the impact on corn global prices and would also free land for the crops and cattle activities originally displaced by the expansion of corn. On the other hand, a reduction of the great sums that the subsidies to the production of biofuels represent in USA and the EU, would also reduce market's distortions, also leading to a greater efficiency in the use of the land resource globally.
- The reduction of the competitiveness gap of first generation biofuels vs. next generation biofuels. Considering the high participation of the feedstock in the production cost of biofuels, a continuous increase in the currently used available feedstocks' prices, would affect the competitiveness of the first generation biofuels. That would accelerate the transition to the production of biofuels made from lignocellulosic feedstocks (second generation biofuels) or from crops or feedstock less sensitive to competition with the production of food (1.5 generation biofuels). The advance towards these generations of biofuels, and the following ones, will result essential to completely avoid the biofuels vs. food dilemma.
- The impact of research and technological development: Both R&D oriented towards feedstocks and biofuels production processes, as the one oriented to the production of food, will play a key role in terms of increases in yields⁷⁶, improvement and/or development of more efficient productive processes and conversion technologies, joint production of food crops and biofuels crops⁷⁷, utilization of non-food feedstocks and/or marginal land, etc. All these advances would also lead to a greater productivity and more efficient uses of the land⁷⁸, contributing to reduce the bullish trend in food commodities prices.

In the specific case of South America, especially in the Southern Region countries, the possibilities of a conflict between the production of biofuels and foods seem to be reduced a priori, considering the high exportable balances that these countries have in their immediately available feedstocks and their significant potential of agricultural expansion.

⁷⁶ The importance of yields increase in food security is clearly stated in the following example: between the beginning of the sixties and the end of the nineties, the increase of productivity reduced the quantity of land necessary to produce a given quantity of food in 56% approximately. This reduction was made possible due to increases in the yields and the agricultural intensities that enabled increasing the production of food. Therefore, even though during this period the crop land slightly increased 11%, in comparison with almost a duplication of the world's population, there was a considerable improvement in the nutrition levels and a decrease in the real prices of food (FAO, 2002).

⁷⁷ A promissory example is the increasing practice of interspersed crops or intercropping, with cases as the Brazilian farmers of the Northeast, who grow castor interspersed with bean, which enables the joint production of food and feedstock for biofuels.

⁷⁸ A good example of the impact of technological efficiency on the use of land is the technicalness and densification of meat and milk productions in Brazil, which in the last years and as a result of the better management of pastures and their cultivation with better quality forage, supported a greater number of animals per hectare, liberating land for other purposes (BNDES-CGE, 2008). In this country, in the last two decades, pastures in rural properties were reduced 4%, at the same time that the drove's size was enlarged 32% and milk's production grew 67% (IBGE, 2008 mentioned by BNDES-CGE, 2008).

Regarding the availability of exportable balances, it is worth mentioning some exceptions that do have restrictions as cereals' ethanol in Chile, Bolivia and the Andean region's countries, sugar cane ethanol in Venezuela, Chile and Uruguay, soybean oil biodiesel in the Andean region's countries or palm oil biodiesel in Venezuela and Peru and the Southern Region's countries. Nevertheless, except for Chile and to a certain extent Ecuador, the rest of the region's countries have a high potential for expanding their agricultural frontiers, determined by potentially cultivable land's endowment, thus, the mentioned restrictions could be overcome in the medium term.

Considering their current (highly a surplus) and potential availability of food resources, the food concern of the region is not related to food production, but to the access to it, which is determined by poverty and inequality levels. Even though it could be argued that food access is an income distribution problem, foreign to biofuels, the possible impact of an increase in food's prices level cannot be denied.

In this regard, FAO establishes that it is very probable that the fast expansion of biofuels production in the world causes important effects on the Latin American agricultural sector in the short term, leading to changes in the demand, in foreign trade, in the allocation of productive inputs (land, water, capital, etc.) and finally, an increase in the prices of energy and traditional crops, that could put food access in risk for the poorest sectors (FAO 2008a).

In relation to such proposal, it is important to distinguish between the different types of biofuels feedstocks and their incidence on the basic diet of people. Thus, while cereals are a part of the base of the food pyramid, fats, oils and sweets (food with a high concentration of sugar) are in the top of such pyramid, among the food recommended to be consumed in a limited or moderate way.

On the other hand, according to FAO, biofuels programs may represent an opportunity if they are focused on small agriculture with little markets access capacity: with the creation of new markets and the integration of the small farmer in the productive chain, peasant families will obtain higher and more stable incomes. In order to make this possible; governments should establish adequate support policies and mechanisms (financial, technological, organizational, etc) that guarantee and promote food access for the most vulnerable sectors (FAO 2008a).

FAO's food security policies recommendations are still of application to biofuels' context. In particular, this institution considers that, for the purposes of generating food security guarantees, governments should adopt policies that⁷⁹:

- favor technologies that can reduce the competition with food supply, in particular bioenergy based upon organic wastes and residues;
- support second generation technology's development using lignocellulosic material and feedstock production on land non suitable for food production;
- assess the socio-economic vulnerability and livelihood impacts of communities affected by the biofuels production such as labor relations, land management and tenure systems;
- discourage large scale cultivation patterns in areas characterized by high poverty, land shortages, land conflicts or tenure insecurity.
- avoid cultivation of water intensive feedstocks and production methods in water-scare environments.
- establish maximum thresholds for biofuels production based on assessments of local risks and vulnerabilities;
- create multi-stakeholder decision-making mechanisms on biofuels production at national and local spheres.

⁷⁹ FAO (2008e).

9.3.2 Biofuels and environmental sustainability

9.3.2.1 Agriculture and environment

One of the main arguments that has led to the promotion and use of biofuels in the world is based on their potential to generate environmental improvements through the reduction of GHG emissions. However, controversies and a profound debate on the environmental impact of the biofuels global chain development have arisen in the last few years. The questions mainly aim at the environmental value of first generation biofuels and, to a lesser extent, of second generation biofuels.

The environmental aspects on debate have to do with:

- a) Risks and eventual negative externalities usually associated with certain conventional agriculture practices;
- b) The energy and environmental efficiency of biofuels produced from different feedstocks⁸⁰ (see section 9.3.2.2).

Regarding the first point, a disorganized development of energy crops to satisfy the demand for biofuels feedstocks could lead to non sustainable processes of expansion of the agricultural frontier or of production intensification, with negative consequences for people and the environment (Table 9.3.2.1)

Table 9.3.2.1: Common practices in conventional agriculture and its consequences

Common practices	Consequences
Deforestation	Loss of biodiversity
Continuous ploughing and harrowing	Loss of soil fertility and decreasing yields
Removal or burning of crop residues	Erosion
Mono-cropping	Increased drought and flood risks
Excessive use of fertilizers	Food insecurity and health risks
Misuse of pesticides	Contamination of ground and surface water
Misuse of water	Contamination and degradation of soils
	Greenhouse gas release
	Pest invasions

Source: FAO

Non sustainable processes of agricultural frontier expansion, based on the deforestation and/or advance of monocultures at large scale, generate a negative impact on the wild and agricultural biodiversity. Likewise, the advance of the agriculture on forest land may release great quantities of carbon, leading to an increase in GHG emissions that would take years to recover through the emission reduction achieved by substituting biofuels for fossil fuels (FAO 2008c). The agricultural frontier expansion process in many countries of the region occurred since the beginning of the nineties, registers relevant antecedents of native forests' clearing, with the subsequent loss of wild biodiversity, as well as the extension of large scale monocultures with the subsequent loss of agricultural biodiversity. These processes have been associated with different agricultural

⁸⁰ Energy efficiency means the energy generated by the biofuel and, according to the methodology, its co-products or by-products – in relation to the energy used for its production, throughout the product's chain or life cycle. Environmental efficiency means the GHG reduction by the biofuels in comparison with fossil fuels, considering GHG emissions throughout the chain and including the effects of land use change.

and forest activities, among them soybean cultivation in Southern Region's countries and oil palm cultivation in Andean Region's main producers.

The intensification processes have the advantage of facilitating the increase of crops' yields and their production, without generating pressures on biodiversity. However, if they are based on inadequate agricultural practices, such as conventional tillage (continuous plowing and harrowing), lack of crop rotation, removal or burning of agricultural residues, excessive or inadequate use of fertilizers, misuse of pesticides or misuse of water, the consequences are extremely negative in terms of erosion, nutrients' depletion and loss of soil's fertility and its future agricultural production capacity, of air, water and soil pollution, as well as in terms of greenhouse gases emissions. As it is detailed herewith, South American agriculture is developed under conservation and environmentally sustainable practices in a very high proportion of its cultivated area, with Southern Region countries leading the statistics on conservation agriculture at global level. Nevertheless, certain practices and concrete situations in certain countries and/or zones need to be attended and overcome, such as the development of monocultures at large scale and the lack of crops rotation organized plans - with its impact in terms of soils degradation -, the intensive use of agrochemicals - with their impact on soils, air and water quality – the sugar cane foliage burning that generates GHG, or the introduction of foreign crops, which could cause the occurrence of new diseases, scrubs and plagues.

In relation with the aforementioned, the concept of sustainability acquires a key role. In a broad sense, sustainable agriculture is defined as an economically viable, technologically adequate, socially acceptable and environmentally healthy system, in a context of favorable policies (IICA, 2000). From a strictly environmental point of view, agriculture's sustainability is associated with the environment's preservation and the conservation of productive resources, through instruments like Spatial Planning and agro-ecological zoning, and of sustainable production systems as *conservation agriculture* (see below).

Both from the point of view of environmental risks linked to agricultural frontier expansion processes, as those linked to intensification, South American countries usually have legal tools and important experiences in conservation agriculture, whose improvement and greater applicability and/or spread would result essential to reduce the eventual negative externalities that the expansion of the agricultural production for biofuels could have on the environment.

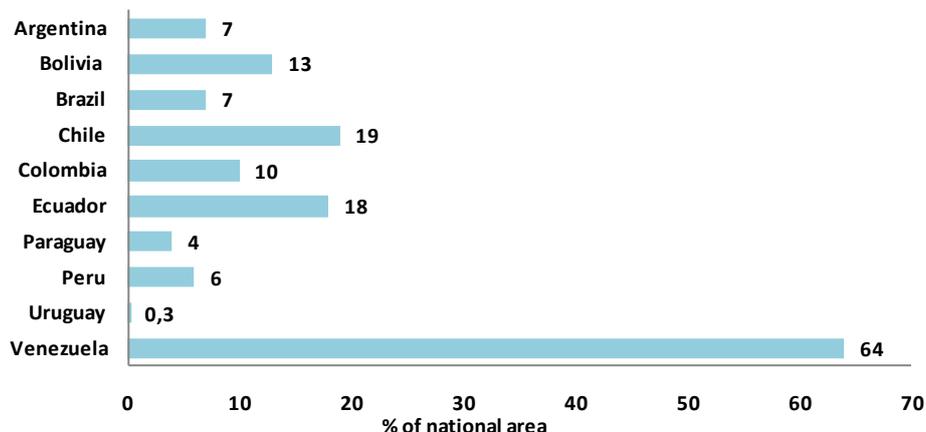
Expansion of the agricultural frontier and environmental sustainability

The region's countries have spatial planning legislations and/or plans and programs⁸¹ –many of them with recent and important advances, as in the case of Argentina, Uruguay and Venezuela⁸² – institutional dependencies that undertake spatial planning, ministries and institutions in charge of environmental management, environmental laws, forestry codes and protected natural areas that aim at, among other objectives, the conservation and responsible management of natural resources, the environmental protection and the rational utilization of land.

⁸¹ According to FARN (Environment and Natural Resources Foundation), spatial planning aims at defining the territory geographical distribution of agricultural, livestock and forest areas, productive and commercialization centers, and protection areas, as well as links and connections between these activities. This will enable to control the spontaneous growth of human activities, to avoid the problems and imbalances it causes, guided by a main principle: every action should be situated where the capacity or aptitude of the territory admitting it is maximized and, at the same time the negative impact or adverse effect of the activity on the environment is minimized (FARN, 2007).

⁸² Argentina: Law 26.331 of Minimum Provisions for the Environmental Protection of Native Forests (2007); Uruguay: Law 18.308, of Sustainable Spatial Planning (2008); Venezuela: Act for Spatial Planning Organization and Management (2006).

Graph 9.3.2.2: Wild protected areas in South American countries (Categories I-IV according to IUCN classification) in proportion to national surface areas. 2003



Source: WRI, 2003 (based on UNEP- WCMC, UNESCO, IUCN, CITES data)

It is important to indicate that between 1997 and 2007, protected areas in Latin America were duplicated, from 160 to 300 million hectares. Of this total, about 270 million protected hectares are concentrated in South America. During this period, important advances were made in the conceptual, regulatory and institutional frameworks of conservation and protection of biodiversity, through spatial planning laws, plans and programs and specific laws for protected areas, increase in the hierarchy of the institutions in charge of conservation (including the creation of environmental ministries), advances in the emergence of protected areas' subsystems (provincial, municipal and private levels) and in the development of participatory processes with the local communities, creation of National Funds for conservation in some countries (tending to compensate jurisdictions for preserved native forests environmental services), among others.

As an example, some recent experiences and advances in countries of the region which tend to coordinate spatial planning with the agricultural frontier expansion are worth mentioning. These measures could result essential regarding the establishment of limits and the generation of a sustainable expansion of the agricultural frontier in the face of the expected increase in the demand for feedstocks for biofuels.

Argentina enacted the *Minimum Provisions for the Environmental Protection of Native Forests* law at the end of 2007, with the following objectives: a) to promote forest preservation through the Spatial Planning of Native Forests and the regulation of the agricultural frontier expansion and any other change in soil use; b) to regulate and control the reduction of existent native forests, in order to achieve a long-lasting area; c) to improve and maintain the ecological and cultural processes in native forests that benefit the society; d) to preserve forests whose environmental benefits or damages generated by their absence cannot be yet demonstrated with the currently available techniques; e) to promote enrichment, conservation, restoration, improvement and sustainable management activities of native forests. Among its dispositions, this Law establishes that all Argentinean provinces must carry out, within a maximum term of a year as from its enactment, a Spatial Planning of native forests⁸³. In this respect the Law establishes three preservation categories for the Spatial Planning of native forests⁸⁴, which must be based on environmental sustainability criteria for the determination

⁸³The provinces that do not carry it out will not be able to authorize clearings or any other type of utilization or exploitation of native forests. No clearings shall be authorized during the course of time between the law's enactment and the performance of the Territorial Planning by each province.

⁸⁴ The preservation categories are:

of the environmental value of native forests units and the environmental services they render⁸⁵. The Law also creates the National Fund for the Enrichment and Preservation of Native Forests, with the purpose of compensating the provinces that preserve native forests, for the environmental services they provide.

In Brazil, the Government is developing the *Agro-ecological Zoning* of sugar cane, in order to generate technical information that enables the Government to define specific policies and foster the sustainable expansion of sugar cane. The objectives of agro-ecological zoning are: identifying areas with agricultural potential (soil and climate) for the cultivation of sugar cane with mechanical harvest; b) identifying the areas with cultivation potential currently used with pastures; c) identifying the potential areas that do not have environmental restrictions. Agro-ecological zoning of sugar cane is an initiative of structural and preventive nature, a pioneer at national level (Cid Caldas, 2008). In line with this initiative, at the end of 2008, officers of the Brazilian government publicly manifested the imminent exclusion of the Amazonia, El Pantanal, and areas with native vegetation, from the location where sugar cane will be grown.

Another Brazilian initiative without antecedents, in this case generated from the private sector, is the *Soybean Moratorium in the Amazon Biome*, launched in 2006 by the Brazilian Association of Vegetable Oil Industries (ABIOVE) and the National Association of Cereal Exporters (ANEC). These entities took the commitment to implement a governance program whose objective is not to commercialize the soybean produced in deforested areas of the Amazon Biome for a period of two years (extended for one more year, until mid 2008), with the intention of curbing deforestation in such region. The sector took the commitment to work jointly with government's entities during such period with the object of: a) elaborating and implementing a mapping and monitoring system of the increases in deforestation related to soybean production in the Amazon Biome; b) refining institutional relations and legislation in order to enhance controls over deforestation and development of soybean production in the Amazon Biome, collaborating with and asking the Government to apply public policies and comply with legislation.

It is worth mentioning that, according to some observers, the legal framework established by Brazil for forestry and environmental protection is among the most progressive in the world (ORNL, 2008). In this framework, and with the objective of reducing deforestation, private land owners are required to set aside part of their property as forest reserves (between 20% and 80% depending on the localization) and to permanently protect all riparian areas (ORNL, 2008).

In Colombia, the World Wildlife Fund and the National Federation of Oil Palm Growers (Fedepalma), with the support of the Ministries of Environment, Housing and Territorial Development and Agriculture and Rural Development, are carrying out an initiative that aims at implementing sustainable practices with Colombian ecosystems that avoid deforestation in identified High Conservation Value Areas (HCVAs)⁸⁶ and that at the

Category 1 (red): sectors of very high preservation value which must not be transformed. This category will include areas that, due to their locations next to reserves, their connectivity value, the presence of outstanding biological values and/or the protection they have on basins, their persistence as perpetual forests is deserved, even though they are habitat of indigenous communities and object of scientific research. No clearing of native forests classified under this category may be authorized.

Category II (yellow): Sectors of medium preservation value which may be degraded but, to the jurisdictional enforcement authorities' judgment and after restoration activities, may acquire a high conservation value and be used for: sustainable exploitation, tourism, scientific sampling and research. No clearing of native forests classified under this category may be authorized.

Category III (green): sectors of low preservation value that may be partially or totally transformed within the criteria of this law.

⁸⁵ The sustainability criteria for the estimation of the conservation value are based on: 1. Area. 2. Link with other natural communities. 3. Link with existent protected areas and regional integration. 4. Availability of existent biological values. 5. Connectivity between eco-regions. 6. Preservation status. 7. Forest potential. 8. Agricultural sustainability potential. 9. Basins' conservation potential. 10. Value granted by the indigenous and farmer communities to forest areas and bordering areas and the use they can make of their natural resources for the purposes of their survival and maintenance of their culture.

⁸⁶ Defining HCVAs as those areas with environmental, socio-economic or cultural values of importance for the local communities, the local and regional economy and the local, regional, national and global environment, and considering 6 types of "high conservation

same time, improve the living conditions of ethnic and peasant communities' who work in the sector, everything in accordance with the Roundtable on Sustainable Palm Oil (RSPO) guidelines. At the same time, the identification process of HCVA's constitutes an input for the identification of high environmental, social and cultural sensitivity areas in the updating of the Zoning Map of suitable areas for the cultivation of oil palm in Colombia with environmental criteria, in the framework of the "Zoning of suitable areas for the cultivation of oil palm" Project (IGAC- MAVDT-IDEAM-Cenipalma, with the technical support of the IAvH and WWF).

For the purposes of guaranteeing a sustainable expansion of feedstocks production for biofuels, in the future, progress made by countries in matters of institutional consolidation and policies and programs of spatial and environmental planning and of agroecological – economic zoning, as well as its coordination with sectorial policies and plans will be essential. Another key aspect consists of guaranteeing the compliance with legal dispositions – many times ignored by the expansion process of agricultural frontiers in the last decades – through the strengthening of the corresponding institutional bodies and a greater availability and modernization of control and monitoring systems.

Some evaluation studies of land availability at large scale⁸⁷ show first approximations that would enable to deduce that the region has certain land categories on which an environmentally sustainable expansion of the agricultural frontier could be based. Fischer and others (2002) estimate, based on satellite images (1995-1996) that the potentially cultivable land in South America, discounting the land covered with forests, is 552 million hectares (of which currently only 22%, about 120 million hectares are under agricultural use). Of this total, 96 million hectares moderately suitable for cultivation could be considered as marginal (FAO 2008c). Houghton (1990) estimates a total area of 100 million hectares of degraded land in South America; while Field (2007) calculates, though at global level, the existence of 386 million hectares of abandoned cultivable land (with a margin of error greater than 50%) (Cotula et al, 2008). FAO proposes that, even though marginal or degraded land would be less productive and would be subject to greater risks, using them for bioenergy plantations could have secondary benefits such as restoration of degraded vegetation, carbon sequestration and local environmental services. Nevertheless, in most countries, the suitability of this land for the sustainable production of biofuels is poorly documented (FAO, 2008c).

In line with the aforementioned, it will be necessary for region's countries to advance in the mapping and zoning of potentially cultivable, marginal or idle lands and high conservation value areas, in order to obtain more specific and detailed information for a more accurate evaluation of the sustainable expansion potential of biofuels feedstocks.

Intensification of agricultural production and environmental sustainability

When environmental sustainability is analyzed in terms of the impact on air's, soil's and water's quality by the intensification of agricultural activity, the type of agricultural production system results determinant, and a clear contrast between conventional agriculture and conservation agriculture is reflected.

Conservation agriculture (Table 9.3.2.3) is a series of techniques with the essential objective of preserving, improving and making a more efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs, contributing to environmental conservation as well as to enhanced and sustained agricultural production (FAO, 2001). This system includes a group of agricultural practices based on three main principles (FAO):

values": Biological richness, Ecosystem integrity, Ecosystem singularity, Delivery of environmental services for local/regional people, Socio-economic importance for local people, Cultural/religious importance for local communities.

⁸⁷ Fischer et al (2002), Field et al (2007) and Houghton (1990, cited by Field), cited by Cotula (2008).

1. Minimal soil disturbance through no-till (direct sowing or zero tillage) or reduced tillage in order to preserve the soil's organic matter.
2. Permanent soil cover (cover crops, residues and mulches) to protect the soil from the sun and rain and enable soil's microorganisms and fauna to “plow” and maintain the nutritious elements’ balance, natural processes that mechanical plow harms.
3. Rotation and association of diverse crops, which promotes soil's microorganisms and disrupts plant pests and diseases.

Table 9.3.2.3: Basic concepts and principles of Conservation Agriculture

Concept of Conservation Agriculture	
<p>Conservation agriculture (CA) is a concept for resource-saving agricultural crop production that strives to achieve profits together with high and sustained production levels while currently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of organic or mineral origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes.</p>	
Basic principles of Conservation Agriculture	
<p>Conservation agriculture is characterized by three interrelated principles:</p>	
<p>1. Direct seeding with minimum soil disturbance</p>	<p>Direct seeding involves growing crops without mechanical seedbed preparation and with minimal soil disturbance since the harvest of the previous crop. The term direct seeding is understood in Conservation Agriculture as a synonymous with non-till farming, zero tillage, no-tillage, direct drilling, etc. Land preparation for seeding or planting under no-tillage involves slashing or rolling the weeds, previous crop residues or cover crops; or spraying herbicides for weed control, and seeding directly through the mulch. Crop residues are retained either completely or to a suitable amount to guarantee the complete soil cover, and fertilizer and amendments are either broadcast on the soil surface or applied during seeding.</p>
<p>2. Permanent organic soil cover, by crop residues and other crops</p>	<p>A soil permanent cover is important to:</p> <ul style="list-style-type: none"> - Protect the soil against the deleterious effects of exposure to rain and sun; - Provide the micro and macro-organisms in the soil with a constant supply of "food"; - Alter the micro-climate in the soil for optimal growth and development of the soil organisms, including plant roots. <p>Effects of the soil cover:</p> <ul style="list-style-type: none"> - Improved infiltration and retention of soil moisture resulting in less severe, less prolonged crop water stress and increased availability of plant nutrients. - Source of food and habitat for diverse soil life: creation of channels for air and water, biological tillage and substrate for biological activity through the recycling of organic matter and plant nutrients. - Increased humus formation. - Reduction of impact of rain drops on soil surface resulting in reduced crusting and surface sealing. - Consequential reduction of runoff and erosion. - Soil regeneration is higher than soil degradation. - Mitigation of temperature variations on and in the soil.
<p>3. Diversified crop rotations in the case of annual crops or plant associations in case of perennial crops</p>	<p>The rotation of crops is not only necessary to offer a diverse "diet" to the soil micro organisms, but as they root at different soil depths, they are capable of exploring different soil layers for nutrients. Nutrients that have been leached to deeper layers and that are no longer available for the commercial crop can be "recycled" by the crops in rotation. This way the rotation crops function as biological pumps. Furthermore, a diversity of crops in rotation leads to a diverse soil flora and fauna, as the roots excrete different organic substances that attract different types of bacteria and fungi, which in turn, play an important role in the transformation of these substances into plant available nutrients. Crop rotation also has an important phytosanitary function as it prevents the carry over of crop-specific pests and diseases from one crop to the next via crop residues.</p>



<p>3. Diversified crop rotations in the case of annual crops or plant associations in case of perennial crops</p>	<p>The effects of crop rotation:</p> <ul style="list-style-type: none"> - Higher diversity in plant production and thus in human and livestock nutrition. - Reduction and reduced risk of pest and weed infestations. - Greater distribution of channels or biopores created by diverse roots (various forms, sizes and depths). - Better distribution of water and nutrients through the soil profile. - Exploration for nutrients and water of diverse strata of the soil profile by roots of many different plant species resulting in a greater use of the available nutrients and water. - Increased nitrogen fixation through certain plant-soil biota symbionts and improved balance of N/P/K from both organic and mineral sources. - Increased humus formation.
<p>Agro-environmental features of Conservation Agriculture</p>	
<p>Soil loss does not exceed rates of soil formation.</p>	
<p>Soil fertility and soil structure are maintained or enhanced.</p>	
<p>Biodiversity is maintained or enhanced.</p>	
<p>Downstream effects of run-off or leaching do not impair water quality.</p>	
<p>Rainfall is managed to avoid excessive runoff.</p>	
<p>Emissions of greenhouse gases are reduced.</p>	
<p>Food production levels are maintained or enhanced.</p>	
<p>Environmental stewardship is engendered amongst rural communities and producers of all types, ensuring continuity of sound land management</p>	

Source: FAO – Agriculture and Consumer Protection Department

According to FAO, conservation agriculture has diverse agronomic and environmental benefits, among them, the increase of organic matter and conservation of water in soil, the improvement of soil structure and subsequently of the rooting zone, the reduction of soil erosion, the improvement of water and air quality, and the increase in biodiversity and carbon sequestration. According to SAGPyA⁸⁸, no-till farming, as a system to maintain and preserve a surface with important levels of coverage contributed by the crop residues, enables controlling erosion, increasing the content of organic matter and improving the soil's physical, chemical and biological properties. These crop residues are considered one of the greatest benefits on soil's conservation, since residues on surface avoids the direct beat of the rain, reduces runoff and evapotranspiration and favors humidity's infiltration and conservation, thus achieving a more efficient use of water, resource that in rainfed crops is generally the limiting factor of production (SAGPyA, 2007). No-till farming also reduces the consumption of fossil fuels⁸⁹, which added to a lower emission of carbon dioxide (due to the absence of tillage) and to carbon sequestration (due to the increase of organic matter) helps to mitigate greenhouse gases emissions (AAPRESID, 2005).

As it was mentioned previously, South America registers an important experience in adoption of conservation agriculture, specifically in the Southern region's countries, which concentrate about 50% of the global cultivated area under conservation techniques.

Brazil and Argentina are, together with USA, among the countries with larger cultivated area with permanent soil coverage and with no-till or minimal tillage. Likewise, Uruguay (77%), Argentina (67%), Paraguay (49%) and Brazil (38%), register the highest adoption rates of the world, in terms of area under conservation agriculture as a percentage of the total cultivated area (Table 9.3.2.4). The adoption rates register much faster growths in South America than in the rest of the world (the area under conservation agriculture in the region

⁸⁸ Secretary of Agriculture, Livestock, Fishing and Food of Argentina.

⁸⁹ In comparison with conventional tillage, direct sowing represents 66% less of fuel consumption (AAPRESID).

increased from 670,000 hectares in 1987 to about 48 million hectares in 2006)⁹⁰. Moreover, the quality of the adoption in South America is higher in terms of non tillage permanence and permanent coverage of the soil (Derpsch, 2005). In that respect, according to Derpsch, in Argentina, Brazil, Bolivia and Paraguay more than 90% of the cultivated area with direct sowing is permanently permanently not being tilled (without the occasional presence of tillage). In contrast, in USA, barely 10% - 12% of the no-till area does not receive tillage sporadically (CTIC, 2005, cited by Derpsch). Derpsch and Benites (cited by Lorenzatti, 2006), estimate that in less than a decade permanent direct sowing will cover more than 85% of the cultivated area in Argentina and Brazil.

Table 9.3.2.4: Conservation agriculture in the world

Country	Year	Conservation agriculture area (1000 ha)	Conservation agriculture area as % of cultivated area
Brazil	2006	25,502	38.3%
USA	2005	25,252	14.3%
Argentina	2006	19,719	66.8%
Canada	2006	13,481	25.9%
Australia	2005	9,000	18.1%
Paraguay	2007	2,094	48.7%
Kazakhstan	2007	1,791	8.0%
Uruguay	2006	1,082	76.7%
Bolivia	2005	550	16.9%
South Africa	2005	300	1.9%
Spain	2005	300	1.6%
Venezuela	2005	300	8.7%
England	1984	275	3.9%
France	2005	150	0.8%
Chile	2005	120	5.2%
Colombia	2005	102	2.8%
China	2005	100	0.1%
New Zealand	1984	75	2.0%
Mexico	2007	23	0.1%
Holland	1984	5	0.6%

1. Land cover > to 30% + disturbed area less than 15 cm wide or 25% of the cropped area (whichever is lower)

Data includes both crop rotation and monoculture.

Source: Elaborated by IICA-Argentina based on FAO, 2008. AQUASTAT Database: <http://www.fao.org/ag/aquastat>

The adoption of direct sowing in the Southern Region's countries helped to revert soil degradation, enabled the expansion of agriculture and livestock in marginal areas, it improved agriculture's profitability and increased the sustainability of the agricultural systems (Ekboir 2001, cited by Lorenzatti).

One of the main challenges of conservation agriculture in the Southern Region's countries consists of advancing in the generalization of the adoption of its third pillar: crops rotation. The Ministers of Agriculture of

⁹⁰ Derpsch, cited by Lorenzatti, identifies 10 key factors or causes that favored this phenomenon: 1) efficient and economic erosion control under climate conditions with high erosion and soil degradation potential; 2) suitable knowledge was available in the region through research and development of technologies as well as farmers' experiences; 3) wide utilization of green fertilizers and coverage crops for weed suppression, organic matter build up and biological pest control; 4) the same positive message about no-tillage was consistently spread by all involved sectors; 5) No-tillage has been the only conservation tillage technology recommended to farmers; 6) a strong spread from farmer to farmer through farmers' associations; 7) publications with adequate and practical information were made available to farmers and extensionists; 8) economic returns favorable to no-tillage; 9) inexistence of major forces against the system; 10) Latin American farmers have been very competitive in the global market, due to the absence of subsidies, incorporating technologies as no-tillage in order to go on being competitive.

the Southern Region, in a recent declaration⁹¹, stated that in most countries, a sustained advance of agricultural production was registered since the beginning of the nineties, accompanied by an extraordinary growth in the cultivated area, particularly with soy, and a tendency towards the simplification crops rotations with negative consequences regarding the soil's conservation and environmental sustainability of the system. Lorenzatti (2006) proposes that in Argentina, the fast growth of no-tillage was produced with a much greater relative increase of soy than of other crops, which indicates that crops rotation practices are not being carried out in the necessary magnitude and intensity. According to AAPRESID⁹², cited by Lorenzatti, "there will be access to all benefits as long as complexity of the agro-ecosystems in which farmer works is understood and the timing of the biological cycles is respected over the urgencies demanded by immediate profitability. Thus, besides the absence of removal, there will be need of a rotation adjusted in diversity - number of different crops - and intensity - number of crops per unit of time - together with a fertilization strategy that at least replaces the nutrients that currently show response (nitrogen, phosphorus and sulphur), all that, accompanied by process and product technologies that enable a more efficient and adjusted use of inputs, with a lower negative environmental impact".

In the case of the Andean Region's countries, that despite their growth still register lower levels of adoption of direct sowing and permanent soil coverage with organic matter, the progress in terms of policies that promote the adoption of these practices, the access and spread of knowledge (*know how*), especially in agronomic management, and the availability of adequate machinery, among other relevant factors, will be essential.

To these mentioned good agricultural practices, other relevant ones for the environmental sustainability of increasing application in the world and the region are summed up, such as integrated pest management (IPM)⁹³, optimization in the use of agrochemicals, rational utilization of fertilizers with nutrients restitution criteria, utilization of organic fertilizers, rational use of supplementary irrigation and Precision Agriculture⁹⁴. This type of practices aim at achieving that the use of inputs as insecticides, agro-chemicals and nutrients of mineral origin are applied in optimal levels and in quantities that do not interrupt the biological processes. Likewise, advances in legislation and practice of the elimination of pre-harvest and post-harvest residues burning, the application of clean technologies- as "green harvesting" in the case of sugar cane-, the application of the adequate treatments and uses of effluents as mud and alcohol's distilling vinasse⁹⁵, the efficient use of energy and the utilization of renewable energies in the processes, also represent essential contributions to the environment's preservation.

⁹¹ Southern's Agricultural Council (CAS). Sustainability of the agricultural production regarding soil's use and conservation policies. Ministers' declaration. Montevideo, 4th. and 5th. December, 2008.

⁹² Argentine No-till Farmers Association.

⁹³ According to FAO's definition, IPM means "the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment". IPM integrates different methods of fighting against plagues (biological, physical or mechanical, ethological, cultural practices, legal, chemical-selective, etc.) - compatible – and preferably not toxic for the environment - and adaptable to agro-ecological and socio-economic conditions of each specific situation. According to FAO, IPM enables farmers to control plagues in their fields, reducing to the absolute minimum the utilization of expensive chemical and potentially harmful and dangerous insecticides.

⁹⁴ Precision agriculture is a group of new tools to improve the efficiency of agricultural production, considering as a premise the very precise recollection of geo-referential data about soil's characteristics; nutritional status and crops water availability; the composition of crops' scrubs' or diseases' population and their relation with the variable yield of a batch; after that with the data, design the most convenient and sustainable diagnosis, and should it be necessary, apply the inputs according to the effective need of the different areas of a batch or field, in order to increase the benefits and maintain the environment's quality (National Project Precision Agriculture, INTA-Manfredi).

⁹⁵ In that respect, it is worth mentioning the case of vinasse treatment in the production process of ethanol in the Colombian sugar industry, considered an example for the world of the environment's care: in the distilleries of the sector a maximum of 3 liters of vinasse per each liter of ethanol are produced, whereas in other countries about 14 liters per liter of ethanol are produced (ASOCAÑA).

The recent declaration of the Ministers of Agriculture of the Southern Agriculture Council (CAS)⁹⁶ about agricultural production sustainability reveals the guidelines to follow in matters of agricultural sustainability policies. In such declaration the Ministers committed themselves to perform the greatest efforts to:

- Promote activities that generate a balance between competitiveness and social equity of CAS countries, that enable a sustainable agricultural production;
- Maintain and increase the activities destined to the sustainability of agriculture, promoting an adequate crops rotation and the rational practice of fertilization;
- Collaborate in the oversight and control of the compliance with the valid regulation;
- Promote an integrated policy of conservation, recovery and soils use based on potentialities and productive regionalization studies, for the different agricultural entries;
- Pay especial attention to the water resource as a decisive component of the productive use of soils and to the subsequent weakening of the groundwater and surface hydrographic basins;
- Foster training, extension and instruments focalization initiatives oriented to the sustainable use of agricultural production according to type of producer and level of production;
- Encourage the horizontal cooperation between the countries and their different actors for the spreading of policies, programs and impact projects on the good use of soils for agricultural production.

Water, agriculture and biofuels

Considering that approximately 70% of the fresh water employed globally is destined to agricultural uses, the impact of biofuels production on water availability deserves an especial comment.

The utilization of water in agricultural activity has increased continuously in time. Demographic growth, economic development and urbanization suppose an additional and increasing pressure on the use of water resources, whose availability for agriculture becomes increasingly scarce in many countries, as a consequence of the greater competition with domestic or industrial uses. According to FAO, water, rather than land, scarcity may prove to be a restricting factor for biofuel feedstock production in many contexts (FAO, 2008c).

Currently, biofuels are responsible for 1% of all water transpired by crops worldwide, and 2% of all irrigation water withdrawals (de Fraiture et al, cited by FAO, 2008c).

Among feedstocks for biofuels production, sugar cane and oil palm have high water requirements (1500-2500 mm/year), whereas cassava, castor, cotton, corn and soybean have medium requirements (500-1000 mm/year) (FAO, 2008a). In countries with water scarcity, where agriculture lies essentially on irrigation, an increase in biofuels production represents an extra pressure on its water stress levels. Nevertheless, it is important to highlight that it is the proportion of irrigation water used to reach such demands, the one that will determine the pressure on water resources (FAO, 2008b).

Globally, as it is shown in the following tables and maps, South America is in a privileged situation in terms of availability of per capita and total renewable water resources (it has the greatest endowment of the planet), and of fresh water withdrawal, total and for agricultural purposes, as share of its renewable water resources. In all the region's countries, the proportion of water used in agriculture in relation to their renewable water resources endowment is in levels substantially lower than 5%, far away from those considered as critical (>40%) and of water stress (20%-40%). Likewise, agriculture in most countries is not noticeably dependent on

⁹⁶ Argentina, Bolivia, Brazil, Chile, Paraguay and Uruguay.

irrigation. It is also worth mentioning that in the cultivated area under conservation agriculture there is a saving in the consumption of water and an efficient use of it.

Even though the aforementioned suggests that, in contrast to the critical situation of water in other regions of the world, in general South America will not be affected by an eventual biofuels vs. water dilemma, it is important to mention that agriculture in some countries of the region (Peru, Chile, Colombia and Ecuador) has a relatively high dependence on irrigation, and water scarcity is a critical problem in certain areas of the continent, as the Northeast of Brazil, the desert coast of the Peruvian-Chilean Pacific⁹⁷ or the Colombian-Venezuelan Caribbean. According to FAO, in the zones with rain water scarcity, the utilization of this resource for energy crops irrigation should be carefully evaluated, prioritizing its use in food agriculture (FAO, 2008d).

Table 9.3.2.5: Global availability and utilization of renewable water resources

Continent/Region	Internal renewable freshwater resources			Total volume of freshwater utilization	Freshwater withdrawal by sector						Irrigated land (2003)		
					Domestic	Industrial	Agricultural	Withdrawal as % of internal renewable water resources	Area (million of hectares)	As % of cultivated land			
	Volume per year (km ³ or 10 ⁹ m ³)	In % of world freshwater resources	Per habitant in 2003 (m ³)	km ³ / year	km ³ / year	%	km ³ / year	%	km ³ / year	%			
World	43 659	100,0	6 900	3 830	381	10	785	20	2 664	70	8,8	277,1	17,9
Africa	3 936	9,0	4 600	215	21	10	9	4	184	86	5,5	13,4	5,9
Asia	11 594	26,6	3 000	2 378	172	7	270	11	1 936	81	20,5	193,9	34,0
Latin America	13 477	30,9	26 700	252	47	19	26	10	178	71	1,9	17,3	11,1
Caribbean	93	0,2	2 400	13	3	23	1	9	68	14,4	1,3	18,2	
North America	6 253	14,3	19 300	525	70	13	252	48	203	39	8,4	23,2	9,9
Oceania	1 703	3,9	54 800	26	5	18	3	10	19	72	1,5	2,8	5,4
Europe	6 603	15,1	9 100	418	63	15	223	53	132	32	6,3	25,2	8,4

Source: FAO 2006. AQUASTAT Database <http://www.fao.org/ag/aquastat>

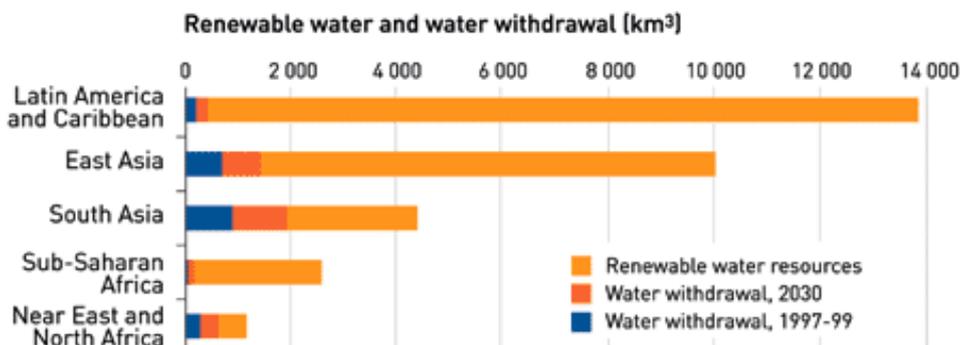
Table 9.3.2.6: Renewable water resources and agriculture in South America

	Total renewable water resources (10 ⁹ m ³ /yr)	Total renewable water resources per capita (m ³ /inhab/yr)	Agricultural water withdrawal as % of the total water withdrawal	Agricultural water withdrawal as % of total renewable water resources	Freshwater withdrawal as % of total renewable water resources	
Southern Region	Argentina	814	20,800	73.7	2.64	3.57
	Brazil	5,418	28,618	61.8	0.45	0.72
	Paraguay	94	15,626	71.4	0.10	0.15
	Uruguay	59	17,711	96.2	2.18	2.27
	Bolivia	304	32,450	80.6	0.19	0.23
	Chile	884	53,688	63.5	0.86	1.36
Andean Region	Venezuela	722	26,569	47.4	0.32	0.68
	Colombia	2,112	46,358	45.9	0.23	0.50
	Ecuador	432	32,722	82.2	3.29	4.00
	Peru	1,616	58,575	81.6	0.86	1.05

Source: FAO. 2009. AQUASTAT Database <http://www.fao.org/ag/aquastat>

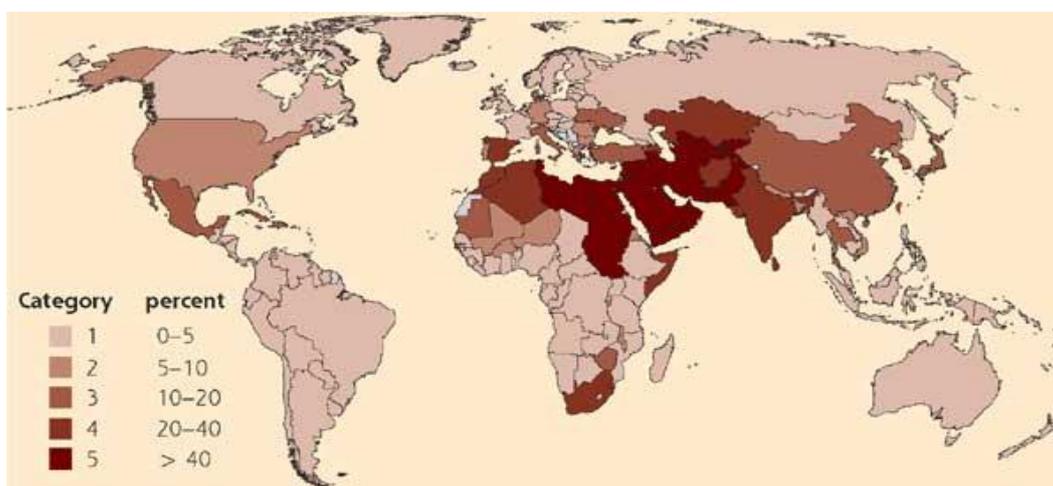
⁹⁷ For example, in Peru, the availability of water resources is highly concentrated on the Jungle region (80% of the total), whereas the Coast region, the most populous, barely has 2% of the resource, leading to a substantial difference in the availability of the resource per capita: 432,052 m³ in the Jungle against 3,060 m³ in the Coast.

Graph 9.3.2.7: Renewable water resources and projected water withdrawal to 2030



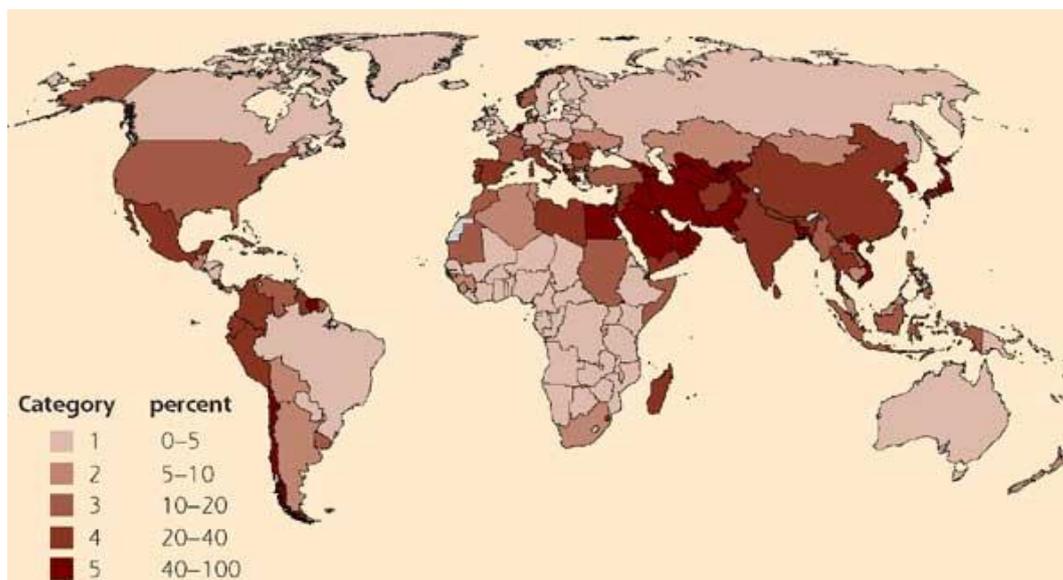
Source: FAO (2002). *World agriculture: towards 2015/2030*.

Figure 9.3.2.8: Agricultural water withdrawals as a percentage of total renewable water resources (1998)



Source: FAO (2002). *Crops and Drops: Making the best use of water for agriculture*.

Figure 9.3.2.9: Area equipped for irrigation as a percentage of cultivated land (1988)



Source: FAO (2002). *Crops and Drops: Making the best use of water for agriculture*



Beyond the great water availability in the region, the sustainable management of water resources must constitute an inevitable premise to assure current and future generations welfare. According to the Öko-Institute (2006), the sustainability standards of bioenergy relative to the use of water by agriculture and to the protection of the resources from agricultural impacts, the following requirements shall be considered:

- Optimized cropping systems demanding low water input should be applied.
- Critical irrigation needs in dry or semi dry regions should be avoided through the application of water management plans.
- Maintain the quality and availability of surface and ground water, and avoid negative impacts of agro-chemicals use (by timing and quantity of application).
- Non utilization of untreated sewage water for irrigation.
- Re-use of treated waste-water shall be a part of the agricultural management system.

9.3.2.2 Energy and emissions balances of biofuels

As it was mentioned at the beginning of this section, a part of the debate on biofuels sustainability deals with their energy and environmental efficiency.

One of the main arguments that has led to the promotion and use of biofuels in the world is based on their potential to generate environmental improvements through the reduction of GHG emissions. However, controversies and a profound debate on the environmental impact of the biofuels global chain development have arisen in the last few years. The questions mainly aim at the environmental value of first generation biofuels and, to a lesser extent, of second generation biofuels.

Energy efficiency, measured through the energy balance, refers to the energy generated by the biofuels in relation to the energy used for its production, throughout the product's chain or life cycle (sowing, harvest and feedstock transportation and the diverse production and distribution phases of the biofuel, etc.)⁹⁸. Tables 9.3.2.10 and 9.3.2.11 present two compilations of results from different studies on fossil energy balances of bioethanol and biodiesel from different feedstocks, carried out by *Worldwatch Institute* (2006) and Castro et al (2007).

Table 9.3.2.10: Fossil energy balance of selected fuels

Fuel (feedstock)	Fossil Energy Balance (approx.)	Data and Source Information
Cellulosic Ethanol	2 - 36	(2.62) Lorenz & Morris (5+) DOE (10.31) Wang (35.7) Elsayed et al.
Biodiesel (palm oil)	≈ 9	(8.66) Azevedo (≈9) Kaltner (9.66) Azevedo
Ethanol (sugar cane)	2 - 8	(2.09) Gehua et al. (8.3) Macedo et al.
Biodiesel (waste vegetable oil)	5 - 6	(4.85 – 5.88) Elsayed et al.
Biodiesel (soybean)	≈ 3	(1.43 – 3.4) Azevedo et al. (3.2) Sheehan et al.

⁹⁸ For example, an energy balance with a ratio between generated energy and consumed energy of value 1, indicates that the production of a biofuel requires the same quantity of energy than the one contained in it; a ratio of value 2, means that the energy contained in the biofuel doubles the used energy to produce it and values of less than 1 reveal energy inefficiency in the sense that the energy used to produce the biofuel is greater than the energy contained in it.

Fuel (feedstock)	Fossil Energy Balance (approx.)	Data and Source Information
Biodiesel (rapeseed, EU)	≈ 2.5	(1.2 – 1.9) Azevedo et al. (2.16 – 2.41) Elsayed et al. (2 - 3) Azevedo et al. (2.5 – 2.9) BOBFO (1.82 – 3.71) Richards; depends on use of straw for energy use and cake for fertilizer. (2.7) NTB (2.99) ADEME/DIREM
Ethanol (wheat)	≈ 2	(1.2) Richards (2.05) ADEME/DIREM (2.02 – 2.31) Elsayed et al (2.81 – 4.25) Gehua
Ethanol (sugar beet)	≈ 2	(1.18) NTB (1.85 – 2.21) ADEME/DIREM (2.02 – 2.31) Elsayad et al (2.05) ADEME/DIREM
Ethanol (corn)	≈ 1.5	(1.34) Shapouri 1995 (1.38) Wang 2005 (1.38) Lorenz & Morris (1.3 – 1.8) Richards
Diesel (crude oil)	0.8 – 0.9	(0.83) Sheehan et al. (0.83 – 0.85) Azevedo (0.88) ADEME/DIREM (0.92) ADEME/DIREM
Gasoline (crude oil)	0.8	(0.84) Elsayed et al. (0.8) Andress (0.81) Wang
Gasoline (tar sands)	≈ 0.75	Larsen et al.

Source: Worldwatch Institute, 2006

Table 9.3.2.11: Energy balance of the production of biodiesel according to different studies

Crop	Country	Energy balance (ratio biodiesel energy / total energy consumed in its attainment)	Assumptions	Source
Rapeseed	EU	1.9	Only biodiesel energy is considered	NTB Liquid biofuels Network 2000, cited by Janulis 2004
Rapeseed	Germany	In order to travel 100 km. the energy necessary to produce 8 liters of diesel are saved.	Honey production of rapeseed flower is assumed and its energy is valued. It is assumed that rapeseed meal is used as animal feed, substituting imported soybean meal. It is assumed that rapeseed production replaces fallow lands. Rapeseed straw is reincorporated to the soil.	Gärther & Reinhardt, 2003
Rapeseed	France	2.6 to 5.4	Includes energy obtained from the processes' by-products. Variability according to incorporation (highest ratio) or not of energy from straw.	ADEME, 1997, cited by Janulis 2004
Rapeseed	Lithuania	1.04 to 1.66	Only biodiesel energy is considered. Agricultural yield: 2 tn/ha. Variability according to agricultural system (better yield with conservation technologies and biofertilizers)	Janulis, 2004

Rapeseed	Lithuania	1.76 to 6.08	Includes energy obtained from the process' by-products. Agricultural yield: 2 tn/ja. Variability according to the incorporation or not of straw's energy and the use of conservation technologies and biofertilizers (highest ratio).	Janulis, 2004
Rapeseed	Lithuania	1.59 to 2.54	Only biodiesel energy is considered. Agricultural yield: 3.5 tn/ha. Variability according to the agricultural system (better yield with conservation technologies and biofertilizers)	Janulis, 2004
Rapeseed	Lithuania	5.81 to 9.29	Includes energy obtained from the process' by-products (including straw). Agricultural yield: 3.5 tn/ha. Variability according to agricultural system (better yield with conservation technologies or biofertilizers).	Janulis, 2004
Sunflower	USA	0.46 to 0.57	Variability according to the consideration of the by-product (sunflower meal) energy value, in the form of its specific heat.	Pimentel & Patzek, 2005
Soybean	USA	3.215	Ratio between biodiesel energy and fossil energy used to produce it.	Sheehan et al., 1998 cited by Janulis, 2004
Soybean	USA	0.76 to 0.94	Variability according to the consideration of the by-product (soybean meal) energy value in the form of its specific heat	Pimentel & Patzek, 2005
Soybean	USA	Saving: 19.25 GJ of non renewable energy /ha/year	Rotation system soybean – corn where corn is used for ethanol and soybean for biodiesel. The energy of various products is considered	Kim & Dale, 2005
Bovine tallow	USA	0.81 to 0.89	It is considered from the animal's growth to the transformation of biodiesel. Only the energy consumption of the animal's growth correspondent to the % in weight of the fat regarding the total of obtained products is considered. Variability depends on how the energy value of the by-products is calculated (according to its heat value, to its economic value or its replacement value with other similar products)	Nelson & Schrock. 2006
Bovine tallow	USA	3.49 to 5.72	Only the energy consumption from the processing of fat into tallow to the transformation in biodiesel is considered. Variability depends on how the energy value of the by-products is calculated.	Nelson & Schrock. 2006
Bovine tallow	USA	5.9 to 17.29	Only the energy consumption in the transformation of fat into biodiesel is considered, assuming that this fat is available as a by-product of the production of meat. Variability depends on how the energy value of the by-products is calculated.	Nelson & Schrock. 2006
Various	Various	2 to 3	Ratio of energy of biodiesel / fossil energy used in its production. Comparison of different studies of biodiesel's life cycle in the EU and USA since the eighties.	Wörgetter et al., 1999

Source: Castro, Paula et al. (2007)

Environmental efficiency, measured through emissions balance, refers to the reduction of GHG emissions by biofuels in comparison with fossil fuels, considering all their chain or life cycle (sowing, harvest and

transportation of feedstock, different phases of conversion into biofuel, transportation, distribution and retail sale of the biofuel and the emissions caused by their combustion), including the effects of land use change. Table 9.3.2.12 presents, as a reference, the typical and default values of GHG emissions balances correspondent to different biofuels elaborated with different feedstocks and technologies, just as they were proposed in the Renewable Energy Directive of the European Commission (Annex VII) and in the text finally adopted by the European Parliament⁹⁹, together with estimations of typical values carried out by Holland's Government. Table 9.3.2.13 presents the same information, but corresponding to biofuels elaborated with lignocellulosic feedstocks.

Both, biofuels' energy balances and those of GHG emissions vary significantly according to different factors. In the case of the energy balance, the type of feedstock used (and its yields), the agricultural practices and the feedstock's production system, the type of energy process used and the degree of the conversion process' efficiency, among others, result determinant. In the case of emissions' balances, besides the fossil energy balance, among the decisive factors are the quantity and type of the used fertilizers and insecticides¹⁰⁰, irrigation technology, soils' treatment, land use changes, the feedstocks used (and its yields) and its location (distances travelled by transportation), production methods and use and conversion technologies. At the same time, the results of the calculations of these balances may differ significantly according to the methodology used and its assumptions.

All this has led to a strong academic controversy, where some studies have reached to negative energy balances (ratios lower than 1) for biodiesel and ethanol or to low levels of contribution to the reduction of GHG (or highly negative balances in cases of land use change based on the advance of agriculture on tropical forests or other ecosystems), while in others, the results of biofuels energy and GHG reduction balances are highly positive¹⁰¹. According to FAO, the most marked differences in the results of this type of studies are due to the assignment methods selected for the complementary products, the assumptions on the nitrous oxide emissions and the changes of carbon emissions derived from the use of land (FAO, 2008c).

Rajagopal and Zilberman (2007) perform a revision and synthesis of the literature, in which they highlight, among others, the following findings of such studies:

- The life cycle of ethanol and sugar cane has been the most widely studied. Sugar cane ethanol registers the highest benefits in matters of energy and GHG reductions, followed by cassava, while corn ethanol offers relatively modest energy and environmental benefits. Likewise, it is expected that cellulosic ethanol registers higher future net energy gains and reduced future GHG¹⁰².
- Co-products have an important bearing on the net energy and environmental benefits, though there is a considerable debate about the most suitable technique for the valuation of their credit.

⁹⁹ Approved on December 17th 2008, to be officially published in the course of 2009.

¹⁰⁰ For example, nitrogenous fertilizers constitute a source of nitrogen oxide emissions, a greenhouse effect gas with a potential of global warming about 300 times greater than carbon dioxide (FAO, 2008 c).

¹⁰¹ For more information on these studies see: Farrell, A., Plevin, R. and others, "Ethanol can contribute to energy and environmental goals". *Science* 2006, 311; Pimentel, D., "Ethanol fuels: energy balance, economics and environmental impacts are negative". 2003. *Natural Resources Research*, Vol. 12 No 2; Pimentel, D., Patzek, T. "Ethanol production using corn, switchgrass, and wood; Biodiesel production using soybean and sunflower" 2005. *Natural Resources Research*, Vol. 14, Nº 1; Hill, J., Nelson, E. and others, "Environmental, economic, and energy costs and benefits of biodiesel and ethanol biofuels". 2006. *Proceedings of the National Academy of Sciences*, 103:30. For more knowledge on calculation methodologies see: Lobato, V. "Metodología para optimizar el análisis de materias primas para biocombustibles en los países del Cono Sur". 2007. PROCISUR-IICA; Gnansounou, E. and others "Estimating Energy and Greenhouse gas balances of biofuels: Concepts and methodologies". Laussane.2008. *Laboratoire de systèmes énergétiques, EPFL*.

¹⁰² It is worth mentioning that, as it is shown in table 23a, the results obtained for the fossil energy balance of cellulosic ethanol are very wide (from 2 to 36). According to FAO, this wide variety of results reflects the uncertainty in relation to this technology and the diversity of lignocellulosic feedstocks and possible production systems.

- Crops rotation and intercropping are better than monocultures, while perennial crops are better than annual crops for achieving soil carbon sequestration, reducing soil erosion and use of agro-chemicals in the production of biomass¹⁰³.
- The production of electricity from biomass (for example the cogeneration of electricity from cane bagasse) also has the potential to offer significant reductions in the consumption of fossil fuels and in GHG emissions.
- Literature on crops and production conditions in the developing countries is scarce with the exception of some studies applied to cane ethanol in Brazil, India and other countries.

Table 9.3.2.12: Biofuels' GHG emissions balances (without land use change)

Biofuel production pathway	Renewable Energy Directive Proposed by the European Commission (Annex VII)		Renewable Energy Directive Text adopted by the European Parliament (Annex V)		GAVE Program (Senter Novem, Government of Holland)
	Typical GHG emission saving	Default GHG emission saving	Typical GHG emission saving	Default GHG emission saving	Typical GHG emission saving
Ethanol					
Sugar beet ethanol	48%	35%	61%	52%	65%
Wheat ethanol (process fuel not specified)	21%	0%	32%	16%	54%
Wheat ethanol (lignite as process fuel in CHP plant)	21%	0%	32%	16%	54%
Wheat ethanol (natural gas as process fuel in conventional boiler)	45%	33%	45%	34%	-
Wheat ethanol (natural gas as process fuel in CHP plant)	54%	45%	53%	47%	54%
Wheat ethanol (straw as process fuel in CHP plant)	69%	67%	69%	69%	-
Corn ethanol (EU) (natural gas as process fuel in CHP plant)	56%	49%	56%	49%	-
Corn ethanol (USA)	-	-	-	-	29%
Sugar cane ethanol	74%	74%	71%	71%	88%
The part from renewable sources of ETBE (ethyl-tertio-butyl-ether)	Equal to that of the ethanol production pathway used		Equal to that of the ethanol production pathway used		-
ETBE					
Sugar beet	48%	35%	61%	52%	65%
Wheat	21%-54%	0%-45%	32%-53%	16%-47%	54%
Corn (EU)	56%	49%	56%	49%	-
Corn (USA)	-	-	-	-	34%
Sugar cane	74%	74%	71%	71%	88%
The part from renewable sources of TAEE (tertiary-amyl-ethyl-ether)	Equal to those of the used process of ethanol production		Equal to those of the used process of ethanol production		-
Biodiesel (FAME)					
Rapeseed biodiesel (EU)	44%	36%	45%	38%	35%
Rapeseed biodiesel (Holland/Germany)	44%	36%	45%	38%	39%
Sunflower biodiesel	58%	51%	58%	51%	-
Soybean biodiesel			40%	31%	
Soybean biodiesel (USA)	-	-	-	-	71%

¹⁰³ It is worth mentioning that the authors do not clarify if they refer exclusively to conventional agriculture or if they are also considering the annual crops in direct sowing and with soils coverage in their affirmation.

Biofuel production pathway	Renewable Energy Directive Proposed by the European Commission (Annex VII)		Renewable Energy Directive Text adopted by the European Parliament (Annex V)		GAVE Program (Senter Novem, Government of Holland)
	Typical GHG emission saving	Default GHG emission saving	Typical GHG emission saving	Default GHG emission saving	Typical GHG emission saving
Soybean biodiesel (Argentina)	-	-	-	-	70%
Palm oil biodiesel (process not specified)	32%	16%	36%	19%	48%
Palm oil biodiesel (process with methane capture at oil mill)	57%	51%	62%	56%	
Waste vegetable or animal oil biodiesel	83%	77%	88%	83%	88%
Hydrotreated vegetable oil from rapeseed	49%	45%	51%	47%	-
Hydrotreated vegetable oil from sunflower	65%	60%	65%	62%	-
Hydrotreated vegetable oil from palm oil (process not specified)	38%	24%	40%	26%	-
Hydrotreated vegetable oil from palm oil (process with methane capture at oil mill)	63%	60%	68%	65%	-
Pure Vegetable Oil					
Pure vegetable oil from rapeseed (EU)	57%	55%	58%	57%	47%
Pure vegetable oil from rapeseed (Holland / Germany)	57%	55%	58%	57%	51%
Used vegetable oils and fats	-	-	-	-	100%
Biomethane (biogas)					
Biogas from municipal organic waste as compressed natural gas	81%	75%	80%	73%	-
Biogas from wet manure as compressed natural gas	86%	83%	84%	81%	100%
Biogas from dry manure as compressed natural gas	88%	85%	86%	82%	-

Source: Renewable Energies Directive: proposal of the European Commission (Jan-2007) and text adopted by the European Parliament (Dec-2008) and GAVE

Table 9.3.2.13: Estimated typical and default values for future biofuels that are not or in negligible quantities on the market in January 2008, if produced with no net carbon emissions from land use change

Biofuels' production process	Typical GHG emission saving	Default GHG emission saving
Wheat straw ethanol	87%	85%
Waste wood ethanol	80%	74%
Farmed wood ethanol	76%	70%
Waste wood Fischer-Tropsch diesel	95%	95%
Farmed wood Fischer-Tropsch diesel	93%	93%
Waste wood DME (dimethylether)	95%	95%
Farmed wood DME (dimethylether)	92%	92%
Waste wood ethanol	94%	94%
Farmed wood methanol	91%	91%
The part from renewable sources of MTBE (methyl-tertiobutyl-ether)	Equal to those of the used process of methanol production	

Source: Renewable Energies Directive: proposal of the European Commission (January 2007)

Bioethanol and biodiesel GHG emissions' balance has acquired a crucial importance from the point of view of policies for biofuels, from the EU Renewable Energy Directive. In the version approved by the European Parliament (December, 2008), the Directive proposes, among other sustainability criteria, that biofuels used in its territory (produced internally or imported), will have to achieve at least a 35% GHG emission saving compared to fossil fuels when the law enters into force, increasing to 50% since 2017¹⁰⁴.

Typical and default values proposed by such Directive have been object of controversy. A clear example is soybean biodiesel, which was not originally included in Annex VII of this directive and was incorporated in the text approved in December 2008 by the European Parliament with a very low value (31%)¹⁰⁵, in comparison with the obtained by other studies (see Table 9.3.2.13)¹⁰⁶. That has motivated a formal claim by the Argentinean Government, arguing that in the calculation of such value there are inconsistencies and application of data that are not compatible with the Argentinean case¹⁰⁷, and that in Annex VII of the Directive it would be important to incorporate soybean biodiesel produced under no-till system, proposing the assignment to such category of an emissions saving value of 74.9%, according to the results obtained in a recent INTA's research¹⁰⁸. These results are more aligned with the value 70% calculated by the Government of Holland for Argentinean soybean biodiesel (see Table 9.3.2.12).

Considering the aforementioned and the fact that the literature about energy and environmental balances applied to the region's countries is scarce, it is very important to advance in the performance of this type of studies, considering the particularities of the crops, the production systems and the agroindustrial chains existent in their territories. These particularities may significantly differ in relation to the parameters and assumptions of the studies mentioned above. The sustainable agricultural practices described in section 9.3.2.1 and of wide application in various South American countries, assume less emissions due to greater carbon accumulation in the soil (consequence of the soil's coverage), to the reduced tillage or non tillage in the soil and to less consumption of fossil fuels (consequence of direct sowing) or to less use of insecticide fertilizers (consequence of crops rotation).

Besides conservation agriculture practices, there are different ways to improve fossil energy's and emissions' balances. The most important one is to avoid deforestation and land use changes, which may generate negative GHG emissions balances in cases as the conversion of humid tropical forests or temperate forests. Likewise, the utilization of artificial fertilizers must be carefully controlled or reduced, in order to prevent the emissions of nitrous oxides (The Royal Society, 2008). The use of varieties with low input demands, the reduction in the use of insecticides through IPM, the reduction in transportation distances, the substitution of the use of methanol in the production of biodiesel and the employment of biofuels in the production and transportation of feedstocks and in the production processes, also constitute other relevant alternatives to improve balances.

¹⁰⁴ The minimum GHG savings will be 60% for new installations from 2017 onwards. For plants that were operating on January 2008, the requirement of minimum savings of GHG will start in April, 2013.

¹⁰⁵ Proposing a 31% default reduction of GHG when the minimum GHG saving established by the Directive is 35%, implies that soybean biodiesel will not be considered sustainable and therefore will be excluded from the biofuels targets, unless its sustainability is demonstrated in every exported batch by means of the specific identification and independent certification (Molina, 2008).

¹⁰⁶ Other critics generated regarding Annex VII of the EU Renewable Energies Directive have to do with increases in typical and default values proposed by the European Parliament for biofuels produced with feedstocks available in Europe (sugar beet and wheat bioethanol and rapeseed biodiesel).

¹⁰⁷ The Joint Research Centre (JRC), the source considered by the CE, reports that it based on information provided by USA and Brazil, to subsequently establish the default value presented in Annex VII of the Directive (Molina, 2008).

¹⁰⁸ INTA (2008). "Analysis of the emissions of biodiesel's production from soybean in Argentina".

9.3.2.3 Sustainability criteria, certification and initiatives in the production of feedstocks for biofuels

Due to the eventual risks and negative potential externalities that biofuels could have from the environmental and social points of view (see section 9.3.3), several institutions and initiatives promoting the sustainability and/or definition of assurance and certification systems of sustainability of biofuels' production and their feedstocks have arisen in the world.

Among the most representative operating international institutions and initiatives for the case of bioenergy and biofuels, the following stand out:

- The Global Bioenergy Partnership (GBEP)¹⁰⁹
- The International Bioenergy Platform (IBEP in the ambit of FAO)
- The Roundtable on Sustainable Biofuels (RSB)¹¹⁰
- International Energy Agency (IEA) task groups Task 29, Task 38 and Task 40 (in the scope of the IEA Bioenergy Implementing Agreement).

Among the international initiatives related to the sustainable production of feedstocks with potential utilization for biofuels, the following stand out:

- The Roundtable on Sustainable Palm Oil (RSPO)
- The Roundtable on Responsible Soy (RTRS)
- The Better Sugar Cane Initiative (BSI)
- The Sustainable Commodity Initiative (ICI)
- The Forest Stewardship Council (FSC)
- The Sustainable Agriculture Network (SAN)

Roughly, the sustainability principles and criteria are based on the basic principles of corporate social responsibility (People, Planet, and Profit), incorporate environmental and social dimensions to economic ones, and aim at:

- ❑ Greenhouse gas balance: reduction of greenhouse gases emissions by the biofuels' productive chain, in comparison with fossil fuels.
- ❑ Environment: protect and also increase soil's, air's and water's quality.
- ❑ Biodiversity: not harm protected or vulnerable biodiversity and strengthen it if possible.
- ❑ Competition with food: the production of biomass should not risk food security and other local applications.
- ❑ Local prosperity and social well-being: poverty mitigation, creation of economic value for workers and local economy, non-negative effects on employees' work conditions and human rights, non-violation of property rights and rights of use land, etc.

¹⁰⁹ Current members: Brazil, Canada, China, France, Germany, Italy, Japan, Mexico, Holland, Russia, Spain, Sudan, Sweden, Tanzania, United Kingdom, USA, FAO, IEA, UNCTAD, UN/DESA, UNDP, UNEP, UNIDO, UNF, World Council for Renewable Energy (WCRE) and the European Biomass Industry Association (EUBIA). Angola, Argentina, Austria, Colombia, India, Indonesia, Israel, Kenya, Madagascar, Malaysia, Morocco, Mozambique, Norway, Peru, SouthAfrica, Switzerland, Tunisia, the European Commission, the EEA, the International Fund for Agricultural Development (IFDA), the World Bank, and the World Business Council for Sustainable Development (WBCSD) are participating as observers.

¹¹⁰ Initiative coordinated by the École Polytechnique Fédérale at Lausanne, and constituted by multiple stakeholders from the entire world (NGOs like WWF and FSC, universities, companies like PETROBRAS, Bunge, Shell and Toyota, agricultural producers associations, like UNICA, United Nations' specialized agencies, and diverse groups of the civil society, among others). Its purpose is to reach a global consensus between the multiple stakeholders, regarding the principles and criteria of biofuels' production sustainability.

Table 9.3.2.14 summarizes, as an example, the so called "Version Zero" of the global principles and criteria for the sustainable production of biofuels, developed in the framework of the Roundtable of Sustainable Biofuels (RSB).

According to the RSB, the standards to develop, based on these principles and criteria, should comply with a series of desirable properties. In this sense, the standards should be:

- Simple: accessible for small producers, inexpensive to measure and easy to explain.
- Generic: applicable to any crop in any country, and allow comparisons across crops and production systems.
- Adaptable: easy to revise, to take into account new technologies and their impacts on relative performance of different biofuels.
- Efficient: they should incorporate other standards and certifications to eliminate duplicative reporting and reduce inspection burdens on producers and processors.

Table 9.3.2.14: RSB, global principles and criteria for the sustainable production of biofuels – “Version Zero”

Criterion	Description
Legal Framework	<p>Biofuel production shall follow all applicable laws of the country in which they occur, and shall endeavour to follow all international treaties relevant to biofuels' production to which the relevant country is a party.</p> <p><i>Includes laws and treaties relating to air quality, water resources, soil conservation, protected areas, biodiversity, labor conditions, agricultural practices, and land rights.</i></p>
Consultation, Planning and Monitoring	<p>Biofuels projects shall be designed and operated under appropriate, comprehensive, transparent, consultative, and participatory processes that involve all relevant stakeholders.</p> <p><i>'Biofuel projects' refers to farms and factories producing biofuels. The intent of this principle is to diffuse conflict situations through an open, transparent process of stakeholder consultation and acceptance, with the scale of consultation proportionate to the scale, scope, and stage of the project, and any potential conflicts.</i></p> <p>a) For new large-scale projects, an environmental and social impact assessment, strategy, and impact mitigation plan (ESIA) covering the full lifespan of the project shall arise through a consultative process to establish rights and obligations and ensure implementation of a long-term plan that results in sustainability for all partners and interested communities. The ESIA shall cover all of the social, environmental, and economic principles outlined in this standard.</p> <p>b) For existing projects, periodic monitoring of environmental and social impacts outlined in this standard is required.</p> <p>c) The scope, length, participation and extent of the consultation and monitoring shall be reasonable and proportionate to the scale, intensity, and stage of the project and the interests at stake.</p> <p>d) Stakeholder engagement shall be active, engaging and participatory, enabling local, indigenous, and tribal peoples and other stakeholders to engage meaningfully.</p> <p>e) Stakeholder consultation shall demonstrate best efforts to reach consensus through free prior and informed consent. The outcome of such consensus-seeking must have an overall benefit to all parties, and shall not violate other principles in this standard.</p> <p>f) Processes linked to this principle shall be open and transparent and all information required for input and decision-making shall be readily available to stakeholders.</p>
Greenhouse gas emissions	<p>Biofuels shall contribute to climate change mitigation by significantly reducing GHG emissions as compared to fossil fuels.</p> <p><i>The aim of this principle is to establish an acceptable standard methodology for comparing the GHG benefits of different biofuels in a way that can be written into regulations and enforced in standards.</i></p> <p>a) Producers and processors shall reduce GHG emissions from biofuel production over time.</p> <p>b) Emissions shall be estimated via a consistent approach to lifecycle assessment, with system boundaries from land to tank.</p> <p>c) At the point of verification, measured or default values shall be provided for the major steps in the biofuel production chain.</p> <p>d) GHG emissions from direct land use change shall be estimated using IPCC Tier 1 methodology and values. Better performance than IPCC default values can be proven through models or field experiments.</p> <p>e) GHG emissions from indirect land use change i.e. that arise through macroeconomic effects of biofuels production shall be minimized. There is no broadly-accepted methodology to determine them. Practical steps that shall be taken to minimize these indirect effects will include:</p> <ul style="list-style-type: none"> - Maximising use of waste and residues as feedstocks; marginal, degraded or previously cleared land; improvements to yields; and efficient crops; - International collaboration to prevent detrimental land use changes; and - Avoiding the use of land or crops that are likely to induce land conversions resulting in emissions of stored carbon. <p>f) The preferred methodology for GHG lifecycle assessment is as such:</p> <ul style="list-style-type: none"> - The functional unit shall be CO₂ equivalent (in kg) per Giga Joule [kgCO₂equ/GJ]. - The greenhouse gases covered shall include CO₂, N₂O and CH₄. The most recent 100-year time horizon Global Warming Potential values and lifetimes from the IPCC shall be used.
Human and Labor rights	<p>Biofuel production shall not violate human rights or labor rights, and shall ensure decent work and the well-being of workers.</p> <p><i>Key international conventions such as the ILO's core labor conventions and the UN Declaration on Human Rights shall form the basis for this principle.</i></p> <p>a) Workers will enjoy freedom of association, the right to organise, and the right to collectively bargain.</p> <p>b) No slave labour or forced labour shall occur.</p>

Criterion	Description
	<p>c) No child labour shall occur, except on family farms and then only when work does not interfere with the child's schooling.</p> <p>d) Workers shall be free of discrimination of any kind, whether in employment or opportunity, with respect to wages, working conditions, and social benefits.</p> <p>e) Workers' wages and working conditions shall respect all applicable laws and international conventions, as well as all relevant collective agreements. They shall also be determined by reference to, at a minimum, the conditions established for work of the same character or offered by comparable employers in the country concerned.</p> <p>f) Conditions of occupational safety and health for workers and communities shall follow internationally-recognised standards.</p>
Rural and Social Development	<p>Biofuel production shall contribute to the social and economic development of local, rural and indigenous peoples and communities.</p> <p>a) The ESIA carried out under 2a and monitoring required under 2b shall result in a baseline social assessment of existing social and economic conditions and a business plan that shall ensure sustainability, local economic development, equity for partners, and social and rural upliftment through all aspects of the value chain.</p> <p>b) Special measures that benefit women, youth, indigenous communities and the vulnerable in the affected and interested communities shall be designed and implemented, where applicable.</p>
Food security	<p>Biofuel production shall not impair food security.</p> <p>a) Biofuel production shall minimize negative impacts on food security by giving particular preference to waste and residues as input (once economically viable), to degraded/marginal/underutilized lands as sources, and to yield improvements that maintain existing food supplies.</p> <p>b) Biofuel producers implementing new large-scale projects shall assess the status of local food security and shall not replace staple crops if there are indications of local food insecurity.</p>
Conservation	<p>Biofuel production shall avoid negative impacts on biodiversity, ecosystems, and areas of High Conservation Value. <i>areas with high conservation value (HCV), native ecosystems, ecological corridors and public and private biological conservation areas can only be exploited as far as conservation values are left intact and can in no case be converted.</i></p> <p>a) High Conservation Value areas, native ecosystems, ecological corridors and other public and private biological conservation areas shall be identified and protected.</p> <p>b) Ecosystem functions and services shall be preserved.</p> <p>c) Buffer zones shall be protected or created.</p> <p>d) Ecological corridors shall be protected or restored.</p>
Soil	<p>Biofuel production shall promote practices that seek to improve soil health and minimize degradation.</p> <p>a) Soil organic matter content shall be maintained at or enhanced to its optimal level under local conditions.</p> <p>b) The physical, chemical, and biological health of the soil shall be maintained at or enhanced to its optimal level under local conditions.</p> <p>c) Wastes and byproducts from processing units shall be managed such that soil health is not damaged.</p>
Water	<p>Biofuel production shall optimize surface and groundwater resource use, including minimizing contamination or depletion of these resources, and shall not violate existing formal and customary water rights.</p> <p>a) The ESIA outlined in 2a shall identify existing water rights, both formal and customary, as potential impacts of the project on water availability within the watershed where the project occurs.</p> <p>b) Biofuel production shall include a water management plan appropriate to the scale and intensity of production.</p> <p>c) Biofuel production shall not deplete surface or groundwater resources.</p> <p>d) The quality of surface and groundwater resources shall be maintained at or enhanced to their optimal level under local conditions.</p>
Air	<p>Air pollution from biofuel production and processing shall be minimized along the supply chain.</p> <p>a) Air pollution from agrochemicals, biofuel processing units, and machinery shall be minimized.</p> <p>b) Open-air burning shall be avoided in biofuel production.</p>
Economic efficiency, technology, and continuous improvement	<p>Biofuels shall be produced in the most cost-effective way. The use of technology must improve production efficiency and social and environmental performance in all stages of the biofuel value chain.</p> <p>a) Biofuel projects shall implement a business plan that reflects a commitment to economic viability.</p> <p>b) Biofuel projects shall demonstrate a commitment to continuous improvement in energy balance, productivity per hectare, and input use.</p> <p>c) Information on the use of technologies along the biofuel value chain must be fully available, unless limited by national law or international agreements on intellectual property.</p> <p>d) The choice of technologies used along the biofuel value chain shall minimize the risk of damages to environment and people, and continuously improve environmental and/or social performance.</p> <p>e) The use of genetically modified plants, micro-organisms, and algae for biofuel production must improve productivity and maintain or improve social and environmental performance, as compared to common practices and materials under local conditions. Adequate monitoring and preventative measures must be taken to prevent gene migration.</p> <p>f) Micro-organisms used in biofuel processing must be used in contained systems only.</p>
Land rights	<p>Biofuel production shall not violate land rights.</p> <p>a) Under the ESIA described under criterion 2a, land use rights for the land earmarked for the biofuel project shall be clearly defined and established, and not be legitimately contested by local communities with demonstrable rights, whether formal or customary.</p> <p>b) Local people shall be fairly and equitably compensated for any agreed land acquisitions and relinquishments of rights. Free prior and informed consent and negotiated agreements shall always be applied in such cases.</p>

Criterion	Description
c) Appropriate mechanisms shall be developed as part of the ESIA to resolve disputes over tenure claims and use rights.	

Source: Roundtable on Sustainable Biofuels (2008)

In line with the base generated by the different institutions mentioned, at the level of countries or community blocks, the most concrete advances towards the definition of sustainability certification systems in biofuels and feedstocks production are given in the EU, from the criteria established in the proposal of the Renewable Energy Directive and in the text approved by the European Parliament, in Holland (development of sustainability criteria by the Cramer Commission and ongoing activities to test such criteria in pilot projects and to define monitoring and certification systems), in the United Kingdom (according to the RTFO, the producers of biofuels shall report the GHG emissions balance and the environmental impact of their products), in USA (the Government has established goals for reducing GHG emissions for biofuels¹¹¹) and in Brazil (the National Institute of Metrology, Normalization and Industrial Quality is developing the Brazilian Program of Technical, Environmental and Social Certification of Biofuels). Such advances have concentrated in GHG and biodiversity criteria as yet.

The development of the global and national systems of sustainability certification could be essential to guarantee that biofuels and their feedstocks are produced in a sustainable way and to avoid the risks and negative environmental externalities mentioned above. Nevertheless, these systems have significant restrictions, establishing certain extremely relevant dilemmas. According to the *Biomass Technology Group* (BTG), the main barriers faced by sustainability certification systems are the following:

- Certification systems are not considered effective to monitor and manage indirect effects of biomass production, like competition with food or undesirable effects of indirect land use changes.
- Only a limited number of mandatory sustainability criteria would hold ground in case of a potential WTO conflict.
- Biomass certification could make biomass producers switch their sales to less eco-sensitive markets.

The compatibility of these systems with the WTO's rules is probably the main point of doubts about the viability and the form that obligatory sustainability certification schemes will adopt in the future recent analyses thereon performed in Holland¹¹² suggest that: a) the requirements related to GHG emissions balances may be probably formulated compliant with WTO rules, as long as foreign products are not treated less favorably than domestic products, and that the measure does not fall under GATT 1994, article XI; b) some of the local environmental criteria (biodiversity, soil and surface water protection, air quality, etc.) may be compliant with WTO rules; c) the criteria aiming at avoiding the competition with food products and social criteria like contribution to local prosperity and social well-being of local population are most probably not compliant with WTO rules.

The aforementioned leads to a distinction between *mandatory* and *voluntary* systems of sustainability certification. According to the BTG, mandatory certification systems will be the best option to effectively guarantee GHG emissions savings, protection of biodiversity (high conservation value forests, wild life habitats, etc.) and protection of local environment (water and soil protection, agrochemicals, etc.); while additionally, voluntary biomass certification would not suffer all limitations of mandatory systems and could play a positive role for the criteria related with social criteria of contribution to local prosperity and social well-

¹¹¹ For conventional biofuels (corn ethanol) the GHG reduction goal is 20%, adjustable towards lower percentages (though not less than 10%) if the determined requirement is not feasible; for biodiesel and others, the GHG reduction goal is 50% (adjustable downwards, though not less than 40%) and for cellulosic biofuels the goal is 60% (adjustable to 50%).

¹¹² Bossche et al (2007) and Bronckers et al (2007), cited by BTG (2008).

being of the local people and employees, rural population's rights, effects on the local environment, protection to biodiversity and GHG emissions balances.

Related with the aforementioned, FAO established certain doubts regarding the immediate application of rules that imply rigorous systems for measuring parameters against defined criteria, whose lack of compliance could impede a country from exporting its product. Regarding that, it asks: "Is the biofuel sector sufficiently developed for the establishment of such a system and, are the risks sufficiently great that its absence would pose significant, irreversible threats to human health or the environment? Should biofuels be treated more stringently than other agricultural commodities?" (FAO, 2008c). Considering that most environmental impacts of biofuels cannot be distinguished from those of increased agricultural production in general, FAO proposes a dilemma: It could be argued that equal standards should be applied at all levels, but restricting land use change could also reduce opportunities for developing countries to benefit from an increased demand for agricultural commodities. In this sense, according to this entity, the regulatory approaches to standards and certifications may not be the first or best option for ensuring broad-based and equitable participation in biofuel production. Based on that, FAO concludes that systems including good practices and capacity building could yield better results in the short term and provide the necessary flexibility to adapt to circumstances in evolution and that in time, more stringent standards and certification systems could be established, accompanied by capacity creation efforts for the countries needing them. It also proposes to explore the option of payment for environmental services, as an instrument for promoting the compliance with sustainable production methods.

Meanwhile, some region's countries represented by their Governments, NGOs or producer associations, are already participating in the different international volunteer initiatives¹¹³, while they advance in national initiatives.

As an example, some national initiatives in the region's countries are mentioned:

- In Brazil apart from the mentioned Brazilian Program of Technical, Environmental and Social Certification of Biofuels, the Agro-environmental Protocol (signed in 2006 by the Government of the State of Sao Paulo and UNICA with the objective of assuring sustainability patterns in the production of ethanol), implemented the Green Bioethanol Program, to foster the good practices of the sugar-alcohol sector by means of a conformity certificate and to determine a positive pattern to be followed by producers. In June 2008, the four main Brazilian producers of sugar cane ethanol exported to Sweden with the first trade contract of ethanol signed in the world under sustainable development principles. EMBRAPA and the French Agricultural Research Centre for International Development (CIRAD) are developing a system of sustainability indicators for the environmental evaluation and management of palm's sustainable production.
- In Bolivia, the Project "Bolivia – Case Study for the Global Roundtable on Sustainable Biofuels" is in development (with the support of the Bolivian Institute of Foreign Commerce (IBCE) and the Chamber of Industry, Commerce, Services and Tourism of Santa Cruz (CAINCO)). This initiative, whose objective is to provide consistent and scientific elements for judgment on biofuels for their economically, socially and environmentally responsible production (IBCE), announced the creation of a Bolivian Platform for Sustainable Biofuels, by June 2008.

¹¹³ Brazil is a current member and Argentina, Colombia and Peru participate as observers in the GBEP; the Brazilian Sugar Cane Industry Association (UNICA) and PETROBRAS are already part of the RSB; UNICA is also part of the Better Sugar Cane Initiative; FEDEPALMA, of Colombia and companies of Ecuador and Brazil are part of the Roundtable on Sustainable Palm Oil; while diverse Brazilian, Argentinean and Paraguayan agricultural producer and industrial organizations and NGOs (ABIOVE, ACSOJA, AAPRESID, APROSMAT, APROSOJA, among others) are active members of the Roundtable on Responsible Soy.



- In Colombia, the process of National Interpretation of the principles and criteria of the Roundtable on Sustainable Palm Oil is being developed aiming at the participation of diverse actors associated with or interested in the value chain of palm oil in Colombia: producers (big and small) and processors, worker associations, small producer cooperatives, the palm trade union, organizations and environmental sector (NGO, MAVDT, CAR and Research institutes), agricultural sector (MADR and SAC among others), social organizations, academy and technical experts (FEDEPALMA, 2008).
- In Argentina, the Argentine No Till Farmers Association (AAPRESID) promotes the initiative of developing an “Environmental and Productive Quality Management System in Conservation Agriculture”, with the possibility of being certifiable. The project aims at achieving a “Certified Agriculture” with the guarantees that adjusting to a Good Agricultural Practices (GAPs) Protocol and of scientific indicators, enabling the measurement of the impact of agriculture on the environment, focus of the certification of the No-till process (AAPRESID).

9.3.3 Biofuels and social inclusion

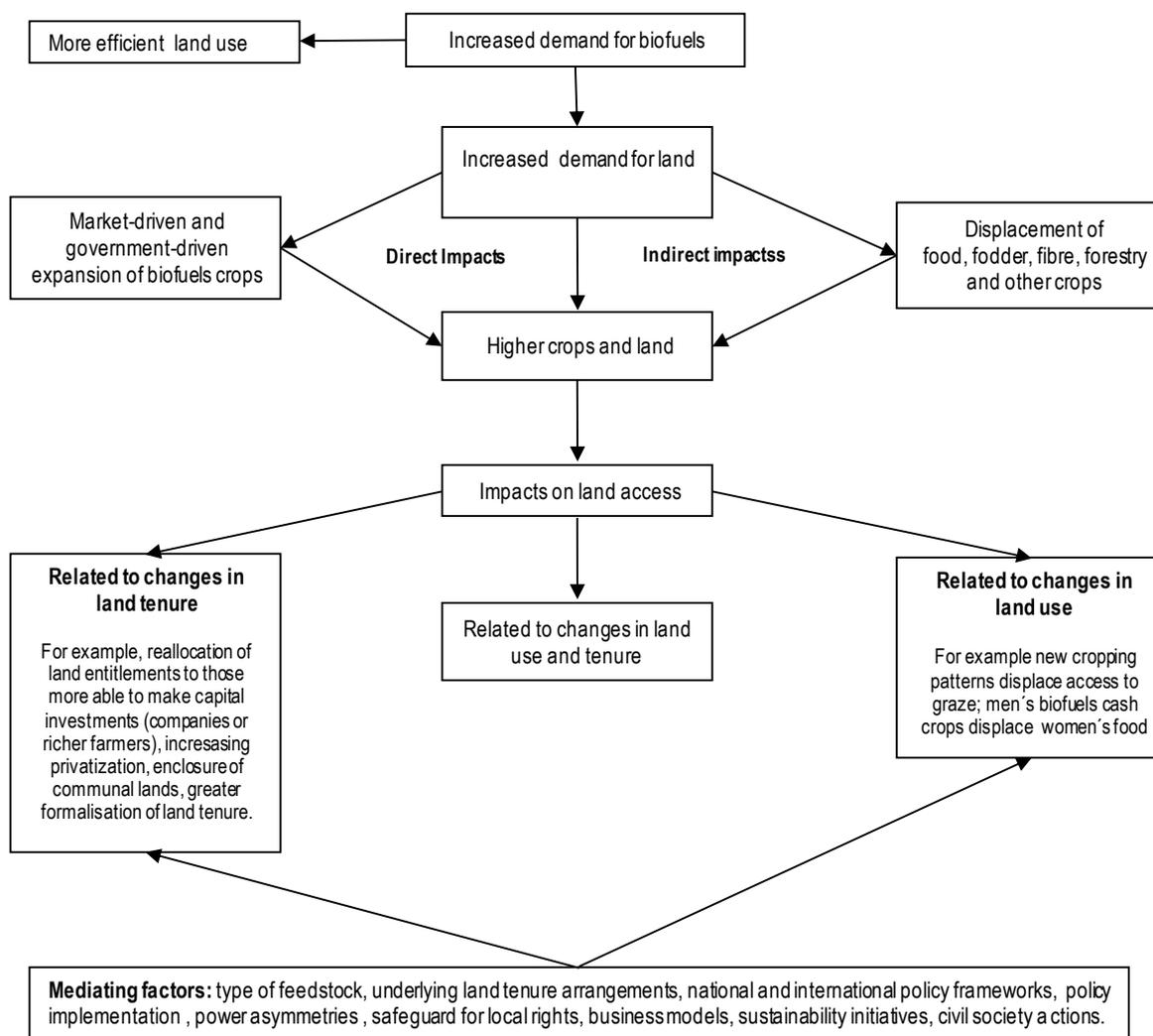
Both in the region’s countries as well as in the rest of the world, the biofuels chain development represents multiple opportunities for rural and postponed regional economies’ development, as well as for family agriculture, the small and medium agricultural producers and rural workers¹¹⁴. According to FAO, biofuels may be decisive to achieve an agricultural revival that revitalizes the land use and livelihood in rural areas. In this sense, price signals for farmers could increase both yields and incomes, assuring a reduction of poverty in the long term in countries with a high dependence on agricultural commodities, while large scale biofuels cultivation could also generate benefits in terms of employment, skills development and secondary industry (Cotula et al, 2008).

Nevertheless, as in the environmental issue, the chain development also implies certain risks from the social point of view, which if not considered, could significantly counteract the mentioned benefits. To the already mentioned risks linked to food security, other possible negative externalities are added:

- The emergence of a demand for biofuels implies an increase in the demand for land, and this in turn represents repercussions on the access, tenure and use of land, which, in certain circumstances could mean the displacement of rural communities (indigenous people, farmers and small agricultural producers) (Figure 9.3.3.1).
- The need to achieve economies of scale could encourage the establishment of crops at large scale, also generating a displacement of small producers (Duffey, 2008) and a higher level of land concentration.
- Some specific market configurations, for example a chain with a high concentration level on the commercial stages, may lead to a concentrated distribution of biofuels’ incomes, with scarce benefits for primary activity.

¹¹⁴ According to a study of the World Bank, about 37% (approximately 65 million people) of the poor people of Latin America and the Caribbean live in rural areas and in some countries like Bolivia, Guatemala, Honduras, Nicaragua, Paraguay and Peru, at least 70% of their rural population lives in poverty. Even though official statistics indicate that rural people in the region is 24% of the total, when the OECD’s definition of rural is applied, the figure increases to 42% (OECD defines rural population based on the population density of at least 150 inhabitants per km² and more than an hour trip to the main urban areas (cities of more than 100,000 inhabitants or more)). (De Ferranti et al, 2005).

Figure 9.3.3.1: Conceptual linkages between the expansion of biofuels and land access



Source FAO-IIED

The institutionality existent in the countries, in terms of protection and creation of opportunities for family agriculture and small producers, will be essential in order to avoid these negative impacts.

The situations that could derive in the displacement of rural communities can be avoided through suitable legal policies and mechanisms, which involve a precise direction and determination on the productive vocations, despite the land's suitability, and guarantees of not affecting the habitat of indigenous and rural people (IBCE, 2008). Particularly, it will be indispensable that the governments develop robust safeguards in procedures for the allocation of land to large scale biofuels feedstocks production where they are lacking and, more importantly, to effectively implement them (Cotula et al, 2008). Safeguards include clear procedures and standards for local consultation and attainment of previous and informed consents, mechanisms for appeal and arbitration and frequent reviews (Cotula et al, 2008). According to IBCE, the possibility of forced displacements of people, especially of ethnic groups, from their land, should not happen if valid international conventions, as Convention N° 169 concerning Indigenous and Tribal Peoples, as well as other similar ones subscribed within the ILO framework, and the valid national dispositions on the matter are strictly applied (IBCE, 2008).



The sustainability principles and criteria mentioned in the previous section include elements linked to the social dimension, related with the respect to property and land rights, human rights and labor rights and to the contribution of biofuels to local people's wellbeing through rural and social development (see Table 9.3.2.14). According to FAO, sustainability certification criteria should include, as an essential requirement, free prior and informed consent, based on secure land tenure of local residents.

Social inclusion and the insertion of family agriculture, agricultural SMEs and small producers' cooperatives to the biofuels chains, represents one of the main challenges faced by the development of this sector in South America. Contributing to rural poverty mitigation, to assure the permanence of people in rural areas and to maximize the possibilities for rural and local development, constitute goals that should be well established in the vision intended to be printed in the region's sector. The achievement of these goals will unfailingly require active and support policies by the Governments.

According to ECLAC, three conditions are essential for biofuels to offer a productive reconversion, especially for small producers: a) there shall be technological packages suitable for the needs of small producers; b) small producers shall have an easy access to biofuels' producing plants; c) there shall be incentives, credits and infrastructure policies, which in turn are inspired in inclusion policies (Razo et al, 2007).

There are diverse alternatives to include family farmares and agricultural SMEs to the regional productive chaining that the biofuels chain development would generate. The simpler ones are surplus channeling or the production of feedstocks for their supply to the chain, while the most challenging ones imply the generation of family agriculture nucleous, cooperatives or other associative modes of small producers, which enable generating economies of scale in crops production and even advance in the added value towards the production of oils, by-products, alcohol and biodiesel (to the extent to which it is economically viable or feasible to be enabled) (Ganduglia, 2008).

These alternatives, oriented to the domestic market, with a territorial approach, do not imply the selection of mutually excluding models with the production of crops at large scale or with the industry of biofuels for export at large scale. These different models are in conditions to coexist and even dovetail.

In this field there are different options for the development of public, private, mixed and third sector actions, which should emerge from the harmonization between biofuels and rural development policies. The integration, articulation and coordination of national rural development programs, the producers' associations, research institutes and provincial and municipal governments, with the programs, instruments and specific institutions of the agroenergy sector, would significantly contribute to generate synergies and a critical mass of resources and initiatives favorable to social inclusion.

Among the policies instruments that could be used to promote the insertion of family agriculture and its organization modalities, the following can be mentioned:

- Technical and material assistance for agricultural production: provision of seeds and basic inputs, training and extension, provision of equipment and technology transfer.
- Access to credit and/or micro-credit for the establishment of cooperatives or other organizational modalities, human and productive capital development and access to markets.
- Mechanisms that motivate and guarantee the acquisition of feedstocks from family agriculture: in this regard, the example of the Social Fuel Label implemented in Brazil stands out. In the course of time, the producer of biofuels who promotes social inclusion will receive access to tax benefits and preferential conditions of access to credit. Therefore, he will have to comply with minimal percentages of feedstocks acquisition from family agriculture; sign contracts with family agriculture, specifying commercial conditions



that guarantee income and terms compatible with the activity (considering minimal conditions such as acquisition guarantee, contractual terms, acquisition value of the feedstock, delivery conditions, etc.) and assure technical assistance and training to family agriculture.

- Technical, financial, and fiscal support to the generation of biofuels production projects by agricultural cooperatives and partnership developments or to the mentioned mixed initiatives of municipal or provincial interest.

At global level, Brazil is one of most advanced countries in terms of approach towards social and regional inclusion in its biofuel policies, especially in the case of biodiesel. The mentioned Social Fuel Label aims at guaranteeing the inclusion of family agriculture in the chain, as well as of the most postponed regions. On the other hand, it is worth mentioning the EU official strategy for biofuels, which intends to create an assistance package to support biofuels' development in developing countries and regions, where the same constitutes an option to reduce poverty in a sustainable way. The Argentinean legislation also aim at promoting the inclusion of regional economies and small and medium enterprises, as in different Latin American and African countries, where diverse actions and programmatic lines tending to social inclusion in the chain are also being developed.

10 Bibliographical references

The following documents were taken as reference to develop section 2 of this handbook:

1. "Boletín mensual Noticias del mercado argentino y mundial de biocombustibles" (online). IICA Argentina. Several numbers. 2006 to 2009. Available in: <http://www.iica.org.ar/at-A&E-NoticiasBiocombustibles.htm>
2. "Remolacha Azucarera". Iglesias Casanueva, R. Oficina de Estudios y Políticas Agrarias – (ODEPA) (Office of Agricultural Studies and Policies). Ministry of Agriculture of Chile. February, 2009. Available on: <http://www.odepa.gob.cl/odepaweb/publicaciones/doc/2163.pdf>
3. "Oportunidades y desafíos de la Producción de Biocombustibles para la Seguridad Alimentaria y del Medio Ambiente en América Latina y el Caribe". 30th. Regional Conference of FAO for Latinamerica and the Caribbean. Brasilia, 14th to 18th. April, 2008. FAO (2008f). Available in: <http://www.rlc.fao.org/es/larc>
4. "Anuario estadístico 2007". Ministry of Livestock, Agriculture and Fishing of Uruguay. Query July, 2008. Also see: http://www.mgap.gub.uy/Diea/Anuario2007/pages/DIEA-Anuario-2007-cd_000.html
5. "Avanços e Próximos Passos. Relatório Apresentado pelo Grupo de Trabalho da Soja". Moratória da Soja. GTS to Minister of Environment Carlos Minc Baumfeld. September, 2008. Available on: http://www.abiove.com.br/sustent/ms_relatorio_ministro_7out08.pdf
6. "Balance energético del sector palmero colombiano 2007". FEDEPALMA. Unit of Economy and Trade. 2008. Available in: http://www.fedepalma.org/document/2008/balance_2007.pdf
7. "Bioenergía, seguridad y sostenibilidad alimentarias: hacia el establecimiento de un marco internacional". FAO (2008e). High level conference on global food security: the challenges of climate change and bioenergy. Rome, Italy. 3rd to 5th. June 2008. Available in: <http://www.abdes.org/fao.pdf>
8. "Bioenergy and Land Tenure: The implications of biofuels for land tenure and land policy". Cotula Lorenzo, Dyer Nat and Vermeulen Sonja. IIED -FAO. Land Tenure Technical Paper 1. Rome, Italy. 2008. Available in: <ftp://ftp.fao.org/docrep/fao/011/aj224e/aj224e00.pdf>
9. "Bioetanol de cana-de-açúcar: energia para o desenvolvimento sustentável / organização BNDES e CGEE". BNDES: Rio de Janeiro, Brazil. 2008. Available in: <http://www.bioetanoldecana.org/pt/download/bioetanol.pdf>
10. "Biocombustibles Sostenibles: Un Enfoque Social desde Bolivia". IBCE. 2008. Available in: http://www.biocombustiblesbolivia.org.bo/public_archivos/comext168.pdf
11. "Bioetanol de cana-de-açúcar: energia para o desenvolvimento sustentável". Organization BNDES and CGEE. Rio de Janeiro, Brazil. 2008. 316 pages. Available in: <http://www.bioetanoldecana.org/>
12. "Bolivia: Estudio de Caso para la Mesa Redonda sobre Biocombustibles Sostenibles". Publication of the Bolivian Institute of Foreign Commerce (IBCE). Nº 163. Santa Cruz de la Sierra, Bolivia. 2008. Available in: http://www.biocombustiblesbolivia.org.bo/public_archivos/comext163.pdf
13. "Bosques y Energía. Cuestiones clave". FAO (2008g). FAO Study: Montes 154. Rome, Italy. 2008. Available in: <ftp://ftp.fao.org/docrep/fao/010/i0139s/i0139s00.pdf>
14. National Confederation of Associations of Venezuelan Agricultural Producers (FEDEAGRO). Agricultural Statistics. Consultation. July, 2008.
15. "Contribuciones para una política agrícola regional en agroenergía". IICA/REDPA/CAS. Group on Public Policies on Agroenergy (GT6). Agricultural Policies Coordination Network (REDPA). Southern Agricultural Council (CAS). Ed. Graphics Suiza. Chile. 2008. 94 pages.
16. "CO₂-tool: Determining greenhouse gas emissions from the production of transport fuels, electricity and heat from biomass". GAVE Programme. SenterNovem, Dutch Ministry of Economic Affairs. 2008. Online: http://www.senternovem.nl/gave_english/co2_tool/index.asp

17. "Cultivos para la producción sostenible de biocombustibles: una alternativa para la generación de empleos e ingresos. Modulo I: Piñón". SNV (2008a). Dutch Service of Cooperation to Development. Honduras. 2008.
18. "Cultivos para la producción sostenible de biocombustibles: una alternativa para la generación de empleos e ingresos. Modulo II: Higuierillo". SNV (2008b). Dutch Service of Cooperation to Development. Honduras. 2008.
19. "Cultivos para la producción sostenible de biocombustibles: una alternativa para la generación de empleos e ingresos. Modulo IV: Palma africana". SNV (2008c). Dutch Service of Cooperation to Development. Honduras. 2008.
20. "Developing Sweet Sorghum to Meet the Challenge of Problems on Food, Energy and Environment in 21st Century". Li Dajue. 2008. Available in: http://www.ifad.org/events/sorghum/b/LiDajue_developing.pdf
21. "Diagnóstico y estrategias para el desarrollo de los biocombustibles en la Argentina". Ganduglia, F. In "Diagnóstico y estrategias para la mejora de la competitividad de la agricultura argentina". Chapter IV. CARI-FAO-IICA. 2008. Available in: http://www.iica.int/Esp/regiones/sur/argentina/Publicaciones%20de%20la%20Oficina/Diagnostico_Estrategia.pdf
22. "Diagnóstico y situación actual de las áreas protegidas en América Latina y el Caribe (2007)". Regional Report. Andean Corporation of Promotion (CAF). 2008. Available in: www.caf.com/publicaciones
23. "Dinámica Agropecuaria 1997-2007". General Directorate of Agricultural Information of the Ministry of Agriculture (MINAG). 2008. Available in <http://www.agroica.gob.pe/dinamica-agropecuaria-1997-2007.shtml>
24. "Economic Assessment of Biofuel Support Policies". OECD Directorate for Trade and Agriculture. 2008. Available in: <http://www.oecd.org/dataoecd/18/48/41014580.pdf>
25. "El estado mundial de la agricultura y la alimentación. Biocombustibles: perspectivas, riesgos y oportunidades". FAO (2008c). Food and Agriculture Organization of the United Nations. Rome, Italy. 2008. Available in: <ftp://ftp.fao.org/docrep/fao/011/i0100s/i0290s.pdf>
26. "Estadísticas Agropecuarias". Ministry of Agriculture, Livestock and Aquaculture of Ecuador. Consultation. July, 2008. Also see: <http://www.mag.gov.ec>
27. "Estadísticas del sector agropecuario". Ministry of Agriculture and Rural Development (MADR). Bogotá, Colombia. 2008.
28. "Estadísticas por actividad económica". Agriculture. National Institute of Statistics of Bolivia. Consultation. July, 2008. Also see: <http://www.ine.gov.bo/indice/indice.aspx?d1=0201&d2=6>
29. "Estimaciones Agrícolas mensuales: cifras oficiales al 19/05/08". Secretary of Agriculture, Livestock, Fishing and Food (SAGPyA). Agricultural Campaign 2007/08. Buenos Aires, Argentina. 2008.
30. "Etanol de mandioca dulce". Ereno, D. Pesquisa FAPESP magazine. Printed Edition 144. Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP). 2008. Available in: <http://www.revistapesquisa.fapesp.br/?art=2295&bd=1&pg=1&lg=es>
31. "Experiencias en Ordenamiento Territorial para Biocombustibles". Cid Caldas. Ministry of Agriculture, Livestock and Supplies (MAPA). III Seminar on Biofuels of Latinamerica and the Caribbean. Brazil, 2008. Available in: <http://www.olade.org/biocombustibles/Documents/PONENCIAS%20III%20SEMINARIO%20BIO/SESION%203/2.%20Cid%20Caldas%20MAPA-%20Brasil%20-%20Sesi%C3%B3n%203.pdf>
32. "Flora Platense y Forrajera Cultivada de la Península Ibérica". UPNA. Department of Agricultural Production. Public University of Navarra, Spain. 2008.
33. "From 1st to 2nd generation biofuel technologies. An overview of current industry and RD&D activities". OECD / IEA. 2008. Available in: http://www.iea.org/textbase/papers/2008/2nd_Biofuel_Gen_Exec_Sum.pdf

34. "Global Agricultural Supply and Demand: Factors Contributing to the Recent Increase in Food Commodity Prices". Trostle, L. Outlook Report No. WRS-0801. Economic Research Service, USDA. May, 2008. Available in: <http://www.ers.usda.gov/Publications/WRS0801>
35. "Global Market Study on Jatropha. Project Inventory: Latin America". GEXSI. Prepared for World Wide Fund for Nature (WWF) by The Global Exchange for Social Investment (GEXSI). London / Berlin. May, 2008. Available in: <http://www.slideshare.net/ginosmit/gexsi-global-jatropha-study-abstract-presentation>
36. "Global principles and criteria for sustainable biofuels production". Roundtable on Sustainable Biofuels (RSB). Initiative of the EPFL Energy Center. Version Zero. 2008. Available in: <http://www.wilsoncenter.org/news/docs/brazil.roundtable.EPFL.en.pdf>
37. "How have countries like Brazil and Argentina managed to double grain production while at the same time protecting their environment?: Lessons to be learned in Europe". Derpsch, R. Presentation in PowerPoint. 1st International Conference on Sustainable Agriculture, Assessment and outlook. IAD, Institut de L'Agriculture Durable. Paris, France. 10th December, 2008.
38. "Increasing Feedstock Production for Biofuels. Economic Drivers, Environmental Implications, and the Role of Research". Biomass Research and Development Board (BR&Di) (2008a). 2008. Available in: http://www.brdisolutions.com/Site%20Docs/Increasing%20Feedstock_revised.pdf
39. "Informe Anual 2007-2008: Sector Azucarero Colombiano". ASOCAÑA. Association of Colombian Sugar Cane Producers. 2008. Available in: http://www.asocana.com.co/Informes_Anuales/2007_2008/Informe2007-2008.pdf
40. "Integración de la producción agrícola, pecuaria y bioenergética. Análisis preliminar para el desarrollo de distintos conglomerados productivos". Patrouilleau, R. coord. Advance report. INTA. Conjuncture and Prospective Unit. Buenos Aires, Argentina. 2008. Available in: www.inta.gov.ar/actual/info/integracion_agropecuariabioener.pdf
41. "Interpretación Nacional de los Principios y Criterios de la RSPO. Reflexiones de WWF". Lou Higgins, Mary. Presentation in PowerPoint. Bogotá, Colombia. 2008. Available in: www.fedepalma.org/document/2008/rspo/ML_Higgins.ppt
42. "Jatropha curcas L. (Pinhão Manso)". Durães, F. VI Technical Meeting of the Biofuels Workteam GT6 of REDPA – Southern Agriculture Council. Presentation in PowerPoint. Buenos Aires, Argentina. 9th December, 2008.
43. "La crisis financiera y las commodities agrícolas". D'Angelo, L. y Pontón R. Magazine of the Commerce Stock Exchange of Rosario. Directorate of Economic Information and Studies of the Commerce Stock Exchange of Rosario, Argentina. December, 2008. Available on: <http://www.bcr.com.ar/Secretara%20de%20Cultura/Revista%20Institucional/2008/Diciembre/Notas/006%20La%20crisis%20financiera%20y%20las%20commodities%20agr%C3%ADcolas.pdf>
44. "La jatropha en Chile". Traub R., A. VI Technical Meeting of the Biofuels Workteam GT6 of REDPA – Southern Agriculture Council. Presentation in PowerPoint. Buenos Aires, Argentina. 9th December, 2008.
45. "La yuca, nuevo potencial para un cultivo tradicional". CLAES. Agrofuels' workshop in Latinamerica. Document 1. Montevideo, Uruguay. 2008.
46. "New study shows way to fourth-generation biofuels: scientists uncover mechanism that regulates carbon dioxide fixation in plants". BIOPACT. March, 2008. Available in: <http://biopact.com/2008/03/new-study-shows-way-to-fourth.html>
47. "Oportunidades y desafíos de la producción de biocombustibles para la seguridad alimentaria y del medio ambiente en América Latina y el Caribe". FAO (2008d). LARC/08/4. 2008. Available in: <http://www.rlc.fao.org/es/prensa/coms/2008/14.swf>
48. "Opportunities and challenges of biofuel production for food security and the environment in Latin America and the Caribbean". FAO (2008a). Document (LARC/8/4) prepared for the 30th Session of

- the Regional Conference of FAO for Latinamerica and the Caribbean carried out in Brasilia, Brazil. 14th to 18th. April 2008. Available in: <ftp://ftp.fao.org/docrep/fao/meeting/013/k1481e.pdf>
49. "Paraguay explora su potencial en biocombustibles". Souto, G. COMUNIICA magazine. Year 4. Second stage. Interamerican Institute of Cooperation for Agriculture. May – August, 2008.
 50. "Potencialidad bioenergética sudamericana a partir de forestaciones con *Jatropha* sp. (*J. curcas*, *hieronymi* y *macrocarpa*)". Falasca, S. and Ulberich A. REDESMA virtual magazine. July, 2008. Available in: <http://revistavirtual.redesma.org/vol4/articulo5.php?id=c1>
 51. "Potencialidades y advertencias sobre la producción de *jatropha*". Hilbert, J. VI Technical Meeting of the Biofuels Workteam GT6 of REDPA – Southern Agriculture Council. Presentation in PowerPoint. Buenos Aires, Argentina. 9th December, 2008. Available in: http://www.iica.org.uy/redpaonline/cyber_ficha.asp?grupo=67&doc=247
 52. "Production of biofuels crops in Florida: Miscanthus". Erickson, J. et al. Institute of Food and Agriculture Sciences (IFAS). University of Florida, USA. 2008.
 53. "Production of biofuels crops in Florida: Switchgrass". Newman Y. et al. Institute of Food and Agriculture Sciences (IFAS). University of Florida, USA. 2008.
 54. "Projeções do agronegócio: Mundial e Brasil até 2006/07 a 2017/18". Ministry of Agriculture, Livestock and Supplies (MAPA). Brazil. January, 2008. Available in: <http://www.agricultura.gov.br>
 55. "Situación y perspectivas de los biocombustibles en el Perú". Ocrosopoma Ramírez, D. IICA. Office in Lima, Peru. 2008. 79 pages.
 56. "Sorgo, un cultivo que se impone". TodoAgro. Vegetable production. 2008. Available in: <http://www.todoagro.com.ar/todoagro2/nota.asp?id=8425>
 57. "Sustainability Criteria and Certification Systems: Final Report". Biomass Technology Group (BTG): DG Tren - European Commission. February, 2008. Available in: http://ec.europa.eu/energy/renewables/bioenergy/doc/sustainability_criteria_and_certification_systems.pdf
 58. "Sustainable biofuels: prospects and challenges". The Royal Society. Policy document 01/08. ISBN 978 0 85403 662 2. January, 2008. Available in: www.royalsociety.org
 59. "Sustentabilidad de la producción agropecuaria respecto a políticas de uso y conservación de suelos". Southern's Agricultural Council /CAS. Ministries' Declaration III (XV – 2008). Montevideo, Uruguay. 4th. and 5th. December, 2008.
 60. "Sweet sorghum R&D at the Nimbkar Agricultural Research Institute". Rajvanshi A.; Nimbkar N. Nimbkar Agricultural Research Institute. India. 2008.
 61. "The Economics of Biomass Feedstocks in the United States. A review of the literature". Biomass Research and Development Board (BR&Di) (2008b). Occasional paper No.1. October, 2008. Available in: <http://www.brdisolutions.com/Site%20Docs/Biomass%20Feedstocks%20Literature%20Review.pdf>
 62. "Una nueva barrera para el biodiesel". Molina, C. Rural Supplement, Clarín Newspaper. Buenos Aires, Argentina. 20th. December, 2008. <http://www.clarin.com/suplementos/rural/2008/12/20/r-01825593.htm>
 63. "Vocaciones Productivas Departamentales para la Producción de Biocombustibles y Seguridad Alimentaria". CAINCO-IBCE. Press Release. 2008. Available in: <http://www.cainco.org.bo/salaPrensa/notasPrensa/Notas%20de%20Prensa/BIOCOMBUSTIBLES.doc>
 64. "Yuca para la seguridad alimentaria y energética". FAO (2008h). Newsroom, FAO. 25th. July, 2008. Available in: <http://www.fao.org/newsroom/ES/news/2008/1000899/index.html>.
 65. "A multistake holder learning & guidance initiative: Towards sustainable *jatropha*". Van Marwijk et al. Draft. 2007. Available in: http://www.jatropha-platform.org/documents/Towards-sustainable-Jatropha_Proposal-051007.pdf
 66. "A quick look at fourth generation biofuels". BIOPACT (2007a). October, 2007. Available in: <http://biopact.com/2007/10/quick-look-at-fourth-generation.html>

67. "Álcool de mandioca pode ser alternativa de energia renovável". *Felipe Fábio and Alves Aparecido*. Article published in the Piracicaba Newspaper. Notebook: Agricultural Life. Page B-5. 7th November, 2007. Available in: http://www.cepea.esalq.usp.br/pdf/Cepea_MandiocaJP.pdf
68. "An in-depth look at biofuels from algae". BIOPACT (2007b). January, 2007. Available in: <http://biopact.com/2007/01/in-depth-look-at-biofuels-from-algae.html>.
69. "Atlas de la agroenergía y los biocombustibles en las Américas: i.Etanol". IICA. San José, Costa Rica. 2007. 181 pages.
70. "Balance energético de los cultivos potenciales para la producción de biocombustibles". Donato, L.; Huerga I. INTA –CNIA- Institute of Rural Engineering. 2007
71. "Biocombustibles y su impacto potencial en la estructura agraria, precios y empleo en América Latina". Razo, C. et al. Productive Development Series N° 178. ECLAC. Santiago, Chile. June, 2007. Available in: <http://www.eclac.cl/ddpe/publicaciones/xml/5/30405/lcl2768e.pdf>
72. "Biomass energy: the scale of the potential resource". Field, C.B., Campbell, J.E., and Lobell, D.B. *Trends in Ecology and Evolution*, 23, pp. 65-72. 2007. Available in: <http://www.cas.muohio.edu/~stevenmh/Field%20et%20al%202008.pdf>
73. "Claims and facts on *Jatropha curcas* L.: Global *Jatropha curcas* evaluation, breeding and propagation programme". Jongschaap et al. Plant Research International B.V., Wageningen UR. October, 2007. Available in: <http://www.ifad.org/events/jatropha/breeding/claims.pdf>
74. "Rapeseed – Canola como alternativa para producir biocombustible: fortalezas y debilidades". Gómez, Nora et al. In Bioenergy 2006. Advances and Perspectives. Faculty of Agronomy, UBA. Argentina. 2007.
75. "Cultivo del tártago". MAG. Unit of Agronomic Studies. General Directorate of Planning. Ministry of Agriculture of Paraguay. Asunción, Paraguay. 2007.
76. "El Estado del Arte de los biocombustibles en Paraguay". Work Document N° 2. IICA, Office in Asunción, Paraguay. 2007. 81 pages.
77. "El ricino como alternativa para diversificar la producción en áreas marginales". In Bioenergy 2006. Advances and Perspectives". Wassner, D. Faculty of Agronomy, UBA. Argentina. 2007.
78. "El tártago: la planta, su importancia y usos". Mazzani, E. CENIAP/INIA. In CENIAP Hoy N° 14. Digital Magazine of the National Center of Agricultural Research. Maracay, Venezuela. April to December, 2007. Available in: http://www.ceniap.gov.ve/pbd/RevistasTecnicas/ceniaphoy/articulos/n14/pdf/e_mazzani.pdf
79. "Ensuring that biofuels deliver on their promise of sustainability". Roundtable on Sustainable Biofuels (RSB). EPFL Energy Center. 2007. Available in: http://www.bioenergywiki.net/images/1/12/RSB_Intro.pdf
80. "Etanol de quê?" Buckeridge, M: Pesquisa FAPESP magazine. Online Edition. November, 2007. Available in: <http://www.revistapesquisa.fapesp.br/?art=4338&bd=2&pg=1&lg>
81. "GreenFuel technologies: a case study for industrial photosynthetic energy capture". Dimitrov, K. 2007. Available in: <http://www.nanosting.net/Algae/CaseStudy.pdf>
82. "Informe sobre a Situação e Perspectivas da Agroenergia e dos Biocombustíveis no Brasil". IICA. Office in Brasilia, Brazil. 2007.
83. "Metodología para optimizar el análisis de materias primas para biocombustibles en los países del Cono Sur". Lobato, V. et al. PROCISUR-IICA. Montevideo, Uruguay. 2007. 93 pages.
84. "Micro-algas bio-diesel". Dela Vega Lozano, A. 2007. Available in: <http://j.delavegal.googlepages.com/algae>
85. "Opciones para la producción y uso del biodiesel en el Perú". Castro, Paula et al. Practical Solutions-ITDG. Lima, Peru. 2007.
86. "Perspectivas de los biocombustibles en la Argentina, con énfasis en el etanol de base celulósica". Patrouilleau, R., Lacoste, C. and others. INTA. Conjunction and Prospective Unit. Buenos Aires, Argentina. 2007. Available in: www.inta.gov.ar/actual/info/perspectiva_%20biocombus.pdf

87. "Plan de Siembra 2007-2011 de la Asociación Venezolana de Cultivadores de Palma Aceitera". ACUPALMA (2007). Available in: <http://www.acupalma.org.ve/index.asp?categoryid=7655&articleid=292236>
88. "Potencial de la agricultura y los territorios rurales para producir bioenergía". Sepúlveda, S. IICA. San José, Costa Rica. 2007. 60 pages.
89. "Potencialidad del cultivo de caña de azúcar en argentina como fuente de bioetanol". Cárdenas, Gerónimo. Agroindustrial Experimental Station, Obispo Colombes, Argenina, 2007. Available in: <http://www.biodiesel.com.ar/download/AapresidBiocombustibesCardenasXVCongreso150807.pdf>
90. "Preguntas y respuestas más frecuentes sobre biocombustibles". IICA. San José, Costa Rica. 2007. 24 pages.
91. "Production of biofuel crops in Florida: Sweet Sorghum". Vermerris, W. et al. University of Florida, USA, 2007. Available in: <http://edis.ifas.ufl.edu/pdf/AG/AG29800.pdf>
92. "Recomendação técnica sobre o plantio de pinhão manso no Brasil". EMBRAPA. 2007. Available in: <http://www.cpa0.embrapa.br/portal/noticias/Position%20Paper.pdf>.
93. "Review of Environmental, Economic and Policy Aspects of Biofuels". Zilberman, David and Rajagopal, Deepak. The World Bank Development Research Group. Sustainable Rural and Urban Development Team. September, 2007. Available in: http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2007/09/04/000158349_20070904162607/Rendered/PDF/wps4341.pdf
94. "Scientist skeptical of algae-to-biofuels potential – interview". BIOPACT (2007c). July, 2007. Available in: <http://biopact.com/2007/07/scientist-skeptical-of-algae-to.html>.
95. "Selección de indicadores que permitan determinar cultivos óptimos para la producción de biodiesel en las eco-regiones Chaco-Pampeana de la República Argentina". García Penela J.M. INTA. 2007. Available in: www.inta.gov.ar/iir/info/documentos/energia/indicadores_biodiesel.pdf
96. "Producción de biomasa para biocombustibles líquidos: el potencial de América Latina". Productive development series N° 181. ECLAC. 2007. Available in: <http://www.ibcperu.org/doc/isis/9189.pdf>
97. "Sistemas de producción utilizados para obtener etanol". MAIZAR. 2007. Available in: <http://www.maizar.org.ar/vertext.php?id=246>
98. "Sustentabilidad de la cadena productiva de la soja argentina y la región desafíos prioritarios y recomendaciones de políticas públicas". FARN. Prior challenges and recommendations on public policies. Work document. 2007. Available in: http://www.oas.org/dsd/EnvironmentLaw/trade/Documents/SOJA/InformeFinal_Recomendaciones_.pdf
99. "Tablero de comando para la producción de biocombustibles en Perú". ECLAC et al. In Modernización del Estado, desarrollo productivo y uso sostenible de recursos naturales. Medio ambiente collections. 2007. Available in: <http://www.bvcooperacion.pe:8080/biblioteca/handle/123456789/2188>
100. "Tecnología brasileña para la agricultura en África". FAO (2007). Enfoques Magazine. Department of Agriculture and Consumer Protection. 2007. Available in: <http://www.fao.org/Ag/esp/revista/0703sp1.htm>
101. "Testing framework for sustainable biomass". Final report from the project Group Sustainable Production of Biomass. Cramer, Jacqueline et al. 2007. Available in: http://www.lowcvp.org.uk/assets/reports/070427-Cramer-FinalReport_EN.pdf
102. "The impact of biofuels on global feedstock markets". F.O. Licht. World Grain Markets Report Vol. 4, N° 8. April, 2008.
103. "The role of agricultural biotechnologies for production of bioenergy in developing countries". FAO (2008b). Works and presentations of the FAO Seminar carried out on the 12th. October, 2007 in FAO's headoffice, Rome, Italy. Available in: <http://www.fao.org/biotech/docs/bioenergy.pdf>
104. "The strange world of carbon-negative bioenergy: the more you drive your car, the more you tackle climate change". BIOPACT (2007d). October, 2007. Available in: <http://biopact.com/2007/10/strange-world-of-carbon-negative.html>.

105. "¿Una plaga nacional utilizable como cultivo energético en áreas semidesérticas de Argentina?". Falasca, S. and Ulberich, A. 2007. Available in: www.biodiesel.com.ar/download/cinea_plaganacional.pdf
106. "Agricultura de Conservación". FAO (2006a). Enfoques Magazine. Department of Agriculture and Consumer Protection. 2006. Available in: <http://www.fao.org/ag/esp/revista/0110sp.htm>
107. "Biofuels for transportation global potential and implications for sustainable agriculture and energy in the 21st century -extended summary". Worldwatch Institute for the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV), Agency for Technical Cooperation (GTZ) and Agency of Renewable Resources (FNR). Washington, D.C., USA. 7th. June, 2006. Available in: http://www.worldwatch.org/system/files/EBF008_1.pdf
108. "Canola: alternativa de renda e beneficios para os cultivos seguintes". Tomm, G. EMBRAPA. 2006. Available in: http://www.cnpt.embrapa.br/culturas/canola/canola-rev_plantio_direto2006.pdf
"Converting Sweet Sorghum into Ethanol". Oklahoma State University (OSU). 2006. Disponible en: http://osu.okstate.edu/index.php?option=com_content&task=view&id=7&Itemid=90
109. "Cultivo de Rapeseed. Foro de Cultivos Alternativos". Iriarte, Liliana. Presentation in PowerPoint. 2006. Available in: www.biodiesel.com.ar/download/l_iriarte.pdf
110. "Cultivos industriales" 1st edition. De La Fuente, E., et al. Faculty of Agronomy. University of Buenos Aires (UBA). Buenos Aires, Argentina. October, 2006. 764 pages.
111. "El Agronegocio del tártago en el mundo". EMBRAPA. Technical Circular 101. EMBRAPA/MAPA. Campinas Grande, Brazil. 2006.
112. "El mercado de almidón añade valor a la yuca". FAO (2006b). Department of Agriculture, Biosecurity, Nutrition and Consumer Protection, FAO. Enfoques. 2006. Available in: <http://www.fao.org/AG/esp/revista/pdf/0610-1.pdf>
113. "Estrategia de desarrollo de biocombustibles: implicaciones para el sector agropecuario". Ministry of Agriculture and Rural Development (MADR). Bogotá, Colombia. 2006.
114. "Experiencia de Brasil en el desarrollo y difusión de especies con fines energéticos". Rosa e Abreu, F. Alternative Crops Forum. Presentation in PowerPoint. 2006. Available in: http://www.biodiesel.com.ar/download/f_rosa.pdf
115. "Factibilidad de implementación de un certificado de agricultura sustentable como herramienta de diferenciación del proceso productivo de siembra directa". Lorenzatti, S. Faculty of Agronomy– University of Buenos Aires, Argentina. 2006. Available in: http://www.agro.uba.ar/agroneg/pdf/afp_lorenzatti.pdf
116. "Issue paper on biofuels in Latin America and the Caribbean". S&T Consultants Inc. Prepared for IDB. Environment Division Sustainable Development Department. Washington DC, USA. September, 2006. Available in: <http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=927710>
117. "Perspectivas de los Biocombustibles en Argentina y en Brasil". SAGPyA/IICA. First edition. March, 2006. Available in: <http://www.sagpya.mecon.gov.ar/new/0-0/agricultura/otros/biodiesel/biocombustibles1.pdf>
118. "Producción y comercio de biocombustibles y desarrollo sustentable: los grandes temas". Dufey, A. International Institute for the Environment and Development, London, England. 2006.
119. "Tendencias y perspectivas del sector forestal en América Latina y el Caribe". FAO (2006c). FAO's studies' publication, Montes 148. 2006.
120. "Sustainability Standards for Bioenergy". Fritsche, U. et al. Öko-Institute. Berlin, Germany. September, 2006. Available in: http://www.wwf.de/fileadmin/fm-wwf/pdf_neu/Sustainability_Standards_for_Bioenergy.pdf
121. "Análise comparativa de custos e preços do biodiesel em diversas regiões do Brasil: suporte à tomada de decisão e à formulação de políticas". ESALQ. CEPEA – ESALQ, University of Sao Paulo, Brazil. 2005.

122. "El sendero de la calidad". AAPRESID. Magazine of the Argentinean Association of Producers in Direct Sowing. 2005.
123. "Impacto regional en la zona semiárida argentina implantando cultivos para biodiesel". Falasca S., Bernabé M.A., Ulberich A. Geographical magazine. 2005. Available in: <http://www.articlearchives.com/science-technology/earth-atmospheric-science/1285865-1.html>
124. "Informe de comisión biocarburantes sobre evaluación económica desde el punto de vista país - caso biodiesel". MGAP-ANCAP-MVOTMA-MEF-OPP-MIEM. Uruguay. 2005. Available in: www.miem.gub.uy/portal/agxppdwn?5,6,298,O,S,0,1147%3BS%3B1%3B208
125. "The extent of Conservation Agriculture adoption worldwide: Implications and impact". Derpsch, R. Paper presented in the 3rd. World Congress on Conservation Agriculture. Nairobi, Kenya. October, 2005.
126. "Desempeño del sector palmicultor". ACUPALMA. Venezuela. 2004. Available in: <http://www.acupalma.org.ve/index.asp?categoryid=7655&articleid=191811>
127. "ICRISAT develops sweet sorghum for ethanol production". International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 2004. Available in: <http://www.icrisat.org/Media/2004/media13.htm>
128. "Widescale biodiesel production from algae". Briggs, M. University of New Hampshire, 2004. Available in: http://www.unh.edu/p2/biodiesel/article_alge.html
129. "Roadmap for Agriculture Biomass Feedstock Supply in the United States". US Department of Energy. Washington DC, USA, 2003. Available in: <http://devafdc.nrel.gov/pdfs/8245.pdf>
130. "Agricultura mundial: hacia los años 2015/2030". FAO (2002). Economic and social Department. 2002. Available in: <http://www.fao.org/docrep/004/Y3557S/y3557s00.HTM>
131. "Agua y Cultivos: logrando el uso óptimo del agua en la agricultura". FAO (2002). Rome, Italy. 2002. Available in: ftp://ftp.fao.org/agl/aglw/docs/cropsdrops_s.pdf
132. "Cultivos industriales". López Bellido, L. Mundi-Prensa Books. Madrid, Spain. 2002. 1071 pages.
133. "El cultivo de Rapeseed en la Argentina". Iriarte, Liliana. In: IDIA XXI N° 3, INTA. 2002. Available in: www.inta.gov.ar/ediciones/idia/oleaginosa/colza01.pdf.
134. "Global agro-ecological assessment for agriculture in the 21st century". Fischer, G., van Velthuisen, H., Shah, M., and Nachtergaele, F. International Institute for Applied Systems Analysis, Laxenburg, Austria and Food and Agriculture Organization of the United Nations, Rome, Italy. 2002. Available in: <http://www.iiasa.ac.at/Admin/PUB/Documents/IR-00-064.pdf>
135. "La yuca en el Tercer Milenio: Sistemas modernos de producción, procesamiento, utilización y comercialización". International Center of Tropical Agriculture (CIAT); Latin American and Caribbean Consortium for Support to Cassava's Research and Development. Cali, Colombia. 2002. 586 pages.
136. "Conservation Agriculture, Matching Production with Sustainability. What is the Goal of Conservation Agriculture?" FAO (2001b). Available in: <ftp://ftp.fao.org/agl/agll/ch10/ch104.pdf>
137. "Labranza cero: cuando menos es más". FAO (2001c) Enfoques Magazine. Department of Agriculture and Consumer Protection. 2001. Available in: <http://www.fao.org/Ag/esp/revista/0101sp1.htm>
138. "Unified Wood Energy Terminology UWET". FAO (2001a). Forests Department FAO. 2001. Available in <http://www.fao.org/docrep/008/j0926s/j0926s00.htm>
139. "Agricultura y medio rural desde la perspectiva tecnológica: retos y oportunidades para las Américas". IICA and FONAGRO. Directorate of Area II – Science, Technology and Natural Resources. Second meeting of FONAGRO. Mexico, D.F. 2000. Available in: www.iica.int/foragro/Reunion/Documentos/VisionCompartidaEsp.doc
140. "Evaluación de las variedades más promisorias para la producción de aceite vegetal y su potencial implementación en Colombia". Corporation for the Industrial Development of Biotechnology and Clean Production (CORPODIB). 2000.
141. "Global Agro-ecological Zones Assessment: Methodology and Results". Fischer, G. van Velthuisen, H. & Nachtergaele, F. Interim Report, International Institute for Systems Analysis (IIASA), Laxenburg, and FAO, Rome, Italy. 2000. Available in: <http://www.iiasa.ac.at/Admin/PUB/Documents/IR-00-064.pdf>

142. "Land Resource Potential and Constraints at Regional and Country Levels". FAO. Land and Water Development Division. Rome, Italy. 2000.
143. "Reflexiones sobre la Agricultura de América Latina". Piñeiro, M. Work document prepared for the Conference on Development of Rural Economy and Reduction of Poverty in Latinamerica and the Caribbean. Annual Assembly of Governors of the Inter-American Development Bank. New Orleans, USA. 2000. Available in: http://www.iadb.org/sds/doc/RUR_MPineiro_s.pdf
144. "Introduction to Oil Palm Production". Fairhurst, T.H.and Mutert, E. Better Crops International. Vol. 13. N° 1. 1999. Available in: [http://www.ppi-far.org/ppiweb/bcropint.nsf/\\$webindex/32EDD1030D2EEF5D852568F600558DE0/\\$file/i99-1p03.pdf](http://www.ppi-far.org/ppiweb/bcropint.nsf/$webindex/32EDD1030D2EEF5D852568F600558DE0/$file/i99-1p03.pdf)
145. "A look back at the U.S. Department of Energy's aquatic species program—Biodiesel from algae". NREL. National Renewable Energy Laboratory. US Department of Energy. 1998. Available in: http://www1.eere.energy.gov/biomass/pdfs/biodiesel_from_algae.pdf
146. "La palma aceitera: El cultivo dorado de los trópicos". Mutert, E. Agronomical information. 1997. Available in: [http://www.inpofos.org/ppiweb/iamex.nsf/\\$webindex/E61D42E7FB567A8306256AE80064CB90/\\$file/La+Palma+Aceitera.pdf](http://www.inpofos.org/ppiweb/iamex.nsf/$webindex/E61D42E7FB567A8306256AE80064CB90/$file/La+Palma+Aceitera.pdf)
147. "Utilização do sorgo sacarino como matéria-prima complementar à cana-de-açúcar para obtenção de etanol em microdestilaria". Teixeira, Cyro el at. 1997. Available in: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0101-20611997000300011
148. "El cultivo de Rapeseed-canola". Integrated Experimental Ranch Barrow, MAA – INTA Agreement. Series: Outreach materials N°2. November, 1996. Available in: http://www.inta.gov.ar/barrow/info/documentos/agricultura/colza/manual_colza.pdf
149. "Physic nut. Jatropha Curcas L. Promoting the conservation and use of underutilized and neglected crops". Heller, J. IPGRI, Rome, Italy. 1996. Available in: http://www.biodiversityinternational.org/publications/pubfile.asp?id_pub=161
151. "Sorghum—for Syrup". Undersander D.J. et al. Alternative field crops manual. Departments of Agronomy and Soil Science, College of Agricultural and Life Sciences and Cooperative Extension Service, University of Wisconsin-Madison. 1990. Available in: <http://www.hort.purdue.edu/newcrop/afcm/syrup.html>
152. "The future role of tropical forests in affecting the carbon dioxide concentration of the atmosphere". Houghton, R.A. *Ambio*, 19, pp. 204-210. 1990. Available in: <http://www.jstor.org/pss/4313693#journalInfo>
153. Cock, James. International Agricultural Development Service, International Center of Tropical Agriculture (CIAT). 1989. 240 pages.
154. "Mother's Alcohol Fuel Seminar". The Mother Earth News. 1980. Available in: http://journeytoforever.org/biofuel_library/ethanol_motherearth/meToC.htm
155. "E14 Manihot esculenta Cranz (M. utilisissima Pohl)". Information system of feed resources. Consultation. March, 2009. Available in: <http://www.fao.org/ag/aGA/AGAP/FRG/afri/Es/Data/535.HTM>
156. "Evolución y estado actual de la agricultura de conservación en Europa. Aspectos legislativos". Martínez, Armando. Spanish Association of Conservation Agriculture/Living soil. 2002. Available in: <http://www.aeac-sv.org/pdfs/legislacion.pdf>
157. "Estimaciones agrícolas: Información general de los cultivos". SAGPyA. Consultation. 2008. Available in: <http://www.sagpya.mecon.gov.ar/new/0-0/agricultura/otros/estimaciones/base.php>
158. "El sorgo". Vallati, A. National Institute of Agricultural Technology. Agroindustrial Experimental Station, Bordenave, Argentina, 2007. Available in: http://www.inta.gov.ar/Bordenave/contactos/autores/vala/sorgo_vala.pdf
159. Centre for Jatropha Promotion & Biodiesel (CJP). Consultation. 2009. Website: <http://www.jatrophabiodiesel.org/index.php>



Websites

1. www.inta.gov.ar/
2. www.corpodib.com.co/
3. <http://www.corpoica.org.co/>
4. www.ornl.gov/
5. www.abiove.com.br/
6. www.sagpya.mecon.gov.ar/
7. www.agroinformacion.com National Institute of Agricultural Research and Extension (INIA)
8. <http://www.inia.gob.pe/cana/resumen.htm>
9. http://www.fao.org/nr/water/infores_databases_cropwat.html
10. <http://www.clayuca.org>
11. www.minag.gob.pe/
12. www.minagricultura.gov.co/
13. www.mag.gov.ec/
14. www.mat.gob.ve/
15. www.agrobolivia.gov.bo/
16. www.agricultura.gov.br/
17. www.mgap.gob.uy/
18. www.mag.gov.py/
19. <http://faostat.fao.org/default.aspx>
20. <http://comtrade.un.org/>

Regional Association of Oil and Natural Gas Companies of Latin America and the Caribbean



REGIONAL ASSOCIATION OF OIL AND NATURAL GAS COMPANIES IN LATIN AMERICA AND THE CARIBBEAN

Established in 1965, ARPEL is an association of 26 oil and natural gas state owned and private companies and institutions with operations in Latin America and the Caribbean, which represent more than 90 percent of the Region's upstream and downstream operations. Since 1976, ARPEL holds formal UN-ECOSOC special consultative status. On 2006, ARPEL expressed its endorsement to the principles of the UN Global Compact.

ARPEL works on three main areas defined in its Strategic Plan:

- *Economic area:* relationship with key stakeholders, industry growth and energy integration.
- *Socio-environmental area:* Environment, Health and Safety Management System to prevent, eliminate and manage the operational risks, encouraging the reduction of incidents with high impact on facilities and individuals, and the relationship with communities where industry operates.
- *Eco-efficiency area:* the priority is focused on emissions reduction and the effective use of non-renewable resources.

To accomplish its objectives, ARPEL works together with its Members on issues of common interest to the industry through its 9 Committees. Four Corporate Committees: Environment, Health and Safety; Social Responsibility; Climate Change and Energy Efficiency and Energy Integration. Three Operational Committees: Refining, Pipelines and Terminals and Exploration and Production. Two Integrating Committees: Communications and the Integration Team, integrated by the Chairpersons of all Committees. ARPEL organizes regional workshops, seminars and symposia to share information and best practices and develops technical documentation to build management capacity on issues of interest to its members. ARPEL has an interactive Portal for its Members in which all documents developed by ARPEL Technical Committees are available. The Portal facilitates the virtual interaction of the ARPEL community and with its stakeholders.

On 2005, on the occasion of the 40th Association anniversary, its members signed a binding Statement of Commitments in the areas of social responsibility, environment, health and safety, energy integration and communications to support sustainable development in the Region.



Inter-American Institute for Cooperation on Agriculture.



The Inter-American Institute for Cooperation on Agriculture (IICA) is a specialized agency of the Inter-American System, and its purposes are to encourage and support the efforts of its Member States to achieve agricultural development and well-being for rural populations.

With more than six decades of institutional life, the Institute is responding to new mandates issued by the Heads of State and Government of the Americas, the General Assembly of the

Organization of American States (OAS) and the ministers of agriculture of the Americas, to reposition itself so that it can meet both the new challenges facing agriculture and the requests for support it receives from its member countries.

As it pursues its vision and carries out its mission, the Institute has competitive advantages it can draw on to carry out its new role. It has accumulated a wealth of knowledge regarding agriculture, rural territories, the diversity of peoples and cultures, and the agro-ecological diversity of the hemisphere, all of which are important for crafting creative solutions to a wide variety of problems and challenges. Its presence in all of the Member States gives the Institute the flexibility it needs to move resources between countries and regions in order to promote and adapt cooperation initiatives intended to address national and regional priorities, facilitate the flow of information and improve the dissemination of best practices.

The Institute has its Headquarters in Costa Rica, and Offices in 34 countries of the Americas, an Office in Miami, which is responsible for the Inter-American Program for the Promotion of Agricultural Trade, Agribusiness and Food Safety, as well as an office for Europe, located in Madrid, Spain. The Directorate for Strategic Partnerships works out of the IICA Office in Washington, D.C.